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Use of whole soy lecithin in diets with energy concentrate from starchy or lipid sources for steers

[*Uso de lecitina integral de soja em dietas com concentrado energético de fontes amiláceas ou lipídicas para novilhos*]

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ABSTRACT

Diets with high energy density and additives that enhance energy use are necessary for finishing feedlot cattle. The objective of the present study was to evaluate the performance, ingestive behavior, apparent digestibility of the diet and the carcass traits of feedlot steers fed concentrates from different energy sources, one derived from starchy sources and the other, from lipid sources, combined or not with whole soy lecithin, at a dose of 40 g animal day^{-1}. The experimental design was completely randomized blocks, in a 2 x 2 factorial arrangement. The combination of whole soy lecithin with the lipid energy source concentrate increased the dry matter digestibility and the carcass yield of the animals (76.03% and 57.20%, respectively). The lipid energy source concentrate showed higher ether extract digestibility and animals fed on it had higher carcass yield (84.18% and 56.85%, respectively). Whole soy lecithin promoted a reduction in fecal pH due to a greater fermentation of carbohydrates and fatty acids in the intestinal lumen. Using whole soy lecithin combined with energy concentrate from a lipid source is recommended due to its improvements in the use of the diet and in the carcass yield.

Keywords: animal performance, carcass gains, emulsifier, fatty acids

RESUMO

O uso de dietas com alta densidade energética e aditivos que potencializem o aproveitamento energético se faz necessário na terminação de bovinos em confinamento. O objetivo do presente estudo foi avaliar o desempenho, o comportamento ingestivo, a digestibilidade aparente da dieta e as características de carcaça de novilhos confinados, alimentados com concentrados de diferentes fontes energéticas, um derivado de fontes amiláceas e outro de fontes lipídicas, associados ou não com lecitina integral de soja, na dose de 40g animal dia^{-1}*. O delineamento experimental foi o de blocos inteiramente ao acaso, em esquema fatorial 2 x 2. A associação da lecitina integral de soja com o concentrado de fonte energética lipídica melhorou a digestibilidade da matéria seca e o rendimento de carcaça dos animais (76,03% e 57,20%, respectivamente). O concentrado de fonte energética lipídica teve maior digestibilidade do extrato etéreo, e os animais alimentados com este possuíram maior rendimento de carcaça (84,18% e 56,85%, respectivamente). A lecitina integral de soja isolada promoveu redução no pH fecal em virtude de uma maior fermentação de carboidratos e ácidos graxos no lúmen intestinal. Utilizar lecitina integral de soja associada com concentrado energético de fonte lipídica é recomendado devido a suas melhorias no aproveitamento da dieta e no rendimento de carcaça.*

Palavras-chave: ácidos graxos, desempenho animal, emulsificante, ganhos de carcaça

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INTRODUCTION

The continuity of animal production, especially beef cattle, is directly related to the types of systems, and, for this practice to be profitable, it is essential that there is greater effort in its intensification and in the search for maximum profitability. One way to achieve these goals is the use of high energy density diets, which has become frequent, especially in the finishing phase, since their use provides improvements in carcass traits, performance, and feed efficiency (Abreu *et al*., 2022).

The increase in the energy density of the diet can come from lipid or starch sources, but each of these has its particularities. The use of starch can be more practical and more accessible, however, its misuse generates metabolic disturbances, such as an excessive reduction in rumen pH, which can trigger acidosis and thus impair performance, and even interfere with the intramuscular fat content of animals (Baldassini *et al.*, 2021). Since lipids have a higher energy density than starch, they may have a smaller inclusion in the diet, however, this level should not exceed 7% due to its toxicity to ruminal microorganisms, since in excess it alters the cell membrane fluidity of microorganisms and reduces fiber digestion (Pitta *et al*., 2018).

Using diets with higher energy density requires the use of technologies that reduce energy loss, maximize the synthesis of short-chain fatty acids, improve conversion efficiency, animal growth rate and, therefore, increase profitability in production systems, and thus tend to be great allies (Min *et al*., 2020).

This maximization can occur through the supply of lecithin, which is extracted mainly from soy, as it has ready availability and excellent functionalities in the animal organism due to its composition of phosphatidyl choline, phosphatidyl ethanolamine, phosphatidyl inositol, glycolipids, triglycerides, and carbohydrates (Li *et al*., 2017).

Whole soy lecithin has great potential for lipid emulsification and helps to enhance the absorption of fatty acids in the small intestine as it is able to pass through the rumen, and these actions allow the use of higher levels of fat in the diet to be practiced without causing damage to rumen fermentation (Abel-Caines *et al*., 1998).

When observing the efficiency in the use of lipid sources in cattle, Drago (2019) reported a concentration of 3 - 5% ether extract in the animal feces, that is, a considerable fraction was not absorbed, alerting to the need for additives with potential to increase the digestibility of this component when used.

Given this context, the hypothesis of the study is that the inclusion of whole soy lecithin in the diet for feedlot cattle provides improvements in performance, in the use of the diet and in carcass traits, when animals were given diets with high energy density, and when using lipid as the energy source, its effects are even more pronounced. To test this hypothesis, the present study aimed to evaluate the effect of the use of whole soy lecithin combined with diets with energy concentrate from starchy or lipid source on the performance, ingestive behavior, apparent digestibility of the diet and the carcass traits of feedlot steers.

