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Effects of Inclusion of Different Levels of Ethiopian Thyme (*Thymus schimperi* Ronniger) as Natural Additive on Chemical Composition and *In Sacco* Dry Matter Degradability of Total Mixed Ration and Feed Ingredients

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Abstract

This study evaluated the effects of the inclusion of Ethiopian thyme (*Thymus schimperi* Ronninger) to natural pasture hay (NPH), noug seed cake (NSC), wheat bran (WB) and total mixed ration (TMR) on the chemical composition and *in Sacco* dry matter (DM) degradability of the feeds. The Thyme plant used for the study was collected from Dinsho and Tarmaber districts in the highlands of Ethiopia. Samples of the TMR and NPH, WB and NSC with or without thyme were divided into two parts and ground to pass through 1 mm screen for chemical analysis and 2 mm screen for *in sacco* DM degradability. The TMR contained 50% NPH, 32.5% WB, 14% NSC, 3% molasses and 0.5% common salt. The feed ingredients (NPH, WB and NSC) and the TMR were incubated without thyme or with thyme substituting the diet at 8%, 16% and 24% levels of treatments. The chemical composition of all the feeds differed significantly ($P < 0.05$) among treatments. In sacco rumen dry matter degradability of NPH, WB, NSC and TMR was increased ($P < 0.05$) with increasing concentration of thyme in the feeds for most incubation hours considered in this study. The *in sacco* DM degradability of NPH at all incubation hours was higher ($P < 0.05$) for 24% thyme inclusion level compared to the 0% and 8% levels. The slowly degradable fraction (B), potential degradability (PD) and effective degradability (ED) fractions for NPH were higher for the highest level of thyme inclusion than the other treatments. The inclusion of the thyme plant leaves and twigs in NPH was observed to lower lag time in the

degradation of NPH. The B and PD fractions of DM were higher ($P < 0.05$) for noug seed cake added with thyme additive at 8% and 16% DM in the diet compared with the control, respectively. Similarly, the dietary inclusion of the herbal additive in the WB was observed to lower the lag time. The A fraction of TMR was lowered for 16% thyme level compared to other treatments, while the B fraction was highest for the 8% and lowest for the 0% thyme inclusion levels in this study. It could be concluded that the inclusion of powder of leaves and twigs of *Thymus schimperi* plant up to a level of 24% DM in feed can reasonably stimulate the growth and activity of the certain rumen microbes that promoted an improvement in ruminal DM degradability of the diet with the thyme inclusion.

Keywords

Natural Additive, Feed Degradability, *Thymus schimperi*, Medicinal Plant, Phytochemicals

1. Introduction

Thymus, an aromatic plant belonging to the Lamiaceae family, has been reported to be found in different parts of Ethiopia [1]. This genus is represented by two indigenous species namely *T. serrulatus* and *T. schimperi* [2], both of which are locally named Tosigni (Afan Oromo) and Tosign (Amharic). These species are endemic to Ethiopian highlands and grow on the edges of roads, in open grassland, on bare rocks and on slopes between 2200 - 4000 meters above sea level. Both species are perennial herbs, woody at the base and are 5 - 40 cm high [3]. Bale, Shewa, Gonder and Wollo are the major growing areas of *Thymus schimperi* in Ethiopia [4]. The major active constituents of *T. schimperi* and *T. serrulatus* are thymol and carvacrol [5]. The pharmacological action of such active plant substances or herbal extracts is well known. However, the impact of the inclusion of such plants on the chemical composition and digestibility of animal feeds has not been investigated.

In Ethiopia, natural pasture is the primary and abundant feed resource [6]. However, its productivity in most parts of Ethiopia is extremely low due to seasonal fluctuation of rainfall and poor grazing land management and conversion of grazing land into crop lands as a result of the increased human population [7] [8]. The feed resources used to supplement livestock under Ethiopian conditions are mainly the agro-industrial by-products such as those residues remaining after oil seed and grain processing that have better nutritional value [9] [10]. Alternatively, hay harvested from natural pasture coupled with agro-industrial by-products can be formulated into total mixed ration (TMR) and fed to livestock.

