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ARTICLE

Milk Production, Composition, and Reproductive Performance of Crossbred Dairy Stock on Smallholder Dairying in Ethiopia

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Abstract Regular evaluation of dairy stock performance under current management practices is essential for the success of dairy production and crossbreeding programs. However, the lack of up-to-date, comprehensive, and location-specific information hinders the implementation of effective intervention strategies to enhance dairy productivity in the tropics. This study aimed to assess the reproductive performance, milk yield, and quality of crossbred dairy stock in the Lemo district. A total of 178 households were surveyed, and 53 milk samples were collected for laboratory analysis. The results indicated that enset leaf and pseudo-stem, pasture, and cereal crop residues were the primary feed resources. Breeding methods included 50% bull service and 33% artificial insemination. The mean daily milk yield of crossbred cows was 7.1±1.27 L/d. Milk yield varied significantly ($p<0.05$) based on agro-ecology, income source, experience, training, feed supplements, water provision, and landholding. The mean age at first service and age at first calving were 27.58±2.14 and 36.65±2.70 mon, respectively. The average calving interval was 17.36±0.93 mon, which exceeds the recommended ranges. The mean values of fat, protein, solid-not-fat, lactose, and total solids were 4.46±1.98%, 3.21±0.20%, 8.85±0.5%, 4.9±0.38%, and 13.29±1.8%, respectively. The compositional quality of milk varied significantly ($p<0.05$) among dairy genotypes, meeting the minimum Ethiopian standards. A smallholder dairy program focusing on improving breeding methods and providing capacity-building training is recommended for dairy producers.

Keywords dairy stock, smallholders, milk yield, chemical composition, reproduction

Introduction

Milk production varies significantly across different production systems worldwide (Britt et al., 2018; Food and Agriculture Organization [FAO], 2016). These variations are influenced by biophysical, socioeconomic, and cultural factors. Generally, the performance of dairy stock is affected by environmental conditions (such as agro-climatic conditions, management practices, nutrition, and diseases) and genotype. Most dairy cows are found on small farms in developing countries, where their production systems are less understood (Phillips, 2018). Additionally, the dairy sector is a crucial socioeconomic pillar for food security and income generation, particularly for smallholders in sub-Saharan Africa. Eastern Africa is the most promising dairy-producing region.

Dairy production is an important industry in Ethiopia, one of the top dairy producers in Africa, alongside Kenya and Tanzania (Seré, 2020). The country has high dairy potential due to factors such as market demand and agro-climate. However, increasing the productivity of dairy stock remains a challenge to meet the rising demand.

Crossbred dairy stock has been shown to be more robust than their purebred counterparts (Clasen et al., 2017; Galukande et al., 2013). Crossbreeding remains an attractive option for improving livestock in the tropics due to its quick results and potential benefits for farmers. However, each case should be carefully evaluated to determine the appropriate intervention strategies (Haile et al., 2011). In the early 1950s, Ethiopians began crossbreeding indigenous zebu with Holstein-Friesian or Jersey cattle to enhance milk production (Clasen et al., 2019). Over the last decade, crossbreeding in the dairy sector has gained popularity, although the practice varies systematically by country.

The success of dairy production, particularly crossbreeding programs, must be regularly monitored by assessing performance under existing management practices. Evaluating the reproductive and productive performance of crossbred dairy stock in smallholder production systems is essential for developing effective breed improvement strategies. Productive and reproductive traits are fundamental factors influencing the profitability of dairy production. Studies on Ethiopian dairy farming and crossbreeding practices have been conducted (Ashagrie et al., 2023; Didanna et al., 2019; Duguma, 2020; Yoseph et al., 2022).

However, the lack of current, comprehensive, and location-specific information on production and reproduction, as well as their constraints, often impedes productivity and improvement efforts, especially in smallholder dairying. Additionally, assessing dairy husbandry practices, performance, and the chemical composition of milk is crucial for realizing improvements in dairy productivity and quality. The information from this study is also valuable for practitioners (governmental and non-governmental organizations) to design appropriate future dairy programs.

