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REGULAR ARTICLES

Effect of feeding oat and vetch forages on milk production and quality in smallholder dairy farms in Central Kenya

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Abstract
Despite the significant livestock contribution to households' nutrition and incomes in many African smallholder farms, milk productivity remains low. Inadequate feeding is the main reason for the underperformance. To contribute towards addressing this, an on-farm feeding trial was undertaken in Ol-joro-Orok Central Kenya. A feed basket using oat (*Avena sativa*) cv Conway and vetch (*Vicia villosa*) was compared to farmers practice. Milk production (kg) and quality parameters, including butterfat, protein, lactose, and density, were monitored, and cost-benefit analysis (CBA) undertaken. Feeding both oat and vetch increased milk production by 21% (morning) and 18%, (evening), equivalent to 1.4 kg/day. Increases (%) in quality were butter fat (18.2), solid-non-fat (16.5), lactose (16.2), and protein (16.1). Concomitantly, the CBA returned positive results, supporting the hypothesis of economic advantage in using oat and vetch in milk production in the area, and possibly in other similar areas.

Keywords Forage · Milk production · Cost-benefit

Introduction

The low levels of livestock productivity in many smallholder farms in Africa are largely attributable to inadequate fodder of good quality (Manaye et al. 2009). The increasing human population in Sub-Saharan Africa (SSA), coupled with urbanization and expansion of the middle class with disposable income (Cohen 2006), contributes to a projected increase in demand for livestock products, predisposing a dire need to increase livestock productivity. If productivity does not rise at the same rate or more to keep up with the demand, a food crisis is likely, and this may exacerbate the situation of poor human nutrition, already a major concern in SSA (FAO 2017).

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Among constraints, inadequate quantity and quality feed is the main limiting factor to dairy improvement in African, yet improved forages can support and enhance livestock productivity (Yami et al. 2013). Forage cultivation is still low with preference accorded to food crops whose residues are often used as livestock feed despite their low feeding value (Methu et al. 2001), resulting in poor performance especially in milk production. To improve lactation yields, cows require access to enough nutrients and clean water (Lukuyu et al. 2012). In smallholder dairy in eastern Africa, feeding accounts for 55–70% of the costs (Odero-Waitituh 2017). As such, using technologies that can increase milk yields and lower production cost would be preferable. Recent evidence shows it is possible to lower cost of milk production by 4.4% without decreasing the output (Odero-Waitituh 2017).

Most studies on cost-benefit analysis (CBA) of milk are rarely technology specific, e.g., Mburu et al. (2007). In addition, important indicators of CBA, e.g., net present value (NPV), internal rate of return (IRR), and payback period (PBP) are not estimated. Therefore, the work entailed here set out to evaluate (a) whether the use of oat and vetch forages has any impact on milk production and quality compared to farmers' practice, and (b) if an economically positive and sound outcome would be realized when feeding oat and vetch.

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Materials and methods

Area of study

The study was done in Ol-joro-Orok sub-county, in central Kenya. The area lies between 0° 09’ S and 36° 24′ E covering an area of about 359 km^2 and about 2359 m above sea level. The average minimum and maximum temperature for the last 24 years ranges 5–8 °C and 20–23 °C, respectively, while annual rainfall over the same period averages 817–977 mm (Jaetzold et al. 2006).

Production of oat and vetch for trial

The study linked to the Eldoville Dairies in Ol-joro-Orok with an existing smallholder dairy farmers’ network who supply milk. Interest in increased milk in this area has increased, and in the attempt to close the supply gap, the Eldoville Dairies processing factory with a daily capacity of about 70,000 l provided 1.5 acres of land for planting oats and vetch.

We used oat (*Avena sativa)* cv Conway and *Vicia villosa* cv purple vetch. Farmers had previously selected Conway as the best bet (Mwendia et al. 2017). Conway seeds from Aberystwyth UK and vetch seeds from the Kenya Agricultural and Livestock Research Organization- Ol-joro-Orok) were used. The land was plowed and harrowed in September 2016. An acre was established with Conway and half an acre with vetch on 9 October 2016. Oat was planted in furrows spaced at 15 cm apart at 100 kg/ha seed rate, while vetch was in 30-cm-apart furrows, at 20 kg/ha seed rate. At planting, inorganic NPK fertilizer, 23:23:0, was applied at 50 kg Nha^{-1} for oat while none was applied for vetch. After establishment, vetch was weeded manually as necessary while the oat field was sprayed with broadleaf herbicide—Bellamine 72%.

