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Dry matter intake, performance and carcass characteristics of hair sheep reared under different grazing systems

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ABSTRACT: The aim of this study was to evaluate the effect of three different grazing systems: isolated, alternate and simultaneous, on feed intake, performance and carcass characteristics of sheep. About 5.2 ha area of Tanzania grass (*Panicum maximun* Jacq cultivate Tanzania) was divided into 13 paddocks. This area was used as a stocking rate of two animal units (AU) per ha for 7 days' occupation and 21 days rest. A total number of 58 animals were used consisting of 12 heifers and 30 Santa Ines lambs with the addition of 16 adult ewes that were used to stabilize grazing pressure in the isolated system. The sheep were fed on 200 g per head per day of concentrate and cattle 2 kg per head per day. The parameters determined were the following: weekly weight (WW), total live weight gain (LWG) and mean daily weight gain (MDW). Also dry matter intake was estimated 84 days after the start of the experiment using external indicators (Purified and Enriched Lignin) in addition to carcass traits and composition which were also estimated. The result obtained for carcass composition revealed that the muscle:bone ratio and bone percentage were better in the alternate system. Moreover, the simultaneous and isolated systems showed higher lamb performance than the alternate system, while there was no effect on dry matter intake. Furthermore, there was no difference of the different systems on carcass traits and feed intake of sheep. Nevertheless, the simultaneous grazing system showed better sheep performance than the alternate grazing system.

Keywords: carcass quality, carcass weight, simultaneous grazing systems, Tanzania grazing area

Introduction

In recent years, grazing systems for ruminants have been the subject of sustainability and environmental impact studies (Saggar et al., 2015), as well as ensuring maintenance of animal welfare (Rutter, 2010). In addition, the use of integrated pasture for different herbivorous species leads to beneficial effects on plant-animal interaction (Blanco et al., 2007), increasing the production at pasture, with improved forage quality and efficiency of utilization, with a consequent increase in production per area and per animal.

The selectivity and forage quality requirements for cattle and sheep are different and can be influenced by vegetation composition and diversity (Wrage et al., 2011). Cattle can encircle forage with their tongues with no selectivity for plant quality as they eat to increase bulk in the rumen; however, sheep, on the other hand, have considerable selectivity for high quality plants although they graze with their tongues just like cattle. Whatsmore, they have the ability to eat grasses close to the ground as they have an upper lip fissure which explains why they are called sweeper animals (Rook et al., 2004; Jerrentrup et al., 2015). Thus, complementary grazing of cattle and sheep could be beneficial from an agronomic point of view (Jerrentrup et al., 2015), allowing for better utilization of pastures resulting in a structurally more homogeneous sward (Forbes and Hodgson, 1985).

Carcass and meat quality of sheep are affected by grazing systems mainly in regard to carcass quality and degree of fattening (McClure et al., 1995; Priolo et al., 2002). However, under tropical conditions and with the complexity of existing ecosystems involved, little information on carcass traits as well as the performance of sheep, under different grazing systems is known (Bailey et al., 2009; Dickhoefer et al., 2014). The aim of the present study was to compare the effect of different grazing systems on feed intake, performance, carcass quality and composition of sheep.

Materials and Methods

Animal care procedures used in this study were the following protocols approved by the ethical committee for animal use at the University of Brasília under the number 44568/2009.

