

Growth performance and meat quality of feedlot steers fed diets with or without natural feed additive

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ABSTRACT - The objective of this study was to evaluate the growth performance and meat quality of feedlot Aberdeen Angus steers fed high-concentrate diets with or without a natural feed additive composed of a mixture of yeasts and essential oils (EO). A completely randomized design with two diets (with or without natural feed additive) and 12 replicates was used. Twenty-four steers with initial shrunk body weight of 402.62±48.2 kg and average age of 18±2.0 months were used. Steers were fed *ad libitum* a diet containing 777.3 g of concentrate/kg dry matter (DM) and 222.7 g of corn silage/kg DM for 74 days. The mixture of yeast and EO was supplied at the rate of 10.0 and 0.117 g/animal/day, respectively. Average daily weight gain and feed efficiency in the adaptation period was greater in animals fed natural feed additive; however, there was no difference for the total experimental period. Dry matter intake, carcass weight, carcass yield, proportion of carcass bone, carcass muscle + fat:bone ratio, round thickness, and arm length were not altered by treatments. The inclusion of a natural feed additive in the diet increased the cooling loss (0.98 vs. 1.25%), proportion of carcass muscle (51.32 vs. 54.56%), carcass muscle:fat ratio (1.70 vs. 2.11%), leg length (68.79 vs. 70.71 cm), and arm perimeter (36.70 vs. 37.88 cm) and reduced the proportion of carcass fat (30.17 vs. 25.92%). Carcass length was greater in animals fed the diet with a natural feed additive. Meat color, texture, and marbling were not altered by treatments. The addition of natural feed additive to high concentrate diets does not alter the productive performance of feedlot Aberdeen Angus steers, although it can increase the proportion of lean meat of carcasses.

Keywords: average daily gain, carcasses muscle, dry matter intake, essential oils, yeasts

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Received: May 16, 2021

Accepted: February 14, 2022

How to cite: Missio, R. L.; Gaspar, R. G.; Paris, W.; Kuss, F.; Souto, G. B.; Severo, M. M. and Menezes, L. F. G. 2022. Growth performance and meat quality of feedlot steers fed diets with or without natural feed additive. *Revista Brasileira de Zootecnia* 51:e20210096. <https://doi.org/10.37496/rbz5120210096>

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1. Introduction

Feeding cattle a high proportion of the concentrate in the diet allows rapid carcass finishing (Augusto et al., 2019). However, high-concentrate diets can cause metabolic disorders, such as acidosis, and lead to inconsistent performance in cattle (Nuñez et al., 2013).

The use of ionophores is the most common strategy used to reduce the incidence of metabolic disorders and increase feeding efficiency and animal performance (Nuñez et al., 2013; Montano et al., 2015). However, the use of these additives has been associated with antibiotic resistance and risks to human health (Landers et al., 2012). Although there is a lack of data conclusively demonstrating the magnitude of this threat (Chang et al., 2015), the use of relevant antibiotics has been prohibited in

some parts of the world, such as the European Union, with enhanced research targeting natural feed additives (Neumann et al., 2013; Kolling et al., 2016), which are more acceptable to consumers.

Research on yeasts and essential oils (EO) has shown that they are safe feed additives that can improve ruminal function (Rivaroli et al., 2017; Zhu et al., 2017). Essential oils reduce ruminal production of acetate and methane, increasing energy efficiency (Simitzis, 2017), growth performance, and carcass characteristics (Valero et al., 2014). Yeasts use rumen O_2 and provide growth factors for bacteria that use lactate, increasing energy and protein efficiency (Zhu et al., 2017) and animal performance (Neumann et al., 2013). In addition, these natural feed additives are known to improve animal immunity (Finck et al., 2014; Zhu et al., 2017). However, some studies have reported that these substances have no effect on animal performance (Vakili et al., 2013; Neumann et al., 2020), whereas other studies have shown worsening of productive performance (Chaves et al., 2008). In addition, there is limited literature available regarding the use of a mixture of yeasts and EO in diet of beef cattle, especially regarding the effect of using a mixture of these additives in the diet with a high proportion of the concentrate on animal performance and meat quality.

