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PROS AND CONS OF HARVESTING HAY VS. SILAGE

Neal P. Martin
Department of Agronomy and Plant Genetics
University of Minnesota
St. Paul, Minnesota 55108

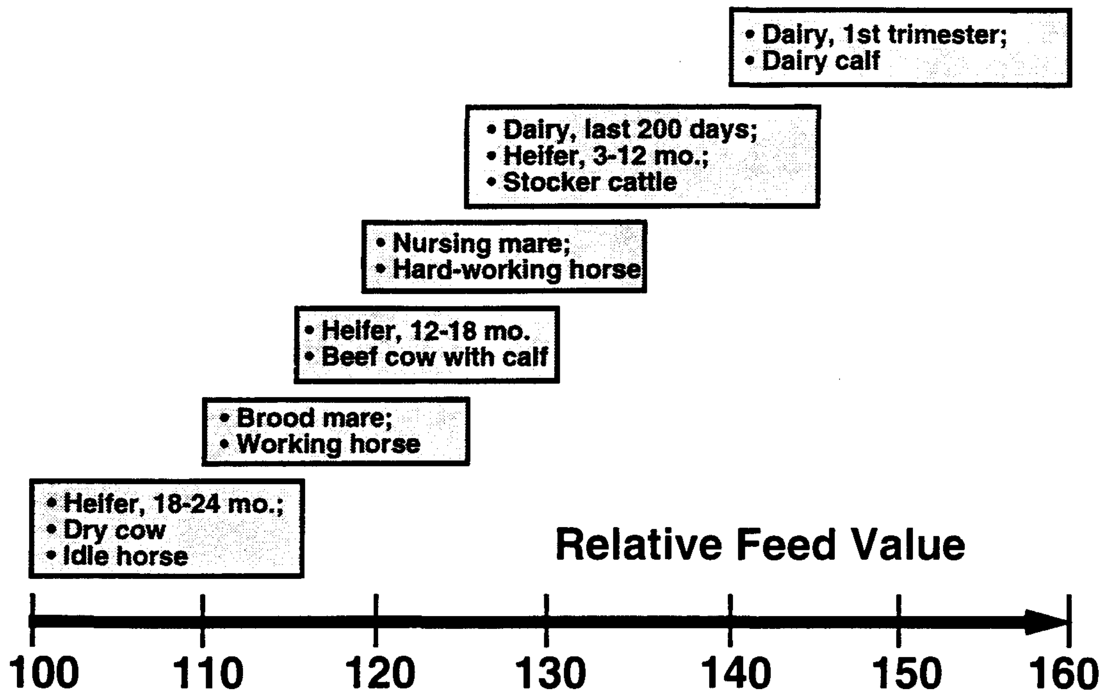
INTRODUCTION

The decision of harvesting hay or silage by dairymen is becoming more complex. Escalating machinery costs while milk prices have leveled off or declined have forced dairy operations to reduce forage harvest and storage costs. Traditionally dairymen have maintained both hay and silage systems, harvesting whichever alfalfa cutting they can at an immature stage without interference from rain for hay. Economics of our smaller herds are dictating reducing harvesting equipment to one line, hay or hay crop silage, or selling all harvesting equipment and utilizing grazing. The purpose of this presentation is to give strengths and weakness of hay and silage harvest and preservation.

Successful harvesting of legumes or grasses for hay or silage or corn silage must be based on the ability of the farming operation to harvest sufficient quantity of forage at the nutritional quality required by the class of livestock required. The high producing dairy cow in first trimester of milk production needs to be fed alfalfa testing 130 to 160 RFV, Figure 1 first and second cutting alfalfa will be at late bud stage for 6 to 7 days under Minnesota conditions. Thus, the harvest capacity of hay or silage dictates the success of the harvest system.

The advantages of hay over silage are: lower storage volume, ease of transport, easier marketing, less affective fiber problems, and fits smaller operations. Silage systems offer greater mechanization of forage handling and feeding, less labor, and less hindrance from weather. Chopped material is also more conveniently used for total mixed rations. However, silage systems require more power or energy for harvesting, handling and feeding and a greater machinery and storage structures, both of which lead to a greater expense than hay. Average total crop loss is 24-28% when hay is properly stored inside a shed or barn. Most of this loss occurs during harvest with about 5% loss during storage. Outside storage losses of hay average 15-20% of dry matter. Average total loss in silage production is 14-24%, with about half of this loss occurring during storage. Since neither offer a clear advantage over the other (using a false assumption all hay is stored inside), both will be used in animal agriculture. My purpose today is to review each system, hay and silage; however, with either system economies of scale and cost control are of utmost importance.

Fig. 1 **Forage Quality Needs of Cattle**



A. HARVEST AND PRESERVATION EXPECTATIONS

From the moment the crop is cut until it is delivered to the animal, biological and mechanical processes take place that decrease quantity and nutritional quality of feed.

1. **Preservation goal:** conserve the digestible fiber, protein, and energy in the forage and maintain protein in form that can be effectively utilized by the ruminant.

2. **Preservation involves:** restricting the actions of bacteria, yeasts, molds, and plant enzymes, as well as browning reactions.

