Comparison of the nutritive value of a native Turkish forages, tumbleweed hay (*Gundelia tournefortii L.*), wheat straw and alfalfa hay using *in situ* and *in vitro* measurements with sheep

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ABSTRACT. Hay from native-growing tumbleweed *(Gundelia tournefortii* L.*)* was compared with wheat (*Triticum estivum*) straw and alfalfa (*Medicago sativa*) hay in terms of chemical composition, *in situ* dry matter (DM) degradation *in vitro* gas production and *in vitro* DM digestibility (IVDMD). Chemical composition of tumbleweed hay was better than wheat straw but comparable to alfalfa hay. Crude protein (CP) concentration of tumbleweed hay was higher (P<0.001) than that of wheat straw but lower than that of alfalfa hay. Crude fibre (CF) concentration of tumbleweed hay was lower (P<0.001) than that of wheat straw but similar to that of alfalfa hay. Mineral concentrations varied among forages. Tumbleweed hay was high in phosphorus (P) and iron (Fe) compared with alfalfa hay and wheat straw. The in situ DM disappearance and corresponding estimated prediction equation parameters of tumbleweed hay were higher (P<0.001) than those of wheat straw but similar to those of alfalfa hay, whereas *in vitro* gas production at all incubation times and corresponding estimated parameters of tumbleweed hay were higher (P<0.001) than those of alfalfa hay and wheat straw. Metabolizable energy (ME) values of the forages varied between 7.1 and 10.5 MJ/kg DM. The ME value of tumbleweed hay exceeded (P<0.001) those of alfalfa hay and wheat straw. *In vitro* DM digestibility (IVDMD) of tumbleweed hay was higher (P<0.001) than that wheat straw but similar to that of alfalfa. It was concluded that the nutritive value of tumbleweed hay is better than that of wheat straw and comparable to that of alfalfa hay. Within the confines of this study, tumbleweed hay seems to have potential as a forage crop for smallholder farmers during periods of forage scarcity.

Keywords: Degradability, digestibility, forage, Gundelia, legumes, straw.

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Comparação do valor nutritivo do feno duma forragem nativa, (*Gundelia tournefortti* L.), paha de trigo e feno de alfafa usando determinações in situ e *in vitro* com ovinos

RESUMO. Feno da planta nativa (tumbleweed) (*Gundelia tounefortii* L.) foi comparado com palha de trigo (Triticum estivum) e feno de alfafa (Medicago sativa) em relação a composição química, degradação in situ da matéria seca (MS), produção de gás in vitro e digestibilidade in vitro da MS (IVDMD). Composição química do feno de tumbleweed foi melhor que o feno de palha de trigo e comparável ao feno de alfafa. Tumbleweed apresentou teor mais elevado de proteína bruta (PB) que a palha de trigo (P<0,001) e menor que o feno de alfafa. Concentração mineral variou entre as forragens com o fósforo e o ferro sendo mais elevados no feno de tumbleweed do que nas demais forragens. Os valores de desaparecimento da MS e parâmetros estimados do feno de tumbleweed foram mais altos que os da palha de trigo, mas similares aos do feno de alfafa (P<0,001), enquanto que a produção de gás in vitro em todos os tempos de incubação e parâmetros estimados foram maiores do feno de tumbleweed que a palha de trigo e o feno de alfafa (P<0,001). Os valores de energia metabolizável (EM) das forragens variaram de entre 7,1 e 10,5 MJ/kg MS, sendo mais altos no feno de tumbleweed. Digestibilidade in vitro da MS do feno de tumbleweed foi maior que da palha de trigo e semelhante a alfafa. Concluiu-se que o feno de tumbleweed apresenta melhor valor nutritivo que a palha de trigo e semelhante ao feno de alfafa, apresentando potencial como forragem arbustiva para pequenos produtores rurais durante os períodos de escassez de forragem.

Palavras-chave: Degradabilidade, digestibilidade, forragem, Gundelia, leguminosa, palha.

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Introduction

Forages represent the major portion of ruminant diets. High quality forages are essential for proper feeding of ruminant animals as they provide energy, proteins, vitamins and minerals. In the semi-arid and arid regions of Turkey, the lowest production of forage occurs during the summer season which is a naturally restricted alementary period for livestock. One strategy towards alleviating this alimentary deficit is through the use of naturally growing forages.

