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Research Article

Effects of feed management on performance, carcass characteristics and meat quality of Boer goats

Efeitos do manejo alimentar sobre o desempenho, características de carcaça e qualidade da carne de caprinos Boer

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ABSTRACT

Goat farming is one of the fastest growing activities in terms of quality of its products. In this scenario, the Boer breed is the most important for the goat meat industry worldwide as it specializes in the production of quality meat, where the animals are slaughtered early and with satisfactory zootechnical indexes. Considering this favorable scenario, it was decided to evaluate the quality characteristics of the carcass and meat of these animals; then, 20 Boer goats were housed and distributed in groups where one group received a diet based on hay ad libitum and fixed amounts of corn meal and soybean meal in compliance with the requirements of maintenance and weight gain; the other group was housed in different paddocks daily and received only the roughage present in the pasture. It was observed that the animals tended to present larger posterior cuts (loin and leg) with no significant difference between the feeding regimes. The animals fed with concentrate accumulated more subcutaneous fat compared to the animals under grazing. The meat of grazing animals showed higher glycolytic potential and shear force (FC), however, it had lower final pH than the meat of animals fed with concentrate. It was also possible to verify a ratio of fatty acids from intramuscular fat 4 times higher in the carcass of animals under concentrated regime in comparison to the carcass of animals under rotational grazing. With this study, it can be stated that, through the adopted feed management, the quality characteristics of the carcass and meat and, consequently, their organoleptic attributes, can be influenced, having effects on the goat meat market.

KEYWORDS: Goats. Pasture. Ration. Feed management. Composition of the carcass. Quality of the meat.

RESUMO

A caprinocultura é uma das atividades que mais cresce em termos de qualidade de seus produtos. Neste cenário, a raça Boer configura como a de maior importância para a indústria da carne caprina em nível mundial, uma vez que é especializada na produção de carne de qualidade, onde os animais são abatidos precocemente e com satisfatórios índices zootécnicos. Diante deste cenário favorável, optou-se pela avaliação das características de qualidade da carcaça e da carne destes animais; logo, 20 caprinos da raça Boer foram alojados e distribuídos em grupos onde um grupo recebeu dieta à base de feno *ad libitum* e quantidades fixas de farelo de milho e farelo de soja em atendimento das exigências de mantença e ganho de peso; o outro grupo foi alojado em piquetes distintos diariamente e receberam apenas o volumoso presente na pastagem. Observou-se que os animais tenderam a apresentar maiores cortes posteriores (lombo e perna) sem diferença significativa entre os regimes de alimentação. Os animais alimentados com concentrado acumularam mais gordura subcutânea em comparação com os animais sob pastejo. A carne dos animais em regime de pastejo apresentou maior e potencial glicolítico e força de cisalhamento (FC), porém, apresentaram menor pH final do que a carne dos animais em regime concentrado. Também pôde-se averiguar uma proporção de ácidos graxos da gordura intramuscular 4 vezes maior na carcaça dos animais em regime concentrado em relação à carcaça de animais sob pastejo rotacionado. Com esse estudo, pode-se afirmar que, mediante o manejo alimentar adotado, as características de qualidade da carcaça e da carne e, consequentemente, seus atributos organolépticos, podem ser influenciadas, tendo efeitos no mercado da carne caprina.

PALAVRAS-CHAVE: Caprinos. Pasto. Ração. Manejo alimentar. Composição da carcaça. Qualidade da carne.

INTRODUCTION

The Boer breed (Capra aegagrus hircus) is a breed originally from South Africa and is considered the ideal breed for meat production given some of its productive and performance characteristics (GAWAT et al. 2023). Its breeding has been increasingly instigated by its reproductive and productive characteristics that make the breed an excellent means of use in breeding programs for native breeds and even dairy breeds (LU 2001). Despite the breed standard defined for meat production and widespread in Brazil, there are five different biotypes of Boer goats recognized in South Africa, all of which come from a mixture of breeds and have been studied and improved since the beginning of the twentieth century (LU 2001).

In recent years, the demand for healthy eating and the dissemination of good food practices has increased significantly, especially in the most developed regions of the country, such as the Center-South, so the perspective of consumption of certain products, as well as the human view of the quality of such products, has changed drastically, increasing and heating up the production chain of products of animal and vegetable origin that meet this domestic demand and perhaps, external. In this scenario of evolution and improvement of society's eating habits, the demand for goat meat has increased, which may be the result of claims related to health benefits, including the constitution of lean meat with reduced concentrations of fat and cholesterol when compared to beef and lamb, for example (MAZHANGARA et al. 2019).

It is known that the feeding system impacts not only on the growth rate, but also the carcass characteristics (DA SILVA 2024a). According to ASIZUA et al. (2014), animals under a concentrated feeding regime, intensive feeding management, allow for a greater daily weight gain (GPD) and carcass yield (RC), while for LIMÉA et al. (2009) and TURNER et al. (2015) goats consuming essentially roughage have lower body weight at slaughter (PCA) and leaner carcasses. A compilation done by DA SILVA (2024a) corroborated the aforementioned results with sheep species. Some meat quality attributes, such as fatty acid (AG) profile, may also be influenced by roughage compared to a feedlot diet rich in grains (concentrate) (GOETSCH et al. 2011). For example, studies by TURNER et al. (2014) and JACQUES et al. (2017) have shown that the carcass of goats fed commercial concentrate and hay or a diet supplemented with cottonseed have a higher proportion of n-6 AG than n-3; In addition, the carcass of animals kept on a roughage diet with pasture and legumes have more n-3 AG and a lower ratio of n-6 to n-3, unlike what occurred in a concentrated diet. Nevertheless, the FC, which is an estimator of meat tenderness, juiciness and general tenderness determined by a sensory panel, were similar when we compared the bulky and variable feed without the inclusion of concentrate with hay-based diets containing 50, 70 and 90% concentrate (RYAN et al. 2007).

