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Comparative evaluation of effect of legume type on feed intake among dairy cows fed maize (*Zea mays*) stover treated with groundnut (*Arachis hypogea*) and soybean (*Glycine max*) stover

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Abstract

This study evaluated the use of maize, groundnut and soybean stover in cattle feeding. The study assessed the value of upgrading the quality of crop residues. The study involved evaluation of palatability of maize stover improved using urea (U), chopped groundnut stover (cGS), chopped soybean stover (cSS), mineralized groundnut stover solution (mGS) and mineralized soybean stover solution (mSS). In the feeding trial, twelve (12) crossbred dairy cows in their second parity were used as experimental units. A 2^2 factorial experiment within a Completely Randomised Design (CRD) was used. Maize stover was chopped before being mixed with urea, chopped legume stover and mineralized legume stover solutions. The effect of supplementation using maize stover upgraded with U, cGS, cSS, mGS and mSS was studied for supplement intake levels. Urea Ensilage Treatment (UET) was used as the novel therapy in the study. Both legume type and processing method had influence on supplement intake of maize stover. Groundnut stover had significantly ($p<0.05$) higher (0.99kg/day, se=0.04) effect on supplement intake of maize stover than soybean stover(0.83kg/day, se=0.04). The use of mineralized legume stover solution proved significant ($p<0.05$) to the use of chopped legume stover in improving the intake of maize stover. Results have indicated that intake was highest (1.01kg/day, s.e=0.04) for mineralised groundnut stover solution and lowest (0.67kg/day, s.e=0.04) for Urea Ensiling Treatment.

Keywords: Feed intake; Maize stover; Legume stover; Urea Ensilage; Mineralization; Chopping

1. Introduction

Seasonal and climatic changes can have significant effects on the quality and availability of livestock feed which ultimately affect animal performance. Smith (2002) [1] reported that dry season nutritional stress is a major constraint to ruminant livestock production in semi-arid areas. After the rainy season has ended, quantity and quality of grazing fall rapidly, leaving cereal crop residues as the major feed resource. These residues are low in N and high in crude fibre, characteristics which restrict intake, digestibility and livestock performance.

During the dry season multi-purpose legume plants or trees (popularly known as MPTs) have the highest potential for livestock feeding especially dairy cattle and goats because they provide forage throughout the year and are a good

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source of proteins. They can best be utilised as supplementary materials when different species are mixed as a blend. Tropical legumes have received much less attention than tropical grasses and temperate legumes and grasses. According to Mahesh and Mohini (2014) [2], global livestock production is constrained by the inadequate supply of feeds and forages for optimum production. Mugerwa et al., (2012) [3], observed that while a number of constraints associated with the low animal productivity have been identified (e.g. disease prevalence, poor extension service, indiscriminate crossbreeding and poor management skills), the major constraint is shortage of quality feed. Needless to emphasize that animal life itself is dependent on the nutrients derived from the feed the animal eats. Thus, inadequate or lack of feed leads to low animal productivity in literally all aspects of animal life including immunity, growth, milk production and reproduction.

Crop residues commonly used for livestock nutrition in Zambia include bran, stover and straws of wheat, sorghum, maize and millet and these are usually not used in the most efficient manner, but rather fed to livestock in-situ during the harvest season without any improvement on their quality (Dzowelo et al., 1987) [4]. Wegad and Dumbe (2013) [5] observed that protein supplements had an effect on weight gain and volume feed intake of maize stover by cattle. It was further suggested by Abdou et al., (2011) [6], that in the dry season, it is practical to supplement sheep with low levels (*i.e.*, 200 g) of groundnut hulls to support moderate live weight gain or with 600 g groundnut hulls + 75 g Wheat Bran to support high live weight gain. Francis and Ndhlovu (1995) [7] while working with Mashona cattle recommended that feeding strategies involving groundnut stover for Mashona draught oxen should aim at providing adequate nutrients to at least maintain live weight during the dry season. These researchers further noted that work output of supplemented oxen in spring was also significantly greater ($P<0{\cdot}05$) than that of non-supplemented ones. This result demonstrated the benefits of supplementary feeding during the dry season.

