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Nutritional evaluation and *in vitro* dry matter digestibility (IVDMD) of *Moringa oleifera, Medicago sativa, Chloris gayana* and their combinations at different ratios

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Abstract
The major factor limiting ruminant production in the tropics is the lack of a year-round supply of quality forage and protein supplements. Therefore, the use of underutilized shrubs and trees such as *Moringa oleifera* is noteworthy due to its rich nutritional composition and potential as a feed resource for ruminants. This study investigated the nutritional composition of *Moringa* leaves, Lucerne hay, and Rhodes grass hay with their combinations at different ratios. The ingredients were grouped into seven in ratios 90:10:0, 90:5:5, 90:0:10, 0:100:0, 0:50:50, 0:0:100, and 100:0:0 of Rhodes grass hay, Lucerne hay and *Moringa* leaves respectively. Proximate, fibre, total phenolic and condensed tannin contents were used to determine the nutritional value of these feed ingredients. The *in vitro* dry matter digestibility was also determined and the result was used in estimating the metabolizable energy (ME), organic matter digestibility (OMD) and short-chain fatty acids (SCFA). *Moringa* has the highest CP, EE and NSC. There was no significant difference ($p<0.05$) in the ash content of Lucerne, *Moringa* and the combination of the two. The NDF, ADF, ADL and CF contents were significantly lower ($p<0.05$) in *Moringa* than in others which explains the increased ($p<0.05$) dry matter digestibility, DE and ME observed in *Moringa*. The organic matter content and hemicellulose were significantly lower ($p<0.05$) in *Moringa*. *Moringa* has the highest total phenolic (6.39%) and the least condensed tannins (0.13%) when compared with the combination of Lucerne and *Moringa*. The gas production was significantly lower ($p<0.05$) in *Moringa* leaves despite its high ME. The results show that *Moringa* reflects a desirable nutritional balance which shows that it can serve as a protein supplement for ruminants including dairy cows and also a substitute for Lucerne which is the major protein supplement utilized by ruminant producers in the tropics.

Keywords: Digestibility, fibre fractions, lucerne, *Moringa*, proximate, ruminants

1. Introduction

Milk production in Kenya accounts for a significant portion of the economy estimated at about 5% of GDP, and the majority of the producers are smallholder dairy farmers who account for 70-80% of Kenya's dairy producers [10]. This implies that they can be used as a tool for economic development, food security, and poverty reduction [33].

Dairy cows are fed on forages such as Napier grass, Rhodes grass, Lucerne, and crop residues which are supplemented with concentrate or compound dairy meal. However, most smallholder farmers are found in the highlands, where demand for food crops restricts access to grazing areas and the availability of feed and fodder [4]. Most of these farmers are also unable to afford high-quality concentrates and supplementary feeds [20] which has led to the challenge of inadequate feed and feeding in dairy production.

One possible option to this challenge of inadequate supply of high-quality forage is the exploration and exploitation of non-conventional feed resources such as protein-rich forage trees with high nutrient content, a balanced profile of amino acids, a reasonable cost and a large proportion of digestible fibre which can serve as a supplement for dairy cows during periods of feed scarcity.

Fodder trees and shrubs have been reported to improve the quality and availability of feed for animals as they are a good and inexpensive source of protein and micronutrients [19].

In this regard, the drought-tolerant *Moringa* tree can be considered one of the numerous top feed resources in the tropics. *Moringa* is a tree native to India but has spread too many areas worldwide. It's a perennial evergreen tree [25] whose forage contains 5.9% moisture, 38.6% carbohydrates, 27.2% protein, and 17.1% fat [35]. Benefits of using *Moringa* as a source of forage for ruminants include the plant's versatility as a forage tree, which allows for multiple harvests throughout the growing season and the storage of its dried leaves for extended periods without loss of nutritional content [14].

Studies have demonstrated that *Moringa* can enhance the health and performance of ruminants, such as oxidative status and milk production [3], improve their nutrition via microbial protein synthesis [29], and regulate rumen microflora as it contains large quantities of active substances, such as flavonoids, and other phenolic compounds [36]. The various nutrients in *Moringa*, including protein, fatty acids, minerals, and vitamins, make it a good feed resource for livestock [19].

