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Forage and *In Vitro* Dry Matter Digestibility Quality of Native Species in Coastal Lowlands of Kenya

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Abstract

In the Coastal Lowlands of Kenya, small-scale mixed crop-livestock system is the dominant form of agricultural production. Feed quantity and quality are inadequate and rarely meets the nutrient demands of growing heifers and lactating cows especially in the dry seasons. The objective of the study was to determine the chemical composition and In Vitro Dry Matter Digestibility (IVDMD) of some native species forage species of the coastal lowlands of Kenya. A cross-sectional survey was conducted for 3 months on a random sample of 415 small-scale dairy cattle producers' to determine the main basal feed resources. Thereafter, feed samples were collected during a longitudinal survey on a purposive sample of 32 farms from the main cross-sectional sample for 12 months. Chemical composition of the forages varied considerably. The mean CP and NDF of grasses ranged from 84.1±10.9 - 97.1±13.5 and 603.8±57.0 - 724.8±45.1 g/kg DM respectively. *Leucaena leucocephala* had the highest CP of 270.8±74.0 g/kg DM while natural pastures mixture had the lowest of 84.1±10.9 g/kg DM. *Asystacia gangetica* and *Commelina benghalensis* had a CP content of 131.8±26.7 and 162.7±22.6 g/kg DM respectively. Napier grass had a CP of 86.4±11.3 g/kg DM while dry maize stover and green maize stover had CP of 72.2±10.4 and 112.8±13.6 g/kg DM respectively. *A. gangetica, C. benghalensis, L. leucocephala* and green maize stover had higher in vitro dry matter digestibility (> 50%) compared to dry maize stover, pastures grasses and napier grass. Pastures grasses in vitro dry matter digestibility ranged from 40.3±7.31 – 44.7±5.48%. Therefore, the available forages were of moderate quality with average to high nutrient content and in vitro dry matter digestibility. Farmers' should be encouraged to harvest pasture grasses at bloom-milk stage in order to take advantage of their rich nutrient supply.

Introduction

Livestock are the world's largest users of land, either directly through grazing or indirectly through consumption of fodder, crop residues and feed grains [1]. Livestock production and productivity is affected by numerous factors and range from climate, nutrition and health aspects [2]. Climatic changes are accompanied by changes in the quantity and quality of rain-fed crops and forage, reduced water availability and more widespread water shortages, changing severity and distribution of important human, livestock and crop diseases [3]. In the tropics animal production is affected by the reliability and length of the wet season and this determines the nature of the animal production enterprise [4]. Therefore, to increase productivity in order to satisfy rising demands, agricultural policies should advocate intensification of production, which requires enhanced external inputs and services [5,6].

In the coastal region of Kenya, forage productivity is largely dependent on rainfall which is highly variable and often unpredictable [7]. The situation is further compounded by decreasing farm sizes due to land fragmentation as a result of increasing population [8]. As a result, forage biomass yield, quality and availability varies substantially from season to season. Therefore, for adequate feeding of livestock, farmers need information about the nutritive value of available feedstuffs. This created a need to develop strategies to synchronize feed availability (quantity and quality) with the nutritional requirements of dairy cattle throughout the year in the Coastal Lowlands of Kenya. Hence, the objective of the study was to determine the chemical composition and In Vitro Dry Matter Digestibility (IVDMD) of some native species forage species of the coastal lowlands of Kenya.

Materials and Methods

Study area

The study was conducted in Kwale and Kilifi counties of the Coastal Lowlands of Kenya which fall in over five agro-ecological zones characterized by different climatic, topographic, soil and environmental features that influence the potential of agricultural development [7]. The relative humidity is high (> 80%) while the mean annual rainfall is 1200 mm and mean monthly minimum and maximum temperatures are 22 and 30 °C respectively.

