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Feed Resources Potential, and Nutritional Quality of Major Feed Stuffs in the Three Agro-Ecological Zone of Mixed Farming System in Arsi Zone, Ethiopia

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The poor nutritional quality of feed resources is one of the major constraints to optimize livestock productivity in the mixed farming systems of the country; however, there is lack of information on the nutritional quality of feeds utilized in the area. Thus this study aimed to evaluate the chemical composition of the livestock feed resources in the three agro-ecologies and farming systems of Arsi zone. Using stratified purposive sampling technique, 150 households who owned cattle were selected from three agro-ecologies to assess feed resources potential and to evaluate the nutritional quality majorly used feed resources. Structured questionnaire and field observation were used to

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collect detail information. The feed samples were analyzed for dry matter basis for organic matter (OM), crude protein (CP), neutral-detergent fiber (NDF), acid-detergent fiber (ADF) acid-detergent lignin, in vitro digestibility organic matter in the dry matter (IVDOMD) and Metabolizable energy (ME). The result had shown that nutrient content of feeds showed variation between the three agro-ecologies. The overall mean OM, CP, NDF, ADF, and ADL contents of natural pasture (dry and rainy season) ranged from 88.4±0.06-90.4±0.2, 7.0 ± 0.3-9.7 ± 0.2 %, 55.6 ± 0.5- 68.4 ± 0.5 %, 27.0 ± 0.97- 37.9 ± 0.3 %, 3.3 ± 0.08-7.3 ±0.3 % and55 ±0.3-78.7±0.8% and 8.2±0.05 -11.8 ± 0.1MJ/kg DM respectively, the corresponding values for crop residues varied from 88.6±0.04-94.7±0.06, 2.4 ± 0.1- 5.7 ± 0.6 %, 63.0 ± 2.8- 78.4 ±1.5 %, 43.2 ± 0.6 – 46.8 ± 0.7%, 7.8 ± 0.9 -14.8 ± 0.2, 49.4 ± 0.1- 54.8 ± 1.3 % and 7.4 ± 0.1 – 8.2 ± 0.2 MJ/kg DM respectively. During rainy season grasses in natural pasture had higher CP than dry season natural pasture grasses and crop residues. In such condition the inclusion of the green grasses during the absence of feed when the quality feed decrease in CP content could be essential. Treating of crop residue (chemical, physical and biological treatment) when reasonable to improve its nutritional quality must be imperative to enhance livestock performance in the study area and for similar situation.

Keywords: Chemical composition; crop residue; natural pasture; season.

ABBREVIATIONS

ADF: Acid-Detergent Fiber; ADL: Acid-Detergent Lignin; AEZ: Agro-Ecological Zone; CP: Crude Protein; GDP: Domestic gross product; HHs: Households; IVDOMD: In vitro digestibility organic matter in the dry matter; ME: Metabolizable Energy; N: Number of sample size; NDF: Neutral-Detergent Fiber; OM: Organic Matter.

1. INTRODUCTION

"In Ethiopia agriculture is the backbone of 's economy and accounts for 34.1 % of the national domestic gross product (GDP), employs 79 % of the population, accounts for 79 % of foreign earnings, and is the major sources of raw material and capital for investment and market" [1]. "The livestock sector significantly contributes to sustainable agricultural development where it accounts approximately 17% of total gross domestic product (GDP) and 39% of agricultural GDP" [2].

According to the [3] "livestock is a resource of significant benefit to society in the form of food, income, nutrients, employment, insurance, traction, and clothing". "Livestock products including live animals, meat, and leather goods are a major source of foreign exchange about 6.4 percent of total exports" [4]. In the present study area, one of the most important and integral component of livestock keeping in the mixed crop-livestock farmers' is to earn income and livelihood activities.

"Livestock development in the country has been constrained by a number of interrelated factors encompassing: technical, infrastructural, organizational, institutional, and environmental and policy aspects. The major technical constraints include: under-nutrition, high disease prevalence, low genetic potential of the indigenous breeds for productive traits, poor husbandry practices and weak marketing system. Among these, shortage of feed supply, low quality and seasonal fluctuations in feed availability are the most limiting factors on account of the fact that feed cost accounts for about 60 to 70% of all costs associated with livestock production" [5]. "Feed both in terms of quantity and quality is a major bottleneck for livestock production in Ethiopia" [6]. Similarly, [7] revealed that "a major constraint of the livestock production in developing countries is the scarcity and fluctuating quantity and quality of the year-round feed supply. Because of this the productivity of ruminant livestock in the tropics and subtropics is limited by inadequacy of good quality and nutritive feed".

