Characterization of feed resources, feeding systems and factors that influence the use of concentrates among smallholder dairy farmers in Kenya

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Abstract
This study aimed to assess feed resources, feeding systems, and factors that influence the use of concentrate among smallholder dairy farmers in Kenya. Data were collected through semi-structured questionnaires administered to 100 smallholder dairy farmers in Trans Mara East, Narok County. The research design adopted was a cross-sectional survey through a multistage sampling procedure. The study revealed that twenty-one major feed resources used by dairy farmers were categorized into protein-giving feeds, fodder trees, energy-giving feeds, and concentrates. Most of the dairy farmers were feeding their dairy cows with energy-giving forages with limited use of fodder trees and protein-based feeds. In both the dry and wet seasons, the most common grazing systems used by dairy farmers are semi-zero-grazing and free grazing. There was limited use of concentrate among most of the farmers with most of them using cereal grains, root and tubers, molasses, and seeds of legumes as concentrates. The results of the logit regression indicated that the major factors positively influencing the decisions to use concentrate feed were the work of the household head ($\beta = 1.89$, $p = 0.01$), total milk produced ($\beta = 0.25$, $p = 0.01$), and access to extension ($\beta = 1.29$, $p = 0.04$). These findings suggest there is a need for sensitization and capacity development of smallholder farmers on alternative higher productive feed resources in the dairy sector.

Keywords: Concentrates, Feed resources, Feeding systems, Fodder, Forage.

1. Background

Smallholder dairy farming (SDF) provides nutrition and income to around 20% of the world's population, primarily rural and peri-urban people (Maleko *et al.,* 2018). In Kenya, the livestock sector holds significant economic importance, contributing around 12% to the country's Gross Domestic Product (GDP). Within this sector, the dairy industry stands out, experiencing consistent growth at a rate of 4% annually and contributing between 4% to 8% of the GDP, as noted by Mwendia *et al.* (2020). This growth is supported by approximately 1.8 million farmers engaged in dairy farming, the majority of whom are smallholder farmers, accounting for 80% of the total (Oloo *et al.,* 2023).

Demand for dairy products is expected to rise dramatically due to fast population growth, urbanization, and dietary changes (Kenduiwa *et al.,* 2016). Internationally, around 116 million farms retain dairy cattle (IFCN, 2019), with an average of 2-3 cows producing 843 million tonnes of milk in 2018. As a result, dairy farming helps to achieve several of the United Nations' 17 worldwide Sustainable Development Goals (SDG), including SDG1: Zero Hunger, SDG3: Good Health and Wellbeing, and SDG8: Decent Work and Economic Growth (Segerkvist *et al.,* 2020).

Global milk production reached over 906 million tons in 2020, up 2.0 percent from 2019, driven by increases in all geographical regions except Africa (FAO, 2021). Milk production has been steadily increasing around the world, but the industry is currently facing a milk crisis due to a lack of raw milk, an imbalanced offer/demand ratio, and a reduction in trade with milk and dairy products in several countries (Proposcu, 2017). Temperature is the most essential environmental component impacting the normal functioning of the farm animal body, with a thermos-neutral zone (comfort zone) for farm animals, particularly exotic cattle and their crosses, ranging from 10 ℃ to 20 ℃ (Krpalkova *et al.,* 2020).

When the temperature changes, these animals reduce their feed intake and growth rate (Krpalkova *et al.,* 2020). The majority of dairy cows kept by small-scale farmers in Africa are very inefficient; for example, the average dairy cow produces only 540 liters of milk per lactation, but dairy cows in Europe and North America generate up to 10,479 liters of milk per lactation (Ghimire, 2021). Besides the obvious differences in breeds, one of the main contributing factors to this difference in production lies in the quantity and quality of their feeds including forages.

Smallholder dairy producers in many developing nations struggle to get access to reasonably priced, high-quality feed supplies. Their limited financial resources frequently prevent them from buying commercial concentrates or supplements, which makes them strongly dependent on feedstuffs that are available locally. Furthermore, farmers' access to information and technologies that could maximize feed use and enhance animal nutrition is hampered by limited infrastructure and extension services (FAO, 2019). Governments, non-governmental organizations, and other stakeholders must work together to address these barriers by offering smallholder dairy farmers infrastructure support, loan options, and training (Smith *et al.,* 2019).