Tumbleweed (*Gundelia tournefortii* L.)is a spiny perennial plant which is collected and dried for ruminant animal feeding when the quality and quantity of other forages are limited. In the desert areas of Israel, mature tumbleweed hay is sometimes used as fodder for camels (Bailey and Dani, 1981). A preliminary experiment indicated that dry matter (DM) yield/ha ranged from 2230 to 2800 kg with a crude protein (CP) concentration of 10 to 12%.

Tumbleweed is one of the naturally-growing plants used to meet ruminant nutritional requirements in some semi-arid regions of Turkey during critical periods of feed scarcity. Nevertheless, few studies have been conducted to validate the nutritional quality of tumbleweed hay. Therefore, additional evaluation of tumbleweed is needed to provide guidelines to regional producers.

The objective of this study was to evaluate the potential value of tumbleweed hay in terms of chemical composition, *in situ* DM degradability, *in vitro* gas production, *in vitro* DM digestibility and some estimated parameters compared to those of wheat (*Triticum estivum*) straw and alfalfa (*Medicago sativa*) hay.

Materials and Methods

Forage samples: A commercial alfalfa (var. Elci) was sown in 2002 in three 10 X 2 m replicated plots at the rate of 30 kg/ha. Fifty kg nitrogen (N) and 150 kg P_2O_5 ha^{-1} were applied on 3 Nowember. Spring wheat was sown at a rate of 250 kg ha^{-1} on 7 November in three 10 X 2 m replicated plots. One hundred eithty kilograms N ha^{-1} and 80 kg P_2O_5 ha^{-1} were applied. Spring wheat straw was obtained after harvesting wheat for grain on 15 June. Naturally-grown tumbleweed plants were hand-harvested from three replicated plots measuring 10 X 2 m. Alfalfa and tumbleweed plants were harvested at the beginning of flowering which is a common practice in Turkey. Samples were shade-dried and representative dry samples (approximately 2.5 kg) from each plot was taken to the laboratory and milled in a hammer mill through a 3- then 1-mm sieve for subsequent analysis. The experimental area was located at an altitude of 630 m above sea level. The mean annual rainfall and temperature are 857.5 mm and 16.2ºC, respectively.

Chemical analysis: Dry matter was determined by drying the samples at 105ºC overnight and ash by igniting the samples in a muffle furnace at 525ºC for 8 h. Nitrogen concentration was measured by the Kjeldahl method (AOAC, 1990). Crude protein was calculated as N X 6.25. Crude fiber (CF) and ether extract (EE) were determined by the methods of AOAC (1996). The mineral compositions of the forages were determined using atomic absorption spectrophotometry (Zohary, 1973). Phosphorous was determined according to the vanadomolybdophosphoric acid method (Shiou, 1996) using a spectrophotometer (Jenway 6100, UK).

In vitro gas production: Ruminal fluid was obtained from two ruminally-fistulated male sheep fed twice daily with a diet containing alfalfa hay (60%) and concentrate (40%). The concentrate consisted of wheat (74%), sunflower meal (24%), calcium carbonate (0.99%), salt (1%) and vitamin and mineral mixture (0.01%). The samples were incubated *in* ruminal fluid in calibrated, 100mL glass syringes following the procedures of Menke and Steingass (1998). The samples (0.2 g) were weighed in triplicate. The syringes were prewarmed at 39ºC before the injection of a 30 mL ruminal fluid-buffer mixture into each syringe followed by incubation in a water bath 39ºC. The syringes were gently shaken 30 min after the start of incubation and every hour for the first 10 h of incubation. Gas production readings were recorded before incubation (0) and after 3, 6, 12, 24, 48, 72 and 96 h of incubation. Total gas values were corrected for blank values. Cumulative gas production data were fitted to the model of Ørskov and McDonald (1979).

$$y = a + b\,(1 - e^{-ct})$$

Where

a= gas production from the immediately soluble fraction (mL)

b= gas production from the insoluble fraction (mL)

c= gas production rate constant for the insoluble fraction (b)

t= incubation time (h)

y= gas produced at time t

The metabolizable energy concentration of the forages was calculated using equations of Menke *et al*. (1979) as follows:

$$ME(MJ/kg\ DM) = 2.20 + 0.136\ GP + 0.057\ CP + 0.0029\ CP^2$$

Where

GP = 24 h net gas production (mL/200mg)

CP = Crude Protein (%)

In vitro dry matter Digestibility (IVDMD): 0.5 g of dry forages samples milled in a hammer mill through a-1 mm sieve were subjected to a 48 h digestion period with the McDougall's buffer/ruminal fluid mixture in sealed plastic bottles followed by 48 h of digestion with pepsin in weak acid (Tilley and Terry, 1963). All incubations were carried out in triplicate. Ruminal fluid was obtained from two ruminally-fistulated sheep fed twice daily with a diet containing alfalfa hay (60%) and concentrate (40%).

