

Evaluation of Nutritive Value and *In-Vitro* Degradation of Sorghum Silage and Rhodes Grass-Based Diets for Finishing Beef Cattle in Feedlot System in Kenya

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Abstract

Proximate analysis of sorghum silage and Rhodes grass (*Chloris gayana*) based diets were determined for their potential to finish different beef cattle breeds in a feedlot system in arid and semi-arid lands (ASALs) of Kenya. Local feed supplements commonly utilized by pastoralists and agro-pastoralists were identified and used as ingredients for the two diets to reduce the high cost of feeds. The chemical composition and in-vitro gas production characteristics of all feed ingredients were determined. The metabolizable energy (ME) content of locally available feeds was 8.7 MJ/Kg DM in *Acacia tortilis* pods and 14.6 MJ/Kg DM in *Balanites aegyptiaca* nuts. The dry matter (DM) content ranged from 890 g/kg-1DM in *Acacia tortilis* pods and 940 g/kg-1DM in *Balanites aegyptiaca* nuts. The crude protein (CP) content was 84.6 g/kg-1DM and 154 g/kg-1DM in *Balanites aegyptiaca* nuts and *Acacia tortilis* pods, respectively. The metabolizable energy content was 11.06 MJ/kg DM in Rhodes grass-based and 12.3 MJ/kg DM in sorghum silage-based diets. Dry matter for sorghum silage and Rhodes grass-based diets were 87.93 and 89.23%, respectively. In the two diets, the CP content of Rhodes grass and sorghum silage-based diets were 15.4g/kg DM and 16 g/kg DM, respectively. Typical feedlot finishing diets should have a minimum ME of 10 MJ/kg DM and 11 - 15% CP/kg DM with rations fed at 2.5 - 3% of live weight. The in-vitro fermentation characteristics of sorghum silage-based and Rhodes grass-based rations varied widely between the two rations. The total gas production (ml/200mg DM) at 48hrs showed variations in the digestibility potential, with Rhodes grass-based ration (14.05) being the higher and sorghum silage-based ration (11.04) being the lower. Typical in-vitro gas production values for high-quality forages range from 14-25 ml gas/200mg DM at 48 hours incubation. These results indicate that the two rations used have potential for beef nutrition. The study concluded and recommended that the sorghum silage and Rhodes grass-based diets formulated using locally available rangelands feed resources have a potential for finishing beef cattle in the ASALs for increased beef production.

Keywords: Rangelands feed resources, Ingredients, Digestibility, Rations Factors, Genetics; Host-Parasite Interactions, Immunology, Vaccine Development, Worm Resistance.

Introduction

Beef cattle finishing in a feedlot production system requires sufficient amounts of quality feeds to ensure adequate feeding and good profitability from beef enterprises (Asimwe *et al.*, 2016; Neto *et al.*, 2018). Population growth for both humans and livestock, as well as pressures on the available productive land for livestock production, have necessitated improved beef productivity per unit head in an intensive system. In ASAL areas, however, there is usually a challenge in the availability of good quality and right quantities of livestock feeds. Seasonality of feeds due to erratic rains and climate variability have limited pasture and fodder production (Mudzengi *et al.*, 2020). In addition, there is competition for food and feed for ingredients like maize between humans and livestock (Wilkinson and Waldron, 2017; Manceron *et al.*, 2014). This necessitates the use of non-competitive local feed resources such as sorghum and rangeland feed resources to formulate feedlot rations (Kemboi *et al.*, 2017). The protein requirements for beef cattle also depend on the physiological state, with growing cattle needing 12-14% crude protein (CP) and mature, non-lactating cows only need 7-9% CP in their diet (NASEM, 2016). Energy requirements for beef cattle vary depending on weight, breed, and production stage, with maintenance needs ranging from 12-20 Mcal per day for mature cows and upwards of 20 Mcal per day for rapidly growing steers (NRC, 2016)

