Original scientific paper - Izvorni znanstveni rad UDK: 631.115.1

Fermented high moisture maize grain as supplement to alfalfa haylage is superior over unfermented dry maize grain in diet dry matter digestibility

Marina Vranić, Mladen Knežević, Goran Perčulija, Krešimir Bošnjak, Josip Leto, Hrvoje Kutnjak, Martina Horg*

Faculty of Agriculture, University of Zagreb, Department of Arable Crops, Forages and Grasses, Grassland Research Centre, Svetošimunska cesta 25, 10000 Zagreb, Croatia

Received - Prispjelo: 28.11.2010.
Accepted - Prihvaćeno: 19.07.2011.

Summary

The objectives of the experiment were to examine whether high moisture maize grain (HMM) is superior to low moisture maize grain (LMM) as supplement to alfalfa haylage (*Medicago sativa* L.) (AH). The effects of HMM and LMM supplementation to AH were studied on feed intake, water intake and dry matter (DM) digestibility in wether sheep. Alfalfa was harvested at the beginning of flowering and ensiled into round bales wrapped with plastic. The average DM and crude protein (CP) concentration of AH was 534.7 g kg^{-1} fresh sample and 141 g kg^{-1} DM, respectively. The average DM content (g kg^{-1} fresh sample) of HMM and LMM were 795.9 and 915.1 g kg^{-1} fresh sample, respectively, while the average CP concentration (g kg^{-1} DM) were 116.8 and 106.0, respectively. The study consisted of five feeding treatments incorporating AH only and AH supplemented with 5 or 10 g HMM or LMM d^{-1} kg^{-1} wether body weight. The inclusion of HMM (5 or 10 g kg^{-1} body weight d^{-1}) into AH based ration resulted in higher diet DM digestibility ($P<0.05$) in comparison with LMM inclusion (5 or 10 g kg^{-1} body weight d^{-1}). Higher daily fresh matter intake (FMI) ($P<0.05$), dry matter intake (DMI) ($P<0.05$) and water intake ($P<0.05$) was achieved with LMM inclusion in comparison with HMM inclusion. The conclusion was that HMM is superior over LMM as supplement to AH in terms of DM digestibility, while LMM has advantages over HMM in the intake characteristics measured.

Key words: alfalfa haylage, high moisture maize grain, low moisture maize grain, intake, digestibility

Introduction

Dairy cows fed alfalfa haylage supplemented with an energy source like maize silage or maize grain will consume more feed and produce more milk (O'Mara et al., 1998) which directly influences farm economy. There are certain advantages in producing high moisture maize grain (HMM) in comparison to dry maize grain (LMM) production. Harvesting HMM allows earlier and longer harvests which reduces field losses and allows the use of higher yielding full-season hybrids. Ensiling HMM as an alternative to artificial drying reduces fuel and labour costs and eliminates costly delays during harvest. Contrary, harvesting and storing the corn grain as HMM reduces the producers' flexibility of marketing the crop since it must be fed to livestock.

*Corresponding author/Dopisni autor: Phone/Tel.: 00385 1 4550 042; E-mail: mvranic@agr.hr

In addition, the spoilage losses can be substantially higher with HMM than LMM.

The previous research show the feeding value of HMM is often equivalent or slightly superior to LMM. Merrill (1971) reported that ensiling HMM was an effective method of handling and feeding corn grain to beef cattle. He concluded that HMM produced more efficient gains (+5 to 10 %) compared to maize grains of the same origin in air dried form. In a review of 21 comparisons of LMM versus HMM, Clark (1975) reported that feedlot cattle fed HMM were 6.1 % more efficient than those fed LMM. Corah (1976) reported in a review of 44 trial comparisons that the feeding value of HMM was slightly superior to LMM when a HMM was stored in either an oxygen limiting silo or acid treated but was slightly inferior when fed as ground ensiled HMM. Owens (1997) reported that finishing beef cattle fed high concentrate rations containing HMM (>80 %) will generally consume less feed dry matter (DM), have similar daily gains and have slightly better feed conversions compared to those fed LMM. Most research trials comparing ensiled HMM to LMM show that HMM gives essentially equal average daily gain but increases feed efficiency by about 10 % (Merrill, 1971; Corah, 1976). Nearly, all of these trials were conducted with HMM having moisture contents ranging from 30-40 %.