This experiment was carried out in the Federal District, Brazil, at 15°57' S and 47°56' W, with altitudes ranging from 1050 to 1250 m. At this location the climate is tropical seasonal, according to the Koppen classification (Alvares et al., 2013). Moreover, a 5.2 ha area of Tanzania grass (*Panicum maximun* Jacq. cultivate Tanzania) was used for this study during the rainy season (Jan to Apr) for 7 days occupation and 21 days rest by dividing it into thirteen paddocks. The thirteen paddocks were then sub-divided into three groups: the first, denominated as "isolated" comprised 4 paddocks with sheep only, the second denominated as "alternate", comprised 5 paddocks with sheep grazing after cattle and the last, denominated as "simultaneous" comprised 4 paddocks with cattle and sheep grazing together. A total number of 58 animals were used which were divided into twelve crossbred heifers (six for the isolated and six for the simultaneous), weighing initially 206.70 + 20.79 kg and 30 Santa Ines lambs weighing 22.70 + 2.23 kg, in addition to 16 adult ewes weighing 47.38 + 7.67 which were used for stabilizing grazing pressure in the isolated system. The cattle remained inside the paddocks all the time, while the sheep were gathered into shelters every night. The sheep were fed on 200 g per head per day of concentrate and cattle 2 kg per head per day. For the sheep, the concentrate mixture consisted of 550 g kg^{-1} corn, 300 g kg^{-1} soya bean meal, 100 g kg^{-1} cotton meal and 50 g kg^{-1} wheat meal, with 880 g kg^{-1} dry matter (DM), 220 g kg^{-1} crude protein (CP), 720 g kg^{-1} total digestible nutrients (TDN) and 2.613 Mcal kg^{-1} of metabolizable energy (ME). For the cattle, the concentrate mixture consisted of 600 g kg^{-1} corn and 400 g kg^{-1} soya bean meal, with 880 g kg^{-1} DM, 230 g kg^{-1} CP, 780 g kg^{-1} TDN and 2.839 Mcal kg^{-1} of ME. The sheep were sent to the pasture at 8h00 and were housed at 16h00, where they received the concentrate individually in the trough daily. The pasture composition is presented in Table 1. Further details are to be found in Brito et al. (2013).

The forage was harvested weekly in the paddocks at the entrance and exit of the animals aiming to estimate the availability of the forage mass (Table 1). In each paddock, four representative samples were collected at a height of approximately 5 cm from the ground in 0.5 × 1.0 m rectangles and together formed a composite sample. This sample was weighed and represented the weight of forage available in 2 m² and was used to calculate the availability in one hectare. For chemical analysis (Table 1) of forage, another sample was collected from each paddock immediately before the animal entrance by simulating grazing. The simulating grazing was done after careful observation of the area and trying to capture samples by hand that closely represent the one ingested by animal grazing (Sollenberger and Cherney, 1995). The neutral and acid detergent fiber content were analyzed according to Van Soest et al. (1991), and the dry matter, crude protein, ether extract, inorganic phosphorus and mineral matter according to Silva and Queiroz (2002). Moreover, total digestible nutrients (TDN) was calculated according to Cappelle et al. (2001) using the equation TDN = 9.6086 – 0.669233 NDF + 0.437932 CP (R2 = 0.71).

The animals were dewormed before the beginning of the study, using the Albendazole and Levamizole combination.

Dry matter intake was estimated 84 days after the beginning of the experiment by an external indicator technique using purified and enriched lignin capsule (LIPE® 250 mg d^{-1}), given orally to the lambs with the aid of a probang tube, for five consecutive days. The fecal samples were collected for four days, stored together and formed a composite sample, making a total of 30 samples, one from each lamb, which were frozen at -20 °C for subsequent analysis. The determination of this indicator in feces was done by infrared spectroscopy. After predrying the feces (in an oven with forced air ventilation at 60-65 °C) they were ground in a Wiley mill through a sieve with a 1 mm mesh size and dry matter content (DM) was determined at 105 °C (AOAC, 2005).

When the lambs were weighed weekly, the following measures were taken including initial weight (IW), weekly weight (WW), final weight (FW), live weight gain (LWG) and average daily gain (ADG). Moreover, dry matter intake from pasture ($DMI_{pasture}$), dry matter intake of crude protein (DMI_{CP}), total dry matter intake (DMI_{total}), dry matter intake in relation to total carcass weight at slaughter ($DMI_{\%CW}$); metabolic weight (MW) and dry matter intake per kg of metabolic weight ($DMI_{0.75}$) were also estimated.

Table 1 – Chemical analysis of forage of different grazing systems (g kg^{-1} dry matter).