In the present study, it was hypothesized that supplementation of natural feed additives to high-concentrate diets benefits growth performance and meat quality of feedlot steers. Thus, the objective of this study was to evaluate the growth performance and meat quality of Aberdeen Angus steers fed high-concentrate diets with or without a natural feed additive composed of a mixture of yeasts and EO.

2. Material and Methods

The experiment was carried out in Dois Vizinhos, Paraná, Brazil (25°42'5" S and 53°03'94" W). Animal research was conducted according to the guidelines of the Institutional Committee on Animal Use (case number 2017-003).

Twenty-four contemporary Aberdeen Angus steers were used in this study. They had an initial shrunk body weight (BW) of 403.88±47.2 kg and average initial age of 18±2.0 months. Before the finishing period, animals grazed for six months on a pasture of Aruana grass (*Panicum maximum* Jacq.) with supplementation of 1.9 g of dry matter (DM)/kg BW (208.7 g of crude protein/kg DM of supplement). Animals were confined to individual pens (10 m²) that were partially covered with concrete floors, individual feeders, and water that was available *ad libitum*. Before the experimental period, animals were treated with control endoparasites and ectoparasites with ivermectin commercial products. The experimental period was 74 days, with the initial 15 days used for adaptation to facilities and diets. During the adaptation period, animals received two transition diets (550 and 650 g of concentrate/kg DM of the diet) for eight days (four days each), after the supply of experimental diet. Animals were weighed at the beginning and end of the feedlot period, and on the 15th and 44th day of the feeding period after a 14-hour fast. The subcutaneous fat thickness (SFT) in the 11th and 12th ribs was determined during animal weighing using an ultrasound device (Pie Medical – Scanner 200 VET, model 51B04UM02).

A completely randomized design with two treatments (diets with or without natural feed additives) and 12 replicates (animals) was used. The diets had 222.7 g/kg corn silage, 684.0 g/kg of corn grain, 73.8 g/kg of soybean meal, 12.4 g/kg of the mineral mixture, 3.1 g/kg of salt, and 3.9 g/kg of urea (DM basis). A unique commercial additive (All Sacch Beef[®]) containing both live dry yeasts (*Saccharomyces cerevisiae* Yea-sacc 1026; 5×10⁸ colony forming units/g) and EO (1.17 g/kg of thymol and 1.17 g/kg of carvacrol) was used. Thus, 50 g/animal/day of the commercial additive was weighed and mixed manually with the ration. The inclusion of yeast and EO mixture (50% thymol and 50% carvacrol) corresponded to 10.0 and 0.117 g/animal/day, respectively.

Feed was supplied *ad libitum*, retaining 5–8% as orts above voluntary intake. Feeding was provided only once a day (09:30 h). Feed intake was recorded daily by weighing the feed provided and as orts from the previous day. Samples of ingredients of diets and orts from each animal were collected weekly, and composite samples were formed every 28 days. All samples were pre-dried in an oven with forced-air circulation at 55 °C for 72 h and ground in a Willey mill (1-mm particle size). Subsequently, chemical compositions of ingredients and diets were determined (Table 1).

Table 1 - Chemical composition of the ingredients and diets (DM basis, g/kg)

Item	DM	MM	CP	EE	NDF	TC	NFC	TDN	ME
Corn silage	227.5	42.1	84.9	10.2	571.9	862.8	290.9	622.0*	2.2
Corn grain	859.5	13.0	94.0	25.6	96.8	867.4	770.6	832.0*	3.0
Soybean meal	873.9	67.1	468.1	31.2	124.1	433.6	309.5	812.0*	2.9
Mineral mixture ¹	999.9	999.9	-	-	-	-	-	-	-
Salt	999.9	999.9	-	-	-	-	-	-	-
Urea	999.9	999.9	281.2**	-	-	-	-	-	-
Diets	722.5	42.7	118.9	22.1	202.7	804.9	614.7	768.0	2.8

DM - dry matter; MM - mineral matter; CP - crude protein; EE - ether extract; NDF - neutral detergent fiber; TC - total carbohydrates; NFC - non-fibrous carbohydrates; TDN - total digestible nutrients (* tabulated values); ME - metabolizable energy (Mcal/kg of DM).

