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An evaluation of alternative grain processing and storage methods (storage and nutrition value)

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Abstract

Traditionally cereals in Lithuania have been dried and processed prior to feeding to farm animals. Alternative options available to farmers for harvesting and storing of whole crop cereals may provide opportunities to reduce food costs and thereby increase income and to make grain harvesting more flexible. In two trials were examined the effect of biological additive *Lactisil Wholecrop* (LWC) and chemical additive AIV-2000 S (AIV) on the fermentation characteristics, aerobic stability of whole-crop winter wheat, spring barley and spring-wheat silages and the effect of barley whole crop silage on feed intake and milk production of dairy cows.

As intended, the inoculated spring wheat silage contained more fermentation products than the untreated silage. The LWC treatment resulted in significantly ($P < 0.05$) higher lactic acid contents, numerically lower butyric acid contents and lower ($P < 0.01$) dry matter (DM) loss, but had no effect on aerobic stability.

Chemical treatment gave the highest water soluble carbohydrates (WSC) contents and produced the most aerobic stable whole crop silages. AIV treatment restricted fermentation of barley and winter wheat silages and gave the lowest organic acids content ($P < 0.01$) without butyric acid and decreased the content of ammonia ($P < 0.01$) in silages. Fermentation loss of AIV whole crop silages were lower than that of not treated ($P < 0.01$, $P < 0.025$). Although the addition of AIV enhanced the nutritive value of whole crop silages and lead to higher DM intake and improve performance of milking dairy cows.

Key words: whole crop cereals, additive, silage, fermentation, dairy cows.

Introduction

Progress in improving silage quality and nutrient use efficiency, advances in plant breeding and additives for manipulating silage fermentation made silage of topmost importance feed. In recent times whole-crops cereals have increased in popularity and have partially and successful replaced grass silage or cereal in the diet (Adesogan et al., 2004). Whole-crop cereal silage has increased in popularity because of high DM yields at single harvest and flexibility of either harvesting the crop for silage or for grain depending on supply of other silage sources or sometimes over weather conditions. Furthermore, the farms which are specialized in grass production may have shortage of open field area for manure spreading, in which case whole crop silage can be the answer. Combinations of whole crop silage from barley and red clover were consumed readily and were found that it is possible to maintain a reasonably high milk production and at the same time have a

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good protein utilization. This gives perequisites for a lower nitrogen loss to environment (Bertilsson and Knicky, 2005). An increasing use of whole-crop cereals has increased interest in development of ways for effective conservation and storage these forages and to achieve a high hygienic quality, because Weissbach and Haacker (1998) states that ensiling of whole-cereals often results in silages with high concentrations of butyric acid and Filya et al. (2000) indicate the problems with poor aerobic stability of these silages. Quality of whole crop cereal for silage may improve by using additives that either promote fermentation of lactic acid or inhibit organisms that are detrimental to proper conservation of silage. Classical microbial inoculants containing homolactic acid bacteria (e.g., *Lactobacillus plantarum*) are often added to silage because they produce large quantities of lactic acid very rapidly, which lowers the pH of silage, however, they can often have no effect or even make the aerobic stability of silages worse (Weinberg et al., 1999). However, the aerobic stability of silages has been markedly improved by inoculation with a heterolactic acid bacterium, *Lactobacillus buchneri* and improvements in aerobic stability brought about by this organism have been reported in wheat and sorghum silages (Weinberg et al., 1999). *Lactobacillus buchneri* has been shown to inhibit the proliferation of yeasts in silage via the production of acetic acid. Propionic acid-based additives have been used to inhibit yeasts that assimilate lactic acid when silages are exposed to air and thus, they improve aerobic stability (Woolford, 1975). Silage additives, chemical and bacterial, were effective in improving the silage quality in wheat or barley forage (Knicky and Lingvall, 2005; Muhonen et al., 2005). However, Adesogan et al. (2002) have highlighted that inoculant treatment and formic acid treatment reduced yeast counts but did not improve the fermentation in wheat silages.

Therefore, these studies were aimed to determine the effect of formic-propionic acids-based preservative and a microbial inoculant on the fermentation characteristics and aerobic stability of whole-crop winter and spring wheat and spring barley. Studies also investigated the chemically treated whole-crop barley silage intake in dairy cows and milk production of dairy cows.

