Effect of different agronomical measures on yield and quality of autumn saved herbage during winter grazing – 2^{nd} communication: Crude protein, energy and ergosterol concentration

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ABSTRACT: In addition to the results published in the first communication (Opitz von Boberfeld et al., 2006) this paper presents crude protein, energy (ME) and ergosterol concentrations of autumn saved herbage at different sites in Central Germany, Poland, Hungary and the Czech Republic. Within these sites, the influence of the factors pre-utilisation and winter harvest date was tested over three consecutive years. Related to the different climatic conditions of the sites, crude protein concentrations of the growths pre-utilised in July varied from 149 g/kg in November to 134 g/kg of dry matter (DM) in January. The influence of climatic conditions was different on each location and varied depending on the year. Generally, the consistent effect of the factor "site" related to altitude could not be observed. While the energy concentrations decreased with advancing winter and partly reached the values below 6 MJ ME/kg of DM in January, the ergosterol concentrations increased. The results demonstrate that under Central European conditions autumn saved herbage, pre-utilised in July, could provide adequate quantity and quality for suckler cows until December. Afterwards, the utilisation of preserved forages becomes essential.

Keywords: winter pasture; grazing livestock; metabolisable energy; ergosterol; mycotoxins

Autumn saved herbage, frequently used in year-round grazing systems to extend the grazing period into late autumn and winter (Boeker, 1957), reduces costs of preserved forage and stables (Deblitz et al., 1993). The economic advantages of this land use option make it interesting as a low-input beef production system for peripheral sites in Central Europe (Opitz von Boberfeld, 1997; Möller et al., 2002; Golinski et al., 2003; Jacob, 2003; Tasi et al., 2003; Skladanka, 2004). Because these growths have to provide a sufficient supply of energy and nutrients to grazing livestock, the knowledge of forage properties such as crude protein and energy concentration of autumn-saved herbage is necessary. Results from Central Germany demonstrated that both features were dependent on the period of accumulation since summer and the date of utilisation in winter (Opitz von Boberfeld and Wöhler, 2002; Opitz von Boberfeld and Wolf, 2002; Wolf, 2002; Wöhler, 2003). A shorter period between summer and winter utilisation increased the concentration of crude protein and metabolisable energy, but at the same time, the later utilisation in winter resulted in lower concentrations. A delayed utilisation of herbage mass is generally connected with a decrease in forage quality due to the advanced stage of maturity (Opitz von Boberfeld, 1994). Furthermore, the degree of fungal infections of the sward increases (Opitz von Boberfeld, 1996). During winter grazing the adverse weather conditions are conducive to decomposition processes and additionally enhance the susceptibility of the growths to fungal decay. Therefore the possibility of mycotoxin (e.g. Zearalenon, Ochratoxin A) accumulation in herbage mass is given (Opitz von Boberfeld and Wolf, 2002; Golinski et al., 2003), but due to the great variety of possible mycotoxins and their inhomogeneous occurrence in the sward, the determination is often difficult and expensive. Therefore, ergosterol, a cell wall component of fungi, is often used as an indicator for the intensity of fungal infections (Seitz et al., 1977) and inferior forage quality. Results obtained under rather humid climatic conditions of Central Germany (Opitz von Boberfeld and Wolf, 2002; Opitz von Boberfeld and Wöhler, 2002) demonstrate that the ergosterol concentrations in autumn saved herbage, based on pure stands of *Festuca arundinacea* and *Lolium perenne* or existing plant communities as *Festuco-* or *Lolio-Cynosuretum* during winter, strongly depend on the pasture management (e.g. period of accumulation since summer, date of utilisation during winter grazing) as well as on the weather conditions during autumn and winter. In addition to the results concerning DM yield and digestibility of organic matter presented in the previous communication (Opitz von Boberfeld et al., 2006) and due to the limited knowledge regarding the mentioned quality aspects under different climatic conditions in Central Europe further examinations are necessary. Therefore, the aim of the study was to investigate the influence of pre-utilisation and date of winter harvest on the concentration of crude protein, metabolisable energy and ergosterol in autumn-saved herbage at three different sites in Poland, Hungary and the Czech Republic, compared to available results from Central Germany.