"The poor feeding system and low quality feeds resulted slow productivity and high enteric CH_4 emissions, making developing countries responsible for high emissions per unit of product" [8]. "These emissions are of worldwide concern, particularly in countries such as Ethiopia where large populations of ruminants are located. Furthermore, CH_4 emissions represent a loss (up to 15%) of digestible energy to the animal as well as a threat to the environment" [9]. "Estimates of CH_4 emission (data from The World Bank) indicate that agriculture, almost entirely through livestock, totaled 60.3 MT CO2-eq. in 2008, which is approximately 71% of the national CH_4 emissions. Given the sizeable ruminant population in the country and the extensive nature of the production systems, the contribution of ruminants to GHG emissions is likely to be much greater than what is currently known. In any case, owing to the rising demand for livestock products, the population of domestic ruminants is likely to increase, which considerably accelerates the increase in GHG emissions" [10]. Only limited documentation exists, however, regarding CH_4 emissions from the ruminant population feeding different feed resources in Ethiopia. As a result, limited mitigation efforts are directed toward this sector. It is therefore important to known the quality of feed to reduce the emissions of CH_4 that aggravate the problems, and to study mitigation options.

Other important things to be gathered is that, information on nutritional characteristics of the major livestock feed resources have not yet been documented in literature and the information from the present study would permit police makers and farmers to plan appropriate intervention strategies. Therefore, better understanding the chemical composition and digestibility of the available feed resources will contribute to highlight potential gaps for quality improvement and proper utilization for livestock productivity improvement. The objective of this study was to assess, evaluate and document chemical composition and in vitro digestibility of the major feed resources in the Arsi zone, Oromia Regional State, Ethiopia.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The study was conducted in Arsi zone of the Oromia Regional State, Ethiopia, located at 175km southeast of Addis Ababa, the capital city of Ethiopia. The zone is located between 6˚45'N to 8˚50'N latitude and 38˚32'E to 40˚50'E longitude. The altitude ranges from 500 to 4,245 m a.s.l. with highland altitude comprising 45.54%, midland altitude 34.88% and low altitude 19.58 % of the study area. The range of annual rainfall is 700-1658 mm and annual range of relative humidity is 43-60%. The mean annual temperature of the Zone ranges between 20˚C - 25˚C in the low land and 10˚C -15˚C in the central high land.

2.2. Feed Sample Collection, Preparation and Analysis

The study area was stratified in to highland, midland and lowland districts based on agro-ecology, farming system, rain fall, livestock population and feed resource availability. From 25 districts, five districts were selected that represented the area. From each district 30 households (HHs) were randomly selected. Structured questionnaire was used to collect information on the all relevant variables.

The major feed resources collected from the farmers' gives high priority regarding their relative abundance and importance as livestock feed. Samples of feed resources collected for chemical composition analysis. During the sampling period, grasses were cut at 5cm above the ground. Representative samples of grasses were collected as hay form during the dry period and wet grasses during the long rainy season (700-1658mm) in the three agro-ecologies. The samples were kept under a shaded area until sampling for the collecting day was completed. While for other feeds such as crop residues representative samples were collected in the seasons of their availability. After plant sampling, the same feed types were bulked together and then thoroughly mixed and further sub-sampled. The samples were immediately weighed after sampling and put in a cloth sack and hung in the shade area until samples were transported to laboratory for drying and subsequent chemical composition analysis. Lastly, samples were dried to constant mass in an oven at 65 ^{o}C for 72 h before subsequent nutrient analysis. The dry samples were ground in Willey mill to pass through 1 mm mesh sieve size and packed in air tight plastic containers until analysis for chemical composition at Debrezeit/ Bishoftu Agricultural Research Center's, Animal Nutrition Laboratory. The samples were analyzed in % DM basis separately for highland, midland and lowland of agro-ecologies. "The DM and ash contents were determined by oven drying at 105^{O}C overnight and igniting in a muffle furnace at 500^{O}C for 6 hours, respectively" [11]. Nitrogen (N) content is determined by the Kjeldahl method and crude protein (CP) were calculated as N * 6.25 [11]. "Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were analyzed" according to Van Soest et al. [12]. In vitro studies were conducted to estimate the potential digestibility of the poled sample of the grasses and crop residues. The in vitro digestibility organic matter in the dry matter

(IVDOMD) was determined by Tilley and Terry method as modified by [13]. Metabolizable energy of a given feed was estimated from IVDOMD employing the following formulae:

ME (MJ kg-1 DM) = [0.15*IVDOMD (%)] [14].

2.3 Statistical Analysis

The collected data were statistically analyzed using Statistical Package for Social Sciences (IBM SPSS) software for window, Version 22.0 [15]. Mean, percentages and standard error of various parameters were calculated for each altitude zones of the study area. Whereas quantitative variables were analyzed using analysis of variance procedures and when the F-test showed significant differences, Tukey HSD at 5% significance level was used for comparison of means. Differences in chemical composition of feeds between AEZs were tested using analysis of variance (ANOVA).

