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Meeting the future demands for grassland production

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Ensiling ability of species-rich mountain swards with elevated contents of condensed tannins

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Abstract

Ensiling forage from species-rich swards is challenging due to low contents of fermentable carbohydrates and a high buffering capacity due to potential protein degradation. Species-rich swards from two mountain meadows were investigated for their fermentation quality and effects of condensed tannins (CT) on protein degradation during ensiling. Swards were obtained from two long-term fertiliser experiments located in the Swiss Alps, cut two or three times during the season of 2017. Swards were either unfertilised or fertilised with PK or NPK. Forages were wilted and ensiled in laboratory silos. Composition of nutrients, protein and CT were determined in wilted and ensiled forage. The fermentation quality was analysed >65 d post ensiling. Silages were characterised by high pH (4.60-5.19) and butyric acid content (1.5-17.8 g kg^{-1} dry matter (DM)), while ammonia-N ranged from 35 to 62 g kg^{-1} of total N. Protein fraction A increased by 20.7% during ensiling. Contents of CT varied from 5.0 to 18.0 g kg^{-1} DM. Contents of CT were not consistently correlated to the increase in protein faction A when related to type of fertilisation or harvest.

Keywords: biodiverse sward, fertilisation, protein fraction A, proteolysis, silage quality

Introduction

Mountain grasslands are rich in plant species composition and provide the major source of forage in mountain areas. Moderate contents of fermentable carbohydrates present in species-rich swards limit the formation of lactic acid to yield well-conserved silages. Legumes and herbs further increase the buffering capacity of the silage due to high contents of proteins, minerals and organic acids (Isselstein and Daniel, 1996). When compared to fresh or dried forage, ensiling increases protein degradation and the formation of readily soluble N, as measured by protein fraction A (Licitra *et al.*, 1996). Condensed tannins (CT), when added as silage additives, were shown to reduce protein degradation during ensiling as well as the formation of butyric acid (Jayanegara *et al.*, 2019). Numerous herbs have been described for their CT contents (Jayanegara *et al.*, 2011) and feed value when ensiled (Weißbach, 1998). However, only few studies have focused on the ensiling ability of species-rich swards with varying proportions of herbs from mountain sites (Wyss *et al.*, 2016). Therefore, this study assessed the ensiling quality and investigated the role of CT for protein degradation during ensiling of species-rich forage harvested from two Swiss mountains sites.

Materials and methods

The forage ensiled was obtained from two long-term mineral fertilisation field experiments located at 930 m a.s.l. (Thomet and Koch, 1993) and 1340 m a.s.l. (Baumberger *et al.*, 1996). Swards were either unfertilised (O) or fertilised with PK or NPK and sampled in three plots at each site. Annual amounts of fertiliser per ha were 75 kg N, 34.9 kg P, 199 kg K (at 930 m a.s.l.) and 80 kg N, 26.2 kg P and 149 kg K (at 1,340 m a.s.l.). During 2017, forage was harvested on 1 June, 8 August and 4 October (930 m a.s.l.) and 16 June and 23 August (1,340 m a.s.l.). The fresh forage was wilted to 30% dry matter (DM) and mechanically chopped to 2 cm and ensiled in 1.5 l laboratory silos for >65 d. Gross nutrient composition of wilted and ensiled forage was determined using near-infrared spectroscopy. Contents of CT (Terrill *et al.*, 1992) and protein fraction A (Licitra *et al.*, 1996) were determined in lyophilised samples.

Fermentation acids and ethanol were determined by gas chromatography. Silage pH and ammonia-N were determined electrometrically. Correlation analysis was applied to assess the effect of CT on the increase in protein fraction A (difference of ensiled to wilted forage). Analysis of variance was conducted including 'harvest, *h*' and 'type of fertilisation, *f*' and their interaction ('$h \times f$') on silage quality using Sigmaplot (V12.5). Differences among arithmetic means were considered significant at $P<0.05$.

Results and discussion

Silage quality of biodiverse swards was affected differently by harvest and fertilisation at the two grassland sites, with an overall more pronounced effect of harvest rather than fertilisation (Table 1). Protein concentrations of wilted forage were low when compared to intensively managed ryegrass swards, but comparable to those from other mountain swards (Wyss *et al.*, 2016). The formation of lactic acid was limited in all silages and, consequently, silage pH was too high in relation to silage DM contents. Ethanol formation in silages was similar between both sites and within expected ranges (Wyss *et al.*, 2016). While the concentrations of acetic acid were lower in silages from the site at 930 m a.s.l. than those at 1,340 m a.s.l., for concentrations of butyric acid the opposite effect was found. The higher the contents of CT, the lower the increase in protein fraction A from wilted to ensiled forage (Figure 1). However, a significant correlation was only observed in silages from forage fertilised with NPK. Those swards were particularly rich in CT, likely due to the presence of *Geranium sylvaticum*, which was particularly abundant in these swards (Ineichen, 2018).

