The Effect of Semi-Natural Grassland Cutting Height on the Nutritive Value of Fermented Forage

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Summary

The objective of this study was to determine the nutritive value of fermented forage from semi-natural grassland harvested at 3 cutting heights: (i) cutting height 2 cm, (ii) cutting height 6 cm and (iii) cutting height 13 cm. Fresh forage was wilted separately according to investigated treatments for 24 hours before ensiling into experimental silos. After 35-day fermentation, the ensiled forage dry matter (DM) was determined while the chemical composition, fermentation quality and biological quality parameters were predicted by NIR spectroscopy. The following parameters were predicted: corrected DM (CDM), crude protein (CP), organic matter (OM), neutral detergent fiber (NDF), acidic detergent fiber (ADF), metabolic energy (ME), fermentable ME in ME (FME/ME), NH_3-N, sugar residues, the digestibility of the OM in the DM (D-value) and CP degradability. Ensiled forage cut at 13 cm above the ground level had significantly lower OM content ($P<0.05$) but higher ME, and D-value ($P<0.05$) in comparison with forage cut at 2 or 6 cm above the ground level. The CP content was significantly affected by the cutting height ($P<0.001$). The CP content was the highest at forage cut at the highest residual stubble height and was getting lower as the cutting height decreased ($P<0.001$). Cutting at 2 cm above the ground level resulted in forage lower in sugar residues ($P<0.05$) in comparison with cutting at higher residual stubble height (6 cm and 13 cm). It was concluded that the higher cutting height promotes higher nutritive value of fermented forage from semi-natural grassland compared to the quality of fermented forage defoliated at the lower cutting height.

Key words

cutting height, semi-natural grassland, fermented forage, nutritive value

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Introduction

Grassland cutting management is determined by the sward mowing frequency and cutting height (Bošnjak et al., 2013). The recommended forage cutting height to provide the optimum dry matter (DM) yield, sward persistency and forage nutritive value varies among different plant species (Yolcu et al., 2006). Higher cutting height (10 cm or more) is recommended to maintain productivity and persistence of orchardgrass swards when harvested for conserved forage (Brink et al., 2010). Similarly, tetraploid hybrid ryegrasses and Italian ryegrass have benefits from higher cutting height (8 cm) in terms of annual DM yield, persistency and the percentage of weed grasses in comparison with the lower cutting height (5 cm) (Jones, 1983). In general, at the low cutting height, varieties of cocksfoot, meadow fescue and tall fescue provide higher annual DM yield in the second harvest year but lower yields in the third harvest year (Jones, 1983). The hay yield of alfalfa increases with the close harvest to base, which may cause reduction in hay yield in successive years (Tosun, 1971).

Contrary, lower cutting of perennial ryegrass as a monoculture, increases the number of tillers per m^2 (Penning et al. 1989) thus maintaining persistency and provides higher annual DM yield (Jones, 1983). Also, decreasing the cutting height, from 6 cm to 4 cm and further to 2 cm, significantly increases the proportion of white clover in the sward (Acuna and Wilman, 1993). At the same time, the total annual DM yield of ryegrass-clover mixture might be reduced more than 3 t ha^{-1} under higher cutting height (10 cm) in comparison with lower cutting height (2 cm) (Acuna and Wilman, 1993).

Higher cutting height generally promotes a higher nutritive value of the forage produced because of higher ratio of leaf to stem (Buxton et al., 1985) and lower forage contamination with soil particles (Wyss, 2009, 2011). Contrary, with white clover and ryegrass sward, the content of N and P decreases with increasing cutting height from 2 to 10 cm because of their morphological characteristics (Acuna and Wilman, 1993). With Napier grass, the frequency of cutting had a greater effect on the growth characteristics, DM yield, chemical components, and IVDMD than the cutting height from 5 to 25 cm (Tessema et al., 2010).

Cutting frequency and cutting height significantly affected the N yield in alfalfa. Although the high quality forage was produced with higher cutting height (10 cm), the total CP yield was reduced due to reduced DM yield in comparison with lower cutting height (5 cm) (Yolcu et al., 2006).

