Effects of Maturity Stage on Chemical Composition and *in situ* Ruminal Degradation Kinetics of Meadow Hay in Awassi Sheep

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Abstract: Chemical composition and *in situ* degradation characteristics of dry matter (DM), crude protein (CP), neutral detergent fiber (NDF) and acid detergent fiber (ADF) for meadow hay cut at early and late bloom stages in Eastern Turkey were investigated in this study. The CP content of meadow hay decreased from 7.6-5.9% and DM (from 89.6-0.8%), NDF (from 54.8-7.5%), ADF (from 37.1-38.4), ADL (from 3.3-3.8) increased with advancing maturity. The rates of DM, CP, NDF and ADF disappearances in rumen of meadow hay cut at early bloom stage (EBS) were significantly higher than those of meadow hay harvested at late bloom stage (LBS). Significant maturity effects were observed for effective degradabilities of DM, CP, NDF and ADF due to increase of cell wall constituents. Rates of DM, CP, NDF and ADF degradation for meadow hay at EBS of the maturity were significantly faster than those for meadow hay cut at LBS.

Key words: *In situ* degradation, maturity, sheep, meadow hay, degradability

INTRODUCTION

Turkey is 9th country in the world in terms of number of sheep raised (FAO, 2005). About 27% of sheep population and half of the meadow and pasture areas exist in the mountainous region of Eastern Turkey (Anonymous, 2005). Meadow areas are one of the major sources of nutrients for sheep raised in this region, but this forage has to be managed correctly so that yield of nutrients can be maximized. Stage of the maturity when harvested is an important agronomic practice that influences yield and quality of the forage. The gross influence of the maturity on forage composition has been studied by several researchers who concluded that delayed cutting increased yield of dry matter and concentration of fiber components, but decreased usually concentration of digestible energy and crude protein as the plant matures (Norton *et al.*, 1997; Ammar *et al.*, 1999; Comakli *et al.*, 2000; Bochi *et al.*, 2001).

Although, the gross effect of the stage of maturity for meadow hay is well documented, there is no reported information about impact of the maturity stage on *in situ* ruminal degradability, fractional rates of digestion and effective degradability of dry matter (DM), crude protein (CP), NDF and ADF for meadow hay in Eastern Region of Turkey. Therefore, this study was undertaken to investigate the influence of the stage of maturity on chemical composition and *in situ* ruminal degradation kinetics of meadow hay.

MATERIALS AND METHODS

Three ruminally cannulated Awassi rams at 2 years old from sheep herd of Research farm of Agricultural College at Atatürk University, Erzurum, Turkey were used in this study. Rams were fed a mixture of good quality of pasture hay and concentrate to meet 1.25x maintenance requirements. Pasture hay contained 90.7% DM, 5.0% CP, 10.0% crude ash (CA), 2.6% ether extract (EE), 55.9% NDF and 38.6% ADF. Chemical composition of the concentrate was 89.6% DM, 10.6% CP, 4.6% crude cellulose (CC), 4.9% CA and 2.6% EE.

Hay samples were cut from meadow area of the Research Farm of Agricultural College at Atatürk University either at early-bloom (EBS) or late-bloom stages (LBS) of the dominant plant species. Then, the samples were dried and ground through a 2 mm screen. Before *in situ* degradability procedure, proximate analyses were performed according to AOAC (1990). NDF, ADF and ADL contents were also determined by the method of Van Soest *et al.* (1991).

Three grams of forage samples were weighed into nylon bags (8×16 cm) with 40-45 μm pore size. Nine subsamples from each stage of maturity were incubated in

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each of the three ram's rumens for each of the testing time periods: 8, 16, 24, 48 and 72 h. After incubation, the bags were removed from the rumen of sheep and rinsed with cold tap water, until the rinse water ran clear and colorless. Then, they were dried at 65°C for 48 h in the oven then weighed as described by Ørskov (1982) and Janicki and Stallings (1988).

Ruminal disappearance (p) at each incubation time was calculated as the difference between in the residue and original samples. The amounts of CP, DM, NDF and ADF in the residues, expressed as percentages of original samples, were determined for each bag.