Hadiya Zone is one of Ethiopia's potential dairy areas. However, few studies have been conducted on the performance and milk quality of crossbred dairy stock. Therefore, this study aimed to assess the reproductive performance, yield, and chemical composition of milk from crossbred dairy stock in the Lemo district of the Hadiya Zone.

Materials and Methods

Study area

The study was conducted in the Lemo district of Hadiya Zone, southwestern Ethiopia. Geographically, the area lies between latitude 07°41′N and longitude 037°31′E, covering a total area of 432.50 km^2. The district comprises 33 kebeles, which are the lowest administrative units. The district office is located in Hosanna, the capital town of the Hadiya Zone. Hosanna is situated 142 km from Hawassa and 230 km from Addis Ababa, the capital city of Ethiopia. The district's altitude ranges from 1,900 to 2,700 m above sea level (m.a.s.l.). It features two agro-ecological zones: 48% highland and 52% mid-altitude. The total cattle population of the district is 53,846, of which 5,923 are crossbreeds (LWARDO, 2020). The crossbred dairy genotypes consist of indigenous cattle crossed with imported bovine genetic stock. The indigenous cattle are classified as Guraghe cattle.

Sampling techniques and sample size

The study population comprised smallholders who kept crossbred dairy stock. Kebeles in the Lemo district were purposefully selected based on their dairy potential (availability of crossbreds). These kebeles were stratified into highland and mid-altitude agro-ecologies. Simple random sampling techniques were used to select households from the data list available in 2023 at the respective kebele agricultural development offices. Consequently, four kebeles were selected from the two agro-ecologies using stratified sampling techniques: Lareba and Hayise from mid-altitude, and Sadama and Omoshora from highland agro-ecology. In the selected kebeles, approximately 325 households had crossbred dairy cows. Using systematic random sampling, a total of 178 households were selected. Fifty-three milk samples were collected for laboratory testing.

We calculated the sample size for the household survey study using the Yamane (1967) formula:

$$n = \frac{N}{1 + Ne^2} \tag{1}$$

where, (n) is the sample size, (N) is the population size, and (e) is the standard error (5%) with a confidence interval of 95%.

Data collection

Dairy households' survey

A cross-sectional study was conducted using questionnaires to gather information from selected households during interviews. The questionnaires were pre-tested, and necessary adjustments were made. The data collected included household characteristics, feeds and feeding practices, breeding methods, health, milk production and disease incidences, dairy housing, manure management, extension services, and the challenges and opportunities for dairy production. Humans and animals were not been used for scientific purposes during the data collection (Ethics approval ID: WSU 41/34/67).

Milk sampling and laboratory analysis

According to O'Connor (1995), approximately 50 mL of milk was sampled from each selected farm unit in the morning and placed in sterile plastic containers. The milk samples were stored in an ice box and transported to the Wolaita Sodo University Animal Science Department laboratory on the same day for chemical analysis. The chemical composition was determined using a digital milk analyzer (LACTOSCAN) to measure milk constituents, including fat, solid non-fat, protein, lactose, and total solids.

Data analyses

The data were analyzed using the Statistical Package for Social Science (SPSS) software, version 20 (IBM, Armonk, NY, USA). Descriptive statistics, including Chi-square tests, means, SD, frequency, and percentages, were employed to describe the characteristics of the dairy households, milk yield, and composition. Differences were considered significant at the $p<0.05$ level. A General Linear Model was used to examine the relationships between independent variables (household characteristics and breed) and the dependent variables (daily milk yield and composition).

The statistical model used was:

$$Y_{ij} = \mu + H_i + B_j + e_{ij} \quad (2)$$

where, Y_{ij} is variable, μ is overall mean, H_i is the effect of household characteristics, B_j is the effect of breed and e_{ij} is random error.

