International Journal of Veterinary Sciences and Animal Husbandry 2019; 4(5): 26-31

International Journal of Veterinary Sciences and Animal Husbandry

ISSN: 2456-2912
VET 2019; 4(5): 26-31

www.veterinarypaper.com
Received: 19-07-2019
Accepted: 21-08-2019

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Evaluation of nutritive value of feeds and feed ration ingredients from different interventions used by dairy farms in Kenya

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Abstract
Dairy cows' production potential in Kenya is affected by inadequate supply of quality feeds. Chemical analysis and *in-vitro* degradability of feed ingredients from twelve farms using each of the three interventions: maize train and bale silage, silage from Service Provider Enterprises (SPEs), and feed ingredients from farms using ration formulation (*Rumen8*) software were compared with 12 control farms for each intervention. Data from the experiments was subjected to analysis of variance using the General linear model. Mean separation was done using least significant difference at 5% level of significance. Dry matter content of maize train silage (34.4%) and baled silage (34.9%) differed from SPEs silages (32.3%) ($p<0.05$). Neutral detergent fibre ranged from 13.9% in soybean meal to 46.6% in SPEs silage. Metabolizable energy ranged from 8.7MJ/kgDM in sunflower meal to14.7MJ/kgDM in maize germ. Organic matter degradability was high in maize train silage (56.4%) and lowest in sunflower meal (25.8%). In conclusion, use of maize train and baler intervention is the best fodder conservation measure for quality silage.

Keywords: Chemical composition, *In-vitro* degradability, maize train silage, short chain fatty acids, service provider enterprises, rumen8 ration

Introduction

Livestock production in the tropical regions of Kenya is affected by the inadequate supply of quality feeds [1]. The optimal dairy cattle feeding regime should consist of 75% energy sources, 24% protein sources and 1% mineral sources [2,3]. The nutritive value of an animal feed is determined predominately by its digestibility, which affects intake. Digestibility and intake, in turn, determine the feeds' influence (such as support of milk synthesis) on productive performance [4]. The performance of animals maintained in resource-poor surroundings is usually poor due to seasonal fluctuations in the quality and supply of animal feeds. When accessible even in limited quantities, the fibrous feeds such as cereal crop residues and poor-quality mature grasses can not maintain animals during much of the year [5].

In-vitro gas methods primarily measure digestion of soluble and insoluble carbohydrates [6], and the amount of gas produced from a feed on incubation reflects production of volatile fatty acids (VFA), which are a major source of energy for ruminants. Rumen fermentation by anaerobic microbes results in production of short chain fatty acids (SCFA), gases (carbon dioxide (CO_2) and methane (CH_4)) and microbial mass [7].

The 3R Project Kenya documentation of KMDP fodder interventions (Maize train/baled silage, service provider enterprises (SPEs) silage, and dairy ration formulation using *Rumen8* software) reported that with good quality (maize, sorghum, grass) silage to replace hay in the total mixed rations, the farmer can reduce the share of dairy meal in the ration and cost price of milk. Use of SPE silage-making services was most frequent among farmers in Central and Eastern regions, where the majority (75%) of farmers used the services at least four times per year [8]. Scarcity and low quality of feed resources constitute one of the major constraints to improved dairy productivity. Therefore, improving the efficiency of feed conversion to milk can have a significant impact on the productivity and profitability of dairy farms.

This experiment determined the actual nutritional quality of dairy ration ingredients and fodder crops used in interventions adopted by dairy farms in Kenya.

Materials and Methods
This experiment involved laboratory analysis to determine the nutritive value of feed samples from different interventions;

