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RESEARCH ARTICLE

EVALUATION OF THE NUTRITIONAL PROFILE OF COMMON LIVESTOCK FEEDS

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ABSTRACT

Twenty livestock feed samples were analyzed for chemical composition, in-vitro gas production, gas characteristics, and in-sacco dry matter (DM) degradability. The dried and milled samples (200 mg/ 30 ml) with inoculum were incubated for 3, 6, 9, 12, 15, 21, 27, 33, 39, 48, 60, 72, and 96 h to determine the in vitro gas and methane production. For in-sacco DM degradability, 300 mg feed samples were incubated in the rumen of fistulated crossbred steers for 3, 6, 12, 24, 48, 72, and 96 h. The crude protein content ranged from 177 to 236 g/kg DM for tree and herbaceous legumes, 88.2 – 139 g/kg DM for grasses, and 88 –337 g/kg DM for concentrates. The local distillery by-product (Arekeatela) had the highest neutral content (722 g/kg DM) the lowest for maize grain (204g/kg DM). The readily degradable fraction (a) of tree and herbaceous legume species was highest for Lablab (31.48%) and lowest for pigeon pea (8.6%). From concentrate ingredients, the effective DM degradability was greatest for maize grain (74.8%) and lowest for brewer spent grain (40.7%). Generally, from the study feeds from tree and herbaceous legumes, lablab, vetch, and tree lucerne, grasses desho and Guatemala, concentrate ingredients maize, oat grain, wheat bran, noug seed cake, and cotton seed cake are preferred for supplementation. However, home brewing and distilling by-products, and brewery spent grain have non-negligible values and are used for the strategic supplementation of poor-quality roughage. Further studies are needed to validate their supplementary value and levels of inclusion in animal diets.

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INTRODUCTION

Livestock feed resources commonly used for dairy cows and other ruminants in Ethiopia are natural pasture, crop residues, agro-industrial by-products, and crop aftermath except for urban dairy producers (Tegegne *et al.* 2013; Mengistu, *et al.* 2017). Natural pasture and crop residues contain high fiber and are low in digestibility, which is not ideal for livestock production (Tolera, 2008). Natural grazing lands have decreased in area due to encroachment by arable farming, they are overgrazed with low productivity and poor nutritional quality. The main problem in livestock feeding systems in the country is the inability to meet the nutrient requirements of animals for maintenance and production (Tolera, 2007). Thus, there is a need to improve the nutritional quality of feeds through supplementation to correct nutrient deficiencies and meet the nutrient requirements of the animals for production and reproduction. Among the non-conventional feeds, *Atela*(a traditional home brewing and distilling residue) and coffee pulp are among the feed resources that can be exploited by farmers (Mekasha, 1999).

The contribution of these feed resources depends on the agroecology, types of crops produced, accessibility, and production system (Tegegne *et al.*2013; Feyissa *et al.* 2015). Most fibrous ruminant feeds are deficient in energy, protein, minerals, and vitamins. In addition, they are highly lignified with low digestibility. A nutritional assessment of alternative feeds is required to establish strategies for the utilization of homemade diets using locally available agricultural and agro-industrial byproducts as sources of protein or energy for smallholder farmers. Periodic assessments and laboratory analyses of nutritional composition of novel and alternative feedstuffs are required to generate updated information so that farmers can use them as resources for balanced dairy diets and improve productivity. In vitro and in sacco analyses provide a more reliable assessment on the feeding value of given feed resources. The use of in vitro techniques in feed evaluation for ruminants has increased due to its ease of adoption, repeatability, cost and does not require use of animals (Getachew *et al*., 2005). Therefore, the present study aimed to assess the nutritional profiles of twenty commonly found local livestock feeds through in vitro gas production, and in sacco degradability analyses.