3. RESULTS

3.1 Major Livestock Feeds in the Study Area

The major feeds used by livestock in the study area were indicated in Table 1. The major feed sources in the highland agro-ecology, crop residues dominants feed resources followed by natural pasture and crop aftermath. This is mainly due to the majority of available land is changed to crop production and little marginal land hand left for animal grazing.

In midland it was indicated that animals depends upon crop residues utilization largely followed by natural pasture and crop aftermath. Grazing land was shrinking to crop production and fringe land left for animal grazing. In the lowland of the study area, natural pasture and browse trees and shrubs were the dominants feed.

3.2 Seasonal Availability of Feed Resources

The seasonal feed availability in the study area was varied across the seasons as shown in (Fig. 1). The utilization of natural pasture was higher during the rainy season (June, July, August, and September) due to sufficient amount of moisture in the soil. During the dry season crop residues were the most available feed sources for all the three agro-ecologies in the study area. The months of March, April and May are periods of highest feed scarcity in the study area.

3.3 Chemical Composition of Natural Pasture

The chemical composition (% of DM) of the natural pastures utilized during seasons and over locations in the study area is presented in Table 2. The nutrient compositions of natural pasture were significantly varied ($P<0.05$) across season and over locations. The NDF, ADF and ADL were significantly higher ($P<0.05$) for lowland while higher ($P<0.05$) CP content was recorded for mid altitudes in both seasons. The CP content of the dry season grasses hay ranged from 5.8 ± 0.2 % in the lowland to 7.9 ± 0.2% in the midland while in the ranged from 9.2 ± 0.05% in the lowland to 10.4 ± 0.03 % in the midland. The mean NDF contents of dry season natural grass hay ranged from 67.2 ± 0.6% in the midland to 70.5 ± 0.3% in the lowland of the study location. Likewise, the mean NDF contents of rainy season natural grasses ranged from 54.41 ± 0.3% in the midland to 57.07 ± 0.3% in the lowland of the agro-ecologies. The ADF contents of dry season grasses hay samples ranged from 37.2 ± 0.1 % in the highland to 39.2 ±0.3 % in the lowland area of the study location. Likewise, the ADF contents of rainy season natural grasses ranged from 24.0± 0.2 % in the midland to 29.1 ± 0.1% in the lowland area of the agro-ecologies.

Table 1. Major feed resource in the study area (percentage of the HH)

Major feed type	Agro-ecology Lowland (N=30)	Midland (N=60)	Highland (N=60)	X^2	P-value
Natural Pasture	90	63.3	66.7	7.3	0.026
Crop Residues	56.7	88.3	71.7	11.52	0.003
Crop Aftermath	36.7	63.3	61.7	6.58	0.037
Improved Forage	6.7	30	31.7	7.33	0.026
Browse Trees and Shrubs	63.3	58.3	13.3	6.7	0.035
Agro-industrial by-products	6.7	36.7	36.7	10.2	0.006
Unconventional feeds	10	35	40	8.69	0.013