¹ Mineral mixture (manufacturer's warranty levels: P = 60 g/kg, Ca = 170 g/kg, Na = 136 g/kg, S = 10 g/kg, Mg = 5000 mg/kg, Cu = 1200 mg/kg, Zn = 3500 mg/kg, Co = 62 mg/kg, I = 75 mg/kg, Se = 18 mg/kg, F (max.) 680 mg/kg).

** Protein equivalent.

The standard procedures of AOAC (2000) were adopted to determine the composition of ingredients in diets and diets: DM (method 934.01), mineral matter (MM; method 924.05), crude protein (CP; method 920.87), and ether extract (EE; method 920.85). The neutral detergent fiber (NDF) content was determined using alpha-amylase, according to Mertens (2002). Total carbohydrate (TC) content was determined according to Sniffen et al. (1992):

$$TC = 100 - (\% CP + \% EE + \% MM)$$

The non-fibrous carbohydrate (NFC) content was determined according to Hall (2000):

$$NFC = 100 - \% MM - \% EE - \% NDF - (\% CP - \% CP_u + \% U),$$

in which CP_u is the CP from urea, and U is the urea content, expressed as % DM.

The tabulated value (Valadares Filho et al., 2018) of the total digestible nutrients (TDN) content of feeds was used to determine the energy content of the diets. The metabolizable energy (ME) of the diets was estimated according to NRC (2000), assuming 1 kg of total digestible nutrients = 4.4 Mcal digestible energy, and 1 Mcal of digestible energy = 0.82 Mcal of ME.

The criterion used for the slaughter of animals was an SFT value of 8 mm as estimated by ultrasound. Animals were slaughtered after a 14-hour fast, following the normal flow of the slaughter line. After slaughter, carcasses were identified, divided in half, weighed, washed, and cooled (2 °C) for 24 h. Afterwards, carcasses were weighed again. Hot carcass yield (HCY) and cold carcass yield (CCY) were determined according to Müller (1987):

$$HCY = \text{hot carcass weight (HCW)}/\text{BW obtained on the farm}$$

$$CCY = \text{cold carcass weight (CCW)}/\text{BW obtained on the farm}$$

Carcass cooling loss (CCL) was determined according to Müller (1987), using the following equation:

$$CCL = (\text{HCW} - \text{CCW})/\text{HCW} \times 100$$

In the right half of the carcass, metrical characteristics were evaluated: carcass length (CL), taken from the cranial medial edge of the first rib to the anterior edge of the pubic bone; leg length (LL), corresponding to the distance between the anterior edge of the pubic bone and tibiotarsal joint; round thickness (RT), taken from the lateral and medial upper portion of the cushion, with the assistance of a compass; arm length (AL), taken from the radiocarpus joint until the olecranon edge; and arm perimeter (AP), determined by the perimeter of the medial region of the arm.

The section comprising the 9th, 10th, and 11th ribs of the right carcass was dissected into muscle, fat, and bone to determine the physical composition of the carcasses according to the methodology described by Hankins and Howe (1946). The SFT of the carcasses was determined between the 11th and 12th ribs using a digital caliper. Fat thickness gain (FTG) was estimated by evaluating the initial SFT (ISFT) measured by ultrasonography and the SFT in the carcass, as follows:

$$FTG = SFT - ISFT$$

Meat color, marbling, and texture were evaluated by a panel of trained evaluators (four evaluators) on the surface of the *longissimus lumborum* located between the 11th and 12th ribs after 30 min of exposure to air (Müller, 1987).

Data were subjected to analysis of variance (F test; $\alpha = 0.10$) using the PROC GLM procedure of SAS (Statistical Analysis System, version 8.02). When necessary, data were transformed using a logarithmic function. Initial body weight was used as a covariate, but when not significant, its effect was removed from the model. The general mathematical model used is represented by:

$$Y_{ijk} = \mu + T_i + C_{ij} + e_{ijk}$$

in which Y_{ijk} is the dependent variable, μ is the general average, T_i is the effect of diets, C_{ij} is the effect of the covariate, and e_{ijk} is the experimental error.