The previous results suggest the optimum forage cutting height from the ground level, to ensure high yield and nutritive value of different types of grasses, should be 7.5 cm (Donkor et al., 2002), 7-8 cm (Wyss, 2011) or 10 cm (Brink et al., 2010).

The nutritive quality of fermented forage is closely related to the fresh forage chemical composition, fermentation and biological parameters (Vranić et al., 2004, 2005, 2014). Semi-natural grassland plant community *Arrhenaretheretum medioeuropaeum* is one of the most widespread plant communities in the Republic of Croatia and most of Central Europe. It is of high productivity and nutritive value, predominantly utilized by mowing. No results are available of the effect of cutting height on the nutritive value of fermented forage originated from semi-natural grassland.

The hypothesis of this experiment was that fermented semi-natural forage of higher cutting height was of higher nutritive value compared to forage defoliated at medium or low cutting height.

Material and Methods

Experimental Site

The experimental site (~0,5 ha) was located at the University of Zagreb, Faculty of Agriculture. For this study, the forage from semi-natural anthropogenic grassland, plant communities *Arrhenaretheretum medioeuropaeum* (Br-Bl-1919), (Hulina, 1983), was used. Forage was harvested at the growth stage E4-E5, just before reproductive stage (Moore et al., 1991).

A 0.25 m^2 quadrat metal frame was used for forage sampling in which it was randomly placed four times per treatment on the plot. Inside the frame, the enclosed bunch of forage was cut for each of the three cutting height treatments separately by hand scissors: (i) cutting height 2 cm (treatment A), (ii) cutting height 6 cm (treatment B) and (iii) cutting height 13 cm (treatment C). The total fresh forage weight inside the frame was determined to calculate forage yield. Thereafter, one sub-sample of fresh forage per treatment (about 0.3 kg) was packed, labeled and taken to laboratory for dry matter (DM) determination and nutritive value prediction by NIR spectroscopy.

The forage from each treatment was wilted separately in the field for 24 hours. During the wilting, the maximum daily temperature was 28°C.

Formation of Experimental Silos

For each treatment, 250 g (fresh basis) of unchopped forage (Vranić, 2014) were packed into four 0.09 mm nylon-polyethylene bags (15.2 × 30.5 cm), vacuumed and sealed. The ensiled forage was left to ferment for 35 days before analysing by wet chemistry or NIR spectroscopy.

Chemical and Statistical Analysis

The DM content (g DM kg^{-1} of fresh sample) was determined by drying the samples in the ELE International dryer at a temperature of 60°C, over 48 hours or to a constant forage weight (AOAC,1990). The dried samples were ground to a particle size of 1mm using Christy hammer mill (Model 11).

The pH of the silage was determined in a water extract containing 10 g of fresh silage and 100 mL of distilled water using a pH meter model 315i (WTW).

The chemical composition, fermentation and the biological parameters were predicted by NIR spectroscopy (instrument Foss, Model 6500) (Vranić et al., 2004). Before scanning, the ground samples were re-dried at a temperature of 105°C for 3 hours and packed in a 5 x 6.5 cm scanning cell. The samples were scanned by infrared electromagnetic spectrum, in a wavelength of 1100-2500 nm, at intervals of 2 nm using ISI SCAN software. Each sample was scanned two times and the average spectral data of the same sample (NIR) was converted into data file (.DAT) using WINISI III software.

The data set were associated with Scottish calibration models by applying SAC1 and SAC2 software. Based on previously determined DM, the instrument predicted: (i) chemical parameters: corrected dry matter (CDM), organic matter (OM), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), metabolic energy (ME), (ii) parameters of the fermentation quality in the silo: fermenting ME in ME (FME/ME), ammonium nitrogen (NH_3-N), sugar residues and (iii) the forage biological parameters: the digestibility of the OM in the DM (D-value) and CP degradability. The results were analysed using mixed model procedures (SAS, 1999).

Results and Discussion

The dry matter (DM) yield of the fresh forage was 3.51 t ha^{-1}, 3.42 t ha^{-1} and 3.15 t ha^{-1} for A, B and C treatments respectively. The treatment C was lower in DM yield ($P<0.05$) compared to treatment A while no significant differences among other treatments in DM yield were determined ($P>0.05$).

