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Effects of fodder conservation and ration formulation interventions on dairy performance in Kenya

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A B S T R A C T

Use of conserved forages and proper ration formulation has great potential to bridge the gap in dairy nutrition and reduce seasonal variations in milk yield. This study determined the effects of various fodder and ration formulation interventions on dairy farm performance in North Rift, Eastern, and Central regions of Kenya. Seventy-two farms were purposively selected as participating farms and assigned into six groups of twelve as follows: two groups on silage production, two groups on ration formulation, and two control groups having similar production systems and in the same geographical locations as the other groups. Data on daily dry matter feed intake and milk yield were recorded while laboratory analysis was done to determine milk butterfat and protein content. The data was analyzed using a multi-linear regression model to assess the relationship between independent and dependent variables. The results showed that farmers using feed rationing with advisory services had the highest average daily milk yield (19.7 kg/cow) compared to maize train silage (16.8 kg/cow) and those with silage support from Service Provider Enterprises (SPE) (13.3 kg/cow) (P<0.05). Daily dry matter feed intake/cow varied significantly across the interventions as well as feed utilization efficiency (P<0.05). Milk butterfat and milk protein content did not differ (P>0.05) across the interventions. In conclusion, use of maize train silage and feed rationing with advisory services increased milk yield and reduced seasonal milk fluctuation.

Keywords: Feed intake, Maize silage, Milk yield, Silage bales, Service provider enterprises.

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Introduction

The dairy sector is the largest agricultural sub-sector in Kenya, and its share in gross domestic product (GDP) is approximately 4% (Odero-Waitituh, 2017). Dairy farming in Kenya is concentrated in the high altitude Agro-ecological zones of the Eastern, Central highlands and North Rift regions with a high and bimodal rainfall and relatively low temperatures between 15-24°C. More than three-quarters of the households in the regions engage in agriculture with 73% practicing integrated crop/dairy production (Wambugu *et al.*, 2011). Dairy feed management and utilization efficiency is the key determinant of dairy farm performance. Conserved forages have great potential to bridge the gap in forage supply and support milk yield during seasonal variations, which will reduce fluctuations in milk supply. The availability of quality forage all year-round is a major challenge of dairy farmers in Kenya leading to low milk yields, low milk solid content and high cost of milk production (Kashangakiand Ericksen, 2018).

Faced with a myriad of constraints, the dairy farmers need to adopt a promising dairy and forage technology especially in utilizing the limited forage resources. This remains critical for increased fodder and milk production and improvement of the performance of dairy industry for economic growth (Mutavi, 2017). This justifies the need to adopt production-enhancing forage innovations and dairy feed rationing as better ways of stimulating milk production to meet the ever-increasing demand for milk.

The SNV Market led Dairy Program (KMDP) in Kenya, funded by the Embassy of the Kingdom of

Netherlands introduced some interventions on fodder conservation and ration formulation on dairy farms in Kenya, i.e. use of maize train/baled silage and production of silage with support from Service Provider Enterprises (SPEs), and supporting on-farm ration formulation. Maize train and baled silage; - is a concept of silage making that involves a lot of mechanization and commercialization as well as the concept of silage baling to facilitate transportation and proper storage practices. Service provider enterprises maize silage; - Involves groups of entrepreneurial youth trained by the Netherlands development organization (SNV) under the KMDP project. This study therefore, determined the effects of these interventions on dairy farm performance.

Materials and Methods

Description of study areas

The study was done in North Rift, Eastern, and Central regions of Kenya. The rainfall in these regions ranged from 900-1300, 1000-2020 and 700-1400 mm/year, respectively. While the altitude ranged from 1800-2500, 1000-2000, and 1800-2500 meters above sea level, respectively (Jaetzold*et al*., 2010).

Data collection and laboratory analysis

The dairy farms were sampled based on the fodder interventions adopted using the purposive sampling technique. A typology of the farms, which had access to these interventions, was done and the farms classified based on the interventions adopted. A structured questionnaire was used to obtain farm characteristics. Two groups of farms were identified, that is farms producing silage and farms practicing feed rationing. These two groups were further sub-divided as follows:

a) Two groups on silage:

i. Smallholder farms with support from Service Provider Enterprises (SPEs).
ii. Medium and large-scale farms using maize train and silage bales.

b) Two groups on feed rationing:

i. Farms practicing ration formulation without regular advisory services and follow-ups.
ii. Farms using the *Rumen8* feed balancing software for ration formulation and with regular farm advisory services.

c) Two control groups representing silage interventions were established comprising of farmers of the same production system in the same geographical location not implementing the interventions and not having access to KMDP farm advisory services.

i. SPE control
ii. Maize train control

Average daily milk yield (kg/cow) was recorded, while laboratory analysis was done per farm for butterfat (Babcock test method), and protein content of the milk (Kjeldahl method) (AOAC, 2012). Average daily feed intake (kg/cow) was determined by weighing feeds offered per day and subtracting feed remaining the following morning before feeding. Feed efficiency was calculated as the ratio of daily milk yield to the daily feed intake per cow.