HH= Household

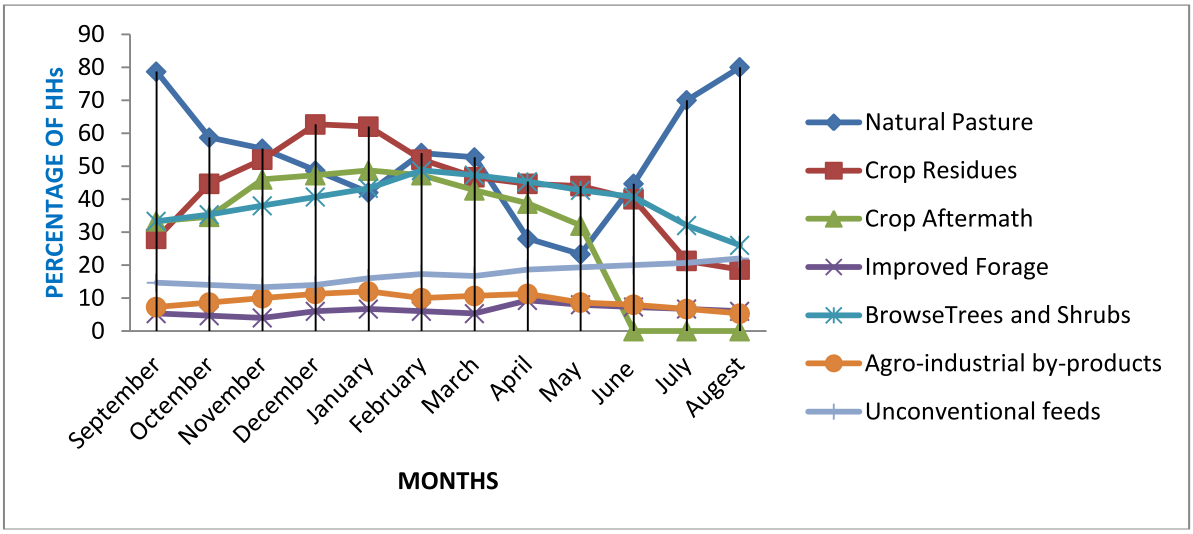

Fig. 1. Months of feed resource availability in the study area

Table 2. Mean ± SE of chemical composition of the seasonal natural pasture grass in the study area

Season	Agro-ecology	OM	Ash	CP	NDF	ADF	ADL
Dry	Lowland	89.5(0.3)[b]	10.65(0.2)[a]	5.8(0.2)[b]	70.5(0.3)[a]	39.2(0.3)[a]	8.5(0.2)[a]
	Midland	90.2(0.2)[ab]	9.8 (0.2)[b]	7.9(0.2)[a]	67.2(0.6)[b]	37.3(0.4)[b]	6.7(0.3)[b]
	Highland	90.4(0.2)[a]	9.56 (0.2)[b]	7.4(0.4)[a]	67.4(0.1)[b]	37.2(0.1)[b]	6.8(0.07)[b]
	Over all	90(0.2)	10.0 (0.2)	7.0(0.3)	68.4(0.5)	37.9(0.3	7.3(0.3)
	P-value	0.034	0.014	0.001	0.000	0.001	0.000
Rainy	Lowland	89.7(0.04)[a]	10.3 (0.05)[b]	9.2(0.05)[c]	57.1(0.3)[a]	29.1(0.1)[a]	3.5(0.05)[a]
	Midland	88.4(0.06)[b]	11.6 (0.07)[a]	10.4(0.03)[a]	54.4(0.3)[b]	24.0(0.2)[c]	3.1(0.01)[b]
	Highland	89.6(0.1)[a]	10.4 (0.1)[b]	9.5(0.03)[b]	55.4(0.2)[b]	27.9(0.08)[b]	3.2(0.04)[b]
	Over all	89.2(0.3)	10.8 (0.3)	9.7(0.2)	55.6(0.5)	27.0(1.0)	3.3(0.1)
	P-value	0.004	0.004	0.000	0.011	0.000	0.008

Means followed by different superscript letters within a column for each feed type are significantly different at P < 0.05; SE = standard error of means; DM =Dry matter; CP = Crude Protein; OM=Organic Matter; NDF= Neutral Detergent Fiber; ADF =Acid Detergent Fiber; ADL=Acid Detergent Lignin

3.4 Chemical Composition of Major Crop Residues

The chemical composition of crop residues is presented in Table 3. The chemical composition of crop residues were significantly (P<0.05) varied over the agro-ecologies. The OM contents of the crop residues ranged from 88.62 ±0.04 % of sorghum stover in lowland to 94.7 ± 0.06 % pea haulms in midland of the agro-ecologies.

The OM contents of maize stover, and teff, barley straws and pea haulms showed a significant (P<0.05) difference between the two agro-ecologies. The OM contents of sorghum stover, wheat straw and faba bean haulms showed a significant (P<0.01) difference between the two location of the study area. The CP contents of crop residues ranged from 2.1 ± 0.03% in wheat straw in midland agro-ecology to 6.7 ± 0.08 % in field pea haulms in midland agro-ecology of the study area. CP content of all crop residues showed significant (P<0.05) difference between the two agro-ecologies.

The NDF contents of crop residues ranged from 58.1 ±0.5 % in Faba bean haulms in the highland area to 81.0 ± 0.4 % in wheat straw in highland area of the agro-ecology and showed a significant difference (P<0.05) between the agro-ecologies. In lowland agro-ecology of the study area, the average ADF contents of maize stover, sorghum stover and teff (*Eragrotis teff*) straw were 49.3 ± 0.02 %, 48.9 ± 0.3 % and 49.3 ± 0.5 % respectively. The ADF contents in midland of agro-ecology of maize stover, sorghum stover, teff (*Eragrotis teff*) straw, barley straw, wheat straw, bean haulms and pea haulms were 43.8 ± 0.4%, 42.1 ±0.6 %, 43.0 ± 0.2 %, 42.1 ± 0.01, 45.3 ± 0.01 %, 47.2 ± 0.07 % and 48.1 ± 0.2 %

respectively. Similarly, the ADF contents in highland of the agro-ecology of barley and wheat straw, bean haulms and pea haulms were 44.2 ±0.01 %, 44.0 ± 0.2 %, 43.6 ±0.08 % and 45.6 ±0.06 % respectively. In three agro-ecologies of the study area, the highest ADF content was recorded in both maize stover and teff straw while the lowest was observed in both sorghum stover and barley straw. The ADF content of all crop residues showed a significant difference (P<0.05) between the two agro-ecologies of the study area.