Therefore, it is essential to access the nutritive value of *Moringa oleifera* as a possible option for feeding dairy cows and compare it with the commonly fed basal diet (Rhodes grass hay) and a protein supplement (Lucerne).

2. Materials and Methods

2.1 Preparation of samples

Dried samples of the three feed ingredients (Rhodes grass hay, Lucerne hay, and *Moringa* leaves) were ground using a hammer mill and passed through a screen with 3 mm holes. These ground ingredients were used in the formulation of the samples as stated in Table 1 where BL is 90% Rhodes grass hay and 10% Lucerne hay; BLM is 90% Rhodes grass hay, 5% Lucerne hay, and 5% *Moringa* leaves; BM is 90% Rhodes grass hay and 10% *Moringa* leaves; L is 100% Lucerne hay; LM is 50% Lucerne hay and 50% *Moringa* leaves; M is 100% *Moringa* leaves; and B is 100% Rhodes grass hay.

Table 1: Composition of the samples used in the determination of the nutritional value of *Moringa oleifera, Medicago sativa, Chloris gayana* and their combinations at different ratios

Ingredients	BL	BLM	BM	L	LM	M	B
Rhodes grass hay (%)	90	90	90	0	0	0	100
Lucerne hay (%)	10	5	0	100	50	0	0
Dried *Moringa* leaves (%)	0	5	10	0	50	100	0
Total (%)	100	100	100	100	100	100	100

2.2 Determination of nutritional composition

The nutritional composition of *Moringa oleifera, Medicago sativa, and Chloris gayana* with their combinations at different ratios was carried out at the Department of Animal Sciences' laboratory, Egerton University, Kenya.

The dry matter (DM), crude protein (CP), ether extract (EE), crude fibre (CF), and ash of the diets and supplements were determined using method 934.01, method 984.13, method 920.39, method 978.10, and method 942.05 of the Association of Analytical Chemists' official procedures respectively [2] and the Organic Matter (OM) was calculated as DM- Ash. The nitrogen-free extract (NFE) was calculated as 100 - (Ash + CP + EE + CF), while the non-structural carbohydrate content (NSC) was calculated as 100 - (Ash + CP + EE + NDF) [22].

Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF), and Acid Detergent Lignin (ADL) were determined in accordance with [32]. Hemicellulose (HC) was calculated as NDF-ADF while the Dry matter digestibility (DMD) was calculated as 88.9 - (0.779 X ADF) [26]. The DMD values were used to estimate digestible energy (DE) using the regression equation reported by [7]: DE (Mcal/kg) = 0.27 + (0.0428xDMD). Then DE values were converted to metabolizable energy (ME) using the formula reported by [21]: ME (Mcal/kg) = 0.821 × DE.

The total phenolic and condensed tannins of M and LM were also analysed following the procedure described by [37].

2.3 Determination of *in vitro* dry matter digestibility

To determine *in vitro* dry matter digestibility (IVDMD) following the procedures of [31] as modified [15], rumen fluid was collected from freshly slaughtered cattle in the neighbouring slaughter slab, and feed particles were removed by straining it through four layers of cheesecloth. The samples were placed in calibrated glass syringes with lubricated pistons and then incubated with the rumen fluid and buffer mixture in a water bath maintained at 39°C. The gas production at 0, 3, 6, 9, 12, 24, 48, 72, and 96 hours were recorded and used in the determination of IVDMD.

Cumulative gas production data were fitted into the exponential model of [23] using the Neway Excel program and the degradation curve was described as

$Y = a+b\,(1-e^{-ct})$ where: Y – the gas produced

A – The soluble fraction.
B – The degradable fraction that is degraded at time t.
A+B – The potential gas produced.
C – The gas production rate is constant.
T – The incubation time.

A graph was plotted to illustrate the progression of the incubation process. The gas generated was also utilized to estimate short-chain fatty acids (SCFA), metabolizable energy (ME), and organic matter digestibility (OMD) as SCFA (mmol/200mg DM) = (0.0222*GP24) - 0.00425, where GP24 is 24h net gas production [8]; OMD (%) =18.53 + (0.9239*GP48) + (0.0540*CP), where GP48 is 48h net gas production and CP is crude protein [15]; ME (MJ/kg DM) = 2.2 + (0.1357 *GP24) +(0.0057*CP) + (0.0002859*EE^2) where GP24 is 24h net gas production, CP is crude protein and EE is ether extract [15].