MATERIALS AND METHODS

Feed samples and sample preparation: The study was conducted at the College of Agriculture, Hawassa University, Sidama Regional State, Ethiopia. In sacco rumen degradation study was carried out at the Holeta Agricultural Research Center of the Ethiopian Institute of Agricultural Research, Holeta, Ethiopia. Holeta Agricultural Research Centre (Oromia Regional State) is located at 38.5°E longitude and 9.8°N latitude and an elevation of 2,400 meters above sea level. It is situated in the central highlands of Ethiopia and the average annual rainfall is approximately 1,200 mm (Demeke *et al*. 2004). Twenty feed samples were collected for analysis. The feed samples were leaves and twinges of tree and herbaceous legumes, *Desmodium spp*. (*Desmodiumuncinatum and Desmodiumintortum*) from Hawassa University; lucerne tree (*Cytisusproliferus*) from the Darra district; Pigeon pea (*Cajanus cajan*) from the Dore Bafana district; Sesbania (*Sesbania sesban*), Lablab (*Lablab purpureus*) and Vetch (*Vicia dasycarpa*) from Shebedino district; Rhodes grass (*Chloris gayana*) and Brachiaria (*Brachiariamulato II*) from Shebedino; Desho (*Pennisetum pedicellatum),* Elephant grass (*Pennisetum purpureum*), and Guatemala (*Tripsacumandersonii*) from the Wondo Genet districts of Sidama regional state. For concentrates, maize grain and oat grain from the Darra and Dore Bafana districts; noug seed cake and cotton seed cake from the Adama district, and home distilling and brewing by-products (*arekeatela* and *telaatela*) were collected from the Arsi-Negelle districts of Oromia Regional State. The brewery spent grain and wheat bran were collected from BGI Hawassa and wheat flour factory in Hawassa city. Approximately 350 g dry matter (DM) of samples were collected for each feed. Dried feed samples were ground to pass through a 2 mm sieve for in sacco DM degradability and a 1 mm sieve for in vitro gas production and chemical analyses using a Wiley mill (AOAC, 1990). The final weight of the samples was measured, and subsamples were taken and stored in plastic bags until further chemical analyses for in sacco DM degradation and in vitro gas production study.

Analyses of feed samples: The DM contents of the feed samples were determined by oven drying overnight at 105°C following the standard methods of the Association of Official Analytical Chemists (AOAC, 1990). The ash content was determined by igniting the feed samples in muffle furnace at 550 °C for 3 hours (AOAC, 1990). Total nitrogen (N) content was determined using the Micro Kjeldahl method. Crude protein (CP) content was determined by multiplying the N content by 6.25. The acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined according to Van Soest and Robertson (1985). Neutral detergent fiber (NDF) content was determined according to Van Soest *et al*. (1991).

Determination of in sacco dry matter degradation: In sacco DM degradability was determined according to procedures of Ørskov and McDonald (1979) by incubating about 300 mg of sample in a nylon bag (40 µm pore size and 10 x 8 cm dimension) with porosity of 0.30 (de Jonge *et al*. 2014). Duplicate nylon bags containing feed samples were incubated in three rumen fistulated Boran-Holstein Friesian crossbred steers (with an average body weight of 510 ± 50 kg) fed 15% CP and 38.5 MJ ME/kg DM. The steers were fed native grass hay free choice for ad libitum intake and 2 kg concentrate supplement twice a day (06:00 and 18:00) in equal parts to maintain the rumen environment. The samples were incubated for 6, 12, 24, 48, 72, and 96 hours. The zero-hour samples were soaked in a water bath maintained at 39°C for 1 hour (Njidda *et al*. 2013). After incubation, all nylon bags were withdrawn at the same time and hand washed under running tap water until the water of the bags was clear. The washed bags were oven-dried at 60°C for 48 hours to determine DM disappearance.

Determination of in vitro gas production: The in vitro gas production was evaluated following the procedure of Menke and Steingass (1988). Rumen fluid was collected from three Arsi-Bale sheep fed native grass hay and 200 g concentrate supplement (16.5% CP and 10 MJ/kg DM ME). Rumen fluid was collected before morning feeding using a suction tube and poured into a pre-warmed thermos flask (39°C). About 200 mg of oven-dried feed samples were put into 100 ml glass syringes. The syringes were pre-warmed overnight at 39°C in a water bath before injecting 30 ml rumen fluid buffer solution. Two blank syringes containing only 30 ml of medium were also incubated. The syringes were gently shaken for 30 minutes after the start and every hour for the first 6 hours of incubation. The in vitro gas production was determined by the differences in the volume of gas increased from the beginning of fermentation at 0 hour and the time intervals set for incubation (0) and 3, 6, 9, 12, 15, 21, 27, 33, 39, 48, 60, 72, and 96 hours.

Determination of methane production and concentration: The volume of in vitro methane gas was determined by dispensing 4 ml of 10 N sodium hydroxide into each incubated feed sample at the end of 24 hours of incubation. Sodium hydroxide was added to absorb carbon dioxide produced during the fermentation process and the remaining volume of gas was recorded as CH_4 according to the method of Fievez *et al*. (2005). The CH_4 and total gas production were calculated by the difference of CH_4 and total gas in the test syringe and the corresponding blank. The CH_4 concentration was calculated according to Jayanegara *et al*. (2009).