3. Results

Dry matter intake (DMI, kg/day or g/kg BW) was not affected at any time during the experimental period by the inclusion of natural feed additives ($P > 0.10$) (Table 2). Average daily gain (ADG) and feed efficiency of the adaptation period was greater in animals fed the diet with the natural feed additives ($P = 0.087$ and $P = 0.089$, respectively). However, there was no difference ($P > 0.10$) in ADG and feed efficiency between diets in the total feedlot period and the other evaluated periods.

Slaughter body weight (SBW), HCW, CCW, HCY, CCY, and SFT did not differ between treatments ($P > 0.10$) (Table 3). The inclusion of natural feed additives increased the CCL and the proportion of carcass muscle (PCM) ($P < 0.10$). In contrast, the inclusion of natural feed additives reduced the

Table 2 - Growth performance of steers fed high-concentrate diets with or without natural feed additive

Item	Diet		SEM	P-value
	With additive	Without additive		
Dry matter intake (DMI, kg/day)				
0 to 15 days (adaptation)	7.28	6.71	1.73	0.362
16 to 30 days	8.61	8.44	1.32	0.722
31 to 59 days	9.19	9.17	1.37	0.970
16 to 59 days	8.90	8.81	1.37	0.841
0 to 74 days	8.58	8.38	1.28	0.646
Dry matter intake (g/kg of BW)				
0 to 15 days (adaptation)	17.51	16.52	3.38	0.498
16 to 30 days	19.96	19.76	2.33	0.833
31 to 59 days	20.14	20.09	2.34	0.959
16 to 59 days	20.05	19.93	2.10	0.877
0 to 74 days	19.54	19.24	1.89	0.550
Average daily gain (kg/day)				
0 to 15 days (adaptation)	1.38	1.03	0.55	0.087
16 to 30 days	0.91	1.03	0.35	0.422
31 to 59 days	0.94	0.98	0.39	0.529
16 to 59 days	0.93	1.00	0.24	0.427
0 to 74 days	1.02	1.01	0.22	0.685
Feed efficiency (kg of BW gain/kg of DMI)				
0 to 15 days (adaptation)	0.19	0.15	0.08	0.089
16 to 30 days	0.11	0.12	0.04	0.211
31 to 59 days	0.10	0.11	0.04	0.825
16 to 59 days	0.10	0.11	0.02	0.161
0 to 74 days	0.12	0.12	0.02	0.930

BW - body weight; SEM - standard error of the mean.

proportion of carcass fat (PCF) ($P < 0.10$). The proportion of carcass bone did not differ between treatments ($P > 0.10$). The carcass muscle:fat ratio (CM:F) was increased by the inclusion of natural feed additives ($P < 0.10$). The carcass muscle + fat:bone ratio (CM+F:B) was not affected by treatment ($P > 0.10$).

The CL was greater in animals fed the diet with the natural feed additives ($P < 0.10$). Round thickness and AL did not differ between the treatments ($P > 0.10$). The inclusion of natural feed additives increased LL and AP ($P < 0.10$).

Color, texture, and marbling of the meat were not affected ($P > 0.10$) by the inclusion of natural feed additives (Table 4).

Table 3 - Slaughter body weight and carcass characteristics of steers fed high-concentrate diets with or without natural feed additive

Item	Diet		SEM	P-value
	With additive	Without additive		
Slaughter body weight (kg)	467.45	471.68	10.41	0.373
Hot carcass weight (kg)	260.23	262.35	5.97	0.508
Cold carcass weight (kg)	256.97	259.77	5.99	0.974
Hot carcass yield (%)	55.67	55.62	0.22	0.708
Cold carcass yield (%)	54.97	55.07	0.22	0.984
Cooling loss (%)	1.25	0.98	0.06	0.013
Fat thickness (mm)	8.55	8.35	0.43	0.825
Fat thickness gain (mm)	5.90	5.73	0.35	0.658
Muscle (%)	54.56	51.32	0.68	0.016
Fat (%)	25.92	30.17	0.90	0.016
Bone (%)	19.51	18.51	0.40	0.224
Muscle:fat	2.11	1.70	0.08	0.016
Muscle + fat:bone	4.12	4.40	0.13	0.216
Carcass length (cm)	139.86	137.39	0.95	0.085
Round thickness (cm)	26.31	27.06	0.43	0.265
Leg length (cm)	70.71	68.79	0.50	0.034
Arm length (cm)	40.13	39.79	0.35	0.635
Arm perimeter (cm)	37.88	36.70	0.43	0.032

Initial body weight was used as a covariate for these variables.
SEM - standard error of the mean.

