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Propolis and essential oils additives in the diets improved animal performance and feed efficiency of bulls finished in feedlot

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ABSTRACT. This work was realized to evaluate the effect of natural additives as propolis or essential oils addition on animal performance, feed intake, apparent digestibility and carcass characteristics of bulls finished in feedlot. Thirty bulls (½ Aberdeen Angus *vs.* ½ Nellore) were randomly assigned in one of three diets (control – CON, propolis – PRO and essential oils – OIL) and kept in feedlot (individual pen) during 55 days. CON diet consists of 45% corn silage, 40% concentrate (cracked corn, soybean meal, limestone and mineral salt) and 15% glycerine. The PRO group received same diet that control plus 3 grams to animal day^{-1} of propolis dry added to the concentrate. The OIL oils group received same diet that control and 3 grams to animal day^{-1} of essential oils (cashew and castor oils) added to the concentrate. Final weight, average daily gain, feed efficiency and hot carcass weightwere better for bulls supplemented with essential oils and propolis than for bulls fed control diet. The feed intake, apparent digestibility, carcass conformation and tissue composition were unaffected by the additives addition. The addition of propolis and essential oils in the diets of bulls finished in feedlot improve animal performance and carcass weight.

Keywords: additives, glycerine, ruminant, plant oils.

Propolis e óleos essenciais na dieta melhoraram o desempenho animal e eficiência alimentar de bovinos não castrados terminados em confinamento

RESUMO. Este trabalho foi realizado para avaliar o efeito da adição de própolis e óleos essenciais sobre o desempenho animal, ingestão de alimentos, digestibilidade aparente, características de carcaça de bovinos não castrados terminados em confinamento. Trinta bovinos (½ Aberdeen Angus *vs.* ½ Nelore) foram designados ao acaso para uma das três dietas (Controle – CON, Própolis – PRO e Óleos essenciais – OIL) e mantidos em confinamento (baias individuais) durante 55 dias. A dieta CON era composta de 45% de silagem de milho, 40% de concentrado (milho moído, farelo de soja, calcário e sal mineral) e 15% de glicerina. O grupo PRO recebeu a mesma dieta que o grupo controle mais 3 gramas animal dia^{-1} propolis seco adicionado ao concentrado. O grupo OIL recebeu a mesma dieta que o controle mais gramas animal dia^{1} de óleos essenciais (óleos de mamona e caju) adicionados ao concentrado. O peso final, ganho médio diário, eficiência alimentar e peso de carcaça quente foram melhores para os bovinos suplementados com óleos essenciais e própolis do que para os animais da dieta controle. A ingestão de alimentos, digestibilidade aparente, conformação de carcaça e composição de tecidos não foram alterados pela adição de aditivos. A adição de própolis e óleos essenciais na dieta de bovinos melhorou o desempenho animal e peso de carcaça.

Palavras-chave: aditivos, glicerina, ruminantes, óleos de plantas.

Introduction

For cattle finishing system with high energy requirements, it is necessary to increase the use of grains and cereals (DUCATTI et al., 2009; PRADO et al., 2009; DIAN et al., 2010). When ruminants are fed with finishing diets containing large amounts of cereal grain, the ruminal pH decrease drastically and can disturb ruminal fermentation (GONZÁLEZ et al., 2012). To modulate rumen fermentation, diets are supplemented with ionophores or natural additives (BENCHAAR et al., 2006a; ZAWADZKI et al., 2011b). However, in recent years, there is major debate over the effects of agricultural antibiotic use on human health. There is concern that the use of antibiotics in food animals can lead to dissemination of antibiotic resistance genes from animals to humans, especially through to human bacterial pathogens (RUSSELL; HOULIHAN, 2003). The World Health Organization classifies the appearance of antibiotic resistance as one of the biggest threats to human health. Therefore, there is a need for internationally coordinated, interdisciplinary, multi-agency (human and animal health) efforts to encourage research on promising products alternatives (BENCHAAR et al., 2008). Alternative antibiotics in food animals can be natural products with antimicrobial activity (BENCHAAR et al., 2008).

