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Peri-urban Dairy Production System in Relation with Feed Availability in the Highlands of Ethiopia

[1]*Zewdie Wondatir,* [2]*Yoseph Mekasha and* [3]*Bram Wouters*

[1]Holetta Research Center, P.O. Box, 2003 Addis Ababa, Ethiopia
[2]Haramaya University, P.O. Box 38 Dire Dawa, Ethiopia
[3]Wageningen University, P.O. Box 65, 8200 AB Lelystad, The Netherlands

Abstract: A study was conducted to assess feed availability and quality in peri-urban dairy production system of Debre Birhan, Jimma and Sebeta Highland areas of Ethiopia. Purposive sampling was employed to select target farms. Structured questionnaire, secondary data sources, field observations and laboratory analysis were employed to generate data. A total of 60 farmers (Debre Birhan=20, Jimma=20 and Sebeta=20) were selected for the study. The result of the study indicated that grass hay was the main basal diet in all study areas. Laboratory analysis of major feed resources indicated that hay had CP content of 6.1% and crop residues varied from 3.1 to 6.7%. In addition, crop residues had lower digestibility (48%) and its energy value ranged from 6.5-7.9 MJ/kg DM. Wheat bran and molasses had ME content of 13.2 and 12.5 MJ/kg DM, respectively. Brewery wet grains had slightly lower CP (27%) than cottonseed cake (42%) and noug seedcake (35%). Annual feed balance estimation revealed that the total estimated available feed supply met 83% of the maintenance DM requirement of livestock per farm per year while, the total estimated CP and ME were in accordance with the livestock requirement merely for maintenance. Therefore, from the current study it was concluded that the quality of available basal roughage feeds is generally low and strategic supplementation of protein and energy rich feeds should be required.

Key words: Crude protein · Feed supply · Feed quality · Metabolisable energy

INTRODUCTION

Ethiopia is believed to have the largest livestock population in Africa. The livestock population census [1] showed that Ethiopia has about 49.3 million heads of cattle, 25.0 million sheep, 21.9 million goats, 1.8 million horses, 5.4 million donkeys, 335 thousand mules, 760 thousand camels and 38.1 million poultry. This does not include livestock population of three zones of Afar and six zones of Somali regions. However, despite the large number of livestock resources in the country, its productivity is extremely low.

In Ethiopia, annual milk production per cow is generally low due to reduced lactation length, extended calving interval, late age at first calving and poor genetic makeup. Another major problem to such low milk production is shortage of livestock feeds both in quantity and quality, especially during the dry season. Furthermore, quality of native pasture is very low, especially in dry season due to their low content of digestible energy and protein and high amount of fiber content. This is much worse for crop residues owing to their lower content of essential nutrients (protein, energy, minerals and vitamins) and lower digestibilities and intake [2, 3]. Despite, these problems, however, ruminants will continue to depend primarily on forages from natural pastures and crop residues.

Peri-urban dairy production systems have been emerged around cities and towns, which heavily rely on purchased fodder. Commercialization of dairy production takes place around cities and towns where the demand for milk and milk products is high (medium and large towns). However, the production system has been constrained by several factors of which in adequate year round feed supply (quantity and quality) is the focal point. Few research works have been carried out with regard to feed availability in relation with dairy animals in urban and peri-urban dairy farms [4]. Current and up-to-date baseline

Corresponding Author: Zewdie Wondatir, Holetta Research Center, P.O.Box, 2003 Addis, Ababa, Ethiopia.
E-mail: zewbt2006@yahoo.com.

information are lacking in peri-urban areas on feed availability and quality under the prevailing situations. This study was therefore designed to gain insight in the temporal and spatial availability of feed and its quality to target interventions in feed production and management in relation to dairy development.

MATERIALS AND METHODS

Description of the Study Areas: In Jimma and Sebeta, there was no grazing land available and dairy cattle did not have access to grazing while in Debre Birhan dairy cattle are managed under indoor feeding system and let to gaze for some hours a day.