Table 4 - Meat characteristics of steers fed high-concentrate diet with or without natural feed additives

Item	Diet		SEM	P-value
	With additive	Without additive		
Color (points) ¹	3.20	3.39	0.15	0.493
Marbling (points) ²	6.55	6.54	0.51	0.464
Texture (points) ³	3.26	3.15	0.07	0.421

SEM - standard error of the mean.

¹ Color: 1 = dark, 2 = dark red, 3 = slightly dark red, 4 = red, and 5 = bright red.

² Marbling: 1 to 3 = dashes, 4 to 6 = light, 7 to 9 = small, 10 to 12 = medium, 13 to 15 = moderate, and 16 to 18 = abundant.

³ Texture: 1 = very coarse, 2 = coarse, 3 = slightly coarse, 4 = thin, and 5 = too thin.

4. Discussion

The similar DMI in high-grain diets is usually attributed to the fact that the energy needs of the animals are met through the high-energy content of diets (Barros et al., 2018). Krehbiel et al. (2006) verified that ruminants on high-grain diets (2.7–3.3 Mcal of ME/kg of DM) eat to maintain constant energy

intake. In this study, it was expected that the DMI would be reduced as a result of the increase in energy efficiency provided by the inclusion of natural feed additives in the diets, as reported by Sartori et al. (2017). However, several studies have found no difference in the DMI of steers fed yeast or EO (Kuss et al., 2009; Pancini et al., 2020; Lockard et al., 2020). According to Sartori et al. (2017), changes in the DMI of European cattle are difficult to perceive when diets with yeast have a concentrate content of less than 75%, a feeding period of less than 90 days, and low yeast doses. Some of these conditions were applied in this study (genotype and feeding time).

Alterations in the DMI (increase) caused by the inclusion of yeast in diets were verified only at the beginning of the feedlot period (Finck et al., 2014; Neumann et al., 2020), which is justified by its benefits on the immune system of animals during the reception/adaptation period (period of greatest stress). On the other hand, the effect of yeast on DMI of the total feedlot period depends on the number of days of feeding (Wagner et al., 2016). According to Neumann et al. (2020), the short feeding period (112 days) of bulls fed diets (50% concentrate) with or without yeast culture was responsible for the absence of lesions in internal organs (related to metabolic disorders) and similar corporal temperature (in the region of the rumen, hind legs, and rectum), indicating the absence of inflammatory reactions in the hooves and rumen. The incidence, prevalence, and severity of ruminal acidosis depend on the number of feeding days and are higher at the end of the finishing phase (Castillo-Lopez et al., 2014). It is worth noting that European animals, like those in this study, are less susceptible to ruminal disorders compared with zebu cattle on high-grain diets (Nuñez et al., 2013).

The increase in animal performance due to dietary inclusion of yeast or EO is quite common in dairy cows (Jiang et al., 2017; Dias et al., 2018) and small ruminants (Chaves et al., 2008; Maamouri et al., 2014). In beef cattle, growth performance increase by dietary inclusion of yeast or EO are more frequent in young cattle (calves) (Neumann et al., 2013; Ornaghi et al., 2017), which is attributed to the more effective action to improve health, because this category has a weaker immune system. Improved health is also an explanation for the increase in growth performance of steers in the initial phase of the experimental period by dietary yeast inclusion (Neumann et al., 2020).

Although the dosage of EO used (0.117 g/animal/day) in this study is lower than that (≥ 3 g/animal/day) used in other studies (Vakili et al., 2013; Valero et al., 2014), the yeast dosage (10 g/animal/day) was higher than that used (5–8 g/animal/day) in studies that verified the positive effect of this additive on the performance of young cattle (Finck et al., 2014; Neumann et al., 2013). This reinforces the results of Sartori et al. (2017), who demonstrated that the positive responses obtained by yeast supplementation depend on other factors, such as dosage and type of yeast, animal category, feeding period, and diet composition. According to these researchers, the challenge of animal nutrition is to understand the interactions of the use of yeast in the performance of beef cattle.

