CONTROL OF THE FERMENTATION PROCESS AND THE QUALITY OF CONSERVED FORAGE

WYSS U.
Agroscope Liebefeld-Posieux Research Station ALP-Haras, 1725 Posieux, Switzerland, ueli.wyss@agroscope.admin.ch

Introduction

Good quality silage and hay are important for the nutrition of ruminants, as well as for the quality and safety of dairy products. Poor silage or hay results in high conservation losses, unpalatable forage and a reduced intake, which in turn causes lower animal performance. Microbial activity in silages or hay can decrease the nutritional value and can lead to health problems for both animals and humans (Lindgren, 1991).

The conservation process involves many steps that should be managed carefully to ensure good quality. This starts in the crop composition; continues with harvest, ensiling, and feed-out management; and is influenced by additives. In Switzerland, most grassland is permanent grassland, and leys are composed of different grasses and clover. Pure swards are very rarely found. Grass-clover mixtures with 30 to 50% of legumes seem to be an optimal system: They yield high amounts of N from symbiotic N fixation and generate high forage yields of high nutritive value, which in turn generates high voluntary intakes and livestock performances (Lüscher *et al.*, 2013).

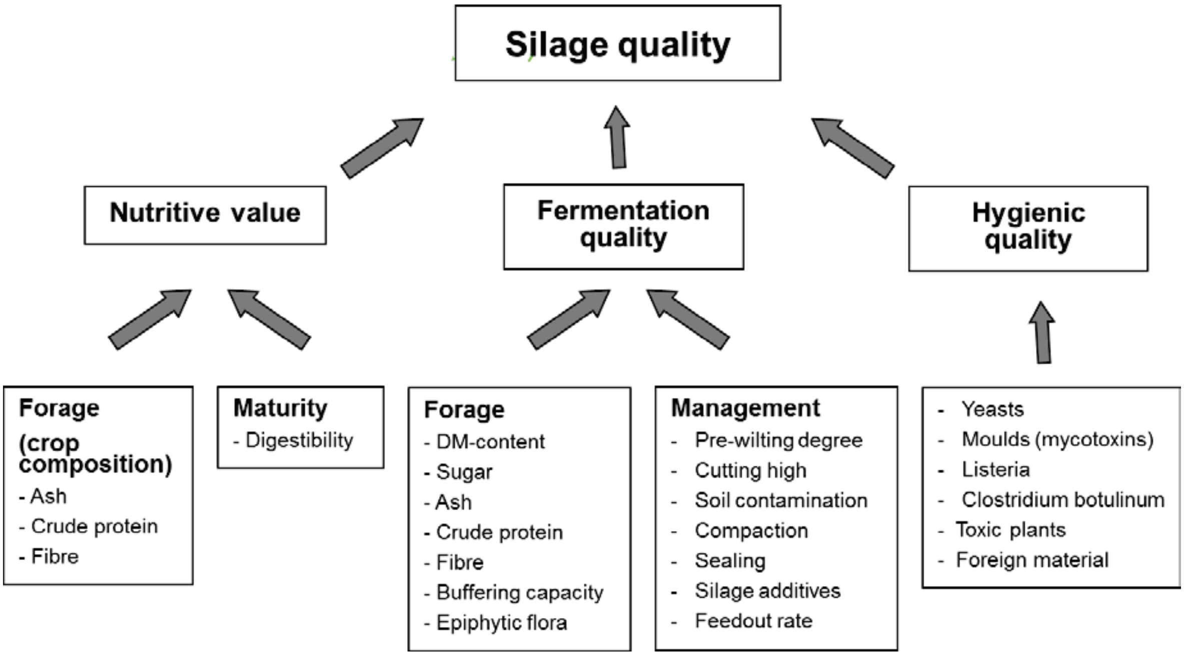
In the present paper, well-known factors that influence the fermentation process are discussed and the results from trials carried out at our research station during the last 20 years are reviewed. In addition, a special element in haymaking—where preservatives are introduced to moist hay—will be discussed.

Forage quality

Silage quality depends on many factors (Figure 1). In terms of the nutritive value of the forage, the botanical composition and the stage of maturity (and therefore the digestibility of the forage) are important. The fermentation quality is also influenced by many elements. The crop composition at harvest has a major impact on the ensiling process and quality of silage (Buxton and O'Kiely, 2003). Furthermore, harvest and ensiling management procedures such as wilting, chopping, compacting, and sealing influence the silage quality (Muck *et al*., 2003) The key factor in producing a well-preserved silage is anaerobic fermentation dominated by lactic acid bacteria (Piltz and Kaiser, 2004). In addition, undesirable bacteria, molds, and toxic plants influence the hygiene quality of the silage. The risk of health problems caused by molds and listeria can almost be eliminated through good silage-making practices (Piltz and Kaiser, 2004).

The factors of nutritive value, fermentation and hygienic quality all influence the silage quality and have an effect on the intake of silage and animal performance. Therefore, producing good quality silage or hay should be the farmer's main objectives.

Figure 1 Different factors influencing silage quality



Crop composition

The composition of the forage at ensiling has a major influence on silage fermentation. The most important components are dry-matter (DM) content, sugar content, and buffering capacity (Piltz and Kaiser, 2004). In relation to these parameters, white and red clovers, as well as lucerne, are known to be more difficult to ensile in comparison to grasses.