Calculations and Statistical Analysis: The data obtained from in vitro gas production was fitted to a nonlinear equation. Cumulative gas production data were fitted to the model of Ørskov and McDonald, (1979):

$Y = a + b (1-e^{-ct})$, where Y is the gas production (ml/200 mg DM) at time t. The in sacco DM disappearance was determined by using the Neway Excel program (Chen, 1995), assuming a passage rate of 3% per hour. The following parameters were estimated as potential degradability PD = a + b; effective degradability (ED) = a + bc / k + c, where k= passage rate. Analysis of variance was conducted according to the following model:$Y_{ij} = \mu + P_i + R_j + e_{ij}$, where$Y_{ij}$ is the independent variable, μ = overall mean, P_i=effects of the i^{th} feed sample, R_j is the effect of the j^{th} experimental run of the i^{th} feed sample and e_{ij} is the residual error. All multiple comparisons among means were performed with Duncan's multiple range tests.

RESULTS

Chemical composition: The observed chemical compositions of the feed samples are presented in Table 1. The CP content for concentrate ingredient group ranged from 88 g/kg DM (oat grain) to 336 g/kg DM (cotton seed cake). The CP for *arekeatela*, *telaatela*, and brewery spent grain was 167, 207, and 256 g/kg DM, respectively.

Table 1. Chemical composition of the selected most common livestock feeds

Feed samples	Chemical composition (g/kg DM)				
	CP	Ash	NDF	ADF	ADL
Tree and herbaceous legumes					
Desmodium uncinatum	200^{g}	79.2^{de}	495^{f}	411^{cd}	149^{b}
Desmodiumintortum	221^{e}	72.3^{e}	532^{e}	431^{b}	152^{b}
Cytisusproliferus	209^{f}	50.9^{gh}	425^{hi}	264^{j}	127c
Cajanus cajan	177^{i}	78.7^{de}	540^{e}	419^{bc}	185^{a}
Sesbania sesban	206^{fg}	77.4^{de}	435^{gh}	292^{i}	78.4^{ef}
Lablab purpureus	186^{h}	112^{c}	395^{i}	316^{gh}	95.1^{d}
Vicia dasycarpa	235^{d}	113^{c}	465^{ef}	364^{f}	74.2^{gh}
Grasses					
Brachiariamulato II	104^{m}	119^{bc}	575^{d}	307^{hi}	40.7^{jk}
Pennisetum pedicellatum	139^{k}	89.5^{d}	626^{c}	392^{e}	56.4^{ij}
Pennisetum purpureum	90.1^{m}	144^{a}	689^{b}	394de	61.7^{hi}
Tripsacumandersonii	125^{L}	128^{b}	685^{b}	412^{cd}	63.7^{hi}
Chloris gayana	88.2^{m}	123^{bc}	692^{ab}	423^{bc}	73.2^{gh}
Concentrate ingredients					
*Noug*seed cake	290^{b}	78.5^{de}	355^{j}	287^{j}	120^{c}
Tela atela	207^{f}	25.1^{j}	651^{c}	277^{jk}	91.9^{de}
Brewers' spent grain	256^{c}	44.9^{ij}	632^{c}	471^{a}	76.8^{ef}
Arekeatela	167^{j}	71.3^{ef}	722^{a}	264^{j}	122^{c}
Oat grain	88.0^{m}	36.4^{hi}	283^{k}	85.8^{L}	46.1^{jk}
Maize grain	93.6^{m}	44.3^{hi}	204^{L}	14.5^{m}	4.60^{L}
Wheat bran	174^{i}	67.7^{ef}	469^{f}	93.0^{L}	28.8^{k}
Cottonseedcake	336^{a}	59.7^{fg}	401^{i}	327^{g}	54.7^{ij}

*NDF= neutral detergent fiber, ADF=acid detergent fiber, ADL= acid detergent lignin, Ash, CP= crude protein and DM= dry matter. Means within the same column with different superscripts are significantly different (P<0.05).

The greatest NDF (722 g/kg DM) was observed in *arekeatela* and the lowest in maize grain (204g/kg DM). The ADF was lower in maize grain at 15g/kg DM compared to the other feed samples. From the grass group of feeds Guatemala, elephant grass, and Rhodes grass had greater NDF values (685, 689, and 692 g/kg DM), and the lowest value was in Brachiaria (575 g/kg DM). The ash content was greatest for Elephant grass (144 g/kg DM) and lowest for Desho grass (90 g/kg DM). Vetch had the greatest CP among the tree and herbaceous legumes feed group (235g/kg DM) and Pigeon pea had the lowest CP (177g/kg DM). However, a greater ADL content was observed for Pigeon pea (185 g/kg DM) and lowest for Vetch (74 g/kg DM).