Beef cattle are often finished in feedlot systems for 3-6 months before marketing. Feedlot finishing provides a consistent nutrient intake compared to grazing, which can help optimize weight gains, especially during periods when pasture or rangeland forage quantity or quality is limited. This consistent nutrition helps to ensure cattle continue to grow and deposit muscle tissue efficiently up until slaughter, especially during drought periods when forages are of poor quality and insufficient in quantities (Greenwood, 2021). This helps ensure adequate body condition and marbling at slaughter, compared to cattle finished solely on pastures. Utilization of locally available feed resources for making beef finishing rations has many advantages such as reduction of feeding cost through sourcing of local feed resources in the rangelands and propagation of drought-tolerant fodder sorghum varieties and adaptable grass species. In addition, the use of beef finishing technology in ASALs could be a solution for the reduction of high mortalities of livestock during dry seasons and increase beef offtake in ASALs of Kenya. Beef finishing technology using local rangeland feed resources has the potential to improve household income, and nutrition, and reverse high trends of poverty index in ASALs of Kenya.

Seasonality affects the availability of the rangelands' feed resources but they could be harvested when they are in season and stored for utilization. Drought-tolerant fodder crops such as forage sorghum and rangeland grasses could be promoted in ASALs for finishing beef cattle (Njagi and Opiyo 2021). For optimal utilization of the locally available feed resources in ASALs, detailed knowledge of their nutritional profiles is required (Ki *et al.*, 2017). This would assist in the formulation of feed rations suitable for different animal species to attain desired levels of performance (Kumar *et al.*, 2015). Attainment of improved levels of performance results from feeding correctly formulated rations daily for animals to meet their biological and physiological needs as well as gain (Gebremariam and Belay 2018; Ki *et al.*, 2015; Kirkpinar and Acikgöz 2017).

The nutrient contents of any ration determine its quality and are influenced by several factors such as parts of the plant used, species, and age of the plant among other factors (Cholewińska *et al.*, 2021; Waghorn and Clark 2004). It is imperative always to conduct feed analysis for all the ingredients before ration formulation and it is equally important to analyze formulated rations before conducting animal performance trials. Thus, this study determined the nutritive values and digestibility of rangeland feed resources and formulated rations using the same ingredients for utilization in feedlot systems in ASALs.

Materials and Methods

Forage Collection Site

Forage collection was conducted in the Marigat sub-county, Baringo County, Kenya. (Figure1), which lies at 1080 m above sea level. It receives 700 – 950 mm of rainfall per year with peaks in April/May and July/August, but it is generally very unreliable. The annual mean temperature is 23°C.

Sourcing and Preparation of Ingredients for Ration Formulation

Prosopis juliflora, *Acacia tortilis* pods, and *Balanites aegyptiaca* nuts were collected from Baringo rangelands.

After harvesting, the pods and nuts were spread on a sheet and air-dried under shade for seven days. The dried forages were put in sacks and stored in a well-ventilated shed until the time of use. The Rhodes grass hay was obtained from pastures grown at the research station where the study was conducted. The sorghum silage was sourced from experimental plots located at the same research station. The sunflower and maize meal was obtained from a commercial feed supplier. Samples of 300 g of each ingredient (Rhodes grass hay, sorghum silage, sunflower meal, maize meal, and indigenous browse species) were ground to pass through a 1mm sieve for proximate analysis and *in-vitro* digestibility. The results from feed ingredients analysis were used for ration formulation after which formulated rations were further subjected to laboratory analysis to ascertain their nutritive value. Two rations 1 (Grass-based ration) and 2 (Silage-based ration) were formulated according to the beef cattle nutrients requirements of NRC (2000). Ration 1 was formulated with Rhodes grass hay as the main roughage along with supplemental indigenous browse leaves, sunflower meal, and maize meal to meet the nutritional requirements for growing beef cattle. Ration 2 was based on sorghum silage as the main roughage, with the same supplemental protein and energy sources as ration one. Both rations were balanced to provide approximately 16 % crude protein and 12 MJ/kg metabolizable energy (NRC, 2000).