Maize train and baled silage
This silage was prepared in the sampled farms by the aid of Kenya market-led dairy program (KMDP) in North Rift region. The process involved land preparation, seed selection (Selection of forage maize variety or hybrid suitable for forage production i.e. with low NDF, cob to stem ratio of 50:50 (DM basis) and high in starch, planting (the correct seed rate to get the desired plant population avoid plant competition and ensure maximum yield per acre or hectare), Weed and pest control, harvesting (done at the right stage aimed at a DM level of the whole crop of 30-35% and a starch level of at least 30%, chopping and kernel which reduced losses, enables easier compaction, increased voluntary feed intake per cow and avoids selective feeding. Transportation, ensiling and Compaction (using the heaviest machine available within 12 hours), covering, and proper feeding-out of silage where quick removal of silage prevented heating up, moulding and rotting of silage at the face of the silo.
Forage Innovation Team Ltd (FIT Ltd), offered professional forage baling services to dairy farmers whereby fresh maize from the field was chopped and baled directly or ensiled maize that is being scooped from a bunker for baling. Silage bales were wrapped with 6 to 8 layers of stretch foil that made them less vulnerable to damage during handling, transport and storage.

Silage made by Service provider enterprises (SPEs)
This silage was made by groups of youth in Central, Eastern and some parts of North Rift (Baringo) regions who had received practical training, facilitated by SNV, on silage making. They offered "next door" services in fodder establishment, silage making and some advisory services. Most farmers were harvesting their maize at milky stage which made it easier for the use of chaff cutters which lack kernel crusher. The chopped maize forages were later transported for ensiling in pit silos. Compared to maize train and baled silages, SPEs silage was made using molasses to enhance fermentation process which compensate poor crop production or silage management.

Feed ingredients used in *Rumen8* software
A dairy ration formulation software was introduced and equipped with a Kenyan Feed Library with support from KMDP. The software balanced rations using the available feed resources (maize silage, hay, maize germ, wheat bran, wheat pollard, cotton seed meal, sunflower meal, soybean meal) on the farms to formulate a total mixed ration that allowed the dairy cows to increase DM intake and thus increase milk production and productivity.

Control diets
The diets included maize silage made on-farm without any advisory services, concentrates (maize germ, wheat bran, cotton seed meal, sunflower meal, soybean meal) from local feed millers) that were used to formulate rations without the use of feed balancing (*Rumen8*) software. The farms which were using the control diets were selected based on the regions where the interventions were being applied.

Proximate analysis
Proximate composition (dry matter (DM), crude protein (CP), Ether Extract (EE) and ash) of the feed samples were analysed in duplicate as per the standard procedures [9]. The cell wall constituents, neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined [10].
Dry matter was determined by drying samples of feed ingredients at 105ºC for 15 hours. Feed ingredients, total mixed ration (TMR) and fecal samples were weighed and dried at 60°C for 48 hours for DM determination. Dried samples were ground to pass a 1-mm screen and analyzed for total N and NDF [10], and ash by combustion in a muffle furnace at 600°C for 8 h. Acid insoluble ash in feed and feces was determined to estimate apparent digestibility of DM.

In-vitro degradability
Rumen liquor was collected in morning (6am) from a fistulated steer animal before feeding and watering into a pre-warmed thermos-flask and taken to the laboratory. One litre of rumen fluid from the cows was kept in a warm flask after filtering through two layers of cheese-cloth to obtain fluid which was then flushed with carbon dioxide (CO_2) and combined with buffers to simulate the action of saliva. A weight of 200mg of feed samples (1mm screen) in duplicate were prepared and placed into 100ml glass syringes in duplicate.
The rumen fluid and buffer medium were mixed in the ratio of 1:2 (v/v). Buffer -rumen fluid mixture, 30ml was added into the syringes containing samples, shaken gently and any air bubbles released. The syringes were incubated at 39ºC in a thermostatically controlled water bath for 0-96 hours. The samples and blanks (rumen fluid +buffer) were run in duplicates. The fermentative activity of the mixed microbial population was determined using the gas production technique [6].
The volume of gas produced was determined at 3, 6, 9, 12, 18, 36, 48, 72, and 96 hours by reading the calibration of the piston. The two blank syringes containing only 30 ml of buffered rumen fluid were incubated to estimate gas production due to endogenous substrates corrections. The gas produced was the total increase in volume minus the mean blank value. The calculated values of gas production were fitted into the model developed by [11] to determine the degradability of the feed ingredients.
$Y= a + b (1-e^{-ct})$ 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)
Then (a+b) represents the potential extent of the gas production.
The *in-vitro* OM digestibility was estimated using methods by [10]. Metabolizable energy (ME) content was calculated using the equation [6] as follows;
ME (MJ/kg DM) = 1.06 + 0.1570 × Gas produced (ml/200 mg DM) + 0.0084 × CP (g/kg DM) + 0.022 × EE (g/kg DM) – 0.0081 × Ash (g/kg DM).

