Forage conservation in mountainous regions – results of the Austrian silage monitoring project

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Introduction and field of problems

Grassland is the most important culture in Austria and covers up to 95% of the agricultural used area in mountainous regions. In these disadvantaged areas grassland and dairy farming represents the main source of agricultural production which is characterised by harsh conditions of climate, topography and infrastructure. In EU-27 Austria is still number one in organic farming (20,100 farms, 13% of AA) of which most are grassland farms. Another 40,000 grassland farms participate in a special measure of the Austrian agri-environmental program "ÖPUL" and abdicate yield increasing products like mineral nitrogen fertiliser or herbicides (PÖTSCH 2009). Most of grassland and dairy farms therefore follow a low-input strategy focussing on the efficient use of farm internal resources, namely farm manure and forage from meadows and pastures (PÖTSCH 2007).

Even disadvantaged areas are supported by the Program of Rural Development there is an increasing economical pressure on farms to reduce costs. It is evident that about two third of the total costs in livestock production are caused by feeding stuff (GREIMEL 2002, PÖTSCH et al. 2007, STOCKINGER 2009). Grazing is known the cheapest source of forage but is strongly limited by short vegetation and long winter periods (up to 7 months) in mountainous regions. Therefore sufficient forage conserves have to be produced for the indoor and winter feeding period. The total yield from Austrian grassland was 8.9 Mio. tons of dry matter in 2008 of which about 4.7 Mio. tons were conserved as hay, aftermath hay and silage. The proportion of silage production has increased continuously from 12% in the seventies to 72% nowadays. It has to be considered that in some specified regions of Austria silage production is not allowed for reasons of hard cheese production (10,235 farms running 115.400 ha grassland). The higher costs occurring on these farms are compensated by a special measure within ÖPUL.

Since forage conservation results in high costs all the more it is very important to obtain high quality of hay and silage. AREC Raumberg-Gumpenstein has therefore conducted a number of field studies and experiments on silage quality covering a wide range of different aspects (e.g. impact of vegetation, pre-wilting, harvesting techniques and additives on the fermentation process and on silage quality). a strong effort was given on the advisory service to introduce scientific findings into agricultural practice (BUCHGRABER et al. 2003; 2008). In 2003 a silage monitoring project was initiated by AREC Raumberg-Gumpenstein in cooperation with the agricultural chambers (STEINWIDDER 2003; RESCH and STEINWIDDER 2005, RESCH 2008a, RESCH 2008b). This project is aiming at the survey and analysis of silage quality in practice both to identify problems and to offer specific solutions. The present paper is presenting results of this project and points out weak points to be worked on in future.

Material and Methods

The Austrian silage monitoring project started first in 2003 and was repeated in the years 2005, 2007 and 2009. Seven of the nine Federal provinces of Austria participated in this project with at all 3,670 silage samples. In addition to the silage sampling a comprehensive collection of management data (e.g. farming type, grassland type, harvesting time, silage system, mowing system, chopping length, charging procedure, use of silage additives) was done by means of questionnaires. The silage samples were analysed for dry matter content, crude nutrients (WEENDER-analysis), minerals, energy concentration (GRUBER et al. 1997 according to DLG 1997) and fermentation quality. a drilling core was taken from the different silo systems to determine the compaction level of the silages. Statistical data analyses were done by using Statgraphics-Plus (Version 5.1) for General Linear Model – procedures respectively SPSS (Version 12.0) for descriptive analysis. For the GLM-procedure fixed effects at different levels and quantitative factors were used (Table 1).

Table 1: Description of the fixed effects used in the Austrian silage monitoring project

fixed effects	variation/groups			
farming system	organic	ecopoint-system	abdication of yield increasing products	non-participation in ÖPUL
year	2003	2005	2007	2009
growth	1st growth	2nd growth	3rd growth	other
grassland type	permanent, red clover, clover-grass mixture, lucerne-grass, lucerne			
mowing system	cutter bar, drum mower, disk mower, mowing conditioner			
cutting height	< 5cm	5-7 cm	> 7cm	
tedding frequency	0	1	2	>2
cutting time	morning	midday	afternoon	evening
harvesting time (hours)	< 6, 6-12, 12-24, 24-36, > 36			
weather conditions	no rain	rain		
silo system	bunker silo	silo heap	tower silo	silo bales
harvesting technique	cutter forage harvester (2), self loading wagon (2), silo press (2)			
chopping length (cm)	< 3, 3-6, 6-10, 10-20, > 20			
compaction level (kg DM/m³)	< 100, 100-150, 150-200, 200-250, >250			
silage additives	no additives, acids and salts, bacteria additives, others			
sample packaging	vacuum package, non vacuum package			