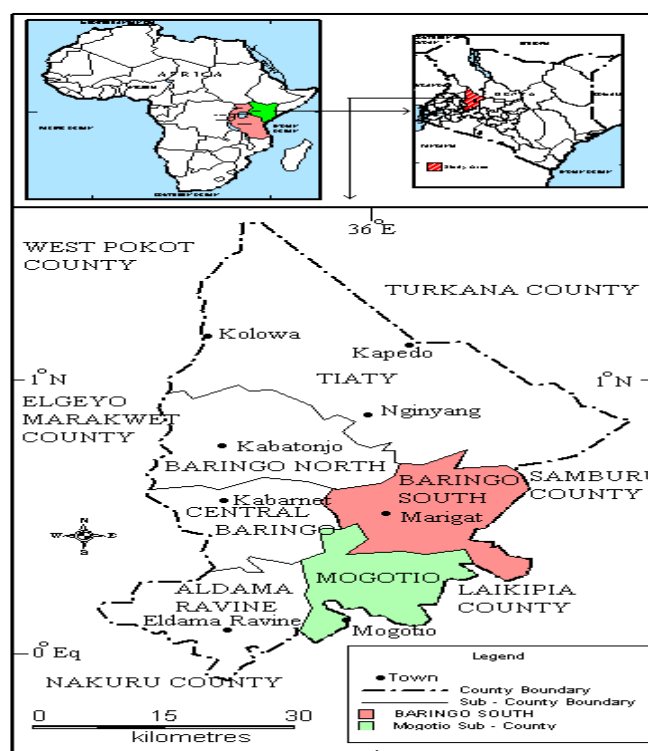


Figure 1: Map of Marigat Sub-County in Baringo County, forage collection site

Laboratory Analysis: Proximate and Fibre Assay of Samples

Proximate analysis was conducted on *P. juliflora* pods, *B. aegyptiaca* nuts, and *A. tortilis* pods, which were preferred feed supplements identified in earlier studies of pastoralist communities in this region (Tura *et al.*, 2020), were analyzed to determine their DM (%), CP (g/kg), and ME (MJ/kg). After ration formulation, the two rations were analyzed to determine their DM, CP, ME (MJ/kg), ether extract, and ash according to the standard methods of AOAC (2006). The CP was calculated as Kjeldahl Nitrogen (N x 6.25). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were analyzed according to the procedure described by Van Soest, *et al.*, (1994).

Statistical Analysis

Data collected on proximate and fibre analysis were subjected to analysis of variance (ANOVA) in a completely randomized design (CRD) using the general linear model procedure of statistical analysis system (SAS, 2002) version 9.0. Significant means were separated using Tukey's HSD (Tukey's Honestly Significant Difference Test) at 5% significance.

The model used for statistical analysis was:

$$Y_{ij} = \mu + \tau_i + \varepsilon_{ij}$$

where:

Y_{ij} = is the j^{th} observation of the i^{th} treatment

μ = is the population mean

τ_i = is the effect of ingredients nutrient & formulated rations

ε_{ij} = random error term

In vitro Gas Production

The milled samples of ration 1 and 2, weighing 200mg DM of each were placed in 100ml glass syringes in triplicate. The fermentative activity of the mixed microbial population was determined using the gas production technique described by Menke and Steingass (1988). The rumen fluid and buffer medium were mixed in a ratio of 1:2 (v/v). Then 30 ml of the buffer-rumen fluid mixture was passed into triplicate syringes holding samples and incubated in a thermostatically controlled water bath at 39°C for 0-96 hours. Both the samples and blank (rumen fluid+buffer) were run in triplicates. Then the volume of gas produced was determined at 0, 3, 6, 9, 12, 18, 36, 48, 72, and 96 hours by reading the calibration of the piston. The gas produced was the total increase in volume minus the mean blank value from the recorded gas production of all samples to give the net gas production. The calculated values of gas production were fitted into the model of Ørskov and McDonald (1979) to determine the degradability of the feed:

$Y = a + b(1 - e^{-ct})$ where:

Y = the volume of gas produced with time (t)

a = initial gas production

b = gas produced during incubation

c = gas production rate constant (fraction /hour), and

a+b represents the potential extent of gas production.