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Data collection

Research design: A cross-sectional survey was conducted on a random sample of 415 small-scale dairy cattle producers' for 3 months to determine the main basal feed resources. Thereafter, feed samples were collected on a purposive sample of 32 farms from the cross-sectional sample during a longitudinal survey for 12 months. The farms were selected based on willingness to participate in the study, stall-fed or semi stall-fed cow(s) and kept farm records. Detailed data on acreage of cultivated and natural fodders and pastures, crop residues and tropical browse species used as livestock feed sourced on- and off-farm were collected.

Feed samples collection: Feed samples were collected during longitudinal survey from 150 plots in 32 farms at harvesting time during season I (short rains dry season: July-September 2012), season II (short rains season: October- December 2012), season III (long rains dry season: January-March 2013) and season IV (long rains season: April- June 2013). In semi stall-fed systems, grass samples were collected shortly before grazing. From each plot, two samples were collected in separate sample bags. A total of 780 samples in duplicates from different 26 forage and crop residue types were collected. To determine species composition of natural pastures, two diagonal transect lines were laid out in each pasture field. Along each transect line; five regularly spaced 1 m^2 quadrants were thrown. In each quadrant, the relative composition of different plant species was determined, clipped and weighed.

Laboratory analyses

Feed samples preparation: The samples were put in cool box and delivered to Kenya Agricultural and Livestock Research Organization (KALRO) – Mtwapa laboratory within 48 hours. Upon delivery, the two samples collected per plot were immediately chopped, thoroughly re-mixed and divided into two equal portions again for DM and chemical composition determination. Samples for chemical composition determination were dried in an air-forced oven at 60°C for 48 hours to a constant weight after which they were ground in a Willey mill to pass through a 2 mm screen and stored in nylon zip-lock bags. After longitudinal survey, due to their low frequency of occurrence and use as feed, 274 samples from 16 forage types were discarded. Thereafter, samples of the same forage type from the same farm and locality was combined, thoroughly mixed and then sub-sampled resulting in 142 samples from 10 feed types for chemical composition determination. These were two forbs: *Asystacia gangetica* and *Commelina benghalensis:* seven grasses: *Cynodon plectostaychus* (star grass), *Panicum maximum* (guinea grass), *Panicum coloratum* (coloured guinea), *Zea mays* (maize stover), *Pennisetum purpureum* (Napier grass), *Rottboelia exaltata* and natural pasture grasses mixture and one tropical browse shrub: *Leucaena leucocephala.*

Chemical composition determination: The DM was determined by oven-drying at 105°C for 12 hours. The organic matter OM) was determined through dry-ashing in a muffle furnace for 4 hours at 500°C. The chemical composition was determined through NIRS using pre-calibrated Multi-Purpose FT-NIR Analyzer (MPA) [9]. The Multi-Purpose FT-NIR Analyzer sequence of calibrations used was developed and supplied by Bruker Optics who had validated it for tropical feedstuffs in their laboratory. Prior to NIRS scanning, the dried and milled forages were re-dried for 4 hours at 60°C in an oven to standardize moisture conditions.

***In vitro* dry matter digestibility:** In vitro dry matter digestibility was determined following the methods of [10] by incubating 5 g of sample in thermostatically controlled water bath at 38°C. All samples were incubated in duplicates. 500 mL of rumen liquor was obtained from the rumen of a cannulated steer fed on Rhodes grass hay and grazed on natural pastures at the University of Nairobi, College of Agriculture and Veterinary Sciences farm. IVDMD was calculated as follows: [1 - (DM residue - blank DM) / DM original)] × 100, where DM residue is the DM recovered after 96 hours of fermentation, blank DM is the DM recovered in the corresponding blank incubated with rumen fluid after the same fermentation time, and DM original is the DM of the substrate placed in the tube [11].

Statistical analyses

The data obtained from in vitro dry matter digestibility was subjected to One-Way Analysis Of Variance (ANOVA) procedure using the SAS program General Linear Model procedure. Significant means were compared using the Duncan's Multiple Range Tests.