In East African Countries, adoption of improved feed production, conservation, and utilization technologies and practices in dairy farming communities is still low (Maleko *et al.*, 2018). It is posited that smallholder dairy farmers contribute significantly to poverty and malnutrition reduction, particularly in rural areas (Kingu & Ndiege, 2018). Dairy intensification is a widely used means of achieving food security, improving farmer incomes, and enhancing overall economic growth (Bosire *et al.,* 2019). Innovation is a major source of improved productivity, competitiveness, and economic growth throughout advanced and emerging economies, and plays an important role in creating jobs, generating income, alleviating poverty, and driving social development (Rajalahti, 2011).

Understanding the various feed resources, feeding systems, and factors that influence the use of concentrate among smallholder dairy farmers to overcome feed shortage is important to identify appropriate agribusiness interventions to enhance smallholder farmers' milk productivity and income. However, there is limited empirical evidence concerning this. Therefore, the contribution of this study was to fill this knowledge gap by assessing feed resources, feeding systems, and factors that influence the use of concentrate among smallholder dairy farmers in Kenya.

2. Methods

2.1 Description of the study area

The study was carried out in the Trans-Mara East sub-County, which is located between latitude 0° 50′ and 6° 50′ south and longitudes 34° 35′ and 35° 14′ East, with a mean altitude of 1450 m above sea level, and area coverage of 320.5 km^2. It covers a significant portion of the Mara ecosystem, renowned for its rich biodiversity and iconic wildlife, including the Maasai Mara National Reserve. Agriculture is the predominant economic activity of Trans Mara East Sub-County, and smallholder farming provides a living for the vast majority of the population. Mixed crop-livestock farming is the most common agricultural technique, with staple crops like maize, beans, and potatoes grown alongside livestock, notably dairy farming.

The Sub-county was purposively selected due to the vibrant dairy sector and the majority of smallholder dairy farmers depend on it as a source lo livelihood. Despite its agricultural potential, Trans Mara East Sub-County confronts numerous obstacles, including feed scarcity, limited market access, insufficient infrastructure, and environmental degradation. Poor road networks and insufficient access to extension services reduce agricultural productivity and market access for smallholder farmers. Therefore, there is a need to establish feed resources, and feeding systems to improve the productivity and income of these smallholder farmers. Figure 1 presents the map of the study area and the study sites.