Debre Birhan is found in North Shoa administrative zone of the Amhara National Regional State and is located 130 km North of the capital Addis Ababa, at 39°30′ E longitude and 09°36′ N latitude. It is a typical Highland area with an elevation of 3360 masl. It receives an annual average rainfall of 731-1068mm and has an annual temperature range of 6-20°C [5].

Sebeta is located 25 km Southwest of Addis Ababa and situated at a latitude and longitude of 8°55'N and 38°37'E, respectively. It has an elevation of 2356 meters above sea level and has annual rainfall of about 1650 mm. The mean annual minimum and maximum temperature is 8°C and 19°C, respectively.

Jimma is located at 350 km away from the capital Addis Ababa. It is the largest city in the South Western Ethiopia. It lies between 36°10′ E longitude and 7°40′ N latitude. Its altitude is 2060 masl.

Sampling Procedures: A reconnaissance survey was conducted in order to select specific dairy farmers and to get general picture of the study sites. A total of 60 dairy farms (20 from each site) were purposively selected from the peri-urban area of each study site. A structured questionnaire was prepared and pre-tested for its applicability before its administration. Interviews were carried out at the farmer's home to enable counterchecking of the farmer's response with respect to the availability of feed resources, livestock population and the overall management system of the farm.

Feed Quantity Assessment: The quantity of feed dry matter obtainable from natural pastures were determined by multiplying the hectare with their respective estimated annual DM yield per hectare i.e. 2.0 t/ha [6]. The amount of purchased dry forages such as hay and straw was determined by estimating a single donkey load or lorry load and for baled hay by asking how many bales of hay would be purchased for a year. Whenever record was available, the quantity of purchased feeds was considered from the record. The quantity of available crop residues produced by farmers was estimated by applying grain to straw ratio [6] and assuming 10% utilization wastage [7]. The quantity of concentrates and non-conventional feed resources were estimated by interviewing the farm owners with regard to the frequency and quantity purchased per month. The grazing potential of crop stubbles was estimated using a mean of 0.5 ton per ha [6].

Chemical Analysis of Feed Samples: Chemical analysis of feedstuffs was performed at Holetta Agricultural Research Center nutrition laboratory. DM and ash contents of feed samples were determined by oven drying at 105°C overnight and by igniting in a muffle furnace at 600°C for 6 hour, respectively. Nitrogen (N) content was determined by Kjeldahl method and Crude Protein (CP) was calculated as N*6.25 [8]. Calcium (Ca) and phosphorous (P) contents were determined by atomic absorption spectrophotometry [9]. Acid Detergent Fiber (ADF), Acid Detergent Lignin (ADL), Neutral Detergent Fiber (NDF) and *In vitro* Digestible Organic Matter in the Dry Matter (IVDOMD) were determined by the modified Tilley and Terry method [10]. Metabolisable Energy (ME) and Digestible Crude Protein (DCP) content of a particular feed were estimated from IVDOMD and CP contents, respectively, as per the following equations:

$$ME\ (MJ/kg\ DM) = 0.015 * IVDOMD\ (g/kg)\ [11].$$

$$DCP\ (g) = 0.929 * CP\ (g) - 3.48\ [12].$$

Assessment of Livestock Feed Requirement: Livestock populations were converted in to Tropical Livestock Unit (TLU) for indigenous zebu cattle [13] and [14] for crossbreds. The dry matter (DM) requirements for maintenance were calculated based on daily DM requirements of a 250 kg dual-purpose tropical cattle (an equivalent of one TLU). Nutrients supplied by each feed types were estimated from the total DM output and nutrients content of that feed on DM basis [15]. The total nutrient requirements (DM, crud protein (CP) and metabolizable energy (ME) per day per livestock species were estimated based on the recommendations [16, 17] for tropical livestock.

Statistical Analysis: Data collected were analysed using Statistical Analysis System software [18]. Descriptive statistics were employed to describe qualitative variables. General Liner Model (GLM) procedure of SAS was employed to analyse the effect of classification variables.