The thyme that exists in grazing areas is being grazed by livestock along with other grazing resources. Similar to the natural pasture, this might have resulted in overgrazing of thyme owing to the palatability for cattle, sheep and goats as

well as the beliefs of inhabitants that animals fed on these plants give tasty meat and milk [5]. Feed additives containing active ingredients like the ones in thyme have been shown to modify the rumen environment and enhance or inhibit specific microbial populations [11]. The effect of dietary inclusion of thyme (*Thymus schimperi*) plant growing in highlands of Ethiopia on feed resource utilization, in general, is not well investigated. This needs the assessment of the effect of inclusion of thyme (*T. schimperi*) growing in Ethiopia in total mixed diet and feed ingredients on chemical composition and degradability of the feeds. Therefore, this study aimed to assess the additive effect of the inclusion of powder of leaves and twigs of *T. schimperi* plant growing in highland of Ethiopia on the chemical composition and *in sacco* dry matter (DM) degradability parameters of natural pasture hay, noug seed cake, wheat bran and total mixed diet of dairy cows.

2. Materials and Methods

2.1. Study Area

Thyme used for the study was collected from two locations, Dinsho and Tarmaber in highlands of Ethiopia. Dinsho is located at the northern edge of the Bale Mountains National Park about 370 km southeast of Addis Ababa. It has altitudinal ranges of 2441 - 3600 meters above sea level (masl) with a mean annual temperature and rainfall of 10.26˚C and 1218.64 mm, respectively [12]. Tarmaber is located about 190 km northeast of Addis Ababa. Its altitude ranges from 1500 to 3100 masl with average annual temperature and rainfall of 15.5˚C and 1200 mm, respectively (Ethiopia.org/index.php//amhara/tarmaber). The laboratory work was conducted at Holeta Agricultural Research Center (HARC) of the Ethiopian Institute of Agricultural Research (EIAR). HARC is located about 30 km west of Addis Ababa along the main road to Ambo. It is situated at 9˚3'N latitude and 38˚30'E longitude and at an altitude of 2400 masl. The center receives an average annual rainfall of 1000 mm with minimum and maximum temperatures of 6˚C and 22˚C, respectively [13].

2.2. Collection and Preparation of Thyme

The edible aerial fraction (leaves and twigs) of Thyme (*Thymus schimperi Ronninger*) plant adequate for the study was collected from its wild-growing localities in Dinsho and Tarmaber districts in highlands of Ethiopia at the peripherial and/or hilly areas of the communal lands at blooming stage of the plant life cycle between June-october, 2020. The plant materials were identified and collected by the group of researchers and botanist at the herbarium of Addis Ababa University. The harvested plant materials were packed into plastic coated sacs, transported to HARC and dried under shade until it became brittle when grasped between fingers. The material was then crushed and packed into properly labeled, airtight and double coated packaging polyethylene bags to avoid loss of some secondary metabolites, and then stored in a dark and cool place pending

the trial.

2.3. Preparation of the Experimental Feeds and Treatments

Natural pasture hay (NPH) containing dominant plant species of *Dactylis glomerata*, *Andropogon virginicus*, *Paspalum plicatulum*, *Phalaris aquatica*, *Setaria sphacelate*, *Pennisetum setacium* and *Medicaco sativa*, *Lotus pedunculatus* and trifolium species were harvested at its blooming stage from HARC pastureland, sun dried for three days and stored in hay shed. Wheat bran (WB), noug seed (*Guizotia abyssinia*) cake (NSC) and salt adequate for the study were purchased from food processing industries in Addis Ababa and the surrounding towns. Cane molasses required for the trial was purchased from Wonji sugar processing factory. NPH was chopped by automatic electric grinder to a size of 3 - 4 cm to make the preparation of TMR easier. The TMR was prepared to contain 50% NPH, 32.5% WB, 14% NSC, 3% molasses and 0.5% common salt based on nutrient requirements for dairy cows [14]. The experimental feeds evaluated the feed ingredients (NPH, WB and NSC) and TMR without thyme or with thyme substituting at 8%, 16% and 24% of the feed.

2.4. Chemical Analysis

Samples of the TMR and ingredients (NPH, WB and NSC) with or without thyme were divided into two parts and ground to pass through 1 mm screen for chemical analysis and 2 mm screen for *in sacco* DM degradability. Feed samples were analyzed for DM and ash using the procedure of AOAC [15]. The thyme leaves and twigs samples were also analyzed for their chemical composition similarly. The nitrogen (N) content of the samples was determined by the micro-Kjeldahl method and CP was calculated as N × 6.25 [16]. Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined according to the procedure of Van Soest and Robertson [17]. Organic matter (OM) content was determined as 100-ash%.

