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HEAT DAMAGE IN HAY-CROP SILAGE

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INTRODUCTION

The use of hay-crop silage is continuing to expand in Ontario. With high-protein forages, farmers can minimize purchases of protein supplements. Since protein content can vary markedly due to species and maturity, producers are encouraged to have their stored feed analyzed for protein content. The forage is normally tested for crude protein content which is assumed to be a standard percentage digestible. It has been known for many years however, that heating of the silage causes a reduction in digestibility through a process known as "browning" or the Maillard reaction. Recently a laboratory test known as the acid-detergent fiber nitrogen test (ADF-N) has become available to test for reduction in protein digestibility by the "browning" reaction.

HEATING IN SILAGE

Silage fermentation, involving the production of lactic acid plus lesser amounts of other compounds, produces very little heat. Similarly, wine does not heat when it ferments.

Heating is caused by air exposure or by air entering the silage mass. There is not enough trapped air in silage to cause serious heating. For silage to heat, oxygen must be present. Heating in silage during the first few days following harvest is caused by: (1) plant respiration and (2) yeast and mold activity. Later in the storage period heating is related to yeast and mold activity only. Thus, essentially all heating is the result of the silage being exposed excessively to air. Prolonged exposure results in silage spoilage.

Minimizing air exposure is the key to the production of good quality silage. Contrary to ideas prior to 1950, there is no advantage to having warm or hot silage.

THE BROWNING REACTION

Heating results in a "toasting" effect on the silage which darkens the color. The darkening color, or browning, is caused by the combination of part of the silage carbohydrate with part of the silage protein to form a brown undigestible compound similar to lignin. **Thus, protein tied up by the browning reaction is relatively unavailable to livestock.**

The browning reaction increases with the length of the heating period. Since silage is stored for relatively long periods under farm conditions, the browning reaction would proceed towards its maximum for the particular temperature level attained. The reaction appears to start at approximately 40°C (100°F). An experiment was conducted to determine the effect of temperature and storage time on the reduction of protein digestibility. Good quality silage was placed in sealed containers and artificially heated. The results are shown in Table 1. Dramatic reduction in digestibility occurred at high temperatures.

Table 1. Protein digestibility (%) as affected by temperature and length of storage.

Heating Period (days)	43°C (110°F)	57°C (135°F)	71°C (160°F)
0 (control)	69.7	69.7	69.7
3	68.7	65.8	60.2
9	68.4	64.4	50.0
18	65.2	58.6	35.8
30	65.4	49.0	30.1

Farmers have recently tended to store silage at lower moisture contents than in the past. There are several reasons for suspecting that lower moisture silages are more susceptible to heat damage than higher moisture silages if excessive air exposure is permitted.

(1) The fermentation process in silage results in a decrease in silage pH and utilizes water soluble carbohydrates in the reactions. Thus the more complete the fermentation, the fewer soluble carbohydrates there are remaining to participate in the browning reaction. Since the amount of fermentation decreases with decreasing moisture content of the silage, it would appear that silages may increase in susceptibility to "browning" as moisture content decreases. It has also been suggested that the extent of the browning reaction increases with higher pH (higher pH occurs when silage is drier and ferments less) although the rate of the reaction may be slower.

(2) Drier silages do not consolidate as well as wetter silages. Therefore drier silages have decreased resistance to air infiltration into the silage and the **probability of heating is increased.**

(3) The specific heat * of silage decreases as the moisture content decreases. Therefore a given amount of heat produced will increase the temperature of a drier silage more than a wetter one, and more damage will occur.

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* *Specific heat — the amount of heat required to raise 1 gram of material 1C°.*

ONTARIO HAY-CROP SILAGES

One hundred and forty-six hay-crop silage samples were collected from Ontario farms in the fall of 1974 and were tested for protein digestibility at the University of Guelph.