Results and Discussion

Socio economic characteristics of households

The household characteristics are presented in Table 1. The majority (84.8%) of the dairy households interviewed were male-headed. The respondents' average family size was 5.4±1.82, which is considered optimal for improving dairy production

Table 1. Socio-economic characteristics of respondents (n=178)

Variables	Frequency (n)	Percentage (%) or mean±SD
Sex		
Male	151	84.83
Female	27	15.17
Age category		
24–34	14	8
35–55	154	87
>55	1	4.5
Marital status		
Married	172	96.6
Single	1	0.56
Divorced	5	2.8
Education level		
Illiterate	62	34.8
Read& write	59	33.1
Elementary school	48	27
High school	6	3.37
Diploma & above	3	1.7
Occupation		
Farming	156	87.6
Daily worker	9	5.1
Public servant	13	7.3
Income source		
Sale of milk	35	19.7
Livestock & crop production	127	71.3
Off-farm activity	16	18.2
Family size		5.43±1.80
Land holding (ha)		0.64±0.23

through labor provision in husbandry practices, calf rearing, and milk processing. The average age of household heads ranged from 35 to 55 years, a productive age range for dairy production activities. Age can also indicate experience and decision-making capacity, which affect dairy activities and productivity. Ninety-six percent (96%) of the households were married. The overall education levels of household heads were 34.8% illiterate, 33.14% able to read and write, and 27% with elementary school education.

The majority of dairy households (71.3%) were primarily engaged in livestock and crop production, with milk and milk product sales being the second most common activity (19.7%). The availability of cooperatives helped households sell milk and milk products. Producers without access to formal markets sold milk by-products, such as cheese and butter, in local markets.

Most of the dairy farmers had more than five years of experience. However, there had been limited capacity-building training (Table 2).

Husbandry practices in the study area

Feeds and feeding

The major feed sources were enset leaf and pseudo-stem (27.5%), followed by natural pasture (21.9%), crop residues (straw from teff and wheat; 21.9%), and improved forages (14.6%) such as Pennisetum purpureum, Phalaris aquatic, and Sesbania sesban (Table 3). Feed scarcity occurs mainly from November to March, and the provision of agro-industrial products serves as a coping mechanism. Effective use of available local feed resources, conserving feed, introducing herbaceous leguminous forage crops, and treating crop residues are sustainable solutions, particularly for use as supplementary feed during the dry season. According to Ashagrie et al. (2023), feeding a ration composed of various ingredients may be more effective in meeting the nutrient requirements of livestock than using separate feed ingredients, as it exploits the differences in dietary qualities.

Households in the study area practiced different feeding systems, including tethering (51.1%), the cut-and-carry system (25%), and herding (23.9%). The dominant source of water was boreholes (44.4%), followed by rivers (36%) and piped water (19.6%). Most farmers (66.3%) provided water to crossbred dairy cows only twice a day due to water scarcity. The mean daily water consumption of cows was 30.7 L/d (Table 4), which is lower than the 52.6 kg/d reported by previous researchers (Didanna et al., 2019), including the water in feeds.

Table 2. Experience in dairy farming and extension service (n=178)

Category	Frequency (n)	Percentage (%)
Farming experience (yr)		
<3	37	20.78
3–5	67	37.6
>5	74	41.57
Access to extension service		
Yes	140	78.65
No	38	21.34
Training received		
Yes	65	36.5
No	113	63.5

Table 3. Feed resource availability in the study area

Variables	Mid-altitude		Highland		Total	
	(n=94)	%	(n=84)	%	(n=178)	%
Natural pasture	20	21.23	16	19.04	39	21.9
Crop residues	21	22.34	18	21.42	39	21.9
Improved forage	15	15.95	11	13.09	26	14.6
Enset leaf & pseudo stem	17	18.08	30	35.7	49	27.5
Banana leaf	5	5.32	0	0	6	3.38
Wheat bran and nug	7	2.12	4	2.38	11	6.2
Attalla	5	7.5	2	4.76	8	4.5

Nug is local name for Guizotia abyssinica; *Attela* is a byproduct of the traditional manufacturing process of tella (beer) or katikala (liquor); *Enset is* Ethiopian Banana (*Ensete ventricosum*).