Materials and methods

Ensilage procedure and treatment. 1. Spring variety of barley from one field was harvested at the middle of dough stage (39.7 % DM) and winter variety of wheat from one field was harvested at the middle of dough stage (41.4 % DM) At harvest either no additive (control - C) or formic-propionic acd-based additive *AIV 2000 S* (AIV- formic acid – 44 %, ammonium formiate- 30 %, propionic acid – 9 %, benzoic acid – 2 %, water – 15 %, color E 150) was used. For whole crop cereals the treatment provided 5.0 l/t of *AIV 2000 S*. **2.** Spring variety of wheat from one field was harvested at the medium to hard dough stage (43.5 % DM).The whole cereals was ensiled without an additive (control-C) and with the inoculant *Lactisil Wholecrop* (LWC) - containing combinations of the lactic acid bacteria *Lactobacillus plantarum* AMY, *Pediococcus acidilactici* 33-06, and *Lactococcus lactis* SR3. Concentration of bacteria in mix: 2.5 x 10^{11} cfu/g) applied at 5 x 10^5 colony-forming units (cfu) g^{-1} fresh weight. Whole-crop cereals was cut and placed in a swath and immediately baled. The baler was equipped with an additive applicator. The additives were applied by spraying it on the swath. Round big bales, 120 by 120 cm were wrapped in six layers of 25 µm stretch film that was700mm wide. Five big bales from each treatment were weighed after wrapping and again after 70 days of storage to determine DM loss.

Sampling and fermentation characteristics analysis. Representative samples of the herbage were taken directly from the swath during silage making time and one composite herbage sample was taken for every ninth bale. Silages were sampled from every ninth bale, from each treatment. After 90 days of storage, four radial cores were taken per bale and pooled to a single sample. The proximate analyses of fresh herbage samples were determined by techniques proposed by Wende (AOAC, 1990). In addition to analyses on herbage, silage was analyzed for pH, lactic acid, acetic acid, butyric acid and ammonia –N.

The aerobic stability was measured over 10 days by recording the days to persistent temperature rice by 3 ºC above 21 ºC ambient (Honig,1990).

Feeding trials with dairy milking cows. Feeding trials was conducted with spring variety whole crop barley silage. Twenty adult dairy cows assigned in two groups (10 cows per additive treatment) according to parity, lactation, date of calving and milk yield were used in experiment. During the experimental period (92 days), cows in each group were fed the respective silages (C or AIV) *ad libitum* offered in two meals per day. Silage given for cows weights were recorded once weekly on two consecutive days and refusals were weighed back and subtracted when calculating daily intake. Milk yield was recorded for two consecutive days every two weeks and aliquot milk samples from morning and evening milk were bulked and content of fat, protein, urea were analyzed.

Statistical analysis. Chemical data of silages are presented on a DM basis. Replications (bales) were used per additive treatment. Data from the feed intake and lactation study were analyzed between-subjects factor, where subjects are cows in this case. Animal groups were treated as the experimental unit. Data from studies were analyzed to one- way analysis of variance (ANOVA). The differences among means were tested using the Fisher's Least Significant Difference (LSD) (Snedecor and Cochran, 1989). All differences quoted in the text are significant at the 0.05 level unless stated otherwise.

Results

Fermentation parameters of chemical treated silages. The DM, crude protein and WSC contents were 397.4 and 414.1 g kg $^{-1}$, 121.3 and 108.9 g kg $^{-1}$ DM and 69.4 and 93.0 g kg $^{-1}$ DM for whole crop barley and wheat respectively. AIV treatment decreased fermentation rate in both barley and wheat silages, resulting in a significant ($P < 0.01$) pH value rise, gave the higher by 10.0 ($P < 0.01$) and 7.6 ($P < 0.05$) g kg $^{-1}$ DM WSC contents and lower ($P < 0.01$) by 29.0 and 15.6 g kg $^{-1}$ DM fermentation acids contents compared with untreated silages. Lactic acid contents were higher ($P < 0.01$) by 16.9 and 11.1 g kg^{-1} DM for barley and wheat silages respectively and without butyric acid compared with controls (Table1). The content of acetic acid was significantly lower in chemically treated silages. Ammonia-N concentration was 1.6 and 1.9 times lower ($P < 0.01$) in AIV barley and wheat silages respectively compared with C silages.