Results and discussion

Silage quality is mainly characterised by nutritive values, fermentation parameters and by sensory properties which can additionally provide important information concerning hygienic and acceptance of feed intake. Table 2 presents target values for good quality grass silages which should be aimed at in practice. The content of crude fibre is indicating the vegetation stage that in general has a very strong impact on forage quality. In contrast to intensive grassland regions of Europe, most of Austrian grassland is permanent grassland with a high number of different species of grass, legumes and herbs. The content of crude protein of silages is normally ranging between 130 and 160 g/kg DM. Previous studies showed that the contamination of forage and silage with earthy material is a very crucial aspect in practice. a high content of ash not only decreases digestibility and energy concentration but very often also causes misfermentation resulting in high concentration of butyric acid. All samples of the Austrian silage monitoring project have been evaluated by means of the mentioned target values and were additionally rated in terms of colour, texture and olfactory in 2009 (results of sensory evaluation are not presented in this paper).

Table 2: Target values of silage and fermentation parameters

parameter/unit	target value
pre-wilting level (g DM/kg FM)	300-400
crude fibre (g/kg DM)	< 270
crude protein (g/kg DM)	> 120
ash (g/kg DM)	< 100
digestibility of organic matter (%)	> 70
energy concentration (MJ NEL/kg DM)	> 5.8
lactic acid (g/kg DM)	20 - 60
acetic acid (g/kg DM)	max. 30
butyric acid (g/kg DM)	max. 3
protein degratation (% NH_4-N of total N)	< 10
DLG (silage quality points)	> 70

Nutrient and energy concentration of grass silages

Data analyses presented in Table 3 show that a high proportion of the silages are well pre-wilted at an average content of 374g DM/kg FM. Nearly 60% of the samples met the given target range of 300 to 400 g DM per kg FM, 13% were below it. Whereas twenty years ago the production of wet silages was standard, a tendency to higher pre-wilting levels and even to the production of haylage can be noticed nowadays (BUCHGRABER et al. 2003). More and more farmers are handling forage conservation (especially production of big bales) with the assistance of machinery rings. Due to an accumulated demand at the main harvest period serious problems with timing occur and often result in a much higher dry matter content than aimed at. The three prior-ranking factors of the multivariate analyses for the DM-content were weather conditions at harvest (1), year (2) and growth (3). The average content of 262 g crude fibre and 148 g crude protein per kg DM indicate that most of the forage was harvested early enough at the time of ear and panicle emergence of the main grasses. But there are still a remarkable proportion of samples (38%) with a high content of crude fibre that causes problems in the fermentation process and leads to lower digestibility and energy concentration in forage. Some farmers are still hesitant especially harvesting the first growth for gaining higher yields and then they sometimes have to wait for even two or three weeks until the next fair weather period.

There was a significant impact of the cutting height on the content of ash in silages, which on average was at 104g/kg DM with a standard deviation of 22g. These results clearly show that the ash content in practice is still too high and some farmers seem not to be aware of mistakes in management.

Two third of the silage samples had an energy concentration between 5.6 and 6.3 MJ NEL per kg DM. Nearly 70% fulfilled the requirements of > 5.8 MJ NEL per kg DM which can be seen as a good basis for sufficient milk or fattening performance from forage. Energy concentration was mainly determined by crude fibre and ash content but also by the number of growth whereupon the first growth reached more than 6 MJ NEL/kg DM on an average. It has to be considered that using the GLM as fitted the coefficient of determination only explained up to about 40% of the variability of the different parameters (RESCH 2008). Even a number of influencing factors were used there are still lack of explanation respectively open questions. One problem could be the quality and reliance of information that is provided by questionnaires where sometimes differences between the real situation on the farm and the subjective perception of the farmers occur (PÖTSCH and GROIER 2005). Another black box is the botanical composition of the plant stand that cannot be provided in such detail which normally is available for exact field trials. It is well known that the botanical composition of grassland has a strong impact on the content of minerals and therefore on ash but there is also a wide but mostly unknown influence of secondary plant metabolites (GIERUS et al. 2007). Another weak point is the fact that forage contamination is not only determined by mineral, earthy substances but also by organic material from soil or dung which is not represented by the ash content (RESCH 2007). Grasslands on boggy or semi-boggy soils which are widespread in mountainous valleys very often show a high activity of moles and voles resulting in lots of earth heaps leading to forage contamination with organic material and clostridia.