Vetch was harvested at the flowering stage and dried under shade, producing 308 kg of hay (equivalent to 1.5 t DM /ha). Oat production was estimated by measuring harvest from three randomly selected 2 m^2 plots, with a mean of 3.37 kg (fresh) equivalent to 6700 kg ~ 16.7 t/ha. This translated to about 2.18 t DM/ha at 13% DM content (Mwendia et al. 2017).

Farmer selection and roles

Ten dairy farmers were selected on the criteria, i.e., sell milk to the Eldoville Dairies, own a cow in early to mid-lactation, and at second or third parity, and willingness to cooperate with data collection from their cows. In a meeting at Eldoville, the feeding trial was explained and roles shared. While farmers were to provide lactating cows and allow data collection, the Eldoville Dairies was to do milk analysis and coordinate issuance of test forages to the farmers. Researchers were to provide forage for the trial and collect data.

Feeding protocol and data collection

A local agricultural extension officer was assigned to collect data from the selected 10 farms on a daily basis. Starting 4 January 2017, data was collected on milk production and quality for 2 weeks. Amounts of morning and evening milk produced (kg) were recorded. Upon milk delivery to the Eldoville Dairies, a milk sample of ~ 50 ml was collected daily for quality analysis (described later). Further, type of feeds fed to the cows was quantified where possible with a spring balance and recorded.

After the 2 weeks, feeding was switched to oat and vetch for the selected 10 cows and for 10 consecutive days. A daily ration of 60 kg of wilted fodder oat (7.8 kg DM) and 2 kg of vetch hay (1.7 kg DM), thus 9.5 kg DM/day, was fed. Where under farmer practice the cows were grazed or supplemented, the type and quantity were maintained under the intervention. As such, the difference was the change of the basal roughage (oat-vetch vs. farmer practice). Throughout the trial, cows had access to clean drinking water adlib. Comparison between farmers’ practice to oat-vetch was within the animals (University of Reading 2000) and not between animals. After 10 days of intervention feeding, the farmers resorted to farmer practice, which was further trailed for 2 weeks. However, two farmers who were not cooperative were dropped.

Milk quality analysis

Milk quality was daily analyzed with a Milk Lactoscan (SL Ultrasonic Milk Analyzer, Tamil Nadu, India) throughout the trial. Measurements included butterfat, solids-non-fat (SNF), density, lactose, and protein levels.

CBA data and variables measurement

The CBA data was collected from the eight farmers who fully participated in the feeding trial. Structured questionnaires through face-to-face interviews were administered, 4 months after the experiment (April 2017). Details on expenses including labor, feed, veterinary, maintenance, and milk income during the feeding trials were collected. For the CBA indicators, we treated the cost of feed additives, water, veterinary services, and commercial feeds as constant. Fixed costs such as depreciation in the value of the milking cows, shed, machinery, and interest cost on capital were ignored. Total milk produced including milk fed to calves and consumed at home was valued at the market price of 0.37 USD/l, the price at which Eldoville pay farmers.

Analytical model

We adopted a cost-benefit approach that comprises of net present value (NPV), internal rate of return (IRR), and payback period (PBP) (Kimenju and De Groote 2010). An intervention is economically viable if the payback is less than the time taken to recover the initially invested amount. In this study, we calculated the payback period using cash flow amounts based on non-discounted dollar amounts.

NPV is the difference between the present value of cash inflows and the present value of cash outflows. It is determined by applying a discount rate to the identified costs and benefits. With investments, one decides what to do with the money today. An investment is viable if NPV is greater than zero. Benefits flow for farmers after adopting an intervention over initial practice can be given by:

$$NPV = \sum_{0}^{t} \frac{(B_t - C_t)}{(1+r)^t}$$

where:

B_t Benefits at time t
C_t Cost at time t
r Discount rate

To compute IRR using the formulae, NPV is set to zero and solve for r -discount rate = IRR. Investment is viable if IRR is positive and greater than the market discount rate.