3.5 IVDOMD and ME of the Feed Type

In vitro DM digestibility and metabolizable energy (% of DM) of the feed type in the study area are presented in Table 4. The In vitro DM digestibility content dry season grasses ranged from 53.7 ± 0.2 % in the lowland to 55.7 ± 0.4% in the midland, with significantly difference (P<0.01) between the agro-ecologies. Similarly, the In vitro DM digestibility content of rainy season grasses ranged from 62.3 ± 0.04% in the lowland to 66.9 ± 0.06 % in the midland, with significantly difference (P<0.001) between the study locations. The crop residues of the IVDOMD content ranged from 47.7 ± 0.5% in wheat straw in midland agro-ecology to 57.0 ± 0.3 % in field pea haulms in midland agro-ecology of the study area. IVDOMD content of all crop residues showed significant difference (P<0.05) between the agro-ecologies. In the study area feeds IVDOMD values ranges between 43.2-53.6% for cereal straw 47.1- 52.1 % stover and 52.6-57 % pulse haulms across the acro-ecologies. The metabolizable energy content dry season grasses ranged from 8.1 ± 0.03 % in the lowland to 8.3± 0.06% in the midland, with significantly difference (P<0.01) between the agro-ecologies. Likewise, metabolizable energy content rainy season grasses ranged from 9.3 ±0.01 % in the lowland to 10.0 ± 0.01 % in the midland, with significantly difference (P<0.001) between the agro-ecologies.

Table 3. Chemical composition (mean ± SE) of major crop residues (% DM basis) in the study area

Crop residue	Agro-ecology	OM	Ash	CP	NDF	ADF	ADL
Maize stover	Lowland	90.3(0.04)[b]	9.7 (0.04)[a]	3.0(0.02)[b]	77.8(0.1)[a]	49.3(0.02)[a]	8.6(0.1)[a]
	Midland	93.2(0.3)[a]	6.8 (0.3)[b]	5.8(0.1)[a]	74.6(0.3)[b]	42.8(0.4)[b]	7.5(00.03)[b]
	Over all	91.7(0.8)	8.3 (0.8)	4.4(0.8)	76.2(0.9)	46.1(1.9)	8.0(0.3)
	P-value	0.012	0.012	0.002	0.002	0.004	0.01
Sorghum stover	Lowland	88.6(0.04)[b]	11.4 (0.04)[a]	2.82(0.3)[b]	73.7(0.04)[a]	48.9(0.3)[a]	9.4(0.07)[a]
	Midland	90.8(0.08)[a]	9.2 (0.08)[b]	4.9(0.3)[a]	66.9(0.07)[b]	42.1(0.6)[b]	6.2(0.03)[b]
	Over all	89.7(0.6)	10.3 (0.6)	3.9(0.6)	70.3(1.9)	45.5(2)	7.8(0.9)
	P-value	0.002	0.002	0.037	0.000	0.008	0.001
Teff Straw	Lowland	90.5(0.2)[b]	9.5 (0.2)[a]	4.5(0.1)[b]	75.9(0.3)[b]	49.3(0.5)[a]	10(0.1)[a]
	Midland	92.8(0.3)[a]	7.2 (0.3)[b]	5.4(0.05)[a]	79.3(0.6)[a]	43.0(0.2)[b]	8.0(0.2)[b]
	Over all	91.6(0.7)	8.4 (0.7)	4.9(0.3)	77.6(1)	46.2(1.8)	9.0(0.6)
	P-value	0.026	0.026	0.015	0.04	0.007	0.017
Barley straw	Midland	92.0(0.1)[b]	8.0 (0.1)[a]	3.7(0.1)[a]	79.8(0.04)[a]	42.1(0.01)[b]	10.3(0.07)[a]
	Highland	93.1(0.2)[a]	6.9 (0.2)[b]	3.0(0.03)[b]	76.1(0.1)[b]	44.2(0.1)[a]	7.7(0.06)[b]
	Over all	92.6(0.3)	7.4 (0.3)	3.3(0.2)	78.0(1)	43.2(0.6)	9.0(0.8
	P-value	0.039	0.039	0.042	0.002	0.004	0.001
Wheat straw	Midland	90.4(0.09)[b]	9.6 (0.1)[a]	2.1(0.03)[b]	75.8(0.5)[b]	45.3(0.01)[a]	11.9(0.2)[a]
	Highland	93.2(0.05)[a]	6.8 (0.05)[b]	2.6(0.05)[a]	81.0(0.4)[a]	44.0(0.2)[b]	7.8(0.4)[b]
	Over all	91.8(0.8)	8.2 (0.8)	2.4(0.1)	78.4(1.5)	44.6(0.4)	9.8(1.2)
	P-value	0.001	0.001	0.016	0.016	0.03	0.011
Bean haulms	Midland	92.3(0.09)[b]	7.7 (0.1)[a]	5.1(0.05)[b]	67.8(0.3)[a]	47.2(0.07)[a]	11.7(0.3)[b]
	Highland	94.4(0.03)[a]	5.6 (0.04)[b]	5.8(0.1)[a]	58.1(0.5)[b]	43.6(0.08)[b]	13.5(0.05)[a]
	Over all	93.4(0.6)	6.6 (0.6)	5.4(0.2)	63.0(2.8)	45.4(1.0)	12.6(0.5)
	P-value	0.002	0.002	0.032	0.003	0.001	0.036
Pea haulms	Midland	94.7(0.06)[a]	5.3 (0.06)[b]	6.7(0.08)[a]	70.1(0.3)[a]	48.1(0.2)[a]	15.2(0.06)[a]
	Highland	93.7(0.2)[b]	6.3 (0.2)[a]	4.7(0.03)[b]	66.3(0.3)[b]	45.6(0.06)[b]	14.5(0.02)[b]
	Over all	94.2(0.30	5.8 (0.3)	5.7(0.6)	68.2(1.1)	46.8(0.7)	14.8(0.2)
	P-value	0.03	0.03	0.002	0.013	0.005	0.008