B. HAY VERSUS SILAGE PRESERVATION

1. **Hay-making and silage-making differ by their moisture preservation strategies**

2. **Fresh forage contains [80%] moisture**

3. **"Juice" contains** soluble protein and soluble sugars

   a. Provides medium

   b. Provides activity

4. **Moisture influences microorganisms and processes, Figure 2.**

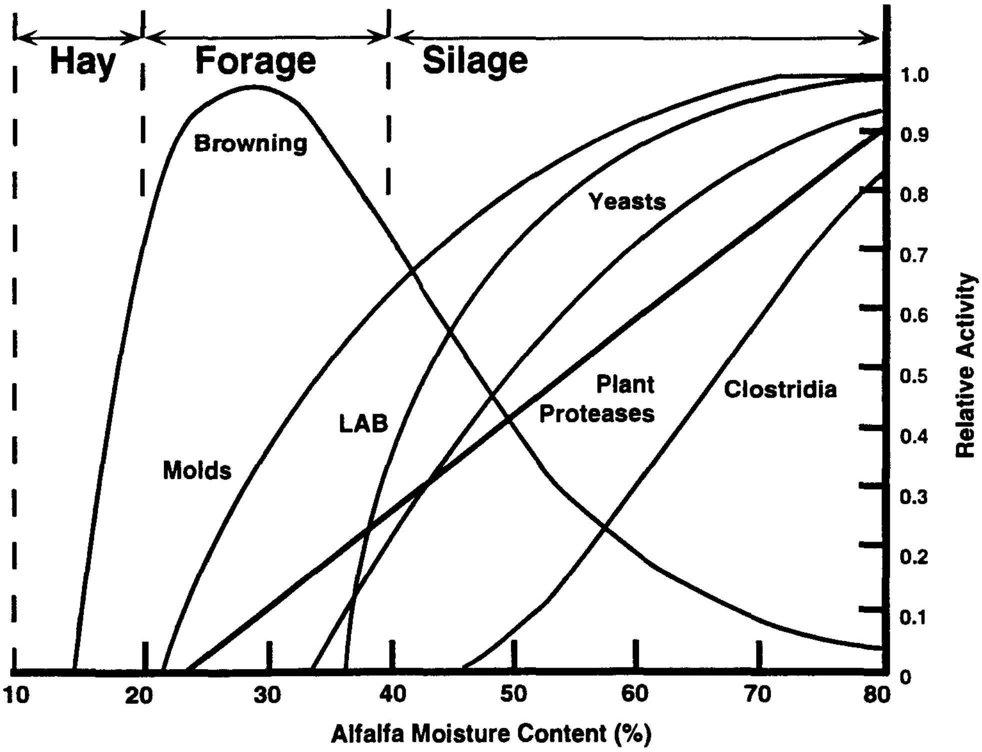
   a. Yeasts and molds are microbes that degrade forage in the presence of oxygen

   b. Lactic acid bacteria (LAB) and clostridia grow without oxygen-LAB are beneficial; but clostridia are detrimental

   c. Plant proteases are enzymes which solubilize plant proteins

   d. Browning reaction is a chemical reaction associated with high temperatures

Fig. 2 Effects of forage moisture content on various microorganisms and processes in forage.



5. **Fundamental strategy in Preservation of Hay**

6. **Fundamental strategy in Preservation of Silage**

   In silage-making, the forage is stored in oxygen-free (anaerobic) conditions which stimulate growth of LAB and prevent the growth of molds and many yeasts. Bacterial growth without O_2 is called fermentation.

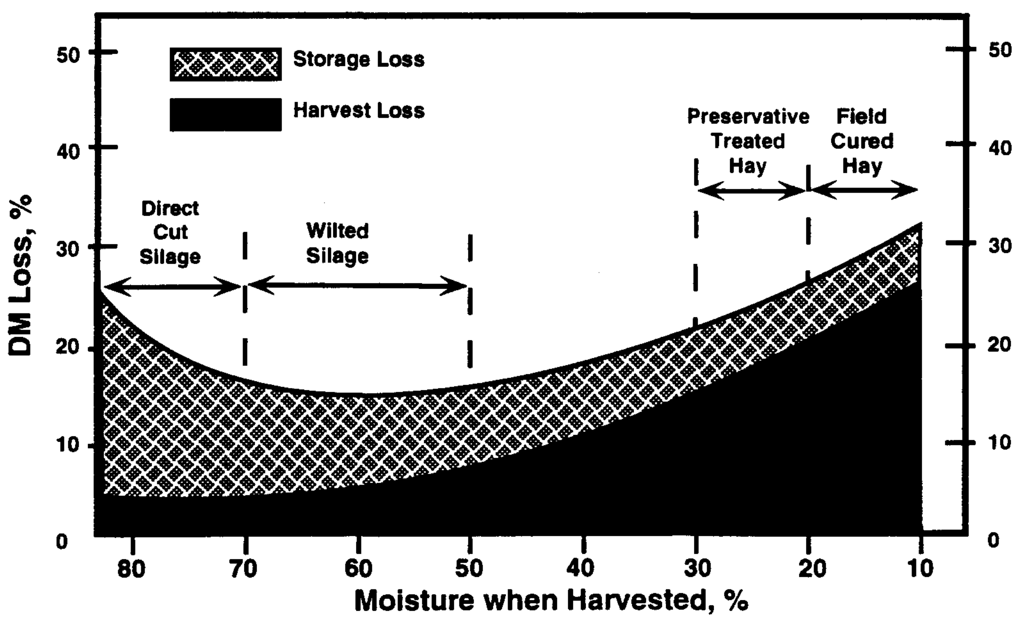
7. **In a moisture range of 20% to 40% neither hay nor silage is effective in preserving forage.**

C. DRY MATTER LOSSES IN HARVEST AND STORAGE

1. **Hay** - large field and small storage losses

2. **Silage** - small field and large storage losses

Fig. 3 **Dry matter losses during harvest and storage as dependent on forage moisture content at harvest.**



