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INFLUENCE OF FEEDING LEVEL ON EFFECTIVE RUMEN DEGRADABILITY OF ALFALFA HAY AND MAIZE SILAGE

UTJECAJ RAZINE HRANIDBE NA DJELOTVORNU RAZGRADLJIVOST SIJENA LUCERNE I KUKURUZNE SILAŽE U BURAGU

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SUMMARY

The objective of this study was to evaluate the effect of feeding level (FL) on effective rumen degradability (ED) and *In situ* disappearance kinetics of dry matter and neutral detergent fiber (NDF) of alfalfa hay and maize silage. Standard procedure for nylon bags technique was used to estimate ruminal disappearance of dry matter (DM) and NDF. Nylon bags containing samples were incubated for 8, 16, 24, 48, 72 and 96 h in the rumen of four ruminally cannulated sheep (wether) and the exponential model of Ørskov and McDonald (1979) was used to calculate degradation kinetics. The ruminal degradability of forages samples were measured at four levels of intake. In maize silage, ED of DM decreased from 56.9% to 40.7% as intake increased from 1 to 2.5 times of maintenance. Values for the ED of dry matter of alfalfa hay at FL 1, 1.5, 2 and 2.5 averaged 60.3, 55.3, 44.5 and 42.9% respectively. In general, ED was significantly ($p<0.01$) higher at the maintenance level of feeding (FL=1) than for other treatments. The same situation was seen in NDF degradation of both forages. ED of NDF decreased from 53.08% at FL 1 to 39.78% at FL 2.5 in alfalfa hay and from 42.58% to 32.18% in maize silage. The results of this experiment indicated that ED of DM and NDF decreased dramatically when FL increased to more than 2 times of maintenance energy

Key words: feeding level, effective degradability, disappearance kinetics

INTRODUCTION

Ration formulation systems require information on nutrient requirements of the animal and reliable values for rumen degradable and undegradable fractions of feed ingredients (Colucci et al., 1990).

Numerous studies have shown a negative relationship between level of feed intake and digestibility in ruminants (Schneider and Flatt, 1975; Galyean and Owens, 1991). This relationship is thought to be due to changes in particle retention time in the rumen, which decreases when intake increases. On the other hand, time distribution of the dry matter stay in the rumen plays a major role in degradation characteristic of feedstuffs, especially in

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forage legumes. (Afzalzadeh and Havell, 1997). Rumen retention time or exposure time of feed components to the rumen degradative processes would influence bypass. Several researchers (Miller, 1973; Ørskov et al., 1971; Tamminga et al., 1979) have also suggested that bypass estimates may be greater with a higher level of feed intake, but the magnitude of the response has not been defined.

The feeding level is defined as ME intake divided by ME requirement for maintenance. Previous results have shown that nutrient disappearance may differ as a function of the animal's basal diet (Siddons and Paradine, 1981; Lindberg, 1981). Susmel et al. (1989) found that the main dietary factors affecting the disappearance of feeds were intake level, forage to concentrate ratio, diet composition and frequency of feeding. Many trials have examined the effect of feeding various hay to concentrate ratios on disappearance values of concentrate feedstuffs (Weakley et al., 1983; Zhao et al., 1993) but experiments on the effect of feeding level on digestibility of feedstuffs are limited and contradictory (Gomez et al., 2002). Even though relationships between intake level and *in situ* degradation can be theorized, there are no studies on such relationships are lacking. If intake does not have an important effect on in situ disappearance, either approach is adequate (Vanzant et al., 1998). However, if intake level significantly alters in situ disappearance, *ad libitum* consumption is incompatible with standardization because many factors will alter voluntary intake (Forbes, 1995). If this is the case, relationships between intake level and degradation will need to be established to allow standard values to be adapted to production situations.

Our study was designed to examine the effect of the level of intake on ED and disappearance kinetics of DM and NDF of alfalfa hay and maize silage as determined by the in situ nylon-bag technique.