Propolis is resin collected by the bees with composition complex, has numerous pharmacological properties, including antimicrobial activity (RIGHI et al., 2011). It's a promising alternative to ionophores. Studies on ruminant the propolis have shown positive results such as increase dry matter and crude protein digestibilities and decreases of number of methanogenic bacteria (PRADO et al., 2010a and b), better feed efficiency, animal performance (ZAWADZKI et al., 2011b) and unaffected composition on meat quality (VALERO et al., 2011; ZAWADZKI et al., 2011a).

Plant oils may also be able to replace the use of antibiotics additives in ruminant nutrition because many plants produce secondary metabolites that have antimicrobial properties (BENCHAAR et al., 2008; ZHANG et al., 2010). These compounds have been shown to modulate ruminal fermentation and improve nutrient utilisation in ruminants (CALSAMIGLIA et al., 2007; HART et al., 2008). The well-documented antimicrobial activities of plant oils and their active components have prompted a number of scientists to examine the ability of these secondary metabolites to manipulate rumen microbial fermentation and to improve the production efficiency of ruminants (BENCHAAR et al., 2008; HART et al., 2008).

The goal of this work was to evaluate the effects of propolis and essential oil (cashew and castor oils) additives on animal performance, intake, apparent digestibility and carcass characteristics of crossbred bulls finished in feedlot.

Material and methods

Local, animals, housing and diets

This experiment was approved by the Department of Animal Production at the State University of Maringá (CIOMS/OMS, 1985). It was conducted at the Rosa & Pedro Sector of Experimental Farm at the Iguatemi, Paraná State, south of Brazil.

Thirty bulls (½ Aberdeen Angus *vs.* ½ Nellore) with 20-months-old and 388 ± 6.3 kg weight were used in this study. The bulls were housed in individual pens (10 m^2) equipped with feeders (that were 60 cm deep and 2 m length) and drinkers with capacity of 250 litres of water. The bulls were fed *ad libitum* (weighed and supplied daily 8 and 16h). Ten bulls received diet control, ten received diet propolis and ten bulls received diet essential oils.

The diet formulation and quantity were designed to provide a weight gain of 1.5 kg day^{-1}, according to the NRC (2000). The chemical compositions of the ingredients of the diets are presented in Table 1. The control diet consisted of 45% corn silage, 40% concentrate (cracked corn, soybean meal, limestone and mineral salt) and 15% glycerine. The propolis diet consisted same diet that control plus 3 grams to animal day^{-1} of propolis premix added to the concentrate. The essential oils diet consisted same diet that control plus 3 grams to animal day^{-1}of essential oils premix added to the concentrate (Table 2).The glycerine of half purity was produced in a soy-diesel facility (BIOPAR, Rolândia, Paraná, State, Brazil) and this was used as a substitute for corn. The propolis product contained 0.054 mg g^{-1} of total flavonoids in chrysine. The essential oil was formulated at Oligo Basics Agroindustrial Laboratory Ltda. and contained ricinoleic acid (extracted from castor oil seed), anacardic acid, cardanol and cardol (extracted from the cashew nut shell liquid and was used vermiculite for the essential oil solidification).

Table 1. Chemical composition of ingredients and diets (g kg^{-1} of DM).

Ingredients	g kg^{-1}									
	DM[1]	OM[2]	CP[3]	Ash	TDN[4]	EE[5]	NDF[6]	ADF[7]	CT[8]	NFC[9]
Corn silage	266	964	72.7	35.4	620	18.2	524	316	873	349
Corn grain	900	987	93.4	12.5	900	33.5	154	49.3	860	706
Soybean meal	896	941	488	58.3	820	30.0	106	103	422	316
Glycerine	942	10.0	1.00	47.6	807	60.0				
Urea	990		262							
Mineral salt[10]	990			100						
Limestone	990			950						
Propolis dry	146									
Essential oils	976	559		440		150				
Diet	434	807	115	40.1	738	29.8	292	166	689	396

[1]Dry matter. [2]Organic matter. [3]Crude protein. [4]Total digestible nutrients, from NRC (2000). [5]Ether extract. [6]Neutral detergent fiber. [7]Acid detergent fiber. [8]Total carbohydrates. [9]Non fibrous carbohydrates. [10]Guarantee levels (per kg): calcium - 175 g; phosphorus – 100 g; sodium – 114 g; selenium – 15 g; magnesium – 15 g; zinc – 6.004 mg; manganese – 1.250 mg; copper – 1.875; iodine – 180 mg; cobalt – 125 mg; selenium – 30 mg; fluorine (maximum) – 1.000 mg.

