THE INFLUENCE OF FORMIC ACID ADDITIVES ON THE QUALITY OF SILAGE FROM DIFFERENT PLANT MATERIAL

Stefan Florek, Cezary Purwin, Dariusz Minakowski, Maria Stanek, Marta Trędowicz.
University of Warmia and Mazury in Olsztyn, Chair of Animal Nutrition and Feed Management, 10-718 Olsztyn, ul. Oczapowskiego 5, tel. (89) 523 3379, fax. (89) 523 3519

Summary. Recapitulating the results, it should be noticed that the tested preparations containing formic acid had a variable effect on the quality and nutritive value of silages. The final effect of Kemisile preparations depended on the type of ensiled material and ensiling technology. In the silages produced on a laboratory scale, the preparations had no influence on the chemical quality, although they were determined to have a beneficial effect on the intake of silages by animals. No significant effect of the concentration of formic acid in the preparations on their effectiveness was observed.

However, one additive (Kemisile 2000) produced much superior results when applied in production of round-bale silages. Addition of Kemisile 2000 for ensiling grasses in bales effectively improved the quality and energy value of silages made from wilted fodder (28.64 % dry matter). In drier grasses, the effect of Kemisile 2000 was less evident. Kemisile 2000 had an ideal effect on the quality of silage from wilted red clover, reducing fermentation and increasing the ratio of lactic acid to total acids.

Key words: silage, formic acid, nutritive value.

SKRUZDŽIŲ RŪGŠTIES PRIEDŲ ĮTAKA SILOSO PAGAMINTO IŠ SKIRTINGŲ AUGALŲ, KOKYBEI

Santrauka. Apibendrinant gautus tyrimo rezultatus pastebėta, kad preparatai, į kurių sudėtį įeina skruzdžių rūgštis, ženkliai veikia silosų kokybę bei maistinę vertę. Galutinis „Kemisile“ preparatų poveikis priklausė nuo silosuotų produktų tipo ir silosavimo technologijos. Silosuose, pagamintuose laboratorinėmis sąlygomis, preparatai neveikė cheminės kokybės, nors siloso buvo suėsta daug. Nepastebėta jokio statistiškai patikimo efekto priklausomo nuo skruzdžių rūgšties koncentracijos preparate.

Tačiau vieną priedą – „Kemisile 2000“, panaudojus ritinio formos silosų gamybai, buvo gauti daug geresni rezultatai. Priedas, „Kemisile 2000“, skirtas silosuotai žolei ritiniuose, efektyviai pagerino siloso, pagaminto iš vytintos žolės, energijos vertės kokybę (28,64% SM). „Kemisile” preparato poveikis sausai žolei buvo mažesnis. Jis sumažino fermentaciją ir padidino pieno rūgšties santykį su bendromis rūgštimis, darė labai gerą poveikį siloso, pagaminto iš vytintų raudonųjų dobilų, kokybei.

Raktažodžiai: silosas, skruzdžių rūgštis, maistinės vertė.

Introduction. Ensiling of wilted green crops is a prevailing technology employed for making silages in Europe (Henderson 1993). Silages are made from green fodders of grasses, legumes and their mixtures.

Studies on ensiling plant material comprise the fermentation stage and evaluation of nutritive value of silages. Factors which influence fermentation include degree of green fodder wilting, length of cut, ensiling technology, type and amount of an additive used (Brzóska et al., 1995; Haigh, 1998). Additives used for ensiling can be divided into stimulators of natural fermentation, fermentation inhibitors and absorbents (Henderson, 1993).

The use of chemical preservatives to ensile high-protein green fodders reduces the magnitude of fermentation and inhibits development of acetic, butyric and proteolytic bacteria, which improves silage palatability, intake and utilization of nutrients by ruminants (Haigh, 1987; Gordon, 1989).

However, the use of chemical preservatives to ensile high-moisture plant material can cause an increased outflow of silage juices (Haigh, 1998) as well as a higher content of water-soluble carbohydrates in juices (Winters, 1996). Seepage losses can be effectively reduced by increasing dry matter content in ensiled material.