Data analyses

All data were managed in Microsoft Excel spreadsheets. Standard errors were calculated as $\sigma/\sqrt{n}$ and plots are done in Excel. Where applicable, analysis of variance was done in the GenStat (2011) software and means separated by least significant (LSD). CBA data was managed in STATA version 14.1. Measures of central tendency (mean, median, and mode) and dispersion (range and standard deviation) were computed using macros in excel 2013. PBP, NPV, and IRR were calculated in an online excel-based tool (www.cbatool.ciat.cgiar.org) developed by the International Center for Tropical Agriculture (CIAT) to assess the economic viability of climate-smart agricultural (CSA) technologies.

Results

Farmers' practice

Among the study farms, feeding was on napier grass and bought hay (~ 2 USD/bale), and to a lesser extent, fodder oat and sorghum. Maize stovers, bean haulms, and weeds were also included. In addition, animals spent at least 3 h/day grazing. There was no estimation of the feed intake from grazing, but fields were overgrazed, suggesting minimal benefit. Supplementation with dairy meal and minerals was adopted in all the farms. While farmer practice fed dry matter ranging 3.3–19.6/day, in some cases higher than the intervention (9.5 DM/day), all the animals increased milk production under intervention. Table 1 summarizes quantities (kg) of feeds offered to the animals.

Milk yields and quality

Morning and evening milk production (Table 2) increased by 21 and 18%, respectively, under the intervention. The difference between milk production under intervention and farmer practice divided by milk production under farmer practice multiplied by 100 constituted the percentages. More milk was produced in the morning than in the evenings, with an average increase of ~ 1.4 kg/day.

Over the 42-day trial period, pooled milked yields across the 8 farms, separately for morning and evening production, increased steadily (Fig. 1) to a peak at day 22, after which there was a drop especially after reverting to farmer practice at day 25. The drop continued steadily to the end of the trial, day 42. At no time did the evening production surpass the morning production; however, the trend was similar.

Figure 2 summarizes the effect on butter fat, lactose, solid-non-fat, density, and protein. Except for butterfat, increases in milk when fed on oat-vetch compared to farmers' practice were not significant. However, were highly significant for butter fat, lactose, solid-non-fat, and protein when computed on the net increase in daily milk production (Table 2). Absolute percentage (%) increases in the weights were in the order butterfat (18.2), protein (16.1), lactose (16.2), and solid-non-fat (16.5) Table 2.

Fodder production costs

Table 3 shows the cost of production for the common feeds in the farms. The costs for all the inputs were based on farmer's land size and scaled accordingly to one acre. Largely, inputs include fertilizer/manure, seeds, pesticides, herbicides, and labor. Vetch had the highest cost of production and Conway-oat the lowest per acre. On production, napier grass yields more per acre. Costs of producing maize stovers, other crop residues, and weeds were not available, but farmers assigned values assuming buying or selling them from an acre.

The CBA indicators revealed that it is economically viable to adopt oat and vetch. The benefit of adopting oat and vetch over 4 months would generate an NPV of \$22. The money invested through inputs and labor is recovered after 65 days while IRR of 15% indicates that money invested in producing forage crops will increase by 15%.

Table 1 Daily feeds and fresh forages offered under farmers' practice during the study in January–February 2017

Farm	NG (20)	MS (90)	Average/day (kg)				FO (18)	DM (90)	Bran (90)	Z (hrs.)	MN (g)	Estimated total dry matter intake/day	ME (MJ)	CP (g)
			Weeds (30)	Hay (87)	BH (53)	FS (23)								
1	21.9	4.7	–	4.7	–	–	–	1.2	1.1	5.6	120	14.8	132.1	1219.8
2	2.6	–	2.7	–	1.6	–	–	1.2	–	7.0	adlib	3.3	36.9	361.0
3	3.7	–	2.8	4.7	0.9	–	2.0	1.4	–	–	100	7.8	77.8	729.6
4	1.1	2.0	13.1	14.5	–	–	–	1.2	–	–	80	19.6	192	1421.4
5	5.3	2.8	3.9	–	–	1.9	–	1.2	–	5.0	80	6.3	65.5	418.7
6	–	5.4	2.5	–	–	–	–	1.2	–	6.1	80	6.7	66.1	248.5
7	6.1	3.0		–	0.5	–	–	0.6	–	3.0	80	4.8	46.3	261.3
8	1.5	5.2	8.3	–	3.5	–	–	1.3	–	7.8	adlib	10.5	109.4	574.8

