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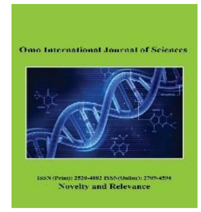

Research Article

On-farm monitoring of feed effects on milk yield and composition in crossbred dairy cows at gidole town, Ethiopia

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Abstract

The study was conducted at Gidole town to evaluate the impact of three feeding practices (low, medium, and better-off) on milk composition and yield in Holstein Friesian crossbred dairy (HFCD) cows at the farm level across three lactation stages (early, mid, and late). In the study area, challenges and opportunities for dairy production were thoroughly assessed. Data were collected from 12 systematically selected households (HHs), representing the three feeding groups (poor, medium, and better-off), shortly after cows gave birth. During early lactation, three feeding households had daily milk yields (DMYs) of 3.61± 0.23, 8.25± 0.69, and 9.47± 0.88, respectively. The DMY was 3.64± 0.75, 7.81± 0.87, and 9.37± 0.71 amid lactation. Across all lactation stages, the feeding groups exhibited significant differences in DMY, fat content, protein levels, and lactose composition ($P < 0.05$). The cows' diets directly influenced these variations. Given the reported differences in dairy cow performance among HHs, optimal practices would be disseminated by extension workers. Lack of land, high feed prices, and low productivity were identified as important constraints in the study area, whereas boosting milk demand, revenue, and knowledge through extension services were studied as potential options for milk production.

Keywords: Feeding practices; Holstein Friesian; Milk composition; Milk yield

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1. Introduction

With at least 600 million people raising livestock for food, cash income, risk management, and asset accumulation, the development of small-scale livestock enterprises could be a critical component of efforts to eradicate extreme poverty and hunger, particularly in rural areas (Hemme and Otte, 2010). Milk production and composition of dairy cows at the farm level are influenced by a variety of external and internal conditions. External factors such as heat stress, season, and humidity (Lambertz et al., 2014) and internal factors such as parity, stage of lactation, udder health, and metabolic status (Tančin et al., 2007; Penev et al., 2014) are common factors that influence dairy cow milk production and composition. According to Tančin *et al*. (2020), the majority of these factors are under experimental conditions, but conditions at the farm level are frequently different due to management practices, even if the breeding conditions are the same.

In smallholder dairy cow production, feeds and feeding practices are most likely to influence milk yield and composition. Smallholder dairy cow herds are fed on-farm-grown fodder, crop residues, forages obtained from outside sources, and commercial dairy meal. Depending on the herd's location, pastoral herds are fed shrubs, dry grasses in rangelands, or Euphorbia tirucalli (Noor et al., 2013). Nutritional or dietary influences have a strong influence on fat concentration and milk protein concentration (Looper, 2012).

Feed scarcity in both quantity and quality dimensions is the major bottleneck for the promotion of the livestock sub-sector in Ethiopia. There is marked seasonality in the quantity and quality of available feed resources due to various environmental determinants such as drought and frost, (Jimma et al., 2016) and low management and conservation techniques. According to Tegegne *et al*. (2013), agro-industrial by-products such as bran, middling, oil seed cakes, and molasses are fed as supplements to crossbred dairy cows in urban and peri-urban areas.

Dairy production in Ethiopia is predicted to increase rapidly in response to the fast-growing demand for livestock products resulting from the increasing human population, especially in urban areas, and rising consumer income, provided that appropriate interventions are made along the dairy value chain (Haile, 2009). The increasing demand for livestock products; particularly for milk and milk by-products has far-reaching implications for human well-being, socio-economics, land use, the environment and animal health. To meet the future demand, production of milk, including milk production per lactating cow would need to be increased significantly if the available feed resources are to be sufficient especially in terms of DM, CP and ME. Moreover, unbalanced feeding could lead to the excess feeding of some nutrients whilst others remain deficient. This not only reduces productivity and increases costs per kg product but also affects various physiological functions including long-term animal health, fertility and productivity (Yisehak and Janssens, 2014).