Oklahoma researchers (Van Koevering et al., 1994) evaluated the feeding value of HMM and LMM in finishing beef cattle diets containing 9 % pelleted alfalfa hay as the roughage source. Intake of DM for steers receiving HMM was 9.5 % higher and the efficiency of feed conversion was 10.3 % greater for steers receiving HMM.

In a summary of 11 lactation studies Clark (1976) reported that mean yield of milk for cows fed ensiled HMM was identical to the yield of milk for cows fed LMM. Merrill (1971) concluded that experimental results with ensiled HMM show that is equal in feeding value of LMM.

The objectives of the experiment were to examine the effects of HMM and LMM supplementation to alfalfa haylage (AH) on feed intake, water intake and DM digestibility in wether sheep. The hypothesis of this study was that HMM is better supplement to AH than LMM in terms of feed intake, water intake and DM digestibility.

Materials and methods

Alfalfa crop and silage making

Alfalfa was mown in 2009 (22nd of May) at the early flowering stage. The crop was mown and allowed to wilt for 24 h (400-500 g DM kg^{-1} fresh sample) before harvesting with a round baler. Bales were wrapped in four layers of 500 mm-wide white plastic film. The weather at harvest was warm and sunny.

The HMM (*Zea mays L., cv. BC 566*) was ensiled grinded without any additive into jumbo bags (600 kg of fresh material bag^{-1}) and allow to ferment for at least 35 days while the LMM was stored ungrinded into 3 plastic bins (50 litres each) until needed for the experimental purposes.

Dietary treatments

The experiment consisted of 5 feeding treatments: (i) AH fed alone (ii) AH supplemented with 5 g HMM d^{-1} kg^{-1} body weight (HMM5); (iii) AH supplemented with 10 g HMM d^{-1} kg^{-1} body weight (HMM10); (iv) AH supplemented with 5 g LMM d^{-1} kg^{-1} body weight (LMM5); (v) AH supplemented with 10 g LMM d^{-1} kg^{-1} body weight (LMM10).

Just before the experiment started the HMM was filled into 5 plastic bags (30 litre each), LMM was grinded with the hummer mill, filled into 5 plastic bags (approximately 30 litre each) while AH was chopped to approximately 3-5 cm using a commercial chopper and filled into 15 plastic bags (approximately 10 kg AH per bag). The forages for the experimental needs (AH, HMM and LMM) were stored in a cold chamber maintained at a temperature of 4 °C.

The AH and the concentrate were fed separately. No supplementary feeds were provided.

HMM and LMM were weighted into plastic bags for daily feeding.

Animals and design

Five Suffolk wethers were selected on the basis of live weight (mean body weight 31.3 kg, s.d. 5.8 kg). All the animals were treated for internal parasites prior to the start of the experiment. The sheep were subjected to artificial lightening from 08:00 to 20:00 hours daily. Each sheep was randomly allocated to treatment sequences in a 5x5 Latin square design with five periods. A 10 day acclimatization period was followed by an 11-day measurement period (4 day *ad libitum* intake was followed by 7 day digestibility measurements) where feed offers and refusals were measured and total faeces were collected.

The animals were housed in individual pens (1.5 × 2.2 m) over the acclimatization period and in individual crates (136 cm x 53 cm x 148.5 cm) during the measurement period. Rations were offered twice a day (8:30 and 16:00 h) in equal amounts, designed to ensure a refusal margin of 10-15 % of AH each day. During the measurement period, fresh weights and DM contents of feed offered and feed refused were recorded daily. Subsamples of offered feed were taken daily and stored at a temperature of -20 °C until the end of the experiment, when they were bulked prior to chemical analysis. Daily subsamples of refusals were bulked on an individual animal basis and stored at a temperature of -20 °C prior to chemical analyses.

Daily production of faeces was collected separately. Total daily faecal production of each animal was stored frozen until completion of the collection period. Bulked faecal output from each animal was then weighed and sub-sampled prior to subsequent analyses. The DM digestibility of the diet was calculated using daily data on DM intake, feed residual DM and faecal DM. The sheep were weighted on the 10^{th}, 14^{th} and 21^{st} day of each period and the mean weight was used to calculate the daily voluntary intake of ration fresh matter (FMI) and DM (DMI) expressed per unit of metabolic weight, i.e., g per kg $M^{0.75}$. Daily water intake was measured. The experiment followed the Council Directive issued by the European Economic Community (EEC) (1986) on the approximation of laws, regulations and administrative provisions of the Member States regarding the protection of animals used for experimental and other scientific purposes.