Means followed by different superscript letters within a column for each feed type are significantly different at P < 0.05; SE = standard error of means; DM =Dry matter; CP = Crude Protein; OM=Organic matter; NDF= Neutral Detergent Fiber; ADF =Acid Detergent Fiber; ADL=Acid Detergent Lignin

Table 4. Mean in vitro dry matter digestibility (% DM) and metabolizable energy (MJ/kg DM) of the major livestock feed resources

Feed type	Nutrient Composition	Agro-ecology Low land	midland	Highland	Over all	P-value
Dry season	IVDOMD	53.7 (0.2)^{b}	55.7 (0.4)^{a}	55.5 (0.1)a	55 (0.3)	0.002
grasses	ME	8.1 (0.03)^{b}	8.3 (0.06)^{a}	8.3 (0.04)a	8.2 (0.05)	0.002
Rainy season	IVDOMD	62.3(0.04)^{c}	66.9 (0.06)^{a}	64.9(0.04)^{b}	78.7(0.8)	0.0001
grasses	ME	9.3 (0.01)^{c}	10.0 (0.01)^{a}	9.7 (0.01)^{b}	11.8 0.1)	0.0001
Maize	IVDOMD	48.0 (0.4)^{b}	52.1 (0.4)^{a}		50.1(1.2)	0.022
stover	ME	7.2 (0.06)^{b}	7.8(0.07)^{a}	NA	7.5(0.2)	0.022
Sorghum	IVDOMD	47.1 (0.4)^{b}	51.2(0.5)^{a}		49.1(1.2)	0.023
stover	ME	7.1 (0.06)^{b}	7.7(0.1)^{a}	NA	7.4(0.2)	0.023
Teff	IVDOMD	50.9 (0.3)^{b}	53.6(0.5)^{a}		52.2(0.8)	0.05
straw	ME	7.6(0.05)^{b}	8.0(0.08)^{a}	NA	7.8 (0.1)	0.049
Barley	IVDOMD		53.0 (0.0)^{a}	52.1(0.03)^{b}	52.6(0.3)	0.048
straw	ME	NA	8.0 (0.03)^{a}	7.8(0.0)^{b}	7.9 (0.04)	0.048
Wheat	IVDOMD		47.7 (0.5)^{b}	51.1(0.4)^{a}	49.4(1)	0.036
straw	ME	NA	7.2 (0.1)^{b}	7.7 (0.1)^{a}	7.4 (0.1)	0.036
Faba bean	IVDOMD		53.2(0.2)b	55.6(0.5)^{a}	54.4(0.7)	0.048
haulms	ME	NA	8.0(0.03)b	8.3(0.08)^{a}	8.2(0.1)	0.046
Field Pea	IVDOMD		57.0 (0.3)^{b}	52.6 (0.07)^{a}	54.8(1.3)	0.025
haulms	ME	NA	8.5(0.04)^{b}	7.9 (0.1)^{a}	8.2(0.2)	0.025

Means followed by different superscript letters within a row for each feed type are significantly different at P < 0.05; 0.01; IVDOMD= in vitro digestibility organic matter in the dry matter; ME= Metabolizable energy; NA= Not available

The metabolizable energy content crop residues ranged from 7.2 ±0.1 % in wheat straw in the midland to 8.5 ±0.04 % in field pea haulms in midland agro-ecology of the study area. metabolizable energy content of all crop residues showed significant difference (P<0.05) between the agro-ecologies.