Archimede et al. (2011) [8] observed that within the vast tropical biodiversity, there are many plant resources to partially or completely replace soybeans in livestock diets. The possibilities of substitution of soybean by other resources are more important for herbivores in relation to non-herbivores. Soybean hulls are an excellent source of energy and digestible crude fiber. The high digestibility of the fibre and physical form of the hulls render soybean hulls a limited source of roughage. They may contain 11 and 15 per cent crude protein and are a good source of magnesium (Guthrie and Joe, 1991) [9]. According to Nawanyakpa and Butterworth (2012) [10], feed intake and utilization were slightly greater for sheep given teff-straw plus urea than for those fed teff-straw alone and significantly greater for sheep on teff-straw plus molasses indicating that N deficiency in cereal crop residues may be a greater cause of poor animal performance than energy deficiency. Work by the same workers revealed that feed intake was in general significantly greater in sheep on teff-straw supplemented with molasses-urea than for those supplemented with urea alone. Therefore, urea is more beneficially administered as part of molasses-urea mixture rather than being dissolved in water and sprinkled onto a cereal crop residue. Nawanyakpa and Butterworth (2012) [10] further indicated that even when offered at a restricted level, molasses reduced the intake of teff-straw and reduced the digestibility of DM, NDF and N of the basal diet. The retention of N was reduced below the levels observed for sheep given un-supplemented teff-straw. Therefore, this means that molasses should probably not be used as the sole supplement to cereal crop residues. Feed quality and quantity have been observed to show seasonal fluctuation, a trend which affects the nutrition of animals hence their performance. Dry seasons in Zambia and many other tropical countries are characterised by periods of feed shortages resulting in general retardation in animal growth and production. It has been observed that the potency of different stover types available on smallholder farms in promoting feed intake and elicit animal performance is not known due to lack of appropriate technology. The effect of improving the quality of maize stover using groundnut and soybean stover on feed intake has not been evaluated. Hence, this study focussed on evaluating the effect of improving the quality of maize stover on feed intake using groundnut and soybean stover.

2. Material and methods

2.1. Research site

The research was conducted in Southern Province of Zambia. The province lies at an altitude range of 400- 1400 metres above sea level. It has a mean annual temperature ranging from 14°C to 28°C. It receives an annual rainfall of 700mm to 1000mm .The soil type ranges from clay to sandy loam (Ministry of Agriculture, 2013) [11].

2.2. Methodology

2.2.1. Study 1: Treatment with urea

Dry maize (*Zea mays*) stover was chopped using a stover chopper and treated using the Urea-Ensiling Technique (UET) before being offered to the cows. The standard method of urea treatment used in other developing countries which involves the making of a solution of urea using four kilograms (4 kg) urea feed grade fertilizer (46%N) into sixty (60) litres of water and mixing this with one hundred kilograms (100 kg) of stover was used. Pits were dug on raised ground for the purpose of the UET. The stover was chopped into 3-5 cm pieces. These were then mixed with the urea solution using a watering can and buried into the pit. A polythene plastic sheet and compacting were used to ensure an airtight environment. The stover and straw were ready for feeding in 21 days (3 weeks urea incubation period). Three kilograms (3 kg) of the feed was given to each cow per day in a 2^2 factorial experiment in a Complete Randomised Design (CRD). UET was taken as a novel therapy or positive control and compared with the test therapies.

2.2.2. Study 2: Treatment with legume stover

The quality of maize (*Zea mays*) stover was improved using mineralised and chopped legume stover [Groundnuts (*Arachis hypogea*) and Soybean (*Glycine max*)]. These feeds constituted test therapies. The feed ingredients (maize and legume stover) were all procured from local farmers. Three kilograms (3 kg) of the feed was given to each cow per day in a 2^2 factorial experiment within a Complete Randomised Design (CRD). Four rations were prepared on the basis of cereal type, legume type, source of nitrogen and method of processing of legumes as follows:

- Chopped Maize stover + mineralized Groundnut stover solution
- Chopped Maize stover + chopped Groundnut stover
- Chopped Maize stover + mineralized Soybean stover solution
- Chopped Maize stover + chopped Soybean stover