At our station, the ensilability and silage quality of four types of botanical composition were investigated (Vogel, 1994). The following four compositions were tested: a grass-rich type with more than 70% grasses (G), a balanced type with 50–70% grasses (E), a legume-rich type with more than 50% white and red clover (L), and a herb-rich type with more than 50% dandelion (H). Forage of the first and fifth cut was moderately pre-wilted (between 22 and 36% DM) and ensiled at two different maturity stages. The lowest sugar contents and the apparently least favorable sugar:crude protein ratios at ensiling did not produce a bad silage quality. The legume-rich and herb-rich forages did not behave more problematically than the others (Table 1). In both cuts, the quality of the silage was poorer with increasing maturity stage. The fermentation quality, expressed as a score according to the DLG evaluation scheme, was negatively correlated with the crude fiber content (-0.63) and with the proportion of grasses (-0.57).

Table 1 Influence of botanical composition and maturity stage on silage quality

			Botanical type			
Cut	Parameter		G	E	L	H
1/early	DM content	%	27.9	29.6	32.1	24.9
	pH		4.6	4.5	4.5	4.1
	DLG points		48	84	97	100
1/late	DM content		34.0	28.1	29.0	32.7
	pH		4.9	5.1	4.7	45
	DLG points		45	36	60	96
5/early	DM content		32.0	31.2	32.2	32.0
	pH		4.9	4.8	4.7	5.0
	DLG points		86	86	87	80
5/late	DM content		23.4	22.2	21.8	22.5
	pH		5.3	4.6	4.8	4.6
	DLG points		28	80	68	64

The negative effect of the stage of maturity on the ensilability and the silage quality was also documented in a trial carried out by Vogel (1996). The grass exhibited low butyric acid production, low pH, relatively low in-silo gaseous losses, and good fermentation quality from the early maturity stage (Table 2). With increasing maturity stage, the butyric acid production and pH increased and the fermentation quality decreased.

Table 2 Influence of the maturity stage of the grass on the silage quality

Maturity		Stage 2	Stage 3	Stage 4
Date of cutting		30th April	14th May	28th May
DM content	%	29.6	28.1	25.6
pH		4.5	5.1	5.9
Lactic acid	g/kg DM	56	57	16
Acetic acid	g/kg DM	12	22	7
Butyric acid	g/kg DM	2	11	34
Gaseous losses	%	5	8	11
DLG points		90	30	-5

The ensilability and silage quality of several grasses and legumes from the first, second, and fourth cuts were investigated (Wyss, 2006). The forage was pre-wilted to 30–35% DM, short chopped, and ensiled in laboratory silos.

Ash, protein, fiber, and sugar content, as well as buffering capacity, were different between the plant species. As a result, the fermentability coefficients varied between 36 and 72. The fermentabily coefficient is calculated with the DM content and the sugar/buffering capacity ratio (Weissbach, 1998).The forage of the first cut had the highest value, while the forage of the fourth cut had the lowest. Furthermore, the fermentability coefficients of the legumes were lower in comparison to the grasses. However, there were also differences within the grasses. The ray-grasses, which had the highest sugar contents, had on average higher values (56) than cocksfoot, which only had an average value of 39. Concerning the legumes, lucerne had a lower value (38) than the white and red clovers (47 and 45). All silages of the first cut had fermentation quality of good to very good. The silages of the fourth and mainly of the second cut were of an inferior quality. The relation between the fermentability coefficients and the fermentation quality (DLG-points) was not very high (Figure 2). A higher relation was found between the sugar content and the fiber content and the fermentation quality (Figure 3). The lowest fermentation quality was shown in the silages using lucerne and cocksfoot. By contrast, with white and red clover good quality silages can be produced

Figure 2 Relation between the fermentability coefficients and the fermentation quality (DLG points)

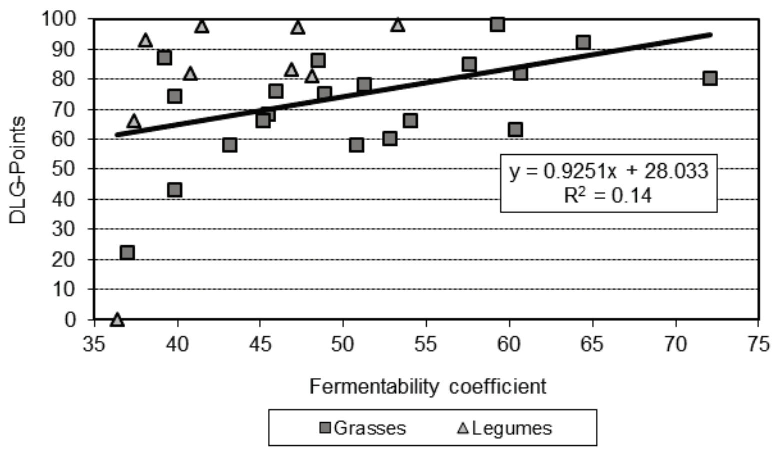


Figure 3 The relation between fermentation quality (DLG points) and the crude fiber and sugar contents