Results and Discussion

Chemical Composition of Feed Ingredients

Table 1 presents the proximate analysis results of ingredients used in the formulation of the two beef finishing rations. The DM content of locally available feed resources from rangelands ranged from 890 gkg⁻¹DM in *A. tortilis* pods and 940 gkg⁻¹DM in *B. aegyptiaca* nuts. The CP content ranged from 84.6 gkg⁻¹DM in *B. aegyptiaca* nuts and 154 gkg⁻¹DM in *A. tortilis* pods. The relatively high CP content range (84.6- 154 gkg⁻¹DM) of *B. aegyptiaca* nuts, *P. juliflora* pods, and *A. tortilis* pods show their potential to be used as protein sources important for the formulation of locally formulated rations in beef cattle finishing in feedlot systems. These results are in tandem with previous studies by Ikanya *et al.*, (2022) and Sagala *et al.*, (2020) especially on *A. tortilis* pods. To improve animal performance, animals consuming basal diets containing less than 7% crude protein (CP) will require supplementation to achieve maximum production, (Leo-Penu *et al.*, 2022; Ondiek *et al.*, 2000). According to NRC, 2000 growing beef cattle requires a CP of more than 10% and metabolizable energy above 9.5 MJ/KgDM.

Table 1. Chemical composition (gkg⁻¹DM) of ingredients used in ration formulation.

Ingredients	DM	ME (MJ/Kg DM)	CP
Rhodes grass hay	918 ^b	10.63 ^d	53.4 ^e
Sorghum silage	917 ^b	9.9 ^e	46.8 ^f
<i>Prosopis juliflora</i> pods	903 ^c	12.8 ^c	112.5 ^c
<i>Balanites aegyptiaca</i> Nuts	940 ^a	14.6 ^b	84.6 ^d
<i>Acacia tortilis</i> Pods	890 ^d	8.7 ^g	154 ^b
Sunflower Meal	891 ^d	9.1 ^f	300 ^a
Ground maize meal	940 ^a	26.16 ^a	71.8 ^e
SEM	0.1279	0.0253	0.0645
P	<.0001	<.0001	<.0001

CP=crude protein, DM=dry matter, ME=Metabolizable energy

The relatively high crude protein content of the locally available indigenous browses (150-249g/kg DM) provides enough nutrients for the utilization as a supplement to low quality natural pastures and crop residues (Amole *et al.*, 2022; Osuga *et al.*, 2006). The ME content of locally available feedstuff from the ASALs ranged from 8.7 MJ/Kg DM in *A. tortilis* pods and 14.6 MJ/Kg DM in *B. aegyptiaca* nuts. *Balanites aegyptiaca* nuts were high in metabolizable energy compared to *P. juliflora* pods and *A. tortilis* pods. Legume tree forages have high crude protein, organic matter, and mineral content and could be used as supplements to help offset the effects of low-quality feeds (Idan *et al.*, 2022; Ondiek *et al.*, 2013). The browse forages have high crude protein content, which makes them good protein supplements to poor quality roughages, particularly during the dry season (Deng *et al.*, 2017). To fill the daily nutrient gaps in terms of energy and protein that are not provided for by the local feed resources, the use of commercial feed resources such as maize germ and sunflower meal is recommended because they are readily available.

Chemical Composition of Rations

Results of the nutrient composition of experimental diets/rations are presented in Table 2.