MATERIAL AND METHODS

The experiment was conducted at the Laboratory of Feed Analysis and Ruminant Nutrition and at the Teaching, Research and Extension Unit in Beef Cattle - Feedlot of the Animal Production Center (NUPRAN) together with the master's Program in Veterinary Sciences of the Agricultural and Environmental Sciences Sector, State University of the Midwest (CEDETEG/UNICENTRO), located in Guarapuava, state of Paraná.

Thirty-two ½ Angus ½ Nellore steers with 476 ± 4 kg average initial weight and 14 ± 1 months, which were assigned to the treatments according to body weight. Experimental procedures were submitted to the Animal Research Ethics Committee (CEUA/UNICENTRO) and approved according to official letter 01/2021 of 09/02/2021.

This was a randomized blocks experimental design, consisting of four treatments, in a 2 × 2 factorial arrangement, with two types of energy concentrate, one from starchy sources and the other from lipid sources, combined or not with supplementation with whole soy lecithin at 40 g per animal day^{-1} as recommended by the manufacturer; and four repetitions, where each repetition was represented by a pen with two animals.

The product used was (Powerbov LC, based on whole soy lecithin, which contains 650 g kg^{-1} of whole soy lecithin, from Empresa Sanex Comércio e Indústria Veterinária Ltda., Brazil).

The experimental period, which corresponded to the finishing phase of the animals, lasted 85 days, divided into 15 days for adaptation to the diets and experimental facilities and three evaluation periods, the first two with 21 days each, and the third period with 28 days.

When the animals arrived at the research unit they were housed in 16 pens with two animals each, with an area of 15 m^2 each (2.5 m × 6.0 m). Each pen had a concrete trough measuring 2.30 m in length, 0.60 m in width and 0.35 m in height, and a metallic drinker, regulated by an automatic float. Immediately after unloading, they were fed corn silage and concentrate, and after one day, they were taken to the pens according to the treatments and body weight and followed the 15-day adaptation to the diets and facilities.

Voluntary intake of feed was recorded daily, by weighing the amount offered and leftovers from the previous day, considering daily intake adjustment, to allow for leftovers at 5% DM delivered.

Feed was provided as a total mixed ration (TMR), that is, ingredients were mixed at the time of delivery to the animals. Diets consisted of 25% ryegrass haylage (*Lolium multiflorum*) and 75% concentrate on a dry matter basis. The starch concentrate was made up of 21% wheat bran, 19% malt root, 17.6% corn grains, 13.9% fatted corn germ, 11.5% soybean hulls, 9.0% forage barley, 2.8% calcitic limestone, 2.0% soybean meal, 1.8% sodium bicarbonate, 0.7% livestock urea, and 0.7% mineral vitamin premix. While the lipid concentrate was composed of 18% wheat bran, 14.9% malt root, 12.8% corn grains, 18% fatted corn germ, 12.4% soybean hull, 9.9% forage barley, 2.6% calcitic limestone, 6.3% soybean meal, 1.8% sodium bicarbonate, 0.7% livestock urea, and 0.7% mineral vitamin premix. Table 1 lists the chemical composition of the feeds used in animal feed and the average values of the experimental diet, on a total dry matter basis. Lecithin was added as top dressing, immediately after feeding, in each meal, at a dose of 40.0 g.animal.day^{-1}.

Table 1. Chemical composition of feeds used for animal feed and mean values of the experimental diet, on a total dry matter basis

Parameter	Ryegrass haylage	Concentrate[1]		Experimental diet	
		Lipid	Starch	Lipid	Starch
DM, %	45.47	91.97	91.72	80.35	80.16
MM, % DM	5.38	7.16	7.06	6.72	6.64
CP, % DM	11.59	17.37	17.34	15.93	15.90
EE, % DM	2.22	5.54	2.53	4.71	2.45
NDF, % DM	54.48	26.69	27.52	33.64	34.26
ADF, % DM	33.09	11.69	12.03	17.04	17.30
Lignin, % MS	5.08	2.39	2.21	3.06	2.93
TDN, % DM	61.73	76.71	76.47	72.96	72.78
Starch, % DM	1.83	34.01	40.33	25.97	30.71
Ca, % DM	0.51	1.2	1.2	1.03	1.03
P, % DM	0.36	0.47	0.45	0.44	0.43

[1] Guarantee levels of the premix per kg concentrate: vit. A: 14,000 IU; vit D3: 1,800 IU; vit. E: 75 IU; Sodium monensin: 40mg; S: 0.70g; Mg: 0.12g; Na: 3.0g; Co: 1.0mg; Cu: 18mg; I: 1.1mg; Mn: 29.0mg; Se: 0.35mg; and Zn: 72.2mg.

Samples of pre-dried silage ryegrass and concentrates were placed in a forced-air oven at 50°C for 72 hours to determine partial dry matter. Pre-dried samples were ground in a Wiley- mill containing a sieve with a mesh of 1 mm in diameter and subsequently sent for chemical analysis.

From the pre-dried samples of the haylage and the concentrates, the contents of dry matter (DM), mineral matter (MM), by incineration at 550ºC (4 hours), ether extract (EE) and crude protein (CP), quantified by the micro Kjeldahl method, were determined, according to AOAC (Official…, 1995) techniques. Neutral detergent fiber (NDF) content was obtained according to Van Soest *et al.* (1991), using thermostable α-amylase and acid detergent fiber (ADF), according to Goering and Van Soest (1970). To determine lignin, sulfuric acid was used at a concentration of 72%.