Currently there are several food management systems based on the extensive production model, without supplementation and offer of cultivated and natural pasture, semi-intensive with the adoption of supplementation and preserved foods such as silage and hay; and the intensive model with the adoption of essentially concentrated diets, each of the systems with its own inherent economic variables (LUPTON et al. 2008). Feed costs represent an important portion of the total expenses and costs of production on any livestock farm (DA SILVA 2023a).

The correct use and management of pastures during the goat growing season, where satisfactory daily weight gains must be obtained for early slaughter, avoiding losses in meat quality and sensory characteristics, can reduce the need for concentrated or preserved feed and, as a consequence, improve the profitability and sustainability of livestock farming (MULLINIKS et al. 2015, DA SILVA 2024a), since grass, legume or cacti, in short, roughage, is the cheapest form of animal feed (KELLAWAY & HARRINGTON 2004, SANTOS & NEIVA 2022).

BECK et al. (2016) states that an intensive rotational grazing system (short period of grazing in limited paddock areas, with a grass of high forage value) reduces the need for supplementation and also allows the harvesting and conservation or supply in the trough, of surplus forage, if any, when compared to continuous grazing. Intensive rotational grazing systems were successfully implemented in the performance of cattle (BECK et al. 2016) and sheep (JACQUES et al. 2011), but not in goats, largely because it is a species that is difficult to manage in this type of system and due to its high natural selectivity (consumption habits).

The objective of this study was to evaluate the effects of diet on growth performance, carcass characteristics and meat quality of Boer goats in the Agreste region of Pernambuco. The hypothesis is that such variables produce similar results regardless of the feeding regime, whether in a concentrated diet or in animals raised in intensively managed pastures.

This study is important in the sphere of the goat production chain in the Northeast of Brazil, since, as much as there is a significant number of personnel in it, the management of animals is still deficient and requires trained and qualified personnel who can provide products that meet the demands of the population. Therefore, the main focus of this study is to provide a basis for producers, researchers, and students of Agricultural Sciences.

MATERIAL AND METHODS

Animals and diet

Twenty Boer beef goats (n = 20), weaned at three months of age, were housed in a control unit of Cabanha Severino in Belo Jardim, Pernambuco State, Brazil. The goats were randomly selected from the commercial herd of Cabanha, where the homogenization of the lot was recommended. The goats received commercial concentrate with 14% crude protein (PB) and 70% total digestible nutrients (NDT), as indicated by DA SILVA (2021), for 6 weeks until the beginning of the experiment. The economic aspects in relation to diet, carcass and meat were not evaluated in this study.

The study began in January 2023. All goats were included in the feeding trial at the same time, at 139±4 days of age (mean±DP) and a body weight (PC) of 23.8±5.4 kg (mean±DP). The goats were divided into 10 groups of two individuals each, according to body weight, and then randomly distributed to a diet based on concentrated ration or pasture in an intensive rotational grazing system.

The goats fed a concentrated diet were managed in total confinement, in individual pens with open bars, which allowed social contact between members. They received Tifton-85 (Cynodon dactylon) grass hay ad libitum (50% leftovers) and a restricted amount of concentrate composed of four mixtures of whole corn, soybean meal and a vitamin-mineral premix, suitable for growing goats served in four different growth phases (Table 1).

The concentrated diets were formulated to meet the requirements of NRC (2007) and DA SILVA (2021) for maintenance and growth with a GPD of 150 g/d^{-1}. The daily feed intake was adjusted according to the body weight of the animals, determined weekly, throughout the experimental period, based on weight x dry matter intake (CMS). Hay and concentrate were supplied twice a day in equal amounts of hay and concentrate, at 8 am and 3 pm.

The goats had free and continuous access to fresh, quality water, periodically treated with chlorine at no more than 5 ppm, and vitamin-mineral block (150g of Ca, 50g of P, 30g of Mg, 155g of common salt, 60g of Na, 50mg of I, 3g of Fe, 2g of Mn, 2.1g of Zn, 30mg of Se, 500,000 IU of vitamin A, 125,000 IU of vitamin D, and 450 IU of vitamin E per kg of commercial product). Feed leftover was collected and weighed every morning, before a new supply, for calculation of the CMS.

Table 1. Amount of concentrate supplied to confined goats at different stages of growth, based on PC x CMS.

Ingredients (g of MS)	Body weight, kg[a]			
	20 - 25	26 - 30	31 - 35	36 - 40
Cornmeal	290	450	460	550
Soybean meal	130	130	130	130
Premix[b]	30	30	30	30

[a] Amount of concentrate calculated based on PC and the desired GPD to meet nutritional needs, based on NRC (2007) and DA SILVA (2021). [b] commercial Premix: content, per kg, 230g Ca, 100g P, 25g Mg, 7g K, 0.5g I, 27g Fe, 4g Cu, 21g Mn, 22g Zn, 0.25g Co, 10mg Se, 920,000 IU vitamin A, 126,000 IU vitamin D and 4,650 IU vitamin E based on natural matter.

An open and non-sloped field area of 0.7 ha^{-1} (8°13'53" S 36°21'00" W 647m) subdivided into 40 paddocks, using electrified poly-wire fence, was used for intensive rotational grazing throughout the experiment. The grazing area was composed of a variable botanical composition with 50% buffel grass (Cenchrus ciliaris cv. Aridus), 40% of Massai grass (Panicum maximum cv. Massai) and 10% andropogon grass (Andropogon gayanus cv. BRS Sarandi).