Source: Hoglund (1964)

D. PRINCIPLES OF ENSILING

1. **Aerobic Phase** O_2 trapped in the air spaces of silage mass is consumed by plant respiration and aerobic microbes

   respiration process is most detrimental to silage quality

   a. loss of dry matter
   b. plant contents are sugar; preservation and nutritional value
   c. prolonged actions allow yeasts and molds to grow
   d. heat produced increases temperature

2. **Lag Phase**

   Plant cell membranes break down allowing the cell juices to become a growth medium for bacteria

3. **Fermentation Phase**

   The anaerobic LAB begin to grow and multiply rapidly, increasing their numbers to approximately 1 million/g of forage

   a. Homofermentative LAB (species in four genera - Table 1) produce only lactic acid from fermenting glucose and other 6-carbon sugars

   b. Heterofermentative LAB produce ethanol or acetic acid plus CO_2 and lactic acid

   c. Natural bacteria a mixture

TABLE 1. LACTIC ACID BACTERIA IN SILAGE

Homofermentative	Heterofermentative
Lactobacillus plantarum	Lactobacillus brevis
Lactobacillus casei	Lactobacillus buchneri
Pediococcus cerevisiae	Lactobacillus fermentum
Streptococcus faecalis	
Streptococcus lactis	
Streptococcus faecium	

SOURCE: McDonald (1981).
Taken from Muck and Bolsen, 1991.

4. Stable Phase

when pH reaches 3.8 - 5.0, the bacteria die out, and the silage

5. Detrimental Processes

a. Plant enzymes
breakdown proteins to soluble non-protein nitrogen (NPN)

b. Enterobacteria and Listeria (aerobic or anaerobic conditions)
form early in ensiling. They produce LA, acetic acid and ethanol.

Listeria bacteria cause listeriosis, disease dangerous to both humans and animals, grows in O_2 and pH's > 5.5

c. Clostridia (anaerobic condition)

grow late in ensiling (pH of 7.0) forming LA and free amino acids, this fermentation looses 50% of DM and 20% of energy, Table 2

TABLE 2. PATHWAYS IN SILAGE FERMENTATION

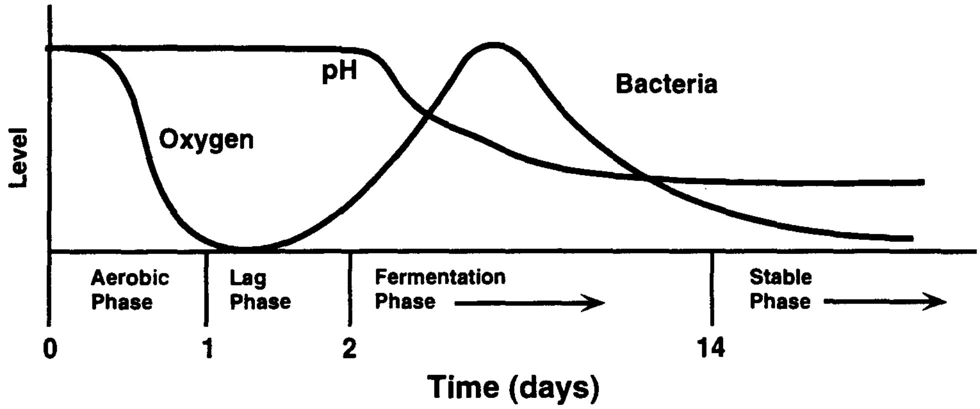
Pathway	Recovery, % Dry Matter	Recovery, % Energy
Homofermentative		
1 Glucose → 2 Lactic acid	100	97
Heterofermentative		
1 Glucose → 1 Lactic acid + 1 Ethanol + 1 CO_2	76	97
3 Fructose → 1 Lactic acid + 2 Mannitol + 1 Acetic acid + 1 CO_2	95	98
Clostridial		
2 Lactic acid → 1 Butyric acid + 2 CO_2 + $2H_2$	49	81
3 Alanine → 2 propionic acid + 1 Acetic acid + 2 NH_3 + 1 CO_2	78	81
Yeast		
1 Glucose → 2 Ethanol + 2 Co_2	51	97

SOURCE: McDonald (1981)
Taken from Muck and Bolsen, 1991.

6. Feedout Phase

The largest loss of DM and nutritional value can occur as aerobic microbes consume

Fig. 4 **Sequences of phases in the silo for a good fermentation.**



Source: Pitt, R.E. 1990.

E. SILAGE MANAGEMENT

1. Dry Matter Losses must be minimized

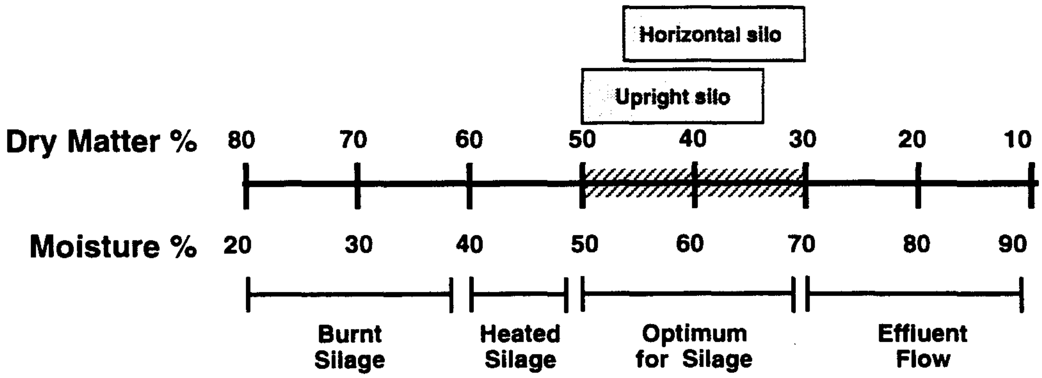
a. Unavoidable

8 - 30% DM
field, plant respiration, and primary fermentation

b. Avoidable

2-40% or more DM
effluent, secondary fermentation and aerobic deterioration

Fig. 5 Optimum DM content for good silage-making.