Total digestible nutrients (TDN) content was calculated according to equations proposed by Weiss *et al*. (1992). To determine the total dry matter, samples were taken to an oven at 105ºC for 16 hours (Silva and Queiroz, 2009) and to determine the P and Ca contents, analyses were performed according to the methodology described by Tedesco *et al*. (1995). Starch was analyzed according to the methodology described by Hendrix (1993), based on the hydrolysis of the starch contained in the sample, after extraction of soluble carbohydrates with successive washings with 80% alcohol, and colorimetric analysis of reducing sugars (glucose), with subsequent conversion of the result to starch.

Performance evaluations were carried out after solid fasting for ten hours, for individual weighing of the animals. Variables evaluated were body weight (BW), dry matter intake, expressed in kg animal day^{-1} (DMI, kg day^{-1}), dry matter intake, expressed as percentage of body weight (DMI, %BW), average daily weight gain (ADG, kg day^{-1}) and feed conversion (FC, kg kg^{-1}).

The DMI was determined by the difference between the daily amount of feed provided and the amount of leftovers from the previous day. The DMI, %BW was obtained by the ratio of DMI to the average BW for the period, multiplied by 100 (DMI, %BW =DMI/BW*100). The ADG was calculated by the difference between the final (BWf) and initial (BWi) BW of the experimental period divided by the evaluated days (ADG= BW - BWi/21 or 28 days). FC was obtained by the ratio of DMI to ADG (FC=DMI/ADG).

The ingestive behavior of the animals was analyzed in a continuous time of 48 hours, in the middle of the second feedlot period, starting at 12:00 on the first day and ending at 12:00 on the third day of evaluation. Observations were made by nine observers per shift, for 48 hours, in a rotation system every 6 hours, with readings taken at regular intervals of 3 minutes. The ingestive behavior was represented by the activities of idle, rumination, water intake and feed intake, expressed in hours day^{-1}. Also, following the same methodology, the frequency of the occurrence of feeding, drinking, urinating and defecating activities, expressed in number of times per day, were observed. In the nocturnal observation, the environment was maintained with artificial lighting since the arrival of the animals to the research unit.

On the same occasion, the apparent digestibility of DM, NDF and EE of the diet was also determined. For this, composite samples of the diets of each treatment were formed during the 48 hours of evaluation. After the end of the evaluation, samples were homogenized to form a composite sample, per pen and treatment. Before starting this evaluation, pens were properly washed and any dirt that could contaminate the samples was removed. At intervals of six hours, the total collection of feces produced inside the pens was carried out, and these were weighed and refrigerated. After 48 hours of evaluation, they were also homogenized, and a sample of 500g of each repetition was destined for analysis of DM, NDF and EE.

DM, NDF and EE of the diets and feces of each replicate were determined using the same procedures adopted in the diet analysis.

The apparent digestibility coefficients (DC) of the DM of the experimental diets were determined according to the following formula: DC (%) = [(g ingested DM – g excreted DM) ÷ g DM ingested] x 100.

To calculate the NDF and EE DC, the same formula was used, but substituting the DM values for NDF and EE, respectively.

During the experiment, feces of each pen were visually observed and daily scored. Fecal consistency was scored from 1 to 6, as follows: 1 = watery feces, not very consistent; 2 = watery feces, with little consistency, with small piles of up to 2.5cm; 3 = intermediate feces with a concentric ring and pile of 3 to 4cm, liquid; 4 = Pasty feces with concentric rings and a pile of more than 5cm; 5 = drier feces with a concentric ring and pile of more than 5cm; 6 = hard or dry feces, based on the methodology adapted from Ferreira *et al.* (2013).

At the end of the feedlot period, after fasting from solids for 10 hours, all animals were weighed before shipment to the slaughterhouse, obtaining the farm weight. Carcass gain in the feedlot period (CG), expressed in kg, was obtained by the difference between the hot carcass weight at slaughter and the initial body weight (BWi) of the animals under a theoretical carcass yield of 50%. Based on the experimental period of 70 feedlot days, the average carcass gain (ACG) was also calculated, expressed in kg day^{-1}, which is obtained by the ratio of CG to BW, as well as the efficiency of conversion of the DM consumed into carcass (ECC), expressed in kg DM kg carcass^{-1}. Warm carcass weights were used for the calculations.

Five development measures were taken in carcasses: carcass length, which is the distance between the medial cranial edge of the pubic bone and the medial cranial edge of the first rib; leg length, which is the distance between the medial cranial edge of the pubic bone and the tibiotarsal joint; and arm length, which is the distance between the olecranon tuberosity and the radiocarpal joint; arm perimeter, obtained in the middle region of the arm, encircling it with a measuring tape; and the thickness of the thigh, measured with a compass, perpendicularly to the carcass length, considering the greatest distance between the cut that separates the two half carcasses and the lateral muscles of the thigh, and fat thickness measured with a digital caliper according to the methodologies suggested by Muller (1987).

At the time of slaughter, the characterization of the body parts called non-carcass components was also carried out: heart, kidneys, liver, lungs, spleen, empty rumen-reticulum, full rumen-reticulum, full abomasum, empty abomasum and full intestines, and also the parts of the body named external carcass components: head, tongue, legs, tail, leather and testicles.

Data referring to performance, ingestive behavior and carcass traits were tested by ANOVA, followed by Tukey's test at 5% significance for means comparison, via the MIXED procedure of SAS (version 6.4). The statistical model included as fixed effects the energy source used in the concentrate, the feed additive (whole soy lecithin) and the energy source used in the concentrate x feed additive. The animal was considered as a random effect.