A similar number of animals fed on a commercial diet (dairy meal) were used as a positive control. Additionally, another similar number of animals that just graze normally (no supplementation) were used as a negative control group. Test diets were formulated such that they were iso – nitrogenous (same CP) and iso – energetic (same GE or ME). To ensure that the diets were iso-nitrogenous and iso-energetic, samples of cereal stover and legume stover were analysed for their GE and nitrogen content respectively before rations were compounded. Quantities of cereal and legumes (maize, groundnut and soybean stover) used were computed by simple proportion to equate the energy and nitrogen content in each feed based on the results of the proximate analysis. This was important for the data to be valid and reliable and hence the conclusions and recommendations.

Mineralization of legume stover

Dry groundnut and soybean stover were tied into bundles each weighing five kilograms (5 kg). Three (3) bundles of groundnut stover bundles were completely immersed in 100 litres of water in a plastic drum of 210 litre capacity. The drum was covered with a tight lid. Another three (3) bundles of soybean stover were treated in a similar manner in another drum. The set up was left for five days to allow for mineralization to take place. A preliminary proximate analysis of samples revealed that a period of five (5) days was the optimum for mineralisation to be effective.

2.3. Ration formulation

Rations were prepared using the BLP 88 computer programme (1987) [12] to meet the nutrient requirements of dairy animals (NRC, 1996) [13]. Amounts generated from the ration formulation programme were measured using a scale and mixed by rolling and turning several times on polythene plastics spread on concrete floor using a garden fork in order to ensure consistence in the composition.

Two (2) types of rations were compounded: one comprising chopped cereal stover and chopped legume stover and the other comprising chopped cereal stover and mineralized legume stover solutions. The mineralised legume solutions were sprayed on the measured quantities of chopped maize stover using a watering can and then turned several times using a garden fork on a concrete floor. To help bind the chopped (ground) legume stover to maize stover as well as to improve palatability molasses solution was sprinkled and mixed with all types of rations at compounding. All other ingredients were the same for the rations but only differed in the source of protein and processing method used. Feeds were then packed in twenty five kilograms (25 kg) plastic bags in readiness for delivery to the feeding or milking parlour site where feeding was carried out.

2.4. Feeding trials

The feeding trials involved twelve (12) lactating dairy cows in their second parity arranged in a 2^2 factorial experiment in a Complete Randomized Design (CRD). The experimental units (dairy cows) were randomly selected using simple random numbers from the herd available at Batoka Livestock Trust Research Centre (BLTRC). Treatments (rations) were randomly allocated to experimental units (dairy cows) by picking lots using animal identities (Ear-tags and feed type) written on pieces of paper and placed in two separate urns (boxes). An adaptation period of five (5) days was allowed for each feed before data was recorded.

The feeding trial commenced by determining the optimum quantity of feed to be given to each animal. Quantities of four kilograms (4 kg), three kilograms (3 kg), two kilograms (2 kg) and one kilogram (1 kg) were tried over a period of seven (7) days. During the trial one kilogram (1 kg) of feed was found to be the appropriate quantity of feeding to appetite during supplementation since rejected quantities were much less.

The experimental cows were allowed to graze from seven (7) to twelve (12) hours and then brought to the milking parlour for milking each day. Each animal was offered one kilogram (1 kg) of the ration being administered at a given time (control or test therapy). The control or test treatments were supplements to the free grazing during times of feed shortage. The parameters used to test the effect of the treatments was feed intake. An adaptation period of seven (7) days was allowed for each feed before data was recorded. Data pertaining to feed intake was taken as the difference between feed offered and feed left in the feeding trough. Data for each experimental unit were recorded on score sheets.

2.5. Statistical model

$Y_i = \mu + R_i + b(x) + \varepsilon_i$

Where Y_i= observed feed intake on an individual cow of a given i^{th} legume type.

μ=Overall mean

b(x)=b is the regression coefficient for initial feed intake used as a covariate

ε_i=random error component

2.6. Research design and data collection

The twelve (12) dairy cows were arranged in a 2^2 factorial experiment in a Complete Randomized Design (CRD). Daily feed intake was recorded on individual score cards identified by animal identity numbers from June 12, 2017 through November 09, 2017.