The grazing goats were grouped and housed continuously at an average density of 15 m^2/$head^{-1}$. The animals were housed in a new paddock every day at 3 pm, with an entry height of 20 to 25 cm (homogenization of the height of the pasture by means of mowing, etc.). The animals had free access to water and the vitamin-mineral premix block in an open shed. The grazing animals did not receive any concentrate.

Diet assessment methodology

Pasture intake was evaluated using the concentration of insoluble ash in acid detergent in grass and feces as a marker according to the methodology of BARNETT et al. (2022). Measurements of fecal production were performed using a fecal collection bag attached to the goats for a period of seven days, during weeks seven and twelve of the grazing period. Feces were collected and weighed twice daily, and samples of 10% of these were stored to form a compound that was kept frozen between each day of sampling.

Twice a week, samples of the pasture were collected using 10 squares (0.3 x 0.3 m) cut manually at ground level. The pasture samples, along with the concentrated feed and feces ingredients, were dried in a forced dry air oven at a controlled temperature of 55 ºC for determination of dry matter (MS) and then these samples were ground using a Wiley mill (standard model 3) to pass through a 1 mm screen. The ground samples of pasture, other ingredients, and feces were scanned by infrared reflectance spectroscopy using a Foss NIR System 6500 monochromator. The samples (n = 75 for each sample type) were selected based on spectral variability, using the WinISI III software (version 1.61).

All samples of ingredients and feces were chemically analyzed for nutritional composition, i.e., nutritional attributes. The analytical concentrations of MS and minerals were determined using a Leco model TGA 701 thermogravimetric analyzer. Organic matter (MO), fiber in neutral (NDF) and acid detergent (FDA) were determined according to the method indicated by MERTENS (2002) and DA SILVA (2023b).

The samples were mineralized with sulfuric and selenious acids to determine the total concentration of nitrogen (N), according to the method described by ISAAC & JOHNSON (1976). PB was calculated as N x 6.25 (DA SILVA 2024b). The concentrate ingredients and pasture samples were analyzed for in vitro digestibility of MS (DIVMS), according to DA SILVA et al. (2013). The AG profile of the diet was determined as indicated by VILLENEUVE et al. (2013).

Evaluations of carcass and non-carcass components

Weekly, the PC was recorded until the animals reached 45 kg PC, this slaughter weight was determined according to the demand of the local market as well as on the premise that animals above this weight could present the characteristics of undesirable odor in the meat. The GPD was calculated as final PC - initial PC/experimental period, in days. The animals were kept fasting for 16 hours with ad libitum water and were transported in individual cages to the public slaughterhouse in the city of Belo Jardim, with an environment controlled and supervised by a veterinarian.

All procedures involving the carcass and the non-carcass components were in accordance with the recommendations of CEZAR & SOUSA (2007). At the time of slaughter, the non-carcass components were removed and properly weighed. The components of the digestive tract were properly emptied, washed, and weighed to calculate the empty body weight (PCVZ). The carcasses were weighed and stored in the slaughterhouse's cold storage chamber at 4ºC. Yield was calculated as hot carcass weight (PCQ) divided by the PCVZ x 100.

24 hours after the slaughter, the carcasses were weighed again and the appropriate measurements were made as described by CEZAR & SOUSA (2007). The carcasses were divided along the vertebral column and the left side was articulated as indicated by COLOMER-ROCHER et al. (1987), with adaptations. Finally, the carcass cutting procedures were performed to evaluate the cutting yields.

Meat Quality Analysis

24 hours after the slaughter, the final pH (pHf) was measured using a pHmeter (Meat pH Test Foodcare Hanna). The index of meat color, perirenal fat, and subcutaneous tail fat, for L* (lightness), a* (redness), and b* (yellowish) were evaluated using the chemical indicator of metamyoglobin (TOMASEVIC et al. 2021). 1cm thick samples of the longissimus thoracis et lumborum (LTL) muscle were taken from the rib and loin cuts and frozen at -20 ºC under vacuum packaging for further analysis.

The rib parts of the LTL were weighed and cooked to analyze cooking losses. About 10 pieces of 1 cm^2 were used to perform the FC test with a Texture Analyzer TA.XT.plus ®Stable Micro Systems Scientific Instruments, England. The glycolytic potential was obtained after the enzymatic determination of glycogen, glucose, glucose-6-P and lactate in a portion of the LTL, as recommended by MONIN et al. (1987).

Muscle Chemical Analysis

The frozen LTL parts were ground and lyophilized for determination of MS. The PB concentration was calculated after the determination of the N concentration in dry samples using an automatic protein-nitrogen analyzer, by the Kjeldahl UDK-169 method, according to the official AOAC method (2005). The concentration of ether extract (crude fat) was analyzed using the VEL XT15 and Ser-158 fat extractors, according to the official AOAC method (2005).

The total AG from intramuscular fat was methylated and extracted using the procedure in accordance with VILLENEUVE et al. (2013), with adaptations. In summary, a primary incubation of 1g of meat in 2mL of sodium methoxide (0.5 M in methanol) at 70 ºC for one hour was performed. Then, a secondary incubation for half an hour at 50 ºC, after the addition of 3 mL of methanolic HCl. The determination of the AG profile was performed with a GC-CP3800 gas chromatograph, in a method recommended by FAUCITANO et al. (2008).

Statistical analysis

Statistical analyses were performed using the DataMelt software, with the animal being the experimental unit. For most of the parameters, diet and its interaction were included in the model as fixed effects, while the block was considered as random effect. When an interaction was identified for a given variable, the primary objective was to analyze the effect of diets on the animals. For this purpose, the DataMelt and Jamovi statements were used, in accordance with HOSHMAND (2006). As the feed intake values were obtained using different methodologies for the type of diet, the statistical analysis was performed within the feed treatment. Statistical significance was declared when $P \leq 0.05$ and trend was considered when $0.05 < P \leq 0.10$.