2.4 Statistical Analysis

Each nutrient analysis was done in triplicates and the data were subjected to an analysis of variance (ANOVA) following a Completely Randomised Design (CRD) using the Generalized Linear Model (GLM) procedure of SAS [28]. The different means were separated using Tukey's Studentized Range (HSD) Test at $P<0.05$.

The statistical model of Completely Randomised Design (CRD) was used and described as

$$Y_{ij} = \mu + \tau_i + \varepsilon_{ij}$$

Where,
Y_{ij} - the j^{th} observation of the i^{th} treatment.
μ - the population mean.
τ_i - the effect of the i^{th} treatment, i = {1, 2, 3, 4, 5, 6, 7}.
ε_{ij} - the random error.

3. Results

3.1 Nutritional composition

The nutritional composition is presented in Table 2**.** The result shows that the DM ranges from 913.01 g/kg to 985.72 g/kg where the highest was found in B and M has the least DM. The Ash content ranges from 102.67 g/kg DM to 127.85 g/kg DM but there was no significant difference between L, LM, and M as well as between BL, BLM, and BM. The CP content ranges from 106.74 g/kg DM to 295.05 g/kg DM where M has the highest CP and B has the least CP. The CF ranges from 109.28 g/kg DM to 356.46 g/kg DM and there was no significant difference between BM and BL. The EE ranges from 12.41 g/kg DM to 82.51 g/kg DM with M having the highest EE content and BL having the least.

The NDF ranges from 138.01 g/kg DM to 743.41 g/kg DM and there was no significant difference between BL and BM. The ADF ranges from 136.82 g/kg DM to 412.63 g/kg DM but there was no significant difference between BM and BL. The ADL ranges from 12.13 g/kg DM to 52.68 g/kg DM and there was no significant difference between BL, BLM, LM, BM, and B. The NFE ranges from 352.36g/kg DM to 405.01 g/kg DM with L having the highest and BLM having the least. The NSC ranges from 1.53 g/kg DM to 360.32 g/kg DM and there was no significant difference between B, BLM, BM, and BL. The OM ranges from 788.89 g/kg DM to 883.05 g/kg DM with B having the highest OM and M having the least. The HC ranges from 1.19 g/kg DM to 330.78 g/kg DM with B having the highest and M having the least.

The DMD ranges from 567.56 g/kg DM to 782.42 g/kg DM and there was no significant difference between BL and BM. The DE ranges from 2.70 g/kg DM to 3.62 g/kg DM with M having the highest and B having the least. The ME ranges from 2.22 g/kg DM to 2.97 g/kg DM and there was no significant difference between BL and BM.

The result shows that LM has more (0.18%) condensed tannins compared to M (0.13%) and the highest total phenolic was observed in M (6.39%) while LM (5.55%) has the least.

Table 2: Nutrient composition of *Moringa oleifera, Medicago sativa, Chloris gayana* and their combinations at different ratios in g/kg DM