Source: Pitt, R.E. 1990.

2. Challenges for making good alfalfa silage

a. Minimum respiration losses

b. Lactic acid fermentation requires:

1) sufficient plant sugars

2) lactic acid bacteria on forage

3) anaerobic conditions

4) proper dry matter content

5) harvest with sufficient sugars

TABLE 3. FACTORS AFFECTING SUGAR CONTENT OF HAYCROP FORAGE BEFORE FERMENTATION

Factor	Effect
Solar radiation on day of cutting	Sunny periods promote the deposition of sugar in the growing plant.
Hour of cutting.	Sugar levels are higher late in the day, lowest in the morning. However, early mowing is recommended to reduce wilting time.
Length of wilting period.	Plant respiration during drying depletes sugars.
Rain damage in field.	Rain on mowed forage leaches out sugars and increases respiration.
Rate of silo filling.	Delays in attainments of anaerobic conditions extend respiration, decrease sugars.
Compaction of forage.	Good compaction shortens the aerobic phase, leaves more sugars for fermentation.
Sealing of silo.	Good sealing keeps out oxygen, limits sugar loss through respiration.

SOURCE: Pitt, R.E., 1990.

c. Provide sufficient LAB - addition of inoculants of LAB, Muck and Bolsen, 1991.

at least 10 X the natural population

1) improved fermentation with alfalfa in 84% of studies

2) reduced ammonia - nitrogen levels in 60% of studies

3) improved DM recovery 74% of studies

4) improved beef and dairy cattle performance 20% - 40% of studies, Table 4.

TABLE 4. RESPONSES IN MILK PRODUCTION FOR INOCULATED VS. CONTROL ALFALFA SILAGES

Ratio of LAB, inoculant to natural population	Milk production response, inoculated as a % of control
151	101.5
140	106.2
110	103.0
46	100.0
36	100.4
18	102.2
11	108.0
	Avg 103.0
8	97.8
7	100.7
6	99.6
4	98.5
1	100.0
1	98.5
	Avg 99.2

SOURCE: Satter et al. (1988).
Taken from Muck and Bolsen, 1991.

See "Using Bacterial Inoculants in Making Alfalfa Silage" to determine when it is most profitable to add inoculants to alfalfa harvested for silage.

d. Minimized protein solubility

TABLE 5. FACTORS AFFECTING PROTEIN SOLUBILIZATION IN SILAGE

Factor	Effect
Crop Species	Leguminous protein, especially that of alfalfa, is more rapidly solubilized in the silo.
Silage temparature	Solubilization rate doubles with a 20°F increase in temperature.
DM content	Solubilization is fastest in direct-cut forage (20% DM content); the rate is reduced by 60% at 50% DM content.
pH	Solubilization is fastest at pH 6; the rate is decreased by 85% at pH 4.
Time in silo	Proteases lose their activity after 1-2 weeks in the silo. Most solubilization occurs in the first few days of ensiling.

SOURCE: Pitt, R.E., 1990.

Using Bacterial Inoculants in Making Alfalfa Silage

by R. E. Muck
USDA, Agricultural Research Service
U.S. Dairy Forage Research Center, Madison, WI

What are bacterial inoculants?

One of the most common additives for making alfalfa silage is the bacterial inoculant. Inoculants contain lactic acid bacteria and supplement the natural lactic acid bacteria on the crop to guarantee a fast and efficient fermentation in the silo. These lactic acid bacteria have been isolated from silages or silage crops and selected because they grow rapidly under a wide variety of conditions and produce mostly lactic acid when growing on the main sugars in the crop.

What should they do?

When the inoculant bacteria dominate the silage fermentation, they change the products formed during ensiling. Average, naturally-occurring lactic acid bacteria produce acetic acid, alcohol and carbon dioxide in addition to lactic acid. In contrast, the inoculant bacteria produce a much greater proportion of lactic acid. This shift in fermentation products lowers silage pH and reduces the loss of dry matter during ensiling by approximately 2 percentage units.

Inoculants have been shown to improve animal performance: increasing feed intake, liveweight gain, milk production and feed efficiency. The cause of the improved performance is uncertain but appears to be due primarily to increased silage digestibility. Other minor factors may be improved palatability, enhanced rumen microbial growth, and increased dietary nitrogen retention.

These additives have had little effect on spoilage of silage or heating in the feed bunk. The shifts in fermentation caused by inoculants may increase bunk life one time and decrease it another. Normally, these effects are small. Inoculant manufacturers are looking for microorganisms which will consistently improve bunk life, and so inoculants should improve in this area. For the present, do not expect an inoculant to provide substantial benefits in bunk life.

Guidelines for profitable inoculant use

To get the most benefit from inoculants, a number of factors must be considered: what to purchase, the method of application and the conditions under which an inoculant will be most effective.