2.5. *In Sacco* DM Degradability

The *in sacco* DM degradability of the experimental feeds was determined using three rumen-fistulated steers fed NPH *ad libitum* and supplemented with 2 kg concentrate mixture containing 51% WB, 39% NSC, 9% cotton seed cake and 1% salt. Samples were incubated in the rumen using nylon bag of 41 μm pore size and 6.5 × 14 cm dimension. Samples (3 g) from each corresponding treatment were incubated in the rumen in triplicates for 0, 2, 4, 6, 12, 24, 48, 72 and 96 hours. Bags in the rumen were carefully removed at the end of each incubation time and immediately put into cold water to stop microbial activity. Bags were then put into the washing tank, manually washed gently under running tap water until the wash was clean and gently squeezed to remove excess water. After washing, the bags with the residues were oven dried at 65˚C for 72 hour, cooled and weighed, and used to determine DM degradability. To determine

water-soluble fraction (zero hour solubility), triplicate bags from each corresponding treatment were passed through the same washing and drying procedures as the incubated bags. The DM degradability was determined for each incubation time using the following formula of Orskov & McDonald [18].

$$\text{DMD}\left(\frac{\text{g}}{\text{kg}}\right)\text{at time } t = 1000 \times \frac{\text{DM in original sample} - \text{DM in residue}}{\text{DM in original sample}}$$

The DM degradability data was fitted to the exponential equation $P = a + b(1 - e^{-ct})$ to determine the DM degradability parameters as described by Orskov & McDonald [18] using Neway Excel program [19]. Where; P is DM degradation (%) at time t. Since washing losses (A) were higher than the estimated rapidly soluble fraction (a), the lag time was estimated according to McDonald [20] by fitting the model $P = A$ for $t < t_0$; $P = a + b(1 - e^{-ct})$ for $t > t_0$. The degradation characteristics of forage samples were defined as A = washing loss (readily soluble fraction); $B = (a + b) - A$, is the insoluble but fermentable material; c = the rate of degradation of B (/h) and the lag phase (L) = $(1/c)\log e[b/(a + b - A)]$. Potential degradability (PD) was estimated as PD = $A + B$; while effective degradability (ED) was calculated according to Dhanoa [21] using the formula ED = $a + [bc/(c + k)]$ at rumen outflow rates (k) of 0.02%, 0.05% and 0.08% h^{-1}.

2.6. Statistical Analysis

Feed compositions and dry matter degradability data were analyzed by using the General Linear Model procedure of SAS [22]. The means were computed using the LSMEANS option and compositions was done using Tukey's test. Differences between the means and the control were declared significant at $P < 0.05$. The following statistical model included a fixed effect of level of thyme additive, random effects of incubation hour and steer.

$$Y_{ijk} = \mu + T_i + \beta_k + P_j + \varepsilon_{ijk}$$

where, Y_{ijk} represents the observation on steer k incubated with i level of thyme treatment at incubation hour j; μ represents the grand mean; T_i represents the fixed effect of the i^{th} level of thyme additive($i = 1, 2, 3, 4$); β_k represents the random effect of k^{th} steer ($k = 1, 2, 3$); P_j is the random effect of j^{th} incubation hour ($k = 0, 2, 4, 6, 12, 24, 48, 72, 96$); ε_{ijk} = random error term.

3. Results

3.1. Chemical Compostion

The chemical compositions of TMR and ingredients at different inclusion level of *Thymus schimperi* are summarized in **Table 1**. With the exception of DM for NPH; DM, CP and NDF for NSC; and CP for TMR, all other chemical composition parameters for all the feed stuffs differed significantly ($P < 0.05$) among treatments. The inclusion of powder of the thyme leaves and twigs in NPH lower the OM, Cp, NDF and ADF contents of feed. In general, with the exception of

Table 1. Chemical compostion of ingredients and TMR at different level of inclusion of powder of leaves and twigs of thyme (*Thymus schimperi*) plant.