Nowak (1999) claims that 30 % dry matter concentration completely eliminates an outflow of juices. Grass or legume silages are usually characterized by lower concentrations of ammonia nitrogen, non-protein nitrogen, acetic and butyric acids (Muck, 1998). Successful ensiling of wilted green crops relies on obtaining proper degree of the ensilaged material density. This means that the raw material should be well chopped or harvested with balers. Quality of silages made as round bales is not always satisfactory. It largely depends on how well the material has been pressed, how many layers of wrap film have been used, what type of fodder is conserved, what physical properties it possesses and how silages are stored (Nowak, 2000).

Apart from grassland fodders, sugar beet pulp is another important type of feed in the nourishment of ruminants. Due to high water content in sugar beet pulp, ensiling is the cheapest method of conserving this type of feed. However, the fact that excessive amounts of sugar extracted during technological processing, leaving only 0.2-0.3% sugar in pulp, hinders the correct progress of fermentation.

A large number of studies on the improvement of ensiling sugar beet pulp has dealt with its molassing application of lactic acid and molasses, addition of lactic acid ,addition of formic and acetic acids or ensiling pressed sugar beet pulp in plastic sleeves. Despite this extensive research, the quality of silage from sugar beet pulp is far too often unsatisfactory (O'Doherty et al., 1998).

The aim of the present investigation was to determine the effect of preparations containing formic acid on the quality of silages from grasses and red clover, produced on a laboratory scale commercially using round baling technology. The use of these preparations in ensiling beet pulp was also analyzed.

Material and methods. The experiments were conducted at the Institute of Animal Nutrition and Feed Management of the University of Warmia and Mazury in Olsztyn.

Silages were prepared with an addition of preparations containing different quantities of formic acid, manufactured by the Kemira Chemicals and sold under the commercial name Kemisile. The three preparations had the following content:

Kemisile 2 (80 % formic acid, 2 % orthophosphoric acid), Kemisile 3 (62 % formic acid, 24 % ammonium formate), and Kemisile 2000 (55 % formic acid, 24 % ammonia formate, 5 % propionic acid, 1 % benzoic acid, 1 % benzoic ethyl).

Silages were produced on a laboratory and comercial scale.

The following silages were made at the Institute of Animal Nutrition and Fodder Management:

- second-cut grasses pre-wilted to about 40 % dry matter
- pressed sugar beet pulp (about 14 % dry matter)

Kemisile preparations were applied by spraying, using 3.5 l/t of the ensiled material. The material mixed with an additive was pressed in 200-litre containers, in two replications, and covered tightly with wrap film and soil.

Silages produced on a commercial scale were prepared at the Experimental Farm in Lipowo.

Second-cut grasses with dominant common cocksfoot were made after 24 hours and 48 hours of wilting on pasture. Only one preservative, Kemisile 2000, was applied at a rate of 3.5 l/t.

Grass was harvested with a roll baler equipped with a Yunkari HP-5 preservative applicator. Silages in bales were wrapped in 4 layers of wrap film. Silages made from red clover harvested at the beginning of flowering were prepared in an identical fashion, using green fodder after 24 hours of wilting on pasture.

Chemical composition of silages.

Samples of the silages were collected after 60 days of storage. With an aid of the standard methods, the basic chemical composition of silage samples was determined. In addition, the content of lactic, acetic and butyric acids was determined by Lepper's distillation method using an H 8314 pH-meter.

Based on the determinations, quality of the silages was assessed on the Flieg-Zimmer scale. Besides, nutritive value of the silages was calculated using INRA system with the help of WINWAR software.

Evaluation of the palatability of silages.

The silages produced under laboratory conditions (grasses, sugar beet pulp) underwent evaluation of their palatability. Two randomly selected silages were fed to 4 young rams. All the silages subjected to the test were available in 4 identical containers placed randomly in the pen. After two days left for the animals to adjust to the pen and the fodders, the rate of fodder intake was measured 2, 4 and 24 hours after the fodders were made available.

Results. Wilted grass silages produced under laboratory conditions.

Silages with Kemisile 2000 had a higher dry matter content than the control silage (Table 1). The levels of organic substances and crude protein in the dry matter of the silages were approximately identical. The crude protein concentration was low in all the silages. Addition of Kemisile 2 and Kemisile 3 to ensiled grasses had a beneficial effect on the ratio of particular carbohydrate fractions in the silages. No butyric acid was found in any silage, although considerably large amounts of acetic acid were determined. Kemisile preparations reduced lactic and alcoholic fermentation, while increasing the amount and value of acetic acid. Moreover, silages produced with an addition of Kemisile were lower in acidity. The ammonium nitrogen to total nitrogen ratio was comprised in the narrow range of 5.30 to 6.70 %.