RESULTS

Diet composition and animal performance

The chemical composition, together with in-vitro digestibility of the pasture, during the grazing season, and the ingredients of the concentrated diet, are presented in Table 2. Pasture fiber concentrations increased, DIVMS decreased, while PB remained similar with the advance of the grazing season. The foraging animals contained more AG of the n-3 family than the corn and soybean fed animals, which were richer in AG of the n-6 family.

The composition of pasture and concentrated ingredients directly influences the carcass characteristics and meat quality of goats, since the nutrients contained in the food physiologically will be the foundation for the entire muscular and skeletal structure of the animal. Therefore, its establishing is essential for discussing the results found in this study.

Nutrient intake (MS, MO, PB, FDA, FDN) and metabolizable energy are shown in Table 3. Although it was not statistically evaluated due to the different measurement methods, it can be observed that goats fed on pasture had a higher CMS (+65.2%) than those on concentrated diet plus hay ad libitum, this is due to the fact that a total diet has nutrients diluted in and needed in a small amount.

In turn, pasture as a single ingredient may not contain the nutrients that the animal needs, so in order not to have a nutritional imbalance, the animal compensates with higher consumption of forage, but to a certain extent, since there is a limitation of consumption to the detriment of fiber intake by the physical regulation of fiber over consumption.

Table 2. Composition and digestibility of the pasture mix available during the 2023 grazing season and concentrate ingredients.

Variable	Pasture						X	Hay	Corn meal	Soybean meal
	JAN	FEB	MAR	APR	MAY	JUN				
MS (% of MN)	27,7	22,9	21,9	21,2	19,6	19,7	22,17	90,7	89,9	90,9
MO (% of MS)	93,0	91,6	90,6	89,3	83,9	82,7	88,52	91,4	98,5	93,3
PB (% of MS)	12,2	13,3	12,4	13,2	13,9	13,1	13,02	12,3	8,4	49,5
FDA (% of MS)	22,9	28,1	31,1	29,6	34,4	33,9	30,0	33,9	2,7	6,9
FDN (% of MS)	42,4	46,2	43,1	42,5	46,5	46,3	44,5	56,1	8,5	8,7
DIVMS (% of MS)	92,7	87,2	85,8	86,2	82,6	83,1	86,27	80,0	97,2	99,7
AG (% of total AG)										
12:0	0,80	1,38	0,87	1,00	1,03	1,20	1,05	0,95	0,15	0,13
14:0	1,62	1,95	1,65	1,82	1,89	2,62	1,93	2,08	0,13	0,19
16:0	28,95	33,34	31,96	29,56	28,98	27,93	30,12	38,38	15,75	19,83
17:0	0,55	0,75	0,72	0,73	0,72	0,80	0,71	0,80	0,22	0,39
18:0	3,59	4,62	4,63	6,04	4,55	4,06	4,58	4,20	2,71	5,69
18:1	7,07	7,76	8,03	7,87	8,15	7,45	7,72	7,21	28,13	14,67
18:2	18,13	19,01	21,28	19,27	20,81	19,75	19,71	17,03	50,70	51,82
18:3	36,87	27,90	27,98	30,95	30,99	33,17	31,31	25,96	1,18	6,27
20:0	1,56	2,06	1,81	1,74	1,71	1,77	1,78	19,0	0,64	0,63

MS, dry matter; MN, natural matter; PC, crude protein; FDA, fiber in acid detergent; FDN, fiber in neutral detergent; DIVMS, in vitro dry matter digestibility.

Table 3. Effect of diet on the feed and nutrient intake of the groups of animals fed with pasture or concentrate.

Variable	Pasture[a]	Concentrate[b]	EPM	P value
CMS				
True ($g \cdot d^{-1}$)	1592	938	56,75	0,67
PM proportion ($g \cdot kg^{-0,75}$)	108	48,4	2,96	0,46
CMO ($g \cdot d^{-1}$)	1203	878	42,05	0,69
CPB ($g \cdot d^{-1}$)	240	137	8,05	0,56
CFDN ($g \cdot d^{-1}$)	712	230	25,15	0,35
CFDA ($g \cdot d^{-1}$)	510	124	17,3	0,40
CEM[c] ($Mcal \cdot d^{-1}$)	3,77	2,64	0,13	0,67

Note: EPM, average standard error; PM, metabolic weight; CMO, organic matter intake; CPB, crude protein intake; CFDN, fiber in neutral detergent intake; CFDA, fiber in acid detergent intake; CEM, metabolizable energy consumption. [a]Based on fecal collection/indigestible marker method. [b]Hay and concentrate intake. [c]Calculated based on the energy concentration of feed ingredients according to NRC (2007).

There was no effect of the two feeding regimens on the average daily gain (ADG) of the goats (Table 4). Nevertheless, goats in rotational grazing tended (P = 0.07) to take longer to reach PCA in comparison to goats in concentrated feeding (115 vs. 106 days). A feed interaction for PCVZ was observed that was higher for animals under concentrate regime compared to animals under grazing.

The carcasses of animals fed with concentrate were heavier than the animals with roughage feed (22.6 vs. 21.1 kg; P < 0.01) and also had higher yields than grazing animals (59.9 vs. 58%; P < 0.01).

Table 4. Effect of diet on the performance of the animals.