Chemical analysis

The DM contents of feed offered, feed refused and faeces were determined by oven drying to a constant weight at a temperature of 60 °C in a fan-assisted oven (ELE International). In AH, the crude protein (CP) concentration, pH value, NH_3-N and neutral detergent fibre (NDF) concentration while in HMM and LMM samples CP concentrations were estimated by NIR spectroscopy. The samples were ground to pass a 1mm screen, than re-dried at a temperature of 105 °C for 3 hours prior the NIR analysis. Two independent scans were recorded for each sample, using a NIR System Model 6500 spectrometer system (Foss-NIR system, Sweden) fitted with a sample transport module and a grind product sample cup. Samples were scanned (32 scans co-added) using the ISI SCAN Version 1.0 (Infrasoft International, Port Matilda, PA, USA) from 1100 to 2498 nm in reflectance mode (R mode: PbS detector). The mean spectral value of each sample was calculated using the WIN ISI III Version 1.5. The Scottish calibration models developed at Scottish Agricultural College (SAC) were applied for AH samples, while the USA calibration models developed at Foss for HMM and LMM samples.

Statistical analysis

Results were analyzed using mixed model procedures (SAS, 1999). Model applied: $Yij= \mu + Ti + Pj + eij$; where Y is the overall model, μ = grand mean, T= treatment, P= period, e = experimental error, i = number of treatments, and j = number of periods. Mean separation was performed if the F-test was significant at P=0.05. The orthogonal contrasts of fresh and DM intake and digestibility of AH vs. HMM5, HMM10, LMM5, LMM10; HMM5, LMM5 vs. HMM10, LMM10 and HMM5, HMM10 vs. LMM5, LMM10 were made using the CONTRAST statement (SAS, 1999). Linear and quadratic effects of the level of LMM and HMM inclusion in AH on FMI, DMI and DM digestibility were examined using the CONTRAST statement (SAS, 1999).

Results and discussion

Alfalfa contains more than 180 g CP kg^{-1}DM if mowed at the beginning of flowering (Ball at al., 2002) which is more than the average CP concentration of AH in this research (141.6 g kg^{-1} DM) (Table

Table 1. Chemical composition of alfalfa haylage

Chemical parameter	Mean value	Minimum value	Maximal value	Coefficient of variation (%)
DM (g kg^{-1} fresh sample)	534.7	512.0	578.5	4.57
Crude proteins (g kg^{-1} DM)	141.6	118.0	155.0	9.08
NDF (g kg^{-1} DM)	504.4	447.0	527.0	5.88
pH	5.2	5.0	5.5	3.49
NH_3-N (g N kg^{-1} total N)	184.8	166.0	212.0	8.29

DM - dry matter; NH_3-N - ammonium N; NDF - neutral detergent fibre

Table 2. Dry matter and crude protein concentration in high and low moisture maize grain

Chemical parameter	Maize grain	Mean value	Minimum value	Maximum value	Coefficient of variation (%)
DM (g kg^{-1} fresh sample)	HMM	795.9	771.7	807.7	1.8
	LMM	915.1	910.1	919.5	0.3
CP (g kg^{-1} DM)	HMM	116.8	111.0	115	3.7
	LMM	106.0	102.0	106	3.7

DM - dry matter; CP - crude protein; HMM - high moisture maize grain; LMM - low moisture maize grain

1) which reflects later stage of maturity (later flowering) at harvest. The mean CP concentration fits well the range between 77.0 and 167.5 g CP kg^{-1} DM determined as minimum and maximum values for grass silages produced at 19 family farms in Croatia in 2004, thus reflecting silage production technology on family farms (Vranić et al., 2005). Concentration of DM in AH varied from 512.0-578.5 g kg^{-1} fresh sample. It was a result of advanced sward maturity and 24-hour wilting prior to harvest. Although, heavy wilting of herbage has the disadvantages of greater mechanical and respiration losses (McDonald et al., 1991) and limited fermentation, which may lead to silage that is aerobically unstable, in this research, higher DM concentration at harvesting was required due to ensiling technology applied. When ensiling forage into big bales wrapped with plastic, the higher forage DM is recommended (400-600 g kg^{-1} DM) as the less water is wrapped, the fewer bales are to be handled and the bales hold their shape that protects damages of the plastic film, aeration of ensiled material and looses of nutrients (Chamberlain and Wilkinson, 1996).