2.7. Statistical analysis

Data was analysed using the Statistical Analysis System on the General Linear Model computer. Treatment means were compared using the F-test (Table 3).

3. Results

3.1. Effect of legume type inclusion on intake of maize stover

The effect of processing method reflected in table 1, indicate that intakes for mineralization and urea ensilage treatment were both significantly ($p<0.05$) higher than that for the two chopping treatments. When evaluated across legume stover and nitrogen source, average supplement intake for groundnut stover based maize stover was observed to be significantly ($p<0.05$) higher (0.94 kg/day, s.e=0.046) than that of both soybean stover (0.57 kg/day, s.e=0.046) and urea feed grade fertilizer (0.65 kg/day, s.e=0.046) (Table 2).

When evaluated within legume type, mineralisation recorded numerically higher (1.01 kg/day, se=0.04) intake of maize

Table 1 Effect of processing method on voluntary intake (VI) of stover

TREATMENT	MEAN ($\bar{y}$) (kg)	SD	SEM
Mineralization	0.90^a	±0.22	0.05
Chopping	0.60^b		
UET	0.63^b		

^{ab}Means with different supercripts differ significantly($p<0.05$); UET=Urea Ensilage Treatment

stover supplement than chopping (0.97 kg/day, se=0.04) for groundnut stover. The opposite was true for soybean stover with mineralization showing lower effect than chopping (0.80 kg/day, 0.86 kg/day, se=0.04) respectively). However, means for effect of processing method on supplement intake did not differ significantly (($p>0.05$) within each legume type (Table 3).

Means for the intake of chopped groundnut and chopped soybean stover were 0.97 kg and 0.86 kg (s.e=0.04) respectively (Table 3). The means for the intake of the maize stover blended with chopped forms of the two types of legume stover differed significantly ($p<0.05$). Similarly, means for intake of maize stover improved with mineralized groundnut and soybean (1.01 kg and 0.80 kg, s.e=0.04 respectively) differed significantly ($p<0.05$). When evaluated across legume type it was observed that feed intake was significantly ($p<0.05$) higher (0.94 kg/day, se=0.05) for groundnut based maize stover supplement than (0.57 kg/day, se=0.05) that of soybean based maize stover supplement.

Table 2 Effect of nitrogen source on voluntary intake (VI) of stover

TREATMENT	MEAN ($\bar{y}$ (Kg)	SD	SEM
G/nut Stover	0.94^{ad}		
S/bean Stover	0.57^{b}	±0.195	0.046
UFGF	0.65^{be}		

^{ab} Means in the same column with different supercripts differ significantly($p<0.01$); ^{de}Means in the same column with different supercripts differ significantly($p<0.05$).; UFGF=Urea Feed Grade Fertilizer,

ble 3 Effect of feed type on voluntary intake (VI) of stover supplement

TREATMENT	MEAN ($\bar{y}$) (Kg)	SD	SEM
Min. G/nut	1.01^{ae}		
Chopped G/nut	0.97^{ae}		
Min. S/bean	0.80^{b}	±0.23	0.04
Chopped S/bean	0.86^{ab}		
UET	0.67^{bd}		

^{ab}Means with different supercripts differ significantly($p<0.01$): ^{de}Means with different supercripts differ significantly($p<0.05$),; UET=Urea Ensilage Treatment

Table 4 Chemical composition of rations

RATION	DM[a] (%)	CF[b] (%)	CP[c] (%)	Ash[d] (%)	NDF[e] (%)	ADF[f] (%)	NFE[g] (%)	EE[h] (%)	GE[I] (%)	Ca[j] (%)	P[k] (%)
[1]MCGNS	94.96	34.25	15.12	1.20	37.48	90.24	47.26	2.17	4360.23	1.59	0.36
2MMGNS	94.62	19.75	18.12	1.00	37.46	84.26	59.82	1.31	3992.50	1.21	0.47
[3]MCSBS	94.81	46.25	14.35	1.93	48.22	94.31	35.69	1.78	4390.13	1.02	0.55
[4]MMSBS	95.11	31.28	15.01	0.89	43.78	82.64	52.33	0.49	4366.20	1.55	0.57
[5]UETMS	86.20	27.44	24.61	0.45	38.02	78.30	47.17	0.33	4375.10	0.33	0.06
AV.	93.14	31.79	17.44	1.09	40.99	85.95	48.45	1.22	4296.83	1.14	0.40