The CP, DM, NDF and ADF degradation data were fitted to the exponential equation of Ørskov and Mc Donald (1979):

$$P = a + b (1-e^{-ct})$$ (1)

where,

p : The disappearance of nutrient during time t.
a : Soluble nutrient fraction which is rapidly washed out of the bags and assumed to be completely degradable.
b : The proportion of insoluble nutrient, which is potentially degradable by microorganisms.
c : The degradation rate of fraction b h^{-1} (percentage).

The kinetic parameters were estimated using a computer package program called NEWAY from Rowett Research Institute, Aberdeen, UK.

The effective degradability (ED) of samples was calculated using the equation of Ørskov and Mc Donald (1979):

$$ED = a+(bc/c+k)$$ (2)

where,

a, b, c, t : The same as in Eq (1).
k : Rumen fractional outflow rates of 2, 5 and 8% h^{-1}.

Data of CP, DM, NDF and ADF disappearance, degradation kinetics were statistically analyzed by completely randomized block design by using General Linear Model (GLM) of SPSS statistics computer program (SPSS, 2002). Because of differences among rams, each ram was considered as a block and stages of maturity were fixed factor in the statistical model.

RESULTS AND DISCUSSION

Means with standard deviations for proximate analysis of the meadow hay cut at EBS and LBS of the maturity are presented in Table 1. Although, no statistical analysis of the forage nutrient composition was

Table 1: Chemical composition of meadow hay cut at EBS and LBS of the maturity

	Stages of maturity	
	Early-Bloom Stage (EBS)	Late-Bloom Stage (LBS)
Dry matter	89.6±0.9	90.8±0.2
Crude protein	7.6±1.5	5.9±1.3
Crude ash	9.2±0.5	10.2±0.3
ADF	37.1±0.7	38.4±0.3
NDF	54.8±6.0	57.5±2.3
ADL	3.3±0.49	3.8±0.6

conducted, the following trends were apparent. The average chemical composition of the meadow hays harvested at EBS and LBS ranged respectively from 89.6-90.8% for DM, from 7.6-5.9 for CP, from 9.2-10.2% for CA, from 54.8-57.5% for NDF, from 37.1-38.4% ADF and from 3.3-3.8% ADL contents. Meadow hay cut at LBS of the maturity tended to have slightly higher concentrations of NDF and ADF and substantially more ADL with lower CP than that harvested at EBS. Therefore, the amount of ADL as a percentage of NDF increased with stage of the maturity from 6.1-6.6%. As already indicated by Messman *et al.* (1991), increased lignification of NDF usually occurs with increasing maturity of the forages. Other comparable results were reported by Balde *et al.* (1993), Hoffman *et al.* (1993), Ammar *et al.* (1999), Coblentz *et al.* (2000) and Bochi *et al.* (2001), who concluded that forage CP declined and NDF and ADF fractions increased with maturity in different forages.

The nutrient composition of the meadow hay regardless of stage of the maturity was different from NRC tables of feed composition (NRC, 1982). The variation in chemical composition of the meadow hay could be attributed to the varieties and ratios of the grass, legume and herbs in the botanical composition, soil type, weather conditions and management practices such as level of fertilization implemented in Eastern Turkey.

The mean values for DM, CP, NDF and ADF disappearance (%) of the meadow hay cut at 2 stages are presented in Table 2. As expected, these values increased with increasing time of incubation. At all incubation time, there were significant differences in DM, NDF and ADF disappearances of meadow hay harvested at EBS and LBS of the maturity. CP disappearances of meadow hay incubated for 8, 16 and 24 h were also significantly (p<0.01) affected by stage of the maturity and the mean values for meadow hay harvested at EBS were higher than these cut at LBS (Table 2). The rates of DM, NDF and ADF disappearances of meadow hay cut at EBS were faster than those of meadow hay harvested at LBS. Similar results were reported by Sarwar *et al.* (1999) and Kamalak *et al.* (2005), who observed greater DM and NDF disappearance rates in early-cut forages than in late-cut forages. The EBS might have provided less structural

Table 2: Means for disappearance of meadow hay from nylon bags suspended in the rumen of sheep