RESULTS AND DISCUSSION

Household Characteristics: In all study areas (Debre Birhan, Sebta and Jimma), about 86.7% of the respondents were male dairy farmers while 13.3% were females (Table 1). Less number of female headed households involved in livestock keeping in the current study could probably be due to cultural issues that force females to get married and/or for economic reason. The results of the current work differ from a previous report [19] which reported 33% female headed households and 67% male headed household livestock keepers in Addis Ababa.

The educational level of the households was better in both Jimma and Sebeta than Debre Birhan (Table 2). In addition, about 10% of the farmers in the Debre Birhan area were illiterate, while in both Jimma and Sebeta the educational level of respondents was in different ranges. The difference could be attributed to better access to schools in both Jimma and Sebeta compared to Debre Birhan. Farmers with high education levels adopt usually new technologies more rapidly than lower educated farmers [20].

Livestock Herd Structure: The average livestock holding per household in all study areas was 15.6±0.2 TLU (Table 3). The number of sheep per household was higher ($P<0.05$) at Debre Birhan than the rest of study sites. This is because of suitable weather conditions and better grazing lands. The average number of horses per household was much larger in Debre Birhan ($P<0.05$) than in Jimma and Sebeta, which might be related to better adaptation to the environment and suitability of these animals for people to overcome transport problems associated with rugged terrains. At Jimma and Sebeta horses were rarely kept, but purchased from other areas for pulling carts. The average number of donkeys per household in Debre Birhan was higher ($P<0.05$) than in Sebeta. Donkeys are mainly used as pack animals in these areas.

Chemical Composition and Nutritive Value of Feeds: Chemical composition and nutritive value of the major feedstuffs in the study areas is shown in table 4. The dry matter (DM) content of all crop residues was above 90%, which corresponds with previous reports [5, 21, 22]. The crude protein (CP) content of crop residues varied from 3.05% in oats straw to 6.7% in field pea straw. Lower CP value for oats reported in this study agrees with the report of [5]. All crop residues evaluated had lower CP contents than the minimum level of 7% CP required for optimum rumen microbial function [23]. The mean *in vitro*

Table 1: Demographic characteristic of the respondents in the Highland peri-urban dairy production system of Ethiopia

	Study sites			
Household variables	Debre Birhan	Jimma	Sebeta	Total
Sex of household head	n=20	n=20	n=20	n=60
Male (%)	100.0	80.0	80.0	86.7
Female (%)	0.0	20.0	20.0	13.3
Overall (%)	100	100	100	100

n = number of respondents

Table 2: Educational level of respondents (household heads) across the study sites

	Educational status of household heads						
Study sites	Illiterate (%)	Read and write only (%)	Primary school (%)	Junior secondary school (%)	High school (%)	Above high school (%)	Total (%)
DB (n=20)	10.0	35.0	30.0	10.0	15.0	0.0	100.0
Jimma (n=20)	0.0	5.0	20.0	0.0	20.0	55.0	100.0
Sebeta (n=20)	0.0	10.0	30.0	15.0	40.0	5.0	100.0
Overall (n=60)	3.3	16.7	26.7	8.3	25.0	20.0	100.0

DB = Debre Birhan, n = number of respondents.

Table 3: Herd size and herd structure (Mean ±SE) per household in the Highland peri-urban dairy production system of Ethiopia