[1]MCGNS=Maize stover + Chopped Groundnut Stover, [2]MMGNS=Maize stover + Mineralized Groundnut Solution, [3]MCSBS=Maize stover + Chopped Soybean Stover, [4]MMSBS= Maize stover + Mineralized Soybean Solution, [5]UET=Urea Ensilage Treated Maize Stover: [a]Dry Matter, [b]Crude Fiber, [c]Crude Protein, [d]Ash, [e]Neutral Detergent Fiber, [f]Acid Detergent Fiber, [g]Nitrogen Free Extractives, [h]Ether Extract, [i]Gross Energy, [j]Calcium, [k]Phosphorus

Figures 1, 2 and 3 show that improvement of quality of maize stover with mineralised groundnut stover solution had the highest effect on feed intake while improving the quality of maize stover by UET had the lowest effect on feed intake over the feeding period

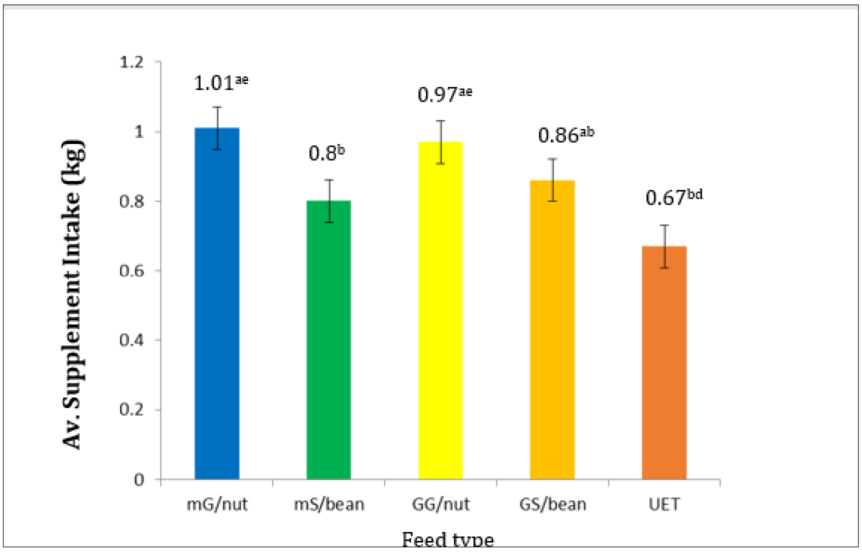

Figure 1 Effect of feed type on average daily feed intake

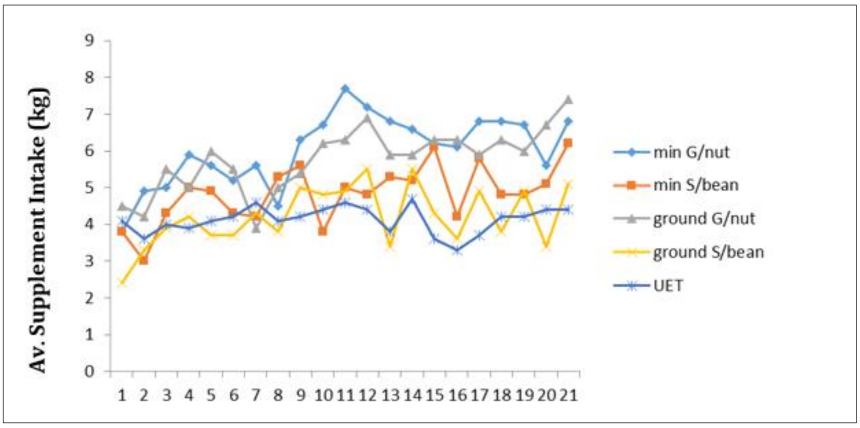

Figure 2 Feed intake response of cows to rations during the feeding trial

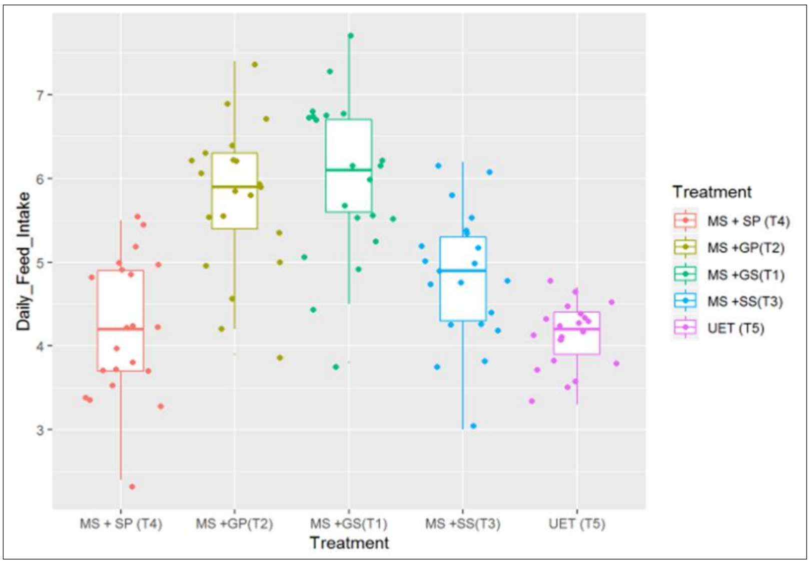

Figure 3 Distribution of feed intake by treatment

4. Discussion

In the current study supplement intake was observed to vary according to protein source in the diets offered to cows. Variation in levels of feed components affects the overall attractiveness of supplements to animals. These results are in agreement with the findings of Vickery et al. (1994) [14] who reported that mice consistently preferred feed with high energy and protein content. Supplement intake differences recorded among the experimental groups can be attributed to the diets' nutrient contents, in particular the protein and energy content which were higher in soybean based diets and lowest in groundnut based diets (Table 4). According to the chemostatic theory animals take in less of high chemical and energy containing feeds. Dietary deficiencies of indispensable amino acids, vitamins and minerals are likely to affect the intake of food.