In sacco ruminal dry matter disappearances: Dry matter disappearance of the selected feed samples from nylon bags at different rumen incubation periods is shown in Table 2. There were significant differences (P<0.05) in the soluble fraction (a) of the concentrate feed ingredients, which ranged from 1.30% (brewery-spent grain) to 27.1% (maize grain). The soluble fraction for grasses was greatest in Guatemala (10.6%) and lowest in Elephant grass (7.4%). Among the tree and herbaceous legumes, the (a) fraction was greatest for Lablab (31.5%) and lowest for Pigeon pea (8.6%). The slowly degradable fraction (b) for grasses was greatest for Desho grass (55.9%) but lowest for Rhodes grass (39.5%). Concentrate ingredients had significantly greater (P<0.05) PD value (96.9%) in maize grain but a lower value (58.5%) in brewery-spent grain. The ED fraction was lower (40.7%) for brewery-spent grain compared to maize grain (74.8%). The in-sacco DM degradation increased with increasing incubation time for the tree and herbaceous legumes such that in Lablab it increased from 43.7% (12h) to 72.8% (48h), and for pigeon pea from 15.4% to 35.4%. For Desho grass DM degradation increased from 21.3% (12h) to 57.9% (72h). For Rhodes grass, it increased from 17.1% to 45% as the time of incubation increased from 12h oursto 72 hours. For maize grain it increased from 54.9% (6h) to 93.6% (48h), and for brewery-spent grain 15% to 53.2% (Figure 1). The significant variation in degradation rate (c) of the degradable b ranged from 0.03 to 0.25 for the concentrate group.

In vitro Gas production: In vitro gas production of feed samples in the study area is shown in Table 3. Gas production from the immediately soluble fraction ranged from −5.7 ml/200 mg DM (maize grain) to 0.9 % ml/200 mg DM (cotton seed cake). Total gas production from the b fraction ranged from 36.4 ml/200 mg DM (brewery spent grain) to 71.1 ml/200 mg DM (maize grain). The greatest gas production among the grasses was for Guatemala (50.4 ml/200 mg DM), and the lowest for elephant grass (37.4 ml/200 mg DM). The b fraction was greatest in lucerne (46.6 ml/200mg DM) and lowest in pigeon pea (23.9 ml/200 mg DM) among the tree and herbaceous legumes. The potential in vitro gas production (a+b) was greatest for wheat bran (62.3 ml/200 mg DM) and maize (65.4 ml/200 mg DM) grain and lowest in brewery spent grain (33 ml/200mg DM). The rate constant of gas production (fraction/h) was greatest for oat grain (0.15ml/h) and lowest for brewery-spent grain (0.04ml/h). Lag time (L) among grasses was greatest for Rhodes grass and lowest for elephant grass while in concentrate ingredients, maize and oat grain had the greatest L cotton seed cake had the lowest.

In vitro methane production, metabolizable energy, short-chain fatty acids, and organic matter digestibility: Methane (CH_4) production and concentration, organic matter digestibility (OMD), short-chain fatty acid (SCFA), and metabolizable energy (ME) production are presented in Table 4. In the 24h in vitro incubation the greatest CH_4 production was observed from tree lucerne (13 ml/200 mg DM), and the lowest was in Desmodium (5 ml/200 mg DM) and pigeon pea (4 ml/200 mg DM). In vitro methane production from concentrate ingredients was greatest in wheat bran, maize, and oat grain but lowest in *arekeatela* (0.68 ml/200 mg DM). The greatest OMD was observed in maize grain (73.6%), and lowest in *arekeatela* (40.1%). Short-chain fatty acid production was greatest in maize grain (1.33 µmol/mg DM) and lowest in *arekeatela* (0.29 µmol/mg DM). Among the tree and herbaceous legumes, the greatest SCFA was observed in tree lucerne (0.91 µmol/mg DM) and lablab (0.87µmol/mg DM) and the lowest in pigeon pea (0.28 µmol/mg DM). Among grasses, Desho grass (67µmol/mg DM) and Guatemala (61 µmol/mg DM) had the greatest while Rhodes grass (0.39µmol/mg DM) had the lowest SCFA. Among legumes, Lablab (7.61 MJ/kg DM) and tree lucerne (7.85 MJ/kg DM) had greater SCFA compared to pigeon peas (5.24 MJ/kg DM), which was the lowest. The estimated ME value at 24h of in vitro incubation was greatest at 10.1 MJ/kg DM for maize grain and lowest (4.3 µmol/mg DM) in *arekeatela*.

Correlation, calculated OMD, in vitro gas production, methane production and ME: The correlation among fiber fractions (NDF, ADF, and ADL), total gas, CH_4 production, ME, and OMD is presented in Table 5. Fiber fractions were negatively correlated with CP content, in vitro total gas production, ME, and OMD. On the other hand, CP content showed a positive correlation (P<0.05) with in vitro gas production and OMD. A positive correlation (P<0.05) was observed among (microbial gas production) in vitro gas production, ME, and OMD. The concentration of CH_4 was positively correlated with OM and ME but negatively correlated with fiber fractions (NDF, ADF, and ADL).