Variable	Pasture	Concentrate	EPM	P value
				P x C[a]
Initial weight (kg)	23,7	23,9	1,5	0,92
Initial age (days)	138	141	1,3	0,80
Final weight (kg)	43,7	45,1	0,7	0,56
Final age (days)	253	247	7,0	0,05
GPD (g)	159	167	11,0	0,63
Duration of the fattening period (days)	115	106	8,0	0,07
Empty body weight (PCVZ) (kg)	36,4	37,7	0,5	0,27
Carcass weight (kg)	21,1	22,6	0,4	<0,01
Carcass yield[b] (%)	58,0	59,9	10,9	<0,01
Retraction (g/kg^{-1})	25	21	76	0,53

EPM, average standard error. [a]Effect of feed management (pasture x concentrate). [b]Carcass yield = (carcass weight/PCVZ x 100).

Non-carcass components and primary cuts

There were significant effects on the non-carcass components expressed as a percentage of the PCVZ (Table 5). The goats in the concentrated group had a higher proportion of the respiratory tract and deposited about twice as much omental, mesenteric, perinephric and pelvic fats compared to the goats in the rotational grazing group (P < 0.01).

While grazing animals had higher gastrointestinal tract (TGI) proportions or tended to have higher kidneys proportions compared to concentrate goats. It is notorious that the feeding diet directly affects the primary cuts of half carcasses (Table 6), as the animals in rotational grazing tended to have a higher proportion of neck than the goats in concentrate diet (71.5 vs. 56.7 g·kg^{-1} of the half carcass); P = 0.06).

Table 5. Effects of rotational grazing and concentrate-based diet on non-carcass components.

Components (% of PCVZ)	Pasture	Concentrate	EPM	P value
				P x C[a]
Head	4,31	4,15	1,2	0,21
Skin (hide)	16,25	15,36	4,7	0,09
Heart	0,44	0,44	0,2	0,12
Respiratory tract	1,43	1,63	0,9	0,01
Liver	2,18	2,05	0,7	0,17
Kidney	0,29	0,25	0,2	0,08
Testicle	0,57	0,47	0,3	0,10
Abomasum	3,15	2,17	1,1	<0,01
Intestine	2,82	2,33	1,3	0,03
Omental e mesenteric fat	3,40	6,17	4,2	<0,01
Renal e pelvic fat	1,05	2,36	1,8	<0,01

EPM, average standard error. [a]Effect of feed management (pasture x concentrate).

Table 6. Effects of rotational grazing and concentrate-based diet on the primary cuts of the half-carcass.

Components (% of PCVZ)	Pasture	Concentrate	EPM	P value
				P x C[a]
Neck	7,15	5,67	5,1	0,06
Ulnar (forearm) e chest	10,09	9,81	7,5	0,76
Shoulder	25,12	25,14	7,4	0,42
Flank	8,72	10,57	4,8	0,07
Ribs	9,20	8,18	4,8	0,30
Loin	10,64	10,89	3,8	0,25
Leg (shank)	33,92	29,73	16,1	0,22

EPM, average standard error. [a]Effect of feed management (pasture x concentrate).

The animals in the concentrate regime had higher proportions of fat in the shoulder, loin and half carcass and tended to have a higher proportion of fat in the shank (leg), forearm and chest ($P < 0.01$) and ribs ($P = 0.08$) compared to the animals on pasture (Table 7).

While animals on pasture had a higher proportion of lean meat in the half-carcass, neck ($P = 0.03$), ribs, loin and shoulders (shoulders) ($P < 0.01$) compared to the animals in concentrate.

Table 7. Effects of the feeding regimen (feeding management) on the weight of the half carcass and tissue proportions of the primary cuts.

Variable	Pasture	Concentrate	EPM	P value
				P x C[a]
Half-carcass				
Muscle (kg)	6,39	6,19	0,20	0,90
Bones (kg)	2,41	2,52	0,09	0,16
Fat (kg)	0,93	1,62	0,08	<0,01
Total (kg)	9,73	10,33	0,29	0,01
Half-carcass				
Muscle (g·kg)	656,73	599,23	24,7	0,01
Bones (g·kg)	247,69	243,95	14,4	0,42
Fat (g·kg)	95,58	156,82	9,8	<0,01
Neck				
Muscle (g·kg)	654,47	599,43	22,3	0,03
Bones (g·kg)	281,61	317,69	23,5	0,35
Fat (g·kg)	63,92	82,88	12,1	0,52
Forearm and chest				
Muscle (g·kg)	539,07	512,27	13,9	0,65
Bones (g·kg)	366,85	346,21	19,1	0,15
Fat (g·kg)	94,08	141,52	12,1	0,01
Shoulder				
Muscle (g·kg)	671,11	599,74	15,6	<0,01
Bones (g·kg)	233,02	238,48	12,8	0,24
Fat (g·kg)	95,87	161,78	8,8	<0,01
Flank				
Muscle (g·kg)	640,75	582,43	25,0	0,23
Bones (g·kg)	208,18	183,86	13,5	0,53
Fat (g·kg)	151,07	233,71	24,9	0,14
Ribs				
Muscle (g·kg)	614,96	515,41	17,7	<0,01
Bones (g·kg)	276,20	292,76	16,7	0,95
Fat (g·kg)	108,84	191,83	28,5	0,08
Loin				
Muscle (g·kg)	621,87	532,43	25,7	0,06
Bones (g·kg)	266,10	252,46	23,6	0,20
Fat (g·kg)	112,03	215,11	14,7	<0,01
Shank (leg)				
Muscle (g·kg)	703,95	681,33	11,3	0,15
Bones (g·kg)	218,35	206,95	8,2	0,65
Fat (g·kg)	77,70	111,72	7,3	0,01

EPM, average standard error. [a]Effect of feed management (pasture x concentrate).