Data analysis
Data (DM, CP, ME, EE, NDF, ADF and Nitrogen use efficiency) from this experiment were subjected to analysis of variance (ANOVA) using the General linear model (GLM) of statistical Analysis system [12]. The Significant means was separated using LSD at 5% level of significance.

Results

Chemical composition

Table 1: Chemical composition of ingredients used in the different interventions

Feed Ingredients	DM %	CP %	EE %	NDF %	ADF %	Ash %
Maize train silage	34.4^{d}	8.1^{f}	3.4^{de}	45.8^{a}	25.7^{d}	4.1^{d}
Maize silage (Baled)	34.9^{d}	7.9^{f}	3.4^{de}	44.6^{a}	25.7^{d}	3.9^{d}
SPEs Silage	32.3^{e}	7.2^{f}	3.1^{e}	46.6^{a}	28.1^{c}	5.2^{c}
Maize germ (*Rumen8)*	89.8^{b}	11.5^{e}	12.3^{a}	35.7^{bc}	9.3^{f}	3.0^{e}
Maize germ (Control)	89.5^{b}	11.5^{e}	12.4^{a}	35.7^{bc}	9.1^{f}	3.2^{e}
Wheat bran (*Rumen8)*	87.3^{c}	16.7^{d}	3.8^{d}	34.5^{c}	13.3^{e}	5.9^{bc}
Wheat bran (Control)	87.2^{c}	16.3^{d}	3.9^{d}	34.8^{c}	13.2^{e}	5.8^{bc}
Cotton seed meal (*Rumen8)*	90.7^{b}	34.9^{b}	7.1^{c}	35.9^{bc}	30.7^{b}	5.4^{c}
Cotton seed meal (Control)	90.5^{b}	35.0^{b}	7.1^{c}	36.1^{bc}	31.0^{b}	5.3^{c}
Sunflower meal (*Rumen8)*	92.5^{a}	34.1^{bc}	9.2^{b}	37.3^{b}	35.9^{a}	6.3^{ab}
Sunflower meal (Control)	90.4^{b}	33.6^{c}	9.3^{b}	37.4^{b}	35.6^{a}	6.4^{ab}
Soybean meal (*Rumen8)*	90.0^{b}	42.7^{a}	3.6^{de}	13.9^{d}	9.5^{f}	7.0^{a}
Soybean meal (Control)	89.6^{b}	42.8^{a}	3.4^{e}	14.1^{d}	9.7^{f}	6.9^{a}
SEM	0.434	0.415	0.259	0.638	0.416	0.259
P	<.0001	<.0001	<.0001	<.0001	<.0001	<.0002

^{abcdef} Means in the same column with different superscripts are different at ($p<0.05$), DM=dry matter; CP=crude protein; EE=ether extracts; ADF=acid detergent fibre; NDF=neutral detergent fibre; SEM-standard error of the mean; SPEs=service provider enterprises.

The DM content was 92.5% in sunflower meal and 32.3% in SPEs silage which was different ($p<0.05$). Dry matter content in maize train silage was higher (34.4%) compared to SPEs silage (32.3%) ($p<0.05$). The CP content was high in Soybean meal 48.80% and lowest in silage from SPEs 7.2%. The NDF of the ingredients sampled from farms using *rumen8* feed formulation software was 46.6% in maize train silage and 13.87% in Soybean meal. Maize train silage had 45.8% NDF which was lower than 46.6% in SPEs silage ($P>0.05$). Acid detergent fibre (ADF) was 35.9% in sunflower meal and 9.3% in maize germ meal. The ash contents were high in soybean meal (7.0%) and lowest in maize germ meal (3.0%) ($p<0.05$). Ether extracts ranged from 12.3% in maize germ to 3.4% in soybean meal.