IVDMD (%)= ((DM input – DM remaining undigested) / DM input)*100

In situ dry matter degradation: The nylon bag technique (Ørskov and McDonald, 1979) was used to measure the kinetics of DM degradation of forages. Forage samples milled in a hammer mill through a 3-mm sieve were subjected to standard ruminal degradability procedures using three ruminally-fistulated male sheep. The sheep were fed a diet containing alfalfa hay (60%) and concentrate

(40%). Throughout the experimental period dacron bags with 40–50 ìm pore size containing approximately 5 g forage sample were incubated in each sheep for each of the testing time periods: 3, 6, 12, 24, 48, 72 and 96 h. The bags were removed alter in situ incubation and washed in cold running water until the washing ran clear and colorless. Time 0 h samples were not incubated in the rumen but were washed in cold water as above to determine solubility at time 0 h. The bags were oven-dried at 60ºC for 48 h.

The DM degradation data were fitted to the exponential equation

$p = a + b\,(1-e^{-ct})$ (Ørskov and McDonald, 1979).

Where

p = disappearance of DM at time t

a = soluble DM which is rapidly washed out of the bags and is assumed to be completely degradable

b = proportion of insoluble DM which is potentially degradable by micro-organisms

c = degradation rate per hour of fraction b.

The effective degradability (P) of samples was calculated using the equation shown below, assuming a ruminal digesta outflow rate (r) of 0.02 h^{-1} which is an average value for animals fed at approximately maintenance level (AFRC, 1992).

$P = a + ((bxc)/(c+r))$.

Statistical Analysis: Analysis of variance was carried out to compare the chemical composition, *in vitro* gas production, *in situ* dry matter disappearance, estimated parameters and *in* IVDMD with forage species as the main factor using General Linear Model of Statistica for Windows (Statistica, 1993). Individual means were separated using the Tukey's multiple range test (Pearse and Hartley, 1996). Mean differences were considered significant at P<0.05. Standard errors of the means were calculated from the residual mean squares of the analysis of variance. A simple correlation analysis was used to establish relationships between the chemical composition and *in vitro* gas production or *in situ* dry matter degradation.

Table 1. Chemical composition of wheat straw, tumbleweed and alfalfa hays

Constituents	Forages			SEM
	Wheat straw	Tumbleweed	Alfalfa	
DM (%)	92.2	92.4	92.7	0.13
CP (%)	3.1[a]	11.2[b]	18.4[c]	0.14
CF (%)	41.8[a]	31.3[b]	27.2[c]	0.15
EE (%)	2.3	2.7	2.6	0.15
Ash (%)	5.8[a]	11.3[b]	10.7[c]	0.38
Ca (%)	0.2[a]	1.2[b]	1.5[b]	0.07
P (%)	0.1[a]	0.3[b]	0.2[c]	0.01
Mg (%)	0.1[a]	0.2[b]	0.2[b]	0.01
Na (%)	0.13[a]	0.02[b]	0.01[a]	0.003
K (%)	1.2	1.8	1.8	0.11
Zn (ppm)	ND	58.1[a]	24.1[b]	2.24
Cu (ppm)	2.8[a]	9.7[b]	6.3[b]	0.63
Fe (ppm)	148.5[a]	362.1[b]	154.4[a]	9.56
Mn (ppm)	36.1[a]	42.6[ab]	50.1[b]	1.46

DM: Dry matter, CP: Crude protein, CF: Crude fibre, EE: ether extract. Means within the same row with different superscripts differ (P<0.05). SEM: Standard error of the mean. ND: Non-detected

Results and Discussion

Chemical composition: Considerable variation was observed among the three forages (Table 1).

The CP concentrations ranged from 4.1% for wheat straw to 15.0% for alfalfa hay . The CP value of tumbleweed hay harvested at the beginning of flowering 11.2% was lower than that obtained by Kamalak *et al*. (2005) who showed that maturity had an important effect on CP concentration. These authors found that the CP concentration of tumbleweed hay harvested at the beginning of flowering was 14.5% and decreased with increasing maturity. The CP concentrations of alfalfa hay and wheat straw were similar to those reported by Zervas *et al*. (1996) and Dhiman *et al*. (2002).