MATERIAL AND METHODS

The trails were established in low-input pasture systems as randomised block designs with three replications at five different sites in Central and Eastern Europe. Further details regarding the design of the trials, site and climatic conditions are given in the previous communication (Opitz von Boberfeld et al., 2006). For analysis, samples of each plot were dried at 60°C and ground to pass a 1-mm screen. Crude protein was analysed by Kjeldahl technique (Anonymus, 1997a). The energy concentration was estimated *in vitro* (Hohenheim Gas Test) as metabolisable energy (ME) using formula 16e (Menke and Steingass, 1987) including the variables rumen liquid, crude protein and crude fat (Anonymus, 1997a). The concentration of ergosterol was determined after saponification and extraction in petroleum ethers by the HPLC-technique (Schwadorf and Müller, 1989; Anonymus, 1997a). All results refer to 103°C and were examined by analysis of variance with $P < 0.05$ as the level of significance and least-significance differ-

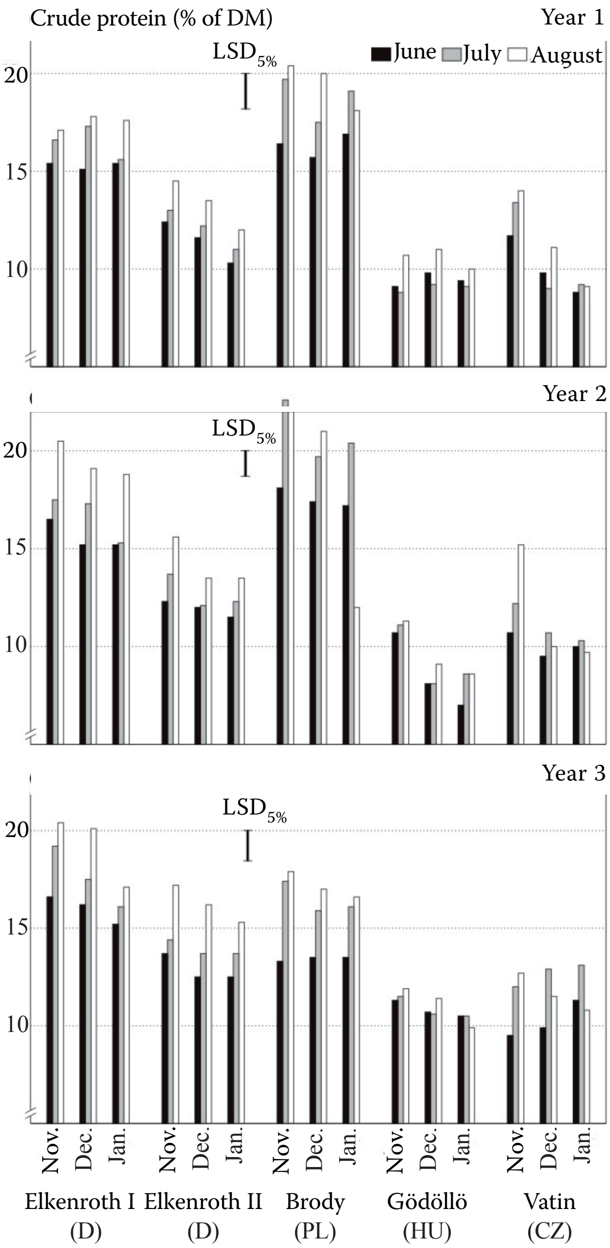

Figure 1. Crude protein concentration depending on pre-utilisation, winter harvest date and site

Table 1. Sources of variation (mean square, F-test) for crude protein, metabolisable energy and ergosterol concentration during the three years of observations