4. DISCUSSION

4.1 Major Livestock Feeds in the Study Area

In the study area natural pasture grazing, crop residues, crop aftermath, forage crops, concentrate feeds and unconventional feeds (atella, weeds and house left over). Which are similar to the feed sources in most highlands of Ethiopia reported by [16–18]. Generally, natural pasture, crop residues and browse tree and shrubs were the dominant feed sources in the study area but improved forages, and concentrate feed were uncommon and rarely available. In each agro-ecology the major feed types in the highland of the study area are crop residues, nature pasture, crop aftermaths, unconventional feeds, concentrate feed and improved forages whereas in midland crop residues, natural pasture and crop aftermath are dominants in their descending order. In lowland area natural pasture, crop residues, and browse tree and shrubs contributed the most dominant feed in their descending order that similar reported by [19] in Adami Tullu Jido Kombolcha district of East Showa Zone.

4.2 Seasonal Availability of Feed Resources

Common forms of grazing, crop residues and Unconventional feeds sources and their season of utilization were given in Fig. 1. The major feed types used by animals in the study area were: natural pasture, crop residues, crop aftermath, improved forage, agro-industrial by-product and unconventional feeds [18,20]. The utilization of natural pasture was higher in rainy seasons (June, July, August, and September) due to sufficient moisture amount in the rain season which is similar reported by [21]. This was caused by the shortage of rainfall in the low lands, drought, and lack of awareness to collect and preserve feed for the dry season feeding throughout in the study area. According to the respondents, feed shortage occurs in April and May. During this period natural pasture becomes extremely poor and HHs provides livestock with any available dry crop residues and tree leaves. Another important challenge in livestock production in the study area is the conversion of grazing lands into cultivated lands at the expense of grazing areas for livestock production due to the increased human population. Improving the quantity and quality of forage produced will also improve animal feed efficiency, reduce CH_4 emissions per unit of animal product, and lead to production benefits for farmers.

4.3 Chemical Composition of Natural Pasture

Based on the laboratory chemical composition analysis of the feeds, CP contents of natural pasture vary across the agro-ecologies and season. This variation in CP content of grasses between the season and agro-ecology might be due to stage of maturity, species, location or climate and fertility of the land. The differences in CP content of the natural pasture might be attributed to management practices (tillage frequency and weeding), degree of soil fertility and differences in the proportion of grass-legume of the grazing areas. This result of the dry season natural pasture grass hay was almost similar the report of [22] between the wealth group in bale zone. Result of rainy season grasses is in agreement with the finding of [23], who reported natural grasses CP contents of 8.46 to 12.9 % in west Wollega zone. The result of dry season grasses is in agreement with the finding of [24] who reported natural pasture grass CP contents of 6.25 to 7.5% in Sidama zone. The CP contents obtained in our study are in the ranges reported for rangeland grasses by [25]. The minimum allowance level of CP level in the feed daily ration is 7% for tropical feed species [26]. The dry season grasses that found in the lowland agro-ecology were below this critical CP level. This variation could be attributed to the species of the grass, soil, temperature, and amount and intensity of rainfall. Feeds with CP content less than 7% inhibits voluntary feed intake and microbial activity, resulting in poor digestibility of roughages [26].

The NDF content of dry season natural grasses from the different altitude were above 65% which are categorized as low quality feed and NDF content of rainy season natural grasses from the different altitude were less than 65% which are categorized as medium quality feed [27]. The NDF contents of the grasses lie above the critical value of 65% which was reported to result in decreased voluntary feed intake, feed conversion efficiency and longer rumination time [28]. Its chemical constituents differ with environmental factors such as altitude, rainfall, soil type, cropping intensity, grazing land management and variation in the genetic characteristics inherent to specific individual plant species [29]. These factors also affect forage yield, intake and digestibility and animal grazing behaviour [30]. The feeding value of animal feed determines the optimal herbivore body size and the relative success of livestock. Hence, evaluating the nutritional value of animal feed is imperative in livestock feeding because effective livestock production is linked to the quantity of nutrients in the feed. The greater NDF, ADF and ADL, and lower CP concentration of natural pasture in the lowland than highland and midland is associated with species compositions and differences in climate, such as warm temperature and moisture stress.