Items	Grazing Systems			CV	Pr > F
	Simultaneous	Alternate	Isolated		
				%	
Forage (kg ha^{-1})	3200	3176	3672	15.26	0.3858
Leaf portion	616^{a}	516^{b}	572^{ab}	13.83	0.0398
Stem portion	255	298	286	12.64	0.5712
Leaf:stem ratio	2.75^{a}	1.90^{b}	2.23^{ab}	19.68	0.0198
Dry matter	229	249	230	6.89	0.6279
Crude protein	158^{a}	120^{b}	151^{a}	8.32	0.0321
Neutral detergent fiber	670^{b}	703^{a}	671^{b}	9.80	0.0453
Acid detergent fiber	372^{ab}	392^{a}	368^{b}	6.88	0.0167
Ether extract	26	24	25	3.10	0.9245
Mineral matter	89	87	85	3.80	0.2287
Inorganic phosphorus	2.7	2.5	2.5	27.57	0.952
Total nutrients digestive	536^{a}	498^{b}	533^{a}	4.66	0.0402

CV = coefficient of variation. Means within the same line with different superscript letters are significantly different (p < 0.05) using the Tukey test.

After 99 days of experimentation, the lambs were sent for slaughter in an abattoir accredited by the Brazilian Federal Inspection System after being fasted for 24 hours then weighed after slaughter to obtain total carcass weight at slaughter and also body condition assessment based on a scale of 1 to 5.

The body score was evaluated subjectively by the amount and distribution of external fat on the carcass in increments, ranging from one (thin) to five (very fat) on a 0.25 interval scale. Moreover, the external carcass length (distance between the base of the tail and the neck base), leg and scrotum circumference were measured with a metric tape.

After bleeding, skin thickness at the navel was measured and then removed and weighed. In addition, the thoracic (lung, heart and trachea), and abdominal cavity (liver, kidneys) viscerae were weighed. After evisceration the carcass was weighed to determine the hot carcass weight. Hot carcass yield (HCY) was calculated as follows: $HCY = HCW/CW \times 100$ then this carcass was stored in a freezer at 4 °C and weighed after 24 hours to obtain both cold carcass weight and cold carcass yield (CCY) and was calculated as: $CCY = CCW/CW \times 100$, where HCW is the hot carcass weight, CCW the cold carcass weight and CW the carcass slaughter weight.

Cooling weight loss (CWL), which constitutes the loss of carcass humidity in cold storage and chemical reactions in the muscle during the cooling process, was measured as: $CWL = (HCW - CCW)/HCW) \times 100$, where HCW is the hot carcass weight and CCW the cold carcass weight.

The carcass was separated into two equal portions with a longitudinal section along the spine. The two halves of carcass were weighed and each was divided into five commercial cuts according to Santos et al. (2008). These cuts were leg, shoulder, loin, rib/flank and neck which were weighed separately. However, the percentage of each cut was calculated by dividing each cut weight by the cold carcass weight of the half of carcass. Furthermore, carcass yield (Killout) was calculated by dividing cold carcass weight (CCW) by carcass slaughter weight (CW) (Killout = CCW/CW).

The eye muscle area (EMA) was determined in the cross section of the *Longissimus lumborum* muscle of the 12th intercostal space, using the checkered transparent standard (Calnan et al., 2014).

The 12^{th} rib was removed from the left half of carcass by a cut made on the cranial face of the 12^{th} and 13^{th} ribs and was packed in plastic bags, identified and stored at -20 °C for subsequent analysis, and was then weighed. Next muscle, bone and fat were separated by scalpel and weighed separately. From the weights of these tissues the following relations were estimated: muscle: bone; muscle: fat and comestible portion (equivalent to the percentage of the sum of muscle and fat relative to the total weight), where comestible portion (%) = (muscle weight + fat weight) × 100/ total weight of 12^{th} rib.

After weighing, the tissues of the rib components were milled together, and dried in an oven at 100 °C to constant weight. All the materials were analysed for crude protein, ether extract, dry matter and mineral matter according to AOAC (2005).