Source of variance	Degrees of freedom	Crude protein			Metabolisable energy			Ergosterol		
		year 1	year 2	year 3	year 1	year 2	year 3	year 1	year 2	year 3
Block (over all sites)	10	4.58**	7.87**	9.48**	0.65**	0.23	0.30*	2 853.05	3 486.29**	1 915.40*
Pre-utilisation (P)	2	42.13**	42.81**	66.64**	1.95**	10.07**	14.13**	9 831.68**	37 095.64**	53 899.95**
Winter harvest (W)	2	23.10**	81.07**	15.78**	48.71**	26.97**	25.65**	111 412.08**	158 055.50**	252 189.57**
Site (S)	4	369.11**	463.46**	213.44**	17.79**	31.83**	6.25**	335 322.15**	101 676.66**	107 619.44**
P × W	4	2.16	8.84**	2.07	0.22	0.23	0.46*	376.93	686.32	3 093.75*
P × S	8	2.89*	9.90**	7.83**	1.52**	0.52**	0.70**	5 504.98**	4 040.42**	2 524.94**
W × S	8	7.90**	5.04**	2.46*	1.43**	3.69**	2.04**	16 760.36**	8 472.41**	11 209.18**
P × W × S	16	1.08	6.55**	1.01	0.41*	0.63**	0.26*	799.56	2 080.59**	1 253.23
Error	80	1.26	0.65	0.92	0.21	0.15	0.14	1 484.49	817.74	881.21
Total	134									

*significant at 0.05 level of probability, **significant at 0.01 level of probability

ences ($LSD_{site/pre-utilisation/winter\ harvest\ date}$) with $P < 0.05$ were calculated. As described in Opitz von Boberfeld et al. (2006), the analysis of variance was done considering all sites under the assumption that the residual errors of several sites did not differ significantly. Generally, years were observed separately due to the great importance of weather conditions in winter.

RESULTS

Crude protein

While in most cases a later date of pre-utilisation in summer resulted in a higher crude protein content during winter, the crude protein content in herbage harvested in Gödöllö was never affected significantly by the factor pre-utilisation (Figure 1); the interaction pre-utilisation × site occurred in all years (Table 1). The interaction winter harvest date × site was examined for the first two years, but actually, a relevance was given only in the first winter. In contrast to the decreasing crude protein concentrations with advancing winter the crude protein level of the growths harvested in Elkenroth I and Gödöllö did not change during winter. In all years the factor site had the greatest effect on crude protein as the herbage of the sites Gödöllö and Vatin always showed the lowest concentrations (Figure 1). Depending on the year the influence of the factors pre-utilisation and winter harvest date varied and their share of variance was comparatively low. The pre-utilisation in August mostly led to the highest crude protein contents; at the same time, the lowest concentrations were observed in January. Almost without exception concentrations in the tested growths were above 100 g/kg in DM.

Energy concentration

Figure 2 presents the energy concentration (metabolisable energy) of the tested herbage. The interaction winter harvest date × site occurred in all years (Table 1). The later the winter harvest date the lower the energy concentration, but depending on the site the extent of decline varied. During the second winter the significance of this interaction was caused by the development of the values in Gödöllö, which