The DM concentration in HMM (Table 2) is similar to DM concentration in HMM (<80 %) in the experiment of Owens (1997). LMM contained more moisture than recommended at storing (max 140 g DM kg^{-1} fresh sample), but no negative visual effect was noticed due to the higher moisture concentration.

The usual CP concentration in corn is about 106 g kg^{-1} DM. The same coefficient of variation was determined at HMM and LMM for CP concentration (3.6 %), but HMM contained relatively more CP in average (116.8 g kg^{-1} DM) in comparison to LMM (106 g kg^{-1} DM).

Intake and digestibility

Voluntary DMI across the five feeding treatments was in the intake range of 800-1100 g d^{-1} for 50 kg intact male lambs (AFRC, 1993) (Table 3).

Table 3. Fresh matter intake, dry matter intake, dry matter digestibility and water intake

Treatment	Diet					Water intake
	FM intake		DM intake		DM digestibility	
	g d^{-1}	g kg^{-1} $M^{0.75}$	g d^{-1}	g kg^{-1} $M^{0.75}$	g kg^{-1} $M^{0.75}$	g kg^{-1} DM
AH	1624.77[a]	113.9[ac]	955.5[ab]	67.2[a]	635[c]	190[a]
LMM5	1633.29[a]	120.0[a]	1021.7[a]	75.3[b]	622[d]	188[a]
LMM10	1439.63[b]	110.2[c]	972.2[ab]	74.0[b]	652[b]	170[b]
HMM5	1508.51[ab]	102.2[b]	937.8[b]	63.5[a]	648[c]	159[b]
HMM10	1528.41[ab]	106.1[b]	988.5[ab]	69.3[a]	655[a]	168[b]
SEM	51.8	7.6	27.6	1.38	13.5	7.16

AH - alfalfa haylage; HMM5 - AH supplemented with 5 g LMM d^{-1} kg^{-1} body weight; LMM10 - AH supplemented with 10 g HMM $d^{-1}kg^{-1}$ body weight; LMM5 - AH supplemented with 5 g HMM d^{-1} kg^{-1} body weight; HMM10 - AH supplemented with 10 g HMM $d^{-1}kg^{-1}$ body weight; SEM - standard error of the mean; FM - fresh matter; DM - dry matter; means with a different letters within columns are significantly different (P<0.05); $M^{0.75}$ - metabolic body weight

Inclusion of HMM to AH based ration (treatment HMM5 and HMM10) resulted in lower FMI (g kg^{-1} $M^{0.75}$) (P<0.001), lower DMI (g kg^{-1} $M^{0.75}$) (P<0.001) in comparison to LMM inclusion (treatment LMM5 and LMM10) (Table 4). Supplementation of LMM linearly increased FMI (g d^{-1} and g kg $^{-1}M^{0.75}$) (P<0.01 and P<0.05, respectively), DMI (g kg $^{-1}M^{0.75}$) (P<0.001) and DM digestibility (P<0.001) (Table 5). A positive associative effect of LMM supplementation was observed for FMI (P<0.05), DMI (g d^{-1} and g kg $^{-1}M^{0.75}$) (P<0.05 and P<0.001, respectively) and for DM digestibility (P<0.001) (table 5). Inclusion of HMM to AH linearly increased diet DM intake (g kg $^{-1}M^{0.75}$) (P<0.001) while a positive associative responses was determined for DMI (g kg $^{-1}M^{0.75}$) (P<0.01) and DM digestibility (P<0.01). This might be explained with higher moisture concentration in HMM than LMM and the negative relationship between forage moisture content and forage DM intake that was already observed (Steen et al., 1998; Mulligan et al., 2002). This is not consistent with some previous studies reporting higher DMI in steers fed forage supplemented with HMM in comparison with LMM supplementation (Van Koevering et al., 1994), but are in agreement with studies reporting decreased DMI with HMM supplementation (Owens, 1997).

Water intake was the same (P>0.05) for wethers fed HMM5, HMM10 and LMM10 (Table 3). Higher water intake (P<0.05) was recorded for LMM5 than for LMM10, HMM5 and HMM10. No differences were recorded in water intake (g kg^{-1} $M^{0.75}$) between AH and LMM5 (P>0.05), but a tendency was toward reduced water intake in LMM5. Wethers fed LMM10 and those fed HMM5 and HMM10 consumed less water (P<0.05) than those fed with AH. This is in agreement with previous research (Ferreira et al., 2002) showing less water consumption of goats and sheep fed ratio rich in energy in comparison with rations poor in energy concentration. Also, lower water intake in HMM5 and HMM10 in comparison with LMM5 and LMM10 might be result of higher water concentration in HMM that reduced water intake in general despite the fact that quantities of feed water intake and pure water intake were used in total water intake calculation.