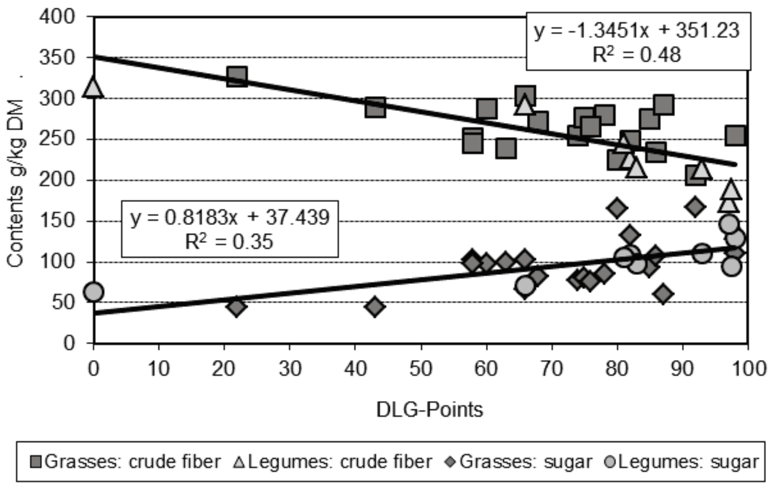
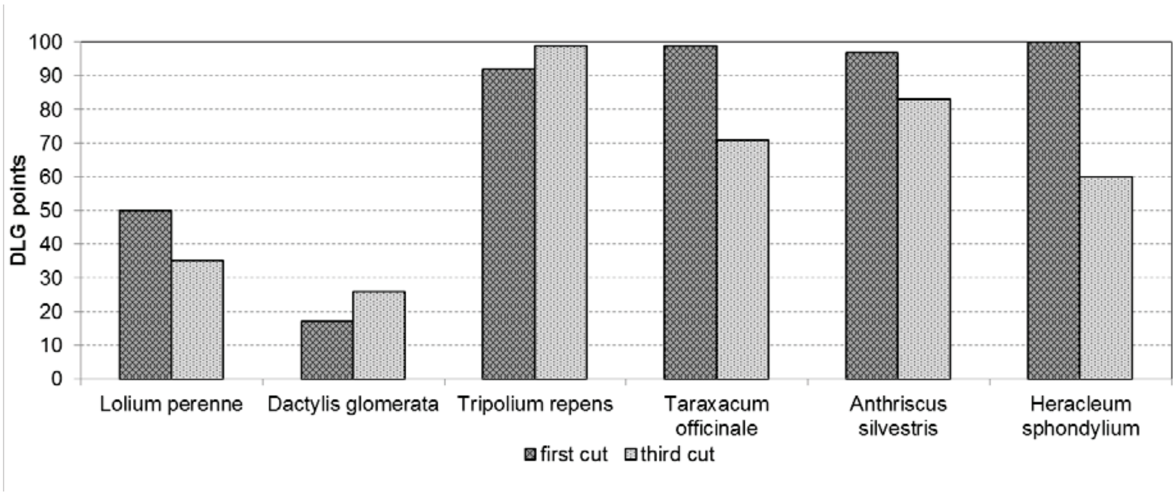


Figure 4 The silage qualities of different plant species



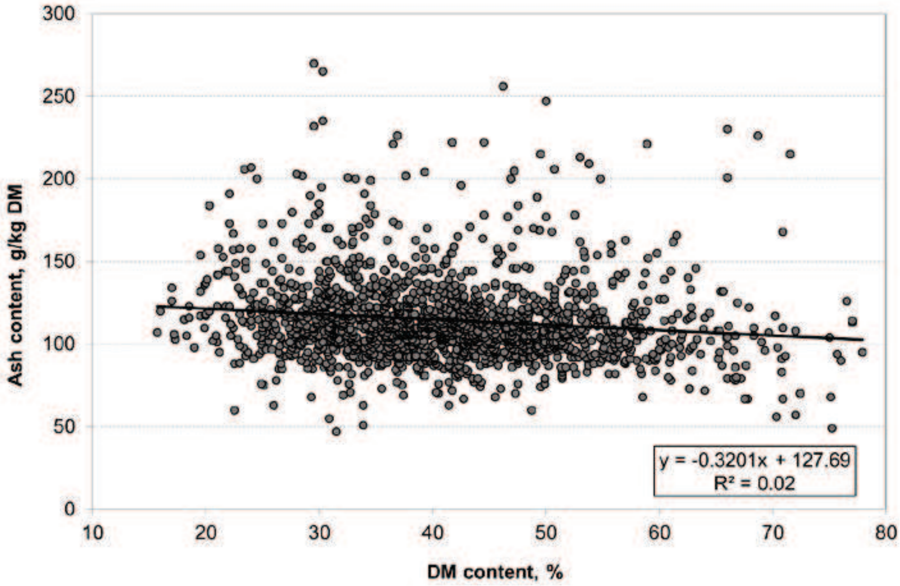
On the grassland, which is cultivated less intensely, the botanical diversity and the proportion of herbs are increased. Moreover, the sugar and buffering capacity of different herbs vary widely. In addition, some herbs contain secondary plant compounds, which can inhibit lactic acid fermentation. According to tests carried out with 52 different plant species, Weissbach (1998) found no indication of secondary plant compounds on the fermentation process.

Trials at our research station showed that almost all tested herbs had higher sugar, higher crude protein, and lower crude fiber content than the two grasses *Lolium perenn*e and *Dactylis glomerata* (Wyss and Vogel 1999). The silages of the herbs and white clover had a better fermentation quality in the first and third cut than the silages with the two grasses (Figure 4).

Harvest and ensiling management

Grass silages produced on farms have often high soil contamination (Figure 5). The average ash content of approximately 2'000 silage samples collected on Swiss farms between 2007 and 2011 was 114 g/kg DM. However, only 25% of the samples had an ash content below 100 g/kg DM. The same problem was also described by Pötsch *et al.* (2010) in Austria and Nussbaum (2007) in Germany. These contaminations result in butyric acid fermentation, higher losses, and lower energy content. According to Hünting and Pries (2008), the net energy content is reduced by 1 MJ for each additional 100 g of soil contamination.

