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Research Article
Influence of Alfalfa Hay Replacement with Acacia Foliage on the Digestibility, Rumen Fermentation and Growth Performance of Ardi Goats

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Abstract

Background and Objective: The contribution of acacia to livestock nutrition is important in marginal lands of arid and semi-arid regions, therefore, the current study planned to evaluate the effects of replacement of alfalfa hay with acacia foliage in feeding goats on rumen fermentation, digestibility and growth performance of Ardi goats. **Materials and Methods:** Goats in-group 1 fed a control diet (C) containing 40% alfalfa hay and 60% concentrate mixture. Goats in groups 2, 3 and 4 fed diets in which 20% (A20), 30% (A30) and 40% (A40) of acacia foliage were replaced as the same percent with alfalfa hay in control diet, respectively. Ammonia concentrations were decreased numerically with acacia contained diets compared to control diet. **Results:** The highest digestibility values of dry matter (DM), organic matter (OM), crude protein (CP), ether extract (EE), crude fiber (CF) and nitrogen free extract (NFE) were recorded in goats fed C diet followed by A30, A20 and A40 diets. The best nitrogen retention was recorded with the goats fed C diet followed by A30, A20 and A40. There were significant differences on average daily gain between A40 and other diets. The best feed conversion was recorded with C and followed by A20, A30 and A40. **Conclusion:** The results suggest that the replacement of acacia foliage up 30% instead of alfalfa hay in goat diets without negative impact on the productivity of the animals.

Key words: Acacia foliage, alfalfa hay, rumen fermentation, nitrogen balance, nutritive values

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

In the tropics and subtropics countries, there is a shortage in green fodder for ruminant, as well as the lack of water needed to grow it, so there must be way to find alternatives resources to cover the deficit between the traditional fodder and requirement of the animals. However, alternative feed resources available to increase livestock production in the tropical and subtropical areas such as grasses, by-product crops, shrubs tree, fruits and foliage[1,2]. Some researchers have been conscious of the value of forage shrubs as animal feeds[3]. Shrub plants *Acacia* sp. had special consideration for their ability to be animal feeds[3,4]. The plants can be grown in a wide range of saline and arid environments[3,4]. Consequently, there is a great possibility for these plants to be livestock feeds. Sheep and goats are mainly livestock and they are the mainstay of the land and most of the rural population depends on these animals and their by-products in their life[5,6]. There is a shortage of green fodder in Saudi Arabia because of the lack of groundwater and low rainfall. The livestock and small holders in the Kingdom mainly used alfalfa as a traditional green fodder to feed their animals. This crop consumed large amounts of water when planted. However, the nutritionists should achieve alternative solutions for green fodder and it must be cheaper than alfalfa and when grown consume less water. However, many tropical foliages or legumes contain secondary plant compounds, such as tannins which may reduce their potential value as feeds and there is an increasing understanding of the effects of these compounds on feed quality and animal production[7]. Acacia is legume shrubs that yield green forage all year round and is considered as a palatable pasture shrub rich in protein[8-12]. Therefore, the objective of this study was amid to evaluate the replacement of alfalfa hay with acacia foliage as an alternative green fodder on digestibility, rumen fermentation and performance growth of goats.

MATERIALS AND METHODS

The current study was carried out during 2013-2014 at Department of Animal Production Farm, King Saud University.

Animals: A total of 92 Ardi male goats were used in this study in three trials, rumen fermentation (12 canulated animals weighing on average 46 kg, 3 each group), digestibility and nitrogen balance (20 animals weighing on average 44 kg, 5 each group) and growth performance (60 animals weighing on average 20 kg, 15 each group). The animals were fed alfalfa hay for 2 weeks prior to being assigned experimental diets.

Table 1: Components of the experimental diets

	Diets			
Ingredients (%)	C	A20	A30	A40
Alfalfa hay	40.0	20.0	10.0	0.0
Acacia	0.0	20.0	30.0	40.0
Soya bean meal	7.0	7.0	7.0	7.0
Barley	21.0	21.0	21.0	21.0
Corn	30.4	20.2	15.0	10.0
Bran	0.0	10.0	15.0	20.0
Salt	0.5	0.5	0.5	0.5
Minerals and vitamins	0.3	0.3	0.3	0.3
Limestone	0.8	1.0	1.2	1.2

Experimental diets: Goats in-group 1 fed a control diet containing 40% alfalfa hay and 60% concentrate mixture (C). Goats in groups 2, 3 and 4 fed diets in which 20% (A20), 30% (A30) and 40% (A40) of acacia replaced as the same percent of alfalfa hay in control diet (Table 1).