The research approach included two systems-based monitoring programs (on-farm and farmlet monitoring programs) in the southeast Queensland region of northern Australia was showed a significant effect of the feeding system on true protein concentration and yield (Barber, 2007). The amount of concentrate fed and DIM were the main factors affecting milk protein concentration within feeding systems, true protein and casein concentration were significantly increased by the fiber and starch-based diet, with starch increasing true protein concentration by 0.08% units/kg starch fed (Barber, 2007). That study concluded that dietary non-fiber carbohydrate content over the range of 35 to 40%, is the main factor affecting milk protein concentration. Increasing the ME intake of dairy cows with starch-based concentrates will increase milk protein and casein concentration. The type of feeding system influenced the level of milk protein and the amount of seasonal variation seen, with feeding systems that provide a higher plane of nutrition and a more even supply of nutrients having higher true protein concentrations and less seasonal variation respectively (Barber, 2007). Therefore, it is important to closely consider how feed and feeding practices affect the productivity of dairy cows. This study investigated the impact of farmer feeding practices on milk yield and composition of Holstein Friesian crossbred dairy cows at Gidole town in south Ethiopia to suggest effective management strategies for the smallholder dairy business.

2. Materials and Methods

2.1. Descriptions of the study area

This study was conducted in the Derashe special district at Gidole town at the on-farm level. The overall goal of the study was to develop management strategies based on existing practices in the smallholder dairy sector.

2.2. Sample size and sampling technique

At the start of the study, 60 households at Gidole town were systematically identified and registered as having a Holstein Friesian (HF) crossbred dairy cow. Parity, blood level (50-75%), and body condition were determined in 12 HF cows with similar lactation stages. This was further subdivided into three groups based on the cow's feeding system. At the farm level, the feeding system identified was low, with households feeding dairy cows mostly crop residues, *enset*, and 4.5 liter of *atella* per day. The feed offered to the cow in this category was approximately 4 kg on a feed basis, excluding the *atella* and improved forage was rarely supplemented to the cow. Cows in the second category had a good feeding system, which included crop residues, *enset*, hay, 6 liters of *atella* per day, and salt. The total amount of feed offered, excluding *atella*, was approximately 5 kg. In the category of good feed management, the cow was given the optimal amount of improved forage. Better-off feeding methods were the third category of management practices for lactating cows. Crop residues, enhanced forages, crop aftermath grazing, green forages, *enset*, agro-industrial byproducts (like molasses), 8 liter of *atella* per day, and salt were all incorporated in the feeding scheme of better-off households. In the better-off category, the cow consumed an average of 7 kg of feed daily excluding *atella*.

2.3. Method of data collection

Beginning with the early lactation period in the household, milk yield data was recorded for 210 days in each feeding system, 70 days for early lactation, 70 days for mid-lactation, and 70 days for late lactation. Similarly, 50 mL composite samples of raw milk from each feeding practice were collected in sterile bottles during the early, mid, and late lactation stages, stored in ice boxes, and transported to Arba Minch University's dairy lab for analysis of milk fat, protein, lactose, total solid not fat, and pH. Three times, samples were collected from the farm and examined at the dairy lab. The study examined factors affecting dairy production in the area, including land availability, credit, skilled workers, and marketing opportunities.

2.4. Data analysis

Using a significance level test set at $P < 0.05$ means and standard errors (SE) were calculated to examine the impact of feeding techniques on milk yield and milk composition. SPSS (Statistical Package for the Social Sciences) 20 for Windows was used to conduct statistical analysis (SPSS Inc., Chicago, USA).

