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Effect of Feed Digestibility and Milk Yield on Feed Intake and Daily Methane Production

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Abstract

The Kenyan cattle industry relies on beef as well as dairy cattle. The population currently being 120 million heads. These are raised in the relatively dry agroecological zones or the crop-livestock production systems where poor-quality forages are used. This study was based in the medium agricultural zone where grazing natural pastures are used as Nandi County is located in the western part of the Rift Valley of Kenya. The study sampled farms across the three agro-ecological zones (AEZs) (Lower highland1, Lower highland 2 and Upper midlands) and four seasons in the County following a sampling protocol. The number of sampling points in each AEZ was based on the total sample size (127 households) weighted by the total area of each AEZ, and 487 dairy cows and data collection spanned one year, from November 2015 to October 2016.. In total, 36 GPS points across the three AEZs were selected, restricted by proximity to roads of 2 km (<2 km distant). GPS points were allocated across the three AEZs (LH1: 22, LH2: 8 and UM: 6) and then used to navigate to the nearest village, and household. Feed intake, nutrient composition, milk yield and quality were determined as well as body condition and activities of the cows. Milk yield, live weight, live weight changes, total metabolizable energy, dry matter intake and daily methane production for each season and agro-ecological zone (AEZ) were assessed. Analysis of variance (ANOVA); linear regression and correlation test was carried out to test the relationship between DMD and DMP. This was done using the R i386 3.4.1 statistical package. Results revealed that feed differed among the agroecological zones and feed types. A higher feed dry matter digestibility led to significant daily methane production. There were differences in DMP between AEZs (p = 0.0002), 39.97% of which was influenced levels of daily milk yield, and seasons (p-value=0.048) and this only between short rains and hot dry season (p<0.000). It is concluded that enteric methane emissions increase with rising levels of milk production and lower feed quality and digestibility.

***Key words**: Agro-ecological zone, Dairy cows, Digestibility, Feed quality, Methane production, Milk yield*

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INTRODUCTION

The Kenya National Bureau of Statistics [12] Kenya population and household census (KPHC) Volume IV Report shows the cattle population of 17,467,774 of which 3,355,407 are dairy. Out of a total of 65,308,644 ruminants and camels (Table 1). Nandi County is located in Rift Valley, which has the highest number of cattle standing at 1,560,222 and 5,919,585 exotic dairy and indigenous breeds, respectively.

Table 1. Ruminant livestock population in 2019 Census year.

	Exotic Cattle	Indigenous Cattle	Sheep	Goats	Camels
KENYA	3,355,407	14,112,367	17,129,606	27,740,153	2,971,111
Nairobi	25,536	29,010	34,717	46,837	20
Central	800,227	325,678	664,237	531,209	231

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Coast	74,119	885,846	467,439	1,570,728	51,045
Eastern	373,307	1,886,854	1,890,898	4,729,057	248,634
North Eastern	80,422	2,694,786	4,264,155	7,886,586	1,700,893
Nyanza	221,670	1,527,000	495,055	961,269	59
Rift Valley	1,560,222	5,919,585	9,079,380	11,750,521	968,192
Western	219,904	843,608	233,725	263,946	2,037

Source: KNBS Population and Household Census (2019)

The ruminant livestock contribute significantly to climate change through greenhouse gas (GHG) emissions and are affected directly by its effect to the environment. Enteric fermentation is one of the major sources of GHG in the livestock sector contributing close to 40% of the agricultural sources [15]. The contribution of large ruminants (dairy and beef) emissions are high (19% and 55% of the total enteric methane emissions)[15]. The Intergovernmental Panel for Climate Change (IPCC) has three methodologies (Tier I, II and III) of enteric methane estimation. Tier II and III use feed intake and feed digestibility to estimate enteric methane emissions [9].This is because energy value of a feed is determined by feed digestibility which is an important factor in determining methane emissions [4] [8]. Digestibility affects the rate at which feed energy is converted to energy required for maintenance and production as well as methane[8]. Milk production is an energy demanding function that can either obtain energy from feed or body reserves. High producing dairy cows require high feed intake for them to sustain their high productivity [2] otherwise insufficient feed intake leads to negative energy balance [11] that leads to body weight loss. Similarly, feed low in digestibility provides low feed energy and this forces the dairy cows to use their body reserves for milk production. Feed intake and feed digestibility therefore becomes important factors in dairy cows feeding management. Research has shown that feed intake directly affects methane emissions [7]. IPCC Tier II method uses average daily feed intake [9] as one of the factor to estimate methane emission therefore, an important aspect. However, it is challenging to measure the intake especially under grazing conditions. Different approaches used to measure intake are such as, conducting pasture biomass before and after grazing though this method may fail due to feed intake based on plant part of species palatability and nature of pasture [3]. Intake can also be measured by use of C-isotopes which are dosed regularly and faeces collected over a period of time [3]. Lastly, use of live-weight and live-weight gain and production data using existing algorithms [3] is also used in intake estimation. The purpose of this study was to investigate the influence different levels of milk production and feed digestibility and on daily methane production as well as digestibility on feed intake.