MATERIALS AND METHODS

2.1. Animals, Diet and Experimental design

Four Iranian *shal* wethers of a body weight of 40±2 kg (2 years old) from the flock of the research farm of the Aburaihan Campus at University of Tehran were used in this study. Sheep were each fitted with a rumen fistula (4 cm internal diameter) and kept in individual stainless steel cages with external feed and water troughs. A diet consisting of 50% forage (60% alfalfa hay and 40% maize silage) and 50% of a concentrate (50% barley grain, 28% wheat bran, 20% cottonseed meal, 0.8% dicalcium phosphate, 0.8% mineral and vitamin premix and 0.4% salt) was offered at four levels of feeding : 1 (maintenance), 1.5, 2 and 2.5 times of the required maintenance. Feed was divided into two equal meals and fed twice a day at 08:00 and 18:00 h. Animals were fed these diets 15 days before the experimental periods. The experiment began in late winter and ended in early summer.

The experiment consisted of four periods. During the first period, the ruminal degradability of forage samples as measured at maintenance level of intake in all four animals, and during the second, third and fourth periods, respectively, the ruminal degradability of forages samples calculated at 1.5, 2 and 2.5 times of maintenance.

In situ procedures

A standard procedure for small nylon bags was used to estimate ruminal disappearance of DM (De Boer et al., 1987). Forage samples were dried and ground through a 2 mm screen. Samples (5 g) were weighed into nylon bags (8×16 cm) with a 40-45 μm pore size. Bags containing samples of each of the forages incubated in the rumen of fistulated sheep for 8, 16, 24, 48, 72 and 96 h. After each incubation time, bags were removed from the rumen and rinsed with cold tap water, until the water remained clear. Two more bags of each sample were washed without incubation in the rumen. All bags were placed in the rumen at the same time and removed at the required intervals thereafter. Upon removal from the rumen, the bags were dried at 65ºC for DM disappearance. The residues were analyzed for NDF and ADF content. Ruminal disappearance (%) at each incubation time was calculated as the difference between the residues and original samples. Four observations (1 bag x 4 wethers) were obtained for each forage sample at each incubation time.

Chemical analyses

Feed DM was determined by oven-drying at 55 °C for 48h. Ash, ether extract and crude protein (CP) were measured as described by procedures of

AOAC (1995). Neutral detergent fiber (NDF) was determined according to procedures described by Van Soest *et al* (1991).

Statistical analyses

Ruminal kinetic parameters were estimated using the exponential equation of Ørskov and McDonald (1979), revised by McDonald (1981), with simultaneous estimation of lag phase as proposed by Dhanoa (1988):

$$P = a + b\,(1-e^{-c\,(t-L)}).\ t \geq L$$

In this model, the constants "*a*" and "*b*" represent, respectively, the washout fraction and the non-soluble but degradable component, which disappears at a constant fractional rate "*c*" per unit time. "PD" is rumen disappearance (%) at time t (h) and "L" is the lag phase (h). The kinetic parameters were estimated using the computer software NEWAY (Rowett Research Institute, Aberdeen, UK). Effective degradability (ED) was calculated applying the equation:

$$ED = a + \frac{bc}{c+k}e^{-kL}$$

Where k is the fractional passage rate from the rumen assumed to be 2%/h and constants "a", "b" and "c" are as defined previously.

Data were analyzed using the general linear models procedure of SAS (1996) with the following statistical model of:

$$y_{ij} = \mu + t_j + \varepsilon_{ij}$$

Where y is the dependent variable, μ the overall mean, t_j the effect of feeding level and ε_{ij} is the residual error, assumed normally and independently distributed. When a significant difference was found, means were separated using Duncan test (Steel and Torrie, 1980). Differences were considered to be significant if $P<0.05$.

RESULT AND DISCUSSION

Chemical composition of forages is presented in table 1. Average values for the individual forages were within the range of values reported elsewhere (Giger-Riverdin, 2000; NRC, 2001; Lopez et al., 2005), with small differences that could be attributed to varieties of forage, stage of maturity at harvest, weather conditions, soil type and management practices.