Table 2. Diets composition (g kg^{-1} of dry matter).

Ingredients	Diets		
	CON[1]	PRO[2]	OIL[3]
Corn silage	455	455	455
Corn grain	304	304	304
Soybean meal	70.8	70.8	70.8
Glycerine	154	154	154
Urea	7.26	7.26	7.26
Mineral salt	4.47	4.47	4.47
Limestone	4.47	4.47	4.47
Propolis dry		0.55	
Essential oils			0.55

[1]Control, [2]Propolis dry, [3]Essential oils.

Animal performance and feed intake

To evaluate animal performance, the bulls were weighed once at the beginning of the experiment and then once every 14 days (after a fasting from solid feed for a period of 16 hours).The daily feed intake was estimated as the difference between the supplied feed and the refusals in the trough. During the collection period, samples of the supplied feed and refusals were collected daily, and a representative composite sample was drafted for each animal in each diet. The feed conversion was calculated dividing the daily feed intake per the average daily gain.

Apparent total-tract digestibility

To calculate the apparent digestibility coefficient of the dry matter and other nutrients, food, refusals and faeces were collected for a period of five days starting on the 40th day of the feedlot period. After drying at 55ºC for 72h, the samples were ground in a feed mill and passed through a 2 mm sieve to analyses of internal marker and 1mm sieve in preparation for chemical analyses. To estimate the flux of the faecal dry matter, indigestible dry matter (iDM) was used as an internal marker (ZEOULA et al., 2002), incubated for 240h in the rumen of a Holstein bull. Faecal excretion (FE) was calculated using the following equations:

Faecal excretion = kg iDM intake kg^{-1} iDM concentration in faeces

The apparent digestibility coefficients for dry matter and nutrients were estimated according to the formula:

Digestibility coefficients = [(Intake – Excreted) $Intake^{-1}$] x 100.

Chemical analyses

The dry matter content of the samples was determined by drying at 105°C for 24h according to the methods described by the AOAC (1998) (method 930.15). The organic matter content was calculated as the difference between the dry matter and ash contents, with ash determined by combustion at 550°C for 5h (AOAC, 1998). The neutral detergent fiber contents were determined using the methods described by Van Soest et al. (1991) and acid detergent fiber (AOAC, 1998) (method 973.18). The nitrogen (N) content was determined by the Kjeldahl method (AOAC, 1998) (Method 976.05), and the total carbohydrates were calculated according Sniffen et al. (1992) using the following equation:

Total carbohydrates = 100 – (% crude protein +% ether extract +% Ash)

Non-fibrous carbohydrates (NFC) were determined as the difference between the TC and NDF. The total digestible nutrient (TDN) content of the diets was obtained by the methodology described by Kearl (1982). The samples were analysed at the laboratory of Feed Analyses and Animal Nutrition at the State University of Maringá.

Carcass characteristics measured by ultrasound

All measurements *in vivo* on were obtained from the 13th rib of right side of each animal by the same operator. The last day feedlot, the *Longissimus* muscle area, fat thicken and marbling were measured using a dynamic imaging real time ultrasound scanner (model – Concept MLV, with 3.5 MHz transducer). The probe was placed perpendicular to the horizontal trajectory of the rib eye muscle at the 13th thoracic rib until bones appeared on the monitor. When a satisfactory image was achieved, it was frozen on the monitor and the depth of the eye muscle (measured at 4 points), fat thickness (measured at 3 points) and marbling was then measured using internal electronic callipers and measurement software.

Carcass characteristics measured *post-mortem*

The bulls were slaughtered according to industrial practices in Brazil at a commercial slaughterhouse located 10 km from the Iguatemi Experimental Farm. The carcasses were then identified and chilled for 24h at 4ºC.