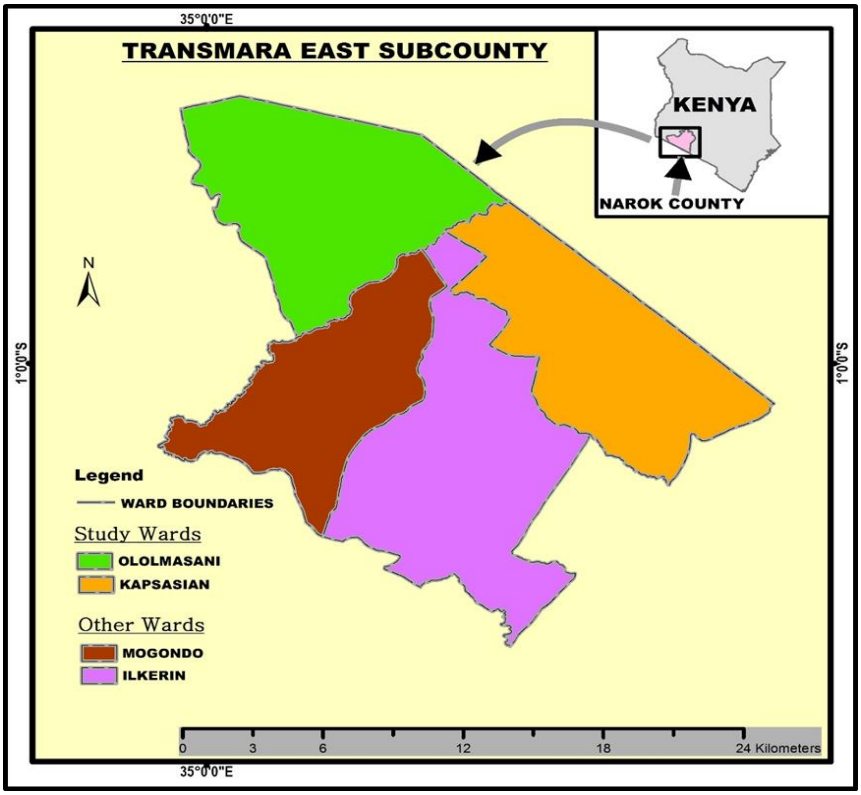

Figure 1. Map of Study Area

2.2 Sampling procedure

The target population for this study was smallholder dairy farmers in Trans Mara East, Narok County. The number of households sampled in the study area was determined by N = 0.25/SE2, where N = number of sampled households, SE = standard error (Arsham 2005). Considering the standard error of 0.05 with a 95 % coefficient interval as follows, $N = 0.25 / (0.05)^2 = 100$. A multistage sampling procedure was used to select the 100 respondents. In the first stage, Trans Mara East Sub-County was purposively selected due to the vibrant dairy sector and most farmers depend on it as a source of livelihood. In the second stage, the two wards (Ololmasani and Kapsasian) were selected purposively due to their higher number of smallholder dairy farmers. The total population for these two wards combined was 11,987 people. In the third stage, smallholder farmers were randomly selected within the villages in the wards to get a sample size of 100.

2.3 Data collection

A cross-sectional survey was used to collect data from the smallholder dairy farmers using pre-tested, semi-structured questionnaires. Before the data collection, a proposal approval letter was secured from the Egerton University Board of Post-Graduate Studies. This letter was used to secure a research permit from the National Commission for Science Technology and Innovation (NACOSTI), which is the legal body mandated to regulate research activities in Kenya. In addition, an ethical permit was also secured from the Egerton University ethics committee. Finally, a permit to collect data was also collected from Narok County Government offices. During the data collection process, the respondents were requested to sign a consent letter and they were assured confidentiality of the information they provided. The researcher then assured the respondents that the information they provided would be used purposely for academic purposes. The data collected included: the socio-economic and institutional characteristics of the respondents, current farm activities and feed resources, feeding practices/system, use of concentrates in feeding, and coping strategies to feed scarcity.

2.4 Data analysis

The collected data was cleaned, edited, coded, and analyzed using the Statistical Package for Social Sciences (SPSS) software (version 16.0) and Stata version 64 computer programs. The analysis included descriptive statistics (means, frequencies, and percentages) and a logistical regression model. The descriptive statistics were used to characterize the feed resources, feeding systems, use of concentrates in feeding dairy cows, and coping strategies for feed scarcity. A logistic regression model was used to determine the factors that influence the use of concentrates in feeding dairy cows.

3. Results and discussions

3.1 Description of Respondents

Table 1 presents the socio-economic characteristics of the smallholder dairy farmers. From the findings, the average age of the respondents was 45 years. The average experience in dairy farming was 15 years with the mean land size under dairy farming being 1.6 acres. The mean number of cows milked and total milk produced per liter daily were 3 cows and 8.2 liters respectively. Results further show that from the total sample of respondents (100), 60% of the households were male-headed. Most (72%) of the respondents had access to extension services. In addition, most of the respondents (71%) had access to access to credit services in the past year.

Table 1. Summary of descriptive statistics

Continuous variables	**Mean**	**Std. dev**
Age of farmers (years)	45.16	1.224
Experience in dairy farming	15.01	0.973
Land size under dairy farming	1.63	1.711
Number of cows milked	3.12	1.086
Total milk per day	8.21	0.512
Categorical variables	**Frequency**	**Percentage (%)**
Male headed households	60	60
Farmers who had access to extension services.	72	72
Farmers who had access to credit.	71	71
Education level of household head	**Frequency**	**Percentage (%)**
Primary level	32	32
Secondary level	30	30
Adult education	9	9
Technical college	18	18
University	11	11
Work of household head	**Frequency**	**Percentage (%)**
Off-farm	27	27
On-farm	73	73

The majority (32%) of the farmers had attained primary education as their highest academic qualification, 30% had secondary education, while 18% and 11% had technical and university education as their highest academic qualifications respectively. Finally, only 9% of the respondents had adult. Generally, the level of education of the respondents was significantly lower. Having a higher education level would make them able to understand the importance of adopting modern feeding practices in dairy farming. Concerning the work of the household head, the majority of the respondents (73%) were working on-farm, and only 27% working off-farm.