Source of Variation	BL	BLM	BM	L	LM	M	B	SEM	P
DM	977.44^{b}	969.26^{d}	972.15^{c}	978.46^{b}	949.73^{e}	913.01^{f}	985.72^{a}	5.18	<.0001
ASH	112.32^{b}	108.36^{b}	109.12^{b}	127.85^{a}	126.28^{a}	124.12^{a}	102.67^{c}	2.10	<.0001
CP	152.40^{d}	171.73^{d}	155.58^{d}	207.16^{c}	252.93^{b}	295.05^{a}	106.74^{e}	13.49	<.0001
CF	335.95^{c}	345.43^{b}	336.89^{c}	239.60^{d}	185.68^{e}	109.28^{f}	356.46^{a}	19.97	<.0001
EE	12.41^{f}	22.11^{d}	15.71^{e}	20.37^{d}	38.81^{b}	82.51^{a}	34.77^{c}	4.99	<.0001
NDF	721.34^{b}	693.50^{c}	716.12^{b}	428.37^{d}	318.45^{e}	138.01^{f}	743.41^{a}	50.15	<.0001
ADF	403.08^{ab}	397.80^{b}	405.16^{ab}	335.74^{c}	247.36^{d}	136.82^{e}	412.63^{a}	21.81	<.0001
ADL	39.86^{b}	36.04^{b}	34.63^{b}	52.68^{a}	35.10^{b}	12.13^{c}	32.53^{b}	2.53	<.0001
NFE	386.92^{ab}	352.36^{c}	382.70^{b}	405.01^{a}	396.30^{ab}	389.04^{ab}	399.37^{ab}	3.83	<.0001
NSC	1.53^{d}	4.29^{d}	3.48^{d}	216.24^{c}	263.53^{b}	360.32^{a}	12.410^{d}	31.66	<.0001
OM	865.12^{b}	860.90^{b}	863.03^{b}	850.61^{c}	823.45^{d}	788.89^{e}	883.05^{a}	6.57	<.0001
HC	318.26^{ab}	295.70^{c}	310.96^{bc}	92.64^{d}	71.09^{e}	1.19^{f}	330.78^{a}	29.36	<.0001
DMD	575.00^{de}	579.11^{d}	573.38^{de}	627.46^{c}	696.30^{b}	782.42^{a}	567.56^{e}	16.99	<.0001
DE	2.73^{de}	2.75^{d}	2.72^{de}	2.96^{c}	3.25^{b}	3.62^{a}	2.70^{e}	0.07	<.0001
ME	2.24^{de}	2.26^{d}	2.24^{de}	2.43^{c}	2.67^{b}	2.97^{a}	2.22^{e}	0.06	<.0001
CT	-	-	-	-	0.18^{a}	0.13^{b}	-	0.01	<.0001
TP	-	-	-	-	5.55^{b}	6.39^{a}	-	0.19	0.0002

^{abcde} Means with the same letter are not significantly different at $p<0.05$; SEM= Standard error of the mean; BL=90% Rhodes grass+10% Lucerne; BLM=90% Rhodes grass+5% Lucerne+5% *Moringa*; BM=90% Rhodes grass+10% *Moringa*; L=100% Lucerne; LM=50% Lucerne+50% *Moringa*; M=100% *Moringa*; B=100% Rhodes grass; DM=dry matter; CP=crude protein; CF=crude fibre; EE=ether extracts; NDF=neutral detergent fibre; ADF=acid detergent fibre; ADL=acid detergent lignin; NFE=nitrogen free extracts; NSC=non-structural carbohydrates; OM=organic matter; HC=hemicellulose; DMD=dry matter digestibility; DE=digestible energy; ME=metabolizable energy; CT=condensed tannins; TEPH=total extractable phenolic.

3.2 *In vitro* gas production and fermentation characteristics

Table 3 presents the *in vitro* gas produced at 24 and 48 hours as well as the fermentation characteristics of the diets and supplements. The result shows that BL produced the highest gas (11.18 ml/200 mg DM) at 24 hours of incubation while BM produced the least (7.93 ml/200 mg DM). At 48 hours of incubation, BL produced the highest gas (12.19 ml/200 mg DM) and there was no significant difference between L, M, and LM.

The initial gas production (A) was highest in LM (2.50 ml/200mg DM) while BLM has the least (0.62 ml/200 mg DM). BM has the highest (5.27 ml/200mg DM) actual gas production during fermentation (B) but there was no significant difference between BM, BL, BLM and L. The rate of gas production (C) was highest in L (9.26 ml/200 mg DM) followed by LM (0.16 ml/200 mg DM) and the least was observed in BM (0.052 ml/200 mg DM). The total gas production (A+B) did not follow the same pattern as A and B as BL produced the highest gas (6.75 ml/200 mg DM) and M produced the least (4.48 ml/200 mg DM).

The residual standard deviation (RSD) varies with BL having the highest (3.73) and there was no significant difference between BM, L, LM, and M. The highest short-chain fatty acids (SCFA) were recorded in BL (0.24 ml/200mg DM) and BM had the least (0.17ml/200mg DM). The organic matter digestibility (OMD) was higher in BL (30.62%) and the least was in LM (25.15%). M has the highest (7.05MJ/kg DM) metabolizable energy (ME) and there was no significant difference between BL and BLM.