Rumen fermentation trial: The rumen contents were collected from 12 canulated goats fed the experimental diets (Table 1) before feeding and 1, 3 and 6 h after feeding to determine the ammonia-N concentration, volatile fatty acids (VFA) concentration and pH. Ammonia-N concentrations were determined according to the procedure of AOAC[13]. Total VFA were determined using steam distillation using Markaham apparatus[14]. The pH was measured immediately using a glass electrode.

Digestibility and nitrogen balance trials: Twenty adult male goats were used to determine the digestibility coefficients, nutritive value and nitrogen retention of the experimental diets (Table 1). During the preliminary and collection periods, the animals were confined in metabolic cages that are equipped to collect feces and urine separately. The diets were offered *ad libitum* and provided to all animals at the same time. The experiment was beginning with a 15 days preliminary period and followed by 7 days of collection period. Feed was offered once daily at 8:00 am. Immediately before each daily feeding, feed residues were collected, weighed and stored. The total feces excreted by each animal were collected every day at 8:00 am. The feces were immediately weighed and a sample of the collected material was weighed in an oven tray to determine the dry matter. Samples of feeds, residues and dried feces were ground and re-dried before chemical analysis. The total urine output of each animal was recorded and collected into a 10 mL solution of 50% H_2SO_4 to prevent nitrogen loss. An aliquot of 10% of total urine was sampled to determined nitrogen. The digestibility coefficients of dry matter (DM), organic matter (OM), crude protein (CP), ether extract (EE), crude fiber (CF), nitrogen free extract (NFE) and neutral detergent fiber (NDF) were measured. Digestible organic matter (DOM), digestible crude protein (DCP), Digestible energy (DE), metabolizable energy (ME), total digestible nutrients (TDN) and nitrogen utilization were estimated.

Growth performance trial: A total of 60 goat male kids were used. The kids were stratified by weight and randomly allocated to 4 treatment groups with 15 kids per dietary experiment. In each group, the goats were equally divided into 5 replicates, each replicate was housed in a concrete-floored pen in an open-sided building. The goats in each group were fed the experimental diet. The experimental diets were prepared as mixed diets. On initiation of the feeding trial, an adequate amount of feed was provided. Throughout the experiment, feed consumption data was recorded weekly and the goats weighed once per fortnight before any feed is offered.

Chemical analysis: Samples of the experimental diets and feces were analyzed for dry matter, ash, ether extract, crude fiber and crude protein according to the procedure outlined by the AOAC[13]. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined according to the method outlined by Van Soest *et al.*[15].

Statistical analysis: The design of samples allocation was a complete randomized design. The collected data were subjected to analysis of variance (ANOVA) using the general linear model (GLM).

Y_{ij} = $\mu+t_i+e_{ij}$
Y_{ij} = Response to the i treatment in the j replicates,
μ = Overall mean
ti = Effect of i treatment (C, A20, A30, A40)
e_{ij} = Residual error

The significant differences between individual means were identified using Duncan's multiple range test using procedure of SAS[16]. The probability value, which denotes statistical significance, was $p<0.05$.

RESULTS

The proximate analysis and fiber fractions of the experimental diets were presented in Table 2.

Rumen fermentation trial: Acacia foliage contained diets in all levels had no effect on pH during 6 h after feeding compared to control diet (Table 3). There were no significant ($p>0.05$) differences among the experimental diets in ammonia nitrogen (NH_3-N) concentrations although it was decreased numerically with acacia contained diets. The lowest value of VFA concentration was recorded with A30 diet and there were no significant ($p>0.05$) differences among the other diets (C, A20, A40).