The hot carcass weight was determined soon after slaughter and prior to carcass chilling. The hot carcass dressing was defined by the ratio hot carcass weight/live weight multiplied by 100. The carcass conformation was determined after excluding fat thickness where the highest value indicated the best conformation. Conformation was evaluated by the following scale – 1 to 3 inferior, 4 to 6 poor, 7 to 9 regular, 10 to 12 good, 13 to 15 very good, 16 to 18 superior.

Longissimus muscle area, fat thickness and marbling were determined after 24 hours post slaughter. *Longissimus* muscle area was measured using a compensating planimeter that measures the area of irregular shaped objects. Fat thickness was measured using a calliper to average three points over the *Longissimus* muscle. Marbling was measured using scoring system (18 to 16 – abundant, 15 to 13 – moderate, 12 to 10, mean, 9 to 7 small, 6 to 4, light and 3 to 1 traces).

The tissue was estimated by composition percentage muscle, fat and bone were physically separated from the *Longissimus* section, which corresponds to the 9th, 10th and 11th ribs, according to the methods of Hankins and Howe (1946).

Statistical analysis

The experimental design was completely randomised with three diets and ten animals per treatment. The results were statistically interpreted using SAS (2004) software. According to statistical model:

$$Yij = \mu + Ti + eij,$$

where:
Yij = dependent variables;
Ti = treatment effect;
eij = residual error.

Results and discussion

Animal performance and feed intake

The initial weight was higher (p > 0.05) for bulls fed with OIL diet and lowers for bulls fed with CON and PRO diets (Table 3). However, the final weight and average daily gain was higher (p > 0.05) for bulls fed the OIL diet; intermediate for bulls fed the PRO diet and lower for bulls fed CON diet (Table 3).

The dry matter intake and other nutrients was similar (p > 0.05) for bulls fed the three diets (Table 3).

The dry matter efficiency was better (p > 0.05) for bulls fed the OIL diet (0.16) than for those fed the CON diet (0.14, Table 3).

Table 3. Animal performance, feed intake and feed efficiency of crossbred bulls finished in feedlot fed with concentrated diet contained propolis or essential oils.

Item	Diets				
	CON[1]	PRO[2]	OIL[3]	SEM[1]	p < F
N	10	10	10		
Initial weight, kg	382b	385b	396a	6.28	0.05
Final weight, kg	457c	469b	484a	8.02	0.05
Average daily gain, kg	1.38c	1.55b	1.63a	0.06	0.05
Dry matter intake, kg day^{-1}	9.72	9.90	10.43	0.33	0.67
Dry matter intake, % LW^{-1}	2.31	2.30	2.39	0.06	0.82
Organic matter intake, kg day^{-1}	9.34	9.51	10.02	0.31	0.67
Crude protein intake, kg day^{-1}	1.15	1.17	1.24	0.04	0.64
Ether extract intake, kg day^{-1}	0.29	0.30	0.31	0.01	0.61
Neutral detergent fiber intake, kg day^{-1}	2.65	2.75	2.88	0.10	0.67
Neutral detergent fiber intake % LW^{-1}	0.63	0.64	0.66	0.02	0.83
Acid detergent fiber intake, kg day^{-1}	1.51	1.55	1.63	0.06	0.72
Acid detergent fiber/LW, %	0.36	0.36	0.37	0.01	0.86
Total carbohydrates intake, kg day^{-1}	7.89	8.04	8.47	0.27	0.67
Non fibrous carbohydrate intake, kg day^{-1}	5.24	5.29	5.59	0.17	0.67
Total digestible nutrient intake, kg day^{-1}	7.17	7.31	7.70	0.24	0.67
Dry matter efficiency[5]	0.14b	0.15ab	0.16a	0.01	0.04

[1]Control, [2]Propolis dry, [3]Essential oils. [4]Standard error of mean. [5]Avarage daily gain/Dry matter intake (kg). Means followed by different letters are different.

Apparent total-tract digestibility

In the present study, the dry matter apparent digestibility and others nutrients were similar (p > 0.05) among the CON, PRO and OIL diets (Table 4).

Table 4. Apparent digestibility of crossbred bulls finished in feedlot fed with concentrated diet contained propolis or essential oils.