Table 3: *In vitro* gas production and fermentation characteristics

Sample	GP24	GP48	A	B	C	A+B	RSD	SCFA	OMD	ME
BL	11.12^{a}	12.19^{a}	1.56^{b}	5.19^{a}	0.08^{b}	6.75^{a}	3.73^{a}	0.24^{a}	30.62^{a}	4.63^{d}
BLM	9.48^{bc}	10.97^{ab}	0.62^{c}	5.18^{a}	0.08^{b}	5.80^{ab}	3.67^{ab}	0.21^{bc}	29.59^{ab}	4.60^{d}
BM	7.93^{c}	9.92^{b}	0.91^{bc}	5.27^{a}	0.05^{b}	6.18^{ab}	3.21^{abc}	0.17^{c}	28.53^{b}	4.23^{e}
L	11.08^{a}	7.05^{c}	1.51^{bc}	3.78^{ab}	9.26^{a}	5.29^{bc}	3.11^{abc}	0.24^{a}	26.17^{c}	5.00^{c}
LM	10.84^{ab}	5.68^{c}	2.50^{a}	2.70^{b}	0.16^{b}	5.20^{bc}	2.88^{bc}	0.24^{ab}	25.15^{c}	5.54^{b}
M	8.99^{c}	6.35^{c}	1.73^{ab}	2.74^{b}	0.13^{b}	4.48^{c}	2.71^{c}	0.20^{c}	25.99^{c}	7.05^{a}
SEM	0.32	0.61	0.16	0.30	0.89	0.20	0.11	0.01	0.51	0.23
P	<.0001	<.0001	0.0002	0.0005	<.0001	0.0003	0.0065	<.0001	<.0001	<.0001

^{abc} Means with the same letter are not significantly different at $p<0.05$; SEM= Standard error of the mean; GP24=gas production at 24hours; GP48=gas production at 48hours; A=initial gas produced; B=actual gas produced during degradation; C=the rate of gas production per hour; A+B=the total gas produced during fermentation; RSD=Residual Standard Deviation; SCFA=short chain fatty acids; OMD=organic matter digestibility; ME=Metabolizable energy; BL=90% Rhodes grass+10% Lucerne; BLM=90% Rhodes grass+5% Lucerne+5% *Moringa*; BM=90% Rhodes grass+10% *Moringa*; L=100% Lucerne; LM=50% Lucerne+50% *Moringa*; M=100% *Moringa*.

Figure 1 presents the *in vitro* gas production measured at 0, 3, 6, 9, 12, 24, 48, 72, and 96 hours and shows the trends in the fermentation of the diets and supplements. This shows that L has the highest degradability while BM has the least degradability. It can also be observed that BLM and M have the same degradability at 48 hours before M starts declining and BLM continues increasing.