3.2 Feeding Systems

In both the dry and wet seasons, the most common grazing systems used by dairy farmers are semi-zero-grazing (54%) and free grazing (28%) as shown in Table 2. This is probably because farmers with limited area or those looking to control labor and feed expenses may choose semi-zero grazing, which is recommended for its ability to maximize feed use and reduce labor inputs. While free grazing may offer plenty of access to natural forage throughout the wet season, semi-zero grazing enables farmers to add supplemental feed to natural grazing, guaranteeing the animals' regular nutrition and possibly increasing milk production. Semi-zero grazing allows farmers to restrict grazing more intensely during the dry season when pasture availability is limited. This helps the dairy farmers in the sub-county to minimize overgrazing and preserve pasture resources for future use.

Furthermore, semi-zero grazing is easier to manage for smallholder farmers with limited resources because it takes less effort than fully zero-grazing systems. Farmers can improve the resilience and productivity of their dairy farming operations while efficiently managing labor inputs and feed supplies all year round by implementing semi-zero grazing strategies. However, a study by Okello *et al.* (2019) and Otieno *et al.* (2020) found that most smallholder farmers in Nyandarua Nakuru and Siaya counties respectively largely practiced zero grazing, which contradicts this study's findings. Duguma and Janssens (2016) found contradicting results indicating that most dairy farmers often practice zero grazing as opposed to a smaller percentage that practices semi-zero grazing.

Table 2. Feeding systems during dry and wet seasons

Feeding systems	Dry season (%)	Wet season (%)	Pooled
Zero grazing only	7	7	7
Tethering	12	11	11
Semi zero-grazing	54	53	54
Free grazing	27	29	28
Total	100	100	100

3.3 Feed resources used by smallholder dairy farmers

The finding, outlined in Table 3, sheds light on the diverse array of feed resources utilized in feeding dairy cattle in the Trans Mara East sub-county, with Super Napier (19.9%) and maize (16.8%) emerging as the primary feed resources. The prevalence of Super Napier and maize hints at a balanced approach to feeding, incorporating both forage and concentrated feed components into the diet of dairy cattle by the smallholder dairy farmers. However, the majority of the smallholder dairy farmers in the sub-county preferred Super Napier due to its renowned high nutritional content, particularly in protein and energy, Super Napier effectively meets the dietary requirements of dairy cattle, especially during lactation. Additionally, its high-yielding nature ensures a consistent and ample food supply throughout the year, even in diverse environmental conditions.

Super Napier's adaptability to varying climates and soil types makes it accessible to farmers across different regions, while its ease of cultivation and propagation further enhances its appeal. Furthermore, its resistance to pests and diseases reduces the need for chemical inputs, contributing to sustainable farming practices. These results further concur with those of Du *et al.* (2022), Islam *et al.* (2023), and Njarui *et al.* (2021) who documented that Napier grass is a major feed for dairy animals in both the tropics and subtropics regions. Due to their high nutrient quality, smallholder dairy animals prefer having it as a primary major feed over other types of feed. Additionally, it is easier for farmers to make silage out of the Super Napier grass and it is easier to produce it compared to other animal feeds hence its preference.

The predominance of various resources is most likely influenced by regional variations in agricultural techniques and feed availability, which reflect elements like cropping patterns and climate adaptability. The relevance of crop diversity in livestock feeding systems is highlighted by the addition of varied feed resources like Guinea grass (9.1%), sweet potatoes (8.2%), and Brachiaria grass (7.3%) in addition to conventional forages and cereals, which promote resilience and sustainability. These results concur with those of Lukuyu *et al.* (2019) who documented that the majority of the smallholder dairy farmers mostly fed their animals on Super Napier grass and Kikuyu grass.