Values in brackets denote (%) dry matter content adapted from, Ayoade et al. 1983; Gietema 2005; ILRI 2016

NG napier grass, *MS* maize stovers, *BH* bean haulms, *FS* fodder sorghum, *FO* fodder oat, *DM* dairy meal, *GZ* grazing, *MN* minerals, − indicates not applicable

Discussion

While the focus of the study was to compare milk quality and production under farmers' practice with improved feeding, understanding what constituted the farmers' practice was also important. Some of the feeds used are of poor quality. In particular, maize stovers contain < 3% crude protein, in addition to poor digestibility

Table 2 Farmers' average milk production (kg) under farmer practice (FP) and intervention (IN) with associated quality attributes (g) during the trial period in Ol-joro-Orok in Nyandarua county in Kenya

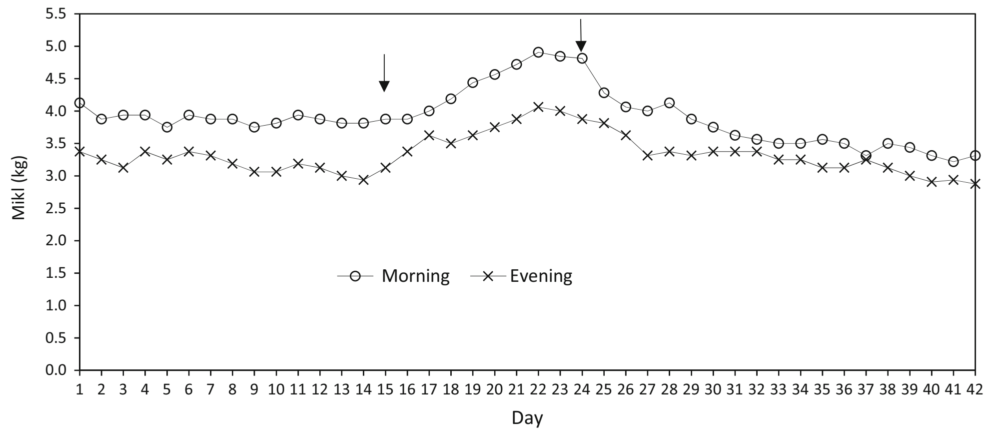
Farm	Treatments	Milk production (kg)		BF (g)	Lactose (g)	Protein (g)	SNF (g)
		Morning	Evening				
1	FP	4.5	3.9	229.5	345.1	230.2	671.9
	IN	5.7	5.3	219.3	477.8	318.4	929.0
2	FP	2.6	2.1	222.6	220.0	146.9	430.6
	IN	2.9	2.6	223.4	225.4	150.6	441.1
3	FP	4.4	4.0	250.6	335.4	223.7	655.4
	IN	4.7	4.3	310.2	356.4	241.7	706.7
4	FP	5.5	5.1	319.9	422.9	281.9	840.3
	IN	6.5	5.5	436.9	475.1	321.7	937.7
5	FP	3.6	2.7	261.0	251.4	167.8	489.2
	IN	4.6	3.3	299.1	326.3	217.8	635.2
6	FP	2.8	2.2	173.4	198.8	132.8	376.5
	IN	3.3	2.8	203.5	234.2	147.3	458.7
7	FP	3.7	3.2	230.2	270.6	182.6	531.9
	IN	4.8	3.7	291.2	307.1	204.9	603.4
8	FP	2.7	2.5	141.1	194.4	129.6	383.1
	IN	3.3	2.7	183.5	224.6	149.7	441.2
LSD		0.5***	0.4***	52.7***	34.2***	24.1***	71.9***
All farms	Farmer practice	3.7	3.2	230.2	284.3	189.9	556.0
	Intervention	4.5	3.8	272.2	330.3	220.4	648.0
LSD		0.3***	0.3**	24.6***	26.5***	18.1***	53.0***

Degree of freedom (df) 209

BF butterfat, *SNF* solids-non-fat, *LSD* least significant difference

$^{**}P < 0.01$; $^{***}P < 0.001$

Fig. 1 Mean morning and evening milk production (kg) over 6 weeks' experimental period at Ol-joro-Orok, in Nyandarua county in Kenya. The 10-day period between the arrows depict intervention feeding