The cutting height affected CP content in fresh forage (Table 1). A higher content of CP ($P<0.05$) was found in treatment C compared to treatment A. No differences in CP content of the fresh forage were determined between A and B as well as B and C treatments ($P>0.05$) (Table 1).

The effect of the cutting height on the chemical composition of fermented forage is presented in Table 2. The DM content (g kg^{-1} of fresh sample) ranged from 643.4 g kg^{-1} fresh sample (treatment A) to 720.0 g kg^{-1} fresh sample (treatment B). The proportion of DM did not differ significantly ($P>0.05$) among the investigated treatments (treatment A, B and C). The desirable DM content in fermented forage was higher than 300 g kg^{-1} of fresh sample (Chamberlain and Wilkinson, 1996) which is consistent with the obtained results.

The corrected DM (CDM) ranged from 653.0 g kg^{-1} fresh sample (treatment A) to 723.5 g kg^{-1} fresh sample (treatment B). The CDM acted the same as DM and did not differ significantly ($P>0.05$) among the investigated treatments.

Table 1. The chemical composition of fresh forage (g kg^{-1} DM if not otherwise stated)

Chemical parameter	Treatment			Significance	SEM
	A	B	C		
DM (g kg^{-1} FS)	172	165	168	N.S.	15.56
OM	966	946	963	N.S.	21.58
CP	116^{a}	147^{ab}	163^{b}	0.05	20.86
NDF	547	536	530	N.S.	16.04
WSC	80	76	75	N.S.	8.8
D-value	700	740	760	N.S.	3.66
ME (MJ kg^{-1} ST)	10.4	11.0	11.3	N.S.	0.55

FS, fresh sample; DM, dry matter; OM, organic matter; CP, crude protein; NDF, neutral detergent fibre; WSC, water soluble carbohydrates; D-value, digestibility of organic matter in the dry matter; ME, metabolic energy; A, cutting height 2 cm; B, cutting height 6 cm; C, cutting height 13 cm; SEM, standard error of the mean; a, b, c, numbers in the same row marked with different letters differ significantly at $P<0.05$; N.S., not significant ($P>0.05$)

Table 2. The effect of the cutting height on the chemical composition of fermented forage (g kg^{-1} DM if not otherwise stated)

Treatment	DM	CDM	OM	CP	NDF	ADF	ME (MJ kg^{-1} DM)
	(g kg^{-1} FS)						
A	643.4	653.0	932.8^{a}	172.0^{a}	467.5	278.8	9.15^{a}
B	720.0	723.5	930.5^{a}	197.8^{b}	466.8	279.3	9.10^{a}
C	716.7	716.5	923.0b	$^{214.3}$c	462.3	271.5	9.25^{b}
Significance	N.S.	N.S.	*	***	N.S.	N.S.	*
SEM	31.9	30.4	3.0	6.6	5.5	4.5	0.05

FS, fresh sample; DM, dry matter; CDM, dry matter corrected for volatiles; OM, organic matter; CP, crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; ME, metabolic energy; A, cutting height 2 cm; B, cutting height 6 cm; C, cutting height 13 cm; SEM, standard error of the mean; a,b,c, numbers in the same column marked with different letters differ significantly at $P<0.05$; N.S., not significant ($P>0.05$); *, ***, significant at $P<0.05$ and $P<0,001$, respectively

The OM ranged from 923.0 g kg^{-1} DM (treatment C) to 932.8 g kg^{-1} DM (treatment A). The treatment C had significantly lower (P<0.05) OM content (923.0 g kg^{-1} DM) compared to treatment A (932.8 g kg^{-1} DM) and treatment B (930.5 g kg^{-1} DM).

The CP content varied from 172.0 g kg^{-1} DM (treatment A) to 214.3 g kg^{-1} DM (treatment C), which fits the fermented forage of high nutritive value (Chamberlain and Wilkinson, 1996). The treatment B had a significantly higher CP content (197.8 g kg^{-1} DM) (P<0.05) compared to treatment A (172.0 g kg^{-1} DM). The treatment C had a significantly higher (P<0.01) CP content (214.3 g kg^{-1} DM) in comparison with treatments A and B.