Table 3: Impact of fixed effects and quantitative factors on nutrient and energy concentration of silages (GLM-analyses of data from the silage monitoring project in Austria, 2003/2005/2007/2009)

parameter	dry matter	crude protein	crude fibre	ash	energy
unit	[g/kg FM]	[g/kg DM]	[g/kg DM]	[g/kg DM]	[MJ NEL/kg DM]
mean value	**374.3**	**148.3**	**262.2**	**103.6**	**5.96**
standard deviation	74.1	19.6	26.7	21.6	0.34
R^2 in %	16.8	37.4	39.1	19.3	85.9
fixed effects (level)	P-value (significance if < 0.05)				
farming system (4)	0.227	0.000	0.000	0.000	0.327
year (4)	0.000	0.000	0.000	0.000	0.099
growth (4)	0.000	0.000	0.000	0.000	0.000
grassland type (5)	0.006	0.000	0.000	0.000	0.000
mowing system (4)	0.014	0.000	0.000	0.000	
cutting height (3)			0.339	0.000	0.003
tedding frequency (4)	0.028	0.159	0.025	0.008	
harvesting time (5)	0.000				
weather conditions (2)	0.000	0.248	0.004	0.137	0.819
silo system (4)		0.345	0.014	0.891	0.778
harvesting technique (6)	0.000			0.068	
chopping length (5)	0.535		0.732	0.645	0.246
compaction level (5)					0.036
silage additives (4)					0.329
Quantitative factors					
dry matter (p-value)		0.000	0.000	0.000	0.000
mean value[g/kg FM]		377.3	377.2	377.4	377.2
regressions coefficient [g/kg resp. MJ NEL]		-0.0024	-0.024	-0.028	-0.0002
crude protein (p-value)			0.000		0.000
mean value [g/kg DM]			148.7		148.9
regressions coefficient [g/kg resp. MJ NEL]			-0.705		0.001
crude fibre (p-value)	0.543	0.000		0.000	0.000
mean value [g/kg DM]	263.8	264.1		263.8	263.7
regressions coefficient [g/kg resp. MJ NEL]	0.033	-0.397		-0.251	-0.01
ash (p-value)		0.000	0.000		0.000
mean value[g/kg DM]		103.0	103.0		103.3
regressions coefficient [g/kg resp. MJ NEL]		-0.149	-0.385		-0.0093

prior-ranking factors

Fermentation properties of grass silages

Beside nutrient content and energy concentration of silage, parameters of fermentation also are of great interest. The analyses of these data are presented in Table 4. The quick reduction of the pH-value on a stable level is seen a basic criteria of lactic acid fermentation and of microbiological stability of silage (ADLER 2002; PÖTSCH und RESCH, 2002). The overall average pH-value of 4.48 corresponds well with the critical pH-value for silages pre-wilted between 30 – 40% DM (WEISSBACH und HONIG 1992; WEISSBACH 2002). Beside the package system of the samples the content of crude fibre (vegetation stage) and ash (contamination) were the strongest significant factors that influenced the pH-value. Whereas the content of dry matter had an unexpected slight impact on the pH-value of the silages the time between baling and wrapping showed a significant and strong influence.

Two third of all samples met the recommended range of the concentration of lactic acid and acetic acid which was strongly determined by the pre-wilting level but also by the year of investigation. The analyses for butyric acid showed that only 25% of the samples were below the given limit of 3g per kg DM! There was a significant and strong relationship between butyric acid concentration and the pre-wilting level as well as with crude fibre and ash content. By means of the used GLM-procedure at least 38% of the variability of butyric acid concentration could be explained. Concerning the fact that most of the analysed silages showed disappointing high concentration of butyric acid, farmers have to be advised of management mistakes and weak points repeatedly (RESCH 2009).