All data were analyzed by Statistical Analysis System (SAS® Institute, Cary, NC, USA, version 9.3) using a general linear model (GLM) procedure. The means were compared by Tukey test, and $p \leq 0.05$ was considered statistically significant. The statistical model used was $Yij = \mu + Si + eij$ (Yij = individual observation, μ = overall mean, Si = grazing systems (i = S, A, I) and eij = experimental error.

Results and Discussion

Evaluation of the dry matter intake of ruminants at pasture has been a great challenge to researchers, due to the difficulty of obtaining accurate estimates of feed intake but this is important when comparing different grazing systems. The dry matter intake estimated through an external indicator technique using purified and enriched lignin capsule was similar under the different grazing systems (Table 2).

Cordova et al. (1978) noted that evaluation of dry matter intake, when expressed as an absolute number, is not appropriate because of the difficulty in comparing experiments with variation in live weight among animals. Generally, an increase in consumption leads to an increase in live weight, suggesting that it is more convenient to express consumption as a function of live weight. In this case it was observed that the average consumption of sheep under different treatments was 2 % CW (carcass slaughter weight), being slightly below the 3 % for a 20 kg lamb suggested by McDonald et al. (2002). Moreover, consumption is directly correlated with forage quality, especially NDF and ADF contents, which are generally higher for tropical grasses as in the case of Tanzania, which may have caused lower intake in relation to temperate grasses.

In response to the different systems of pasture management the quality of Tanzania grass during this experiment was not similar (Santos et al., 2011). According

Table 2 – Average of dry matter intake (DMI) for sheep in different grazing systems, through an external indicator technique using purified and enriched lignin capsule marker.

Items	Grazing Systems			CV	Pr > F
	Simultaneous	Alternate	Isolated		
				%	
DMI_{total} (kg)	0.725	0.779	0.898	12.00	0.1213
$DMI_{pasture}$ (kg)	0.549	0.603	0.722	15.55	0.4933
DMI_{CP} (kg)	0.135	0.133	0.143	21.74	0.4170
$DMI_{\%CW}$ (%)	2.22	2.37	2.64	13.51	0.3164
$DMI^{0.75}$ ($_{gMW}{}^{-1\ 0.75}$ kg)	52.98	56.73	63.73	18.18	0.2494

CV = coefficient of variation; CP = crude protein, % CW = total carcass weight at slaughter; $MW^{0.75}$ = metabolic weight.

Table 3 – Least square means of initial weight, final weight, live weight gain (LWG) and average daily gain (ADG), of sheep obtained during the trial period.

Items	Grazing Systems			CV	Pr > F
	Simultaneous	Alternate	Isolated		
				%	
Initial weight (kg)	21.98	23.44	22.68	9.79	0.4243
Final weight (kg)	35.64	34.94	35.90	8.53	0.4264
LWG (kg)	13.66[a]	11.50[b]	13.19[ab]	16.04	0.0485
ADG (kg head^{-1} d^{-1})	0.145[a]	0.122[b]	0.140[ab]	16.04	0.0379

CV = coefficient of variation. Means within the same line with different superscript letters are significantly different ($p < 0.05$) using Tukey test.

to Santos et al. (2011) simultaneous and isolated systems presented better quality of grass than the alternate. The leaf:stem ratio, protein content, neutral detergent fiber content and total digestible nutrients in the simultaneous system, resulted in better performance of sheep in the simultaneous system compared to the alternate system (Table 3). It was evident that the better pasture quality in the simultaneous system provided greater weight gain for the sheep, with a possible increase in the digestibility of forage and greater concentration of nutrients from the diet guaranteeing better animal performance (Hodgson, 1990). In the simultaneous grazing system, the animals had higher live weight gains than under the alternate system, while the isolated system showed intermediate results, which was no different from the others. The lamb weight gain in both simultaneous (0.145 kg per head per day) and isolated (0.140 kg per head per day) systems were higher than that found by Silva et al. (2007) which was 0.123 kg per head per day in Tanzania pasture without concentrate supplementation which was close to the alternate (0.122 kg per head per day) with concentrate supplementation.