The *ad libitum* fodder intake test on growing rams showed that the silage conserved with Kemisile 2 was more readily eaten. The silage with Kemisile 2000, on the other hand, was less eagerly consumed than the control silage.

The energy value of silages calculated on the basis of their chemical composition, expressed in UFL (milk production feed units) and UFV (livestock production feed units), as well as the content of intestinally digested protein limited by the level of nitrogen (PDIN) did not differ. The Kemisile conserved silages were characterized by a much higher content of PDIE.

Grass silages in bales.

Dry matter content in pre-wilted grass silages (Table 2) was identical in the control and Kemisile conserved silage, whereas in silages made from drier grass it differed by 6.5 %. Higher-moisture silages contained more organic substance.

Silages from grasses wilted for 24 hours and ensiled with Kemisile 2000 contained much more water-soluble carbohydrates and less crude fiber than the control silage. Such differences in the concentration of carbohydrates were not found in silages containing more dry matter.

The crude protein content in the silages was low and variable. The differences were independent of dry matter content and application of a preserving preparation. The use of Kemisile distinctly increased acidity of the silages, regardless of the ensiled material wilting degree.

Kemisile 2000 added to baled silages did not limit production of silage acids. The preparation caused an increase in the content of lactic acid in the conserved silages. It also elevated the ratio of lactic acid in total acids. No unambiguous influence of the preservative on alcoholic fermentation in round-bale grass silages was detected. Kemisile 2000 depressed alcohol content in higher-moisture silages, in contrast to drier silages, where it had an opposite effect. No silage was found to contain butyric acid. The presence of Kemisile did not constrain the processes of proteolysis and deamination in silages. Lower $N\text{-}NH_3$ to total N ratio was found in lower-moisture silages. On Flieg-Zimmer scale all silages were scored as very good. Kemisile 2000 also slightly enhanced the energy value of round-bale silages.

Table 1. **Quality and nutritive value of wilted grass silages (microsilos)**

Item	Silage			
	without additive	Kemisile 2000	Kemisile 2	Kemisile 3
dry matter , %	44.22	48.86	49.89	48.02
content in dry matter (%)				
organic substance	90.05	90.24	90.42	90.38
crude protein	9.10	9.23	9.10	9.04
crude fibre	32.76	34.40	32.45	31.47
NFE	44.35	43.31	45.54	46.63
UFL	0.82	0.81	0.81	0.82
UFV	0.75	0.74	0.74	0.75
PDIN (g)	52.95	53.77	53.01	52.65
PDIE (g)	59.30	59.82	61.14	62.24
pH	5.62	5.97	5.77	5.76
lactic acid	5.74	4.05	4.55	3.69
acetic acid	1.83	4.09	2.49	1.71
butyric acid	-	-	-	-
ethyl alcohol	1.85	1.63	1.21	1.63
$N\text{-}NH_3$/total N %	6.70	5.30	6.20	5.50
Silage quality according to Flieg-Zimmer scale:				
score	93	62	77	82
quality	very good	good	good	very good

Table 2. **Quality and nutritive value of grass silages with different dry matter content (round bales)**

Item	Silage			
	without additive		Kemisile 2000	
dry matter, %	28.64	46.01	28.64	39.49
content in dry matter (%)				
organic substance	93.05	90.21	93.29	91.44
crude protein	9.25	8.95	8.06	10.28
crude fibre	35.93	32.86	26.92	32.13
NFE	45.11	45.23	55.42	46.24
UFL	0.78	0.79	0.81	0.81
UFV	0.69	0.70	0.73	0.73
PDIN (g)	53.90	52.16	48.43	61.73
PDIE (g)	60.63	57.52	36.11	65.62
pH	4.74	5.84	4.15	4.96
lactic acid	3.449	5.160	9.528	7.095
acetic acid	1.746	1.606	2.322	1.441
butyric acid	-	-	-	-
ethyl alcohol	1.588	0.643	1.264	1.124
$N\text{-}NH_3$/total N %	8.96	6.52	12.17	7.69
Silage quality according to Flieg-Zimmer scale:				
score	81	96	98	98
quality	very good	very good	very good	very good

Round-bale red clover silage.