Forage NDF affects forage intake (Cannas et al., 2007; Dewhurst et al., 2010). It is negatively correlated with the CP content. Potential forage intake decreases with increasing NDF (Ball et al., 2002). NDF content ranged from 462.3 g kg^{-1} DM in treatment C to 467.5 g kg^{-1} DM in treatment A. The proportion of NDF did not differ significantly (P>0.05) among the treatments (treatment A, B and C). According to Chamberlain and Wilkinson (1996), the optimal NDF in forage is 500 to 550 g kg^{-1} DM, which is higher than determined in this study. Feed energy value and ADF highly correlate, because the digestibility and the energy the animal receives from the feed depends on the ADF content (Raffrenato and Erasmus, 2013). With increasing ADF, feed digestibility and energy content is decreasing, which directly affects milk production (Ball et al., 2002). The ADF content ranged from 271.5 g kg^{-1} DM (treatment C) to 279.3 g kg^{-1} DM (treatment B). No significant differences in ADF (P>0.05) were found between the investigated treatments (A, B and C).

The forage ME is positively correlated with CP concentration. The ME content ranged from 9.10 MJ kg^{-1} DM in treatment B to 9.25 MJ kg^{-1} DM in treatment C. It was lower than the optimal ME in fermented forage (11.00 MJ ME kg^{-1} DM) (Chamberlain and Wilkinson, 1996). No significant differences in ME (P<0.05) were found between the treatments A and B while the treatment C was higher in ME content compared to treatments A and B (P<0.05).

Table 3 shows the effect of cutting height on the forage fermentation quality in the silo. The feed energy available to rumen microbes is referred to as fermentative metabolic energy in the metabolic energy (FME/ME). Chamberlain and Wilkinson (1996) reported preferred FME/ME to be higher than 0.70 MJ kg^{-1} DM. The FME/ME was equal in treatments B and C (0.85 MJ kg^{-1} DM), while slightly lower in treatment A (0.84 MJ kg^{-1} DM). Given the very similar results among the investigated treatments (A, B and C), it was found that the cutting height did not significantly affect the FME/ME content (P>0.05) among the investigated treatments.

The amount of NH_3-N in the silage, i.e. the amount of total N degraded to ammonia during silage making, in high quality silage should be as low as possible (lower than 50 g kg^{-1} DM of total N in the form of NH_3-N) (Chamberlain and Wilkinson, 1996). In all the investigated treatments (A, B, and C), the amount of NH_3-N was higher than 50 g of NH_3-N kg^{-1} total N reported for grass silage of high fermentation quality (Chamberlain and Wilkinson, 1996). The amount of NH_3-N ranged from 101.3 g N kg^{-1} total N (treatment A) to 136.0 g N kg^{-1} total N (treatment C). The higher NH_3-N content in the fermented forage may be the result of prolonged proteolysis due to the prolonged aerobic conditions in the silo. This is often observed while ensiling forage higher in DM and / or at advanced maturity (Lukšić et al., 2017). The most common measurement used for evaluating silage fermentation quality includes pH value which measures silage acidity. Silage of desirable quality has pH of 4.2 or lower but the pH of silage highly depends on silage DM concentration. This is because the silage of high DM has lack of water for good forage compaction and to support lactic acid bacteria activity, thus less acids are produced (Whiter and Kung, 2001). High DM content of fermented forage in this research resulted in higher pH values. The NH_3-N content did not differ significantly among the investigated treatments (P>0.05) neither the pH value (P>0.05).

According to Chamberlain and Wilkinson (1996), the grass silage should contain at least 100 g of sugar residues kg^{-1} DM, which is more than reported. The proportion of sugar residues ranged from 80.0 g kg^{-1} DM (treatment B) to 90.5 g kg^{-1} DM (treatment C). The amount of sugar residues did not differ significantly between the treatments B (80.0 g kg^{-1} DM) and A (85.0 g kg^{-1} DM) (P>0.05). The treatment C had significantly higher sugar residues (90.5 g kg^{-1} DM) compared to treatment B (80.0 g kg^{-1} DM) (P<0.05).