Palatability is a very important factor for increased feed intake in all livestock. It corresponds to nutrient content of the diet. Hence, diet nutrient content reduction especially that of protein and energy may be accompanied by a reduction of intake levels (Nyachoti et al., 2006) [15]. In this study, the lowest supplement intake was observed in urea based diet. This result could be related to the diets' chemical composition which reveals a high fiber content (about 11% crude cellulose). Accordingly to Wenjuan et al., (2013) [16] and Ndou et al., (2018) [17], findings, diet with high fiber content can have a gastric bulky effect that gives an animal a full stomach feeling and therefore limits its feed ingestion ability. The quality of the protein in urea diet is likely to have been poorer, no amino acids, just urea (NPN). The legumes had protein which contained some essential amino acids which promoted intake!!

In the current study, the low supplement intake recorded in soybean diets (MSBP and MSBS), could be related to the high energy and protein content in diet as reflected results of the proximate analysis. Proximate analysis revealed higher crude fiber (CF), nitrogen detergent fiber(ADF), gross energy(GE) and acid detergent fiber (ADF). High values of these components limit feed intake as explained by the gut fill factors and chemostatic theory. These laboratory analysis results indicate that Soybean stover is highly lignified compared to that of groundnut stover. However, the findings by Suárez-Belloch et al., (2015) [18], reported on the contrary a significant positive effect of dietary protein content on feed intake. According to Qingyun and Patience (2017) [19] results, if pigs have the capacity to increase their feed intake, and therefore their energy and protein intake, as their levels in the diet decrease, their performance is less likely to be affected by a diet with low nutritional value. This hypothesis seems to be confirmed in this study since the results obtained in lactating cows show an increase in supplement consumption with a reduction in dietary protein and energy content. Results of the current study are in agreement with those of Allen (2014) [20] who observed that because Neutral detergent fiber (NDF) generally ferments and passes from the Reticulo-rumen more slowly than other dietary constituents, it has a greater filling effect over time than non-fibrous feed components and has been found to be the best single chemical predictor of voluntary dry matter intake.