Samples were collected at random from:

(1) steel glass-lined oxygen-limiting silos
(2) concrete oxygen-limiting silos
(3) stave concrete tower silos
(4) poured concrete tower silos
(5) horizontal silos

The results follow:

Crude Protein

The average crude protein content of all samples was 13.8% with a range of 7.1 to 22.9%. Table 2 shows the number of samples in various ranges of protein content. These results indicate that **improved feed quality could be obtained by more attention to timely harvesting and growing of the proper species of forages.** Thirty samples had crude protein contents over 17.5%, indicating good crop management. The data indicated that owners of the different silo types were placing equal emphasis on crop management practices, since the average crude protein content was essentially the same for all silo types.

Table 2. Number of samples with crude protein contents in the ranges shown.

	% Crude Protein (DM basis)							
Sample Origin	**7.5**	**7.5 to 10**	**10 to 12.5**	**12.5 to 15**	**15 to 17.5**	**17.5 to 20**	**20**	**TOTAL**
All Samples	4	21	33	33	25	23	7	146
Oxygen-limiting Steel glass-lined	1	4	9	17	7	7	3	48
Oxygen-limiting Concrete	1			1		2	1	5
Stave		3	14	3	6	5	2	33
Cast-in-place	1	7	7	8	9	5	1	38
Horizontal	1	7	3	4	3	4		22

RANGE: 7.1 to 22.9%
MEAN: 13.8%

Heat Damage

When the nitrogen content measured using the ADF-nitrogen test is above 0.29% (dm basis), the sample is said to be heat damaged. In the survey, 17.1% of the samples were heat damaged. An ADF-nitrogen value of 0.29% corresponds to a protein digestibility of about 60%. For the purposes of this Factsheet, samples above 60% protein digestibility will be considered to be of good quality and samples below 60% protein digestibility will be considered heat damaged. Excellent quality silage should have protein digestibilities in excess of 65%. The summary of protein digestibilities from the various types of silos is shown in Table 3. The average protein digestibility was 64.3% with values ranging from 23.8 to 78%. Regardless of silo type, the majority of silage samples had protein digestibilities between 60 and 70%. The results indicated that top quality silage can be made in all types of silos providing proper management is used. However, under less than ideal management the probability of heat damage is greater in conventional tower silos and horizontals.

Table 3. Number of samples with protein digestibility in the defined ranges shown.

Sample Origin	**Calculated Protein Digestibility** Above 65% (excellent)	60 to 65% (good)	less than 60% (heat damaged)
Oxygen-limiting Steel	35	8	5
Oxygen-limiting Concrete	4	1	
Stave	28	4	1
Cast-in-place	24	8	7
Horizontal	9	5	8

Moisture Content

In the present survey, protein digestibility had no relationship with moisture content. We believe it is still unwise to place excessively dry material in conventional tower silos and horizontals for the reasons mentioned earlier. Hay-crop silage should be more than 50% moisture when put in conventional tower silos, and preferably should be between 55 and 65% moisture. Drier silage can be stored in such silos but extreme care is required. Silage in oxygen-limiting silos should be between 40 to 50% moisture to facilitate unloading.

The moisture content distribution of the silage samples in the survey is shown in Table 4. Clearly many farmers are putting relatively dry forage into conventional tower silos. Such a practice will be successful only under top management.

Table 4. Number of samples with moisture contents in the following ranges.

	% Moisture							
Sample Origin	**20-29**	**30-39**	**40-49**	**50-59**	**60-69**	**70-79**	**80-89**	**Total**
All Samples	4	18	43	35	36	8	2	146
Oxygen-limiting Steel glass-lined	3	11	20	10	4			48
Oxygen-limiting			2	1	2			5
Stave		4	9	12	7	1		33
Cast-in-place	1	3	11	8	10	5		38
Horizontal			1	4	13	2	2	22

RANGE: 23.9 to 85.0%
MEAN: 52.5%

Color and Odor

Dark color and burnt odor are general indicators of heat damage. However, unless samples are black and/or have a distinct burnt odor, these characteristics are not good indicators of silage quality. If the silage is a darker brown than normal, or is black in color, a protein digestibility test should be performed as outlined in the section on sampling procedures.