Table 4. Water source, consumptions and water related problems in the study area

Water source	Mid-altitude		Highland		Overall	
	n=94	%	n=84	%	n=178	%
River	2	2.13	62	73.8	64	36
Bore hole	75	79.8	4	4.76	79	44.4
Pipe	17	18	18	21.4	35	19.6
Frequency of watering						
Once a day	29	30.8	31	37	50	33.7
Twice a day	65	69.2	53	63	118	66.3
Water related problems						
Scarcity	74	78.75	64	76.19	138	77.5
Parasite	16	17	8	9.52	24	13.5
Impurity	4	4.25	12	14.3	16	9
Daily water consumption	32.54±5.138		28.86±9.150		30.7±10.395	

Major diseases and health management practices

The main diseases and parasites identified were mastitis, bovine tuberculosis, internal parasites, contagious bovine pleuropneumonia, and lumpy skin disease, in descending order. Most of the prevalent diseases in the study area are associated with intensification, requiring careful disease prevention and control measures. The primary health service-related issues were a shortage of veterinary drugs (27.5%), a shortage of skilled animal health technicians (18.5%), and the distance to animal health centers (17%). The government was the most frequently mentioned source of veterinary services (84.3%; Table 5). These findings align with those of Didanna et al. (2019), who reported that dairy animal health is influenced by problems with veterinary service access, disease incidence, and the high cost of private veterinary services.

Source of crossbred dairy stock and breeding methods in study area

Most dairy farmers (89.3%) obtained their foundation stock from their neighbors. Fifty percent of the dairy producers used bull service for breeding their dairy cows. The most widespread constraints in the study area, in descending order, were the

Table 5. **Animal health related problems and veterinary services in study area**

Problems	Frequency (n)	Percentage (%)
Shortage of skilled animal health technician	33	18.5
Shortage of drugs	49	27.5
Lack of animal health clinic and laboratory services	27	15.2
Distance to animal health centre	30	17
Lack of timely vaccination	15	9
In-frequent animal health service	23	13
Source of veterinary services		
Government	150	84.3
Private	28	15.7

lack of liquid nitrogen and semen, limited access to AI centers, and a shortage of skilled AI operators (Table 6). Didanna et al. (2019) emphasized the need for reliable and proven genotype sources of improved dairy breeding stock as a foundation.

Reproductive performance of crossbred cows

Age at first service

The mean age at first service (AFS) of crossbred dairy cows was 27.58±2.14 mon (Table 7). This value is lower than the 32.28±8.01 mon reported by Duguma (2020) but higher than the 24.8±2.1 mon found by Beshada and Asaminew (2023) in Jimma Town and around Addis Ababa, respectively. It aligns with Wondair (2010), who reported an AFS of 27.5 mon in the highland and central rift valley of Ethiopia. The differences could be attributed to variations in genotypes, management

Table 6. **Breeding, sources of crossbred cows, and associated constraints in the study area**

Breeding method	Frequency (n)	Percentage (%)
Natural mating	30	17
AI	89	50
Both	58	33
Source of crossbred dairy cows		
Purchase from neighbor	159	89.3
Purchase from market	16	8.9
Through AI	3	1.7
Constraints	**Index**	**Rank**
Lack of access	0.11	4
Shortage of LN & semen	0.33	1
Lack of skilled AI technician	0.24	3
Distance to AI station	0.27	2

Index = [(3 × number of households ranking as first + 2 × number of households ranking as second + 1 × number of households ranking as third) for each constraints to artificial insemination] / [(3 × number of households ranking as first + 2 × number of households ranking as second + 1 × number of households ranking as third) for all constraints to artificial insemination].
AI, artificial insemination.