The following mathematical model was used: $Yijk = \mu + Ci + Lj + (C*L)ij + Bk + Eijk$, where: Yijk = response criterion; μ = overall mean common to all observations (constant); Ci = effect of the i-th treatment, where 1 = high starch concentrate and 2 = high oil concentrate; Lj = effect of the j-th treatment, where 1 = with soy lecithin and 2 = without soy lecithin; (C*L)ij = effect of the interaction between type of concentrate and soy lecithin; Bk = Effect of block of order "k", where 1 = first, 2 = second, 3 = third and 4 = fourth; and Eijk = Residual random effect.
Differences were considered significant when $P<0.05$, while trends were declared when $0.05<P<0.10$.

RESULTS

Weight gain as well as feed conversion of the animals showed no interaction of the use or not of whole soy lecithin and the type of concentrate, regardless of the evaluation period (Table 2). When analyzing these factors separately, it was also observed that there was no significant effect ($P>0.05$), however, it can be inferred that the weight gain of the animals was satisfactory, since they presented, in general, gains greater than 1.300 kg day^{-1}.

Table 2. Average daily weight gain and feed conversion of feedlot finished steers receiving different types of concentrate with or without inclusion of soy lecithin in the diet

		Feedlot period		
Concentrate	Additive	0 to 21 days	0 to 42 days	0 to 70 days
		Average daily weight gain, kg day^{-1}		
Lipid	With lecithin	1.530	1.390	1,431
Lipid	Without lecithin	1.381	1.235	1,249
Starch	With lecithin	1.470	1.274	1,279
Starch	Without lecithin	1.490	1.315	1,315
Lipid Concentrate Mean		1.455	1.313	1.340
Starch Concentrate Mean		1.480	1.295	1.297
Mean with lecithin		1.500	1.332	1.355
Mean without lecithin		1.435	1.275	1.282
SEM		0.097	0.070	0.063
P-value:				
. Concentrate (C)		0.7898	0.8081	0.5061
. Lecithin (L)		0.5387	0.4402	0.2721
. Interaction (C*L)		0.3977	0.1938	0.1229
		Feed conversion, DM intake Weight gain^{-1}		
Lipid	With lecithin	7.05	7.06	6.99
Lipid	Without lecithin	7.54	7.69	7.62
Starch	With lecithin	7.45	7.77	7.67
Starch	Without lecithin	6.97	7.48	7.44
Lipid Concentrate Mean		7.30 a	7.38 a	7.33 a
Starch Concentrate Mean		7.21 a	7.63 a	7.53 a
Mean with lecithin		7.25 A	7.42 A	7.33 A
Mean without lecithin		7.24 A	7.59 A	7.53 A
SEM		0.562	0.591	0.532
P-value:				
. Concentrate (C)		0.8900	0.6850	0.6481
. Lecithin (L)		0.9931	0.7800	0.7141
. Interaction (C*L)		0.4087	0.4537	0.4386

Mean values, in the same column, followed by different lowercase letters, are significantly different by F-Test at 5% in the comparison between types of concentrate.
Mean values, in the same column, followed by different uppercase letters, are significantly different by F-Test at 5% in the comparison between diets with and without soy lecithin.
C: Concentrate; L: Lecithin; C*L: Interaction of concentrate and lecithin; SEM: Standard error of the mean.

For dry matter intake, expressed in kg day^{-1} or in percentage of body weight, there was no interaction of the use or not of whole soy lecithin combined with concentrates from different energy sources, as well as there was no significant effect when evaluating these factors separately (Table 3).

There was a significant interaction (P<0.05) of the use of lecithin and the type of concentrate used in the diet for DM digestibility (DMD), in which the diet with lecithin combined with lipid energy concentrate showed higher digestibility (76.03%; Table 4), but when used together with energy concentrate from a starchy source, it resulted in the lowest digestibility observed, however, without difference from the diet with lipid source concentrate without the use of lecithin (73.27 and 72.60%, respectively).

Ether extract digestibility (EED) differed between types of concentrate, with higher values for the lipid energy source concentrate in relation to the starch energy source concentrate (84.18% against 79.32%). As for the variables, NDF digestibility, fecal output, in kg NM or kg DM, there was no significant difference (P>0.05).

The fecal score, as well as the DM content and pH of the feces showed no interaction of types of concentrate and the use or not of whole soy lecithin (Table 5). When evaluating these factors separately, there was no significant difference for the fecal score and DM content, with mean values of 2.62 and 18.48%, respectively. Therefore, the pH of the feces showed a significant difference (P<0.05), with lower values for animals that received whole soy lecithin in their diets (7.1) compared to those that did not (7.4).

Table 3. Dry matter intake, expressed in kg day^{-1} or per 100 kg body weight of feedlot finished steers receiving different types of concentrate with or without inclusion of soy lecithin in the diet