Materials and Methods

Study site

The study site, Nandi County is located in the western part of the Rift Valley of Kenya. One hundred and twenty-seven households were randomly selected across the three agro-ecological zones (AEZs) (Lower highland1, Lower highland 2 and Upper midlands) in the County following a sampling protocol explained in [12].

Milk yield records

The livestock farmers were trained on daily milk yield record keeping. They were provided with an exercise book, pencil and Mazzican graduated milk urn (http://mazzican.com/Ashut Engineering Limited, Kenya) for a duration of approximately one year, between November 2015 to October 2016.

Metabolizable energy requirement (MER), dry matter intake (DMI) and daily methane production (DMP) estimation

Data on MER, DMI and DMP estimates that was used was from [12]. To achieve the estimates, data on individual animal live-weights, average daily milk yield, milk quality, and average distance travelled daily during grazing was collected from 487 dairy cows on a time interval of three months for one year. This also represents the four weather seasons (short rains, long rains, hot dry and cold dry). Feed samples were collected and nutrient analysis was performed by wet chemistry for dry matter (DM) (AOAC method 930.15), total N (AOAC method 990.03), organic matter (OM), neutral detergent fibre (NDF) and acid detergent fibre (ADF:AOAC method 973.18) following standard procedures of [1]). Dry matter digestibility (DMD) was estimated using the equation of [14]:

DMD(g⁄(100g DM)=83.58-0.824*ADF(g⁄(100g DM)+(2.626*N(g⁄(100g DM)))))

Average daily weight gain or loss and dry matter digestibility of Nandi County's AEZ feed basket was computed. Estimates on MER for maintenance, growth, lactation and locomotion were computed following equations from[7] derived from "Nutrient Requirements of Domestic Ruminants" [6]. Total MER was computed and was used to compute dry matter intake was calculated as follows;

$$\mathrm{DMI(kg)} = \mathrm{MER_{Total}(MJ/day)} / (\mathrm{GE\ (MJ/Kg)} * (\mathrm{DMD}/100))/0.81$$

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Where GE= gross energy of the diet assumed to be 18.1MJ/kg DM and 0.81 as the factor to convert metabolizable energy to digestible energy. The estimated DMI was used to calculate DMP using equation of [5]:

$$DMP\ (g) = 20.7 * DMI\ (Kg/day).$$

Statistical analysis

Descriptive statistics (mean, standard error of means (SEM)) were calculated for milk yield, LW, LW flux, total MER, DMI and DMP for each season and AEZ. Analysis of variance (ANOVA) was used to evaluate differences between seasons and location for DMD, and milk production. A linear regression model was fit to examine the influence of milk yield on DMP, DMD on DMP. A correlation test was carried out to test the relationship between DMD and DMP. The R i386 3.4.1 statistical package was used to carry out the analysis.

Results and Discussion

Data was arranged in AEZs and seasons. Table 2 shows the DMD of the defined feed basket for Nandi County. There was no significant difference in DMD among the three AEZ (p-value= 0.37) and no difference between seasons (p-value= 0.74). Between the AEZs in Nandi County, the defined feed-basket differed due to different feed resources availability across the AEZ and some of the feed types could only be found in different season for example maize stover, which were only available during the harvesting seasons. The DMD across all zones did not differ significantly. However, this may have resulted to the difference in DMP as DMD was used in calculation of MER and DMI. There was a significant DMD influence on DMP where results showed that an increase in DMD results in a decrease in DMP.