Figure 5 Ash contents of silage samples from farms



In one trial, the influence of the cutting height was investigated on the silage quality (Wyss, 2009). In autumn, the forage of a ley was cut at 7–8 and 3–4 cm. Cutting high strongly influenced the ash content, as well as the energy content, in both the fresh forage and the silages (Table 3). As a result of the high nitrate contents in the green forage (about 10 g/kg DM), no butyric acid was produced. Nevertheless, due to the high pH values and high acetic acid content, the quality of both silages was poor.

Table 3 Influence of the cutting height on the nutritive values and the fermentation quality

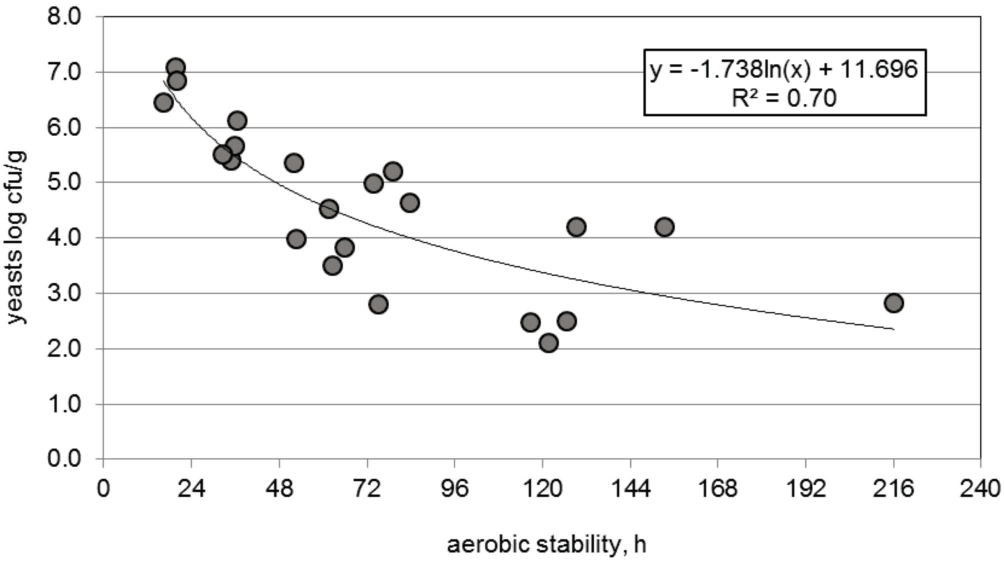
		Fresh material		Silage	
Cutting height		High	Low	High	Low
DM content	%	17.4	17.9	16.7	16.6
Ash	g/kg DM	145	237	177	267
Crude protein	g/kg DM	216	180	224	183
Crude fiber	g/kg DM	230	215	242	231
Sugar	g/kg DM	72	59	7	5
NEL	MJ/kg DM	6.0	5.2	5.6	4.7
pH				4.9	4.9
Lactic acid	g/kg DM			80	67
Acetic acid	g/kg DM			87	77
Butyric acid	g/kg DM			0	0
Gaseous losses	%			6.6	6.3
DLG points				20	28

The feed-out phase

The anaerobic storage phase ends when the sealed silage is opened and the feeding period begins. Silage is a perishable product and aerobic spoilage begins as soon as it is exposed to air. Silage density and porosity are key factors that affect the rate of ingress of oxygen into the silage mass during the feed-out period (Wilkinson and Davis, 2012). However, the feed-out rate is also very important. In farm-scale studies on maize silages in Italy, Borreani and Tabacco (2012) showed that a feed-out rate below 0.5 and 0.8 m per week, for winter and summer consumption, respectively, cannot prevent aerobic deterioration even if very good silo management practices are applied.

Yeasts initiate the aerobic deterioration process and the silage starts to heat up. Figure 6 shows that the higher the yeast content in silage, the less aerobically stable the silage will be (Wyss and Aeby, 2009).

Figure 6 Relation between the aerobic stability and the yeast concentration in maize silage



Use of silage additives

One way to control fermentation is to apply additives. There are countless numbers of inoculants and chemical additives on the market in Europe. With the new EU regulation (No 1831/2003), silage additives are included in the Community Register of Feed Additives in the category of technological additives. According to Wilkinson and Toivonen (2003), additives are used to a very small extent in several countries around the world. The reason for this is that farmers think that under good conditions, the silage will still have good quality without silage additives, or that they are skeptical about their cost effectiveness. On the other hand, Davis (2010) showed that silage additives will play a greater role in the future, as they can help to reduce the environmental impact of ruminant farming and can improve the safety and healthfulness of human food.

It is not always easy for farmers to choose the right silage additive. We revised Nussbaum's (2004) scheme to choose the right additive for grass silage (Figure 7). Here, the farmer has to decide whether he or she wants to improve the fermentation quality by inhibiting butyric acid production or whether he or she wants to improve the aerobic stability of the silage. The main criteria for this are DM content and crude fiber content in relation to the age of the forage.

Trials by Wyss and Vogel (1994) showed that in forage that is difficult to ensile—that with low DM and sugar contents—inoculants can only improve the silage quality if sugar is added (Table 4).