Table 2. In sacco DM degradability of common livestock feeds (mean ± SE)

Feed samples	In sacco DM degradability Parameters*				
	A	*b*	PD	ED	*C*
Tree and herbaceous legumes					
D. uncinatum	12.9±0.16^{de}	44.5±1.06^{ef}	57.4±1.20^{gh}	38.0±0.75^{h}	0.04g^{h}
D. intortum	9.7±0.35^{gh}	45.7±0.95^{e}	55.4±1.12^{gh}	38.4±1.33^{h}	0.05^{ef}
Cajanus cajan	8.6±1.06^{gh}	30.6±4.02^{h}	39.2±2.99^{i}	28.7±1.12^{k}	0.06^{d}
C. proliferus	11.0±0.68^{e}	55.1±0.16^{c}	66.2±0.63^{de}	53.0±0.89^{d}	0.09^{c}
S. sesban	21.7±0.13^{c}	44.7±0.40^{ef}	66.4±0.39^{de}	52.4±1.05^{ed}	0.07^{de}
V. dasycarpa	25.7±1.30^{b}	35.9±1.74^{gh}	60.5±0.50^{fg}	50.9±0.76^{e}	0.08^{cd}
L. purpureus	31.5±0.65^{a}	42.4±0.54^{ef}	73.9±0.21^{bc}	64.2±0.63^{c}	0.10^{c}
Grasses					
Brachiariamulato II	10.5±0.35^{ef}	44.4±0.95^{ef}	54.9±0.62^{gh}	33.3±0.56^{h}	0.03^{gh}
P. pedicellatum	7.9±0.92^{hi}	55.9±0.95^{c}	63.7±0.30^{ef}	38.2±0.88^{h}	0.04^{gh}
P. purpureum	7.4±0.91^{i}	43.3±1.12^{ef}	50.7±1.60^{h}	31.9±0.97^{j}	0.04^{gh}
T. andersonii	10.6±0.33^{ef}	47.4±4.51^{e}	58.0±4.29^{gh}	32.5±0.82^{h}	0.03^{h}
Chloris gayana	9.7±0.39^{gh}	39.5±0.89^{fg}	49.2±0.52^{h}	29.4±0.36^{k}	0.03^{h}
Concentrate ingredients					
Brewers' spent grain	1.30±0.22^{j}	57.2±0.85^{bc}	58.5±0.65^{gh}	40.7±1.65^{h}	0.06^{d}
ArekeAtela	9.4±1.59^{g}	60.0±1.81^{bc}	68.4±0.88^{d}	46.5±1.39^{f}	0.05^{ef}
Tela Atela	119±1.03^{e}	62.6±0.99^{b}	74.5±0.47^{b}	52.6±1.17^{de}	0.05^{ef}
Noug cake	10.3±0.74^{ef}	63.0±0.64^{b}	73.3±0.18^{bc}	65.8±0.72^{c}	0.23^{ab}
Oat grain	22.4±1.60^{c}	53.0±1.86^{d}	75.3±0.42^{b}	68.8±0.18^{b}	0.21^{b}
Wheat bran	22.0±2.76^{c}	53.0±2.92^{d}	75.0±0.22^{b}	69.3±0.59^{b}	0.25^{a}
Maize grain	27.1±0.90^{b}	69.8±0.49^{a}	96.9±0.53^{a}	74.8±0.72^{a}	0.06^{d}
Cotton seed cake	14.9±0.82^{d}	55.2±1.51^{c}	70.1±1.42^{cd}	43.5±0.97^{g}	0.03^{gh}

*a = soluble fraction, b = slowly degradable fraction, c = rate of degradation, PD = potential degradability, ED = effective degradability. Means within the same column with different superscripts are significantly different (P<0.05).

Table 3. Kinetics of in vitro gas production (ml /200 mg DM) of common livestock feeds incubated for 96hours