Table 7. Performance of dairy cows in the study area

Variables	Mean±SD
Daily milk yield/stock	
Early lactation (L)	8.3±1.745
Mid lactation (L)	6.27±1.9
Late lactation (L)	3.05±0.926
Average (L)	7.1±1.27
Lactation length (d)	274±29.8
AFS (mon)	27.58±2.14
AFC (mon)	36.65±2.7
CI (mon)	17.36±0.93

AFS, age at first service, AFC, age at first calving; CI, calving interval.

practices, and feeding of calves and heifers, which affect growth rates and puberty onset. The recommended age for a heifer's first service, depending on weight and breed, is 12–14 mon. AFS influences both production and reproductive life by affecting the number of calves a cow can produce in her lifetime.

Age at first calving

The mean±SD age at first calving (AFC) of crossbred dairy cows was 36.65±2.7 mon (Table 7). This value is higher than the 32.7±2.7 mon reported by Beshada and Asaminew (2023) but lower than the 44.4±0.13 mon found by Duguma (2020). The AFC may be influenced by genotypes and husbandry practices, which can affect growth, leading to slower growth, delayed puberty, reduced fertility, and lower conception rates. The optimal AFC is 24 mon. Early AFC is crucial for any dairy herd as it lowers rearing costs, extends productive life, and shortens generation intervals, allowing for earlier progeny. The first calving marks the beginning of a cow's productive life. Cows that calve at a young age and do so regularly are the most productive.

Calving interval

The average calving interval (CI) of the crossbred dairy cows was 17.36±0.93 mon (Table 7). This mean CI is lower than the 21.2±1.37 mon reported by Duguma (2020) but higher than the 13.5 mon found by Yifat et al. (2009). The disparities in CI reports could be due to delayed resumption of ovarian activity after parturition, as well as husbandry practices such as heat detection, breeding after calving, feeding, and disease control. The recommended total CI is 12 mon. Long CIs reduce the efficiency of dairy cow reproduction by decreasing the number of replacement stock and milk production.

Milk production performance of crossbreed stock

Milk production

The average daily milk production for crossbred cows in the current study was 7.1±1.27 L. Significant differences in milk yield ($p<0.05$) were observed across various factors, including agro-ecological zones, income sources, experience, training, feed supplements, water provision, and landholding (Table 8).

Table 8. Effects of household characteristics on milk production (LSM±SE)

Description	n	Daily milk yield (LSM±SE)
Gender		NS
M	151	7.2±1.36
F	27	7.1±1.25
Age		NS
>35	9	8±1.5
35–55	161	7±1.2
>55	8	6.83±1.2
Education		NS
Illiterate	62	6.7±1.6
Read& write	59	7.14±1.1
Elementary school	48	7.15±0.19
High school	6	7.64±1.9
Diploma & above	3	7.83±2.1
Agro ecology		**
Mid-altitude	94	7.33±1.33
Highland	84	6.85±1.1
Income source		**
Sale of milk	35	7.8±0.54
Lives &crop production	130	7.3±1.7
Off farm activity	13	6.98±1.14
Experience- selecting breed		**
Yes	170	7.1±1.26
No	8	5.8±0.65
Training provision		
Yes	148	6.4±1.3
No	30	5.03±1.05
Feed supplementation		**
Concentrate	158	7.5±0.6
No supplement	20	6.0±1.25
Watering frequency		**
One time/day	50	5.9±0.68
Two times/day	128	7±1.01
Quantity of water consumed		**
<25 L/d	58	4.96±0.7
35 L/d	82	6.12±0.6
<40 L/d	61	7.75±1.5
Land holding		NS
>0.5 ha/household	125	7.5±1.5
<0.5 ha/ha/household	53	6.9±1.13

** $p<0.01$.
LSM, least squares means; NS, not significant.

This finding is lower than the 10.1±1.6 L per cow reported by Beshada and Asaminew (2023). However, it exceeds the mean milk production of 6.47 L reported in Kenya (Wanjala and Njehia, 2014). The current study also found that households with dairy as their primary source of income, those with more experience, those using concentrate feed supplements, those providing increased water, and those receiving training had higher milk yields.