Wheat straw was of very poor quality in terms of low CP and high CF, in agreement with the findings of Chaudhry (2000). The CF concentration ranged among the forages from 27.2 to 41.8%. Tumbleweed and alfalfa hays had similar CF concentrations. The values of alfalfa hay was similar to values reported by Giger-Reverdin (2000) and Mir *et al*. (1996). The CF concentration of wheat straw was similar to that reported by Zervas (1996). The ash concentration ranged from 8.6 to 11.3%. The ash concentration of tumbleweed hay harvested before flowering was comparable with that obtained by Kamalak *et al*. (2005) but was higher (P<0.001) than in alfalfa hay. The ash concentration of alfalfa hay is similar to that reported by Giger-Riverdin (2000).

There was also considerable variation between forages in mineral composition (Table 1). The Ca, P, Mg, and Cu concentrations of tumbleweed hay was higher (P<0.001) than those of wheat straw. The P, Na,Zn and Fe contents of tumbleweed hay were significantly (P<0.001) higher than those of alfalfa hay whereas the Ca, Mg, Cu and Mn contents of tumbleweed hay were similar to those obtained for Alfalfa hay. The mineral composition of alfalfa hay and wheat straw were consistent with values reported by Ramirez (1998) and NRC (2001). The mineral composition of tumbleweed hay has not been previously reported in the literature.

Gas production and estimated parameters: The cumulative volume of gas production increased with increasing incubation time (Table 2).

Gas produced after 96 h of incubation ranged between 45.3 and 57.7 mL per 0.2 g DM of substrate. There were differences between forages (P<0.001) at each incubation times. Gas production of tumbleweed hay at 3 h of incubation was similar to that of alfalfa hay but higher (P<0.001) than that of wheat straw. Gas production of tumbleweed hay at

Table 2. *In vitro* gas production and estimated parameters of wheat straw, and tumbleweed and alfalfa hays incubated with ruminal fluid

Incubation time(h)	Forages			SEM
	Wheat Straw	Tumbleweed	Alfalfa	
3	13.5[a]	18.8[b]	16.3[ab]	0.66
6	19.2[a]	28.0[b]	24.5[c]	0.56
12	27.2[a]	36.8[b]	33.2[c]	0.67
24	34.3[a]	47.3[b]	42.3[c]	0.60
48	40.3[c]	53.0[a]	49.7[b]	0.54
72	43.2[a]	55.8[b]	53.5[c]	0.51
96	45.3[a]	57.7[b]	55.8[c]	0.62
		Estimated parameters		
c	8.0[a]	1.0[b]	8.0[a]	0.20
a	2.0[a]	2.4[a]	3.3[b]	0.09
b	40.5[a]	53.2[b]	49.6[c]	0.38
(a + b)	42.9[a]	55.5[b]	52.9[c]	0.40
ME	7.1[a]	10.5[b]	9.5[c]	0.06
IVDMD	46.5[a]	71.7[b]	71.9[b]	0.17

Means within the same row wiht different superscripts differ ($P<0.05$). ***$P<0.001$, **$P<0.01$ NS- Non-significant, SEM: Standard error of the mean. Sig: Significance level, c: rate of gas production (%), a: gas production (mL) from quickly soluble fraction, b: gas production (mL) from slowly fermentable fraction, (a+b): potential gas production (mL), ME: Metabolizable energy (MJ/kg DM), IVDMD: *In vitro* dry matter digestibility (%).

6, 12, 24, 48, 72, 96 h of incubation was higher ($P<0.001$) than that of alfalfa hay and wheat straw. Gas production of alfalfa hay at 24 h was similar to those reported by Getachew *et al*. (2002). There were differences ($P<0.001$) between forages in estimated parameters (Table 2). Tumbleweed hay had a higher ($P<0.001$) gas production rate (c) than that of alfalfa hay or wheat straw whereas alfalfa hay had a higher ($P<0.001$) gas production rate from the quickly soluble carbohydrate fraction (a) than that of tumbleweed hay or wheat straw. It seems plausible that alfalfa hay will provide soluble carbohydrates faster for fermentation by micro-organisms.

Tumbleweed hay had a higher ($P<0.001$) gas production (b) from the slowly fermentable carbohydrate fraction and potential gas production (a+b) than that of alfalfa or wheat straw. Ruminal micro-organisms need energy to grow and synthesize protein which is used by the animal itself. Gas production is associated with volatile fatty acid production following fermentation of carbohydrates so the more fermentation of carbohydrate the greater the gas production (Blummel and Orskov, 1993). Quickly fermentable carbohydrates produce a relatively higher propionate concentration than acetate and the reverse takes place when slowly fermentable carbohydrates are fermented (Getachew *et al*., 1998). The gas production (b) from the slowly fermentable fraction and the gas production (a) from the slowly fermentable fraction of alfalfa hay was consistent with the findings of El Hassan *et al*. (2000) whereas the gas production rate (c) was higher than values reported by the same authors. This difference may possibly be due to the dilution factor of ruminal fluid or maturity differences in alfalfa hays used in these experiments.