The majority had even planted Napier grass on their farms. Also, maize crop residues were the second most sought-after animal feed as it was mostly available because almost all the households in the region had planted it on their farms. Houwers *et al.* (2015) also established similar results by indicating that Napier grass was a predominant source of feed, however, animals are majorly supplemented by other supplements such as crop residues and rice straws to increase domestic milk production.

Table 3. Major types of feed resources available for feeding dairy cattle

		Frequency	Percentage (%)
Feed resources used by dairy farmers	Super Napier	92	19.9
	Cowpea M66	7	1.5
	Leucaena	7	1.5
	Caliandra	12	2.6
	Cassava	15	3.2
	Guinea grass	42	9.1
	Maize	78	16.8
	Velvet beans	11	2.4
	Lucerne	18	3.9
	Camello	29	6.3
	Sugar graze	16	3.5
	Sesbania	8	1.7
	Brachiaria Cobra	34	7.3
	Greenleaf Desmodium	19	4.1
	Sweet potatoes	38	8.2
	Lupin	5	1.1
	Purple vedge	6	1.3
	Sunn hemp	4	0.9
	Dolichos lablab	6	1.3
	Brachiaria CV Cayman	7	1.5
	Nutrifeed	9	1.9
Total		**463**	**100.0**

Note: the frequencies in this table are based on multiple response statistics

3.4 Forage Categories

Table 4 provides a detailed breakdown of protein and energy-giving feeds commonly used in feeding dairy cattle. In the protein-giving feeds section, various sources rich in protein are listed, including legumes like Cowpea M66, Dolichos lablab, and Lupin, which are known for their high protein content and digestibility, essential for muscle development and milk production in dairy cattle. Additionally, forage crops such as Lucerne, Greenleaf Desmodium, and Velvet beans are included, which not only provide protein but also contribute to overall forage quality and rumen health. The inclusion of Sweet Potato and Purple Vedge, although not traditional protein sources, suggests their potential as supplementary feedstuffs, likely due to their nutritional value or availability in specific regions. Moreover, fodder trees like Calliandra, Leucaena, and Sesbania highlight the utilization of tree fodders rich in protein, often used in agroforestry systems to supplement the diet of dairy animals.

Table 4. Forages categories

Protein giving feeds
Cowpea M66 (*Vigna unguiculata*)
Dolichos lablab (*Lablab purpureus)*
Lucerne (*Medicago sativa)*
Greenleaf Desmodium (*Desmodium intortum)*
Sweet Potato (Ipomoea Batattas CV Ex-Mukruweini)
Lupin
Velvet beans (Mucuna pruriens)
Purple vedge
Fodder trees
Sunn hemp (Crotalaria juncea)
Caliandra
Leuceana
Sesbania
Energy giving feed
Sugar graze (Sorghum bicolour Hybrid)
Camello (Brachiaria Hybrid)
Nutrifeed (Pennisetum glaucum hybrid)
Guinea grass (Panicum maximum CV Mombasa)
Brachiaria Cv Cayman
Brachiaria Cobra
Super Napier

The energy-giving feed section lists various grasses and cereal crops known for their high energy content, crucial for meeting the metabolic demands of dairy cattle (Mutwedu *et al.,* 2020). Sugar Graze, Camello, and Nutrifeed represent energy-rich forages such as sorghum hybrids and pearl millet, providing carbohydrates for energy production and fiber for rumen health. Additionally, traditional forages like Guinea Grass and Super Napier are included, known for their high biomass production and digestibility, thus serving as reliable sources of energy for dairy cattle.

The findings of Mutwedu *et al.* (2020) and Samad (2020) conform to these findings by indicating that Super Napier and Guinea grass are highly preferred forages due to their digestibility as opposed to maize among the smallholder dairy farmers. The mention of different varieties of Brachiaria grass underscores their importance as energy-rich forages adaptable to diverse environmental conditions. Overall, the table provides a comprehensive overview of protein and energy-giving feeds, showcasing the diversity of feed resources utilized in dairy cattle nutrition and highlighting the importance of balanced diets to support optimal health and productivity.