Concentrate	Additive	Feedlot period		
		0 to 21 days	0 to 42 days	0 to 70 days
		Dry matter intake, kg day^{-1}		
Lipid	With lecithin	10.32	9.76	9.98
Lipid	Without lecithin	10.04	9.16	9.25
Starch	With lecithin	10.58	9.66	9.76
Starch	Without lecithin	10.41	9.62	9.73
Lipid Concentrate Mean		10.18 a	9.46 a	9.62 a
Starch Concentrate Mean		10.50 a	9.64 a	9.75 a
Mean with lecithin		10.45 A	9.71 A	9.87 A
Mean without lecithin		10.23 A	9.39 A	9.49 A
SEM		0.420	0.364	0.355
P-value:				
. Concentrate (C)		0.4664	0.6287	0.7255
. Lecithin (L)		0.6097	0.4029	0.3083
. Interaction (C*L)		0.9034	0.4739	0.3587
		Dry matter intake, % BW		
Lipid	With lecithin	2.08	1.92	1.90
Lipid	Without lecithin	2.04	1.82	1.78
Starch	With lecithin	2.18	1.94	1.91
Starch	Without lecithin	2.10	1.89	1.86
Lipid Concentrate Mean		2.06 a	1.87 a	1.84 a
Starch Concentrate Mean		2.14 a	1.92 a	1.89 a
Mean with lecithin		2.13 A	1.93 A	1.91 A
Mean without lecithin		2.07 A	1.86 A	1.82 A
SEM		0.060	0.051	0.052
P-value:				
. Concentrate (C)		0.2231	0.3913	0.4626
. Lecithin (L)		0.3544	0.1849	0.1713
. Interaction (C*L)		0.7625	0.6548	0.5188

Mean values, in the same column, followed by different lowercase letters, are significantly different by F-Test at 5% in the comparison between types of concentrate.
Mean values, in the same column, followed by different uppercase letters, are significantly different by F-Test at 5% in the comparison between diets with and without soy lecithin.
BW: body weight; C: Concentrate; L: Lecithin; C*L: Interaction of concentrate and lecithin; SEM: Standard error of the mean.

Table 4. Fecal output and apparent digestibility of dry matter, neutral detergent fiber and ether extract of feedlot finished steers receiving different types of concentrate with or without inclusion of soy lecithin in the diet

	Soy lecithin		Mean	SEM	*P*-value		
Concentrate	With	Without			C	L	(C*L)
	Fecal output, kg NM day^{-1}						
Lipid	12.68	13.56	13.12 A	0.902	0.2646	0.5885	0.1589
Starch	15.14	13.25	14.20 A				
Mean	13.91 a	13.41 a					
	Fecal output, kg DM day^{-1}						
Lipid	2.37	2.54	2.46 A	0.130	0.3527	0.6164	0.1012
Starch	2.73	2.43	2.58 A				
Mean	2.55 a	2.49 a					
	DM digestibility, %						
Lipid	76.03 a	72.60 bc	74.32	0.958	0.2625	0.6278	0.0409
Starch	73.27 c	74.41 b	73.84				
Mean	74.65	73.51					
	NDF digestibility, %						
Lipid	57.87	53.03	55.45 A	1.587	0.2581	0.2616	0.0979
Starch	53.02	54.05	53.53 A				
Mean	55.44 a	53.54 a					
	EE digestibility, %						
Lipid	85.44	82.92	84.18 A	1.886	0.0299	0.8701	0.2741
Starch	78.38	80.26	79.32 B				
Mean	81.91 a	81.59 a					

Mean values followed by different uppercase letters, in the same column, or different lowercase letters, in the same row, are significantly different by F-Test at 5%.
NM: Natural matter; C: Concentrate; L: Lecithin; C*L: Interaction of concentrate and lecithin; SEM: Standard error of the mean.

Table 5. Fecal score, fecal dry matter content and fecal pH of feedlot finished steers receiving different types of concentrate with or without inclusion of soy lecithin in the diet

	Soy lecithin		Mean	SEM	*P*-value		
Concentrate	With	Without			C	L	(C*L)
	Fecal score						
Lipid	2.72	2.56	2.64 A	0.119	0.6993	0.5185	0.5314
Starch	2.59	2.59	2.59 A				
Mean	2.66 a	2.58 a					
	Fecal dry matter content, %						
Lipid	18.74	18.70	18.72 A	0.583	0.4460	0.9104	0.8677
Starch	18.18	18.34	18.26 A				
Mean	18.46 a	18.52 a					
	Fecal pH						
Lipid	7.1	7.4	7.3 A	0.097	0.5358	0.0243	0.5358
Starch	7.1	7.3	7.2 A				
Mean	7.1 b	7.4 a					

Mean values followed by different uppercase letters, in the same column, or different lowercase letters, in the same row, are significantly different by F-Test at 5%.
C: Concentrate; L: Lecithin; C*L: Interaction of concentrate and lecithin; SEM: Standard error of the mean.

Regarding ingestive behavior expressed in hours day^{-1} (Table 6), there was no interaction of types of concentrate and the use or not of whole soy lecithin, and there was also no significant difference when evaluating these factors separately.

As for the ingestive behavior expressed in times day^{-1} (Table 7), there was no interaction of types of concentrate and the use or not of whole soy lecithin. When evaluating these factors separately, there was also a significant difference (P>0.05) for the variables eating, solid and liquid excretions, however, water consumption activity was influenced by the type of concentrate, where the animals fed with a concentrate of lipid energy source made fewer visits to the water trough compared to those fed a starchy energy source concentrate (8.00 against 9.56 times day^{-1}, respectively).

Carcass gains showed no interaction of types of concentrates and the use or not of whole soy lecithin (Table 8). However, the carcass gain during the total feedlot period and the daily carcass gain tended to differ when evaluating the concentrate separately, with animals fed the lipid energy source concentrate showing the highest gains.

Table 9 lists the quantitative characteristics of carcasses at the time of slaughter, of these, the carcass yield showed interaction (P<0.05) of types of concentrates and the use or not of whole soy lecithin.