Item	Diets			SEM[4]	p < F
	CON[1]	PRO[2]	OIL[3]		
N	10	10	10		
Dry matter	69.8	70.9	69.9	0.75	0.83
Organic matter	64.2	66.1	65.1	0.83	0.68
Crude protein	64.3	65.0	64.6	0.73	0.93
Ether extract	75.5	78.4	77.1	1.03	0.52
Neutral detergent fiber	48.3	49.4	48.2	0.95	0.86
Acid detergent fiber	44.5	46.3	44.6	0.91	0.68
Non fibrous carbohydrates	81.4	81.9	81.5	0.35	0.83
Total carbohydrates	65.4	67.2	66.2	0.89	0.73
Total digestible nutrients	71.7	73.5	72.4	0.94	0.74

[1]Control, [2]Propolis dry, [3]Essential oils. [4]Standard error of mean.

Carcass characteristics measured by ultrasound

Longissimus muscle area, fat thickness and marbling evaluated *in vivo* by ultrasound or *post-mortem* on carcass were similar (p > 0.05) among the CON, PRO and OIL diets (Table 5).

Table 5. Ultrasound measurements*in vivo* carcass of crossbred bulls finished in feedlot fed with concentrated diet contained propolis or essential oils.

Item	Diets			SEM[4]	p < F
	CON[1]	PRO[2]	OIL[3]		
N	10	10	10		
	Ultrasound measurements				
Longissimus muscle, cm^2	76.2	80.6	79.0	1.5	0.50
Fat thickness, mm	5.02	6.19	5.52	0.3	0.21
Marbling, points	1.80	1.94	1.88	0.1	0.89
	Post-mortem measurements				
Longissimus muscle, cm^2	58.3	57.2	58.4	1.27	0.93
Fat thickness, mm	4.35	5.81	4.78	0.30	0.12
Marbling, points[5]	4.60	5.90	5.70	0.25	0.45

[1]Control, [2]Propolis dry, [3]Essential oils. [4]Standard error of mean.

The *Longissimus* muscle area was higher (p < 0.01) on live animal than 24h after slaughter (Table 6). At contrary, the marbling was lower (p < 0.01) when measured by ultrasound than when measured on carcass *post-mortem*. The fat thickness was similar (p > 0.05) between two measurements methods (Table 6).

Table 6. Carcass measurements by ultrasound and*post-mortem* of crossbred bulls finished in feedlot fed with concentrated diet contained propolis or essential oils.

Item	Evaluation method		SEM[1]	p < F
	Ultrasound	*Post-mortem*		
N	30	30		
Longissimus muscle, cm^2	78.6	58.0	1.67	0.01
Fat thickness, mm	5.58	4.98	0.20	0.14
Marbling, points	1.87	5.40	0.33	0.01

[1]Control, [2]Propolis dry, [3]Essential oils. [4]Standard error of mean.

Carcass characteristics measured *post-mortem*

Hot carcass weight was higher (p > 0.05) for bulls fed the OIL diet; intermediate for bulls fed the PRO diet and lower for bulls fed CON diet (Table 7). On the other hand, hot carcass dressing and conformation were similar (p > 0.05) among the three diets (Table 6). Likewise, muscle, fat and bone percentages after carcass dissection were similar ($p > 0.05$) among three diets (Table 7).

Table 7. Carcass weight and characteristics of crossbred bulls finished in feedlot fed with concentrated diet contained propolis or essential oils.

Item	Diets				
	CON[1]	PRO[2]	OIL[3]	SEM[4]	p < F
N	10	10	10		
Hot carcass weight, kg	249c	252b	260a	4.66	0.05
Hot carcass dressing, %	54.5	53.8	53.9	0.23	0.31
Conformation, points[4]	11.9	11.8	12.5	0.14	0.22
Muscle, %	59.4	58.3	59.7	0.86	0.70
Fat, %	25.1	27.2	25.6	0.76	0.34
Bone, %	15.5	14.5	14.7	0.55	0.45

[1]Control, [2]Propolis dry, [3]Essential oils. [4]Standard error of mean. [4]Scale, points – 1 to 3 inferior, 4 to 6 poor, 7 to 9 regular, 10 to 12 good, 13 to 15 very good, 16 to 18 superior.