Livestock species	Study sites				Study sites			
	TLU							
	DB	Jimma	Sebeta	Overall mean	DB	Jimma	Sebeta	Overall mean
Cattle	11.8±0.7	11.9±1.5	8.8±1.5	10.8±0.7	14.6±0.9	13.3±1.7	11.6±1.9	13.2±0.9
Cows	3.7±0.3	5.0±0.7	5.0±0.7	4.6±0.4	6.6±0.6	9.0±1.3	9.0±1.3	8.2±0.6
Oxen	2.8±0.3[a]	0.2±0.1[b]	0.6±0.3[b]	1.2±0.2	4.2±0.5	0.2±0.1	0.7±0.3	1.7±0.3
Heifers	1.5±0.3	3.1±0.6	1.7±0.4	2.1±0.3	1.0±0.2	2.1±0.4	1.2±0.3	1.4±0.2
Bulls	1.0±0.2[a]	0.7±0.2[a]	0.1±0.1[b]	0.6±0.1	1.6±0.4	0.8±0.2	0.2±0.1	0.9±0.2
Calves	3.0±0.3	3.0±0.5	1.4±0.3	2.4±0.2	1.2±0.1	1.2±0.2	0.6±0.1	1.0±0.1
Sheep	24.2±2.9[a]	0.7±0.6[c]	2.7±0.8[b]	9.2±1.7	2.4±0.3	0.1±0.0	0.3±0.1	0.9±0.2
Goats	0.7±0.5	-	0.4±0.3	0.3±0.2	0.1±0.0	-	0.1±0.0	0.1±0.0
Horses	1.9±0.3[a]	1.1±0.2[b]	0.1±0.0[c]	1.0±0.2	1.5±0.2	0.8±0.2	0.1±0.0	0.8±0.1
Donkeys	3.1±0.3[a]	-	1.0±0.26[b]	1.4±0.2	1.5±0.1	-	0.5±0.1	1.0±0.1
Total herd size					20.1±0.3	14.3±0.4	12.5±0.3	15.6±0.2

[a-b-c] means with different letters of superscripts in the same row differ significantly (P<0.05), TLU = Tropical Livestock Unit. DB = Debre Birhan.

Table 4: Chemical composition and nutritive value of major feedstuffs in the study areas

Feedstuff	DM (%)	Chemical composition (% DM)						Nutritive values				
		Ash	OM	NDF	ADF	Lignin	CP	DCP (g/kg DM)	IVDOMD%	ME (MJ/kg DM)	Ca (g/kg)	P (g/kg)
Crop residue												
Wheat straw	93.41	9.47	90.53	80.31	56.30	13.10	3.14	25.69	43.18	6.48	0.2	0.9
Barley straw	91.62	8.53	91.47	76.77	52.84	12.14	3.55	29.5	52.59	7.89	3.3	0.8
Oats straw	92.36	7.07	92.93	75.25	54.53	15.04	3.05	24.85	48.81	7.32	0.4	1.0
Faba bean straw	92.59	6.56	93.44	73.41	50.96	9.97	6.13	53.47	47.11	7.07	1.5	0.8
Field pea straw	91.76	6.46	93.54	72.73	52.25	11.12	6.74	59.13	48.39	7.26	1.4	1.0
Grass												
Hay	92.43	13.73	86.27	76.04	49.24	10.61	6.13	53.47	48.68	7.30	0.4	1.3
Non-conventional feeds												
Coffee pulp	90.33	9.04	90.96	55.45	48.58	6.65	11.13	99.92	49.04	7.36	0.5	1.1
Bean hull	90.87	3.06	96.94	72.71	61.42	8.19	6.54	57.28	55.96	8.39	0.6	3.0
Pea hull	91.02	3.62	96.38	58.57	40.82	7.45	16.38	148.69	63.66	9.55	0.4	2.0
Atela	21.83	5.80	94.20	60.21	22.53	11.02	21.00	167.27	87.8	13.20	0.2	0.6
AIBP												
Brewery wet grain	22.20	4.74	95.26	78.58	29.94	10.72	26.82	245.68	60.31	9.05	0.3	1.7
Wheat bran	86.53	4.42	95.58	52.84	8.13	-	16.87	153.24	83.00	12.45	0.2	0.8
Cotton seedcake	92.31	7.61	92.39	47.21	20.75	6.33	42.00	386.70	60.22	9.03	0.2	1.1
Noug seedcake	93.41	10.94	89.06	33.10	27.23	7.10	34.50	317.03	68.15	10.22	1.1	0.2
Molasses	72.35	18.50	81.50	-	-	-	3.99	29.04	99.69	14.95	0.8	0.2
Crop stubbles												
Barley stubble	92.53	6.24	93.76	80.32	68.54	7.52	2.20	16.96	53.50	8.03	0.9	0.3
Wheat stubble	92.98	6.41	93.59	81.66	69.72	8.13	2.09	15.94	48.26	7.24	0.4	0.7
Faba bean stubble	92.67	4.25	95.75	75.96	62.39	10.21	3.05	24.85	44.32	6.60	0.8	0.3
Field pea stubble	92.45	3.82	96.18	77.80	58.66	12.86	3.75	31.36	41.37	6.21	0.5	0.4
Oats stubble	93.15	7.32	92.68	79.82	71.53	7.68	1.95	14.64	50.20	7.53	0.3	0.2