(Methu et al. 2001) compared to 13–18% considered appropriate (Lukuyu et al. 2012). Napier grass is neither of superior quality with crude protein ranging 8–10% (Tessema et al. 2010). However, maize stovers and Napier grass are used substantially in the study area to support livestock production and may be contributing to the low productivity. Although farmers grazed animals (Table 1), visually, the overgrazed paddocks suggested minimal nutritional animal benefit. Poor feeding limits the production potential and negates gains in livestock

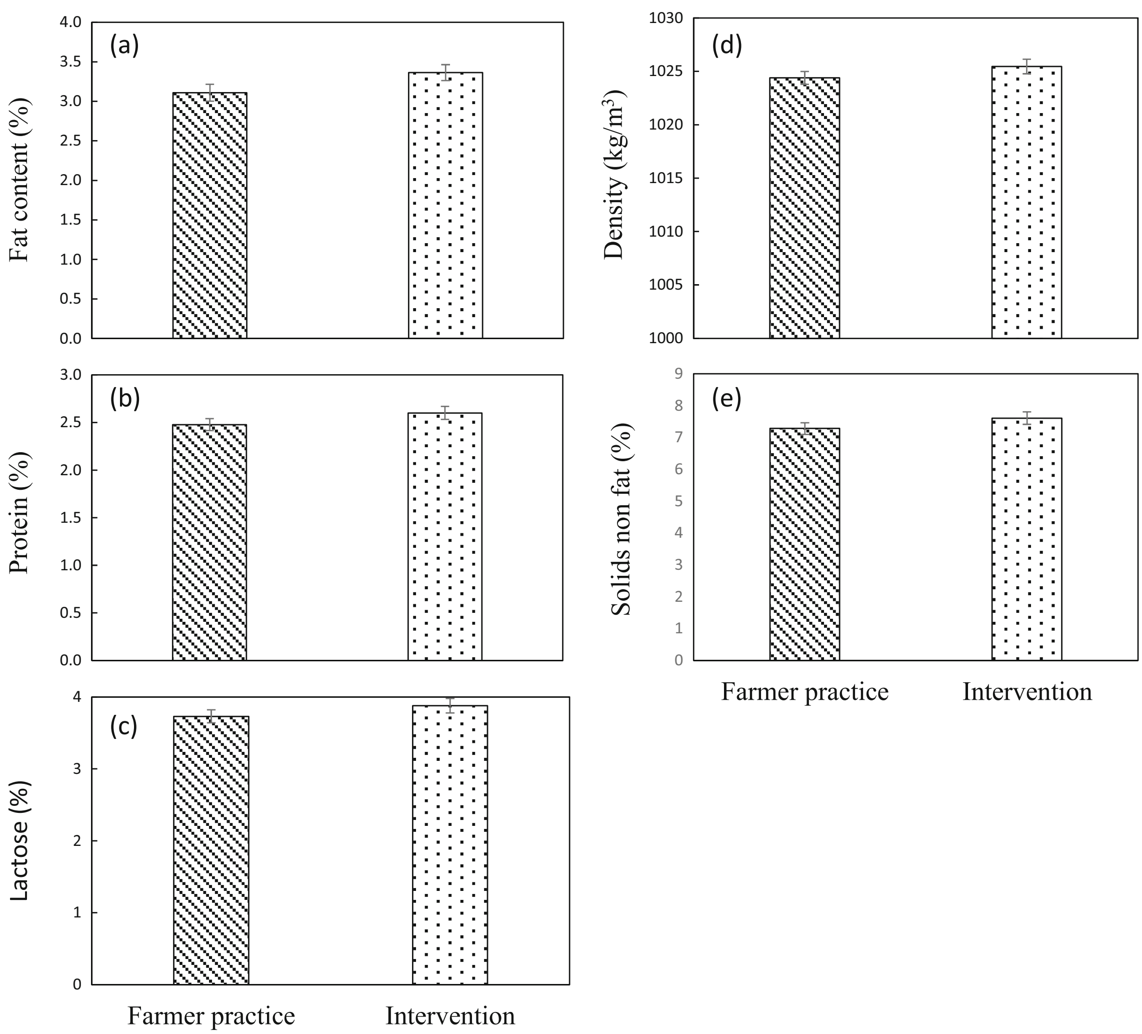


Fig. 2 Means (± se) for milk quality attributes measured under farmer practice or intervention for **a** fat content, **b** protein, **c** lactose, **d** density, and **e** solid non-fat at Ol-joro-Orok, in Nyandarua county in Kenya in January 2017