Table 2: Chemical composition (gkg⁻¹ DM) of experimental diets

Parameters	Ration 1 (Grass-based ration)	Ration 2 (Silage-based ration)	SEM	P
CP (g/kgDM)	15.40 ^a	16.0 ^a	0.07	<.0001
ME (MJ/kgDM)	11.06 ^a	12.30 ^a	0.09	<.0001
ASH (%)	7.26 ^b	5.14 ^a	0.003	<.0001
EE (gkg ⁻¹ DM)	17.16 ^a	15.93 ^a	0.009	<.0001
DM (%)	89.23 ^a	87.93 ^a	0.009	<.0001
NDF (g/kgDM)	65.0 ^b	81.0 ^a	0.306	>.0001
ADF (g/kgDM)	41.0 ^b	47.0 ^a	0.24	>.0001

CP=crude protein, ME=Metabolizable energy, EE=Ether extract, DM=dry matter, OM=organic matter, NDF=Neutral detergent fiber, ADF= Acid detergent fiber.

The two rations were formulated according to the growing beef cattle daily requirements NRC, (2000) which states that well-finished beef cattle in a feedlot system require a CP of about 14-15% and energy between 9.5-11.5 MJ/kg).

The CP content was 15.4 g/kg DM in Rhodes-based and 16 g/kg DM in sorghum-based. The metabolizable energy content was 11.06MJ/kg DM in ration one, which is sorghum-based, and 12.3 MJ/kg DM in ration two which is sorghum-based, the results suggest that these rations formulated from locally available feedstuffs have a potential for finishing rangelands beef cattle in the ASALs of Kenya because they are adequate in energy and protein required by growing beef cattle to attain its daily growth.

Other previous studies have established that typical feedlot finishing diets should have a minimum of 10 ME MJ /kg DM and 11–15% CP/kg DM in diets with rations fed at 2.5–3% of live weight (Gaughan and Sullivan, 2014). This agrees with the results of Drouillard, (2018) on feedlot finishing diets containing 11MEMJ/Kg DM and more than 11% CP/kg DM.

In vitro Degradability for the Rations

The total gas production (ml/200mg DM) at 24hr and 48hr shown in Table 4 and Figure 2 below show variations in the digestibility potential with grass-based ration (14.05) being the highest and silage-based ration (11.04) being the lowest at 48hrs. Sorghum-based ration and Rhodes-based ration were highly degraded at the 48 hours compared to the 24 hours. The ration's degradation improved from 24 to 48 hours, indicating that they need more time to degrade effectively. The differences in gas production between the two rations could be attributed to the amount of substrate fermented. Grass-based fermented faster as compared to silage-based implying that it is low in fiber and lignin. Differences in gas production between feeding materials could be attributed to the amount of substrate fermented, which is in line with findings, by Garcia *et al.*, (2020). The lower gas production observed for the sorghum silage-based ration compared to the Rhodes grass-based ration can be partially attributed to the organic matter that was fermented during the silage-making process. Silage undergoes fermentation by lactic acid bacteria which convert

sugars and other readily fermentable carbohydrates into organic acids, mainly lactic acid. This lowers the pH and helps preserve the silage. A study by Getachew *et al.*, (2004) found *in vitro* gas production ranging from 17.7 to 25.2 ml/200mg DM at 48 hours incubation for high quality alfalfa, corn silage, and berseem clover samples. The lower gas production for the sorghum and Rhodes grass rations in the 11-14 ml/200mg DM range would indicate moderate to low digestibility based on these reference values.

Table 3: Formula used in the formulation of Ration 1 and 2.