Table 2: Proximate analysis and fiber fractions of the experimental diets

	Diets			
Components (%)	C	A20	A30	A40
Dry matter	91.77	91.98	91.75	91.79
Ash	6.74	8.96	10.16	11.10
Crude protein	15.03	14.83	14.89	14.64
Ether extract	2.51	2.55	2.37	2.56
Crude fiber	12.18	11.38	11.27	10.82
Nitrogen free extract	63.54	62.28	61.31	60.88
Fiber fractions				
Neutral detergent fiber	23.14	25.73	27.31	27.76
Acid detergent fiber	14.74	14.65	15.25	15.15

Table 3: Effect of the experimental diets on pH, NH_3-N and VFA in the rumen of Ardi goats

	Diets					
Parameters	C	A20	A30	A40	SEM[1]	p-value
pH	6.08	6.20	5.96	6.16	0.043	0.211
NH_3-N	9.49	9.37	8.37	8.14	0.363	0.484
VFA	3.23^{ba}	3.60^{a}	2.55^{b}	3.28^{a}	0.141	0.041

[1]Standard error of mean, NH_3-N: Ammonia nitrogen (mg/100 mL R.L), VFA: Volatile fatty acids (m.eq/100 mL R.L)

Digestibility and nitrogen balance trials: The digestibility coefficients of the experimental diets were presented in Table 4. The highest values of dry matter (DM), organic matter (OM), crude protein (CP), ether extract (EE), crude fiber (CF), nitrogen free extract (NFE) were recorded in goats fed control diet (C) followed by A30, A20 and A40 diets. There were no significant differences ($p>0.05$) among the experimental diets in neutral detergent fiber (NDF), the highest value was recorded for A30 followed by control, A20 and A40 diets. There were significant ($p<0.05$) differences among the experimental diets for digestible crude protein (DCP), total digestible nutrients (TDN), digestible of organic matter (DOM), digestible energy (DE) and metabolizable energy (ME). The nitrogen utilization values were presented in Table 5. The lowest nitrogen intake was recorded with the goats fed the diet A40 followed by A30, C and A20 ($p<0.199$). The lowest fecal nitrogen was recorded with C diet followed by A30, A40 and A20 ($p<0.064$). There were no significant ($p>0.05$) differences in urinary nitrogen among goats fed the experimental diets, therefore, the best nitrogen retention was recorded with the goats fed C followed by A30, A20 and A40.

Table 4: Digestibility coefficients and nutritive values of the experimental diets

Items	Diets					
	C	A20	A30	A40	SEM[1]	p-value
Digestibility coefficients (%)						
DM	73.19[a]	65.34[b]	69.18[ab]	65.06[b]	1.084	0.007
OM	75.59[a]	68.68[b]	71.80[ab]	67.86[b]	1.031	0.013
CP	66.77[a]	56.51[bc]	61.91[ab]	55.05[c]	1.557	0.011
EE	73.98	71.63	75.65	75.02	1.054	0.598
CF	42.67	35.60	43.97	38.07	1.773	0.323
NFE	84.05[a]	77.50[b]	79.17[b]	75.94[b]	0.931	0.001
NDF	39.77	33.72	41.26	33.31	2.11	0.457
Nutritive values (%)						
DOM	70.50[a]	62.53[bc]	64.50[b]	60.333[c]	1.148	0.001
DCP	10.04[a]	8.39[bc]	9.22[ab]	8.06[c]	0.247	0.005
DE	3.15[a]	2.74[bc]	2.93[b]	2.71[c]	0.055	0.003
ME[2]	2.55[a]	2.22[bc]	2.37[b]	2.20[c]	0.044	0.003
TDN	74.57[a]	64.81[b]	66.74[b]	62.73[b]	1.356	0.001

DM: Dry matter, OM: Organic matter, CP: Crude protein, EE: Ether extract, CF: Crude fiber, NFE: Nitrogen free extract, NDF: Neutral detergent fiber, DOM: Digestible organic matter, DCP: Digestible crude protein, DE: Digestible energy, ME: Metabolizable energy, TDN: Total digestible nutrients, [1]Standard error of mean, [2]ME = DE x 0.81, [a,b,c] Mean values within a row with unlike superscript letters were significantly different (p<0.05)