What to purchase

In purchasing inoculants, look for products formulated for use on alfalfa or haylage. This will help insure success. Second, be concerned about the types and numbers of bacteria applied by the inoculant. Inoculants should contain *Lactobacillus plantarum*, other *Lactobacillus* species, *Pediococcus* species, and/or *Streptococcus* (or *Enterococcus*) *faecium*. Ignore the size of the product or the numbers of bacteria in the product. Instead be concerned about how many live or viable bacteria will be delivered to the crop. Look for products that will guarantee an application of at least 100,000 viable lactic acid bacteria (or colony forming units) per gram wet alfalfa or 90 billion per ton wet alfalfa. For example, the package may say that it contains 5 trillion live lactic acid bacteria and treats 25 tons of crop. Five trillion bacteria divided by 25 ton is 200 billion bacteria per ton of crop or more than twice the minimum recommended level. Third, these bacteria cannot move around by themselves. So it is important to mix them thoroughly with the forage. In this regard, products applied as a liquid are generally easier to apply uniformly.

How to apply

Application of products varies with the type purchased. Products that are applied in dry form are typically applied with a Gandy™-type applicator either mounted on the forage harvester or at the silo blower. Applying at the harvester is better because it provides several opportunities for the inoculant to be mixed with the forage.

Many products are applied as liquids after dilution with water. If at all possible, use unchlorinated water for diluting these products. Chlorine will kill lactic acid bacteria just like it does other bacteria. Some inoculants contain compounds to inactivate the chlorine, but many do not. If you need to use chlorinated water, use a swimming pool test kit and make sure the residual chlorine level is below 1 ppm. If it is above 1 ppm, allow the water to sit exposed to air overnight to remove excess chlorine, and test the water again before using.

Liquid products can also be added either at the forage harvester or at the silo. Small, electrically-operated diaphragm pumps are usually used to apply inoculants on forage harvesters, with the product being sprayed on the crop between the knives and blower. Liquid inoculants can be similarly applied at the silo. As with dry products, application at the forage harvester is preferred.

When should you use inoculants?

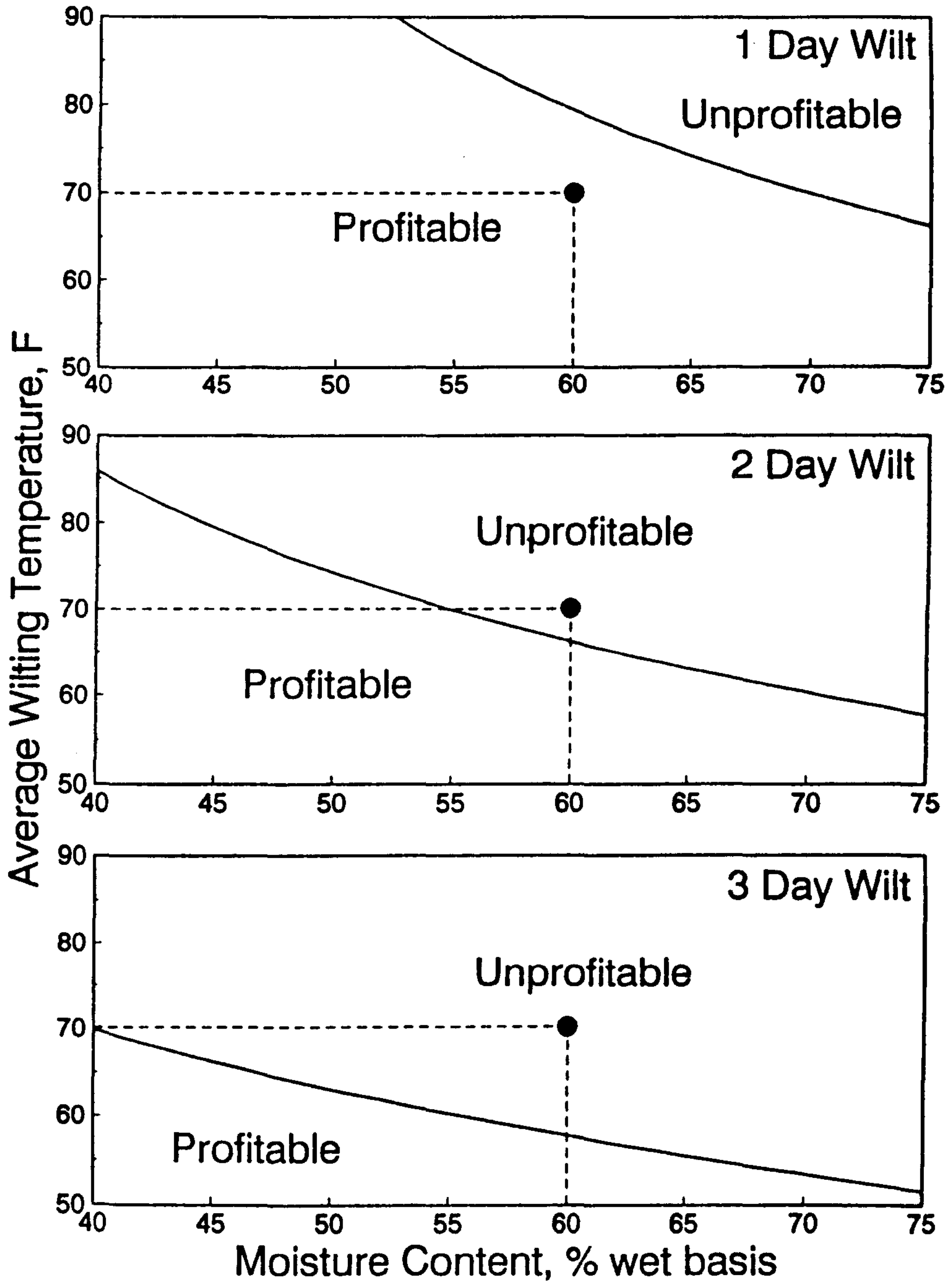
Inoculants are not always successful. A recent survey of research results found that inoculants affected fermentation in approximately 70-75% of the studies in grass and legume silages. Significant improvements in animal performance occurred about half as often. Inoculants fail most often because the forage contains high levels of natural lactic acid bacteria that overwhelm those added from the inoculant.