Feed samples	In vitro gas production parameters*				
	a	*b*	*a+b*	*c*	L
Tree and herbaceous legume					
Desmodium uncinatum	-1.6	32.1	30.5^{g}	0.07	0.7
Desmodiumintortum	-1.3	33.3	32.0^{g}	0.07	0.6
Cytisusproliferus	-2.9	46.6	43.7^{de}	0.10	0.7
Cajanus cajan	-0.8	23.9	23.1^{h}	0.06	0.5
Sesbania sesban	-1.8	37.7	35.9^{fg}	0.08	0.6
Lablab purpureus	-3.0	41.8	38.8^{fg}	0.08	0.9
Vicia dasycarpa	-2.4	43.0	40.6^{ef}	0.09	0.6
Grasses					
Brachiariamulato II	-3.2	50.1	46.9^{cd}	0.05	1.3
Pennisetum pedicellatum	-4.1	43.6	39.5^{fg}	0.06	1.7
Pennisetum purpureum	-2.2	37.4	35.2^{fg}	0.08	0.8
Tripsacumandersonii	-3.0	50.4	47.4^{cd}	0.05	1.3
Chloris gayana	-3.7	37.9	34.2^{fg}	0.05	2.0
Concentrates ingredient					
*Noug*seed cake	-1.0	36.4	35.4^{fg}	0.12	0.2
Tela atela	-0.7	48.5	47.8^{bc}	0.06	0.3
Brewerys' spent grain	-0.7	33.7	33.0^{g}	0.04	0.5
Arekeatela	-0.9	47.2	46.3^{cd}	0.05	0.4
Oat grain	-3.5	53.7	50.2^{b}	0.15	0.5
Maize grain	-5.7	71.1	65.4^{a}	0.10	0.8
Wheat bran	-3.0	65.2	62.2^{a}	0.07	0.7
Cotton seed cake	0.9	37.3	38.2^{fg}	0.06	0.0

*a = Gas production from the immediately soluble fraction (ml), b = Gas production from the insoluble but degradable fraction (ml), $a + b$ = Potential gas production (ml), c = The rate constant of gas production (fraction/h) L= Lag time, SEM= Standard error of mean. Means within the same column with different superscripts are significantly different (P<0.05).

Table 4. In-vitro methane production and concentration, metabolizable energy and organic matter digestibility of the selected most common livestock feeds (24 hours)

Feed samples	Gas production (24h)	Calculated parameters				
	CH_4 (ml/200 mg DM)	*TG (ml/200 mg DM)*	CH_4/TG (v:v)	OMD (%)	SCFA (µmol/ mgDM)	ME (MJ /kgDM)
Tree and herbaceous legume						
Desmodium uncinatum	4.00^{de}	20.3^{fg}	0.20^{de}	47.2^{fg}	0.41^{ef}	5.08^{ef}
Desmodiumintortum	5.33^{de}	23.7^{ef}	0.24^{cd}	48.9^{f}	0.46^{ef}	5.27^{ef}
Cytisusproliferus	13.0^{a}	40.7^{c}	0.32^{bc}	63.8^{cd}	0.91^{c}	7.85^{c}
Cajanus cajan	4.00^{de}	14.3^{h}	0.28^{cd}	40.8^{h}	0.28^{h}	4.25^{g}
Sesbania sesban	6.33^{cd}	17.0^{gh}	0.38^{ab}	44.2^{gh}	0.35^{fg}	4.63^{fg}
Lablab purpureus	8.67^{bc}	39.0^{c}	0.22^{de}	65.4^{bc}	0.87^{c}	7.61^{c}
Vicia dasycarpa	9.33^{bc}	31.3^{d}	0.30^{cd}	60.6^{d}	0.69^{d}	6.60^{d}
Grasses						
Brachiariamulato II	4.00^{de}	20.0^{fg}	0.20^{de}	45.1^{fg}	0.42^{ef}	5.00^{ef}
P. pedicellatum	5.33^{de}	30.7^{d}	0.17^{ef}	54.0^{e}	0.67^{d}	6.45^{d}
Pennisetum purpureum	7.66^{bc}	20.7^{fg}	0.37^{ab}	46.6^{fg}	0.43^{ef}	5.06^{ef}
Tripsacumandersonii	12.3^{ab}	28.0^{de}	0.43^{a}	53.7^{e}	0.61^{d}	6.08^{d}
Chloris gayana	7.33^{cd}	18.7^{ef}	0.30^{cd}	43.4^{gh}	0.39^{fg}	4.79^{fg}
Concentrates ingredient						
*Noug*seed cake	8.33^{bc}	31.0^{d}	0.27^{cd}	60.5^{d}	0.68^{d}	6.58^{d}
Tela atela	1.67^{ef}	9.33^{i}	0.17^{ef}	46.3^{fg}	0.49^{e}	5.44^{e}
Brewerys' spent grain	3.33^{ef}	21.0^{fg}	0.16^{ef}	46.6^{fg}	0.44^{ef}	5.18^{ef}
Arekeatela	0.68^{g}	14.7^{h}	0.05^{f}	40.1^{h}	0.29^{gh}	4.29^{g}
Oat grain	10.0^{abc}	50.0^{b}	0.20^{de}	65.4^{bc}	1.13^{b}	9.05^{b}
Maize grain	10.6^{abc}	58.0^{a}	0.18^{ef}	73.6^{a}	1.33^{a}	10.1^{a}
Wheat bran	9.66^{abc}	47.0^{b}	0.21^{de}	68.9^{b}	1.06^{b}	8.69^{b}
Cotton seed cake	7.33^{bc}	22.7^{ef}	0.33^{bc}	53.9^{e}	0.48^{e}	5.47^{e}

*CH_4= methane, ml= milliliter, TG= total gas production, OMD= organic matter digestibility, SCFA= short chain fatty acid, ME= metabolizable energy and MJ= mega joule. Means within the same column with different superscripts are significantly different (P<0.05).