Feeds	Chemical compostion (g/kg DM)					
	DM	OM	CP	NDF	ADF	ADL
Natural pasture Hay (NPH)						
NPH without thyme	940	917^{a}	86^{a}	719 ^{a}	442^{a}	71^{b}
NPH + 8% thyme	923	912^{ab}	84^{ab}	697^{ab}	423^{ab}	73^{b}
NPH + 16% thyme	922	906^{bc}	81^{ab}	682^{b}	418^{ab}	79^{a}
NPH + 24% thyme	910	903^{c}	80^{b}	680^{b}	403^{b}	81^{a}
SEM	5.01	1.48	1.12	4.35	5.81	0.93
P-value	0.0585	0.0094	0.032	0.01	0.0376	0.0043
Noug seed cake (NSC)						
NSC without thyme	929	909^{d}	334	342	234^{b}	56^{b}
NSC + 8% thyme	928	912^{c}	330	343	241^{b}	59^{b}
NSC + 16% thyme	925	913^{b}	331	349	280^{a}	62^{ab}
NSC + 24% thyme	915	919^{a}	319	374	299^{a}	72^{a}
SEM	2.85	0.23	2.15	5.63	3.84	1.51
P-value	0.1201	0.0003	0.0544	0.0714	0.0031	0.0145
Wheat bran (WB)						
WB without thyme	894^{c}	949^{b}	171^{a}	407^{b}	135^{a}	34
WB + 8% thyme	895^{c}	951^{ab}	169^{ab}	430^{a}	133^{a}	37
WB + 16% thyme	904^{b}	953^{ab}	166^{ab}	432^{a}	121^{b}	39
WB + 24% thyme	917^{a}	956^{a}	162^{b}	447^{a}	116^{c}	42
SEM	1.25	0.98	1.14	3.23	0.41	1.55
P-value	0.0026	0.047	0.0373	0.0122	0.0002	0.146
Total mixed ration (TMR)						
TMR without thyme	925^{a}	913^{a}	155	507^{b}	273^{b}	62^{a}
TMR + 8% thyme	918^{b}	905^{b}	153	516^{ab}	282^{b}	57^{b}
TMR + 16% thyme	916^{b}	900^{bc}	152	528^{ab}	292^{ab}	54^{c}
TMR + 24% thyme	914^{b}	892^{c}	151	542^{a}	310^{a}	50^{c}
SEM	0.98	2.44	1.08	0.98	3.14	2.73
P-value	0.0109	0.0039	0.131	0.0257	0.0125	0.0016

$^{a-d}$Means within a column with no common superscript differ ($P < 0.05$); DM = dry matter; OM = organic matter; CP = crude protein; ADF = acid detergetent fiber; NDF = neutral detergent fiber; ADL = acid detergent lignin; SEM = standard error of the mean.

ADL, other chemical components of NPH showed a declining trend with the increasing inclusion of the thyme. The OM, ADF and ADL contents of NSC showed an increasing trend with increasing levels of the herbal additive in the diet. The ADF and CP content of WB showed a declining trend while the other chemical components had an increasing trend with the increase in thymus in the diet. The dietary inclusion of thyme in TMR at increasing levels has led to an increasing trend in NDF and ADF contnets, but while the reverse happened for the concentrations of DM, OM, and ADL.

3.2. *In Sacco* Dry Matter Degradability

The *in sacco* DM degradability of NPH at all incubation hour was higher ($P < 0.05$) for 24% thyme inclusion level compared to the 0% and 8% levels (Table 2). The DM degradability values for 16% thyme inclusion were similar with that of 0% and 8% levels in most of the incubation hours, while values for the 16% level were lower than the 24% treatment after 6 hours of incubation. The DM degradability for NPH at all incubation hours did not differ between the 0% and 8% levels of thymus inclusion.

The zero hour dry matter disappearance showed an increasing trend with increasing levels of addition of thyme in the hay. At the 0, 2, 4 and 12 hours of incubation, *in sacco* DM degradability for NSC was higher for the 24% level compared with the 0% and 8% levels ($P < 0.05$). For 24 hour and above incubation hours, although treatment effect was significant a consisntent trend on effects of thyme on DM degradability was not observed. The *in sacco* DM degradability of WB was similar among treatments for the 0 hour of incubation, while from 4 hour of incubation onwards the values were higher for the 24% compared to the 0% and 8% thyme levels, with the general trend of increasing DM degradability with increasing levels of thyme. The *in sacco* DM degradability for TMR was unaffected by treatment for the 0, 6 and 96 hours of incubation ($P > 0.05$). The DM degradability values for TMR in other incubation hours differed among treatments ($P < 0.05$) with inconsistent trend. While the values for 16% and 24% thyme levels were lower than the other treatments on 2 and 4 incubation hours, the vise versa happened on 12 and 24 incubation hours. The DM degradability of TMR for 48 hour was lower for 0% than the 24% thyme and that for 72 hour of incubation was lower for 0% than the 8% and 16% thyme level.