3. Results and Discussion

3.1 Milk yield and milk composition analysis

3.1.1 Early lactation

Table 1 shows the influence of feed and feeding practices on the milk yield and composition of an HF crossbred dairy cow during early lactation. During early lactation, a crossbred dairy cow in the low nutrition management group produced an average daily milk yield (DMY) of 3.61 ± 0.23 liter. The average DMY in a good feeding management category was 8.25 ± 0.69 liter, while the better-off feed management category was 9.47 ± 0.88 liter. During early lactation, DMY varied significantly ($P < 0.01$) depending on household feeding practices. The variability in milk yield seen in dairy cows was mostly attributed to family nutrition, feeding, and management variables.

In households with varying levels of feed management—low, medium, and better-off—the average fat percentage during early lactation in crossbred cows exhibited distinct differences. Specifically, it was 3.03± 0.77, 3.42 ±0.34, and 3.76± 0.64, respectively in poor, good and better-off feeding practices. Notable variation (P < 0.01) among family feeding practices. Similarly, the average crude protein content (%) in dairy cow feed management categories during early lactation showed significant differences (Table 1).

It's worth noting that changes in rumen fermentation or fat supplementation, as outlined by the National Research Council (NRC, 1988), can impact the primary precursors of milk fat. These include acetic and butyric acids produced from rumen fermentation, as well as long-chain fatty acids from dietary sources and endogenous pathways. Additionally, Tanin *et al*. (2020) highlighted that milk production and components are influenced by factors such as season, parity, stage of lactation, and somatic cell count.

Table 1. Early lactation milk yield and composition (Mean±SE) of crossbred dairy cows in different feed management practices in the Gidole town

Feed management category	Mean ± SE in early lactation					
	Daily milk yield (liter)	Fat %	Lactose content %	Solid not fat %	Protein content %	pH
Low	3.61±0.23[c]	3.03±0.77[c]	4.01±0.47[a]	6.98 ±0.87[a]	2.62±0.31[c]	6.63±0.07[a]
Medium	8.25±0.69[b]	3.42±0.34[b]	3.91±0.49[a]	7.21±0.74[a]	3.02±0.17[b]	6.69±0.10[a]
Better-off	9.47±0.88[a]	3.76±0.64[a]	4.01±0.23[a]	7.17±0.40[a]	3.14±0.12[a]	6.67±0.09[a]
P- value	< 0.01	0.01	0.08	0.69	< 0.01	0.28

[abc] means in the column with the same superscript are not significantly different (P < 0.05).

3.1.2 Mid-lactation

The influence of feed management practices on milk yield and composition in HF crossbred dairy cows during mid-lactation is presented in Table 2. The average DMY (liter) for cows under feed management categories were 3.64 ±0.751, 7.81± 0.87, and 9.37 ±0.71 for low, medium and better-off, respectively. Significant variation was observed among the three households in average DMY based on feeding practices of dairy cows (P < 0.01). This variation highlights the importance of tailored feeding strategies for dairy cows based on their specific conditions.

A previous study revealed significant elements that influence milk composition (Barber, 2007). Dietary non-fiber carbohydrates (NFC) content played a crucial role in determining milk protein and casein levels. Specifically, it affected the proportion of β-casein within the casein fraction. Several farm-level factors influenced milk composition. Whey protein and urea concentrations are affected by dietary acid detergent fiber (ADF) content, temperature-humidity index (THI), radiation, and maximum temperature. Dietary ADF concentration, THI, radiation, and maximum temperature all impact the proportions of αS- and κ-casein fractions. The amount of concentrate fed and Days in Milk (DIM) are important factors in determining milk protein content across different feeding regimes. In general, knowing and optimizing feed management procedures is critical for increasing milk yield and preserving optimum milk composition in crossbred dairy cows.

The feeding system, particularly the form of management (known as "farmlet"), has a significant impact on milk protein concentration and overall productivity. A study by Barber (2007) at the farm level revealed that different feeding systems significantly influenced milk protein levels. Specifically, feeding systems with a higher plane of nutrition resulted in higher real protein concentrations, but systems with a more consistent supply of nutrients showed less seasonal volatility in milk protein content. Additionally, a higher body condition score at calving positively impacted milk protein concentration, especially during the early to mid-lactation period.