In-vitro Degradability

Table 2: *In-vitro* degradability of selected feed resources used in different interventions in Kenyan Dairy Farms

Feed Ingredients	Total Degradation (%)		Fermentation Characteristics				
	24	48	a	B	a+b	C	RSD
Maize train Silage	42.5^{c}	26.6^{c}	10.9^{c}	9.8^{c}	20.8^{c}	0.2^{e}	16.7^{c}
Maize baled Silage	56.7^{a}	40.5^{a}	13.8^{a}	15.3^{a}	29.1^{a}	0.2^{e}	21.2^{a}
SPEs Silage	45.4^{b}	34.7^{b}	12.6^{b}	11.9^{c}	24.6^{b}	0.2^{e}	17.5^{b}
Maize germ (*Rumen*8)	12.1^{h}	9.1^{h}	8.0^{e}	13.8^{b}	15.7^{d}	12.0^{c}	3.9^{i}
Maize germ (Control)	12.6^{g}	11.6^{e}	4.4^{l}	2.5^{i}	6.9^{k}	0.1^{e}	4.8^{g}
Wheat bran (*Rumen8*)	14.2^{ef}	13.1^{d}	6.0^{g}	5.2^{e}	11.2^{f}	32.2^{a}	7.4^{f}
Wheat bran (Control)	15.3^{d}	13.2^{d}	7.1^{f}	4.3^{f}	11.4^{e}	22.3^{b}	7.5^{f}
Cotton seed meal (*Rumen8*)	12.1^{h}	10.1^{g}	8.7^{d}	3.0^{g}	8.7^{h}	22.1^{b}	4.2^{h}
Cotton seed meal (Control)	12.5^{g}	10.4^{f}	5.7^{i}	2.7^{h}	8.5^{i}	7.1^{d}	4.1^{h}
Sunflower meal (*Rumen8*)	7.9^{i}	5.9^{l}	4.4^{l}	1.3^{k}	5.8^{m}	7.5^{d}	4.7^{g}
Sunflower meal (Control)	7.1^{j}	6.1^{k}	4.6^{k}	1.4^{k}	5.9^{l}	7.2^{d}	5.0^{g}
Soybean meal (*Rumen8*)	13.8^{f}	7.4^{j}	5.8^{h}	2.4^{j}	8.2^{j}	12.6^{c}	7.8^{e}
Soybean meal (Control)	14.4^{e}	7.7^{i}	4.9^{j}	4.4^{f}	9.3^{g}	12.51^{c}	9.1^{d}
SEM	0.124	0.023	0.025	0.057	0.033	0.093	0.095
P	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

SPEs = Service provider enterprises; a, b, c are constants; ^{abcdefghijk} Means in the same column with different superscripts are different at ($P<0.05$); C gas=gas production rate; a gas=gas production (ml) from readily soluble fraction; b gas=gas production (ml) from insoluble fraction; (a+b)=potential gas production; SEM=standard error of the means.

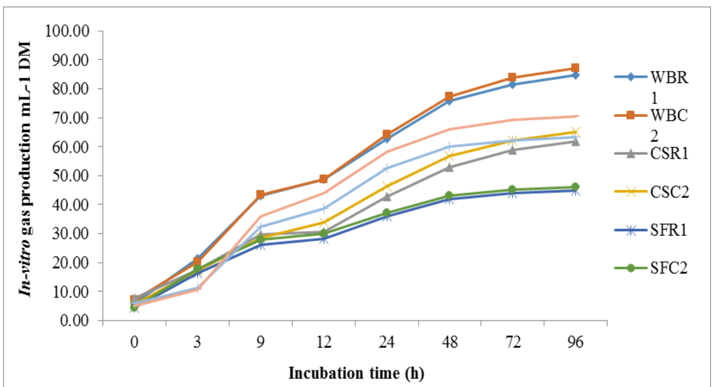

Fig 1: *In-Vitro* Dry Matter degradability for selected feed ingredients from different intervention levels

WBR1=wheat bran (*Rumen8* intervention); WBC2=wheat bran (control farms); CSR1=cotton seed meal (*Rumen8* intervention); CSC2= cotton seed meal (control farms); SFR1=sunflower meal (*Rumen8* intervention); SFC2=sunflower meal (control farms); SBR1=soybean meal (*Rumen8* intervention); SBC2=soybean meal (control farms).