Meat Quality Attributes

The final pH (pHf) of the meat was higher (6.02 vs. 5.69; P < 0.01), while the glycolytic potential was lower (113.5 vs. 158.7 μmol lactate eq·g^{-1} of tissue; P < 0.01; Table 8) in the meat of animals in a concentrated diet compared to animals in rotational grazing. The meat of grazing goats had higher FC compared to the meat of confined animals (6.82 vs. 5.09 kgf; P < 0.01).

Table 8. Effects of the feeding system on meat quality attributes.

Variable	Pasture	Concentrate	EPM	P value
				P x C[a]
Final pH	5,69	6,02	0,09	<0,01
Cooking losses (g·kg^{-1})	266,7	268,9	10,6	0,22
FC (kgf)	66,9	49,9	5,2	<0,01
Glycolytic potential (μmol lactate·g^{-1})	158,7	113,5	11,3	<0,01
Loin ear area (cm^2)	15,2	15,7	0,08	0,16
humidity (g·kg^{-1})	742	742,1	4,3	0,48
Protein (g·kg^{-1})	234	223,9	2,9	<0,01
Fat (g·kg^{-1})	19,6	30,9	2,1	<0,01
Thickness of rib fat (cm)	0,12	0,15	0,01	0,38
Color of meat				
L*	42,39	41,42	0,68	0,05
a*	14,21	13,26	0,76	0,58
b*	7,46	7,08	0,57	0,70
Color of subcutaneous fat				
L*	74,06	75,01	1,52	0,59
a*	2,25	0,26	0,81	0,01
b*	10,40	8,84	0,70	0,36
Color of perinephric fat				
L*	84,09	83,41	0,62	0,29
a*	0,21	-2,33	0,38	<0,01
b*	7,54	6,18	0,57	<0,01

EPM, average standard error. [a]Effect of feed management (pasture x concentrate).

Feeding management influenced meat composition, where in the grazing system there was a higher concentration of protein (234.0 vs. 223.9 g·kg^{-1}; P < 0.01) and lower fat content (19.6 vs. 30.9 g·kg^{-1}; P < 0.01) compared to the concentrate-based confined system. The L* of the meat was higher for the meat produced on pasture compared to the meat in the concentrate regime (42.39 vs. 41.42; P = 0.05). The a* value of subcutaneous and perirenal fats was higher in the pasture diet compared to the concentrated diet (P ≤ 0.01). The b* value of perirenal fat was higher for grass-fed beef.

Intramuscular fatty acid profile

The AG profile of intramuscular fat was affected by dietary management (Table 9). The animals in the concentrated regime accumulated more 16:0, but less 18:0 compared to the animals in the pasture regime (P = 0.01). As a result of these effects on the total AG portion, the intramuscular fat of the animals fed with concentrate showed an increase of almost four times the proportion of n-6/n-3 FA compared to the intramuscular fat of grazing animals.

Table 9. Effects of dietary management on the fatty acid profile of intramuscular fat.

Fatty acid (mg·g^{-1} of total AG)	Pasture	Concentrate	EPM	P value
				P x C[a]
12:0	1,39	0,93	0,19	0,36
14:0	19,03	19,52	1,49	0,23
15:0	4,55	3,67	0,28	<0,01
16:0	192,70	209,2	5,69	0,01
17:0	10,63	10,74	0,62	0,01
18:0	170,85	133,58	6,55	<0,01
20:0	0,83	0,5	0,06	0,01
22:0	0,21	0,17	0,02	0,27
24:0	0,25	0,15	0,03	0,06
Other AG	599,56	621,54	-	-
Sum				
*t*18:1 AG	25,73	16,82	1,48	<0,01
*c*18:1 AG	392,00	479,24	-	-
n-6 AG	71,66	61,69	6,02	0,39
n-3 AG	44,25	8,98	1,80	<0,01
Feed				
n-6/n-3 AG ratio	1,65	7,34	0,60	<0,01

EPM, average standard error. [a]Effect of feed management (pasture x concentrate).

Finally, the intramuscular fat of animals in the concentrated diet was composed of lower concentrations of odd and branched chain fatty acids compared to the fat of the goats on pasture.

DISCUSSION

Diet composition and consumption

The nutritional value of pasture gradually decreased over the grazing period (6 months), with higher concentrations of FDA and FDN and lower concentration of MO and DIVMS in May than in January (Table 2). Such variations were similar and reported by PEREIRA (2016) in pasture cultivated for beef sheep.

The AG profile of pasture animals was representative of a mixed botanical composition of tropical grasses, when compared with data reported by GAMA et al. (2020), with a predominance of 16:0, 18:2 and 18:3. The 18:3 concentration of available forage was minimal in February and March, corresponding to the rainy months in the experimental region, and in agreement with a maximum for most of the other AG, which is in line with the AG profile of mixed grasses reported by BODNÁR et al. (2021).

It is known that the energy cost for maintaining beef goats is 126 kcal·kg PC$^{0.75}$ (NRC 2007, DA SILVA 2021). Nevertheless, there was a significant difference ($P > 0.05$) in CMS, either expressed as g·day^{-1} or as a percentage of metabolic weight, between animals in rotational grazing and animals in total confinement with concentrate diet (Table 3). Analogous results were reported by RUVUGA et al. (2022) who determined that goats had higher consumption on pasture compared to consumption on a concentrate-based diet.

The difference in CMS between grazing (1592 g·day^{-1}) and concentrate (938 g·day^{-1}) animals should be interpreted with reservations, since two different methods of determining intake were used. Nevertheless, the magnitude of variation (+65.2% in grazing animals) suggests that other factors, in addition to consumption measurement techniques, may be involved. In this scenario, the results found agree with those reported by SALDANHA et al. (2021), who observed higher consumption in roughage-fed lambs compared to lambs on a concentrated diet.