Neutral detergent fibre is an index of gut fill and is used to predict voluntary feed intake. The higher the fiber content, the higher the dry matter intake (Gidenne et al., 1998) [21]. Results obtained in the present study are at variance with results reported by Gidenne et al., (1998) [21]. These workers indicated that dry matter intake in rabbits tended to reduce from 60.5 g/day to 38 g/day with reduction in fiber content. They observed that rabbits tend to eat more feed when diets offered are high in crude fiber (CF) and crude protein (CF).

Generally, supplement intake increased progressively with increase in days (Fig. 2). In this study supplement intake varied with the processing method (Fig. 2 and Fig. 3). Supplement intake was highly influenced by both processing method and legume type. Throughout the feeding period the mineralised groundnut stover solution had a higher effect on supplement intake of maize stover while UET had the lowest effect (Fig.2). Results have indicated that intake was highest (1.01 kg/day, s.e=0.04) for mineralised groundnut stover solution and lowest (0.67 kg/day, s.e=0.04) for Urea Ensiling Treatment (Table 4).

Work by Wambui et al., (2006) [22], indicated that total dry matter Intake was significantly ($p<0.05$) influenced by supplementation with Tithonia foliage legume. The 10 and 20% levels of Tithonia inclusion seemed to have an additive effect on consumption of maize stover but at 30 and 40%, the intake of basal diet declined marginally. The study has revealed that the use of Urea Ensilage Treatment (UET) in improving the quality of maize stover during the dry season depresses intake initially due to the effect of ammonia which reduces palatability. When evaluated within legume type, mineralisation recorded higher (1.01 kg/day, se=0.04) feed intake of maize stover for groundnut stover than chopping (0.97 kg/day, se=0.04). The reverse was true for soybean stover with mineralization showing lower effect than chopping (0.80 kg/day, 0.86 kg/day, se=0.04) respectively) (Table 4). When evaluated across legume type it was observed that supplement intake was higher (0.99 kg/day, se=0.04) for groundnut based maize stover than (0.83 kg/day, se=0.04) that of soybean based maize stover.

Results of the current study are in agreement with those of Munthali et al., (2014) [23], who reported that supplementing water-treated stover with urea-molasses block, or treating the stover with urea, was sufficient to support maintenance plus small live-weight gains in cattle. Supplementing urea-treated stover with a suitable source of energy (such as starch, as in maize bran) promoted high live-weight gains and milk yield.

The current study has revealed that the intake of Urea Ensilage Treated maize stover had the lowest effect on supplement intake. The plausible interpretation is that intake level does not necessarily translate into higher milk yield. Nutritive value and palatability should be considered when determining materials for use in feed formulation for livestock. Though there are dangers associated with the use of urea in livestock feed, greater benefits exist when correct inclusion levels are observed. Hence, there is need to evaluate the chemical composition of locally available materials before they are used in feed mixing.

5. Conclusion

Results of the study have shown that while legume stover mineralization method had higher potential than chopping method in groundnut stover, the observation was opposite for soybean. It was observed during the study that the intake of low quality maize stover can be improved by use of legume stover. The intake of maize stover was observed to be lowest when urea was used for improvement of quality of maize stover. Supplement intake was highly influenced by the source of protein used in the improvement of the quality of maize stover. Results of this study suggest that intake of maize stover is generally higher when treated with groundnut stover than when soybean is used to improve their quality. Results also indicate that supplementation with leguminous fodders, particularly groundnut and soybean stover is beneficial for increased supplement intake. Therefore, smallholder dairy farmers can mitigate effects of drought by improving the quality of maize stover by using groundnut stover as evidenced by higher supplement intake when these materials were used in this study. Other legume species commonly available on smallholder farms should be evaluated for their efficacy in improving the palatability of low quality maize stover.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that they have no competing interests. There is no conflict of interest regarding the publication of this article.

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