Higher DM digestibility (P<0.001) was achieved with HMM supplementation than with LMM supplementation (Table 4). This improvement in DM digestibility with HMM over LMM supplementation may be attributed to possibly reduction in content of less digestible NDF during grain fermentation process. Besides, compared with feeding LMM, feeding HMM might decrease faecal excretion of starch and increase starch digestibility as reported in the experiment with steers (Archibeque et al., 2006). This further explains higher DM digestibility as increased content of more digestible starch and non-fibre concentration in the diet results in more energy available for rumen microorganisms fed AH based diet. This means that HMM supplementation improved microbial activity by developing a better environment for rumen fermentation and reduced indigestible materials of the diets (Matsui et al., 1998).

Table 4. Contrasts of fresh matter intake, dry matter intake and dry matter digestibility

	Parameter	AH vs. HMM5, HMM10, LMM5, LMM10	LMM5, HMM5 vs. LMM10, HMM10	LMM5, LMM10 vs. HMM5, HMM10
Intake	Fresh matter (g d day^{-1})	NS	NS	NS
	Fresh matter (g kg $^{-1}$ M$^{0.75}$)	NS	NS	***
	Dry matter (g day^{-1})	NS	NS	NS
	Dry matter (g kg $^{-1}$M$^{0.75}$)	***	***	***
Dry matter digestibility (g kg^{-1})		*	NS	***

AH - alfalfa haylage; HMM5 - AH supplemented with 5 g LMM d^{-1} kg^{-1} body weight; LMM10 - AH supplemented with 10 g HMM d^{-1} kg^{-1} body weight; LMM5 - AH supplemented with 5 g HMM d^{-1} kg^{-1} body weight; HMM10 - AH supplemented with 10 g HMM d^{-1} kg^{-1} body weight.; SEM - standard error of the mean; M$^{0.75}$ - metabolic body weight; values within the same column with different mark differ significantly (*, P<0.05; ***, P<0.001); NS - non significant

Table 5. Linear and quadratic effect of high moisture corn or dry corn inclusion into alfalfa haylage on fresh matter intake, dry matter intake and dry matter digestibility

	Parameter	Treatment					
		AH vs. LMM5, LMM10			AH vs. HMM5, HMM10		
		L	Q	SEM	L	Q	SEM
Intake	Fresh matter intake (g d^{-1})	**	*	40.27	NS	NS	55.7
	Fresh matter intake (g kg $^{-1}$M$^{0.75}$)	*	NS	0.29	NS	NS	0.36
	Dry matter (g d^{-1})	NS	*	20.6	NS	NS	29.7
	Dry matter (g kg $^{-1}$M$^{0.75}$)	***	***	0.84	***	**	1.46
Dry matter digestibility (g kg^{-1})		***	***	8.1	NS	**	14.5

AH - alfalfa haylage; HMM5 - AH supplemented with 5 g LMM d^{-1} kg^{-1} body weight; LMM10 - AH supplemented with 10 g HMM d^{-1} kg^{-1} body weight; LMM5 - AH supplemented with 5 g HMM d^{-1} kg^{-1} body weight; HMM10 - AH supplemented with 10 g HMM d^{-1} kg^{-1} body weight; SEM - standard error of the mean; values within the same column with different mark differ significantly (*, P<0.05; **, P<0.01, ***, P<0.001); NS - non significant; L - linear effect of supplementation; Q - quadratic effect of supplementation

Table 4 shows that maize grain supplementation (both, fermented and unfermented) improved diet DMI (P<0.001) and DM digestibility (P<0.05). Higher level of maize grain supplementation (10 g d^{-1}kg^{-1} body weight) was superior over lower level (5 g d^{-1}kg^{-1} body weight) of maize grain supplementation.

It has been indicated that forage NDF content (Van Soest et al., 1991) and digestibility, are important in the regulation of forage intake. Increasing level of LMM or HMM probably reduced NDF and resulted in a linear increase in diet intake and digestibility parameters. Besides, sheep develop preferences for feeds that are richer in energy (Provenza, 1995) and prefer corn to grass silage based diets (O'Doherty et al., 1997).