Statistical analysis

A multiple-linear regression analysis was used for the relationship between milk yield, butterfat, protein content, feed efficiency, feed intake (DM) and the feeding interventions used. Analysis of variance (PROC GLM) was used to determine differences in feeding interventions and mean separation done using least significant different (LSD) (P<0.05). Data was analyzed using Statistical Analysis Software (SAS, 2008). The model used was:

$$\gamma = \beta_0 + \beta_1 X_1 + \beta_2 (X_1 X_2) + \beta_3 (X_1 X_3) + \beta_4 (X_1 X_4) + \beta_5 (X_1 X_2 X_3) + \beta_6 (X_1 X_2 X_4) + \beta_7 (X_1 X_3 X_4) + \beta_8 (X_1 X_2 X_3 X_4) + \varepsilon$$

Where,

Y = is the predicted value of a dependent variable (Daily dry matter intake, Milk yield, milk butter fat, milk protein content, and feed efficiency).
β_0=the intercept
$\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7$, and β_8= regression coefficients
X_1, X_2, X_3, and X_4=independent variables (interventions, region, farm size and grazing system).
ε= random error term

Results

The results from the study on milk yield, milk quality, feed intake, and feed efficiency are presented in Table 1, Figure 1 and Figure 2. Milk yield from different interventions differed (P<0.05), where by farms using feed rationing with regular visits and advisory services recorded the highest daily milk yield (19.7 kg/cow) compared to farms using maize train/baled silage and those with support from SPEs interventions (16.8 and 13.3 kg/cow), respectively (Table 1). Rationing without visits, maize train/baled and SPEs controls had the lowest daily milk yield per cow compared to their respective farms using the interventions (P<0.05) (Table 1).

Table 1. Dairy performance under different Interventions.

Interventions	DMFI (kg)	Milk yield per farm (kg)	Milk yield per cow (kg)	MP (%)	MBF (%)	FE
Maize train silage (n=5)	16.3±0.32^{a}	438.7±53.49^{ab}	16.8±0.53^{b}	2.7±0.03^{b}	3.6±0.04^{b}	1.1±0.03^{a}
Maize train Control (n=5)	14.4±0.18^{b}	220.2±50.96^{bc}	14.2±0.27^{cd}	2.6±0.02^{c}	3.7±0.04^{a}	0.9±0.04^{b}
Rationing and advisory services (n=5)	17.3±0.34^{a}	630.4±181.92^{a}	19.7±0.64^{a}	2.8±0.02^{a}	3.6±0.04^{b}	1.1±0.05^{a}
Rationing without visits (n=5)	14.9±0.42^{b}	467.8±132.82^{ab}	15.1±0.61^{bc}	2.7±0.02^{b}	3.7±0.02^{a}	1.0±0.03^{b}
SPEs silage (n=5)	13.7±0.45^{c}	113.8±39.23^{c}	13.3±0.88^{d}	2.6±0.02^{c}	3.7±0.04^{a}	0.9±0.08^{b}
SPEs Control (n=5)	13.2±0.73^{c}	23.1±4.05^{c}	10.4±0.47^{e}	2.6±0.03^{c}	3.7±0.04^{a}	0.8±0.04^{c}
P value	*<0.0001*	*0.0014*	*<0.0001*	*0.1336*	*<0.0001*	*0.0010*
R^2	*0.72*	*0.54*	*0.85*	*0.28*	*0.70*	*0.55*

DMFI= Dry matter feed intake, FE= Feed efficiency, MBF= Milk butterfat, MP= Milk protein, SPEs= Service provider enterprises, ^{abc}Means within columns with different superscripts differ significantly at P<0.05.

Medium/large scale farms practicing feed rationing with advisory services and regular visits performed better than farms using maize train/baled silage interventions (P<0.05). While their medium/large scale control farms' (maize train control and farms practicing feed rationing without advisory services and regular visits) performance did not vary significantly.