A higher energy demand is needed, as a result of higher energy expenditures of grazing animals for activities such as displacement for forage selection (BRASSARD et al. 2016). In addition, outdoor grazing conditions and the rate of caloric increment result in a greater heat increment that may be associated with increased FDN intake of goats in rotational grazing (MOOSE et al. 1969). Higher caloric demand may explain the increase in the CMS of pasture animals. As a result, the animals on rotational grazing consumed numerically more metabolizable energy compared to the animals on concentrate-based diet.

Animal Performance

The nutritional value of the managed grass under the intensive rotational grazing allowed a similar GPD in both feeding regimes. The average growth rate, evaluated as the average daily gain in the two systems (163 g·day^{-1}; Table 4), was higher than the objective of the experiment of 150 g·day^{-1}. The nutritive value of the pasture was variable during the grazing season, but it was maintained at the ideal level for short periods of grazing in limited paddock areas. A lower performance was expected in animals raised on less intensively managed pastures (HUANG et al. 2023).

The goats submitted to the grazing regime were 3 days younger at the beginning of the experiment and had a lower PC. They also performed less than the animals on a concentrate-based diet. The duration of the fattening period was similar for both feeding regimes, but with a significant difference of 9 extra days needed to conclude the goats on pasture ($P > 0.05$; Table 4). As a result, the slaughter age of the animals in both feeding systems was similar ($P = 0.05$).

Regarding the development stage of the Boer breed, MOKOENA & TYASI (2021) point out that the adult weight of the breed is 80 to 120 kg, so the final body weight for both feeding regimes (44.4 kg average; Table 4) was, therefore, far from his adult weight. However, with equivalent weights and ages, the animals of both feeding systems were at an equivalent stage of maturity at the time of slaughter.

Beef goats are generally known for their higher growth rate, for example, than dairy breeds (DUTTA et al. 2020). However, regardless of the feeding regime, animals in both regimes had a satisfactory GPD in our study, so that the duration of the fattening period, although it presented a significant difference, to reach the desired slaughter weight was similar in both feeding systems.

The lack of large differences between feeding systems for GMD suggests that there is potential for goat farming exclusively with intensive management of rotational pastures with high potential for nutritive value (LOPES et al. 2020). In addition, it took less than two additional weeks (9 days) on low-cost roughage feed for the animals on pasture compared to those on a diet based on limited concentrate and hay ad libitum to reach the recommended slaughter weight during an average fattening period of around 16 weeks.

Non-carcass components and primary cuts

The trend towards heavier skin (hide) and significantly higher proportion of the gastric tract in animals on pasture than for animals on a concentrated diet (Table 5) coincides with the observations of SOUZA et al. (2015) and EKIZ et al. (2020). SANTOS et al. (2023) stated, in their study with goats, that higher feed intake increases the weight of the gastrointestinal tract (TGI) and liver. More specifically, the accumulation of epithelium related to higher CMS and the physical effects of digesta in grazing animals could be part of the explanation.

According to MIRANDA et al. (2019), a higher proportion of TGI in relation to PCVZ may contribute to an increase in thermogenesis related to the metabolism of its constituent organs in forage-fed animals compared to ruminants on a concentrate-based diet. Therefore, this factor may have contributed to an increase in energy demand and higher CMS and EM in the goats on pasture during the experiment.

The increase in internal fat deposition was obtained in animals on a concentrate-based diet. This observation is corroborated by the results of BAMBOU et al. (2021) in Creole goats raised with or without concentrate, and with APLOCINA (2020) in Boer and SPRD crossbred goats when comparing mixed feeding with hay-based diets supplemented with different types of concentrate and inclusion levels. Similarly, the cuts revealed a higher amount of fat in the half carcass and higher proportions of adipose tissue in several primary cuts (loin, shank, etc.) in goats in a concentrate-based diet compared to pasture, corroborating the data from GAMA et al. (2022).

It is noteworthy that the effects of the feeding treatments did not have a significantly relevant effect. A limited impact of feed management on the yield of primary cuts was also observed in this present experiment, which is in accordance with the data reported by DUTTA et al. (2023) in goats that received different levels of commercial concentrate. The increase in relative weight of the posterior cuts to the detriment of the previous cuts results from the selection of the Boer breed specialized in meat production, that is, selected for muscle growth, which leads to a higher meat yield for this breed, a fact that is corroborated to the detriment of the loin eye area in the present study, being documented by KANDIWA et al. (2020).

Nevertheless, it was expected that primary cuts would not suffer so much interference from feeding management due to their representativeness on the animal's weight, namely for a standard carcass, the proportion of neck, rib, loin and shank are more or less 11.5-12%, 19-20%, 11-12% and >30%, respectively. In this sense, the proportion of primary cutoffs in the present study deviated from the values recommended by CEZAR & SOUSA (2007).

Meat quality

The lower glycolytic potential of meat from animals in a concentrated diet resulted in a higher pHf and a tendency towards darker coloration. These results were unexpected, mainly because it is known that concentrated feeding favors the production of propionate in the rumen, which is the main precursor of gluconeogenesis and, therefore, allows greater glycogen accumulation in the muscle (CARRILLO-MURO et al. 2022, PONNAMPALAM et al. 2024). However, the conditions of animal handling and the stress involved during the slaughter operation may have influenced this phenomenon.

According to POPHIWA et al. (2020), meat quality characteristics are affected by stress, resulting in higher pHf and darker color. In this study, the average time spent by the team to slaughter animals in a concentrated regime was shorter compared to rotational grazing (11±4 versus 15±2 minutes/head for transport to the appropriate location and stunning for slaughter and bleeding).