Table 4 Effects of additives in difficult-to-ensile forage on the fermentation quality

		Without Additives	Chemical product	Dextrose	Inoculant	Inoculant + dextrose
DM content	%	16.9	18.8	17.0	17.2	18.8
pH		5.9	4.6	5.6	5.8	4.5
Lactic acid	g/kg DM	12	93	8	7	93
Acetic acid	g/kg DM	56	27	36	24	26
Butyric acid	g/kg DM	68	0	82	85	0
Gaseous losses	%	15	4	14	13	4

Inoculants containing lactic acid bacteria (LAB) are the most common additives used in silage making. The homofermentative strains promote intensive lactic acid production and a rapid decrease in pH. Inoculants with heterofermentative LAB particularly improve the aerobic stability of silages. In heavily wilted forage, the water availability becomes a limiting factor for the development of LAB (Pahlow and Weissbach1996).

In one trial, the efficacy of three different silage inoculants on fermentation quality and the aerobic stability of ryegrass silage with three different pre-wilting degrees were investigated (Wyss and Rubenschuh, 2012). Inoculant 1 contained homo- and heterofermentative LAB. Inoculants 2 and 3 contained only homofermentative LAB. The DM losses decreased in the treatments without additives with increasing DM content (Table 5). The three inoculants reduced the DM losses in the treatments with 34 and 46% DM. In the treatment with 61% DM, only inoculant 1 with homo- and heterofermentative LAB strongly reduced the DM losses. Concerning the fermentation quality, most silages showed high DLG points and therefore a very good quality except for the treatment without additive and 34% DM. Here, butyric acid was produced. When the inoculants were applied, the pH had already decreased after 3 days in the forages with 34 and 46% DM, but not in the forage with 61% DM.

Figure 7 Scheme for the use of silage additives in grass silages

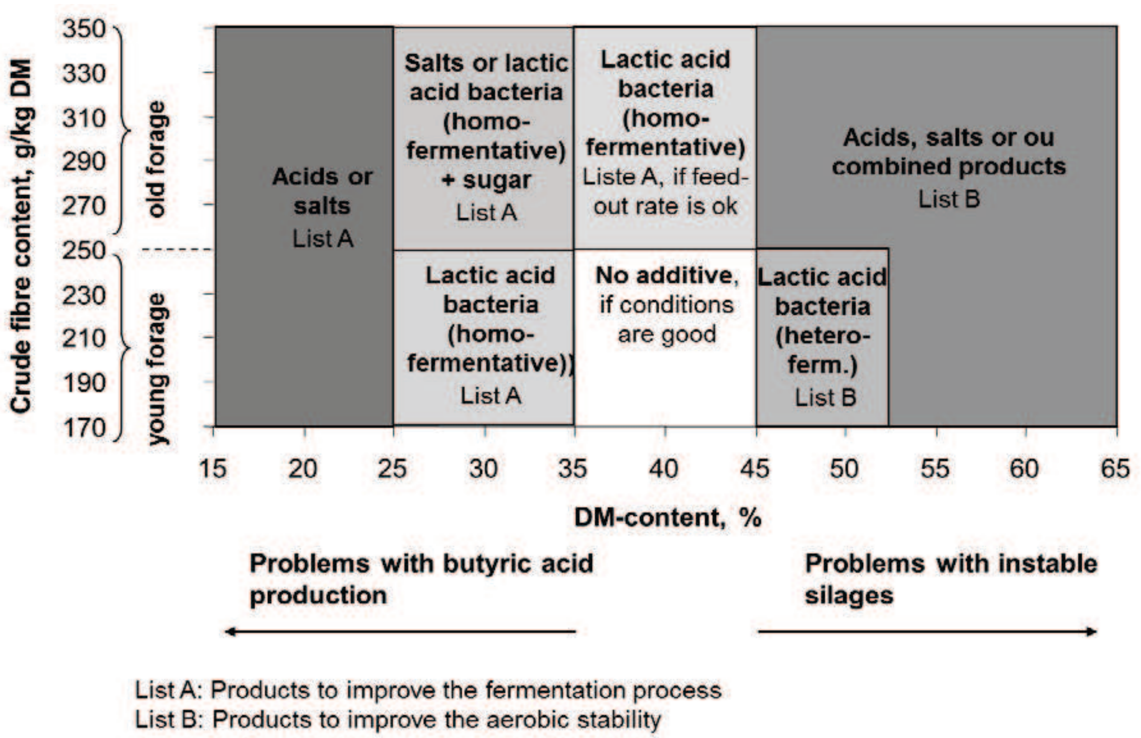


Table 5 Influence of different inoculants on the fermentation quality at different degrees of pre-wilting

Treatment	DM	pH	pH	Lactic	Acetic	Butyric	Ethanol	DLG	DM

		Day 3	Day 91	acid	acid	Acid		points	losses
	%			g/kg DM					%
Control	30.7	6.0	4.9	35	2	17	24	38	11.7
Inoculant 1	33.3	4.3	3.9	118	15	0	3	100	4.5
Inoculant 2	33.0	4.3	4.0	114	5	0	9	100	4.4
Inoculant 3	33.1	4.4	4.0	111	6	0	6	100	4.4
Control	43.1	6.1	5.8	21	3	1	55	90	10.5
Inoculant 1	45.2	4.9	4.1	100	16	0	2	100	4.6
Inoculant 2	44.2	5.0	4.2	92	4	0	3	100	3.8
Inoculant 3	45.2	5.3	4.2	92	4	0	2	100	3.9
Control	59.3	6.1	6.0	4	1	0	46	90	8.1
Inoculant 1	59.4	6.1	4.4	47	24	0	3	100	5.0
Inoculant 2	59.6	6.1	5.3	36	2	0	38	90	7.6
Inoculant 3	58.6	6.1	4.9	46	2	0	30	90	6.7

A good choice is to use silage additives that have been tested by the DLG. The DLG approval scheme for silage additives takes into account different aims of actions, especially the two main ones, which are to improve the fermentation process on the one hand and improve aerobic stability on the other (Staudacher *et al.* 1999). The tests were mainly carried out in small-scale laboratory silos. It is more difficult to distribute silage additives in round bales than in other systems, as round bales are often made of unchopped forage with high dry matter content.