Table 5: Nitrogen (N) utilization in Ardi goats fed the experimental diets

Items	Diets[1]					
	C	A20	A30	A40	SEM[1]	p-value
Nitrogen balance						
N intake (g/day)	20.34[ab]	23.07[a]	19.14[ab]	17.14[b]	0.959	0.199
N excretion						
Fecal (g/day)	6.76[b]	10.02[a]	7.51[b]	7.62[ab]	0.475	0.064
Urinary (g/day)	8.96	10.20	7.36	7.16	0.625	0.283
N absorbed (g/day)	13.57	13.05	11.81	9.70	0.632	0.122
N retention (g/day)	4.62	2.85	4.45	2.53	0.603	0.542
N intake (%)	22.78	12.31	23.59	12.54	3.155	0.441
N absorbed (%)	34.37	21.81	37.89	20.28	5.439	0.621

[1]Standard error of mean, [a,b]Mean values within a row with unlike superscript letters were significantly different (p<0.05)

Growth performance trial: The growth of goats fed of the experimental diets was shown in Table 6. There were no significant (p>0.05) differences among the experimental diets in initial weight, but there were significant differences between acacia foliage contained diets and control diet in final weight and total gain. For dry matter intake, there were no significant (p>0.05) differences between control diet, A20 and A30 diets but there were significant (p<0.05) differences between A40 diet vs control, A20 and A30 diets. The lowest value of dry matter intake was recorded with A40 diets. The highest overall of average daily gain during the periods of growth (84 days) was recorded with control diet and followed by A20, A30 and A40 diets but there was no significant (p>0.05) difference between A20 and A30 diets. The best feed conversion was recorded with control diet followed by A20, A30 and A40 and there were no significant (p>0.05) differences between C, A20 and A30 diets. Therefore, the A40 diet had the lowest feed intake, daily gain and feed conversion.

DISCUSSION

There was no significant difference among the experimental diets in pH and hence, the pH was in range 5.96-6.20 and it is favorable for important microbial activity in the rumen. In the current study, there were no significant differences among the experimental diets in ammonia nitrogen (NH_3-N) concentration at the times after feeding although it was decreased numerically with acacia foliage contained diets (Table 3). The lowest value was recorded with the diet A40 and A30 compared to control diet attributed to the presence tannins in acacia foliage which decreased the degradation of protein in the diet[12,17]. The formation of undegradable complex between tannins and protein and/or carbohydrates may have reduced the amount of available substrate for fermentation[18]. The escape of these undegradable complexes from the rumen to the abomasum could also explain the low concentrations of protein in the rumen fluid[18]. The reducing of protein degradation was

Table 6: Performance growth of Ardi male goats fed the experimental diets[1]

	Diets					
Items	C	A20	A30	A40	SEM[2]	p-value
Live weight (kg)						
Initial	20.66	20.32	20.38	20.60	0.265	0.9684
Final	34.70[a]	31.05[b]	30.68[b]	27.31[c]	0.752	0.0008
Total gain	14.04[a]	10.73[b]	10.30[b]	6.72[c]	0.721	0.0003
DM intake (g/day)						
0-28	758.6[ba]	745.9[ba]	792.4[a]	680.4[b]	16.57	0.0989
28-56	1166.0[a]	1066.2[ba]	1125.8[a]	974.2[b]	26.11	0.0370
56-84	1302.1[a]	1267.5[a]	1201.7[a]	1050.4[b]	31.56	0.0110
0-84	1075.6[a]	1026.5[a]	1040.0[a]	901.6[b]	21.49	0.0113
Gain (g/day)						
0-28	141.4[a]	101.9[ba]	98.43[b]	53.29[c]	9.61	0.0039
28-56	233.9[a]	162.6[bc]	170.6[b]	122.4[c]	11.71	0.0014
56-84	126.1[a]	118.9[a]	98.79[ba]	64.21[b]	7.85	0.0110
0-84	167.1[a]	127.8[b]	122.6[b]	80.0[c]	8.58	0.0003
Gain: Intake ratio (day)						
0-28	5.64[b]	7.78[b]	8.74[b]	14.91[a]	0.96	0.0047
28-56	5.10[b]	6.70[ba]	6.69[ba]	8.70[a]	0.45	0.0299
56-84	10.83	10.79	12.81	23.11	2.30	0.1770
0-84	6.52[b]	8.10[b]	8.62[b]	12.31[a]	0.68	0.0084