Animal performance and feed intake

The higher initial weight for the bulls fed with OIL diet in comparison to bulls fed with CON and PRO diets was due to greater average daily gain during a previous growing study using the same diet and sorghum silage. There is little data in the literature regarding the use of propolis as additives in the diets for cattle finished in feedlot. However, the data show great variation between the results of various additives included in the diets of ruminants (BENCHAAR et al., 2008; ZHANG et al., 2010). As in this study, Zawadzki et al. (2011b) observed better animal performance in bulls finished in a feedlot with propolis extract added to the diet. The improvement of animal performance and feed efficiency with the addition of propolis to the diet can be explained by the antimicrobial activity of propolis compounds (STRADIOTTI JÚNIOR et al., 2004; PRADO et al., 2010a). Others (BENCHAAR et al., 2008; HART et al., 2008) have shown that plant extracts may be useful alternatives to antibiotics because many plants produce secondary metabolites, such as saponins and tannins, that have antimicrobial properties. Similarly, the well-documented antimicrobial activity of essential oils and their active components has prompted a number of scientists to examine the ability of these secondary metabolites to manipulate rumen microbial fermentation and improve production efficiency (CALSAMIGLIA et al., 2007; BENCHAAR et al., 2008). The inclusion of these products therefore also reduces the methane emissions that have a greenhouse effect (STRADIOTTI JÚNIOR et al., 2004; BENCHAAR; GREATHEAD, 2011)

The dry matter intake was 10 kg animal^{-1} day^{-1} or 2.3% of body weight. Generally, the dry matter intake for cattle finished in a feedlot and fed a diet containing 50% roughage and 50% concentrate ranges from 2.0 to 2.5% of the body weight (PRADO et al., 2000; MAGGIONI et al., 2009; DIAN et al., 2010). The crude protein intake was 1.2 kg animal^{-1} day^{-1}. According to NRC (2000), cattle in the final period of growing and finishing require 1.0 to1.2 kg day^{-1} of crude protein to gain an average of 1.4 kg day^{-1}. The neutral detergent fiber content and acid detergent fiber intake were low for all three diets because the diets included glycerine as an energy source, and glycerine is disproved fiber content.

The better feed efficiency for bulls fed PRO and OIL diets may be due to the bioactivities of the propolis and plants extracts, particularly the anti-bacterial action due to bio-flavonoids (MARCUCCI, 1995; BENCHAAR et al., 2008; ZHANG et al., 2010). Propolis extract reduces the number of gram-positive microorganisms responsible for methane production in the rumen (PRADO et al., 2010b). The inclusion of these products therefore also reduces the methane emissions that have a greenhouse effect (STRADIOTTI JÚNIOR et al., 2004; BENCHAAR; GREATHEAD, 2011). Broudiscou et al. (2000) studied the effects of thirteen dry plant extracts with high flavonoids levels on fermentation and methanogenesis in cultures of rumen microorganisms, and they observed that plant extracts increased propionate production (energy source) by 10.3% and reduced the population of the microorganisms. They also observed that the plants extracts did not alter the dry matter intake, pH, ammonia levels or microbial protein in the rumen liquid of cattle fed roughage. However, plant extracts hindered deamination by rumen microorganisms. This suggests that ammonia levels may be reduced in the rumen of animals on diets that have elevated protein degradable/fermentation carbohydrates.