Beyond diet and dairy cow health, several other factors influence crossbred dairy cows. Milk production is influenced by the number of lactation periods and the season of calving. Dairy farm management strategies and technology have an impact on overall milk yield, as do temperature, humidity, and radiation. The slope of the lactation function, which takes into account both milk supply and overall yield, needs to be carefully analyzed.

Jentsch *et al*. (2001) found that different feeding system management methods have a substantial impact on mid-lactation cows. Novak *et al*. (2009) found that early lactation cows are less influenced. In general, understanding and optimizing feeding systems is critical for maintaining milk quality and increasing production in dairy farming.

Table 2. Mid-lactation milk yield and composition (Mean±SE) of crossbred dairy cow in different feed management practices at the Gidole town

Feed management category	Mean ± SE in mid-lactation					
	Daily milk yield (liter)	Fat %	Lactose content %	Solid not fat %	Protein content %	pH
Low	$3.64±0.75^c$	$3.17± 0.73^c$	$4.34±0.29^a$	$7.85±0.55^a$	$2.86±0.23^c$	$6.63±0.02^a$
Medium	$7.81±0.87^b$	$3.21±0.22^b$	$4.35±0.22^a$	$7.74±0.24^a$	$3.10±0.16^b$	$6.69±0.03^a$
Better-off	$9.37±0.71^a$	$5.01±0.66^a$	$4.29±0.34^a$	$7.22±0.41^a$	$3.21±0.15^a$	$6.67±0.02^a$
P –value	<0.01	<0.01	0.88	0.58	<0.01	0.28

$^{a\ b\ c}$ means in the column with the same superscript are not significantly different (P < 0.05).

3.1.3 Late lactation

The influence of household feed management practices on milk yield and composition of HF crossbred dairy cows during the late lactation period is indicated in Table 3. Under different household feed management categories, the average DMY (liter) for crossbred cows was 2.01± 0.24, 3.03± 0.41, and 3.63± 0.39, respectively, which was significant (P< 0.01). The fat and protein content in milk was also significantly affected (P < 0.01). Fat content is particularly sensitive to dietary changes. According to Looper (2012), changing the diet can affect fat levels by roughly 3.0 percentage points, although other milk constituents such as lactose and minerals do not respond reliably to dietary changes. These findings highlight the significance of tailored feed management strategies in optimizing milk yield and maintaining desirable milk composition in late-lactation crossbred dairy cows.

Table 3. Late lactation milk yield and composition (Mean ± SE) of crossbred dairy cows in different feed management practices at the Gidole town

Feed management category	Mean ± SE in late lactation					
	Daily milk yield (liter)	Fat %	Lactose content %	Solid not fat %	Protein content of %	pH
Low	2.01±0.24^{c}	2.85±0.48^{c}	4.36±0.44^{a}	8.53±0.53^{a}	3.11± 0.19^{c}	6.48±0.12^{a}
Medium	3.03±0.41^{b}	3.26 ±0.38^{b}	4.61±0.22^{a}	8.06± 0.26^{b}	3.25±0.16^{b}	6.15±0.15^{a}
Better-off	3.63±0.39^{a}	4.20 ±0.53^{a}	4.32±0.28^{a}	7.62±0.35^{c}	3.29±0.12^{a}	6.50±0.14^{a}
P- value	<0.01	<0.01	0.07	<0.01	<0.01	0.84

$^{a\ b\ c}$ means in the column with the same superscript are not significantly different (P < 0.05).