AIBP = Agro-Industrial By-products, Atela = a by-product of local beverage

digestible organic matter in the dry matter (IVDOMD) for cereal crop residues was about 48%, which is lower than the minimum level required for quality roughages [24; 25]. The results of the current work agree with the previous report [25] that cereal crop residues are normally characterized by low digestibility and energy value, which are both inherent in their chemical composition. The neutral detergent fiber (NDF) content of all crop residues was above 65%. [21] reported higher (> 70%) NDF contents for cereal crop residues and their stubbles. Roughage feeds with NDF content of less than 45% are categorized as high quality, 45-65% as medium quality and those with more than 65% as low quality roughages [26]. All crop residues and stubbles in this study might be categorized as low quality roughages that may inflict limitations on animal performance. The ADF content of crop residues varied from 51.0% in field pea straw to 56.3% in wheat straw. The ADF content for both crop residues and stubbles was within the recorded range [5, 22]. However, a lower ADF values for barley and wheat straw was reported [22], which could be attributed to differences in climate, crop management and soil fertility. Generally, [28] roughages were category with less than 40% ADF as high quality and above 40% as low quality. All crop residues and stubbles could be categorized as low quality roughages. The lignin content was high for both crop residues and grass hay as compared to the maximum level of 7% [29], which limits DM intake. Lignin is completely indigestible and forms lignin-cellulose/hemicelluloses complexes [28] due to physical encrustation of the plant fiber and making it unavailable to microbial enzymes [30]. The energy content of crop residues ranged from 6.48 MJ/kg DM (wheat) to 7.89 MJ/kg DM (barley) straw. The energy contents for crop residues in this study were within the reported range [25], but higher than the value of 7.0 MJ/kg DM [24]. Differences might be due to differences in management practices, soil fertility and/or crop variety used [31].

Hay obtained from native grass had CP content of 6.13%. The value observed in the present study is lower than the minimum reported value [23]. Hay had also high NDF content. NDF content of hay reported in this study was also closer to the reported values [5]. The higher NDF content could be a limiting factor on feed intake, since voluntary feed intake and NDF content are negatively correlated [32].

Metabolizable energy (ME) of commonly used energy supplements such as wheat bran, molasses and *Atela* varied from 12.5 to 13.2 MJ/kg DM. Molasses had the lowest CP content as compared to wheat bran and *Atela*. The cell wall content of molasses was almost negligible, whereas wheat bran had relatively higher fiber contents. The nutritional values for the current feeds are compatible with that reported value [25]. A standard for energy supplements was proposed [33] as those feeds, which contain high CP (13.9%), IVDOMD (82.2%) and ME (13.1 MJ/kg DM). With the exception of CP content of molasses, energy supplements (wheat bran, *Atela*) evaluated in the present work closely matched to this standard.

Among the protein supplements, brewery wet grains had slightly lower CP (26.8%) than cotton seed cake (42.0%) and nouge seedcake (34.5%). This might be due to differences in the chemical composition and type of grains used as a raw material to produce these by-products [34]. The ME contents of protein supplements were not much different. The energy content, protein content and IVDOMD in protein supplements were high though slightly lower than the reported thresholds [33] for good quality protein supplements of (CP = 32.6%), (IVDOMD = 65.5%) and (ME = 10.2 MJ/kg DM).

Calcium (Ca) and Phosphorous (P) concentrations of the major feedstuffs in the study areas except for barley straw were low as compared to the recommendations: <2.0 g/kg DM low, 2.0-3.5 g/kg DM normal and >4.0 g/kg DM high for both Ca and P [28,30].