Animals fed energy concentrate from a lipid source, receiving whole soy lecithin had the highest mean value for carcass yield (57.20%), while animals fed an energy concentrate from a starchy source, receiving whole soy lecithin showed the lowest mean value for carcass yield (56.02%). When evaluating the factors separately, the carcass yield also showed a significant difference (P<0.05) between types of concentrate, with higher values for animals fed energy concentrate from a lipid source (56.85%).

Table 6. Ingestive behavior (hours day^{-1}), of feedlot finished steers receiving different types of concentrate with or without inclusion of soy lecithin in the diet

	Soy lecithin		Mean	SEM	*P*-value		
Concentrate	With	Without			C	L	(C*L)
		Consuming feed, hours day^{-1}					
Lipid	2.22	2.52	2.37 A	0.100	0.2109	0.3113	0.0905
Starch	2.54	2.46	2.50 A				
Mean	2.38 a	2.49 a					
		Consuming water, hours day^{-1}					
Lipid	0.30	0.32	0.33 A	0.054	0.6705	0.9104	0.8048
Starch	0.33	0.34	0.31 A				
Mean	0.32 a	0.32 a					
		Rumination, hours day^{-1}					
Lipid	5.00	4.43	4.71 A	0.342	0.6771	0.4350	0.4194
Starch	4.86	4.87	4.86 A				
Mean	4.93 a	4.65 a					
		Idle, hours day^{-1}					
Lipid	16.52	16.98	16.75 A	0.339	0.2088	0.3965	0.6439
Starch	16.22	16.36	16.29 A				
Mean	16.37 a	16.67 a					

Mean values followed by different uppercase letters, in the same column, or different lowercase letters, in the same row, are significantly different by F-Test at 5%.

C: Concentrate; C: Concentrate; L: Lecithin; C*L: Interaction of concentrate and lecithin; SEM: Standard error of the mean.

Table 7. Ingestive behavior, represented by the frequency of activities performed (times day^{-1}), of feedlot finished steers receiving different types of concentrate with or without inclusion of soy lecithin in the diet

	Soy lecithin		Mean	SEM	*P*-value		
Concentrateo	With	Without			C	L	(C*L)
		Eating, times day^{-1}					
Lipid	15.62	18.75	17.18 A	1.308	0.2293	0.1494	0.4377
Starch	18.37	19.37	18.87 A				
Mean	17.00 a	19.06 a					
		Water consumption, times day^{-1}					
Lipid	8.12	7.87	8.00 B	0.359	0.0018	0.8657	0.6141
Starch	9.50	9.62	9.56 A				
Mean	8.81 a	8.75 a					
		Solid excretions, times day^{-1}					
Lipid	7.3	7.5	7.4 A	0.731	0.9867	0.6322	0.4243
Starch	7.9	6.9	7.4 A				
Mean	7.6 a	7.2 a					
		Liquid excretions, times day^{-1}					
Lipid	7.0	8.0	7.5 A	0.531	0.1295	0.8018	0.0660
Starch	9.0	7.7	8.4 A				
Mean	8.0 a	7.9 a					

Mean values followed by different uppercase letters, in the same column, or different lowercase letters, in the same row, are significantly different by F-Test at 5%.
C: Concentrate; L: Lecithin; C*L: Interaction of concentrate and lecithin; SEM: Standard error of the mean.

Table 8. Total carcass gain in the finishing period (CG), daily carcass gain (DCG) and efficiency of conversion of dry matter into carcass (ECC), of feedlot finished steers receiving different types of concentrate with or without inclusion of soy lecithin in the diet

	Soy lecithin		Mean	SEM	*P*-value		
Concentrate	Soy	Soy lecithin			C	L	(C*L)
		CG, kg					
Lipid	93.20	80.72	86.96 A	4.741	0.0944	0.5410	0.0771
Starch	74.87	81.32	78.10 A				
Mean	84.03 a	81.02 a					
		DCG, kg day^{-1}					
Lipid	1.331	1.153	1.242 A	0.051	0.0941	0.5375	0.0765
Starch	1.069	1.161	1.115 A				
Mean	1.200 a	1.157 a					
		ECC, kg DM kg gain^{-1}					
Lipid	7.53	8.07	7.80 A	0.635	0.1169	0.8053	0.2933
Starch	9.33	8.47	8.90 A				
Mean	8.43 a	8.27 a					

Mean values followed by different uppercase letters, in the same column, or different lowercase letters, in the same row, are significantly different by F-Test at 5%.
C: Concentrate; L: Lecithin; C*L: Interaction of concentrate and lecithin; SEM: Standard error of the mean.

Table 9. Farm weight and quantitative characterization of carcasses at slaughter of feedlot finished steers receiving different types of concentrate with or without inclusion of soy lecithin in the diet

	Soy lecithin		Mean	SEM	*P*-value		
Concentrate	With	Without			C	L	(C*L)
		Farm weight, kg					
Lipid	580	564	572.0 A	13.090	0.6642	0.8893	0.3336
Starch	560	571	566.0 A				
Mean	569.9 a	568.0 a					
		Warm carcass weight, kg					
Lipid	333	319	326.0 A	8.420	0.2621	0.8853	0.1773
Starch	310	321	315.5 A				
Mean	321.5 a	320.0 a					
		Carcass yield, %					
Lipid	57.20 a	56.50 ab	56.85 A	0.187	0.0144	0.6493	0.0093
Starch	56.02 b	56.55 ab	56.28 B				
Mean	56.61	56.52					
		Fat thickness, mm					
Lipid	5.63	5.42	5.53 A	0.497	0.5968	0.7770	0.9027
Starch	5.83	5.75	5.79 A				
Mean	5.73 a	5.59 a					
		Carcass length, cm					
Lipid	136.1	134.5	135.3 A	1.672	0.5046	0.7663	0.2332
Starch	135.1	137.7	136.4 A				
Mean	135.6 a	136.1 a					
		Thigh thickness, cm					
Lipid	27.6	26.9	27.3 A	0.443	0.1553	0.4659	0.4659
Starch	26.6	26.6	26.6 A				
Mean	27.1 a	26.8 a					
		Arm length, cm					
Lipid	39.75	40.47	40.11 A	0.757	0.9488	0.3329	0.9488
Starch	39.75	40.57	40.16 A				
Mean	39.75 a	40.52 a					
		Arm perimeter, cm					
Lipid	41.7	42.1	41.9 A	0.458	0.2509	0.5809	0.7710
Starch	42.4	42.6	42.5 A				
Mean	42.1 a	42.4 a					