Farms using maize train silage interventions in North Rift region of Kenya had higher average daily milk yield (16.7 kg/cow) compared to those with support from service provider enterprises (SPE) intervention in both Eastern and Central regions of Kenya (13.8 and 13.2 kg/cow), respectively (Fig. 1).

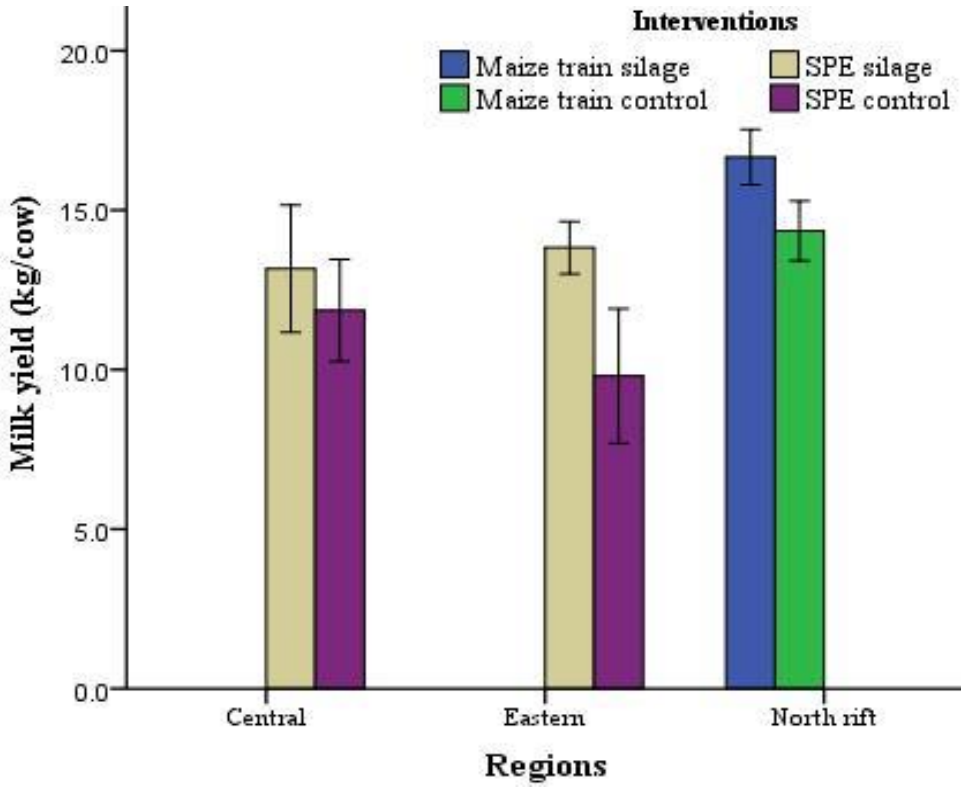

Fig. 1. Comparison of fodder conservation interventions in different regions of Kenya.

However, farms in Central and Eastern regions of Kenya practicing feed rationing with advisory services and regular visits had higher daily milk yield (19.1 and 18.6 kg/cow), respectively, compared to those practicing fodder conservations using maize train intervention in North Rift (Fig. 2).