The washing loss of DM for alfalfa hay and maize silage was 29.7% and 19.1% respectively. The effects of FL on parameter values obtained by fitting the Ørskov-McDonald model, defining the kinetics of DM degradation and effective degradability (ED), are presented in table 2. Comparing forages, the soluble fraction (a) and potentially fermentable fraction (b) were higher for alfalfa hay than for maize silage, whereas the rate of degradation (c) was higher for maize silage.

Table 1. Chemical composition of forages
Tablica 1. Kemijski sastav krmiva

	Forage composition (%) - Sastav krmiva (%)	
	Alfalfa hay - Sijeno lucerne	Maize silage - Kukuruzna silaža
Dry matter - Suha tvar	90.3	39.0
Crude protein - Sirova bjelančevina	17.0	9.1
NDF[1]	41.6	55.3
ADF[2]	32.8	30.0
Ether extract	2.5	2.7
Ash - Pepeo	11.0	8.5

1: Neutral Detergent Fiber

2: Acid Detergent fiber

Table 2. Influence of feeding level on ruminal kinetic parameters and effective degradability of DM of alfalfa hay and maize silage

Tablica 2. Utjecaj razine hranidbe na parametre kinetike buraga i djelotvorna razgradljivost suhe tvari sijena lucerne i kukuruzne silaže

Intake[1] Unos	a	b	c	PD (%)	ED (%)
Alfalfa - Lucerna					
1	24.5	63.2^{a}	0.026^{bc}	87.7^{a}	60.3^{a}
1.5	25.8	60.3^{b}	0.019^{c}	86.2^{a}	55.3^{b}
2	25.6	28.7^{c}	0.038^{ab}	54.4^{b}	44.5^{c}
2.5	25.6	25.3^{d}	0.043^{a}	50.8^{c}	42.9^{d}
Significance - Značajnost	NS	**	**	**	**
SD	0.68	2.14	0.003	3.21	0.73
Maize silage - Kukuruzna silaža					
1	12.0^{c}	59.4^{a}	0.061^{b}	71.4^{a}	56.9^{a}
1.5	15.3^{b}	47.9^{b}	0.066^{b}	63.2^{b}	52.0^{b}
2	14.0^{b}	31.2^{c}	0.112^{a}	45.2^{c}	40.6^{c}
2.5	15.9^{a}	29.4^{d}	0.110^{a}	45.2^{c}	40.7^{c}
Significance - Značajnost	**	**	**	**	**
SD	0.29	1.22	0.002	0.27	2.11

1: Multiple of maintenance requirement

Means within each column and for each source of variation (treatment or forage) with different superscripts (amebic) differ significantly ($p<0.05$).

a: soluble fraction (%); **b:** insoluble but potentially degradable fraction (%); **c:** fractional rate of degradation (h-1); **PD**: is rumen disappearance (%) at time t (h); **ED**: Effective degradability when K=2%/h.

NS: non significant; *$p<0.05$; **$p<0.01$.

SD: Standard deviation.

The increase of feeding level induced a decrease in the value of “b” ($p<0.01$) and ED ($p<0.01$), but had no effect ($p>0.05$) on parameter “a” in alfalfa hay. Both the fraction “b” and ED were significantly ($p<0.01$) higher for the FL=1 than for other treatments. ED of DM decreased from 60.3% to 42.9% in alfalfa hay and from 56.9% to 40.7% in maize silage as intake increased from 1 to 2.5 times of maintenance. Level of feed intake did not alter soluble fraction of DM of both forages and it was not statistically significant ($p<0.01$) in alfalfa hay. Zinn and Owens (1983) detected a linear depression in ruminal organic matter (OM) digestion in steers as intakes increased from 1.2 to 2.1% of BW. Galyean et al. (1979) also noted a trend toward reduced ruminal OM digestibility as intake of 84% corn diet increased from 1 to 2 times maintenance. The tendency towards decreased ED in the rumen is like a reflection of the numerical increases in ruminal passage rate that occurred when intake increased. Galyean et al. (1979) observed numerical increases in rumen passage rate with increasing intake.