Table 2: Average dry matter digestibility (DMD) of Nandi County feed basket for lower highland 1, lower highland 2 and upper midlands zones during short and long rains, hot and cold dry season

AEZ	DMD (%)			
	Short rains	Hot dry	Long rains	Cold dry
Lower highland 1	63.4	63.4	65.4	68.4
Lower highland 2	60.3	60.3	65.1	66
Upper midlands	64.2	64.2	60	60.4

AEZ= agro-ecological zone, DMD= dry matter digestibility

From a previous study, MER for maintenance was the largest component in the total MER that largely depended on the live-weights. This means that the high the live-weight, the high the MER for maintenance. Energy requirement for production comes second. Determining the feed intake required the total energy requirement and the digestibility of the feed basket. Table 3 shows that average DMI for the dairy cows in the three AEZs across all the seasons. The calculated DMI varied across the AEZ in line with the live-weights and milk production of the dairy cows in the three zones as illustrated by [12].

Table 3: Average dry matter intake (kg/day) (and standard error of means) for dairy cows in lower highland 1, lower highland 2 and upper midlands zones of Nandi County during short and long rains and hot and cold dry seasons

AEZ	Average DMI (kg/day)			
	Short rains	Hot dry	Long rains	Cold dry
Lower highland 1	7.6±0.21	6.1±0.17	6.5±0.19	6.4±0.18
Lower highland 2	8.0±0.50	6.8±0.40	6.8±0.43	7.4±0.42
Upper midlands	6.3±0.39	5.4±0.29	6.3±0.41	6.8±0.42

AEZ=agro-ecological zone, DMI= dry matter intake

Analysis of variance showed that there was a significant difference in DMP between AEZs (p = 0.0002), however there was a difference between seasons (p-value=0.048) and this only between short rains and hot dry season (p<0.000). Using the Tukey's HSD, all AEZs were different with each other as well as the seasons except for the short rains and hot dry seasons, which did not show a significant difference. Further analysis was carried out to investigate the relationship between DMD and DMP and the two factors were negatively correlated (r= -0.057). This means that an increase in DMD causes a decrease in DMP and vice versa. This finding is in close agreement with studies by [4] and [10] that feed digestibility directly affects methane emissions[8] mainly because the level of has an effect on the type of volatile fatty acid (VFA; propionate, acetate, butyrate) to be produced after fermentation. Feed with high digestibility when fermented, *Clostridium propionicum* competes closely with methanogens for free hydrogen for production of propionate and methane, respectively. In this, less methane is produced. Where feed is less digestible, acetate and butyrate are produced as the fermentation products that have free hydrogen that promotes production of more methane.

In dairy cows, MER for lactation is the second largest component of total MER as seen in [12]. A linear model was used to test the influence of milk yield to daily methane production. The model showed that 39.97% of DMP was influenced by daily milk yield. Table 4 shows that milk yield had significant influence on DMP across the three AEZs in the four seasons. The level of milk production therefore, was associated with calculated DMI that was high and ultimately affected DMP and this explains the significant relationship between milk yield and DMP. The level of milk production directly influences emissions as feed intake increases and leads to high DMP. Thus, it is anticipate that enteric methane emissions will tend to increase with rising levels of milk production. The efficiency of production in milk yield and body weight gain or growth is determined by the digestibility and quality of the feeds. To improve on these parameters, the

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animals need to consume better nutrients and convert faster so that they take a shorter time to optimum milk production or reach slaughter weight [8]. This will save time and have eventually lower emission load.

Table 4: Linear model output showing the influence of milk yield agro-ecological zones (AEZs) and seasons on daily methane production (DMP)

Coefficients	Estimate	Standard Error	t-value	p-value
Intercept	75.32	2.357	31.96	<0.001***
Milk yield	5.39	0.255	21.45	<0.001***
AEZLH2	13.42	2.173	6.18	<0.001***
AEZUM	12.45	2.644	4.71	<0.001***
SeasonHD	-1.80	2.408	-0.75	0.454
SeasonLR	2.03	2.378	0.85	0.393
SeasonSR	27.04	2.438	11.09	<0.001***

The Lower Highland 1 (LH1) zone and cold dry (CD) seasons are reference levels, assumed as zero. LH2= Lower Highland 2, UM= Upper Midlands, HD= hot dry season, LR= long rains season, SR= short rains season

Conclusion

This study has shown that digestibility as well as feed intake, continue to be the driving forces in enteric methane emissions from livestock. Africa rangelands and pasture is categorized to be of poor quality. In addition, this study has identified feed quality to be very dependent on seasons as well as in different agro-ecological zones. Therefore, there is need to sensitize on feeding the livestock with quality feed as an enteric methane emission mitigation option. This option will also be able to address the increased methane emissions per kilogram of milk as seen in this study. Improved feeding in Kenyan livestock involving feeds with high digestibility will improve productivity as well as reduction of both total emissions and emission intensity.

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