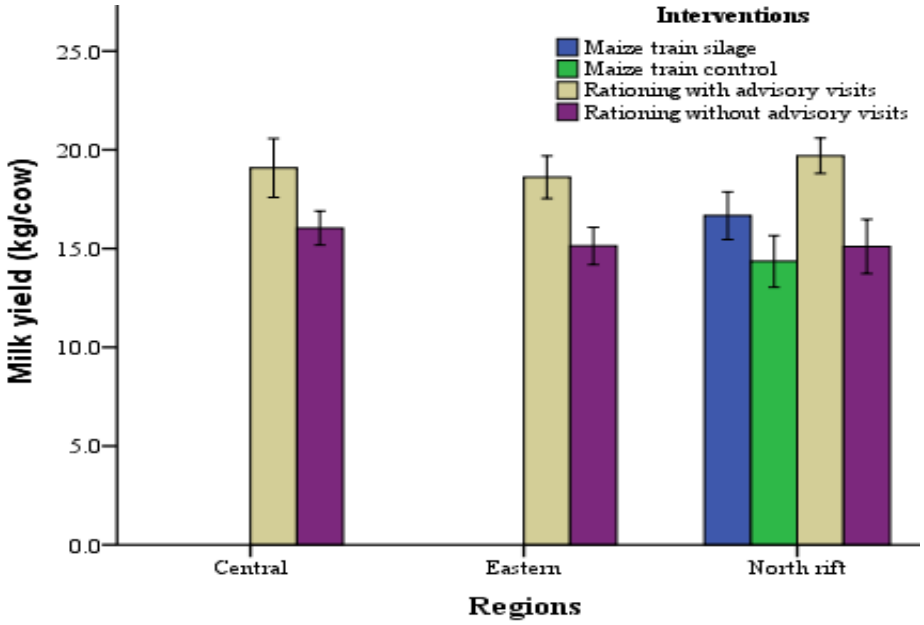

Fig. 2. Comparison of rationing and fodder interventions in different regions of Kenya.

Milk butterfat and milk protein contents differed (P<0.05) across the interventions. Medium/large-scale farms not using the interventions and the smallholder farms under SPE had higher milk butter fat content (3.7%) than those medium/large-scale farms using maize train and feed rationing with advisory services interventions (3.6%) (Table 1). Milk protein content was higher in medium/large-scale farms practicing feed rationing with advisory services (2.8%) and lowest in smallholder farms using support from SPE and the medium/large-scale maize train control farms (Table 1).

Average daily dry matter feed intake (DMFI kg/cow) varied significantly across the interventions. Medium/large-scale farms practicing feed rationing with advisory services and those using maize train silage interventions had the highest average DMFI per cow was 17.3 kg and 16.3 kg, respectively. Medium/large-scale farms under maize train control and feed rationing without advisory services, and the smallholder farms with support from SPEs had the lowest daily DMFI per cow was 14.4 kg, 14.9 kg, and 13.7 kg, respectively (Table 1).

Feed efficiency which measures the effectiveness of a diet on milk yield, varied significantly (P<0.05) across the interventions. Medium/large farms practicing feed rationing with advisory services and those using maize train interventions had an average feed efficiency of 1.1 higher than 0.8 from smallholder SPE control farms (Table 1).

The results from the regression models used are presented in Table 2 below for the derived optimal models on the basis of smallest AIC, BIC, C(p) and SSE values and largest R^2. About 70% of the variations in daily milk yield/cow was explained by the interventions and grazing systems. Only 30% variability in daily milk yield/cow was due to variations in region and farm size. Similarly, 66% of the variability in feed intake per cow per day (kg DM) was explained by the different intervention levels and grazing systems. In contrast, variability in milk butter fat (26%), milk protein (0.7%) and feed efficiency (45%) was due to different interventions, grazing systems, farm sizes and grazing systems, respectively (Table 2).

Table 2. Optimal models selected for explaining dependent variables.

Model	Variables in the model	R^2	AIC	BIC	C(p)	SSE	*P*
Daily milk yield/cow	Interventions, grazing system	0.7	27.3	31.1	1.7	59.4	0.004
Daily dry matter feed intake/cow	Interventions, grazing system	0.7	22.8	25.9	2.9	45.7	0.007
Milk butter fat content	Interventions	0.3	-63.2	-60.6	1.8	0.3	0.425
Milk protein content	Interventions, grazing system	0.1	-95.8	-92.6	-0.4	0.1	0.912
Feed efficiency	Intervention, grazing system	0.5	-78.1	-74.3	1.2	0.1	0.102

The optimal models derived for estimating the dependent variables were:

Milk yield = 25.97 - 0.63R - 1.77Int + 0.69FS - 2.95GS
Dry matter feed intake = 24.50 – 0.69R – 1.28Int – 0.55FS – 2.40GS
Milk butter fat = 3.45 + 0.08R + 0.03Int – 0.06FS – 0.09GS
Milk protein content = 2.68 – 0.002R + 0.01Int + 0.02FG – 0.02GS
Feed efficiency = 0.89 + 0.01R – 0.01Int + 0.11FG – 0.07GS

Where,

R = Regions (North Rift, Central and Eastern)
Int = Interventions (FRASV=Feed rationing with advisory services and regular follow-ups, Maize train/baled silage, Service provider enterprises (SPEs) silage)
FS = Farm sizes (Large and Medium scale)
GS = Grazing systems (Zero grazing and Semi-zero grazing system).
R^2= coefficient of determination, *AIC*= Akaike information criterion, *BIC*= Bayesian information criteria, *C(p)*=Cp statistic metric, and *SSE*= residual sum of squares. (Metrics used for comparing regression models quality and selection, measuring the performance of regression model. The higher the R^2 the better the model, while the lower the *AIC*, *BIC* gives the optimal model).