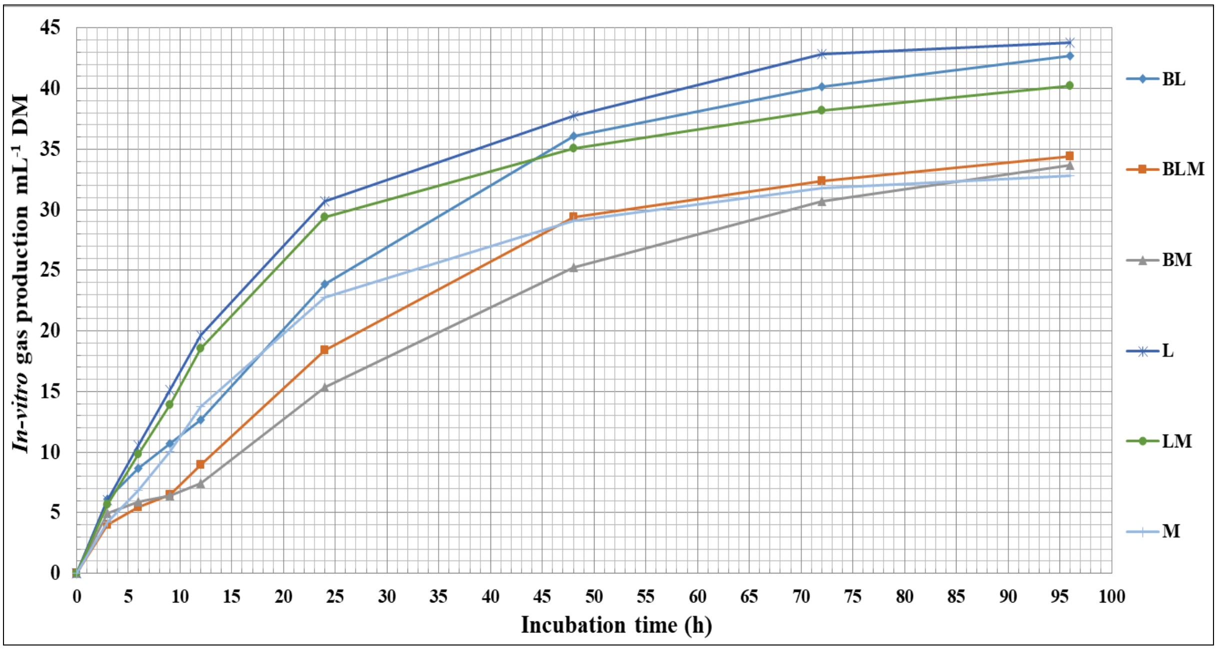

Fig 1: *In vitro* gas production of *Moringa oleifera, Medicago sativa, Chloris gayana,* and their combinations at different ratios

4. Discussion

Moringa oleifera is one of the alternative forage protein sources and the nutritional composition can be compared to *Leucaena leucocephala* and *Gliricidia sepium* mostly in terms of crude protein [24]. The result shows that *Moringa* leaves have the highest CP (295.047g/kg DM) which is within the range reported by [34]. It can also be observed that its combination with Lucerne and Rhodes grass at different ratios improves the CP of these ingredients which shows its suitability as a protein source for dairy cows and also a replacement for Lucerne hay.

The result shows that *Moringa* has an ash content of 124.12 g/kg DM which is within the range reported by [30] and there was no significant difference in the ash content of Lucerne, *Moringa*, and their combination which implies that *Moringa* also has a high mineral content and can serve as an option for Lucerne as a protein supplement in the diet of dairy cows.

Crude fibre enhances chewing, rumination, and production of saliva in ruminant animals which helps in the maintenance of the rumen pH and normal rumen function. This result shows that *Moringa* has the least crude fibre (109.28 g/kg DM) which is higher than the value reported by [19] while Rhodes grass hay has the highest (356.46 g/kg DM). This result shows the suitability of *Moringa* leaves as a supplement rather than a basal diet in ruminant nutrition. It is also good to note that low CF will improve the palatability of the diet which make a *Moringa*-supplemented diet highly acceptable by dairy cows.

Fat is important in ruminant nutrition as it increases the palatability of a diet and the rate of passage which in turn increase the digestibility of feed. This result shows that *Moringa* has the highest crude fat (82.51 g/kg DM) when compared to Lucerne, Rhodes grass, and their different combinations. This result is slightly higher than what [19] reported, which might result from different stages of harvest, soil type, the season of harvesting, post-harvesting treatment, and agro-climatic condition. This high crude fat content indicates the presence of fatty acids which have been reported to be mostly unsaturated fatty acids [30] that can improve feed efficiency and energy available from the diet despite it being a protein supplement.

Fibre fraction determines the extent and rate at which feed is digestible [27]. The NDF is the structural component of the plant, specifically the cell wall, and serves as a predictor of voluntary intake because it provides rumen fill. Adequate NDF in dairy cow diets enables proper rumen function, but a high NDF diet may lead to excessive gut fill and limited feed intake. The study showed that *Moringa* leaves have the least NDF (138.01 g/kg DM) when compared to Lucerne, Rhodes grass, and their different combinations and this result is lower than the findings of [19] and [6]. It was also observed that the addition of *Moringa* leaves to Lucerne and Rhodes grass hay at different ratios reduces the NDF.