3.3. Ruminal Dry Matter Degradation Parameters

The ruminal DM degradation parameters of ingredients and TMR are shown in Table 3. The A fraction for NPH was lower ($P < 0.05$) for the 8% thyme level compared to the other treatments. The B, PD and ED fractions for NPH were higher for the highest level of thyme than the other treatments. The A and B fraction for NSC was unaffected by treatment ($P > 0.05$). However, the PD and ED were higher for 16% thyme level compared to the other treatments. The A fraction for WB was higher and that of the B fraction was lower for the 0% and 16% thyme levels compared to the other two treatments. The PD of wheat bran

Table 2. In sacco ruminal dry matter degradability of TMR and ingredients at different inclusion levels of powder of leaves and twigs of thyme (*Thymus schimperi*) plant for different incubation hours.

Feeds	Incubation hours								
	0	2	4	6	12	24	48	72	96
Natural Pasture hay (NPH)									
NPH without thyme	108^{c}	146^{b}	169^{b}	198^{b}	264^{b}	362^{b}	457^{c}	544^{b}	626^{b}
NPH + 8% thyme	116^{bc}	142^{b}	163^{b}	199^{b}	262^{b}	349^{b}	468^{bc}	537^{b}	602^{b}
NPH + 16% thyme	146^{ab}	174^{a}	191^{ab}	236^{ab}	301^{b}	392^{ab}	500^{b}	562^{b}	623^{b}
NPH + 24% thyme	155^{a}	176^{a}	207^{a}	269^{a}	322^{a}	439^{a}	565^{a}	642^{a}	710^{a}
SEM	5.0	5.09	7.44	11.58	13.32	17.49	9.50	11.48	9.79
P-value	0.0169	0.0001	0.0020	0.0009	0.0119	0.0091	<0.0001	<0.0001	<0.0001
Noug seed cake (NSC)									
NSC without thyme	103^{c}	73.6^{c}	266^{c}	335	467^{c}	613^{ab}	720^{b}	753^{b}	787^{b}
NSC + 8% thyme	114^{bc}	108^{b}	267^{bc}	324	484^{bc}	592^{b}	744^{a}	781^{a}	810^{a}
NSC + 16% thyme	121^{b}	119^{b}	286^{ab}	327	508^{ab}	637^{a}	744^{a}	772^{a}	804^{ab}
NSC + 24% thyme	130^{a}	174^{a}	294^{a}	339	528^{a}	610^{ab}	714^{c}	771^{a}	801^{ab}
SEM	15.56	4.73	4.75	6.26	9.55	9.41	8.19	3.67	4.45
P-value	0.004	<0.0001	0.0013	0.3366	0.0011	0.0263	0.0290	0.0003	0.0135
Wheat bran (WB)									
WB without thyme	135	437^{ab}	448^{b}	500^{c}	554^{b}	646^{b}	732^{c}	821^{c}	871^{b}
WB + 8% thyme	109	440^{ab}	469^{b}	533^{bc}	581^{b}	659^{b}	736^{c}	834^{bc}	877^{ab}
WB + 16% thyme	124	394^{b}	442^{b}	542^{ab}	647^{a}	767^{a}	816^{b}	844^{b}	885^{a}
WB + 24% thyme	167	465^{a}	523^{a}	575^{a}	682^{a}	755^{a}	835^{a}	860^{a}	875^{b}
SEM	18.63	14.02	15.44	9.4	9.52	6.82	2.86	3.37	2.23
P-value	0.333	0.017	0.0062	0.0003	<0.0001	<0.0001	<0.0001	<0.0001	0.002
Total mixed ration (TMR)									
TMR without thyme	135	266^{a}	332^{a}	355	441^{b}	539^{c}	668^{b}	704^{b}	736
TMR + 8% thyme	109	262^{a}	298^{b}	356	446^{b}	547^{bc}	680^{ab}	729^{a}	768
TMR + 16% thyme	124	206^{b}	279^{b}	380	515^{a}	599^{a}	697^{ab}	729^{a}	762
TMR + 24% thyme	167	193^{b}	272^{b}	382	467^{b}	603^{a}	698^{a}	724^{ab}	747
SEM	18.63	10.72	7.95	12.39	11.21	14.09	7.531	5.26	9.05
P-value	0.1243	0.0001	0.0002	0.2771	0.0007	0.0062	0.0289	0.0087	0.0896