Lactation length

Lactation length is a key parameter that determines the profitability of dairy owners and the productivity of dairy cows. The mean lactation length of cows in this study was 274±29.8 d (Table 7). This lactation length is shorter than the 303 d reported by Ketema (2014) for crossbred cows in the Kersa district. In Kenya, the average lactation length was 230 d (Wanjala and Njehia, 2014). Ideally, a good dairy cow produces milk for about 305 d. It is evident that the lactation length in the present study is lower.

Milk chemical composition

Fat content

The average fat content of milk samples was 4.46±1.98%. There was significant variation between the dairy genotypes reared ($p<0.05$; Table 9). The minimum fat percentage for whole milk should be at least 3.5% (Ethiopian Standard, 2009). Thus, the fat content obtained in the present study meets the recommended standards.

The overall fat percentage found in this research is comparable to that reported by Gemechu et al. (2015), who found 4.10% milk fat in Shashemene town, and Yoseph et al. (2022), who reported 3.98±0.89% from milk sampled in peri-urban areas of Wolaita. Higher fat percentages were reported by Negash et al. (2012; 5.02±0.25%) and lower fat content by Asefa and Teshome (2019; 2.42%).

The variability in milk fat could be attributed to genetic factors (with higher values observed in Jersey crosses) or other environmental factors such as nutrition, lactation stage, and animal age. Higher fat content is advantageous for households with limited market access for fresh milk, as it allows for butter production from milk processing.

Protein content

The average protein content of raw milk samples was 3.21±0.20%. There was significant variation ($p<0.05$) in values among the two cow genotypes (Table 9). The minimum protein content in milk should be 3.2% (Ethiopian Standard, 2009). Therefore, the mean milk protein content in the present study aligns with the recommended Ethiopian standard.

Table 9. Breed effect on chemical composition of milk

Composition of milk (%)	Jersey crosses (n=26)	Holstein Friesian crosses (n=27)	Total (n=53)	p-value
Fat	3.75±1.17	3.25±1.53	4.46±1.98	0.000
Protein	3.36±0.20	3.12±0.16	3.21±0.20	0.000
SNF	9.19±0.53	8.6±0.44	8.85±0.59	0.002
Lactose	5.06±0.29	4.73±0.24	4.9±0.38	0.021
Total solids	12.52±1.44	12.44±1.05	13.29±1.86	0.000

Values are presented as mean±SD.
n, sample size; SNF, solid not fat.

The current finding of average protein content is similar to the report by Dehinenet et al. (2013; 3.12%). However, Gemechu et al. (2015) reported a higher value (4.25%) for milk sampled from smallholder dairy farms in Dire Dawa town. Negash et al. (2012) found a slightly higher value (3.46±0.04%) for milk samples in the Mid-Rift Valley of Ethiopia.

Milk protein composition is mostly unaffected by changes in feeding and husbandry practices (Walker et al., 2004), whereas cow genetics and lactation stage may significantly impact protein concentration in milk.

Lactose

The average lactose percentage of raw milk obtained in the study area was 4.9±0.38%. There was a significant difference ($p<0.05$) between cow genotypes (Table 9). The lactose content of milk should not be less than 4.2%, as recommended by EU quality standards (Tamime, 2009). Therefore, the current lactose percentage found in the milk samples exceeds the suggested standards.