Improvements in feed efficiency in beef cattle fed yeast or EO are generally a result of reduced DMI (Meyer et al., 2009) or increased growth performance (Neumann et al., 2013), although these positive results are not often found in the literature (Alemu et al., 2019; Neumann et al., 2020). The consensus is that positive results from the use of yeast are more pronounced in calves under stress or exposed to high levels of disease-causing agents (Alugongo et al., 2017).

Variations in slaughter body weight and carcass fat cover are the main factors responsible for the variation in carcass characteristics of the same cattle genotype or animal category (Berg and Butterfield, 1976). As a consequence, most results in the literature do not show the effect of dietary inclusion of natural feed additives on the carcass characteristics of steers with similar slaughter body weights (Kuss et al., 2009; Neumann et al., 2013).

The most intriguing results of this study are related to the increases in PCM and CM:F and reduction in the PCF of animals fed natural additives. This change does not seem to occur by chance, as it was accompanied by a change in the CCL and metric measurements of the carcasses. The greater CCL of the animals that received natural additives can be explained by the greater PCM, as the muscle tissue has higher water content than the fat tissue (Owens et al., 1995).

The similar proportion of carcass bone between treatments can be justified by the fact that bone tissue is the least variable fraction of the carcass, as it develops before muscle and adipose tissue (Berg and Butterfield, 1976). The highest CL, LL, and AP indicated that animals fed natural additives showed greater body development than those fed the control diet, even though this was not evidenced in growth performance. The increase in the AP of the carcass of steers fed natural additives compared with those fed a control diet has drawn attention because this region is made up of bone and muscle (Silva et al., 2015) and is sensitive to variations in carcass muscle tissue (Restle et al., 2002). Additionally, the AP variation in the absence of the RT variation indicates that muscle deposition may have occurred most intensely in the forequarter, a region in which muscles show prolonged growth with advancing age (Jorge et al., 1997).

The increase in PCM may be related to improvements in rumen function, which occur due to an increase in the supply of energy and protein with the use of natural additives in cattle diet (Zhu et al., 2017). Some studies have shown an increase in carcass muscle of beef cattle, without alterations in growth performance, through changes in correlated characteristics, such as rib eye area (Narvaez et al., 2014), CCL (Gomes et al., 2009), and AP (Neumann et al., 2020). Lockard et al. (2020) observed an increase in lean meat yield (calculated yield grade) and CCL in steers fed a yeast-based additive complex, without alterations in growth performance, HCW, and fat thickness. However, these researchers did not clarify the factors of cause and effect that led to these results.

Most of the results in literature do not show significant changes in meat color, texture, and marbling of steers or heifers fed natural additives (Gomes et al., 2009; Neumann et al., 2013; Lockard et al., 2020), which is justified by the lack of variation in animal performance and marbling. Titi et al. (2008) observed that the color of the meat of calves fed diets with yeast was lighter (b^*) and less red (chroma), which is attributed to the higher marbling content of the meat of these animals. However, according to Calnan et al. (2017), light reflection of white intramuscular fat has a positive influence on yellowness (b^*) and chroma of the meat.

The similar meat color between treatments was consistent with the marbling of the meat in this study. Additionally, similar slaughter age can contribute to these results, as age is one of the main factors affecting the color and texture of the meat, as discussed by Silva et al. (2014). Lastly, the similar ADG and SFT between treatments corroborate the degree of marbling, since higher rates of weight gain increase fat deposition, especially intramuscular fat (Pethick et al., 2004).

5. Conclusions

The addition of natural feed additive to high concentrate diets does not alter the productive performance of feedlot Aberdeen Angus steers, although it can increase the proportion of lean meat of the carcasses.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Investigation: R.G. Gaspar, G.B. Souto and M.M. Severo. Supervision: R.L. Missio, F. Kuss, W. Paris and L.F.G. Menezes.

Acknowledgments

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001. We thank the company Nutrivital - Saúde e Nutrição Animal for supplying inputs.

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