After ten weeks storing fermentation DM loss of AIV whole crop barley and wheat silages were lower ($P < 0.01$ and $P < 0.025$) by 1.7 and 1.9 % respectively than that of not treated.

Fermentation parameters of bacterial treated silages. The chemical composition of whole crop spring wheat before ensiling is presented in Table 2. The lower ($P < 0.05$) by 3.1 % DM contents of the LWC silages compare with non treated can be associated with using water during treatment.

As intended, bacterial treatment increased fermentation rate in whole crop spring wheat silages, resulting in numerically more fermentation products and pH drop compared with controls. In the inoculated silage WSC concentration was less by 10 g kg^{-1} DM when compare with control. Lactic acid concentration was increased ($P < 0.05$) by 13.6 kg^{-1} DM and butyric acid concentration was decreased by application of LWC additive. However, LWC not reflected in concentration of ammonia-N in spring wheat silage. Inoculation decreased ($P < 0.01$) by 1.8 % DM loss.

The aerobic stability. The inoculated spring wheat silage was more prone to aerobic deterioration than untreated silage. LWC silage had a temperature rise of more than 3 ºC above the ambient temperature after 80 h (Figure 1). Both summer barley and winter wheat AIV silage had an enhanced aerobic stability compared with these untreated. More stable for aerobic deterioration was AIV winter wheat silage, because no had a temperature rise more than 3 ºC above the ambient temperature all exposure time to air.

Feed intake and dairy cows production. There were no significant differences in silage DM intake and milk yield between treatments over whole experiment. However, as shown in Table 1, whole crop barley silage DM intake was higher by 0.63

kg with AIV restricted compared with untreated these silage fermentation. Including compound feed, total DM intake per cow per day were 16.47 and 17.29 kg with C silage and AIV silage, respectively. The additional energy intake resulted in a higher milk yield. The AIV whole barley silage enhanced the milk yield by 1.07 kg and energy- corrected milk by 1.30 kg per cow and day and marginally

Table 1. Composition of control (C) and AIV treated whole crop cereals silages.

	Experiment 1			Experiment 2		
		Spring barley silages			Winter wheat silages	
	H[1]	C	AIV	H[1]	C	AIV
Dry matter, DM (g kg^{-1})	397.4	430.4	435.5	414.1	423.3	435.1**
Crude protein (g kg^{-1} DM)	121.3	100.2	103.4	108.8	98.5	99.4
Crude fibre (g kg^{-1} DM)	248.0	241.2	231.2**	280.0	276.7	254.3*
WSC (g kg^{-1} DM)	69.6	30.2	40.2**	93.0	29.0	36.6*
NDF (g kg^{-1} DM)	478.8	458.9	498.2	385.8	378.9	387.2
ADF (g kg^{-1} DM)	358.3	326.4	312.9	294.9	226.6	248.7
Total organic acids (g kg^{-1} DM)		50.42	21.40**		34.74	19.14**
Lactic acid (g kg^{-1} DM)		33.65	16.75**		26.55	15.37**
Acetic acid (g kg^{-1} DM)		16.32	4.62*		7.93	3.73*
Butyric acid (g kg^{-1} DM)		0.41	0.00*		0.22	0.00*
Ammonia N (g kg^{-1} total N)		63.4	38.7**		73.4	39.1**
pH		4.02	4.33*		4.13	4.38**
DM losses (g kg^{-1} DM)		106.1	89.6*		112.2	93.4**
Silage DM intake (kg day)		13.45	14.08			
ECM[2] (kg day)		17.09	18.39			
Milk fat (g day)		0.702	0.761			
Milk protein (g day)		0.544	0.596			

[1] Herbages
[2] ECM- energy corrected milk;
* and ** denotes significant at level 0.05 and 0.01 respectively.

Table 2. Composition of control (C) and inoculated (LWC) whole crop spring wheat silage.