The lactose level in this study is higher than the 4.43±0.06% reported by Gemechu et al. (2015) but lower than the 5.17% found by Alemu et al. (2013). This variation could be due to the action of lactose-hydrolyzing enzymes produced by microorganisms as a result of temperature fluctuations during storage (Pandey and Voskuil, 2011). The lactose value detected in the study area is above the quality standard. According to Habtamu et al. (2015), lactose intolerance is thought to affect milk consumption in Ethiopia. To increase milk consumption, dairy processors should consider making yogurt or removing lactose to produce lactose-free milk for lactose-intolerant consumers.

Solid-not-fat

The solid-not-fat (SNF) percentage of milk in this research was 8.85±0.59%. The SNF content of milk samples varied significantly between the dairy genotypes ($p<0.05$; Table 9). According to the Food and Drug Administration (FDA, 2010), milk must have a minimum SNF content of 8.25%. The mean SNF value in this study slightly exceeds the quality standards.

The current SNF percentage of raw milk is relatively similar to the findings of Dehinenet et al. (2013), who reported an average SNF of 8.44±0.72% in milk from selected areas of the Amhara and Oromia regions, and Desye et al. (2023), who reported an SNF value of 8.18±0.48% in milk sampled from producers in Gondar, Northwest Ethiopia. However, lower SNF values were found by Hawaz et al. (2015; 7.98±0.98%), and higher values were reported by Negash et al. (2012; 9.05±0.16%) elsewhere in Ethiopia. The SNF content in the study area could be influenced by various factors, including nutrition, genetics, and lactation stage.

Total-solids

The total solids (TS) percentage of milk in this study was 13.29±1.86%. There were significant variations among the dairy genotypes reared ($p<0.05$; Table 9). The total solids content of milk must be at least 12.5% (EU, 2006). Therefore, the percentage of total solids content found in the current study is above the suggested standards.

The TS content obtained in this study aligns with the findings of Gemechu et al. (2015), who reported a milk total solids percentage of 12.87±0.11%. However, it is lower than the 13.10±0.84% reported by Eshetu et al. (2019) and higher than the 12.58% found by Teklemichael (2012). Increasing total solids is economically beneficial for farmers, as milk solids can be converted into a diverse range of products upon processing (Hayes et al., 2023).

Conclusion

This study assessed the reproductive performance, milk production, and quality of milk sampled from crossbred dairy stock in Ethiopia. Milk yield varied significantly based on agro-ecology, income source, experience, training, feed supplements, water provision, and land holding. The compositional quality of milk also varied significantly among dairy genotypes, meeting the minimum Ethiopian standards. The values for AFS, AFC, and CI in this research exceeded the recommended values but were better than those of indigenous breeds. Management inconsistencies and environmental differences appear to influence milk production, lactation length, and reproductive performance. Household factors such as family size, productive age, literacy, and experience of household heads, along with some formal market access, were advantageous. Enhanced heat detection and balanced feeding that considers maintenance and growth requirements are necessary to reduce the AFC and the CI. Integrating postpartum reproductive health management into farm operations can help shorten the postpartum period and CI. A market-oriented approach is also needed, focusing on improving genetic potential through crossbreeding, enhancing feed quantity and quality, and providing better healthcare. Stakeholders, including governmental and non-governmental organizations and the private sector, need to be involved in the agro-industry to ensure adequate food-feed supply, large-scale crop production, forage seed production, water development, genetic improvement, milk quality control, and forage extension. Training on various aspects of dairy management, such as proper feeding, forage production, heat detection, health care, and other good dairy practices, should be provided.

Conflicts of Interest

The authors declare no potential conflicts of interest.

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Author Contributions

Conceptualization: Abate A, Didanna HL, Ayza A. Formal analysis: Abate A. Methodology: Abate A, Didanna HL, Ayza A. Validation: Didanna HL, Ayza A. Investigation: Abate A. Writing - original draft: Abate A. Writing - review & editing: Abate A, Didanna HL, Ayza A.

Ethics Approval

Humans and animals were not used for scientific purposes during the data collection as approved by the Research Review Board of Wolaita Sodo University (Approval ID: WSU 41/34/67).

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