Under the simultaneous and isolated systems there was better forage utilization, as the same dry matter production and the forage available for the animals was richer in leaves, where most digestible nutrients are concentrated. This difference can be explained by the fact that under the simultaneous and isolated systems, the instantaneous stocking rate was higher during the period of occupation, since all the animals allocated to their respective grazing systems consumed the available forage in one week while under the alternate system the same paddock was occupied for 14 consecutive days, and 7 days for each of the cattle and sheep categories, which have different grazing habits. Under the alternate system, cattle had already passed through the paddock before sheep had access. Thus, most of the leaves had been consumed leaving the sheep a lower quality forage. In this study, the option of cattle grazing prior to sheep was selected due to the fact that cattle may eat tip larvae thereby reducing the grass parasite load. Infective larvae of sheep parasites are destroyed when ingested by cattle (Amarante et al., 1997; Torres et al., 2009).

According to Nolan and Connolly (1977), who studied the effect of mixed exploration of cattle and sheep on variables of the plant animal interface, concluded that this type of exploration increases the production per area and per animal compared to the use of forage with only one species. This effect is related to three consequences of this exploration: increased pasture production, improved forage quality and use efficiency (Nolan and Connolly, 1989). Furthermore Baker (1985) and Nolan and Connolly (1989), stated that the origin of this positive effect would be the complementary grazing patterns associated with the different preferences of each animal species for different plants, plant parts or geographical locations. In this same study, Santos et al. (2011), observed the preference for plant parts and geographical location.

There was no significant difference between different grazing systems for sheep carcass traits, body components and commercial cuts (Tables 4 and 5).

The yield average for the hot carcass obtained in the present study was close to that found by Cardoso et al. (2013) in Santa Ines sheep (47 %) slaughtered between 30 and 45 kg CW. These results were close to the lower limit of the normal range for this parameter which ranged from 45 to 60 % depending on various factors such as genetics, gender, age, body weight, birth weight, fasting time and diet effect on animals (Petit et al., 1997; Fimbres et al., 2002).

Cooling losses were the same in lambs from different grazing systems averaging 5 %. However, previous studies state that these losses range from 1 to 7 % depending on the uniformity of fat cover, sex, weight, temperature and relative humidity of the storage room (Lan-

Table 4 – Least square means of carcass characteristics and body components of sheep reared in different grazing systems.

Items	Grazing Systems			CV	Pr > F
	Simultaneous	Alternate	Isolated		
				%	
Live weight (kg)	34.25	34.30	34.56	8.12	0.9684
ECL (cm)	73.35	75.30	73.61	3.99	0.2977
Hot carcass weight (kg)	15.67	15.31	15.82	10.27	0.7732
CCW (kg)	15.25	15.00	15.20	11.06	0.9409
HCY (%)	46	45	46	5.57	0.4966
CCY (%)	44	44	44	5.08	0.8121
WLC (%)	5	4	5	62.11	0.9416
DF (1-5)	2.53	2.33	2.47	17.44	0.6146
SW (kg)	2.60	2.50	2.50	10.67	0.6436
ST (mm)	3.72	3.51	3.42	20.67	0.6629
WTO (kg)	1.00	1.05	1.00	9.14	0.4011
WAO (kg)	0.90	0.95	0.89	21.61	0.7700
SC (cm)	28.50	28.75	28.89	7.80	0.9287
LC (cm)	36.15	36.72	35.06	7.94	0.4633

CV = coeficient of variation; ECL = external carcass length; CCW = cold carcass weight; HCY = hot carcass yield; CCY = cold carcass yield; WLC = weight loss by cooling; DF = degree of fat; SW = skin weight; ST = skin thickness; WTO = weight of thoracic organs; WAO = weight of abdominal organs; SC = scrotal circumference; LC = leg circumference.

Table 5 – Least square means of weights and yields of commercial cuts of sheep reared in different grazing systems.