3.5 Use of Concentrates in Feeding Dairy Cows

Table 5 presents the results on the use of concentrates in feeding dairy cows. The majority (69%) of smallholder dairy farmers use concentrates while feeding their animals. This is justifiable in the sense that concentrates play a key role in supplementing essential nutrients such as energy and proteins thus enhancing the production of milk and optimal body condition maintenance of the dairy cows. Concentrates mixed with dairy feeds ensure that deficiencies in forages and roughages are balanced by providing the same to dairy animals ensuring maximum milk yields and animal health. In many cases, the forages and roughages are often deficient in nutrients such as protein or minerals.

As such, concentrates allow farmers to address these deficiencies by providing targeted supplementation, hence leading to improvement in the overall nutritional quality of the diet and promoting better animal health and productivity. Furthermore, the reliability and annual availability of concentrates mitigates seasonal variations in forage supply, offering farmers a consistent feeding solution. Simultaneously, concentrates on streamlining feeding management, offering ease of handling and storage, contributing to improved feeding efficiency and reduced wastage.

Similar results were anchored by Duguma and Janssens (2016) indicating that other than green feeds, using concentrates on animal feeds ranked second. Wilkes *et al.* (2020) also record similar findings that the use of concentrates in animal feeds is a common practice among Kenyan dairy farmers. According to Wilkes *et al.* (2020), the concentrates can either be homemade or purchased as commercially produced/manufactured concentrates. On the contrary, a study by Odinya (2023) found that smallholder dairy farmers in Murang'a County did not embrace feeding their dairy cattle with feed concentrates. This was particularly due to the high cost of protein concentrates and the compromised yet unreliable quality of the commercially produced concentrate feeds.

Of the 69 smallholder dairy farmers who fed their animals with concentrates, it's notable that a significant portion (37%) indicated occasional feeding of concentrates to their dairy animals. This implies that while concentrates are recognized as beneficial supplements, they are not consistently incorporated into the animals' diets, possibly due to factors such as availability, affordability, or feeding management practices. Furthermore, 20% of farmers reported feeding concentrates once a day to their dairy animals, indicating a more regular but still relatively moderate usage pattern.

The practice of feeding concentrates twice a day and three times a day was less common among smallholder dairy farmers, with only 7% and 5%, respectively, adopting these feeding frequencies. This shows that the majority of smallholder dairy farmers prefer less frequent feeding of concentrates, possibly due to factors such as labor constraints, perceived cost-effectiveness, or cultural norms regarding feeding frequency.

Table 5. Feeding of animals with concentrates and feed frequency

Variables		Frequency	Percentage (%)
Using concentrates to feed animals	No	31	31.0
	Yes	69	69.0
	Total	100	100.0
Frequency of feeding animals with concentrates	No	31	31.0
	Once a day	20	20.0
	Twice a day	7	7.0
	three times a day	5	5.0
	Occasionally	37	37.0
	Total	100	100.0

The information shown in Table 6 illustrates how common it is for smallholder farmers to feed various concentrates to dairy animals. With 27.1% of farmers reporting their use, cereal grains emerged as the most popular kind of concentrate. Cereal grains, such as wheat, oats, barley, and maize, are excellent sources of protein and energy for dairy cows, especially during lactation or other times when their energy needs are higher. It was reported that with 21.3% of farmers using them, root and tuber concentrates were the second most popular kind of animal feed concentrates used by smallholder dairy farmers that were reported.

Concentrates of roots and tubers, such as beet pulp, sweet potatoes, or cassava, provide a source of fiber and energy and help maintain the diet's nutritional balance. Molasses, a by-product of sugar production, ranked third in usage, with 20.2% of farmers incorporating it into their animals' diets. Molasses is often used as a palatable source of energy and serves as a binding agent in feed formulations. These three concentrate kinds are widely used, which highlights their significance in smallholder dairy farming systems. They supply vital nutrients that boost milk production, preserve animal health, and maximize feeding efficiency.