Wilted red clover silages (Table 3) were comparable in terms of dry matter, organic substance and crude protein content. Kemisile 2000 had a positive effect on NFE content. No differences in the energy and protein value between the silages were determined. The silages did not contain butyric acid. Kemisile added to ensiled red clover considerably depressed the content of lactic and acetate acids, simultaneously improving the ratio between the two acids. Kemisile 2000 also constrained alcoholic fermentation and proteolytic processes during fermentation. Irrespective of considerable differences in the course of fermentation, both silages were scored as very good on Flieg-Zimmer scale.

Sugar beet pulp silage.

The data on the chemical composition and quality of the sugar beet pulp silages (Table 4) show that the lowest dry matter content was determined for the control silage. Crude fiber content in the dry matter of the silages was similar. The Kemisile 2000-preserved silage of the lowest NFE concentration was determined to have the lowest crude protein content. Beet pulp silages were also characterized by the lowest acidity, with the control silage being the least acidic.

Table 3. **Quality and nutritive value of red clover silages**

Item	Silage	
	without additive	KemiSile 2000
Dry matter (%)	32.02	30.30
content in dry matter (%)		
crude protein	17.36	16.86
organic substance	88.48	89.32
crude fibre	30.07	26.57
NFE	38.44	41.39
UFL	0.86	0.86
UFV	0.79	0.78
PDIN (g)	101.35	98.45
PDIE (g)	69.82	75.76
pH	4.70	4.60
Acids: lactic acetic butyric	 9.722 4.750 -	 6.600 2.082 -
ethyl alcohol	1.302	1.026
$N\text{-}NH_3$ / N-t (%)	8.31	6.71
Silage quality according to Flieg-Zimmer scale: score quality	 81 very good	 96 very good

Table 4. **Quality and nutritive value of sugar beet pulp silages (microsilos)**

Item	Silage			
	without additive	Kemisile 2000	Kemisile 2	Kemisile 3
dry matter, %	13.36	15.58	15.35	14.41
content in dry matter (%)				
organic substance	92.13	92.85	93.16	92.89
crude protein	9.63	9.98	9.32	10.10
crude fibre	20.93	20.58	20.37	20.18
NFE	60.60	61.49	62.92	61.81
UFL	0.82	0.85	0.82	0.82
UFV	0.76	0.80	0.76	0.76
PDIN (g)	58.76	60.94	56.70	61.28
PDIE (g)	80.42	75.66	84.89	84.06
pH	3.93	3.63	3.50	3.69
lactic acid	3.196	2.940	3.062	2.817
acetic acid	2.201	4.872	3.023	5.684
butyric acid	0.052	-	-	-
ethyl alcohol	12.463	6.033	7.446	7.370
$N\text{-}NH_3$/total N, %	3.16	7.23	1.97	7.95
Silage quality according to Flieg-Zimmer scale: score quality	 64 good	 58 satisfactory	 64 good	 54 satisfactory

The content of lactic acid was low in all the silages. Addition of Kemisile preparations enhanced the content of acetic acid in the silages. The silages preserved with Kemisile 2000 and Kemsile 3 had considerably elevated levels of acetic acid. The ammonium nitrogen to total nitrogen ratio was on a desirable level in all the silages. The control silage prepared from sugar beet pulp without additives was observed to contain high ethyl alcohol concentration.

Analysis of the *ad libitum* DM intake of the silages proves that silages with Kemisile were consumed more readily than the control silage. The fodder intake was most dynamic for the silage with Kemisile 3, with 95 % of the fodder consumed 24 hours after it had been offered. The silages conserved with an additive were consumed 2.8 (Kemisile 2) to 6.3-fold more eagerly than the control silage.

Discussion. The influence of Kemisile preparations on chemical parameters and quality of the laboratory silages varied. Addition of Kemisile to ensiled grasses constrained lactic and alcoholic fermentation. Similar observations were reported by Brzóska (1993) and Haigh (1998). Absence of butyric acid and low rate of proteolysis in the silages produced on a laboratory scale may have resulted from high degree of pre-wilting of the ensiled grasses (Haigh, 1998; Patterson et al., 1997).