Rumen incubation time (h)	Stages of maturity		
	Early-bloom stage	Late-bloom stage	Significance
Dry matter disappearance (%)			
8	37.9±0.7	34.0±0.7	**
16	49.3±0.8	47.2±0.8	**
24	55.0±1.4	47.0±1.4	**
48	65.3±1.3	59.6±1.3	**
72	73.8±1.2	69.4±1.2	**
Crude protein disappearance (%)			
8	65.4±1.5	54.2±2.19	**
16	69.1±1.1	56.6±1.79	**
24	75.0±1.4	59.3±1.95	**
48	77.3±0.8	78.9±0.92	ns
72	81.7±1.0	80.9±1.53	ns
NDF disappearance (%)			
8	9.4±0.9	7.8±0.9	**
16	26.2±1.0	25.5±1.0	*
24	35.6±1.8	24.7±1.8	**
48	52.0±1.7	44.9±1.7	**
72	64.5±0.3	61.3±0.3	**
ADF disappearance (%)			
8	5.8±0.9	2.8±0.9	**
16	21.4±1.5	18.6±1.5	*
24	33.3±1.8	22.1±1.8	**
48	49.4±1.9	40.4±1.9	**
72	62.2±0.3	58.2±0.3	**

*: $p<0.05$, **: $p<0.01$, ns: non-significant

Table 3: Means for ruminal kinetic parameters and effective degradabilities of DM, CP, NDF and ADF of meadow hay cut at different maturities

Items	Stages of maturity		
	Early-bloom stage	Late-bloom stage	Significance
Degradation kinetics	**Dry matter degradability (%)**		
a (%)	25.1±0.1	24.6±0.1	*
b (%)	53.9±2.0	56.0±2.0	ns
a+b (%)	79.0±2.0	80.6±2.0	ns
c (h^{-1})	3.9±0.2	2.7±0.2	**
Effective degradability (%)			
$k = 0.02$ (h^{-1})	59.0±0.4	54.6±0.4	**
$k = 0.05$ (h^{-1})	47.3±0.6	42.7±0.6	**
$k = 0.08$ (h^{-1})	41.7±0.6	37.7±0.6	**
Degradation kinetics	**Crude protein degradability (%)**		
a (%)	52.2±0.8	44.6±0.8	**
b (%)	30.7±1.3	51.3±1.3	**
a+b (%)	82.9±1.2	96.0±1.2	**
c (h^{-1})	6.7±0.7	2.1±0.7	**
Effective degradability (%)			
$k = 0.02$ (h^{-1})	74.1±0.4	69.5±0.4	**
$k = 0.05$ (h^{-1})	68.1±0.6	58.9±0.6	**
$k = 0.08$ (h^{-1})	64.8±0.7	54.7±0.7	**
Degradation kinetics	**NDF degradability (%)**		
a (%)	-13.2±1.6	-3.0±1.6	**
b (%)	86.9±1.9	82.5±1.9	ns
a+b (%)	73.7±2.4	79.6±2.4	ns
c (h^{-1})	4.0±0.3	2.3±0.3	**
Effective degradability (%)			
$k = 0.02$ (h^{-1})	41.8±0.4	39.2±0.4	**
$k = 0.05$ (h^{-1})	23.4±0.6	21.8±0.6	*
$k = 0.08$ (h^{-1})	15.1±0.7	14.6±0.7	*
Degradation kinetics	**ADF degradability (%)**		
a (%)	-14.3±1.2	-9.8±1.2	**
b (%)	88.6±2.1	86.3±2.1	ns
a+b (%)	74.3±2.9	76.5±2.9	ns
c (h^{-1})	3.9±0.3	2.4±0.3	**
Effective degradability (%)			
$k = 0.02$ (h^{-1})	39.3±0.3	35.3±0.3	**
$k = 0.05$ (h^{-1})	20.7±0.5	17.0±0.5	**
$k = 0.08$ (h^{-1})	11.8±0.5	9.4±0.5	**

*: $p<0.05$, **: $p<0.01$, ns: non-significant

resistance to bacterial attachment from lignification, resulting in increased bacterial colonization and digestion of less mature vs. more mature forage (Sarwar *et al.*, 1999).

In situ DM degradation kinetic parameters of meadow hay by maturity are presented in Table 3. Rapidly degradable DM fraction (a) in meadow hay decreased ($p<0.05$) with increasing maturity. The potentially fermentable fraction (b) for DM was not influenced significantly by the stage of the maturity. The rate of DM degradation was lower ($p<0.01$) for hay cut at LBS than earlier stage of the maturity. The results are consistent with findings of Balde *et al.* (1993) and Hadjipanayiotou *et al.* (1996). Stages of the maturity also affected significantly on the effective degradability of DM and the values decreased with increased stage of the maturity as already indicated by Sarwar *et al.* (1999), Coblentz *et al.* (2000), Galdemez-Cabrera *et al.* (2003) and Chaves *et al.* (2006).