[a-c]Means within a column with no common superscript differ ($P < 0.05$); SEM = Standard error of the mean.

Table 3. Dry Matter (DM) degradability parameters of natural pasture hay, wheat bran and noug seed (*Guzzitica abyssinica*) cake and total mixed ration at different inclusion levels of powder of leaves and twigs of thyme (*Thymus schimperi*) plant.

Treatment (Trt)	DM Degradability Parameters (g/kg DM)							
	A (g/kg DM)	B (g/kg DM)	C (/h)	PD (g/kg DM)	Lt (%/h)	ED (g/kg DM) at KP		
						0.02	0.05	0.08
Natural Pasture hay (NPH)								
NPH without thyme	136^{a}	508^{b}	0.021	644^{bc}	5.20	416^{b}	323	272
NPH + 8% thyme	95^{b}	514^{b}	0.026	609^{c}	5.85	411^{b}	319	261
NPH + 16% thyme	138^{a}	527^{b}	0.024	666^{b}	4.30	429^{ab}	322	278
NPH + 24% thyme	144^{a}	621^{a}	0.027	765^{a}	4.35	440^{a}	321	279
SEM	0.47	1.13	0.003	1.06	0.504	0.59	1.55	1.19
P-value	0.0059	0.0060	0.2223	0.0019	0.2341	0.050	0.9986	0.6952
Noug Seed Cake (NSC)								
NSC without thyme	138	616	0.061	756^{bc}	0.60^{c}	613	489^{ab}	420
NSC + 8% thyme	115	655.5	0.052	770^{ab}	0.95^{bc}	618	479^{bc}	410
NSC + 16% thyme	143	648.5	0.058	791^{a}	2.05^{ab}	619	499^{a}	398
NSC + 24% thyme	95	647.5	0.058	743^{c}	2.55^{a}	595	467^{c}	394
SEM	1.24	0.84	0.006	0.40	0.327	0.79	0.45	0.66
P-value	0.1504	0.0940	0.7356	0.0041	0.0377	0.2743	0.0281	0.1374
Wheat Bran (WB)								
WB without thyme	246^{a}	593^{b}	0.052	839	0.45	694^{b}	567^{c}	499^{c}
WB + 8% thyme	184^{b}	642^{a}	0.062	827	0.18	719^{ab}	613^{b}	542^{b}
WB + 16% thyme	197^{b}	613^{ab}	0.088	810	0.11	704^{ab}	615^{b}	552^{b}
WB + 24% thyme	226^{a}	598^{b}	0.166	817	0.05	734^{a}	644^{a}	584^{a}
SEM	1.36	0.91	0.026	1.33	0.226	0.68	0.68	0.87
P-value	0.0121	0.0461	0.1295	0.3528	0.6393	0.0318	0.0062	0.0061
Total Mixed Ration (TMR)								
TMR without thyme	204^{a}	519^{c}	0.05	723^{c}	0.045^{b}	584	463	413
TMR + 8% thyme	199^{a}	620^{a}	0.046	819^{a}	0.045^{b}	591	461	399
TMR + 16% thyme	160^{b}	604^{ab}	0.052	765^{b}	1.00^{a}	579	462	396
TMR + 24% thyme	198^{a}	582^{b}	0.045	780^{b}	0.06^{b}	589	469	407
SEM	0.61	0.54	0.002	0.66	0.066	0.77	0.60	0.73
P-value	0.0210	0.0007	0.2362	0.0024	0.0012	0.7013	0.7981	0.4327