The degradation rate of crude protein to ammonia can be seen as a quality indicator of the fermentation process (WEISSBACH und HONIG 1992). The proportion of ammonia related to total nitrogen should not exceed 10% and the analyses showed that this requirement was fulfilled by 75% of all silage samples. Nevertheless protein degradation can further be decreased by the reduction of chopping length (management) but also by optimal weather conditions. In the meantime protein degradation is no longer used as criteria for the DLG- silage classification.

For about 20% of the investigated grass silages additives were used to improve the fermentation process and to increase silage quality. In organic farming some special groups of silage additives are not allowed to be used, namely salts and most combined products which are in general recommended for unfavourable conditions (bad weather periods, contaminated and old plant material). Silage additives based on homo-fermentative and hetero-fermentative bacteria may also be used in organic farming. In Austria the use of silage additives is mostly related to the regulations of the DLG-quality label occasionally added by own national tests (RESCH 2008c). Results from silage experiments at AREC Raumberg-Gumpenstein have shown that under optimal conditions a successful fermentation process with high silage quality can be achieved without using any additives. From other field studies it is known that farmers often misuse silage additives and sometimes they are convinced that the use of additives can compensate mistakes in management.

Concerning energy concentration no significant effect of silage additives could be found in the Austrian silage monitoring project even a significant influence on the concentration of fermentation acids occurred. Silages with bacteria products had a higher content of lactic acid (+ 6.2 g/kg DM) and a significant lower concentration of butyric acid.

Table 4: Impact of fixed effects and quantitative factors on fermentation parameters and feed quality of silages (GLM-analyses of data from the silage monitoring project in Austria, 2003/2005/2007/2009)

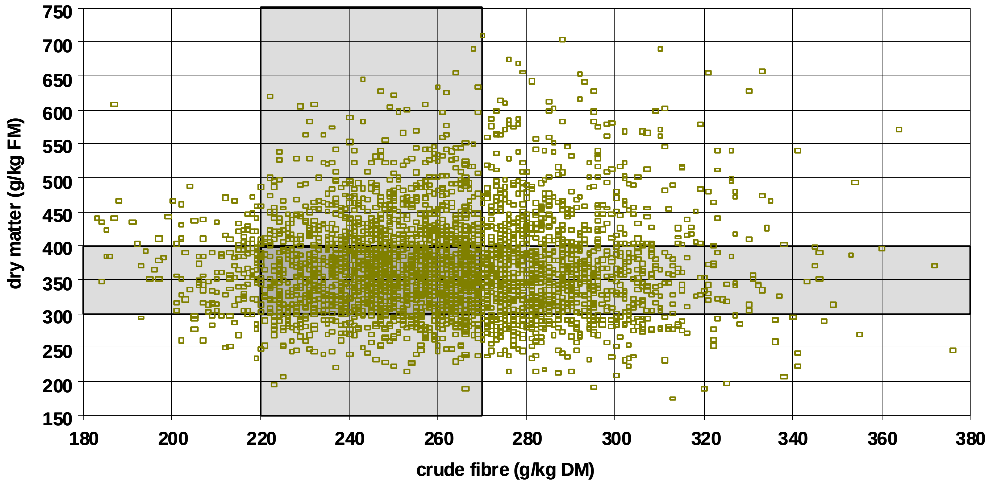
parameter	pH value	lactic acid	acetic acid	butyric acid	ammonia	DLG-value
unit		[g/kg DM]	[g/kg DM]	[g/kg DM]	[% of total N]	(0-100)
mean value	**4.48**	**43.8**	**11.6**	**10.9**	**8.4**	**75.8**
standard deviation	0.35	24.4	7.1	9.6	4.8	19.9
R^2 in %	23.1	14.3	14.6	38.5	20.2	40.1
fixed effects (level)	p-value (significance if < 0.05)					
farming system (4)	0.070	0.013	0.012	0.019	0.216	0.024
year (4)	0.000	0.000	0.000	0.033	0.000	0.000
growth (4)	0.001	0.168	0.101	0.000	0.067	0.000
grassland type (5)	0.006	0.001	0.000	0.001	0.024	0.021
cutting height (3)	0.094	0.007	0.912	0.043	0.539	0.006
weather conditions (2)	0.369	0.596	0.043	0.044	0.000	0.008
silo system (4)	0.000	0.000	0.269	0.000	0.051	0.000
chopping length (5)	0.001	0.046	0.000	0.000	0.000	0.000
compaction level (5)	0.006	0.004	0.532	0.027	0.457	0.003
silage additives (4)	0.000	0.004	0.000	0.000	0.083	0.000
sample packaging (2)	0.000	0.410	0.634	0.024	0.410	0.347
quantitative factors						
dry matter (p-value)	0.000	0.000	0.000	0.000	0.000	0.000
mean value[g/kg FM]	378.2	374.6	374.6	374.6	374.6	374.6
regressions coefficient [pH value, g/kg resp. MJ NEL]	0.001	-0.039	-0.018	-0.051	-0.015	0.073
crude fibre (p-value)	0.000	0.000	0.165	0.000	0.000	0.000
mean value [g/kg DM]	265.5	265.6	265.6	265.6	265.6	265.6
regressions coefficient [pH value, g/kg resp. MJ NEL]	0.003	-0.132	-0.009	0.089	0.048	-0.189
ash (p-value)	0.000	0.000	0.516	0.000	0.000	0.000
mean value[g/kg DM]	103.2	103.7	103.7	103.7	103.7	103.6
regressions coefficient [pH value, g/kg resp. MJ NEL]	0.004	-0.130	0.005	0.070	0.032	-0.136