It is difficult to account for the increased content of acetic acid in the silages conserved with Kemisile 2, and especially Kemisile 2000. Kemisile added to round-bale grass silages produced on a commercial scale distinctly improved the chemical composition of silages from wilted grasses (28.64 % DM). This improvement lay in the increased lactic acid to total acids ratio, which is a generally observed effect attained by formic acid (Brzóska, 1993; Nowak, 2000). A slight increase in the intensity of lactic and acetic fermentation relative to the control silage was observed. This was accompanied by a decrease in pH from 4.74 to 4.15. Similar high acidity in grass silages was determined by Haigh and Chapple (1998), who compared the effect of formic acid and formic acid salts on quality of silages made from grasses containing various dry matter percentages.

Fermentation in the silages with higher dry matter content was affected by Kemisile in a similar way, although the results of silage quality tests were unaffected.

When analyzing the results of the evaluation of chemical composition of round-bale silages, it should be noticed that the pre-wilting of greed fodder produced a typical effect of lower acidity and content of acids in silages with an additive.

Long-term observations carried out by Haigh (1996) have been confirmed in that the decisive factor affecting progress of fermentation is dry matter content in green fodder. Over 75 % of silages containing 30 % DM were classified as very good quality fodders.

Higher production of acids in silages conserved with Kemisile was concomitant with elevated degradability of proteins and deamination of amino acids. This tendency is in agreement with the observations reported by Brzóska (1995). According to Field et al. (1999), in order to produce silage in round bales with a $N\text{-}NH_3$ to total N ratio not exceeding 10 %, it is necessary to wilt green fodder to at least 31 % dry matter.

Inhibitory effect of formic acid from Kemisile 2000 on fermentation appeared during ensilage of red clover containing about 30 % dry matter. For this crop, the effect of conservation was most typical and evident. Kemisile 2000 depressed lactic, acetic and alcoholic fermentation, maintaining the pH of silage at 4.6. An equally effective influence of formic acid and its salts on fermentation in red clover silage was reported by Fairbain et al. (1992). Improved quality of Kemisile conserved red clover silage was not accompanied by improved energy value expressed in PDIN and PDIE.

Addition of Kemisile preparations to ensiled sugar beet pulp, which is a raw material of a different chemical composition and lower buffer capacity than grasses or legumes, increased acetic acid content and decreased pH of silages.

Concentration of particular acids and their respective ratios may have been also affected by some amounts of acids introduced to silages with Kemisile preparations.

Woolford (1989) suggested that formic acid depressed pH. Low percentage of lactic acid was caused by low sugar content in the fodder to be ensiled. Concentration of pectins and pentosans, on the other hand, favoured formation of acetic acid (Woolford 1994).

In a study completed by sugar beet pulp used for making silages had higher acetic acid content and lacked lactic or butyric acids. The level of ammonium nitrogen in ensiled sugar beet pulp can imply low activity of *Clostridium*, while the high level of ethyl alcohol in the control silage suggests an inhibitory effect of formic acid preparations on yeast activity.

The results of the palatability tests on silages produced on a laboratory scale, carried out on growing rams, both for grass and sugar beet pulp silages, were only partially convergent with the results of the chemical evaluation. As regards grass silages, the silage conserved with Kemisile 2, containing the lowest amount of ethyl alcohol, was most willingly consumed. The silage with Kemisile 2000, containing the highest level of acetic acid and alcohol, was the least preferred. The results of *ad libitum* intake experiments comply with the findings obtained by Brzóska et al. (1995).

Addition of the same preparations to ensiled sugar beet pulp had a reverse effect on the palatability of the silages. The control silage and the silage with Kemisile 2 were the least preferred. According to the chemical evaluation, these two silages were of a very good quality. The silages with Kemisile 3 and Kemisile 2000 were evidently much more readily consumed. These silages contained less alcohol and higher $N\text{-}NH_3$ to total N ratio. Such observations seem to be conflicting and very difficult to elucidate, mainly because Mc Donald et al. (1991) claim that inferior intake of fodders by animals depends on the amount of protein degradation products, which have an adverse effect on appetite and motor activity of the digestive tract.

Much superior results were achieved by using one of the preparations (Kemisile 2000) for producing round-bale silages. Kemisile 2000 added to round-bale grass silages effectively improved the quality and energy value of silages from well wilted grasses (28.64 % DM). In slightly wilted grasses, the effect of Kemisile 2000 was less obvious.

Quality of silages was ideally improved by Kemisile 2000 in the case of ensiled well wilted red clover, in which the preparation constrained fermentation and increased the percentage of lactic acid in total acids.

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