		Silages			
	H	C	LWC	$LSD_{0.05}$	Sx
Dry matter, DM (g kg^{-1})	436	429	398*	26.6	1.43
Crude protein (g kg^{-1} DM)	98	93	101	13.9	3.16
Crude fibre (g kg^{-1} DM)	296	293	286	13.5	1.04
WSC (g kg^{-1} DM)	63	36	26	38.2	27.5
NDF (g kg^{-1} DM)	491	391	386	33.9	1.94
ADF (g kg^{-1} DM)	372	254	231	50.7	4.64
Total organic acids (g kg^{-1} DM)		34	46	14.6	8.34
Lactic acid (g kg^{-1} DM)		23.6	37.2*	13.1	9.56
Acetic acid (g kg^{-1} DM)		8	7	2.2	6.28
Butyric acid (g kg^{-1} DM)		1.7	0.7	2.08	29.04
Ammonia N (g kg^{-1} total N)		35	34	16.3	10.43
pH		4.16	4.07	0.192	1.03
DM losses (g kg^{-1} DM)		108	90**	1.0	0.22

* and ** denotes significant at level 0.05 and 0.01 respectively.

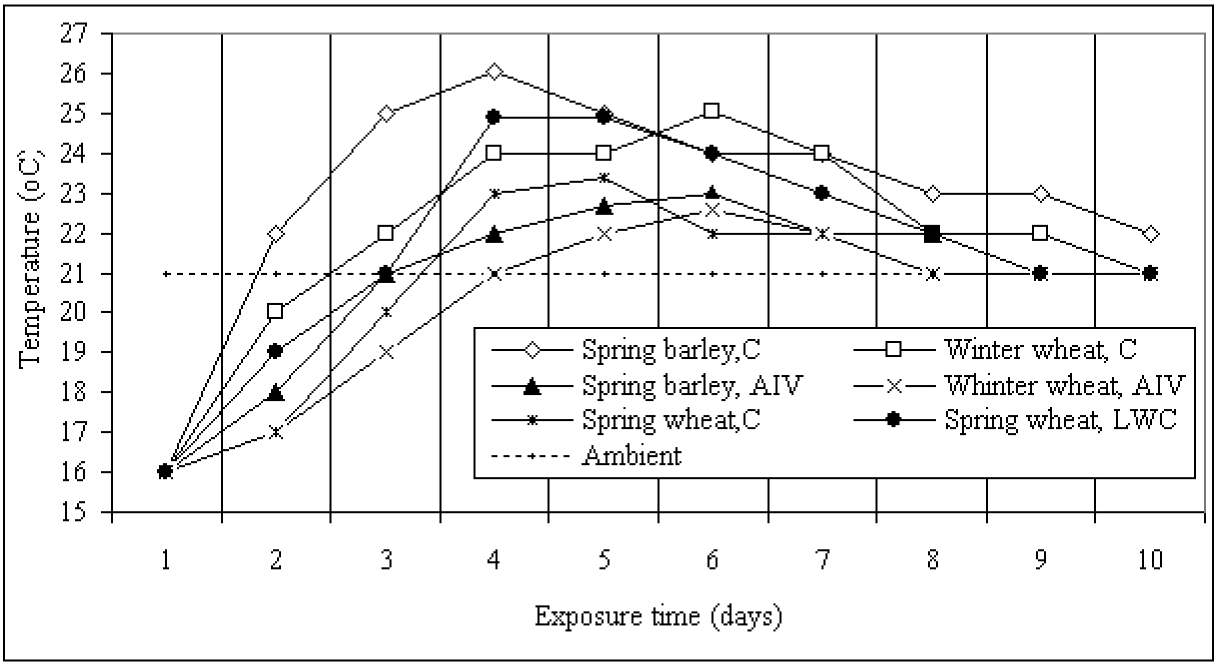

Figure 1. Changes of temperature in silages with different additives.

increased milk fat and protein contents. Consequently, dairy cows fed chemically treated whole crop barley silage tended to be more efficient to give 1 kg of milk compared dairy cows fed not treated silage.