$^{a-c}$Means within a column with no common superscript differ ($P < 0.05$); SEM = Standard error of the mean; A = immediately soluble (washing loss) fraction; B = insoluble but potentially degradable fraction; A + B = potential degradability (PD); C = Rate constant for degradation/rate of degradation of b component (fraction/hour); ED = effective degradability; Kp = Rate Constant of passage (h^{-1}/the rumen out flow rate of particle; Lt = lag time (%/).

was similar ($P > 0.05$) among treatments, while ED was higher for the 24% thyme level compared to the other treatments. For TMR, the A fraction was lower for 16% thyme level compared to other treatments, while the B fraction was highest for 8% and lowest for the 0% thyme levels in the ration. The PD of TMR was improved ($P < 0.05$) at lower level of inclusion (8%) of the powder of leaves and twigs of the additive plant when compared to the control. Whereas ED was similar among treatments ($P > 0.05$). In general, dietary inclusion of the powder of leaves and twigs of thyme plant improved the DM degradability of TMR compared to the control, the TMR without the additive plant.

4. Discussion

Studies have concluded that the degradability of feeds in the rumen is greatly influenced by feed properties being digested, such as neutral detergent fibre and crude protein content [23]. The CP level of NPH in this study is sufficient to support the optimum activity of rumen microorganisms and can satisfy the maintenance requirement of the animals [24]. The NDF value noted for NPH used in this study was consistent with the 662 g/kg average value of NDF for tropical grass [25]. The inclusion of thyme at different levels in NPH did not show a consistent trend in the chemical composition of the hay, although increasing level of thyme tended to increase the ash and decrease the fiber contents of the hay presumably associated with differences in the content of such components between hay and thyme in this study. Thus, dietary inclusion of the additive plant leaves and twigs in the hay may enhance some rumen microbial growth and activity resulting in improving the feed degradability especially for animals mainly depending on natural pasture hay as their sole diet. The CP and NDF contents recorded for NSC in this study were consistent with values reported by others [26]. The inclusion of aerial fractions of the thyme plant to the high CP content NSC feed increased OM and decreased the fiber content of the diet in this study, indicating that the plant additive could improve the rumen dry matter degradability of the diet. The chemical composition of wheat bran may vary depending on the quality of wheat being milled and the processing method employed [27]. In the present study the CP and ADF levels were decreased while those of OM and NDF contents were increased with thyme inclusion in WB. Further, the dietary inclusion of thyme to TMR lowered lignin content and increased ash and cellulose contents in the present work indicating that dietary inclusion of the additive plant leaves and twigs may improve the digestibility and mineral content of the ration. In general, differences in chemical composition of NSC, WB and TMR with inclusion of thyme appear to be a consequence of differences in chemical composition of the ingredients and thyme. The DM disappearance of NPH increased with higher level of thyme inclusion in the feed. This is improvement in DM digestibility of the hay is consistent with the decrease in fiber content with higher level of thyme inclusion in the hay because high fiber levels in feeds limits ruminal DM degradability. Thus, it may well suggest that the bioactive secondary metabolites in the thyme can stimulate the activity of

certain ruminal microorganisms responsible for the fiber degradability that related to increase in DM degradability of the hay. In contrast, EO had no effect on ruminal DM degradability and rate degradability of hay in sheep receiving EO in their diet at a daily intake of 110 mg [28]. A significantly increased in DM degradability of a high nitrogenous diet (NSC) was noted for a high level 24% thyme inclusion in most incubation hours and for the 8% level of thyme at the later stages of incubation period in this study. This indicating the dietary inclusion of the thyme plant that containing the mono-phenolics EO compounds at a low level in the diet may not modify the proteolytic rumen microbes. Similarly, essential oil (EO) had a selective effect on the ruminal degradation of different protein supplements [29] and rumen bacterial population [28]. On the other hand, Fernandez *et al.* [30] reported that protein meal digestion was inhibited significantly by EO at the highest level almost ten times more than that of 110 mg/sheep per day. The improvement in DM degradability of WB with thyme inclusion in most incubation hours may be related to the decrease in ADF and increase in OM contents with thyme inclusion observed in this study. The thyme containing active chemical compounds that likely maintain the ruminal pH changes during fermentation and/or stimulate the activity of certain rumen microbes promoted ruminal DM degradability of WB with thyme inclusion. The present finding agrees with Wallace *et al.* [31] who indicated that EO might suppress the colonization and/or digestion of readily degradable substrates by amylolytic and proteolytic bacteria without affecting the fiber digesting ruminal microorganisms. The increase in DM degradability of TMR with thyme inclusion was apparent at 24 to 72 hours of incubation. This might be associated with some exposure time needed for the additive effects of some bioactive chemical compounds from thyme when rumen microbes are exposed to the secondary metabolites in the herb. As opposed to the current result, Mostafa *et al.* [32] concluded that adding thyme at low levels to ruminant's diet had potential positive effect on ruminal fermentation and gas production, reduced NH_3-N concentration with no negative effect on DM, OM, NDF and ADF digestibility. Effective degradability represents the amount of the DM substrate which will actually be degraded in the rumen.