Conclusions

The silage quality of the mountain grassland swards subjected to either no, PK or NKP fertilisation was insufficient with respect to silage pH and butyric acid contents. The silage quality produced from swards harvested from the grassland located at the lower elevation mountain site were primarily affected by harvest rather than fertilisation, while those from the higher located site showed more of interactions of '$h \times f$'. Based on the correlation of the CT content and the increase in protein fraction A from wilted to ensiled forages (i.e. ΔA), the effect of harvest tends to be stronger than that of fertilisation. The seasonal occurrence of specific tanniferous forage species may primarily contribute to the harvest-related effect.

Table 1. Content of condensed tannins (CT) and crude protein (CP) of wilted forage and silage quality (g kg^{-1} dry matter (DM) unless otherwise stated) of forage harvested from species-rich swards of two long-term mineral fertilisation field experiments in the Swiss mountains.

	930 m a.s.l.							1,340 m a.s.l.						
	0	PK	NPK	SEM	*h*	*f*	$h \times f$	0	PK	NPK	SEM	*h*	*f*	$h \times f$
Wilted														
CT	10.3	12.9	12.5	0.53	**	*	ns	7.9	7.4	8.7	0.44	ns	ns	**
CP	131	130	115	2.9	*	*	ns	118	129	130	2.9	ns	*	**
Ensiled														
DM	351	394	347	14.4	**	**	ns	322	357	334	6.00	*	*	ns
pH [1]	4.60	5.19	4.88	0.059	**	**	ns	4.96	5.15	5.03	0.052	**	ns	*
Lactic acid	35.0	24.2	32.1	1.85	**	**	**	34.5	31.7	33.8	1.62	ns	ns	*
Acetic acid	3.29	2.29	2.95	0.340	*	ns	ns	9.45	3.89	7.45	1.069	**	**	**
Butyric acid	11.2	7.9	13.3	1.25	**	ns	ns	3.9	4.1	2.1	0.55	ns	ns	*
Ethanol	5.37	6.10	5.46	0.542	**	ns	ns	5.39	5.81	5.03	0.496	ns	ns	ns
NH_3-N [g kg N^{-1}]	45.2	41.9	36.7	3.25	**	ns	ns	44.2	52.5	62.5	2.77	ns	*	ns
Fraction A	54.5	48.1	36.6	3.82	**	*	ns	48.6	51.3	49.6	1.79	ns	ns	ns

[1] Type of fertilisation: unfertilised swards (0), PK or NPK; *h* = harvest; *f* = fertilisation; $h \times f$ = interaction of harvest and fertilisation; SEM = standard error of means; fraction A = protein fraction A (Licitra *et al.*, 1996); ns = not significant; * $P<0.05$; ** $P<0.01$.

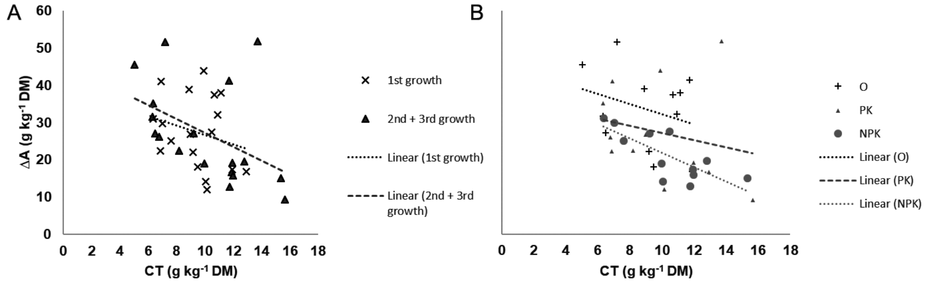

Figure 1. Relationship between condensed tannins (CT) content (g kg^{-1} dry matter (DM)) and the increase in protein fraction A from wilted to ensiled forage during the first ($y = -1.26x + 39.4$, $P>0.05$, $R^2=0.0582$) or following regrowth ($y = -1.87x + 45.9$, $P=0.05$, $R^2=0.2193$) (A) and in relation to type of fertilisation: 0: $y = -1.38x + 45.9$, $P>0.05$, $R^2=0.0876$; PK: $y = -0.98x + 36.9$, $P>0.05$, $R^2=0.0529$; NPK: $y = -1.93x + 41.3$, $P<0.05$, $R^2=0.5877$ (B).

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