prior-ranking factors

Classification of grass silages

Fermentation properties can also be used to evaluate silage quality by DLG-points (WEISSBACH und HONIG 1992) resulting in a classification system ranging from 1 = excellent to 5 = very bad). 58% of the silage samples reached > 70 DLG-points and can be judged good to excellent. Additionally the tested silages were classified by means of selected target values of silage and fermentation parameters presented in Table 2.

Figure 1: distribution of grass silages concerning pre-wilting level and crude fibre content expressing vegetation stage (data of the Austrian silage monitoring project, 2003/2005/2007/2009)



35% of all analysed forage samples (n=3,679) were harvested well-timed and pre-wilted between the recommended range of 300-400 g DM. When the criteria of forage contamination (ash content > 100 g) are added as a very important issue the percentage of optimal grass silages is reduced to 14%! Of course it can be discussed if the strictness of this classification is too high but we must not forget that the silage samples of this monitoring project are probably the premium third. No farmer would send in silage of bad quality for this monitoring project which is at the same time a silage competition. These results therefore very clearly show that there is both a lack of knowledge in practise respectively advisory demand and a high potential of improvement concerning forage and silage quality.

Conclusions

For grassland and dairy farmers following a low-input strategy it is essential to reduce farm-external feedstuffs and to optimise the quality of home-grown forage from meadows and pastures. The results of a comprehensive monitoring project organised and conducted by AREC Raumberg-Gumpenstein shows that there is a considerable potential in Austria to improve silage quality in practice. Apart from unfavourable natural weather conditions in mountainous areas the main reasons for unsatisfying silage quality are obvious in management mistakes. Too late harvest time resulting in high content of crude fibre, low concentration of easy fermentable sugar and serious problems with the compaction of such bulky material is still a big problem in practice. Forage contamination resulting in an increased risk of clostridia respectively butyric acid in the fermentation process is another serious problem that has to be faced with.

During the last years the mechanisation chain for silage production has improved a lot and a growing number of farmers make demands on the machinery rings to process ensiling. In many cases the charging of the silos on farms become the bottleneck and time is too short to ensure sufficient and proper compaction of the applied material.

Strong efforts have to be made to advise farmers specifically how to improve the ensiling procedure and to increase silage quality by means of field days, working teams, leaflets and articles.

Changes in management and avoiding mistakes mostly do not cause any extra costs, which is a clear and understandable argument to farmers.

How can science and research institutes contribute to the known issues? Exact silage experiments focus on specific questions, which can be worked on under controlled conditions and environments and are therefore still essential. Additionally field studies like the introduced monitoring project provide important data and findings reflecting the situation in practice. Such projects can identify weak points, show trends both negative and positive and provide a good basis to react precisely on the actual problems.

Beyond chemical and microbiological analyses which are generally used to evaluate forage and silage quality, sensory properties like colour, texture and olfactory could provide important additional information concerning feed intake and feed acceptance. Up to now there is no sufficient implementation of the sensory rating into the feed value system – this could be an interesting challenge.

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