In our research, we have found that high natural levels of lactic acid bacteria normally occur with longer wilting times under warm, poor-drying conditions. The accompanying graphs will help you know when you are unlikely to gain a benefit from using a typical inoculant supplying 100,000 bacteria/g alfalfa. The lines represent the break-even conditions for using an inoculant. Inoculant use is unprofitable on average for conditions above the line; conditions below the line should be profitable.

To use the graphs, you need to know the average air temperature during wilting, the moisture content of the alfalfa at chopping, and the wilting time in days. Average temperature can be estimated from the high and low temperatures for the day. For example, if the alfalfa is mowed on Monday and chopped on Wednesday, average together these four temperatures: the afternoon highs for Monday and Tuesday and the morning lows on Tuesday and Wednesday. Moisture content can be determined by using a microwave oven or moisture tester or with practice using feel.

How wilting time affects whether to use an inoculant is shown in the following example, which is also marked on the graphs. If the average temperature is 70°F and the moisture content of the chopped alfalfa is 60%, then you should use an inoculant if there has only been one day between mowing and harvest. If the crop takes two or more days to reach 60% moisture, an inoculant would not be profitable.

If you follow these guidelines, inoculant use should make your good alfalfa silage even better, and you will limit inoculant use to those situations where you will make the most profit.



F. HAY HARVEST AND PRESERVATION

1. **Losses.** Each step in preservation process (mowing, raking, baling,and storing) causes a loss of forage dry matter, Table 8.

   mechanical: 7% - 31% DM

   biological: 3-4% DM/day; total 10-15%

TABLE 6. LOSSES FROM ALFALFA DURING HARVEST OPERATIONS

Operation	Percent of DM lost	Percent of leaves lost
Mowing	1	2
Mowing/conditioning	2-4	3-5
Raking (70%-20% moisture)	2-12	2-21
Tedding (70%-20%)	1-11	2-21
Baling, pickup and chamber	3-6	4-8
Baling at 18%	5-13	8-21
Stack wagon	15	24
Total	7-31	12-50

SOURCE: Hundloft (1965), Kjelgaard (1979), Rotz (1989).
Taken from Pitt, R.E., 1990.

TABLE 7. HOURS TO DRY ALFALFA FROM 80 TO 20 PERCENT MOISTURE IN CONSTANT WEATHER CONDITIONS

		Air Temperature, °F				
Sun[1]	Soil Conditions[2]	50	60	70	80	90
Cloudy	Wet	44	41	38	35	33
Cloudy	Dry	36	34	31	29	27
Sunny	Wet	16	16	15	15	15
Sunny	Dry	14	13	13	12	12

[1]Cloudy = 100 Btu/hr-ft^2 solar radiation; sunny = 280 Btu/hr-ft^2 solar radiation.
[2]Wet = 20% moisture content; dry = 9% moisture content

Source: Rotz and Chien (1985).
Taken from Bolson, et al., 1991

2. Factors affecting drying rate

a. Weather
- temperature
- relative humidity
- soil moisture
- solar radiation
- wind speed
- rain

TABLE 8. FINAL MOISTURE CONTENT (%) OF BALED HAY AS DEPENDENT ON AIR TEMPERATURE AND RELATIVE HUMIDITY

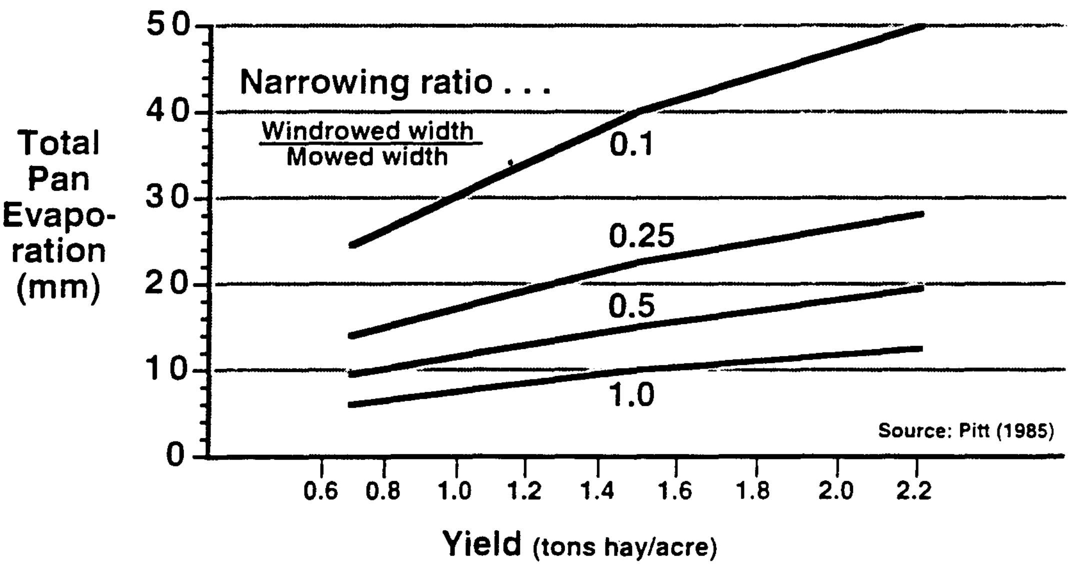
	Relative humidity (%)			
Temperature (°F)	30	50	70	90
70	10	13	21	39
80	8	12	20	38
85	7	10	18	37
95	5	8	16	36