Table 6 Silage quality and aerobic stability of the 2010 silages

Country	Parameter	Laboratory silos			Round bales		
		No add.	Inoculant	Chemical product	No add.	Inoculant	Chemical product
D	DM content, %	35.1	36.4	36.6	37.9	37.2	38.2
	pH	4.3	4.1	4.3	4.7	4.5	5.3
	DLG points	82	100	87	94	98	91
	DM losses, %	7.6	9.7	6.5	6.1	7.8	4.5
	Aerobic stability, days	6.5	16.8	14.4	6.0	13.6	5.7
S	DM content, %	45.3	45.0	45.1	43.9	47.0	46.3
	pH	5.0	4.1	5.1	5.7	4.4	5.9
	DLG points	90	100	90	90	100	90
	DM losses, %	4.4	5.0	3.8	5.7	5.7	4.1
	Aerobic stability, days	1.4	7.0	7.0	1.5	7.0	4.0
CH	DM content, %	37.8	37.9	37.9	35.6	36.6	39.6
	pH	4.6	4.4	4.6	5.0	4.6	5.3
	DLG points	96	98	95	91	97	90
	DM losses, %	5.4	5.5	5.2	4.8	5.2	4.2
	Aerobic stability, days	14.0	14.0	14.0	12.1	14.0	14.0

D: Germany, S: Sweden, CH: Switzerland

To study the efficacy of silage additives in round bales in comparison to laboratory silos, different trials have been carried out in Germany, Sweden and Switzerland in 2010 and 2011 (Wyss *et al.*, 2012). Some results are indicated in Tables 6 and 7. They show that silage additives can also be tested in round bales provided that the treated and untreated forages have the same DM content and that silage additives have been applied homogeneously and in the recommended dose. Furthermore, it is also possible to generate for the tests air stress on the round bales and thereby to make the conditions more difficult for the silage additives.

Table 7 Silage quality and aerobic stability of the 2011 silages

Country	Parameter	Laboratory silos		Round bales					
		No stress		No stress		Stress 1		Stress 2	
		No add.	Ino-culant	No add.	Ino-culant	No add.	Ino-culant	No. add.	Ino-culant
D	DM content, %	36.8	39.9	39.3	43.1	41.8	43.7	43.1	48.2
	pH	4.3	4.2	5.2	4.7	5.1	4.9	5.1	4.8
	DLG points	100	100	90	93	90	91	90	91
	DM losses, %	4.5	4.9	9.1	9.2	9.8	9.3	9.5	9.6
	Aerobic stability, days	7.1	13.5	10.5	7.0	9.5	9.3	7.9	11.0
CH	DM content, %	39.9	40.0	37.9	39.8	40.0	39.4	38.3	40.5
	pH	4.4	4.1	4.6	4.4	4.7	4.4	4.6	4.4
	DLG points	100	100	91	100	84	100	94	100
	DM losses	5.3	5.2	5.4	5.3	5.4	5.3	5.4	5.3
	Aerobic stability, days	8.6	14.0	8.5	14.0	8.1	14.0	6.4	12.8

D: Germany, S: Sweden, CH: Switzerland
Stress1: Four holes (diameter 2 cm) were made 7 days before opening the bales; the holes were closed after 24 hours.
Stress 2: Twenty holes were made with a nail (diameter 0.2 cm) 7 days before opening the bales. Here, the holes were not sealed until the samples were taken.

Haymaking: moist hay

Haymaking has decreased greatly in Europe in recent years. Nowadays, only 3% of milk in Europe is produced without silage. In Switzerland, on the other hand, this proportion is quite a bit higher, at 37%.

Weather conditions make it difficult to produce good hay with a DM content over 85% in the field. The alternatives to making good hay are barn drying systems; however, these systems are expensive and their capacity is limited.