Items	Grazing System			CV	Pr > F
	Simultaneous	Alternate	Isolated		
				%	
Carcass cut weights (kg)					
Half cold carcass	7.71	7.48	7.77	10.39	0.6988
Leg	2.43	2.29	2.43	10.76	0.3567
Shoulder	1.38	1.45	1.51	12.10	0.3084
Neck	0.49	0.55	0.55	21.52	0.3565
Loin	0.55	0.60	0.58	24.35	0.7209
Rib/flank	2.60	2.33	2.59	15.72	0.2451
Cut yields (%)					
Leg	32	31	31	12.15	0.4746
Shoulder	18	19	19	10.35	0.2798
Neck	6	7	7	18.21	0.2545
Loin	7	8	7	20.91	0.4502
Rib/flank	33	31	33	10.23	0.2744

CV = coefficient of variation. Means within the same line with different superscript letters are significantly different ($p < 0.05$) using the Tukey test.

Table 6 – Least square means of eye muscle area measurements and chemical composition of 12th rib tissue of sheep reared in different grazing systems.

Items	Grazing Systems			CV	Pr > F
	Simultaneous	Alternate	Isolated		
				%	
Area, weight and percentage					
EMA (cm²)	12.92	12.77	12.08	16.56	0.6586
Weight (g)	87.19	82.74	93.95	18.03	0.3176
Muscle (g)	66.12	62.93	66.04	17.93	0.3567
Muscle (%)	73	76	72	6.56	0.2359
Bone (g)	9^{ab}	7^{b}	9^{a}	23.44	0.0460
Bone (%)	10	9	10	17.23	0.1591
Fat (g)	14.95	12.64	16.05	36.76	0.555
Fat (%)	17	15	18	28.47	0.5339
Ratio					
muscle:bone (%)	7^{b}	9^{a}	8^{b}	20.23	0.0530
muscle:fat (%)	5	6	4	50.97	0.1474
Edibe portion (%)	90	91	90	1.81	0.1591
Chemical composition					
Humidity (%)	63	62	63	5.67	0.6680
Dry matter (%)	37	38	37	9.55	0.6680
Protein (%)	20	20	19	6.03	0.1008
Ether extract (%)	11	12	13	34.99	0.3579
Mineral matter (%)	5	5	4	14.23	0.6030

CV = coefficient of variation; EMA = eye muscle area. Means within the same line with different superscript letters are significantly different ($p < 0.05$) using the Tukey test.

dim et al., 2011; Cardoso et al., 2013). Furthermore, the sheep carcasses recorded an intermediate fatness score (Russo et al., 2003) due to the degree of fat found which ranged between 2.33 and 2.53 which is consistent with the standard range for Santa Ines sheep which present less fat cover than wool sheep as specialized meat breeds that may facilitate the loss of water during cooling process. On the other hand, the other carcass traits, body components and commercial cuts were within normal variations of slaughtered Santa Ines sheep weighing 30 kg (Cardoso et al., 2013).

The results pertaining to the measurements of eye muscle area (Table 6) were close to those observed by Landim et al. (2011) and Cardoso et al. (2013). Moreover, this muscle has a late maturity, and is the most suitable for representing the development and size of muscle tissue (Rahman, 2007), as the greater the accumulation of fat, the lower the proportion of muscles (Forrest et al., 1975).

The ether extract percentage in the *Longissimus lumborum* muscle is an important indicator of the percentage of intramuscular carcass fat (Monteiro et al., 2006). In this study, the ether extract percentage mean value observed was 12 %. The parameters of humidity, protein and mineral matter of eye muscle in this study were lower than those found by Liu et al. (2015) working with Oula lamb slaughter with different live weight.

With regard to the bone and muscle:bone ratio percentage, they were affected by different grazing systems in that the alternate system showed less bone percentage and higher muscle:bone ratio. Moreover, this relationship has great commercial interest since it is directly related to the edible portion and, therefore, the higher the ratio, the greater the benefit to the consumer. However, this relationship should be analyzed with caution.

Conclusions

The different grazing systems did not affect the quantitative carcass traits nor the dry matter intake of sheep. However, the choice of the most appropriate grazing system results in the best forage production and animal performance, which was observed under the simultaneous grazing system of sheep and cattle and the isolated system of sheep only.

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