DISCUSSION

Chemical composition of feeds: In this study the chemical composition of various types of feed commonly found in Ethiopia were analyzed to facilitate their use in dairy diets as part of a sustainable diet. The CP content of locally sourced noug seed cake (290 g/kg DM) was lower than the value (356 g/kg DM) reported by Mekonen *et al*. (2015) but greater than the value (285 g/kg DM) reported byFeyissa *et al*. (2015). This variation may be due to differences in oil seed extraction methods (mechanical or chemical) and differences in the oilseed composition based of the species or cultivars used (Jan*et al*., 2021). The CP content in the current study of *telaatela* (207 g/kg DM) was lower than the value (212 g/kg DM) reported by Feyissa *et al*. (2015). Similarly, the CP in *arekeatela* (167 g/kg DM) was lower than the values (193 g/kg DM and 176 g/kg DM) reported by Wakshuma *et al*. (2020) and Asaminew *et al*. (2012), respectively. These variations might be due to the differences in crop varieties used for making *tela.* The neutral detergent fiber (NDF) in Brachiaria (575g/kg DM) and elephant grass (689 g/kg DM) was lower than the value (657g/kg DM and 715g/kg DM) observed by Terefe *et al*. (2022), respectively. In the tree and herbaceous legumes feed group the observed CP for Pigeon pea (177g/kg DM) was lower than the value (200 g/kg DM) by Melesse *et al*. (2019). Such variations could be due to the age of the plant at sampling, the collection season, and the type of soil (Melesse *et al*., 2019). The observed high CP content in most of the tree and herbaceous legumes and concentrate ingredients of the selected feeds suggest that they could be a potential protein supplement to enhance feed intake and utilization of low-quality grass and fibrous crop residues.

In sacco DM degradability characteristics: The in sacco DM degradability increased with increasing microbial and enzymatic activity in the rumen (McDonald *et al*., 2002). In this study, DM disappearance at zero hours and maximum disappearance at 60 hours for wheat bran (22 % and 75.0%) were lower than the values (26% and 89.5%) by Terefe *et al*. (2022), respectively. This variation might be due to the milling process of the wheat grain. Khan *et al*. (2009) suggested that DM disappearance at 0-hour is mainly due to mechanical action rather than microbial fermentation. The degradable values for soluble fraction *a* were lower for brewers' spent grain (1.3%) and greatest for maize grain (27.1%), which is lower than the value observed by Mupangwa *et al*. (2003). The ED fraction in Lablab is similar to the value (64.2%) reported by Terefe *et al*. (2022). The *b* fraction value for maize grain (69.8%) was greater than the value observed by Mondal *et al*. (2008), perhaps due to differences in soluble fractions of maize grain. The ED at 96 hours of incubation was lower (40.7%) for brewery-spent grain and greatest (74.8%) for maize grain. Effective degradable and PD values were 28.7% to 39.2% for Pigeon peas and 74.8% to 96.9% for maize grain, which were similar to the values observed by Terefe *et al*. (2022). The greatest PD (73.9%) and ED (64.2%) values were in Lablab. However, the lowest PD and ED were in pigeon peas (39.2% and 28.7%) and the rate of degradation fraction was lower (0.03%) for Guatemala, Rhodes grass, and cotton seed cake and greatest (0.25%) for wheat bran. These variations between ED and PD of the feed samples might be due to several factors including chemical composition of the feed (NDF, ADF, and ADL), agronomic practices, processing technologies, nature of the feed sample, nylon bag (porous, size, new and re-used) differences, feed and breeds of the incubated animal (Mc Donald *et al*., 2002). In vivo DM digestibility can be predicted from a long-term (72h to 96h) in-sacco DM degradability and voluntary DM intake from short-term (16 h) gas production (Giger *et al*., 2005).