Results

Natural pastures grass species composition

The dominant grasses were *C. plectostaychus* (38.6%) and *P. maximum* (20.7%) with *R. exaltata* having the lowest occurrence (13.2%). *C. benghalensis* which is a common weed in pastures and crops fields had 9.1% occurrence. Other pasture grass species constituted 1.1% (Table 1).

Chemical composition of common forages

There were considerable variations in chemical composition between the forages as shown in Table 2. The CP content of *A. gangetica* and *C. benghalensis* was higher than that of all the other forages except the *L. leucocephala.* They also had lower NDF than pasture grasses which were harvested at an advanced stage of maturity. *C. benghalensis* had a CP content of 162.7 g/kg DM which was higher than 133.5 g/kg DM [12]. *L. leucocephala* was fed as a mixture of leaves and twigs and had a CP content of 270.8 g/kg DM which was higher than 244 g/kg DM [13]. However, its CP was comparable to 276 g/kg DM [14] and 268 g/kg DM of leaves harvested at 12 weeks interval [15].

Maize forage was cut from the fields immediately after green cobs were harvested and as a result more nutritious while the dry maize stover was harvested an advanced stage of growth after maturity. Dry maize stover CP was higher than 46 g/kg DM [16] and 52.0 g/kg DM [17]. Napier grass CP content was higher than 64 g/kg DM in the coastal Kenya region reported by [18]. Napier grass had ash and NDF contents of 135.6 and 716.6 g/kg DM which were comparable to 134

Table 1: Proportionate species composition of natural pastures grasses.

Natural pastures mixture composition	Proportion (%)
Cynodon plectostaychus	38.6
Panicum maximum	20.7
Panicum coloratum	17.3
Rottboelia exaltata	13.2
Commelina benghalensis	9.1
Other grasses	1.1

Table 2: Chemical composition (g/kg DM) of common feed resources.

Forages	DM (g/kg)	CP	Ash	CF	EE	NDF	ADF
Forbs							
A. gangetica	273.4±72.6	131.8±26.7	127.6±8.8	282.5±22.0	12.2±10.5	493.4±50.5	385.8±22.9
C. benghalensis	168.5±59.8	162.7±22.6	117.3±14.7	284.1±17.0	31.9±11.9	403.8±53.7	386.8±34.2
Crop residues							
Maize stover	587.2±179.8	72.2±10.4	88.0±11.5	345.7±22.8	0.0	721.1±52.7	438.0±29.7
Maize forage	389.0±155.1	112.8±13.6	107.1±21.8	319.5±15.3	0.41±1.1	676.6±46.7	419.0±17.7
Planted fodder							
Napier grass	227.5±90.5	86.4±11.3	135.6±24.2	337.7±12.0	0.1±0.2	716.6±40.4	455.4±18.1
Pasture grasses							
P. maximum	274.3±78.4	85.7±7.9	97.2±0.3	351.7±17.1	0.0	724.8±45.1	461.2±19.6
P. coloratum	264.7±94.7	85.2±6.6	112.5±14.4	342.6±13.2	0.0	675.5±56.6	478.4±17.3
C. plectostaychus	466.7±171.5	84.5±6.7	82.0±12.4	344.1±14.8	0.4±0.7	723.1±51.1	477.3±21.4
R. exaltata	367.7±153.7	97.1±13.5	117.8±18.9	320.5±21.6	1.1±3.0	671.4±72.8	456.2±21.2
Natural pastures mixture	369.0±199.5	84.1±10.9	113.7±14.7	323.0±13.9	3.8±5.4	603.8±57.0	454.6±19.5
Tropical browse shrub							
L. leucocephala	372.8±74.0	270.8±39.1	99.2±5.7	199.7±32.4	71.8±16.5	333.6±72.1	357.4±55.1

DM *- Dry Matter;* ***CP*** *- Crude Protein;* ***EE*** *-Ether Extract;* ***NDF*** *- Neutral Detergent Fibre;* ***ADF*** *- Acid Detergent Fibre.*

± - indicates the spread of the mean.

and 721.4 g/kg DM and 136 and 703.0 g/kg DM reported by [13,18] respectively. In the study area, pasture grasses were harvested at different stages of growth based on availability rather than maturity, hence the wide range in CP and CF values.