NDF degradation of both forages decreased as the level of intake increased (Table 3), reflecting the

decrease in retention time for fermentation. The decrease in ED of NDF of both forages was about 25% when the FL increased from 1 to 2.5 times of maintenance. Rate of degradation decreased linearly ($P < 0.01$) on both forages as FL increased but the rate of decrease in alfalfa hay was greater than in maize silage. This finding is in agreement with Andersen et al. (1959), who found that increase in the level of feeding of a basal diet results in a decrease in digestion due to a shorter retention time of feed in the rumen. Gabel *et al*. (2003) reported that the rate of depression in digestibility of energy amounted to 3.2 units, or 4.1%, for each increase in FL. In a review, Tyrrell and Moe (1975) found the value of about 4% for total digestible nutrients. Finger et al. (1998) published similar findings on the influence of DM intake increase (DMI). In their study, the energy content decreased from 6.9 to 6.3 MJ of NEL/kg of DMI as level of DMI increased from 8.4 to 21.0 kg/d per cow. These results indicate that depressions in digestibility at high feeding levels are associated with higher rumen turnover rates. Figure 1 shows *in situ* DM disappearance of alfalfa hay and maize silage during incubation.

Table 3. Influence of feeding level on ruminal kinetic parameters and effective degradability of NDF of alfalfa hay and maize silage

Tablica 2. Utjecaj razine hranidbe na parametre kinetike buraga i djelotvorna razgradljivost NDV sijena lucerne i kukuruzne silaže

Intake[1] Unos	a	b	c	PD(%)	ED (%)
Alfalfa - Lucerna					
1	13.1^{c}	53.9^{a}	0.0555^{a}	67.0^{a}	53.1^{a}
1.5	17.3^{a}	46.4^{b}	0.0467^{b}	63.7^{b}	49.8^{b}
2	16.6^{b}	41.9^{c}	0.0364^{c}	58.5^{c}	43.7^{c}
2.5	17.0^{ab}	39.8^{d}	0.0266^{d}	56.9^{d}	39.8^{d}
Significance - Značajnost	**	**	**	**	**
SD	0.68	0.67	0.005	0.35	0.87
Maize silage - Kukuruzna silaža					
1	9.0^{d}	58.5^{a}	0.0257^{a}	67.5^{a}	42.6^{a}
1.5	12.5^{c}	51.8^{b}	0.02^{b}	64.2^{b}	38.7^{b}
2	14.3^{b}	46.6^{c}	0.0177^{c}	60.9^{c}	36.5^{c}
2.5	16.2^{a}	36.8^{d}	0.0152^{d}	53.0^{d}	32.2^{d}
Significance - Značajnost	**	**	**	**	**
SD	0.41	0.25	0.0003	0.82	0.36

1: Multiple of maintenance requirement

Means within each column and for each source of variation (treatment or forage) with different superscripts (amebic) differ significantly ($p<0.05$).

a: soluble fraction (%); **b:** insoluble but potentially degradable fraction (%); **c:** fractional rate of degradation (h-1); **PD**: rumen disappearance (%) at time t (h); **ED**: Effective degradability when K=2%/h.

NS: non significant; *$p<0.05$; **$p<0.01$.

SD: Standard deviation.