Ration 1 (Grass-based ration)			
Ingredients	Quantity	CP	ME
Rhodes grass hay	37	1.98	3.93
<i>Prosopis juliflora</i> pods	27	4.04	3.46
Molasses	1	0	0
<i>Balanites aegyptica</i> nuts	3	0.25	0.44
<i>Acacia tortilis</i> pods	2	1.31	0.17
Sunflower meal	24	7.2	2.18
Maize meal	6	0.43	1.57
Total	100	15.21	11.75
Ration 2(Silage-based ration)			
Ingredients	Quantity	CP	ME
Sorghum silage	35	1.64	3.47
<i>Prosopis juliflora</i> pods	27	4.04	3.46
Molasses	1	0	0
<i>Balanites aegyptica</i> nuts	2	0.17	0.29
<i>Acacia tortilis</i> pods	2	1.31	0.17
Sunflower meal	25	7.5	2.275
Maize meal	8	0.57	2.09
Total	100	15.23	11.75



Plate 1: *Acacia tortilis* pods



Plate 2: *Balanites aegyptiaca* nuts



Plate 3: *Prosopis juliflora* pods



Plate 4: Ration 1: Grass-based ration **Plate 5: Ration 2:** Silage-based ration

Plates: *Acacia tortilis* pods, *Balanites aegyptiaca* nuts and *Prosopis juliflora* pods, and formulated rations

Table 4. *In-vitro* gas production (ml/200mg DM) of sorghum and Rhodes-based rations

Fermentation Characteristics							
Sample	24	48	A	B	C	A+B	RSD
Sorghum Based Ration	8.97	11.04	0.15	7.20	8.10	7.35	4.34
Rhodes Based Ration	9.20	14.05	1.18	4.46	6.94	5.64	3.52

A, B, C are constants (Ørskov and McDonald, 1979)

The higher digestibility in sorghum and Rhodes-based rations could have been attributed to high nutritional quality (Table 2) as reported by Kidake *et al.*, (2016). This also indicates that these rations are potentially degradable and can become potential complete animal feeds especially in arid and semi-arid regions for beef animals where quality feeds are deficient.

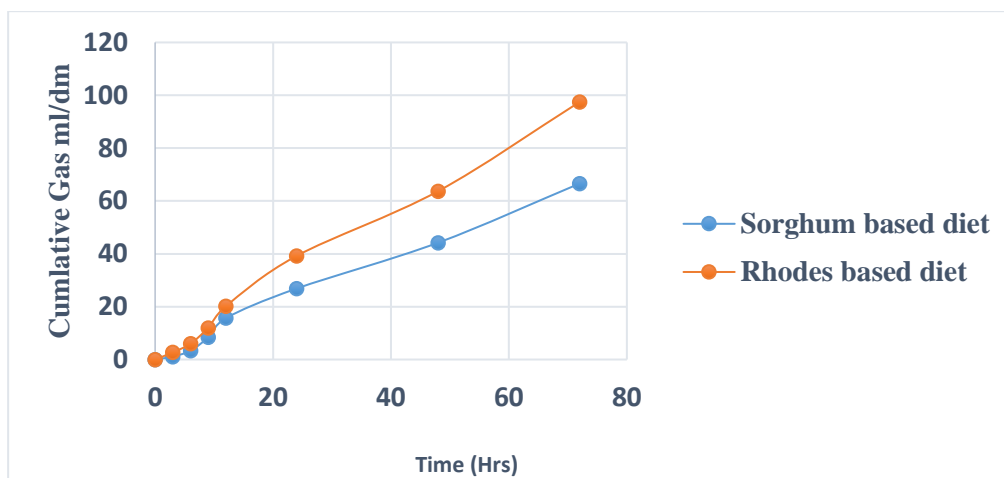


Figure 2. Patterns of *in vitro* cumulative gas production of Sorghum and Rhodes-based rations

Conclusion and Recommendation

The analyzed rangeland feed resources offer great potential as feed ingredients for the provision of energy and protein in the formulation of feedlot rations. It is recommended that the formulated rations are adequate in energy and protein to meet the requirements for finishing beef cattle and thus could be utilized for increased daily weight gain.

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Contribution by Authors

Equal contribution. All authors declared that ‘written informed’ consent was obtained from the approved parties for the publication of this article and accompanying images.

Conflict of Interests

There is no conflict of interest.

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