3.2 Constraints and opportunities of milk production

3.2.1 Constraints

The study household identified several critical constraints affecting crossbred dairy cattle production (Table 4). Limited available land (33.33%) poses a significant obstacle to efficient dairy farming. Grazing space and cultivation areas for improved forage are in short supply. The expense (20%) associated with feeding the cattle is a major concern. Balancing cost-effective nutrition with production is critical. Achieving optimal milk yield (20%) remains a challenge. Factors affecting production need careful consideration. Skilled professionals (16.66%) are essential for successful artificial insemination. Addressing this shortage is critical for breeding programs. Availability of credit (10%) impacts investment in dairy farming. Accessible credit services can facilitate growth.

According to Getabalew *et al*. (2019), broader constraints in Ethiopian dairy production include disease and parasite management, poor cattle performance, insufficient veterinary services, labor shortages and lack of artificial insemination services. Ayalew and Abatenhe (2017) highlighted feed and land shortages as major challenges across different regions in Ethiopia. Unbalanced feed costs (including concentrate feed, mill byproducts, roughage, and forage seeds) also contribute to these challenges. To address these issues, collaborative efforts involving farmers, researchers, and extension workers are essential for sustainable dairy production.

Table 1. The rank of constraint on crossbred dairy cow production in the household in the Gidole town

Constraints	N=60	Percent	Rank
Shortage of land	20	33.33	1st
High feed cost	12	20.00	2nd
Low milk production	12	20.00	2nd
Lack of well-trained artificial insemination technicians	10	16.66	3rd
Access to credit	6	10.00	4th

3.2.2 Opportunity

Table 5 presents several possibilities for enhancing crossbred dairy cattle production in the study area. As the population grows (40%), so does the potential for increased milk consumption. A larger consumer base creates demand for dairy products. Consumer income (26.66%) directly influences dairy product demand. Stable revenue sources contribute to sustained market growth. Educating farmers (20%) about best practices and modern techniques is crucial. Extension services play a vital role in disseminating knowledge. Dairy production generates employment (13.33%) opportunities. From on-farm activities to processing and distribution, the entire dairy chain benefits.

Previous study by Solomon (2014) and Kassa (2019) revealed comparable opportunities: rapidly rising populations, particularly in urban areas, increased milk consumption, and dairy production generates income for producers. Small-scale milk production not only enhances food security but also supports rural employment. The dairy industry plays a critical role in Ethiopia's rural economy, especially in highland and pastoral regions. Continued urbanization and increasing demand for milk position the dairy sector for significant contributions to income generation, food security, and employment (Hemme and Otte, 2010). Strategic efforts to capitalize on these opportunities can lead to sustainable growth in crossbred dairy cattle production.

Table 5. Ranks on opportunity for crossbred dairy cow production in the household in the Gidole town

Opportunity	N=60	Percent	Rank
Increasing population growth	24	40	1st
Consumer income source	16	26.66	2nd
Awareness through extension service	12	20	3rd
Expanding employment	8	13.33	4th

4. Conclusions

Crop residues, particularly '*teff*' straw, crop aftermath grazing, hay, improved forages (primarily elephant grass, *desho* grass (*Pennisetum pedicellatum*), Guatemala grass), *enset* pseudo stem, root and leaf, roughages, and non-conventional feeds, were identified as the main feed resources in the study area. Several physiological factors of the cow, as well as other external factors, influence established milk production and components. In the current study, feeding systems of various categories have a significant influence on milk yield and milk composition. The major constraints of cross-breed dairy cows in the study area were a lack of quality and quantity of feed, lack of land, high feed costs, low milk yield, and access to credit services. On the other hand, the major opportunities of producing milk in the study area were high demand for milk, capacity for income generation, job creation, and increased farmers' awareness through extension services. The feeding system of the cow in the household can affect not only the yield of cow milk but also many intermediary products such as butter and cheese of small-scale rural processors. Farm-level production and feed management should be aware of the effect of feed and feeding on milk yield and components. According to the study, there is an opportunity to develop management strategies for the smallholder dairy sector by implementing a farm-level feeding system.

Conflict of Interest

The authors declare no conflict of interest.

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