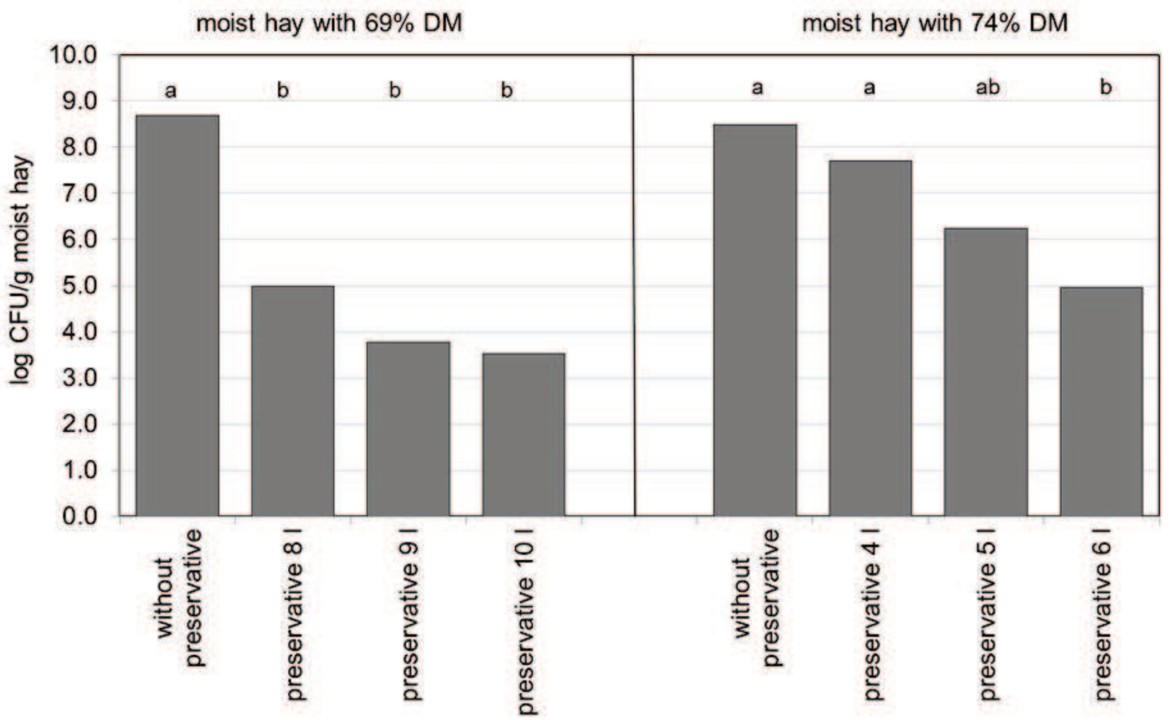
Another technology for preserving hay harvested above optimum moisture levels is to apply organic acids to the hay at harvest time. The use of organic acids has proven to be an effective strategy for preserving baled hay. Interest in using such products has increased with improvements in application equipment, product handling, and corrosiveness, and increased use of large bale packages However, when hay is baled and put into storage at moderate moisture levels (18–30%), a favorable environment exists for the growth of undesirable bacteria, fungi, and yeast. Both moisture and temperature drive the population growth of these microorganisms. Fungi such as Aspergillus and Fusarium can produce a wide range of toxic metabolites and greatly reduce hay palatability (Rankin, 2000).

Propionic acid was the first additive used for hay stabilization; this was examined on a practical scale in the 1970s. Due to its volatility, however, the effects were not always satisfactory (Küntzel, 1991). Less volatile additives with neutral compounds like ammonium-propionate were then developed. Meisser and Wyss (1999) used big square bales to test the effect of an additive based on ammonium-propionate under practical conditions in three trials. The hay was pressed with 70, 69, and 79% DM content. The untreated and treated forage heated up. The poor quality of treated hay was obviously attributable to technical problems (dosage and distribution of the additive).

A further trial was conducted with a two-factorial design comprising preservative dosage (0, 1.6, and 2.0 l per bale) and baler type (round baler with constant and variable press chamber); the design was investigated under field conditions (Meisser, 2003). The hay was pressed with DM-contents of 76%. Big balers with a constant press chamber proved to be better suited than those with a variable press chamber. The former produced bales with a relatively soft core, which facilitated the elimination of excess moisture. Although the preservative limited the rise in temperature, however, its fungi-static effect was unsatisfactory in certain cases. Some treated bales presented a high degree of mold infection. The only distinct difference in nutrient contents between treated and untreated bales concerned the sugar content. The significantly lower sugar contents of the untreated bales reflected microbial growth and activity.

Detailed knowledge of the DM content and the correct dosage is important for a successful conservation procedure. In a trial under laboratory conditions, the efficacy of a preservative containing buffered propionic acid was investigated in hay with two different dry matter contents (69 and 74% DM) and three different dosages per DM-content. Dosages 8, 9, and 10 l/t were applied to the hay with the lower DM-content and dosages of 4, 5, and 6 l/t were applied to that with the higher DM-content. As negative control, variants without additives were tested (Wyss, 2012). Temperature was continuously controlled over a period of 30 days. Before and after this period, the dry DM and other parameters were analyzed. At both DM levels, the untreated hay heated strongly, and at the end of the experiment, it was totally moldy. The mold contents are indicated in Figure 8. Independent of the dosage, it was possible to prevent the heating up and deterioration in quality completely with the addition of preservative to the hay with 69.2% DM. In contrast, in the hay with 74.2% DM, the dosage of 4 l could not prevent spoilage.

Figure 8 Mold contents in moist hay with two DM contents and untreated and treated variants (CFU: colony forming units)



Conclusions

Good quality of silage and the hay is important for the improved nutrition of ruminants and the resulting dairy products. Apart from unfavorable weather conditions, the main reasons for a bad forage quality are obvious management mistakes during harvest, ensiling, or the feed-out period. The factors that influence the forage quality are well known and many trial results have shown that with good management, quality can be improved. Silages of clover or of herbs do not automatically exhibit inferior silage quality in comparison with grass silages. Additives to silages or moist hay can be used to improve the forage quality; however, additives do not compensate for poor management.
On farms, problems remain in relation to bad forage quality—e.g., high soil contamination—or unstable silages, as well as moldy forage during the feeding period. Bringing the results and knowledge obtained from the research to the farmer continues to represent a big challenge.

References

Borreani G. and Tabacco E., 2012. Effect of silo management factors on aerobic stability and extent of spoilage in farm maize silages. Proceedings of the XVI International Silage Conference, Hämeenlinna, Finland, 71-72.