SOURCE: Hill, et al., 1976.

b. Crop
  - species
  - maturity
  - yield
  - current crop moisture

c. Management
  - time of mowing
  - use of weather forecast
  - spread of the swath

Fig. 6 Effect of crop yield and narrowing of the swath on total pan evaporation required to dry alfalfa from 80% to 20% moisture content.



  - raking or tedding
  - swath structure
  - window inversion

TABLE 9. AVERAGE DAILY PAN EVAPORATION (mm) AT SELECTED LOCATIONS AND MONTHS

	May	June	July	August	September	October
California						
Alturas	5.0	5.8	7.0	6.7	4.7	2.9
Davis (non-irrigated)	7.6	9.0	9.8	8.6	7.0	4.6
Fresno	7.8	9.5	10.3	9.0	6.5	4.2
Sacramento	6.9	8.9	9.4	8.4	6.4	4.2
San Diego	5.3	4.6	5.7	5.6	4.8	4.0
Colorado						
Denver	6.2	7.5	8.2	7.6	5.5	4.0
Grand Junction	8.2	10.4	10.8	9.2	6.8	4.5
Delaware						
Wilmington	4.6	5.3	5.3	4.9	3.9	2.8
Georgia						
Atlanta	5.8	5.9	5.9	5.6	4.4	3.4
Augusta	5.2	5.5	5.4	5.3	4.2	3.5
Columbus	5.6	5.6	5.1	5.1	4.4	3.6
Michigan						
Alpena	3.9	4.8	5.3	4.1	2.5	1.6
East Lansing	5.2	5.9	6.2	5.2	3.8	2.5
Grand Rapids	5.0	6.0	6.1	5.2	3.4	2.3
Minnesota						
Duluth	4.3	4.7	5.5	4.4	2.6	2.0
Minneapolis	5.2	6.1	6.7	5.5	3.4	2.5
Waseca	5.4	7.1	7.2	5.7	4.3	NA
New York						
Aurora	4.5	5.4	5.9	4.9	3.4	2.4
Buffalo	4.3	5.5	5.9	4.8	3.4	2.3
Canton	4.9	6.1	5.9	4.7	3.1	2.2
Geneva	4.7	5.7	6.4	5.1	3.5	2.3
Ithaca	4.3	5.0	5.4	4.6	3.2	2.1
Pennsylvania						
Confluence	4.1	4.6	4.7	3.9	2.9	1.2
Harrisburg	5.2	5.9	6.4	5.4	3.7	2.6
Pittsburgh	4.7	5.4	5.7	5.0	3.6	2.7
Scranton	4.6	5.2	5.3	4.6	3.1	2.2
Vermont						
Burlington	3.8	4.7	5.0	4.3	2.6	1.8
Washington						
Olympia	3.3	3.9	4.9	4.1	2.6	1.2
Spokane	5.2	6.5	8.9	7.2	4.5	2.2
Yakima	5.5	6.5	8.1	6.6	4.4	2.4
Wisconsin						
Arlington	5.9	6.4	6.9	5.7	4.1	2.7
Green Bay	4.4	5.2	5.6	4.5	2.9	2.0
LaCrosse	5.2	5.9	6.1	5.2	3.2	2.7
Marshfield	5.5	5.5	5.9	5.2	3.7	2.7

Source: Fransworth and Thompson (1982).

Fig. 7 **Days Required to Dry Alfalfa**

	Duluth	Mpls.
June evaporation rate (mm/day)	4.7	6.1
Days to evaporate 10mm e.g. 10/4.7 = 2.1 days	2.1	1.6
Days to evaporate 22mm e.g. 22/4.7 = 4.7 days	4.7	3.6

3. Quality Changes

a. leaf shatter: 5-15% in DM
b. leaching loss: 5-20% in DM
c. rain damage: 10-20% in DM
d. soluble carbohydrates: decrease
e. crude protein: constant to decrease
f. dry matter digestibility: declines
g. fibers: increase

TABLE 10. CHANGES IN ALFALFA QUALITY WITH RAIN DAMAGE

Condition	CP	DDM	NDF	RFV	DM
	----------	% of dry wt.	----------	index	ton/ac
Standing Crop	23	66	43	143	2.0
Hay: no rain damage	20	60	46	121	1.7
Hay: rain damage	20	53	54	91	1.5

SOURCE: Adapted from Collins. 1988.

4. Management

TABLE 11. SUMMARY OF GOOD HAY-MAKING PRACTICES

Practices	Reasons	Benefits
Mow early in the day.	Allow a full day's drying	Faster drop in moisture. Less respiration loss. Less likelihood of rain damage. Higher quantity and quality.
Form into spread swath.	Increase drying rate.	Faster drop in moisture Less respiration loss. Less likelihood of rain damage. Higher quantity and quality.
Rake or ted at 40% to 50% moisture content.	Increase drying rate.	Faster drop in moisture. Less respiration loss. Less likelihood of rain damage. Less leaf shatter. Higher quantity and quality.
Bale at 18% to 20% moisture.	Optimize preservation.	Less leaf shatter. Inhibition of molds and browning. Low chance of fire. Higher quantity and quality.
Store hay under cover.	Protect from rain and sun.	Inhibition of molds and browning. Less loss from rain damage. Higher quantity and quality.