ADF is a measure of the least digestible component of a forage and as the ADF increases digestibility of the forage decreases. The ADF and ADL of the *Moringa* used in this study differs from the findings of [18] and [6] but it was lower (136.82 g/kg DM and 12.130 g/kg DM) than Lucerne, Rhodes grass and their different combination. This shows that *Moringa* leaves have higher digestibility than Lucerne hay and its combination with Rhodes grass hay improves its digestibility.

This result also showed that there is no significant difference between the NFE value of Lucerne, *Moringa* and their combination which implies that they have the same amount of soluble carbohydrates and *Moringa* can replace Lucerne as a protein supplement in dairy cow diets. NSC is an important factor in the diet of dairy cows as they are required for propionate and microbial protein synthesis which are essential for milk and milk protein synthesis. The observed concentration of NSC of the *Moringa* used in this study differs from the findings of [11] but is within the acceptable range (30-40% on a DM basis) for lactating dairy cows and its combination with Lucerne increases the value.

It can also be noted from this study that *Moringa* has a high deposit of mineral elements evident from its low OM (788.89g/kg DM) when compared with Lucerne, Rhodes grass and their different combinations and its addition to Lucerne, and Rhodes grass at different ratios increases their mineral contents. This value differs from the study of [11] and the mineral composition explains the nutritional and therapeutic role of *Moringa* in animal diets [1].

Hemicellulose (HC) is a polysaccharide whose hydrolysis serves as a source of energy in ruminal fermentation [17]. The findings from this study show that *Moringa* has the least (1.187 g/kg DM) HC and its combination with Lucerne and Rhodes grass reduces the HC contents of these ingredients which shows that it's a good source of protein rather than energy. This also differs from the findings of [11].

This result shows that *Moringa* has the highest DMD, DE, and ME (782.42 g/kg DM, 3.619 Mcal/kg, and 2.971 Mcal/kg respectively) evident from its fibre fractions and CF content when compared to Lucerne, Rhodes grass and their combinations at different ratios. This result is consistent with the values reported by [11].

This result also indicates that *Moringa* has a negligible amount of anti-nutritional factors evident from the low percentage of condensed tannins (0.1311%) and total phenolic (6.3943%). This study differs from [18] who reported the value of condensed tannins and total phenolic as 3.12mg/g and 2.02% respectively and [11] who reported it as 26g/kg DM and 45 g/kg DM respectively. The CT content can reduce protein degradation in the rumen and increase protein flow to the intestine [16]. The concentration of phenols in this study has been reported to have no adverse effect when included in animal diets [6] but rather have beneficial biological effects such as antimicrobial and antioxidant activities [9].

The *in vitro* gas production and fermentation characteristics of these samples varied widely and it showed that *Moringa* has the least digestibility evident from its low gas production. This can be a result of the presence of anti-nutritional factors which inhibits microbial degradation but at the same time increases the flow of nutrients to the small intestine for enzymatic degradation. It can also be a result of the microbial population in the rumen liquor used for the incubation because the animals found in this area are commonly fed Rhodes grass and Lucerne as supplements which explain their high degradation compared to *Moringa*. These results show that supplementation with *Moringa* will improve the proper utilization of the nutrients by increasing the ratio of rumen undegradable protein to the rumen degradable protein.

Microbial fermentation of carbohydrates results in SCFA which is used as an energy source by ruminants and they have been estimated to produce around 75% of the metabolizable energy required by cattle [5]. This result showed that *Moringa* produced low SCFA and has low OMD which emphasizes its low susceptibility to microbial degradation in the rumen and increased flow of nutrients to the small intestine for enzymatic degradation.

5. Conclusion

Based on the nutritional composition reported in this study, *Moringa* can be recommended as a potential supplement for ruminant animals and can improve their productivity when fed with coarse fodders or crop residues in arid and semiarid regions. The variation in the nutritional composition of *Moringa* leaves used in this study might be a result of different stages and seasons of harvest, soil type, post-harvesting treatment, drying method and agro-climatic conditions.

The low *in vitro* gas production and fermentation of *Moringa* shows low feed degradability by rumen microbes due to the presence of anti-nutritional factors. However, feeding trials are required to determine its palatability and to ascertain its degradability.

6. Acknowledgement

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7. Disclosure Statement

The authors report no potential conflict in the publication of the manuscript.

8. References

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