In Vitro dry matter digestibility of common forages

Table 3: *In Vitro* Dry Matter Digestibility (% DM) of common forages.

Forages	Mean*	Std. Deviation
Forbs		
A. gangetica	56.8^{ab}	6.94
C. benghalensis	63.3^{a}	4.06
Crop residues		
Maize stover	39.1^{c}	1.45
Maize forage	52.9^{b}	5.30
Planted fodder		
Napier grass	40.3^{c}	4.06
Pasture grasses		
Panicum maximum	41.4^{c}	2.01
Panicum coloratum	44.7^{c}	5.48
Cynodon plectostaychus	41.6^{c}	6.51
Rottboelia exaltata	41.7^{c}	5.27
Natural pastures mixture	40.3^{c}	7.31
Tropical shrub		
L. leucocephala	54.3^{b}	1.61

**Means with different superscripts within a column are significantly different (P < 0.05).*

There were significant differences (P < 0.05) between IVDMD of some forages (Table 3).

C. benghalensis had the highest IVDMD and was significantly different (P < 0.05) with all the other forages except *A. gangetica*. Dry maize stover and green maize stover IVDMD were significantly different (P < 0.05) which could be attributed to stage of growth at harvesting.

Discussion

Chemical composition is a major determinant of animal production from tropical forages and could affect ruminant performance at both plant and animal levels. It also varies to greater or lesser extent, according to the growth stage and environmental conditions during growth [19,20]. Therefore, variations in chemical composition in Table 2 and IVDMD in Table 3 could be attributed to conditions of soil, stage of maturity at harvest, forage species, variety or hybrid and weather conditions. As a result, differences exist in changes in nutrient quality associated with increased maturity in tropical forages which is accompanied by an increase in cell wall and a decrease in cell contents and results in lower CP [21-23]. The ash content indicates total inorganic materials in feeds and can sometimes provide an indication of feeds contamination with soil.

High CP content ranging from 131.8 to 270.8 g/kg DM of *A. gangetica* and *C. benghalensis* and *L. leucocephala* is an important nutritional aspect (Table 2). They can supplement poor conventional feed resources both during the wet and dry seasons. *L. leucocephala* is available during the dry season making it a cheap and valuable feeding resource to supply the much needed protein. This could be attributed to its nitrogen fixing and relatively deep root systems giving them drought resistance. In addition, its protein content does not change with leaf maturity even when they dry and fall to the ground [24].

Consequently, as a means of increasing yields of DM and CP in small-scale farms, efforts have been directed to introducing multi-purpose trees like *Leucaena* sp. *Gliricidia* sp. and *Calliandra* sp. in alley cropping systems and around the homestead in the coastal region. However, utilization of tropical browse species like *L. leucocephala* is limited by presence of anti-nutritional factors generated in natural feedstuffs through normal metabolism of species and by different mechanisms [25,26].

The low CP of dry maize stover could be attributed to the stage of harvesting and methods of storage. Field observations showed that the most common methods of handling dry maize stover after harvesting were storing under trees or in barns that were not roofed around homestead or stacking in open fields for gradual collection as required for feeding. These methods exposed the stover to vulgarities of weather and leaf shattering leading to loss of considerable amounts. In addition, most of maize was harvested at post hard grain stage and as a result most of dry maize stover available to farmers was of low quality. The presence of EE in pasture grasses could be attributed to presence of seeds which are rich in oils.

