Baled Silage

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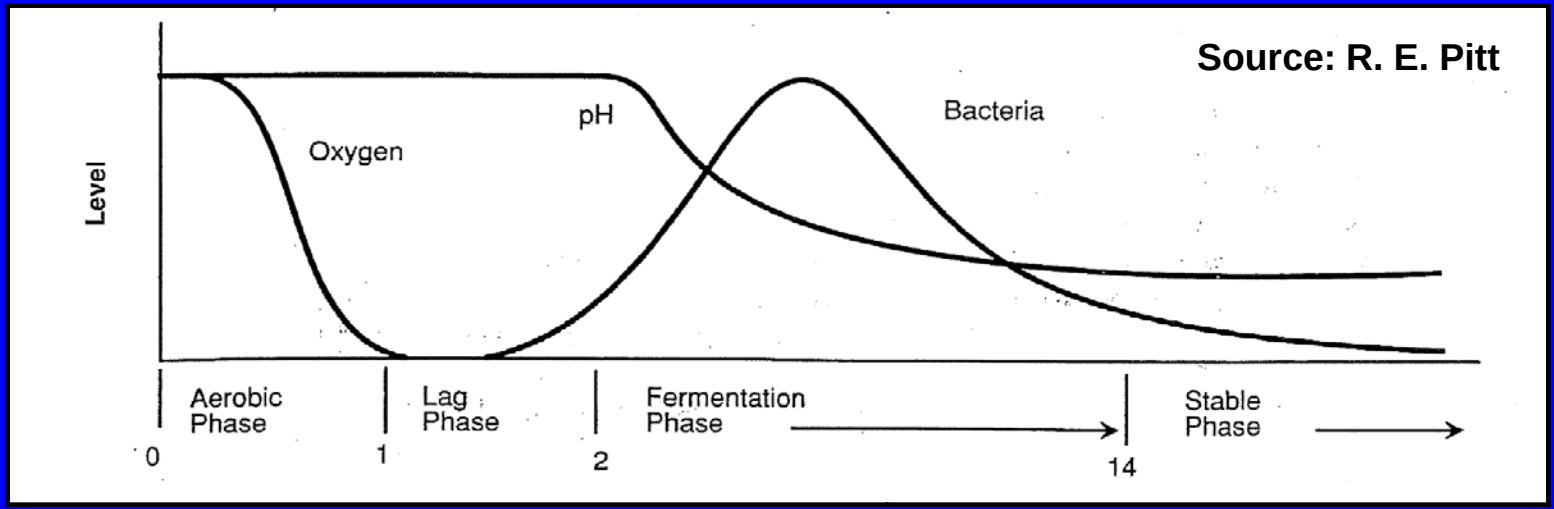
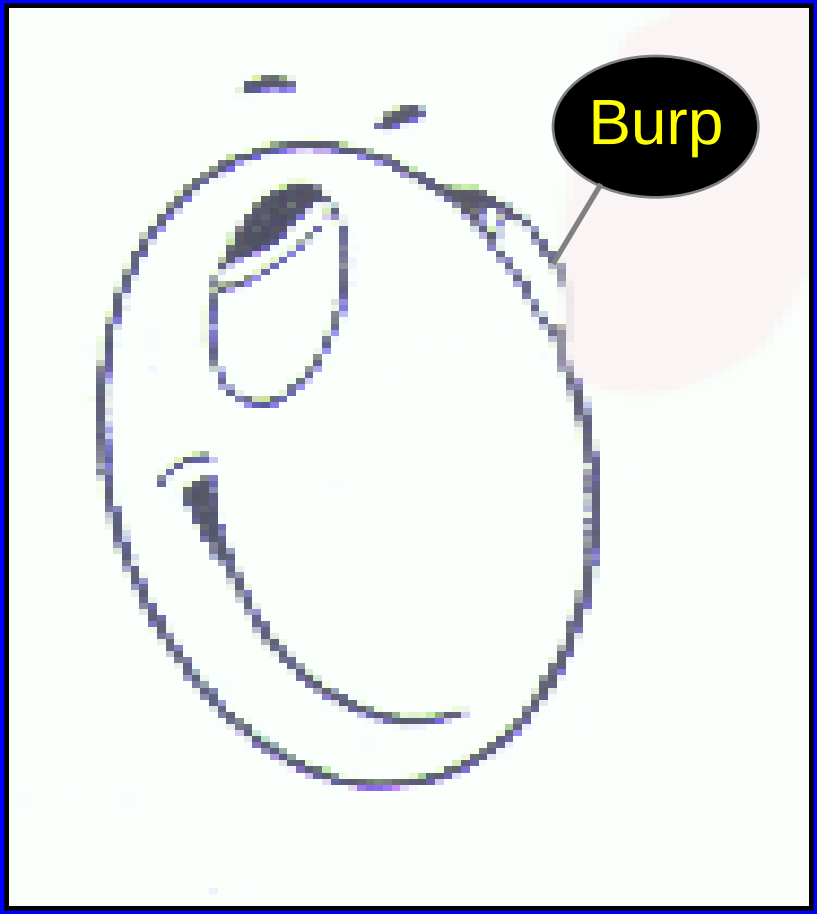
Goal: Silage Preservation