Length of Cut

As length of cut increases, there is a tendency for less compaction to occur in silage, and therefore length of cut may be an indicator of air infiltration and heating. The data indicated that good quality silage can be made with any length of cut providing proper management is used. The probability of incurring heat damage is probably greater if the silage is cut very long (10 to 15 cm or 4 to 6 inches).

SAMPLING PROCEDURES

Samples should not be taken until the silo has been filled for some time and fermentation is complete. Silage should be mailed immediately after sampling or frozen for later shipment, and should be shipped early in the week to avoid delays over the weekend. If the silo has not been sealed with plastic sheeting, care should be taken to avoid areas that have been heat damaged at the surface by air infiltration. Further information on sampling procedures as well as sample bags and cost information are available from your county office of the Ontario Ministry of Agriculture and Food.

SILO MANAGEMENT

The practices required in storing good quality silage for livestock are similar to those for preserving food for humans. In preserving jam or fruit, a person starts with a good container, fills it quickly and seals it with a lid or layer of wax until required. With such a procedure, good quality food is usually obtained. In contrast, if a person filled a jar of peaches over a period of 2 weeks by adding a thin layer each day, and in addition, permitted the full jar to sit uncovered for several weeks, lower quality food is likely to result. Yet, the latter procedure is frequently used in ensiling crops for livestock feed.

There are a number of practices which must be followed if good quality silage is to be made. First, the forage must arrive at the silo in good quality. In addition, there are a number of specific recommendations for silo management.

A. Oxygen-limiting silos

(1) Fill rapidly to minimize air exposure.

(2) Close hatches at night, weekends, and during interruptions in filling because of bad weather or breakdowns. If hatches are left open during the whole filling period, much of the possible advantages over conventional silos will be lost in reduced dry matter and in reduced heating. Research has shown that dry matter losses can increase by at least 4% when the top hatch is left open at nights while filling. Leaving the hatch open for several days after silo filling is completed can cause serious reduction in feed quality.

B. Conventional Tower Silos

(1) Fill rapidly.

(2) If bad weather causes a stoppage in filling for several days, the silage should be covered with plastic.

(3) It is very important to cover the silage with plastic after the silo is filled. Hold the plastic in place with about 3 inches of silage. The silage should remain covered for 5 to 10 days before feeding. After this period, the plant cells will no longer be respiring and the chances of serious heating and dry matter losses will be greatly reduced. For farmers with two silos to fill, it is a good idea to fill and seal one silo, fill and seal the second and then start feeding out of the first.

If the above practices are followed during filling, and if 2½ to 3 inches are removed from the silo each day during feeding, the losses from the surface of the silage each day will be very small. Research in the Crop Science Department indicates that losses are less than 0.1% per day from surfaces of well-managed silos.

C. Horizontal Silos

A successful horizontal silo must look like a tower silo on its side when filling is completed. A farmer would never build a tower silo with one side made of concrete or steel and the other side of wire mesh to hold the material in the silo. Clearly, excessive losses would result. Yet, many farmers still are unconvinced about the need to cover horizontal silos and leave one side of the silo (the top) open to air exposure.

(1) Rapid filling is critical.

(2) Filling the silo completely at one end and then moving towards the other, filling the silo fully in the procedure, is better than adding layers to the whole silo daily.

(3) *Cover with plastic.* Hold the plastic firmly in place and do not allow it to flop. The plastic does far more than just reduce surface spoilage. **Well-laid plastic will improve silage quality for several feet down into the silo.**

CONCLUSIONS

(1) Generally Ontario farmers are producing hay-crop silage with good protein quality.

(2) Proper attention to forage species selection and timely harvest will increase protein content.

(3) Air infiltration must be responsible for any serious rise in temperature of the silage. Therefore extreme care must be taken to stop air infiltration by packing to consolidate the silage and by sealing with plastic. Any significant delay in filling the silo may result in heat damage where the silage is in contact with air.

(4) Color and odor of the silage are not good indicators of protein digestibility unless the silage is extremely dark and/or has a burnt odor. Any indication of browning of the silage or burnt odors should be checked by a digestibility test.