Table 3 Cost (in US$) of producing main fodder crops per acre and value of crop residues and weeds used as livestock feed

Cost	Oat (Conway)	Vetch	Napier grass	Local oats	Maize stover	Irish potatoes residues	Beans haulms	Weeds
Inputs								
Vegetative materials (cuttings/splits)	0	0	33.95	0	–	–	–	–
Seeds	38.8	38.8	0	43.65	–	–	–	–
Fertilizer (DAP)	38.8	0	0	29.1	–	–	–	–
Fertilizer (CAN)	0	0	0	27.16	–	–	–	–
Organic manure	0	0	58.2	0	–	–	–	–
Herbicide (round up)	7.76	0	0	0	–	–	–	–
Omex (foliar feed—oats)	2.43	0	0	0	–	–	–	–
Bellamine (herbicide broad leaf)	5.82	0	0	0	–	–	–	–
Orus (control rust in oat)	12.61	0	0	0	–	–	–	–
Labor								
Plowing and harrowing	38.8	38.8	38.8	38.8	–	–	–	–
Planting and fertilizer/manure application	29.1	19.4	38.8	29.1	–	–	–	–
Manual weeding	0	38.8	29.1	0	–	–	–	–
Spraying herbicides and pesticides	4.85	0	0	0	–	–	–	–
Harvesting and transportation	83.42	102.82	14.55	33.95	–	–	–	–
Total cost of production per acre	83.42	228.92	213.4	201.76	–	–	–	–
Production potential (kg/acre)	7769.97	623.22	19,600	2000				
Value per acre	–	–	–	–	19.4	17.46	24.25	17.46

Source: Authors Survey, 2017; − indicates not applicable

breed improvement. As such, most likely the farmers in the study were not fully exploiting their cross-bred animals.

Feeding oat and vetch compared to the farmers practice increased milk production and quality (Table 2). Although improved milk production is influenced by several aspects, including animal breeding, health, and feeding; feeding have immediate results as shown here. If a large number of farmers embraced improved feeding, increasing milk production is possible, and would contribute to addressing present and future demands. Studies about feeding rarely look at the economic potential. However, positive economic benefits in this study are likely to provide the impetus for adoption. Rising demand for animal products linked to population growth is likely to provide the market pull that could favorably catalyze adoption (Kimenye and McEwan 2014).

Milk is a raw material for other products, e.g., butter, whey, and cheese which require high-quality milk. To increase butter and cheese at processing, high milk butter fat and protein contents, respectively, are paramount (Rønholt et al. 2013; Wedholm et al. 2006). Elsewhere, raw milk prices are pegged on the milk quality (Jesse and Cropp 2004), and likely to attract improved feeding. The Eldoville Dairies is involved in butter and cheese production, and envisage paying milk based on quality (A. Waithaka Pers. Comm.) to encourage dairy keepers to improve feeding Table 4.

To realize adoption at a scale of such promising forage technologies, awareness creation and functioning forage seed systems need to happen concurrently. Lack of forage seeds is a major bottleneck curtailing adoption of improved forage technologies (Negassa et al. 2016). In Kenya, the forage seed system is limited, with few options from the private sector (Mwendia et al. 2016). Governments should facilitate certification of proven forage technologies without lengthy institutional requirements.

Table 4 Profitability of oats and vetch acre/cow/season (values in US$)

Attribute	Farmer practice	Intervention
Costs		
Cost of inputs	134.93	201.08
Cost of labor	38.80	26.68
Total costs	173.73	237.46
Benefits		
Revenue—sale of milk	331.74	419.84
Profit of milk/acre/cow	158.01	192.08
CBA indicator		
NPV	22	
IRR	15%	
PBP	65 days	

In conclusion, our results show feeding improved forages has the potential to increase milk production and quality. Unimproved feeding suggests that farmers are not exploiting the productivity potential of their animals. However, economic benefit would most likely drive farmers to improve feeding. Awareness creation is vital coupled with strengthening the forage seed systems.

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Compliance with ethical standards

Farmers gave informed consent to data collection from their farms and animals.

Conflict of interest The authors declare that they have no conflict of interest.

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