Discussion

The two silages additives, AIV and LWC produced whole crop cereals silages with different levels of fermentation. Whole crop spring barley and winter wheat silages AIV contained roughly half as much fermentation products and significantly higher pH value and lactic acid concentration as compared with untreated (C) silages. Muhonen et al., 2005 indicate that whole crop barley or wheat silages treated with acid-based additives had higher pH and lower content of lactic acid. The low lactic acid content is consistent with the reported bacteriostatic properties of formic acid (Woolford, 1984) resulting in a restricted fermentation. Our results concurs with other studies in which organic acid treatment reduced WSC fermentation (Mayne, 1993; Salawu et al., 2001; Adesogan and Salawu, 2002) and the contents of WSC reflected very well the extent of fermentation. The higher production of acetic acid without treatment compared with treatment AIV indicates a more homolactic type of fermentation with the organic acids. It could also be that enterobacteria were sufficiently inhibited by formic and propionic acids. Acetic acid always produces higher DM losses than lactic acid in a homofermentative pathway (McDonald et al., 1991). Consequently, can be explain why fermentation DM loss of AIV treated whole crop barley and wheat silages were significantly lower than that of not treated. AIV decreased effectively the content of ammonia ($P < 0.01$) in the silages and this suggest that protein breakdown was suppressed in these silages. This may in part be caused by a rapid drop in pH during the initial phase of ensilage and suppressed growth of the potentially proteolytic species of enterobacteria and lactic acid bacteria (Winters et al., 2001).

With the inoculant LWC with spring wheat experiment, the differences in pH values, total fermentation acids and ammonia-N failed to attain significance. However lactic acid concentration was increased ($P < 0.05$) by application of bacterial additive. The higher production of lactic acid in with treatment LWC indicates a more homofermentative fermentation compare with ordinary made silage (McDonald et al., 1991). Using bacterial additives is to ensure that lactic acid bacteria dominate the fermentation, which results in well-preserved silage and reduced dry matter losses (Knicky and Lingvall, 2005; Muhonen et al., 2005). There is reason to consider DM losses. It is appear that in spring wheat silage LWC prevented the accumulation of butyric acid and resulted in silages that had undergone a more homolactic acid fermentation. That's can be related to decreased ($P < 0.01$) DM loss in whole crop spring wheat silage. Knicky and Lingvall (2005) and Muhonen et al., (2005) showed that the success of preserving nutrients in the silage related to the homofermentative fermentation of the crop.

Aerobic stability is an important factor and care should be taken to minimize losses associated with it. The data presented indicate that AIV can improve aerobic stability of whole crop cereals silages. Mostly authors indicate that formic or propionic-acid-based additives inhibited mould and yeast growth, reduced CO_2 production and heating of silages (Filya et al., 2000, Weissbach and Haacker, 1998, McDonald et al., 1991, Kung and Ranjit, 2001, Fellner et al., 2001).

Microbial inoculation was not effective in improving aerobic stability. The poor stability of the LWC silage in experiment was probably related to high initial numbers of yeasts in the silage at opening. Nordang (1991) revealed that the inoculant produced silage with more frequent problems of self-heating than with the formic-acid-based additives. Furthermore, when applied at 1×10^5, as was the case in our study, aerobic stability was slightly lower in silages treated with the inoculant. Kung and Ranjit (2001) also showed that when applied at less than 5×10^5 cfu/g, *L. buchneri* inoculants did not improve aerobic stability. Fellner et al. (2001) reported that microbial inoculation with *L. plantarum* and *Enterococcus faecium* had no effect on the aerobic stability. However, Filya et al., 2000 noted that propionic acid bacteria, which produce propionic and acetic acid in silage effective in protecting the wheat silage from aerobic deterioration, but combination of propionic and lactic acid bacteria do not look promising in protecting wheat silage upon aerobic exposure.

Dry matter intake was numerically higher with restrictively fermented silage (AIV) than with ordinary fermented silage (C). There are well documented that higher contents of silage fermentation products reduce feed intake (Miettinen et al., 1991) Differences in the feeding value of treated with AIV or non treated whole crop barley silages can, in part, be attributed to the effect of additive treatment on silage intake and energy concentration. The response to the higher feed intake with silage AIV compared with untreated silage was 1.3 kg ECM as a experiment mean. Other studies have observed somewhat higher milk yields with organic acids treated silage compared with extensive silage fermentation (Heikkila and Toivonen, 2005, Mittinen et al., 1991; Kung et al., 1987).

In conclusion, the results from these experiments showed that when whole crop cereals silage fermentation was restricted by use of an formic-propionic-acids additive (AIV treatment), silage DM loss was decreased, aerobic stability enhanced, silage feeding value and intake of dairy cows was increased and the milk yield was increased compared with ordinary fermented silage (C treatment). Bacterial additive (LWC) do not look promising in protecting spring wheat silage upon aerobic exposure.

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