According to [27], forages are considered of low quality if they have less than 80 g CP /kg DM, this being the critical level below which voluntary intake of tropical forages is limited and of high quality if having 100 g CP /kg DM and above. Based on these criteria, *L. leucocephala,* green maize stover, *A. gangetica* and *C. benghalensis* had nearly 1 to 3 fold CP levels above 80 g/kg DM, and can be considered as medium to high quality forages in study area. Napier grass and pasture grasses had CP content of more than 80 g/kg DM but less than 100 g/kg DM and may be considered as marginal sources of CP. Dry maize stover had a CP content of 72.2 g/kg DM and therefore of low quality. However, the CP content of the diet should be 120 g/kg DM if moderate production in dairy cattle is to be attained [28]. Though some of the forages had less than 80 CP g/kg DM, they are seldom fed exclusively alone and the mixtures used perhaps provided the required CP content. As a result, the high nutritive value of *C. benghalensis*, *A. gangetica*, *L. leucocephala* and green maize stover is diluted by those with low crude protein, low IVDMD and high fibre content. The variations in dry matter loss may be related to the differences in chemical composition or to variations in physical structure, such as the distribution within the tissues of lignified cells [29]. In addition, the forage species could affect voluntary feed intake and milk yields or body weight changes.

C. benghalensis, *A. gangetica*, *L. leucocephala* and green maize stover had IVDMD higher than 45% which, according to [30], is the level needed for maintenance of cattle in the tropics. Due to this higher digestibility, they can be used as feed by cattle in the study area for both maintenance and some level of productivity. However, when farmers harvest the forages for feeding, they do not separate them but were usually fed as mixtures in different combinations. The low protein levels in mature tropical grasses have been reported as one of the major factors contributing to poor digestibility and animal performance. Natural pasture grasses differed in quality (Table 2) and in the extent and rate of rumen degradation (Table 3) and hence influence the yield of fermentable substrate. This could be attributable to the stage of maturity at harvesting as in coastal lowlands, natural pastures are usually cut from the field for feeding when required. As the grasses matures, the leaf: steam ratio declines causing a change in the chemical composition with concomitant reduction in feeding value. In addition, pasture grasses and Napier grass fields were poorly maintained with no weeding and fertilization application. *A. gangetica* and *C. benghalensis* were weeds within food crops fields where manure and fertilization were applied hence their high nutritive values.

Deficiency of protein can be a major limitation to the intake and utilization of most tropical forages due to rapid growth and maturity during the wet season. NRC [31] reported that the minimum CP content required for lactation and growth in cattle is 150 g/kg DM while [22] suggested a minimum requirement of 75 g/kg DM for adequate rumen function. Feeds containing less than 60 g CP /kg DM are considered as CP deficient. Such feed cannot provide the minimum level of ammonia (50 - 80 mg/l) required for maximum microbial growth. In the study area, the CP content of the forages was adequate to meet the requirements of the host animal and rumen microbes. As such, depending on the forage fed, they are able to satisfy CP requirements of livestock animals ranging from mature beef cows (70 g/kg DM) [32] to high producing dairy cows (152.0 g/kg DM) [33].

Conclusions and recommendations

The chemical composition and rumen fermentation kinetics of the weeds, crop residues, napier grass, pasture grasses and tropical browse shrub presented significant variations between the feed resources studied. In particular, *C. benghalensis* could be considered potential source of roughage in this climatic zone in the dry season when regular feed resources are in short supply and low in quality. As a result, they can be used to supplement poor quality grass particularly during the dry season and as a consequence, help to reduce the high feed costs of dairy cattle in small-scale farms in Coastal Lowlands of Kenya. The results of chemical composition and intro dry matter digestibility could also be important when considering feed ration formulation and supplementation strategies for ruminant diets. The information could be useful in the planning of ruminant diets particularly during the dry season in the study area. Therefore, farmers' should be encouraged to harvest pasture grasses at bloom-milk stage in order to take advantage of their rich nutrient supply.

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