Positive associative response was noted when different forage sources, such as grasses and legumes, are fed in combination (Hunt et al., 1985). These effects are usually only observed when one forage source supplies a nutrient, most often protein, which is deficient in the other forage source. Positive associative responses in intake and digestibility are commonly noted when protein or energy supplements are provided to ruminants fed lower quality forage (Hannah et al., 1991). The moderate quality AH used in this experiment as the protein source and LMM or HMM as sources of energy, fed in combination resulted in positive associative responses for intake and digestibility parameters measured.

Conclusions

This study shows that the inclusion of HMM into AH based diet is superior over LMM inclusion in terms of DM digestibility, while LMM has advantages over HMM in terms of FMI and DMI. The higher level of HMM or LMM inclusion did not result in higher FMI neither diet DM digestibility over the lower level of maize grain inclusion.

Fermentirano vlažno zrno kukuruza kao dodatak sjenaži lucerne djeluje superiorno na probavljivost suhe tvari obroka u odnosu na suho zrno kukuruza

Sažetak

Cilj istraživanja bio je utvrditi je li vlažno zrno kukuruza (HMM) kao dodatak sjenaži lucerne (AH) superiorno u odnosu na suho zrno kukuruza (LMM) obzirom na konzumaciju hrane i vode, te probavljivost obroka u hranidbi kastriranih ovnova. Lucerna (*Medicago sativa* L.) je košena u fenološkoj fazi početka cvatnje i silirana u bale ovijene plastičnom folijom. Prosječan udio suhe tvari (ST) i sirovih proteina (SP) u AH bio je 534,7 g kg^{-1} svježeg uzorka i 141 g kg^{-1} DM, respektivno. Prosječan udio ST u HMM i LMM bio je 795,9 i 915,1 g kg^{-1} svježeg uzorka, respektivno, a prosječan udio SP (g kg^{-1} DM) bio je 116,8 i 106, respektivno. Istraživano je ukupno 5 hranidbenih tretmana uključujući hranidbu samo s AH, te AH s dodatkom HMM ili LMM u količini od 5 ili 10 g d^{-1} kg^{-1} tjelesne mase kastrata. Veća probavljiost ST obroka (P<0,05) je utvrđena kod dodatka HMM sjenaži lucerne (5 ili 10 g d^{-1}kg^{-1} tjelesne mase) u usporedbi s dodatkom LMM (5 ili 10 g d^{-1}kg^{-1} tjelesne mase). Veća konzumacija svježeg obroka (P<0,05), ST obroka (P<0,05) i vode je utvrđena kod dodatka LMM u usporedbi s dodatkom HMM. Zaključeno je da HMM kao dodatak AH djeluje superiorno na probavljivost ST obroka u odnosu na LMM, a dodatak LMM ima prednosti u konzumaciji obroka odnosu na HMM.

Ključne riječi: sjenaža lucerne, vlažno zrno kukuruza, suho zrno kukuruza, konzumacija, probavljivost