Mean values followed by different uppercase letters, in the same column, or different lowercase letters, in the same row, are significantly different by F-Test at 5%.
C: Concentrate; L: Lecithin; C*L: Interaction of concentrate and lecithin; SEM: Standard error of the mean.

For the other variables analyzed, there was no significant effect of treatments, with an average of 568.94kg farm weight, 320.77kg hot carcass weight, 5.66mm fat thickness, 135.89cm carcass length, 26.97cm thigh thickness, 40.13cm arm length and 42.13cm arm perimeter.

Table 10 presents the non-carcass components, parameters that showed no interaction between types of concentrates and the use or not of whole soy lecithin. However, when these factors were evaluated separately, there was a significant effect ($P<0.05$) for the empty rumen-reticulum weight.

Animals that received the lipid energy source concentrate had lower weight of these empty organs compared to those fed the starchy energy source concentrate (1.78kg against 2.02kg), and the animals receiving whole soy lecithin on the diet also had lower weight of these organs (1.81kg) compared to those who did not receive it (1.99kg).

Table 10. Average weights of non-carcass components, expressed as % body weight of feedlot finished steers receiving different types of concentrate with or without inclusion of soy lecithin in the diet

	Soy lecithin		Mean	SEM	*P*-value		
Concentrate	With	Without			C	L	(C*L)
		Heart weight, % BW					
Lipid	0.35	0.35	0.35 A	0.023	0.4992	0.4376	0.5661
Starch	0.38	0.35	0.36 A				
Mean	0.36 a	0.35 a					
		Lung weight, % BW					
Lipid	0.82	0.82	0.82 A	0.053	0.8716	0.7298	0.6299
Starch	0.79	0.83	0.81 A				
Mean	0.81 a	0.83 a					
		Spleen weight, % BW					
Lipid	0.43	0.46	0.45 A	0.039	0.6932	0.5661	0.8312
Starch	0.46	0.47	0.46 A				
Mean	0.44 a	0.47 a					
		Kidney weight, % BW					
Lipid	0.21	0.22	0.21 A	0.011	0.8341	0.6764	1.0000
Starch	0.22	0.22	0.22 A				
Mean	0.21 a	0.22 a					
		Liver weight, % BW					
Lipid	1.09	1.09	1.09 A	0.048	0.1775	0.3715	0.4533
Starch	1.12	1.20	1.16 A				
Mean	1.11 a	1.15 a					
		Full rumen-reticulum weight, % BW					
Lipid	5.44	5.61	5.53 A	0.253	0.1407	0.6275	0.8707
Starch	5.89	5.98	5.94 A				
Mean	5.67 a	5.80 a					
		Empty rumen-reticulum weight, % BW					
Lipid	1.72	1.85	1.78 B	0.079	0.0154	0.0479	0.5736
Starch	1.91	2.13	2.02 A				
Mean	1.81 b	1.99 a					
		Empty abomasum weight, % BW					
Lipid	0.49	0.47	0.48 A	0.053	0.6997	0.6667	0.9093
Starch	0.47	0.44	0.46 A				
Mean	0.48 a	0.46 a					
		Full abomasum weight, % BW					
Lipid	0.52	0.51	0.52 A	0.039	0.6134	0.9189	0.8388
Starch	0.49	0.49	0.49 A				
Mean	0.51 a	0.50 a					
		Full intestines, % BW					
Lipid	2.96	3.41	3.18 A	0.199	0.1997	0.2397	0.3396
Starch	3.44	3.48	3.46 A				
Mean	3.20 a	3.45 a					

Mean values followed by different uppercase letters, in the same column, or different lowercase letters, in the same row, are significantly different by F-Test at 5%.
BW: Body weight; C: Concentrate; L: Lecithin; C*L: Interaction of concentrate and lecithin; SEM: Standard error of the mean.

The other components showed no significant difference between their weights, where they had mean values of 0.35; 0.82; 0.46; 0.22; 1.13; 5.73; 1,90; 0.47; 0.50; and 3.32% body weight for heart, lung, spleen, kidneys, liver, full rumen-reticulum, empty rumen reticulum empty abomasum, full abomasum, and full intestines, respectively.

The average weight of the external components of the carcass was not affected by the concentrates used or by the use or not of whole soy lecithin (Table11). Mean values were, in % body weight of 2.24; 0.14; 1.88; 0.25; 8.96; and 0.29% body weight for head, tongue, legs, tail, leather, and testicles.