In this study, results revealed that ruminal degradability parameters of NPH at 24% level of inclusion of thyme increased the B, PD and ED fractions of the hay, which is partly attributed to the lower fiber content of the hay with the inclusion of thyme to the feed. Whereas, the dietary inclusion of the herbal additive did not vary the rate of degradation (C) for NPH perhaps due to high lignin despite lower NDF and ADF contents at high inclusion level of thyme to the hay. The present results are in agreement with Batalha *et al.* [33] who indicated that EO supplementation increased the potential degradation of the feed DM. The A fraction for NSC (protein supplement diet) noted in the current study was lower than the 165 g/kg DM reported by Getu *et al.* [13]. The B, C and ED fractions of DM of NSC in the present study are comparable with the reported of Gebrematiam *et al.* [34] but lower than those reported by Getu *et al.* [13]. Also, the effec-

tive DM degradability value of noug seed cake was gradually increased as the level of inclusion of the additive plant was increased in this protein supplement indicating the more the lag time elapsed for the diet in the rumen which extends the time for feed particulate exposure to microbial action, and slow the rate of solubility and fermentation of feed particles in the rumen. Whereas, in situ studies noted that the addition of BEO resulted in a decrease in ED, and the rate of ruminal degradation of protein supplements [29], which was associated with a decrease in the attachment and colonization of these feeds by proteolytic microbes [35]. The DM degradability of the insoluble but potentially degradable fractions in wheat bran was slightly lower as inclusion level of thyme in this energy diet was increasing which suggesting an increasing the level of thyme in the energy diet may result in increased the concentration of phenolic EO in the rumen which might have a distressing effect on the rumen microbial activity thus the decreased in the number of available carbohydrates for rumen digestion. The NDF content of WB was increased as level of thyme inclusion was increased in this energy diet so that enhanced in retention time and digestion of the substrate. Also, it could be explained that the effective rumen degradation kinetics for WB was enhanced as inclusion level of thyme increased in the diet in this study, reflecting that the oil in thyme may lower the turnover rate of the rumen digesta. The DM degradation characteristics of A, B and PD of TMR are consistent with the 210, 503 and 713 g/kg report of Gebremariam *et al.* [34], respectively. Whereas, dietary inclusion of thyme at a lower level (8% DM) in TMR resulted in higher degradability of B and PD fractions of DM in the diet compared with the control attributed to the additive effect of the secondary metabolites in the thyme additive may provoke the bacterial activity in the rumen. In general, this study's results revealed that inclusion of edible aerial fractions thyme plant (leaves and twigs) to the ingredients and TMR appeared to have a positive effect on the *in sacco* degradation of dry matter, although the level of impact vary among the type of feed tested. The differences in DM degradability among feeds in this study and other may be due to variation in feed composition, stage of maturity at harvesting, ruminal condition, the source, dose level and chemical structure in the additive material employed.

5. Conclusion

The dietary inclusion of the additive thyme leaves and twigs in the feeds improved the fiber and minerals contents of the diets that may enhance the rumen microbial growth and activity, resulting in improving rumen microbial activity, thus DM degradability of the feeds. By considering the positive impact of the inclusion of thyme plant as a natural feed additive in the animal diet in this study, it could be concluded that the dietary inclusion of *Thymus schimperi* plant up to a level of 24% DM in feed can reasonably stimulate the activity of the certain rumen microbes that promoted an improvement in ruminal degradability of the diet with the thyme inclusion.

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Data Availablity

The data sets used for this investigation are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interests.

Authors' Contribution

The authors were involved in the work presented in this paper.

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