Buxton D.R. and O'Kiely P., 2003. Preharvest plant factors affecting ensiling. In: Silage Science and Technology (Buxton D.R., Muck R.E. and Harrison J.H., Eds.). ASA-CSSA-SSSA, Madison, 199-250.

Davies D.R., 2010. Silage Inoculants – where next? Proceedings of 14th International Symposium Forage Conservation, Brno, Czech Republic, 32-39.

Hünting K. and Pries M., 2008. Siliermittel lohnen immer. Landwirtschaftliches Wochenblatt/Westfalen-Lippe, 17, 26-27.

Küntzel U., 1991. Stabilisierung von feuchtem Heu durch Konservierungsmittel (Stabilization of wet hay by preservatives). Übersichten zur Tierernährung 19, 87-132.

Lindgren S., 1991. Hygienic problems in conserved forage. Landbauforschung Völkenrode 123, 177-190.

Lüscher A., Mueller-Harvey I., Soussana J.F., Rees R.M. and Peyraud J.L., 2013. Potential of legume-based grassland-livestock systems in Europe. Grassland Science in Europe 18,3-29.

Meisser, M., 2003. Mikrobiologische Qualität und Nährwert von Feuchtheu. Agrarforschung. 10 (9), 348-353.

Meisser, M. and Wyss, U. , 1999. Qualität von unterschiedlich konserviertem Dürrfutter. Agrarforschung. 6 (11-12), 437-440.

Muck R.E., Moser L.E. and Pitt R.E., 2003. Postharvest factors affecting ensiling. In: Silage Science and Technology (Buxton D.R., Muck R.E. and Harrison J.H., Eds.). ASA-CSSA-SSSA, Madison, 251-304.

Nussbaum H., 2004. Siliermittel gezielt verwenden. DLZ Agrarmagazin, Sonderheft 12, 96-98.

Nussbaum H., 2007. Dreck bringt keine Leistung. Sonderheft Wirtschaftseigenes Futter der Zeitschrift Neue Landwirtschaft, 12-14.

Pahlow G. and Weissbach F. 1996. Effect of numbers of epiphytic lactic acid bacteria (LAB) and of inoculation on the rate of pH-decline in direct cut and wilted grass silages. 11th International Silage Conference, Aberytwyth, 104-105.

Pilz J.W. and Kaiser A.G., 2004. Principles of silage preservation. In: Successful Silage (Kaiser A.G., Pilz J.W., Burns H.M. and Griffiths N.W., Eds.). Edition 2. Dairy Australia and NSW Department of Primary industries, NSW DPI, Orange. 25-56.

Pötsch E.M., Resch R. and Buchgraber K., 2010. Forage conservation in mountainous regions – results of the Austrian silage monitoring project. Proceedings of 14th International Symposium Forage Conservation, Brno, Czech Republic, 4-11.

Rankin M., 2000. Preserving Baled Hay with Organic Acids. Focus on Forage 5,1-2. http://www.uwex.edu/ces/crops/uwforage/Hay-OA.htm.

Staudacher W., Pahlow G. and Honig H. 1999. Certification of silage additives in Germany by DLG. 12th International Silage Conference, Uppsala, July 1999, pp. 239-240.

Vogel, R., 1994. Siliereignung verschiedener Futterbestände. Agrarforschung. 1 (4), 159-162.

Vogel, R., 1996. Alter des Futters und Anwelkgrad beeinflussen Silierergolg. Agrarforschung. 3 (4), 161-164.

Weissbach F., 1998. Untersuchungen über die Beeinflussung des Gärungsverlaufes bei der Bereitung von Silage durch Wiesenkräuter verschiedener Spezies im Aufwuchs extensiv genutzter Wiesen. Landbauforschung Völkenrode 185, 1-103.

Wilkinson J.M. and Toivonen M.I., 2003. Word Silage, Chalcombe Publications, Lincoln, UK, pp. 204.

Wilkinson J.M. and Davis D.R., 2012.The aerobic stability of silage: key findings and recent developments. Grass and Forage Science 68, 1-19.

Wyss, U., 2006. Silierbarkeit und Silagequalität von Gräsern und Leguminosen. Agrarforschung. 13 (10), 442-447.

Wyss, U., 2009. Silierbedingungen beeinflussen den Nährwert von Grassilage. Agrarforschung. 16 (5), 140-145.

Wyss U., 2012. Wirkung eines Konservierungsmittels bei Feuchtheu – Ergebnisse 2011. Agrarforschung Schweiz. 3 (6), 314-321.

Wyss U. and Vogel R., 1994. Ergebnisse der Siliermittelprüfung 1993. Agrarforschung. 1 (3), 136-139.

Wyss U. and Vogel R., 1999. Siliereignung von Kräutern aus intensiven BeständenAgrarforschung 6 (5), 185-188.

Wyss U. and Aeby P., 2009. Nutritive value and microbiological quality of maize silages. Proceedings of 15th International Silage Conference, Madison. 485-486.

Wyss U. and Rubenschuh U., 2012. Efficacy of three different silage inoculants on the fermentation quality and aerobic stability of ryegrass ensiled with three different prewilting degrees. Proceedings of the XVI International Silage Conference, Hämeenlinna, Finland, 386-387.

Wyss U., Thaysen J., Pauly Th. and Rubenschuh U., 2012. Testing inoculant and chemical additives in round bales in comparison to laboratory silos. Proceedings of the XVI International Silage Conference, Hämeenlinna, Finland, 294-295.