The estimated *in situ* degradation kinetics and effective degradabilities of CP obtained at 3 different outflow rates are given in Table 3. Rapidly soluble CP fraction (a) declined with maturity and *a* fraction of CP of the meadow hay cut at EBS was 7.6% higher ($p<0.01$) compared with these of the meadow hay harvested at LBS. The potentially fermentable fraction (b) for CP was also affected ($p<0.01$) by the stages of the maturity. The rate of CP degradation (c) for meadow hay harvested at

EBS was significantly greater than that for hay cut at LBS. Cutting stages also have had significant ($p<0.01$) influence on the effective degradability of CP and these values declined with advancing stage of harvesting. The results are in agreement with findings of Giraldez-Garcia (1993) and Aguiar *et al.* (1999).

In situ NDF degradation kinetic parameters of meadow hay by stage of maturity are presented in Table 3. Stage of maturity had significant effect on the rapidly soluble NDF fraction (a) and NDF degradation rate (c). The rate of NDF degradation of hay cut at EBS was faster than that of EBL. Similar results were reported by Cherney *et al.* (1992) and Huhtanen and Jaakkola (1994), who observed greater rates of NDF digestion in early-cut grasses than in late-cut grass hay. Effective degradability of NDF was also significantly influenced by stage of the maturity. The result is in agreement with findings of the Huhtanen and Jaakkola (1994) and Coblentz *et al.* (2000).

Degradation kinetic parameters for ADF are given in Table 3. Maturation altered (p<0.01) rate of ADF degradation as reported by Messman *et al.* (1991), who indicated significant decrease of degradation rate of ADF with advanced maturity. Effective degradability of the meadow hay cut at EBS of the maturity was also lower (p<0.01) than that of the meadow hay harvested at LBS of the maturity.

CONCLUSION

Results of the study illustrated that fiber digestion rates along with the established for age quality parameters clearly declined with increased maturity. In order to produce high quality meadow hay for sheep feeding, forage must be harvested at EBS of the dominant plant species in the meadow land.

REFERENCES

Aguiar, R.S., H.M. Vasguez and J.F.C. Silva, 1999. *In situ* degradabilities of dry matter, crude protein and neutral detergent fiber of furachao grass under fertilization and cutting ages. Rev. Brasil. Zoot., 28: 799-807.

Ammar, H., S. Lopez, O. Bochi, R. Garcia and M.J. Ranilla, 1999. Composition and *in vitro* digestibility of leaves and stems of grasses and legumes harvested from permanent mountain meadows at different stages of maturity. J. Anim. Feed Sci., 8: 599-610.

Anonymous, 2005. Agricultural structure 2002 (Production, Price, Value). State institute of statistics prime ministry republic of Turkey. State institute of statistics printing division, Ankara, Turkey.

AOAC, 1990. Official Methods of Analysis. 15th Edn. Association of Official Analytical Chemists, Washington, DC, USA.

Balde, A.T., J.H. Vandersal, R.A. Erdman, J.B. Reeves and B.P. Glenn, 1993. Effect of stage of maturity of alfalfa and orchardgrass on *in situ* dry matter and crude protein degradability and amino acid composition. Anim. Feed Sci. Technol., 44: 29-43.

Bochi, O., S. Lopez, R. Garcia, A. Calleja, M. Perez and J.S. Gonzalez, 2001. Composicion quimica, botanica y digestibilidad *in vitro* de forrajes de prados permanentes en relacion con la fecha de siega. ITEA, 22: 358-360.

Chaves, A.V., G.C. Waghorn, I.M. Brookes and D.R. Woodfield, 2006. Effect of maturation and initial harvest dates on the nutritive characteristics of ryegrass. Anim. Feed Sci. Technol., 127: 293-318.

Cherney, D.J.R., J.H. Cherney and R.F. Lucey, 1992. *in vitro* digestion kinetics and quality of perennial grasses as influenced by forage maturity. J. Dairy Sci., 76: 790-797.