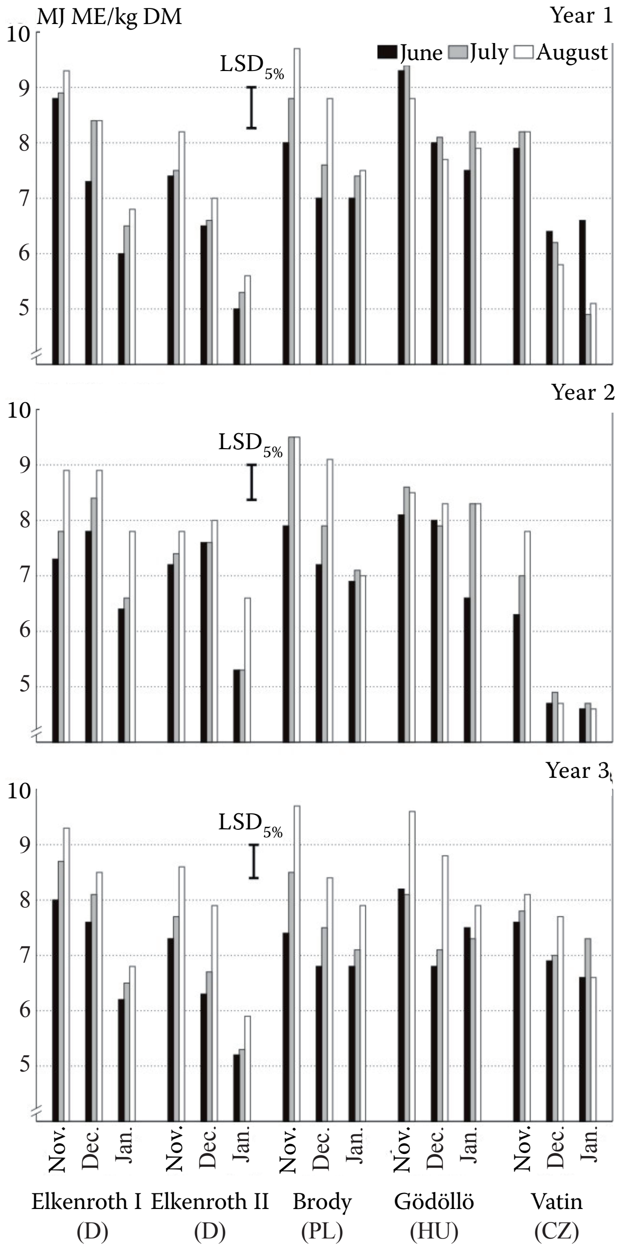

Figure 2. Energy concentration depending on pre-utilisation, winter harvest date and site

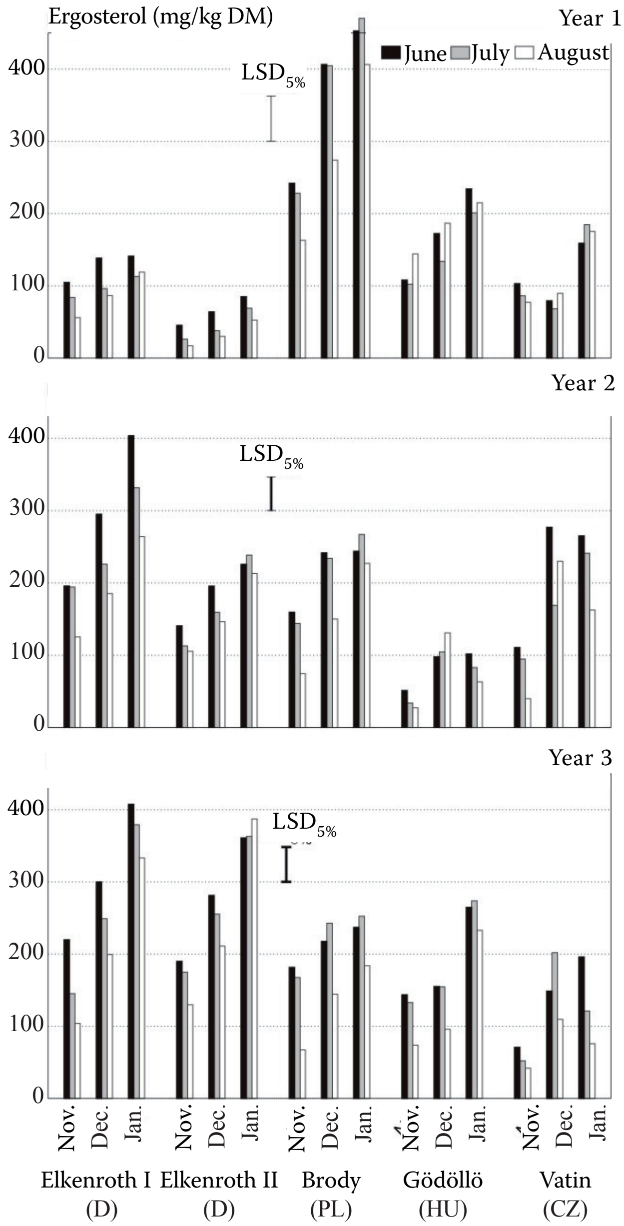

Figure 3. Ergosterol concentration depending on pre-utilisation, winter harvest date and site