Table 11. Average weights of external carcass components, expressed as % body weight of feedlot finished steers receiving different types of concentrate with or without inclusion of soy lecithin in the diet

	Soy lecithin		Mean	SEM	*P*-value		
Concentrate	With	Without			C	L	(C*L)
		Head weight, % BW					
Lipid	2.23	2.19	2.21 A	0.041	0.2631	0.9531	0.3882
Starch	2.25	2.28	2.26 A				
Mean	2.24 a	2.24 a					
		Tongue weight, % BW					
Lipid	0.16	0.13	0.15 A	0.010	0.7088	0.3918	0.1161
Starch	0.14	0.16	0.15 A				
Mean	0.15 a	0.15 a					
		Legs weight, % BW					
Lipid	1.89	1.89	1.89 A	0.091	0.9148	0.8726	0.8726
Starch	1.86	1.89	1.88 A				
Mean	1.88 a	1.89 a					
		Tail weight, % BW					
Lipid	0.25	0.20	0.23 A	0.039	0.3697	0.2622	0.9512
Starch	0.29	0.24	0.26 A				
Mean	0.27 a	0.22 a					
		Leather weight, % BW					
Lipid	8.51	9.35	8.93 A	0.352	0.8739	0.6751	0.0826
Starch	9.26	8.72	9.00 A				
Mean	8.89 a	9.04 a					
		Testicle weight, % BW					
Lipid	0.27	0.31	0.29 A	0.029	0.7754	0.9674	0.2861
Starch	0.32	0.28	0.30 A				
Mean	0.30 a	0.29 a					

Mean values followed by different uppercase letters, in the same column, or different lowercase letters, in the same row, are significantly different by F-Test at 5%.
BW: Body weight; C: Concentrate; L: Lecithin; C*L: Interaction of concentrate and lecithin; SEM: Standard error of the mean.

DISCUSSION

In a previous study, Li *et al.* (2017) found no significant effect on feed conversion and dry matter intake when supplementing beef cattle with soy lecithin. The lack of a significant difference (P>0.05) in these parameters in the present study, regardless of the use of whole soy lecithin and the concentrate used, is probably because both diets are isoproteic and isoenergetic, and for presenting very similar NDF content (Table 1), a component that directly influences the feed intake of the animals.

The highest mean value for DM digestibility using the combination of whole soy lecithin and concentrate from a lipid energy source (76.03%) and the highest ether extract digestibility (81.18%) for the concentrate also from a lipid source (Table 4) is due to the presence of whole soy lecithin.

Its emulsifying action makes the fiber free of fat particles, favoring its digestion (Drago, 2019). This emulsification effect also helps in the digestibility of the lipid fraction of the diet (ether extract), due to its ability to promote the emulsification of fatty acids, making them more available for biohydrogenation, which enhances their absorption in the small intestine (Rico *et al*., 2017; Abel-Caines *et al*., 1998).

When there is high intestinal fermentation and greater production of short-chain fatty acids, there may be a reduction in fecal pH, which was observed in the present study (Table 5). Values of pH below 7.0 in the intestinal lumen can cause the disintegration of its mucus layer, which is responsible for protecting the intestinal epithelium, and can also lead to dysbiosis (Neubauer *et al*., 2020).

Nevertheless, in the present study, even with the reduction in fecal pH, it is not possible to affirm the occurrence of intestinal acidosis or dysbiosis, since the fecal score did not change, and the loss of consistency is a strong indication of injury at the level of the intestine or rumen.

When evaluating the ingestive behavior, the smaller number of times the animals fed with energy concentrate from a lipid source went to the drinking fountain to drink water (Table 7) indicates the longer time spent in this activity, even with no significant difference, numerically these animals remained longer drinking water (Table 6), which perhaps reduced the number of visits to the water trough.

The non-alteration in the other parameters evaluated in the ingestive behavior is positive, since the inclusion of lipids or starch in the diet can cause metabolic disorders (Baldassini *et al*., 2021; Pitta *et al*., 2018). Such disorders certainly and directly influence the ingestive behavior of the animals, and an important point to be highlighted in relation to the non-alteration in the ingestive behavior is that the animals did not promote diet selection.

The trends of greater carcass gains in the total feedlot period and daily for the animals that received whole soy lecithin and consumed the concentrate from a lipid energy source (Table 8), suggests that it is a consequence of the presence of soy lecithin. As its action improves feed digestibility, the absorption of both fatty acids and other nutrients is increased, and when these improvements reach the carcass, it is important for the rancher, as the remuneration is given per kg marketed carcass, which enables the use of emulsifiers in the diet.

Higher mean values for carcass yield of animals fed the lipid energy source concentrate combined with whole soy lecithin (Table 9) are probably related to carcass gains that tended to be higher for animals on these treatments. Importantly, carcass yield is an economically important parameter, as the price to be paid per carcass is determined by its weight, and also contributes to the search for maximum efficiency in production systems, where the objective is to produce more, with quality, increasing profitability (Zhang *et al*., 2019).

Lower weights of rumen-reticulum organs for animals fed the energy concentrate from a lipid source and supplemented with whole soy lecithin is positive. According to Fitzsimons *et al.* (2014), inefficient animals have greater rumen-reticulum weight, and the same authors infer that the weight of these empty organs can be a parameter to analyze the variation in feed efficiency.

CONCLUSION

The supply of whole soy lecithin alone reduced the fecal pH and the weight of the empty rumen-reticulum, whereas the energy concentrate from a lipid source alone showed higher ether extract digestibility and resulted in higher carcass yield of feedlot steers. The use of whole soy lecithin combined with a diet containing energy concentrate derived from a lipid source promoted improvements in the dry matter digestibility of the diet and in the carcass yield of feedlot steers.

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