Coblentz, W.K., K.P. Coffey, J.E. Turner, D.A. Scarbrough, J.S. Weyers, K.F. Harrison, Z.B. Johnson, L.B. Daniels, C.F. Rosenkrans, D.W. Kellogg and D.S. Hubbell, 2000. Effect of maturity on degradation kinetics of sod-seeded cereal grain forage grown in northern Arkansas. J. Dairy Sci., 83: 2499-2511.

Comakli, B., M. Yanar, O. Mentese and L. Turgut, 2000. Effects of cultural practices on nutritional value of the roughage. In: Proceeding International Animal Nutrition Congress, Isparta, Turkey.

FAO, 2005. FAOSTAT. http: //faostat.fao.org/site/568/ Desktop Default. Aspx ? PageID = 568.

Galdemez-Cabrera, N.W., K.P. Coffey, W.K. Cablantez, J.E. Turmer, D.A. Scarbrough, Z.B. Johnson, J.L. Gunsavlis, M. Daniels and D.H. Helwig, 2003. *In situ* ruminal degradation of dry matter and fiber from bermudagrass fertilized with different nitrogen rates and harvested on two dates. Anim. Feed Sci. Technol., 105: 185-198.

Giraldez Garcia, F.J., J.S. Gonzalez Alvarez, F.J. Ovejero Martinez and S.C. Valdes, 1993. Ruminal degradation of hay from permanent pastures: Effect of stage of maturity. Arch. Zoot., 42: 13-20.

Hadjipanayiotou, M., I. Antoniou, M. Theodoridou and A. Photiou, 1996. *In situ* degradability of forages cut at different stages of growth. Livest. Prod. Sci., 45: 49-53.

Hoffman, P.C., S.J. Sievert, R.D. Shaver, D.A. Welch and D.K. Combs, 1993. *In situ* dry matter, protein and fiber degradation of perennial for ages. J. Dairy Sci., 76: 2632-2643.

Huhtanen, P. and S. Jaakkola, 1994. Influence of grass maturity and diet on ruminal dry matter and neutral detergent fibre digestion kinetics. Arch. Anim. Nut., 47: 153-157.

Messman, M.A., W.P. Weiss and D.O. Ericson, 1991. Effects of nitrogen fertilization and maturity of brome grass on *in situ* ruminal digestion kinetics of fiber. J. Anim. Sci., 69: 1151-1161.

Janicki, F.J. and C.C. Stallings, 1988. Degradation of crude protein in forages determined by *in vitro* and *in situ* procedures. J. Dairy Sci., 71: 2440-2448.

Kamalak, A., O. Canbolat, Y. Gurbuz, A. Erol and O. Ozay, 2005. Effect of maturity stage on chemical composition, *in vitro* and *in situ* dry matter degradation of tumbleweed hay (*Gundelia tournefortii L.*) Small Rumin. Res., 58: 149-156.

Norton, N.A., R.T. Clark, P.E. Reece and K.M. Eskridge, 1997. Quality as a factor in the optimal choice of fertilization and harvest date of meadow hay. J. Prod. Agric., 10: 551-557.

NRC, 1982. United State-Canadian Tables of Feed Composition. 3rd Rev. Subcommittee on feed composition committee on Animal Nutrition Board and Renewable Resources Commission on Natural Resources National Research Council. National Academy Press, Washington, D.C., USA.

Ørskov, E.R. and L. McDonald, 1979. The estimation of protein degradability in the rumen from incubation measurement weighed according to rate of passage. J. Agric. Sci. (Camb.), 92: 499.

Ørskov, E.R., 1982. Protein Nutrition in Ruminants. 2nd Edn. Academic Press, London, UK.

Sarwar, M., M.N. Khan and M.H. Saeed, 1999. Influence of nitrogen fertilization and stage of maturity of mottgrass on its composition, dry matter intake, ruminal characteristics and digestion kinetics in cannulated buffalo bulls. Anim. Feed Sci. Technol., 82: 121-130.

SPSS, 2002. SPSS for windows, release 11.5.0. SPSS Inc. Chicago, IL. USA.

Van Soest, P.J., J.B. Robertson and B.A. Lewis, 1991. Methods of dietary fiber, neutral detergent fiber and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci., 74: 3583-3597.