Apparent total-tract digestibility

There is very limited information available on the effects of the addition of propolis and functional oils on digestion in ruminants. The dry matter digestibility was 70%, and the digestibility of the crude protein was 65%. The results observed for the dry matter digestibility differ from those reported by Prado et al. (2010b) for diets containing forage and concentrate. They observed an *in vitro* increase of 8.3 and 6.2% in dry matter digestibility with the addition of propolis compared to the control and monensin diets, respectively. The difference between our results may be due to the volume of the rumen, the dry matter intake, the passage rate in the rumen and the basal diet. In dairy cows, Benchaar et al. (2006b) observed that the apparent digestibilities of dry matter, organic matter, neutral detergent fiber and starch were similar among animals fed a control diet and those supplemented with essential oils or sodium monensin. However, the apparent digestibility of acid detergent fiber increased when diets were supplemented with functional oils. Benchaar et al. (2006a) work indicates that in beef cattle, the dry matter digestibility and nitrogen digestibility are not changed by the addition of functional oils in the diet. Likewise, Ando et al. (2003) observed no changes in total tract digestibility of dry matter and crude protein when steers were fed peppermint (200 grams steer $^{-1}$ day^{-1}) in which menthol is the main functional oil. Castillejos et al. (2005) observed no effect on nitrogen degradation when a mixture of essential oils (Crina Ruminants®) was added to continuous culture fermenters. Mcintosh et al. (2003) observed a reduction in the rate of ammonia production when casein acid hydrolysed (i.e., free amino acids) was incubated *in vitro* with strained rumen fluid collected from cows receiving a TMR supplemented with 1 gram animal^{-1} day^{-1} of a blend of oil components (Crina Ruminants®). The discrepancies between studies could be explained by differences in the procedure used (*in vivo vs. in vitro*), the duration for which the bacteria were exposed to the functional oils and by a possible adaptation of the ruminal bacteria to the functional oils.

The TDN values obtained averaged of 73.0%, and are close to pre-established values of 73.8% (Table 1).

Carcass characteristics measured by ultrasound

The LM area, ratio, marbling and fat thickness were measured by linear array ultrasound before and after slaughter. Real-time ultrasound has been shown to be an accurate predictor of carcass 12th rib fat thickness and LM area in beef cattle (HAMLIN et al., 1995). However, in this study the LM area and fat thickness were 78.6 cm^2 and 5.9 mm, respectively, by ultrasound methods and 57.9 cm^2 and 5.0 mm, respectively, after slaughter. Thus, ultrasonic 12th rib fat thickness and LM area were greater when estimated on live animals, due clearness which animals were submitted at the slaughterhouse. This research suggests that ultrasonic measurements of fat thickness and LM area taken before slaughter can be a predictors of final carcass fat thickness and LM area. Real-time, linear array ultrasound offers a means of predicting these measures of individual carcass merit on alive animal basis, and this could be important in identifying animals with superior genetic potential to take advantage of incentives offered under a value-based marketing system.

Carcass characteristics measured *post-mortem*

The diets did not affect the hot weight, hot carcass dressing or carcass conformation (Table 6). The hot carcass dressing was 54%, and the carcass conformation was 12.5 points on scale used. In Brazil, crossbred bulls (*Bos taurus vs. Bos indicus*) fed high-energy density diets and finished in feedlot generally present hot carcass dressing percentages between 52 and 56% and carcass conformation scores between 10 to 12 points (ROTTA et al., 2009; PRADO et al., 2012). Thus, the inclusion of propolis and functional oils in the diets had no effect on the dressing percentage of beef cattle finished in the feedlot.

The muscle, fat and bone percentages after carcass dissection were similar among the three diets (Table 6) and featured average values of 60, 25 and 15%, respectively. Generally, the muscle, fat and bone percentages of carcasses of *Bos taurus vs. Bos indicus* crossbred bulls finished in a feedlot and fed high-energy density diets that are slaughtered between 460 and 520 kg ranges from 60 to 64% for muscle, 20 to 25% for fat and 14 to 18% for bone (MAGGIONI et al., 2009; ITO et al., 2010; MAGGIONI et al., 2010; ITO et al., 2012). Thus, the inclusion of propolis and functional oils in the diets no had effect on tissue percentages in the carcasses of bulls finished in a feedlot.

Conclusion

The addition of propolis dry to the diets of bulls finished in a feedlot did not change animal performance, apparent digestibility, carcass characteristics or meat quality. Thus, this compound could be used in the diets of feedlot bulls if desired by the producer. However, the addition of functional oils (cashew and castor oils) to the diets of bulls finished in a feedlot improved animal performance and feed efficiency but did not change the carcass characteristics or meat quality. Thus, addition functional oils could also be used in the diets of bulls finished in feedlot.

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products in this publication are mentioned solely for the purpose of providing specific information and do not imply recommendations or endorsement by the Department of Animal Science, State University of Maringá, Maringá Paraná State, Brazil.

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