actually were affected by the delayed harvest date due to the lasting snow cover in December. Other interactions, such as pre-utilisation × site, occurred, but had no relevance in this case. The date of winter harvest had the biggest influence on the energy concentrations in the winter of each year (Table 1); in most cases the values declined from November to January. Especially at the sites Elkenroth II and Vatin the herbage cut in January showed energy concentrations below 6 MJ ME/kg DM. The impact of the factors site and pre-utilisation varied in dependence on the year and was comparatively less important. The growths harvested in Vatin contained the lowest energy concentrations during the second winter, but independent of the year the consistent ranking order regarding the factor site could not be observed. Especially during the last winter the factor pre-utilisation had a distinctive effect as the longer period of accumulation resulted in the lowest energy levels.

Ergosterol

The concentration of ergosterol is shown in Figure 3 as an indicator for the degree of fungal infection. The interaction winter harvest date × site occurred in all years (Table 1). Actually, the interaction was caused by the site dependent differences in the extent of the increase during winter. The effect of the factor pre-utilisation, leading to significantly lower ergosterol concentrations if the sward was saved since August, was not evident for all sites. Therefore, the interaction pre-utilisation × site occurred in all years. Generally, the impact of the factor pre-utilisation was comparatively small in contrast to the effect of the factors site and winter harvest date (Table 1). Related to the significantly higher ergosterol concentrations of the herbage grown in Brody, the factor site was the most important source of variation in the first winter. In the following years the factor winter harvest date was of major importance as the highest ergosterol concentrations were often detected in January.

DISCUSSION

The significant influence of the factor site on the crude protein concentrations in winter (Table 1) was obviously based upon the rather continental climate at the sites in Vatin and Gödöllö. Differences in the crude protein level between the sites related to their different altitude could not be observed. For an adequate supply of the grazing livestock crude protein concentrations above 100 g/kg in DM are necessary (Menke and Steingass, 1987). From this aspect the influence of the factor site became negligible because even the growths in Vatin as well as in Gödöllö contained sufficient concentrations until the end of the year (Figure 1). Only in December and January of the second year the concentrations of the herbage harvested in Gödöllö were below this value, but the delayed harvest date limited the significance of this result. As a consequence of different periods of accumulation since summer, caused by the different variants of pre-utilisation, the growths differed in the stage of maturity (Fribourg and Bell, 1984). In accordance with the results of Wolf (2002) and Wöhler (2003), the herbage mass, pre-utilised in August, was comparatively younger than that saved since June or July, and therefore often contained the higher concentration. At the same time, in some cases a later date of utilisation in winter resulted in a lower crude protein concentration due to an advanced stage of maturity (Opitz von Boberfeld, 1994). Depending on the site and year, the impact of the factor pre-utilisation as well as winter harvest date varied and was comparatively small each year. Especially the crude protein content of the herbage harvested in Gödöllö was not often affected. Available Central Germany (Wolf and Opitz von Boberfeld, 2003; Wöhler, 2003) also described the inconsistent impact of agronomical measures influencing the maturity stage on the crude protein content during winter. Wolf (2002) considered different climatic conditions as the crucial factor for these observations. Other authors (Ziegler, 1991; Yu and Griffiths, 1999) found that plants tended to maintain the crude protein level as a part of defence reactions against biotic stressors ("antifreeze proteins") so that concentrations hardly changed with advancing winter. Finally, related to the comparatively high crude protein level (x = 138 g/kg in DM) in all years, the tested autumn saved herbage provided an adequate supply for the grazing livestock, but in some cases the extremely low dry matter yields in January as well as lasting snow layer (Opitz von Boberfeld et al., 2006) limited the utilisation of the growths as winter pasture. Besides it should be mentioned that the comparatively high crude protein level was contrary to the development of crude protein in growths during the vegetation period. Sterzenbach (2000) observed a decline of crude protein below 100 g/kg in DM of the growths after delaying the utilisation of the primary growth.