SOURCE: Pitt, R.E., 1991.

5. Storage

Processes to be controlled or inhibited are mold growth and browning reaction.

a. Mold growth

1) mold grows

- 20% to 35% moisture
- consume nutrients → CO_2, H_2O and heat
  respiration causes heating → hay fires
- produce toxins detrimental to animal health and decrease food intake
- produce spores - if inhaled cause lung disease

TABLE 12. CHANGES IN ALFALFA HAY COMPOSITION DURING SIX-MONTHS STORAGE

Hay moisture content at harvest,	DM loss, %	Digestible DM loss, %	Crude protein loss, %	Increase in ADIP, %	Increase in NDF content, % of the hay
11 to 20	5	6	6	1	1
20 to 25	5	12	9	7	4
25 to 34	11	14	8	9	5

Note: Losses are expressed in terms of percent of initial content.

SOURCE: Rotz and Abrams (1988).
Taken from Pitt, R.E. 1991.

presence reduces value of hay sold

b. Browning

1) If mold growth heats up hay to 100°F or higher, severe browning reactions begin. Amino acids and sugars combine to form ADF-CP, insoluble N - unavailable to animals.

2) Reactions are undesirable

- increases ADF and ADF-CP; at high levels decrease DM digestibility
- these reactions may lead to spontaneous ignition

5. Hay Additives

a. enhance field drying

b. increase moisture range for safe storage

c. effectiveness of additive

application
mix product thoroughly with forage
minimize loss active ingredients to environment
minimize slow down in harvesting
prevent damages

TABLE 13. HAY ADDITIVES USED TO PROMOTE PRESERVATION

Drying agents	Inhibitors
Potassium carbonate	Ammonia
Calcium carbonate	Urea
Methyl esters	Inoculants
Formic acid	Propionic acid
	Acetic acid
	Buffered acids
	Acid salts
	Ethoxyquin

Note: Not all of the additives listed are effective.
SOURCE: Pitt, R.E., 1991

APPENDIX A. TYPES OF SILAGE ADDITIVES AND ADDITIVE INGREDIENTS[1,2]

Stimulants			Inhibitors[6]		
Bacterial inoculants[3]	Enzymes[4]	Substrate sources[5]	Acids	Others	Nutrient sources
Lactic acid bacteria	Amylases	Molasses	Formic	Ammonia	Ammonia
	Cellulases	Glucose	Propionic	Urea	Urea
	Hemicellulases	Sucrose	Acetic	Sodium chloride	Limestone
	Pectinases	Dextrose	Lactic	Carbon dioxide	Other minerals
	Proteases	Whey	Caproic	Sodium sulfate	
		Beet pulp	Benzoic	Sodium hydroxide	
		Citrus pulp	Acrylic	Formaldehyde	
			Hydrochloric	Paraformaldehyde	

1 Adapted from McDonald (1981), Holland and Kezar (1990), and Wilkinson (1990).
2 Not all additives or ingredients used for silage are listed, not all listed are approved for use on ensiled material intended for livestock.
3 Most contain live cultures of LAB from Genus Lactobacillus, Pediococcus, or Streptococcus.
4 Most enzymes are microbial by-products having enzymatic activity.
5 Most ingredients can also be listed under nutrient sources.
6 Some inhibitors work aerobically, suppressing the growth of yeasts, molds, and aerobic bacteria; others work anaerobically, restricting undesirable bacteria (i.e., clostridia and Enterobacteriaceae), plant enzymes, and, possibly lactic acid bacteria.

Taken from Muck and Bolsen, 1991.

TABLE 14. COMPARISON OF ALFALFA HAY AND HAYLAGE

Test	Trial #1[1] Haylage	Trial #1[1] Hay	Trial #2[2] Haylage	Trial #2[2] Hay
	% of dry wt.			
Moisture	58.7	15.0	59.4	14.1
DM	41.3	85.0	40.6	85.9
RDF	26.5	25.7	31.6	31.6
NDF	35.4	35.2	40.0	41.4
Ash	9.6	9.1	11.2	10.2
CP	21.2	19.7	19.9	16.5
NPN, % of N	49.4	7.7	54.4	8.3
RFV index	179	182	149	144

SOURCE: Adapted from Boderick. 1995. JDS 78:320.
[1]Trial 1 was 2nd cut
[2]Trial 2 was 1st cut

TABLE 15. COMPARISON OF ALFALFA HAY AND HAYLAGE

Cow performance	Haylage	Hay	AS + FM	AH + FM
Trial #1	lb/head/day			
DM intake	49.5	51.3	51.3	52.4
BW change	-0.88	0.86	0.44	1.14
Milk	79.0	78.5	81.8	79.9
3.5 FCM	76.8	73.7	79.9	75.7
	% of dry wt.			
Fat	3.34	3.14	3.36	3.17
Trial #2	lb/head/day			
DM intake	48.4	54.1	51.0	54.1
BW change	-0.84	1.12	-0.09	0.99
Milk	76.1	80.3	82.5	82.5
3.5 FCM	76.1	79.2	82.1	81.6
	% of dry wt.			
Fat	3.53	3.42	3.47	3.45

SOURCE: Boderick, 1995. JDS 78:320.