Table 4 shows the effect of the cutting height on the biological parameters investigated in the fermented forage.

Table 3. The effect of cutting height on the forage fermentation quality

Treatment	FME/ME (MJ kg^{-1} DM)	NH_3-N (g N kg^{-1} total N)	pH	Sugar residues (g kg^{-1} DM)
A	0.84	101.3	5.4	85.0^{ab}
B	0.85	109.0	5.2	80.0^{a}
C	0.85	136.0	5.1	90.5^{b}
Significance	N.S.	N.S.	N.S.	*
SEM	0.004	15.9	0.3	3.6

FME/ME, fermentable metabolic energy in the metabolic energy (the energy available for rumen microorganisms); NH_3-N, the amount of ammonium nitrogen in the total nitrogen; Sugar residues, residues of sugars after fermentation; A, cutting height 2 cm; B, cutting height 6 cm; C, cutting height 13 cm; SEM, standard error of the mean; a, b, c, numbers in the same column marked with different letters differ significantly at P<0.05; N.S., not significant (P>0.05); *, significant at P<0.05

Table 4. The effect of cutting height on the ensiled forage biological parameters (%)

Treatment	D-value	CP degradability
A	57.0[a]	89[a]
B	56.8[a]	81[ab]
C	58.0[b]	77[b]
Significance	*	*
SEM	0.4	4.0

D-value, the digestibility of the organic matter in the dry matter; CP degradability, CP degraded in rumen; A, cutting height 2 cm; B, cutting height 6 cm; C, cutting height 13 cm; SEM, standard error of the mean; a, b, c, numbers in the same column marked with different letters differ significantly at $P<0.05$; N.S., not significant ($P>0.05$); *, significant at $P<0.05$

Digestibility of OM in the DM (D-value) affects the intake and performance of dairy cows in a way that highly digestible and well-conserved grass silage has higher intake, supports higher milk production, increases milk protein content, but reduces milk fat concentration (Bosh et al., 1992; Cushnahan et al., 1996). Grass silage with higher D-value has a lower fiber content, shorter time is needed for chewing, so less acetic acid is produced which results in lower milk fat content. Digestion of lower quality forage takes longer than digestion of higher quality forage (Ørskov, 1998).

It can be seen from Table 3 that the D-value of the fermented forage ranged from 56.8% (treatment B) to 58.0% (treatment C). The D-value was lower in treatment B (56.8%) compared to treatment A (57.0%), but the difference was not significant ($P>0.05$). The treatment C (58.0%) had a significantly higher D-value ($P<0.05$) compared to treatments A and B. The investigated treatments had a lower D-value than previously reported by Castle et al. (1977) for high quality grass silage (71.2%), which supports 10.8 kg milk production d^{-1} per cow.

Grass silage proteins are highly soluble in rumen thus providing large amounts of N for microbial protein synthesis. In order to make the released N be effectively used for the synthesis of microbial protein, the quickly available energy is needed, which should be provided from other sources (e.g. corn silage).

The CP degradability in the rumen ranged from 77% (treatment C) to 89% (treatment A). The CP degradability was lower in treatment B (81%) compared to treatment A (89%), but the difference was not significant ($P>0.05$). A significant reduction in CP degradability ($P<0.05$) was found in treatment C (77%) compared with treatment A (89%). The CP degradability of fermented forage in rumen most often ranges from 65-95% (Chamberlain and Wilkinson, 1996; Vranić et al., 2005) which fits the CP degradability range of the investigated treatments.

Conclusion

It was concluded that the cutting height of semi-natural grassland affected the forage nutritive value. As the cutting height increased, so did the forage nutritive value. The mean cutting height did not differ from higher or lower cutting heights in some of the investigated parameters. The greatest differences in forage nutritive value were determined between the highest and the lowest cutting height. The highest cutting height investigated (13 cm above the ground level) resulted in higher nutritive value of fermented semi-natural forage (higher content of crude protein, metabolic energy, sugar residues and higher digestibility of organic matter in dry matter) compared to nutritional value of semi-fermented fodder lawn defoliated at 2 cm from ground level.

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