Table 6. Types of concentrate feeds used for feeding dairy cattle in the Trans Mara East sub-county

Variables		Frequency	Percentage (%)
Types of concentrates	Cereal grains	52	27.7
	Root and tubers	40	21.3
	Molasses	38	20.2
	Brewery residue	14	7.4
	Seeds of legumes	23	12.2
	Oilseeds	15	8.0
	Proteins of animal origin	6	3.2

3.5.1 Factors that influence the use of concentrates in feeding dairy cows

The factors that influence the use of concentrates in feeding dairy cows among smallholder farmers were regressed using the logit model. The logit form was estimated using the dummy variable of the use of concentrates, where farmers using concentrates to feed their dairy animals were scored 1 and those not using concentrates were scored 0. The results of the regression are presented in Table 7. The logit model results revealed that the log-likelihood value (-45.981), the pseudo-R^2 (0.257), and the chi-square value (31.86) were significant (P=0.01), which indicates that the overall model was well-fitted. The explanatory variables used in the model were collectively able to explain the farmers' decisions regarding the use of concentrates in feeding dairy cows.

Table 7. Odds Ratios for logistic estimates of factors influencing the use of concentrates in feeding dairy cows

Variables	Coefficient	dy/dx	Standard Error	P>z
Gender	-0.341	-0.056	0.556	0.539
Age	-0.009	-0.002	0.028	0.743
Work of household head	1.887***	0.246***	0.753	0.012
Education	-0.065	-0.011	0.197	0.740
Total milk produced	0.253***	0.042***	0.085	0.003
Livestock breed	1.235	0.251	0.784	0.115
Access to credit	0.225	0.039	0.632	0.722
Access to extension	1.289**	0.247**	0.640	0.044
Experience in dairy farming	0.051	0.008	0.033	0.121

Note: ***, and *** represent significance levels at 5% and 1% respectively.*

According to the regression results, some of the factors that influenced the use of concentrates include the work of the household head, total milk produced, and access to extension. Work of the household head was treated as a dummy variable (1 for off-farm, 0=on-farm) and the model results show it was significant at a 1 % significance level and positively associated with the use of concentrates in feeding dairy cows. The marginal effect indicates that on average working off-farm will increase a farmer's use of concentrates in feeding dairy cows by 24.6%. this implies that household heads who were working in other sectors and were also engaged in dairy farming were more likely to use concentrates which could be attributed to the extra income as a result of the off-farm work.

The positive sign conforms to what was expected since participation in off-farm activities had been used as a proxy for an extra source of income for dairy farming. Therefore, it appears that smallholder dairy farmers who have jobs outside the farm are more likely to use concentrates in feeding their cows due to the extra income. Because concentrate feeding increases milk production costs, smallholder farmers need an extra source of income to be able to use concentrates in feeding animals which is consistent with previous studies (Hanrahan *et al.*, 2018).

Total milk produced by dairy cows was found to be of great importance for decisions on concentrate use. Results revealed total milk produced in liters was positively and significantly associated use of concentrates (P=0.01). The marginal effect indicates that on average an increase in milk production will increase a farmer's use of concentrates by 4.2%. This indicates that if smallholder farmers increase their milk production, their tendency to use concentrates increases which is in line with the prior study by Lima *et al.* (2023), who found that farmers can increase the use of concentrate feed to meet the nutritional requirements of lactating cows, thereby increasing cow productivity.

Access to extension agencies also positively and significantly influenced the use of concentrates decisions of the farmers (P=0.05). The marginal effect indicates that a one percentage change in access to the extension will increase the use of concentrates by 0.8%. Access to extension agents increased the use of concentrates compared with farmers who did not have contact with extension agents. This difference could be attributed to information access about the benefits of concentrates on dairy cows from extension agents. These findings conform with previous findings which have shown the critical role extension agents have played in disseminating new technologies to smallholder farmers in Africa. (Arinaitwe & Baluka, 2091).

3.6 Smallholder dairy farmers' coping strategies to feed scarcity

Smallholder dairy farmers' coping strategies for feed shortage in the study area are presented in Table 8. Feed shortage, especially during the dry season is a key impediment in dairy farming. The majority (61%) of the respondents reported that they experienced feed shortages at their farm, especially during the dry periods as presented in Figure 2.