Discussion

This study gave an insight into the impact of fodder conservation and ration formulation interventions on daily dry matter feed intake, milk yield, milk butterfat, milk protein, and feed efficiency among dairy farms in Kenya. The genetic potential of a cow is achieved only when the diet fed meets the nutritional requirements commensurate with the genetic potential. Therefore, a well-formulated feed ration and quality conserved fodder is required for increased productivity (FAO, 2012; Garg *et al.,* 2013). However, cows kept in most of the dairy farms in Kenya are rarely fed based on their nutritional requirement (Garg *et al.,* 2013). This is confirmed by this study among the farms not using the interventions.

When all the animal factors (breed, stage of lactation, and body weight) were kept constant, dairy cows on rations from feed balancing with advisory services and regular follow-ups had better performance compared to the other interventions and their controls. The variations in milk yield within the interventions may be explained by variations in feed quality and quantity being used. The feed balancing with advisory services and regular follow-ups enabled dairy ration formulation by considering the animal's nutrient requirements for production. An increase in metabolizable energy and crude protein intake leads to an increase in milk yield (Johnson *et al.,* 2016). Significant high daily milk yield was observed among the farms practicing feed rationing with advisory services and regular visits. This demonstrated that the cows responded well to well-balanced rations. This is in line with findings by FAO, (2012) where a ration balancing was introduced. Research carried out by Kannan *et al.* (2011); Sherasia *et al.* (2016); Deen *et al.* (2019) showed a positive effect of balanced rations on daily milk yield. This shows that feed rationing with advisory services and regular visits can be an effective way to increase dairy performance among dairy farms in Kenya.

During the adoption of these interventions by most dairy farms, general advisory services and regular follow-ups were given to improve farm management. Examples of the advices were on forage production, conservation and storage, housing, re-grouping of cows based on their production potential, calf rearing, etc. (Ettema, 2015). These general improvements in management probably led to better animal health and welfare and thereby an increase in dairy performance (Moran, 2009). Therefore, in addition to a well-balanced feed rations, changes in farm management were likely contributors to the observed increase in dairy productivity among the farms practicing feed balancing with advisory services.

Farms, which were not using any of the interventions (control farms) had lower milk yield, which was attributed to the feeding rations that did not meet the production potential of the dairy cows. This was due to feeding of low-quality feed resources, predominantly Napier grass, natural pastures, and crop residues that are low in metabolizable energy and crude protein. Kashongwe *et al.* (2017) reported that Napier grass and other natural pastures are low in dry matter content (20-35%), crude protein (8-10%) and contain high crude fibre of over 37%, which makes them insufficient to support high milk production.

The low milk yield observed in smallholder SPEs farms was due to low quality and quantity of feeds. Most farms relied on Napier grass and little silage for their dairy cows. The cows were often fed concentrates, either dairy meal or other industrial by-products (maize germ, wheat bran, wheat pollard) most often in low amounts of less than 2 kg DM/day. Feeding in these farms was not adjusted based on the production potential of cows. Similar observations are reported by Richards *et al.* (2015, 2016). The low rates of

energy and protein supplied resulted to under-nutrition in the early part of the lactation cycle and affected milk production throughout the lactation, a similar observation was reported by Moghaddam (2016). Jansen *et al.* (2019) reported increases in daily milk production and better animal health, linking the change to the SPE services. Farms from Meru County in Eastern region, where SPEs made the most silage, reported daily milk increases from between 5.0-6.0 to between 8.0-9.5 litres per cow. This was lower than 13.8 litres per cow increase reported in this study in Eastern region. This was due to more improved and availability of conserved maize silage in the region.