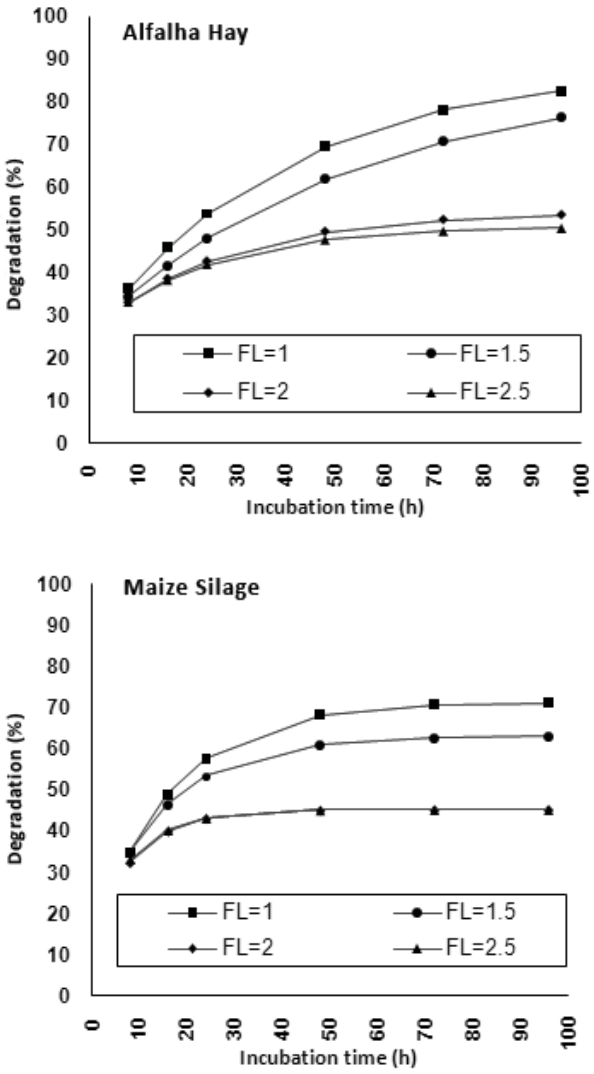

Figure 1. Effect of feeding level (FL) 1 , 1.5, 2 and 2.5 times of maintenance on rumen DM degradation of alfalfa hay and maize silage
Slika 1. Djelovanje razine hranidbe od 1, 1.5, 2 i 2.5 puta veće od uzdržnih potreba na degradaciju suhe tvari buraga sijena lucerne i kukuruzne silaže

CONCLUSIONS

This study confirms the decrease in effective degradability of DM and NDF when feeding level increases particularly to more than 2 times of maintenance. The results of this experiment also indicate an important effect of feeding level on degradability parameters “a”, “b” and “c”. Therefore, altering energy intake plays a major role in digestibility of forages, so feeding level should be considered in feed evaluation systems and feed formulation. Further studies on the nitrogen and organic matter degradability may prove useful in further determining the influence of feeding level on effective degradability of alfalfa hay and maize silage.

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SAŽETAK

Cilj ovog rada bio je ocijeniti djelovanje razine hranidbe (RH) na djelotvornu razgradljivost (DR) u buragu i nestanak *in situ* kinetike suhe tvari (ST) i neutralna deterdženta vlakna (NDV) sijena lucerne i kukuruzne silaže.

Primijenjen je standardni postupak najlonskih vreća za procjenu nestanka suhe tvari i neutralna deterdženta vlakna. Najlonske vreće s uzorcima inkubirane su na 8,16, 24, 48, 72 i 96 sati kanilama u burag četiriju ovaca (wether), a primijenjen je eksponencijalni model Orskova i McDonalda (1979) za izračunavanje kinetike degradacije. Mjerena je razgradljivost u buragu uzoraka krmiva na četiri razine unosa. U kukuruznoj silaži smanjili su se djelotvorna razgradljivost suhe tvari od 56.9% na 40.7% s povećanjem unosa od 1 do 2.5 puta većeg od uzdržnih potreba. Vrijednosti za DR suhe tvari sijena lucerne na razini hranidbe 1, 1.5, 2 i 2.5 u prosjeku su bile 60.3, 55.3, 44.5 i 42.9%. Općenito, DR je bila značajno viša ($p>0.01$) za RH=1 nego za druge postupke. Isto je primijećeno u NDV degradaciji oba krmiva. Djelotvorna razgradljivost NDV-a smanjila se od 53.08% uz RH 1 do 39.78% uz RH 2.5 u sijenu lucerne i od 42.58% na 32.18% u kukuruznoj silaži. Rezultati ovog isrraživanja pokazuju da se DR suhe tvari i NDF dramatično snizuje kad RH raste više od 2 puta od potreba za uzdržnu energiju.

Ključne riječi: razina hranidbe, djelotvorna razgradljivost, kinetika nestajanja