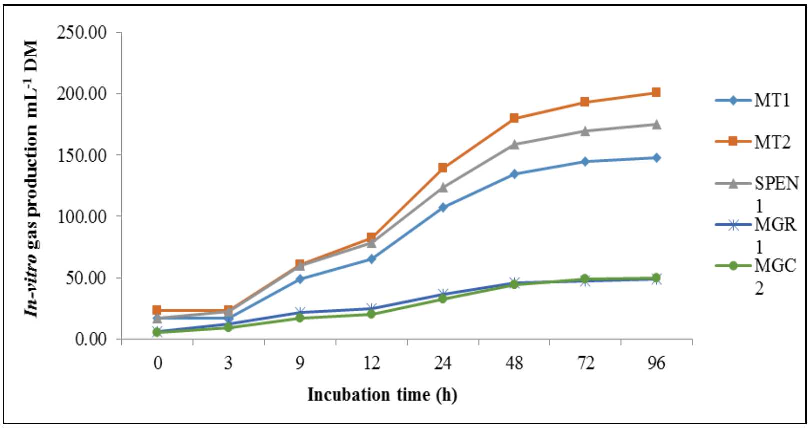

Fig 2: *In-Vitro* Dry Matter degradability for selected feed resources from different interventions

MT1=maize train silage; MT2=maize train silage (baled); SPEN=service provider enterprises network silage; MGR1=maize germ (*Rumen8* intervention); MGC2=maize germ (control).

There were significant variations in the feed ingredients in gas production and estimated parameters. The gas production of maize train silage (179.39ml/200g DM) was higher than SPEs silage (158.71ml/200g DM) ($p<0.05$) at 48h. Sunflower meal produced the lowest gas at 48h (43.11ml/200g DM). The rate of gas production was highest in wheat bran (32.2%/h) and the lowest in maize train silage (0.2%/h). Potential gas production (b) differed ($P<0.0001$) among the feed ingredients. While there was a wide range in rates of gas production (c) among feeds, there were no differences ($P>0.05$).

Table 3: Metabolizable energy (ME MJ/kg DM), Organic matter digestibility (OMD%), and Short chain fatty acids (SCFA mmol/200mg DM) determined by *in-vitro* digestibility

Feed Ingredients	SCFA	ME MJ/Kg DM	OMD% 48HR
Maize train Silage	0.9^{a}	10.7^{e}	43.5^{b}
Maize baled Silage	1.3^{a}	11.9^{dc}	56.4^{a}
SPEs Silage (Central)	1.0^{a}	9.2^{g}	50.9^{ab}
Maize germ (*Rumen*8)	0.6^{b}	14.7^{a}	27.5^{cd}
Maize germ (Control)	0.3^{bc}	13.4^{b}	29.9^{c}
Wheat bran (*Rumen*8)	0.3^{bc}	12.3^{c}	31.5^{c}
Wheat bran (Control)	0.3^{bc}	11.7^{d}	31.6^{c}
Cotton seed meal (*Rumen8*)	0.3^{bc}	10.1^{f}	29.7^{c}
Cotton seed meal (Control)	0.2^{bc}	11.1^{e}	30.0^{c}
Sunflower meal (*Rumen8*)	0.2^{bc}	9.7^{gf}	25.8^{cd}
Sunflower meal (Control)	0.1^{c}	8.7^{h}	26.0^{d}
Soybean meal (*Rumen8*)	0.3^{bc}	13.1^{b}	28.0^{cd}
Soybean meal (Control)	0.3^{bc}	12.3^{c}	28.4^{cd}
SEM	0.075	0.159	2.668
P	<.0001	<.0001	<.0001

SPEs = Service provider enterprises; OMD = Organic matter digestibility; ME= Metabolizable energy; SCFA = Short chain fatty acids; SEM = Standard error of the mean.