Farms using maize train silage had better daily milk yield/cow compared to SPE silage farms. This can be attributed to the good quality of maize train silage in terms of metabolizable energy (11.9 MJ/kg DM), dry matter (>30%) and organic matter digestibility (56.4%) compared to SPE silage which had metabolizable energy of 9.2 MJ/kg DM, <30% dry matter content, and organic matter digestibility of 50.9%. Most of the SPE farmers in Central and Eastern regions lacked sufficient land for forage production, majority of who own between 0.5 to 5.0 acres out of which 80% is committed to food crop production (Kashangaki and Ericksen, 2018). This contributed to high milk yield in North Rift region under the interventions and low yield in Central and Eastern regions. Similar findings were reported by Kilelu *et al.* (2017, 2018) in a study done in Central, Eastern and Rift Valley regions of Kenya. Farms under maize train silage and those practicing feed rationing with advisory services in North Rift Kenya performed better due to the sustainable intensification of feeding systems with efficient use of fodder and concentrate feed, so that the proportion of the intake from feeds remained high, and the efficiency of use of concentrate (kg milk/kg concentrate) was also high compared to their controls which was attributed to feeding systems with low input grazing strategy adopted. Similar observations were reported by Llanos *et al.* (2018).

Medium/large-scale farms in Central and Eastern regions invested more in commercial concentrates to supplement their dairy cows with the required metabolizable energy and protein for milk production. This was possible due to close proximity of readily available market for milk-as the urban centres are very near, hence need for high energy and protein feeds for their dairy cows. However, the quantity of concentrates used in smallholder farms using support from SPE silage was low (<2 kg/cow/day) which was not commensurate with amount of milk produced due to unavailability of quality feeds throughout the year. Similar observations were reported by Muia *et al.* (2011).

Lukuyu *et al.* (2011) attributed low milk yield to poor nutrition and lack of supplementation with high proteins. The results from small-scale dairy farms using SPEs silage concurs with reports by Kilelu *et al.* (2017, 2018) who noted that farms using support from SPEs intervention performed better than the controls. However, comparing with farms using maize train silage in North Rift region, SPEs had low performances, which is attributed to in adequate and low-quality feed resources.

The low milk yield of 10.4 kg/cow/day observed in the farms without support from SPE intervention was comparable to the results by Muia *et al.* (2011) who reported milk production of 8.4 kg/cow/day in the Central regions while Mungube *et al.* (2014) reported milk yield of 6kg/cow/day in the semi-arid region of Eastern Kenya. This shows that dairy interventions had a significant improvement on dairy cow performance. Feeding higher amounts of concentrate in early-mid lactation stages is reported to increase milk yield by 20% (Purcell *et al.*, 2016). This finding was observed in medium/large-scale farms using feed rationing with advisory services, where large amounts of concentrates was being used to supply enough nutrients for milk synthesis.

High daily feed intake was attributed to quality feed rations, made of quality maize silage and concentrates formulated with advisory services and regular follow-ups by the feed nutritionists from the Kenya market-led dairy program (KMDP), this concurs with reports by Ferguson, (2017) and Ayuya *et al.* (2018) who noted that dairy feed ration balanced with all nutrients particularly for protein and calcium is essential for both rumen digestion of feedstuffs and milk production. This also suggests that cows in control farms lacked a balanced supply of nutrients in the feeds and feed rations provided, which led to low dry matter feed intake as well as milk production. Explanations can be lack of nutritional knowledge, costs of diet ingredients or availability of feed resources. With the increase in human population, increasing acreage for forage production to meet nutritional requirements is not the solution (FAO, 2018). Sustainable production intensification is required to meet fodder productivity potential (Jayne *et al.*, 2014). Therefore, high quality forage should be produced and conserved (Ettema, 2015; Lukuyu *et al.*, 2011).

This study shows a significant effect of quality feed rations on milk yield as observed among farms using the feed balancing software. Maize train silage intervention farms had better feed intake compared to farms using silage from SPEs that was attributed to the quality of silage used based on the right stage of harvesting and proper ensiling process that increases organic matter digestibility, dry matter intake, and energy

content. Lawrence, (2019) noted that highest dry matter intake of conserved maize silage in dairy cows occurs when maize is harvested at physiological maturity stage with (32 to 40% DM).

Low milk butterfat recorded in farms with feed balancing software was attributed to the type of rations used, which was high in concentrate to forage ratio. Farms using SPEs silage intervention had high milk butter fat content attributed to the high proportion of forages used compared to concentrates. Roughages are associated with higher acetate production, hence higher milk butter fat content (Kashongwe *et al.*, 2014).

Conclusion

The study revealed that use of maize train/baled silage and feed rationing with advisory services and regular follow-ups are ideal and sustainable interventions for increased milk yield in medium/large-scale farms. Similarly, use of SPE silage by smallholder farms in Central and Eastern regions of Kenya increased milk production leading to increased farm incomes and growth in sustainable and competitive farming enterprises.

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Conflicts of Interest

The authors declare no conflict of interest.

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