[1]Values represent means of 5 pens, 3 kids each/treatment. Feeding period lasted 84 days, [2]Standard error of means, [a,b,c] Means within rows not sharing the same letter(s) differ ($p<0.05$)

associated with a lower of NH_3-N concentrations and greater non protein nitrogen such as amino acids or peptides flow to the duodenum[18]. Low and steady production of VFA and ruminal NH_3-N may result from high fiber content in acacia foliage and from inhibition of rumen microbes by tannins which lead to low rate of deamination[17] and this evidence was confirmed in the present study. Many studies have noted that the effect of tannins on ruminal fermentation is dose dependent and a negative effect only occurs when they are fed at high concentrations. There were no significant differences between the control group and group 3 fed 30% acacia foliage, in digestion coefficients of DM, OM, CP and CF (Table 4). There were no significant differences among all groups in the digestibility of EE, CF and NDF. The goats fed 30% of acacia foliage almost similar with control diet in nutrients digestion. The lowest digestion coefficients of DM, OM, CP and CF decreased with increasing acacia foliage with the A40 diet. The highest CP digestibility was that of C followed by A30, A20 and A40. The adverse effect of acacia foliage on the digestibility of the ration should be attributed to the inhibitory effect of its high tannin content on microbial activity. The highest values of TDN and DCP were recorded with C followed by A30, A20 and A40 (Table 4). A30 was recorded the best values of TDN and DCP compared to A20 and A40, this result is parallel with CP digestibility. Tannins mainly utilize this effect on proteins, but they also affect other feed components to different degrees. Evidently, the modifications of the digestibility caused by tannin ingestion are mainly associated with changes in the ruminal fermentation pattern, along with changes in intestinal digestibility[19]. There were no significant ($p>0.05$) differences among all the experimental diets in N retention (Table 5). Numerically, the highest value was recorded with C followed by A30, A20 and A40, however, A30 was recorded the best value of N retention compared to A20 and A40. The best value of N retained/N absorbed (the biological values) was also recorded with A30 compared to other 3 groups (C, A20 and A40). When goats fed acacia foliage containing diet (A30), it tended to excrete lower amount of N in urine and higher amounts of fecal N compared to control diet (C), may be due to the presence tannins which could be bounded with nitrogen but the values between C and A30 are not significantly differences. The advantage of the present tannins is reduced the excessive of ammonia production in the rumen and decreased urinary N losses and hence, nitrogen retention may increase in ruminants fed tannin-rich plants or remain without effect[20]. The highest gain was recorded with C and followed by A20, A30 and A40 but there was no significant difference between A20 and A30. The lowest gain was recorded with goats fed A40. The current study confirmed the adverse relationship between gain and tannins contents. There was significant ($p<0.05$) difference between A40 vs C, A20 and A30 in feed intake (on average of 84 days), but the diets C, A20 and A30 had no significant differences ($p>0.05$). The same manner of feed intake was found in feed conversion. The best feed conversion was recorded with C (6.4) and followed by A20 (8.0), A30 (8.5) and A40 (11.3) and there were no significant differences between C, A20 and A30. It would seem that the consumption of plant species with high tannins contents significantly reduces feed intake. Gebru *et al.*[21] reported that adding *Acacia saligna* in rams' diets helps in obtaining a better body weight. On the other hand, Ahmed *et al.*[22] found that untreated mixture of *Atriplex nummularia* and *Acacia saligna* (at 1:1 DM) can be substituted for berseem (*Medicago sativa*) hay without affecting Bakri lambs performance. Ahmed *et al.*[23] evaluated partial or whole substitution of berseem (*Trifolium alexandrinum*) hay with *Atriplex nummularia* and/or *Acacia saligna* in diets for feeding lambs. It was concluded that *Atriplex nummularia* and *Acacia saligna* could replace berseem hay up to 50% in the diet of Barki lambs without compromise of lamb growth performance.

CONCLUSION

It is concluded that acacia foliage contained diets up to 30% had no negative effect on rumen fermentation, nutrients digestion, nitrogen retention, biological value, growth and feed conversion. Therefore, acacia foliage is promising and valuable alternative feeds and could be incorporated in feed mixtures to replace conventional roughage such as alfalfa hay.

SIGNIFICANCE STATEMENT

This study discovers the replacement of alfalfa hay with acacia foliage as a nontraditional fodder that can be integrated in feed mixtures for goats during critical period in tropics and subtropics area and it will help the researchers to reduce the cost of animal nutrition for producers.

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