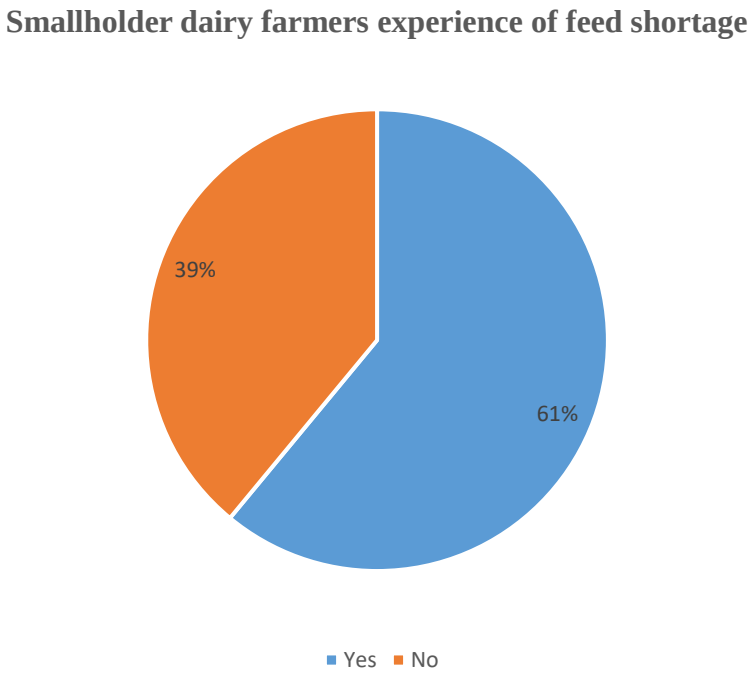

Figure 2. Smallholder dairy farmers' experience of feed shortage

Some of the main strategies that smallholder farmers adopted to mitigate feed scarcity were the purchase of fodder (18.3%), rent grazing of land (18.0%), feeding less to all animals (11.0%), delayed cutting of Napier grass (9.7%), reducing the herd size (9.0%) and feeding animals using tree leaves (9.0%).

Table 8. Smallholder dairy farmers' coping strategies to feed scarcity

Coping strategies to feed scarcity	Frequency	Percentage (%)
Use of stored silage	23	7.7
Feed less to all animals	33	11.0
Feed less to certain categories of animal	19	6.3
Selling some animals	20	6.7
Rent grazing of land	54	18.0
Send cattle on transhumance	3	1.0
Reduce herd size	27	9.0
Purchase fodder	55	18.3
Purchase concentrate feed	10	3.3
Feed tree leaves/forage not normally used	27	9.0
Delay cutting of Napier grass	29	9.7

Note: Multiresponse frequencies of coping strategies

4. Conclusions

The results of the study have shown that the main feed resources used by the smallholder dairy farmers in the Trans Mara East sub-county were Super Napier, maize, guinea grass, sweet potato, and Brachiaria Cobra. It can be concluded that most dairy farmers are feeding the dairy cows with energy-giving forages with limited use of fodder trees and protein-based feeds such as Cowpea M66, Dolichos lablab, Lucerne, Greenleaf Desmodium, and Lupin. In both the dry and wet seasons, the most common grazing systems used by dairy farmers are semi-zero-grazing and free grazing. The adoption status of concentrate feeding revealed that despite concentrate feeding having great benefits to dairy cows' productivity, not all the smallholder farmers had adopted this technology. The study also pointed out that most of the farmers were using cereal grains, root and tubers, molasses, and seeds of legumes as concentrates. Further, we identified that the major factors positively influencing the decisions to use concentrate feed were the work of the household head, total milk produced, and access to extension. Feed scarcity was identified as the most important constraint limiting the smallholder farmers from increasing their milk yield and some of the major coping strategies adopted by the smallholder farmers were; purchase of fodder, rent grazing of land, feeding less to all animals, and delayed cutting of Napier grass Finally, the results of this study provide support for the development of strategies aimed at increasing the use of feed resources among dairy farmers to feed their dairy cows. It is recommended that there is a need for sensitization and capacity development of smallholder farmers on alternative higher productive feed resources in the dairy sector**.**

Acknowledgments

This paper is part of PhD research work for the corresponding author. The study was funded by ……. We are very thankful to all the enumerators, contact persons, and respondents who made the data collection process not only possible but enjoyable across the Trans Mara East sub-county.

Competing interests

The author has declared that no competing interests exist.

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