The ME was highest (14.7MJKg^{-1} DM) in maize germ meal and lowest (8.7MJKg^{-1} DM) in sunflower meal (Table 3). However, ME did not differ between the maize train and SPEs silages ($P>0.05$). The SCFA was highest (1.3%) in maize baled silage and lowest (0.1%) in sunflower meal. The SCFA did not differ among the silage samples (maize train and SPEs silages) ($P>0.05$). There was no significant difference ($P>0.05$) in SCFA among the concentrate feed ingredients. Organic matter digestibility (OMD %) was highest in maize baled silage (56.4%) and lowest in sunflower meal (25.8%). The OMD did not vary among the concentrates ($P>0.05$).

Discussion

The NDF and ADF results in maize silages from both interventions were comparable to results by [13] who reported NDF and ADF contents of 48.6% and 25.3%, respectively.The difference in NDF and ADF content in SPEs silage compared to maize train/baled silages was attributed to the quality of maize harvested for ensiling, stage of harvesting, crushing of maize kernels, and proper compaction which guarantees good quality silage. It was noted that farmers using maize train and baler interventions in the North Rift region considered the cutting height of the maize forage compared to farmers using SPEs intervention in Central and Eastern regions. [13] noted that increasing the cutting height from 10cm-30cm increases the dry matter (DM%) content by 1.5%, since most of the wet stem materials were left in the field, but decreases yield by 0.4ton DM/acre. The low detergent insoluble cell walls (NDF and ADF) content was attributed to good characteristic of the feed, same observations were made by [14]. High NDF and ADF result to longer eating time, low feed intake, low digestibility as well as animal's poor performance [15]. Due to limited land and feed availability in both Central and Eastern regions, dairy farmers were relying on poor quality maize (with high moisture and not ripe) for silage making which increased the NDF and ADF contents.

The results of organic matter digestibility (OMD%) in maize train and baled silage (50.9 and 56.4%) were lower than (58.1%) reported by [13]. While silage from SPEs had the lowest OMD which was attributed to high NDF. The *in-vitro* gas production and fermentation parameters indicate the presence of potential degradable nutrient in the feed ingredients. The high gas production of maize train silage compared to silage from SPEs (Figure 2) was attributed to organic matter (OM) availability which was fermented to form volatile fatty acids and, therefore, high gas volumes was produced. [4] attributed high gas production to nutrient availability and accessibility of feed to microbial enzymes hence high extent of fermentation, same observations were reported by [16].

The ME value of the feeds were within the ranges reported by [6], where values of various European feeds (from forages to cereals) ranged from 4.5 to 15MJkg^{-1} DM respectively. A study by [13] reported an average ME of 11.5MJ/kg DM in maize train and baled silage, which were close to 11.3MJ/kg DM found in this study. This demonstrates that the effect of NDF on fermentation becomes less important as the level of NDF declines. Higher NDF-ADF contents gives lower ME/kg DM, same observations were found by [13]. The dairy cow requires approximately 5.2 MJ ME/kg DM to produce a litre of milk. Increasing ME in maize silage can lead to an increase of milk production with about 13% (11.4/10.1 MJ/kg DM) [13].

In addition to carbohydrate fermentation, protein degradation also leads to a proportionally smaller amount of SCFA [17] as observed among the protein concentrates. Although gas production reflects the amount of substrate used for VFA production, it has also been shown that gas production is positively related to feed intake [7] and microbial protein synthesis [18].

Conclusion

Maize train and baler intervention are the best fodder conservation measure that can guarantee quality silage for the dairy cows.

Fodder preservation requires the right mechanization measures to ensure longer shelf-life for enhanced quality (fermentation, nutritive value) and reduction of losses.

Chemical analysis of feed ingredients did not vary across the interventions.

Recommendation

1. Farmers should focus on quality in the execution of all steps in the silage making process which is the shortest route to reduce the losses.
2. Farmers across the regions can use the feed balancing (*Rumen8*) software to ensure compounding quality feed.

Acknowledgement

The authors thank the 3R (Resilient, Robust and Reliable) project under SNV-Kenya and CESAAM (Centre of Excellence in Sustainable Agriculture and Agri-business Management) for financial support to carry out this study.

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