4.4 Chemical Composition of Major Crop Residues

Crop residues are becoming increasingly important as sources of roughage feeds for ruminants. These include cereal straws like teff, wheat, barley, maize, and sorghum, grain legume haulms, such as faba beans and field peas. Similarly, [31] reported crop residues are the major feed for animal feeding. The CP content of crop residues in this study is similar to the findings by [23,32] who found 2.98% in wheat straw to 5.97 % in haricot bean straw and 2.39 ± 0.16% in wheat straw to 7.2 ±0.09 % in faba bean straw. This difference could be due to variation in crop variety, soil fertility, climate, temperature and harvesting techniques of the crop residues. In earlier studies, Adugna, [33] who reported CP content of crop residues ranging from 2.8 %–5.6 %, respectively. The CP content of this finding is lower the finding by [4,34] who found 2.01% in wheat straw to 8.34 % Pisum sativum straw and 3.94% sorghum stover to 9.19 % in noug chaff respectively. Feeds with the CP level less than 7.5 % inhibits voluntary feed intakes and the activity of microbial action declines, resulting in lower digestibility of roughages [26]. In the current study, cereal straws and stovers varied greatly in their CP content, which could be attributed to differences in crop species and variety, agronomic practices (fertilizer application), soil and temperature, stage of growth and variation in different parts of the same plant [34,35].

The NDF contents of crop residues obtained in the current study are lower than the range of 33.97 % to 93.05 % reported by [34]. NDF content of roughage feeds with less than 45 % is categorized as a high quality feed and 45–65 % as medium quality feed [27]. Based on these categories, the NDF content of crop residues in our study was high. NDF content of feeds above 55% was reported to limit DM intake [36]. Hence, the high fiber content can hamper the feed intake of animals, resulting in reduced animal performance. Crop residues are low in protein and high in fiber and lignin. As a result, digestion is slow, rate of passage is low and voluntary intake is limited [26]. In general crop residues, mainly cereal crops are used as major feeds for ruminant livestock, particularly during the dry season. However, the fact that straws and stover are high in structural components and their associated fiber contents, their utilization for animals is limited due to their poor quality.

4.5 IVDOMD and ME of the Feed Type

The type, quality, quantity and stage of maturity of available feed resource are influenced by season. The IVDOMD from the rainy season grasses was better than other dry season grasses followed by roughage feeds (stovers, straws and pulse haulms) across the agro-ecologies Whereas, the IVDODM from natural pasture (dry and rainy) season grasses of the agro-ecologies looks good and the values where comparable to 57.2% native grass hay of Ethiopia feeds [33]. Mosi and Butterworth, (1985) stated that feeds with less than 50% OMD reduce the intake to 50 g/kg $LW^{0.75}$ or less. The natural pasture IVDOMD value was within the range of roughage feeds IVDOMD values to maintain the voluntary intake of the animals though the annual DM yield from natural pasture was very low in the area. There is a positive correlation between CP and IVDOMD [34]. This means that in the availability of CP, better digestibility and increase the productivity of the livestock. This results complements with the findings of [33,34] in southern Ethiopia. The mean in vitro digestibility organic matter in the dry matter (IVDODM) for crop residues was 51.8% which is higher than the minimum level of 50 % required for quality roughages [37].

The ME (MJ/Kg DM) of wheat and feff straw, maize and sorghum stover were comparable, while that dry and rainy season grasses, barley straw, faba bean and field pea haulms (Table 4) higher than the value 7.3 MJ/kg DM reported on roughage feeds in Ethiopia [38]. The result of the current study was higher than 7.73 MJ/kg DM energy content of green feeds in Adami Tulu area [32]. Straws and stovers are potential energy feeds of their high cellulose and hemicellulose contents. Unfortunately the energy in cellulose and hemicellulose is only partly available to animals, because of poor digestibility due to inhibitory elements in the straw [27].

5. CONCLUSION

The results of the present study showed that greater NDF, ADF and ADL, and lower CP concentration of natural pasture in the lowland than highland and midland is associated with species compositions and differences in climate, such as warm temperature. This study showed that dry season lowland natural pastures and crop residues are of poor quality due to high cell wall fiber components (NDF, ADF and ADL) hence their digestibility is low. Besides, these feed resources showed CP contents below the critical level (7%) required for optimum rumen function and feed intake resulting in low livestock productivity. Crop residues and natural pasture, the most widely available feed resources, are very low in CP, IVDMD and ME but high in NDF and ADF, which indicates that they cannot meet the nutrient requirement of animals unless supplemented with better quality feeds. Therefore, it is suggested that improved forage trees and chemical treatment (urea treatment) of crop residues to improve their nutritive value or using concentrate feed that have good energy and protein sources of feeds would be vital to enhance productivity and sustainable development of livestock in the study area. Further study should be directed towards the improvement of supplying improved forage and supplementary feed for enhancing the crop residues and matured natural pasture in the animal diet inclusion.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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