References

1. Archibeque, S.L., Miller, D.N., Freetly, H.C., Ferrell, C.L. (2006): Feeding high-moisture corn instead of dry-rolled corn reduces odorous compound production in manure of finishing beef cattle without decreasing performance. Journal of Animal Science, *84*, 1767-1777.
2. AFRC (1993): Energy and protein requirements of ruminants. In: An advisory Manual prepared by the AFRC technical Committee of Responses to Nutrients. *CAB International*, Wallingford, UK.
3. Ball, D.M., Hoveland, C.S., Lacefield, G.D. (2002): Southern Forages. Third edition. Published by the Potash & Phosphate Institute (PPI), Georgia, USA.
4. Chamberlain, A.T., Wilkinson, J.M. (1996): Feeding the Dairy Cow. Chalcombe Publications, PainShall, Ln2 3LT, UK
5. Clark, J.H. (1975): Utilization of high moisture grains by dairy and beef cattle. In: tech paper, 2nd Int. Silage res. Conf. int. Silo Association, Lenexa, Kansas.
6. Clark, J.H. (1976): Dairy production using high moisture corn. Proc. High Moisture Grain Symposium. Okla. St. Univ., Stillwater.p.179.
7. Corah, L.R. (1976): Nutritional value of high moisture corn and milo. Proc. High Moisture Grain Symposium. Okla. St. Univ., Stillwater.p.120.
8. European Economic Community (EEC) (1986): The Council Directive on the approximation of laws, regulations and administrative provisions of the Member States regarding the protection of animals used for experimental and other scientific purposes (86/609/EEC).
9. Ferreira, A.V., Hoffman, L.C., Schoeman, S.J., Sheirdan. R. (2002): Water intake of Boer goats and Mutton merinos receiving either a low or high energy feedlot diet. *Small Ruminant Research 43*, 245-248.
10. Hannah, S.M., Cochran, R.C., Vanzant, E.S., Harmon, D.L. (1991): Influence of protein supplementation on site and extent of digestion, forage intake and nutrient flow characteristics in steers consuming dormant bluestem-range forage. *Journal of Animal Science 69*, 2624-2633.
11. Hunt, C.W., Paterson, J.A., Williams, J.E. (1985): Intake and digestibility of alfalfa-tall fescue combinations diets fed to lambs. *Journal of Animal Science 60*, 301-312.
12. Matsui, H., Ushida, K., Miyazaki, K., Kojima, Y. (1998): Use of ration of digested xylan to digested cellulose (X/C) as an index of fiber digestion in plant cell-wall material by ruminal microorganisms. *Animal Feed Science and Technology 71*, 207-215.
13. McDonald, P., Henderson, A.R., Heron, S.J.E. (1991): The biochemistry of silage, 2nd edn. Marlow, UK: Chalcombe Publications, 82-122.
14. Merrill, W.G. (1971): The place of silage in production rations. Feeding high moisture corn grain silages. Proc. Int. Silage and Res. Conf. p.156.

15. Mulligan, F.J., Caffrey, P.J., Rath, M., Callan, J.J., Brophy, P.O., O'Mara, E.P. (2002): An investigation of feeding level effects on digestibility of cattle for diets grass silage and high fibre concentrates at two forage: concentrate rations. *Livestock Production Science 77*, 311-323.
16. O'Doherty, J.V., Maher, P.F., Crosby, T.F. (1997): The performance of pregnant ewes and their progeny when offered grass silage, maize silage or a maize silage/ensiled super pressed pulp mixture during late pregnancy. *Livestock Production Science 52*, 11.
17. O'Mara, F.P., Fitzgerald; J.J., Murphy, J.J., Rath, M. (1998): The effect on milk production of replacing grass silage with maize silage in the diet of dairy cows. *Livestock Production Science 55*, 79-87.
18. Owens, F.N., Secrist, D.S., Hill, W.J., Gill, D.R. (1997): The effect of grain source and grain processing on performance of feedlot cattle: A review. *Journal of Animal Science, 75* 868-879.
19. Provenza, F.D. (1995): Role of learning in food preferences in ruminants: Greenhalgh and Reid revisited. In: Engelhardt, W.V., Leonhard-Marek, S., Breves, G., Giesecke, D. (Eds.), Proceedings of the Eighth International Symposium on Ruminant Physiology, Ruminant Physiology: Digestion, Metabolism, Growth and Reproduction, Ferdinand Enke Verlag, Stuttgard, pp. 233-247.
20. SAS (1999): SAS® Software, SAS Institute Inc., Cary, North Carolina, USA
21. Steen, R.W., Gordon, F.J., Dawson, L.E., Park, R.S., Mayne, C.S., Agnew, R.E., Kilpatrick, D.J., Porter, M.G. (1998): Factors affecting the intake of grass silage by cattle and prediction of silage intake. *Animal Science, 66*, 115-127.
22. Van Koevering, M.T., Hill, W.J., Owens, F.N., Strasia, S.A., Gill, D.R., Martin, J.J. (1994): High moisture earcorn for feedlot steers. Okla Agr. Exp. Sta. Res. Rep. P-939, p134.
23. Van Soest, P.J., Robertson, J.B., Lewis, B.A. (1991): Method for dietary fiber, neutral detergent fiber and nonstarch polysaccharides in relation to animal nutrition. *Journal of Dairy Science 74*, 3583-3597.
24. Vranić, M., Knežević, M., Leto, J., Perčulija, G., Bošnjak, K., Kutnjak, H., Maslov, L. (2005): Kvaliteta voluminozne krme na obiteljskim poljoprivrednim gospodarstvima u Republici Hrvatskoj: Monitoring kvalitete travne silaže tijekom dvije sezone zimske hranidbe muznih krava. *Mljekarstvo 55* (4) 283-296.