All management and measurements related to fence treatments, pasture sampling or feces collection required greater interaction with the goats on pasture. Although the transport conditions and pre-slaughter management were the same for both treatments, it can be speculated that the animals on a concentrated diet were less adapted to human contact and, therefore, more prone to the stress that all pre-slaughter management provided.

Although the pHf of the meat was lower, the animals in the pasture regime had higher FC. SILVA (2021) indicates that, through an evaluation of FC (N), that the meat of grass-fed lambs was less tender than that of lamb fed concentrate (50.4 x 27.06 N). As observed in the present study with Boer goats, the meat of lambs fed with concentrate contained a higher concentration of fat than the meat of lambs fed on pasture, and fat, according to SILVA (2021), the main factor that increases the sensation of tenderness of the meat, originating from the action of the calpain and calpastatin complex, as it is softer than lean tissue (muscle).

On the other hand, in the studies by SANTOS et al. (2021), meat from animals fed with concentrate, compared to that from animals on pasture, showed greater juiciness and tenderness, but was less accepted by the consumer market due to the increase in flavor intensity and fat concentration. While the effect of feed management on meat tenderness seems to be variable, since MOLONEY et al. (2021), studying the meat of grass-fed beef cattle compared to concentrate-fed animals observed an analogous FC and overall tenderness, even with the marbling score significantly higher for goats under concentrate regime.

A higher value for a* in fat deposit in goats on pasture than with concentrate may be an effect of the increase in the concentration of antioxidants in mixed pasture in natura, which could effectively prevent the formation of oxidized molecules that interfere with fat color, such as the conversion of red oxymyoglobin to brown metamyoglobin (MANCINI & RAMANATHAN 2020). The higher value for b* of perinephric fat observed in pastured animals may be influenced by the accumulation of lutein resulting from green pasture (REY-CADILHAC et al. 2024). An analogous phenomenon has been observed in lambs (REY-CADILHAC et al. 2024).

Intramuscular fatty acid profile

In this experiment, the whole corn and soybean meal used as basic ingredients of the concentrated mixture contained 18:2 (n-6 family) as the predominant AG in the composition, while the pasture mixture was rich in 18:3 (n-3 family). As a result, the intramuscular fat of the animals from the pasture diet, compared to animals on the concentrated diet, contained higher concentrations of 18:3, as well as several other AG of the n-3 family. This effect was noticeable despite the fact that an 18:3 ratio of the diet underwent biohydrogenation in the rumen, a fact corroborated by the increase in the concentration of intermediates of this process in the intramuscular fat of goats on pasture (i.e., AG of the order 18:3, 18:2 and 18:1).

The digestive tract of beef goats, in both feeding systems, was efficient to partially hydrogenate the 18:2 AG of the concentrate. This assumption was corroborated by the accumulation in the meat of several intermediates of rumen biohydrogenation.

Concentrated feeding decreased the ratio of 18:0 in intramuscular fat, but increased the ratio of 18:1, a fact evaluated and corroborated by TAFFAREL et al. (2020) in beef steers and by COUGO et al. (2024) in lambs.

The intramuscular fat of the LTL of animals on pasture contained higher proportions of branched-chain AG compared to animals in the concentrated regime. Data on the factors that affect the branched-chain AG profile of intramuscular fat in beef goats, especially Boer, are still scarce. In alpine goats, LOPEZ et al. (2022), established a positive correlation between the concentration of FDN in the diet and the concentration of 15:0, 16:0 and 17:0 AG in milk fat. This relationship is consistent when the intake of FDN in goats on pasture is increased in the present experiment.

It is expected that further studies, with other sources of roughage and concentrates or even with a larger number of animals, can be evaluated based on the observations reported in this study, corroborating or contradicting the results that the carcass characteristics and quality of goat meat are directly related to feed management and how important this factor may be on the economic impact on the farms.

CONCLUSION

In conclusion, animals managed in intensively rotational grazing presented similar GPD to animals raised in feedlot with a concentrate-based diet, however it resulted in less accumulation of subcutaneous and intramuscular fat essential for the rigor mortis process, and the meat showed higher FC resulting in lower tenderness compared to a concentrate-based diet. The results of this comparison would have been different if there had not been a dietary restriction imposed on the animals on a concentrated diet.

Nevertheless, the results suggest that the fattening of Boer goats in an intensive rotational grazing system can be an alternative to concentrate-based diets without loss of quality in meat products and without significant impact on the consumer market. The reciprocal influence between the feeding systems for the primary cuts showed that the animals on pasture were more influenced by the feeding management with regard to the accumulation of fat and muscle tissue compared to the animals on concentrate diet.

The essentially roughage diet increased the proportion of n-3 AG, while the concentrate diet resulted in an increase in the concentrations of n-6 AG in intramuscular fat. However, meat from goats raised essentially on pasture will continue to be a seasonal product in the fresh produce market, since there is seasonality of forage supply to the detriment of climatic variations in the semi-arid region of Brazil, so the inclusion of concentrate in the animals' diet is an indispensable practice to maintain the supply of product in the market.

AUTHOR CONTRIBUTIONS

Emanuel Isaque Cordeiro da Silva: Conceptualization, data curation, formal analysis, fundraising, investigation, methodology, project management, supervision, validation and writing – review and editing.

Eduarda Carvalho da Silva Fontain: Data analysis, investigation, methodology, resources, software, writing – preparation of the original draft.

All authors have read and agreed with the published version of the manuscript.

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STATEMENT OF THE INSTITUTIONAL REVIEW BOARD

The handling and care of the animals was done in accordance with guidelines and recommendations of the Ethics Committee on the Use of Animals (CEUA), license 010705/2008.

INFORMED CONSENT STATEMENT

Not applicable because this study did not involve humans.

DATA AVAILABILITY STATEMENT

The data can be made available upon request.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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