In vitro gas production: In the current study, negative values of gas production for fraction *a* were observed in all experimental feed samples except cotton seed cake (0.09). The *a*fraction of Brachiaria grass in this study (-3.20) was similar to the value (-3.27) obtained by Bezabih *et al*. (2013). The negative values for soluble fractions (*a*) could be due to differences in the lag phase during the fermentation of insoluble feed components that led to a deviation from the exponential curve of fermentation (Blummel and Becker, 1997). The lag time varied from 0.8 in elephant grass to 2.0 in Rhodes grass and the lowest was for cotton seed cake among the concentrate ingredients. According to Melesse *et al*. (2019), the total in vitro gas value of Pigeon peas after 24 hours of incubation was 17.2 ml/200 mg DM, which was lower than our findings. This variation might be due to the plant sampling parts (leaves, flowers, and twigs) and the season of harvesting (September vs March-May). Daning and Riyant (2017) reported that in vitro total gas production value in Brachairia (15.9 ml/200 mg DM), was lower than our findings (20 ml/200 mg DM). However, the values observed by Melesse *et al*., (2019) for Sesbania (44.6 ml/200 mg DM) was greater than our finding (35.9 ml/200 mg DM). The differences might be due to variations in soluble carbohydrates (sucrose, fructose, and glucose) and structural carbohydrates (cellulose, hemicellulose, pectin) (Ngodigha and Anyanwu, 2009). Forages with OMD of 70% or more are considered to be of high quality (Meissner *et al*., 2000). Three of the 8 tree and herbaceous legume species in our study had OMD values ranging from 61–65% (Lablab, tree lucerne, and vetch), which may be considered moderate-quality feeds under tropical conditions (Kumara *et al*., 2009). The grass species had the lowest OMD content (43.4 -54%) compared to values observed by Bezabih *et al*. (2013). The in vitro gas method is an ideal technique to generate kinetics of fermentation, as it allows the recording of gas produced at several times in the incubation period, which is used to predict the rate at which feed is digested (Getachew *et al*, 2005). This information is particularly useful for process-based models for a better prediction of feed utilization.

In vitro methane production: A high variation is observed in in vitro CH_4 production after 24 hours of incubation (Table 4). In the current study, the CH_4 production value in Sesbania was comparable with the value reported by Melesse *et al*. (2019) (6.33 vs 6.16 ml/200 mg DM), respectively. Methane concentration in Pigeon peas (0.38 v:v) was greatest than the value (0.28 v: v) observed by Melesse *et al*. (2019). In this study, CH_4 production ranged from 0.68 (*arekeatela*) to 10.6 ml/200 mg DM for (maize grain). This result indicates that CH_4 production was reduced in mixed diets and had the greatest fiber levels (722 g/kg DM NDF), which may have interrupted fermentation and reduced total gas production (Meads *et al*., 2021). This study showed a lower OMD in *arekeatela* (38.6%) and lower methane production (0.68 ml/200 mg DM) and greatest OMD of 73.6% (maize grain) and greatest CH_4 (10.6 ml/200 mg DM) production. These results are consistent with those reported by Getachew *et al*. (2005) who found a positive correlation between CH_4 production and OMD, NDF, and DM digestibility in the first

24 h of in vitro incubation. It could be of great value in the development of supplementation strategies using locally available conventional and non-conventional feed constituents to achieve maximum microbial efficiency in the rumen.

Relationship between total gas, short-chain fatty acids, methane and ME content: Forage materials with high fiber contents are related to poor digestibility. In this study, a negative correlation was observed between total gas production (r^2= -0.66 and r^2= -0.79) and fiber fractions (NDF and ADF), but a positive correlation between ME and OMD (r2=0.77). The CH_4 production was positively correlated with OMD and ME ($P \leq 0.05$) but negatively correlated with fiber content. The increase in gas production with greater inclusion of maize silage is consistent with the general trend of in vitro gas production where increases starch content was observed to increase gas production (Chai *et al*. 2004). There was a positive relation between ME and methane (r^2=0.68) production. The SCFA was positively correlated with total gas production (r^2=0.97). The results of our study were supported by the findings of Andualem *et al*. (2015), who studied methane concentration, OMD, ME, and SCFA production of morphological fractions of stinging nettle (*urticasimensis*) measured through an in vitro gas test.

CONCLUSION

A comparative estimate of the nutritional profiles of selected common livestock feeds of Ethiopia can facilitate their inclusion in the dairy diets as a supplement or part of a balanced diet. The observed nutritional values (CP, ME, SCFA, and OMD) of the selected common feeds ranged from tree and herbaceous legumes (lablab, vetch, and tree lucerne), from grasses (desho and Guatemala) and from concentrate ingredients (maize grain, oat grain, wheat bran, noug seed cake, and cotton seed cake). Home brewing and distilling by-products (*Tela and Arekeatela*), and brewery spent grain may offer nutritional benefits to dairy cattle. Generally, tree and herbaceous legumes, home brewing, distilling by-products, brewery-spent grain, and concentrate ingredients have the potential for strategic supplementation of poor-quality feeds. Further studies in feeding trials would be necessary to validate their supplementary value and level of inclusion in animal diets.

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