Estimated Annual Feed Availability: The total estimated feed dry matter (DM), digestible crude protein (DCP) and metabolisable energy (ME) production per farm in the study areas is shown in table 5. The major feed resources include hay, agro-industrial by-products and crop residues. Feed dry matter was commonly obtained from hay in all study sites. However, farmers at Debre Birhan heavily rely on crop residues compared to Jimma and Sebeta. Agro-industrial by-products and non-conventional feeds were important feed resources next to hay in both Jimma and Sebeta. Use of improved fodder trees as animal feed in the study sites was rare and the dry matter calculation did not account these feed resources.

Estimated Annual Feed Balance: The total annual nutrient intake, nutrient requirement and feed balances in the study areas are shown in table 6. In all study areas, the estimated available feed supply met about 83% of the maintenance DM requirement of livestock per farm per year while the total estimated DCP and ME for maintenance were 40 and 10% surplus per year per farm, respectively. At Debre Birhan the existing feed supply on

Table 5: Estimated available dry matter production, DCP and ME supply per annum per farm in the Highland peri-urban dairy production system of Ethiopia

	Study sites								
	Debre Birhan			Jimma			Sebeta		
Feedstuffs	DM (t)	DCP (kg)	ME (MJ)	DM (t)	DCP (kg)	ME (MJ)	DM (t)	DCP (kg)	ME (MJ)
Crop residues	11.2	330.1	86141.3	-	-	-	4.6	119.1	30047.8
Hay	10.9	608.1	81578.2	14.4	770.4	105178.4	10.2	542.4	74054.9
AIBP	4.2	773.1	50442.7	8.8	1341.3	110208.9	10.2	2118.2	108726.9
Non-conventional feeds	-	-	-	4.4	508.2	43136.6	0.2	19.0	1597.7
Total	26.3	1711.3	218162	27.6	2620.0	258524.0	25.2	2798.7	214427

- Not available, Atela = a by-product of local beverage, AIBP = Agro-Industrial By-products

Table 6: Estimated annual feed dry matter and nutrient balance of livestock per farm per annum in the Highland peri-urban dairy production system of Ethiopia

	Annual nutrient supply			Estimated annual nutrient requirement			Balance of supply and requirements		
Study sites	TDM (t)	TDCP (kg)	TME (MJ)	TDM (t)	TDCP (kg)	TME (MJ)	TDM	TDCP	TME
DB TLU=20.1	26.4	1711.1	218162	41.4	2602	270912	-15	-891	-52750
Jimma TLU=14.3	27.6	2620.0	258524	31.2	1733	206889	-3.6	+887	+51635
Sebeta TLU=12.5	25.2	2798.7	219427	26.0	1387	174106	-0.8	+1412	+45321
Average	26.4	2376.6	232038	32.9	1907.3	217302	-6.5	+469	+14736

DB = Debre Birhan, TDM = Total Dry Matter, TDCP = Total Digestible Crude Protein, TME = Total Metabolizable Energy.

a year round basis satisfies only 64% of the maintenance DM requirement of the animals per farm. Similarly, the total available DCP and ME in the same area satisfy only 66% and 81% of the total livestock requirement per farm on a yearly basis. In Jimma, total annual DM requirement was 11.5% less than the annual DM requirement for maintenance. On the other hand, the total DCP and ME were 51% and 25% per farm, respectively, above the total annual maintenance requirement. In Sebeta, the total annual DM requirement for maintenance was 3% less than the requirement for maintenance while total DCP and ME were 102% and 26% above the total annual requirement per farm. Surplus DCP and ME above the maintenance requirement in Jimma and Sebeta could probably be attributed to the use of better energy and protein supplements. The larger deficit observed mostly under Debre Birhan area may be associated with poor quality of roughages and absence of supplements. Negative balance of DM requirement observed in the current study agrees with earlier works reported for different areas [7; 35]. However, reported surplus DM supply than the total annual livestock requirement in North Gondar [21].

In conclusion, the quality of available basal roughage feeds for dairy cattle in peri-urban areas of Ethiopia is generally low. Alternative means of feed production and supply particularly in dry season should be in place with the involvement of all stakeholders and development actors. Furthermore, optional feeds like brewery wet grains and other non-conventional feed resources should be further considered.

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