The estimated ME value of tumbleweed hay was higher ($P<0.001$) than that of alfalfa hay or wheat straw whereas only IVDMD of tumbleweed hay was greater ($P<0.001$)than that of wheat straw. The estimated ME value of alfalfa hay was similar to those reported by Gatechew *et al*. (1998). Gas production at all incubation times were considerable lower than those obtained by Kamalak *et al*. (2005) possibly due to differences in the chemical composition of tumbleweed hay obtained different from a different location and year. However, the ME concentration of tumbleweed hay obtained at the beginning of flowering was in consitent with findings of Kamalak *et al*. (2005).

The IVDMD of alfalfa hay obtained in this study was in agreement with findings obtained by Tejido *et al*. (2002). The IVDMD of wheat straw was lower than that reported by Chaudhry (1998) but similar to values reported by Chander and Singh (1995) and Sahoo *et al*. (2002).

The estimated parameters (a, b, a+b) were negatively ($P<0.001$) correlated with CF (Table 3). This result is consistent with findings reported by Ndlovu *et al*. (1997), Larbi *et al*. (1998) and Abdulrazak *et al*. (2000). Conversely, b, a+b, IVDMD and ME were correlated ($P<0.001$) with CP, one of the limiting factors for microbial growth (Norton, 2003). Similar findings were reported by Tolera *et al.* (1997) and Larbi *et al*. (1998). No correlation ($P>0.05$) between the estimated parameters and EE was observed.

Wheat straw had low IVDMD and ME values due to a high CF concentration which is less fermentable by micro-organisms. Therefore IVDMD and ME were negatively ($P<0.001$) correlated with CF, as also reported by Buxton *et al*.(1995).

The major factors affecting the voluntary feed intake of ruminants are the cell-wall concentration and the

Table 3. Correlation coefficients (r) between chemical composition and *in vitro* gas production (at 24 hour incubation time) or estimated parameters

Parameters	CF	CP	EE	Ash
24 h	-0.875**	0.952***	0.853**	-0.651[NS]
c	-0.273[NS]	0.537[NS]	0.508[NS]	-0.873***
a	-0.808***	0.580[NS]	0.459 [NS]	0.490 [NS]
b	-0.862***	0.971***	0.641 [NS]	-0.562 [NS]
(a + b)	-0.899***	0.984***	0.617 [NS]	-0.495 [NS]
IVDMD	-0.962***	0.993***	0.679 [NS]	-0.323 [NS]
ME	-0.860***	0.976***	0.650 [NS]	-0.560 [NS]

CF: Crude fibre, CP: Crude protein, EE: Ether extract, Significance level ***$P<0.001$, **$P<0.01$, *$P<0.05$, NS = Non-significant, c: rate of gas production (%), a: gas production (mL) from quickly soluble fraction, b: gas production (mL) from slowly fermentable fraction, (a+b): potential gas production (mL), IVDMD: *In vitro* dry matter digestibility (%), ME: Metabolizable energy (MJ/kg DM) digestibility of forages. The inclusion of tumbleweed hay into ruminant diets may increase the voluntary intake due to its low CF concentration compared with wheat straw.

***In situ* dry matter disappearance and estimated parameters:** The DM disappearance from nylon bags incubated in the rumen increased with increasing incubation time (Table 4). At aeach incubation time, the DM disappearance of tumbleweed hay was higher (P<0.001) than that of wheat straw but similar that of alfalfa hay. Therefore the estimated parameters of tumbleweed and alfalfa hays were similar and higher (P<0.001) than that of wheat straw except for the rate (c) of DM disappearance. The rate (c) of dry matter disappearance of tumbleweed hay was similar to that of wheat straw (P<0.01) but higher than that of alfalfa hay.

At all incubation times, the gas production and nylon bag techniques allowed discrimination among forages. There were differences (P<0.001) between tumbleweed and alfalfa hays for gas production whereas there was no difference (P>0.05) between these forages *in situ* DM disappearance.