The energy concentrations, as a measure of the sward productivity (Opitz von Boberfeld, 1994), declined with advancing winter (Figure 2) due to the increasing content of structural material with advancing maturity (Opitz von Boberfeld and Wolf, 2002). Processes linked to senescence led to a translocation of reserve carbohydrates in the base culm or roots resulting in decreasing energy concentrations as well as in a decline in digestibility of organic matter (Opitz von Boberfeld et al., 2006). Similar results were presented by Wolf (2002) for Central Germany. In accordance with the results published by Wöhler (2003) concerning the utilisation of existing plant communities at peripheral sites in Central Germany, the degree of decline was different at each site, demonstrated by the interaction winter harvest date × site. Thereby, already in December the sites in Elkenroth II and Vatin showed energy values which lay below the energy content of wheat straw (Anonymus, 1997b). Considering the results of a literature review summarised by Wolf (2002), different weather conditions led to a high variability of the energy levels already at one site. In this context the differences between the sites as well as the different impact of the factor pre-utilisation might be explainable. The distinctive decrease in energy concentration during the severe second winter at the site in Vatin was obviously associated with the lasting snow cover from December to January and the delayed harvest dates. The tendency of higher energy concentrations in herbage with the shorter time of accumulation since summer apparently was a result of its younger stage of maturity (Opitz von Boberfeld, 1994). In contrast to the significance of the factor pre-utilisation for the energy concentration in pure stands of *Festuca arundinacea* and *Lolium perenne* during winter (Opitz von Boberfeld and Wolf, 2002; Wolf, 2002) its effect on the tested herbage was less important. In addition to the advancing senescence, the adverse weather conditions during autumn and winter increase herbage degradation and susceptibility to a fungal invasion (Opitz von Boberfeld and Wolf, 2002). Therefore, a later utilisation in winter resulted in higher ergosterol concentrations (Figure 3). Especially under a lasting snow cover the resistibility of grasses was diminished (Schlösser, 1997) so that the ergosterol contents often increased decisively with the incidence of a snow layer. In this context the connection between decreasing energy concentrations (Figure 2) and increasing ergosterol concentrations became evident. After invasion, fungi decomposed the cell constituents such as non-structural carbohydrates at first and therefore additionally led to a decrease in the energy level (Lechtenburg et al., 1972). Due to the climatic differences at the sites (Opitz von Boberfeld et al., 2006) the degree and date of increase in ergosterol concentration varied. Under the rather continental climate (lasting snow cover) in Gödöllö and Vatin the harvest dates were often postponed into February or even March, with the result of a marked increase in ergosterol content. In the first year the comparatively high ergosterol level detected in Brody was obviously connected with the higher dry matter productivity combined with higher precipitation in the autumn and winter period of that year (Opitz von Boberfeld et al., 2006), which provided favourable conditions for fungi invasion. In contrast to the variants with accumulation since June or July, the growths pre-utilised in August frequently showed lower ergosterol concentrations apparently caused by a higher resistibility and vitality of physiologically younger growths (Hoffmann et al., 1994; Schlösser, 1997; Opitz von Boberfeld and Wolf, 2002; Wolf, 2002). In accordance with the results reported by Wöhler (2003), the extent of fungal infection – measured by the ergosterol concentration – was mainly influenced by the winter harvest date. Irrespective of the year, pre-utilisation and site the highest concentration was recorded in January. Regarding the animal welfare recent results (Wolf, 2002; Wöhler, 2003) indicated the sporadic occurrence of mycotoxins in December, but the concentrations were mostly below the toxic effective level. Furthermore, Opitz von Boberfeld (1996) as well as Wolf (2002) could not examine the correlation between the ergosterol concentration and the incidence of mycotoxins. However, it has to be considered that conditions which promote the invasion of fungi might increase the incidence of fungi which are able to produce mycotoxins. Finally, more specific examinations considering the conditions for mycotoxin production in swards are necessary.

For the management of winter grazing systems it can be concluded that crude protein and energy concentrations of the tested autumn saved herbage met the requirements of grazing ruminants until the end of the year if they were pre-utilised in July. In consideration of the low energy values, high ergosterol contents in the tested herbage as well as the marked decline of dry matter productivity (Opitz von Boberfeld et al., 2006), the utilisation after December seems not to be adequate for animal welfare.

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