This study revealed a general problem of overestimation of degradability by the *in situ* dacron bag technique. The ability to use *in vitro* gas production methods to study the kinetics of degradation of forage DM instead of the *in situ* technique would have advantages, including avoiding the error associated with the loss of small particles through the pores of the dacron bags.

The concentration of CF negatively correlated (Table 5) with *in situ* DM disappearance at 24 h incubation time and some estimated parameters whereas CP positively correlated with the same parameters. These results are in agreement with findings of Abdulrazak *et al*. (2000) who reported that cell wall concentrations were negatively correlated with DM disappearance or estimated parameters. Tolera *et al*. (1997) found that DM disappearance at 24 and 48 h of incubation were positively correlated with CP concentrations, results that are consistent with the findings observed in this experiment.

The potential nutritive value of tumbleweed hay is better than wheat straw and comparable to alfalfa hay. In Turkey, the smallholders farmers have limited available resources for feeding their animals during critical periods of the year. The results of this experiment showed that tumbleweed hay holds promise for ruminant nutrition. It is likely that the cost of protein supplementation may be reduced with the inclusion of tumbleweed hay into ruminant diets.

The use of cereal straw for ruminant nutrition is essentially limited by it low voluntary intake and digestibility, so that even maintenance energy requirement are not met when offered as the sole source of feed (Castillo *et al*., 1981). Thus, it seems possible to meet maintenance energy and protein requirement of goat and sheep using a diet consisting solely of tumbleweed hay.

Table 4. *In situ* dry matter disappearance, estimated parameters of wheat straw, tumbleweed and alfalfa incubated with rumen fluid

	Forages			
Incubation time(h)	Wheat Straw	Tumbleweed	Alfalfa	SEM
0	13.1^{a}	24.8^{b}	28.4^{b}	0.57
3	21.8^{a}	34.6^{b}	31.3^{b}	0.59
6	26.2^{a}	39.8^{b}	37.3^{b}	0.39
12	34.2^{a}	45.9^{b}	41.2^{b}	0.72
24	42.5^{a}	55.4^{b}	54.1^{b}	0.76
48	50.2^{a}	64.7^{b}	59.3^{b}	0.84
72	54.9^{a}	64.7^{b}	64.2^{b}	0.64
96	60.1^{a}	67.1^{b}	68.1^{b}	0.60
		Estimated parameters		
c	4.1^{a}	4.3^{a}	3.5^{b}	0.10
a	15.4^{a}	28.0^{b}	27.8^{b}	0.40
b	42.8^{a}	39.7^{b}	39.8^{b}	0.48
P	44.4^{a}	55.2^{b}	53.3^{b}	0.27

Means within the same row wiht different superscript differ. ***P<0.001, **P<0.01 NS- Non-significant, SEM: Standard error of the mean, Sig: Significance level, a: the soluble dry matter (%) which is rapidly washed out of the bags and is assumed to be completely degradable, b: the proportion (%) of insoluble DM which is potentially degradable by micro-organism, c: the degradation rate (%) of fraction b per hour, P: The effective degradability(%) of samples calculated at a ruminal out flow rate (r) of 0.02/h.

Table 5. Correlation coefficients (r) chemical composition and *in situ* dry matter disappearance (at 24 hour incubation time) or estimated parameters

Parameters	CF	CP	EE	Ash
24 h	-0.962***	0.977***	0.904***	-0.389^{NS}
c	-0.112^{NS}	0.282^{NS}	-0.180 ^{NS}	-0.788*
a	-0.987***	0.992***	0.919***	-0.323 ^{NS}
b	0.888***	-0.909***	-0.784*	0.325^{NS}
P	-0.955***	0.990***	0.901***	-0.468^{NS}

CF: Crude fibre, CP: Crude protein, EE: Ether extract, Significance level, *** P<0.001, **P<0.01, *P<0.05, NS- Non-significant, a: the soluble dry matter (%) which is rapidly washed out of the bags and is assumed to be completely degradable, b: the proportion (%) of insoluble DM which is potentially degradable by micro-organisms, c: the degradation rate (%) of fraction b per hour. P: The effective degradability (%) of samples calculated at a ruminal out flow rate (r) of 0.02/h.

Conclusions

Tumbleweed hay is a forage with a medium to high protein concentration, effective DM degradability, *in vitro* DM digestibility and ME value. As such, it has potential as a forage crop for small farmers during critical periods of year when feed is scarce. By replacing lower quality forages with tumbleweed hay in ruminant diets, dairy producers could decrease concentrate input, decrease feed costs and increase the amount and utilization of forage in small ruminant dairy diets.

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