- ***Anaerobic (without air) bacteria convert plant sugars to lactic acid.***
- ***This process lowers the pH and preserves the forage as silage.***

Sequence of Phases in the Silo for Good Fermentation



Lactic Acid Bacteria Consuming Sugar



Lactic Acid, The "Good Silage" Acid

Regardless of silo type, most management principles are the same.

- *start with high-quality forage*

- *manage the moisture content of the forage*

- *excessively wet or dry silages can both be problematic*
- *standards vary somewhat with silo type*

- *eliminate air*

- *maintain silo integrity*

- *particularly important for plastic structures*

- *avoid poor feedout management*

- *too much exposure to air is problematic*

Baled Silage:

Some Specifics

1. Baled Silage vs. Hay

2. Baled vs. Conventional Silage

3. Crop Factors

4. Moisture Management

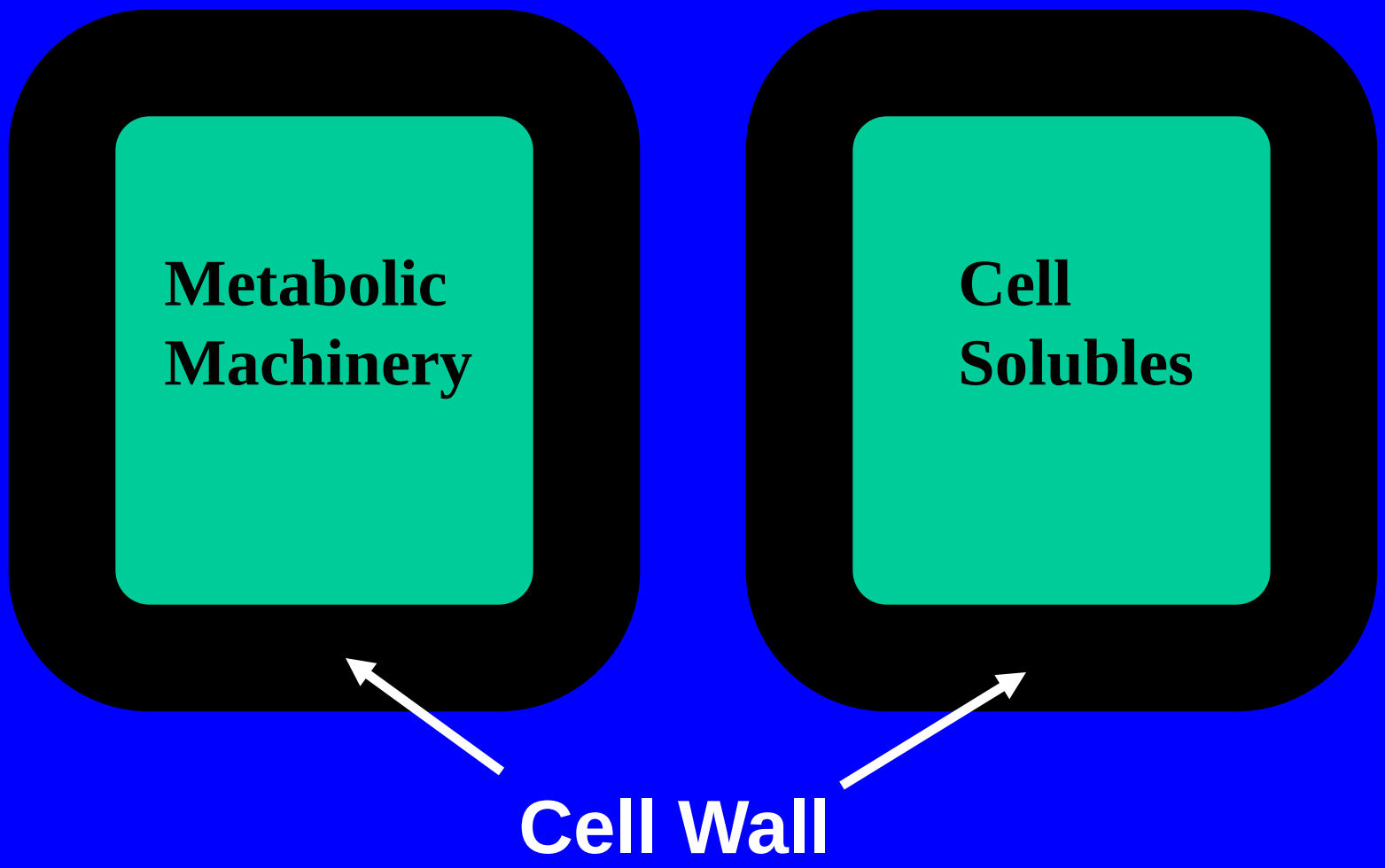
5. Elimination of Air

6. Feedout Management

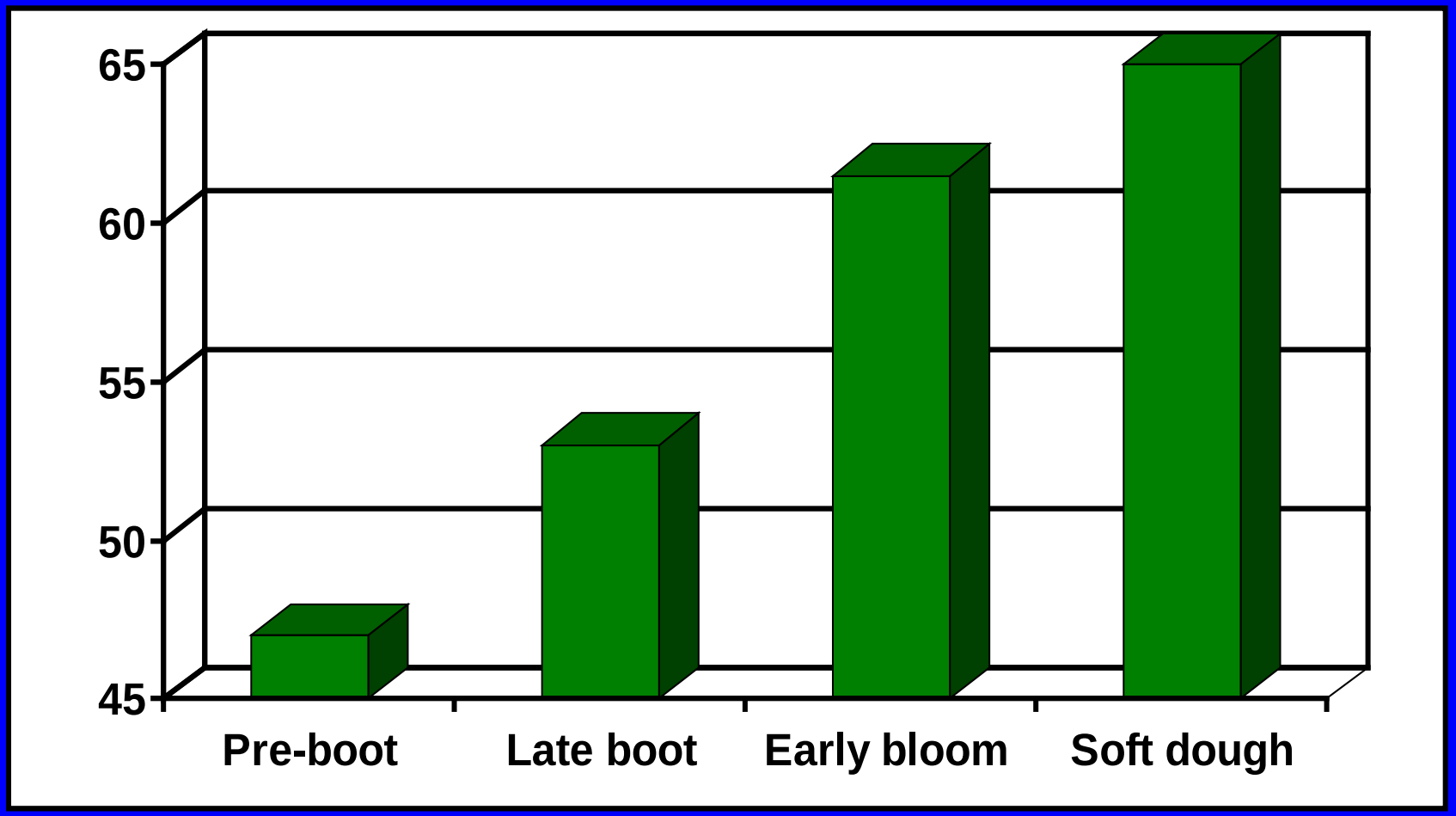
1. Why Choose Baled Silage over Hay?

- ***well-made baled silage will often exhibit better quality characteristics than corresponding hays***
  - ***increased leaf losses (hay)***
  - ***harvest delays (inclement weather)***
  - ***rain damage***
  - ***spontaneous heating***
  - ***weathering after baling (outdoor storage)***

Plant Cell



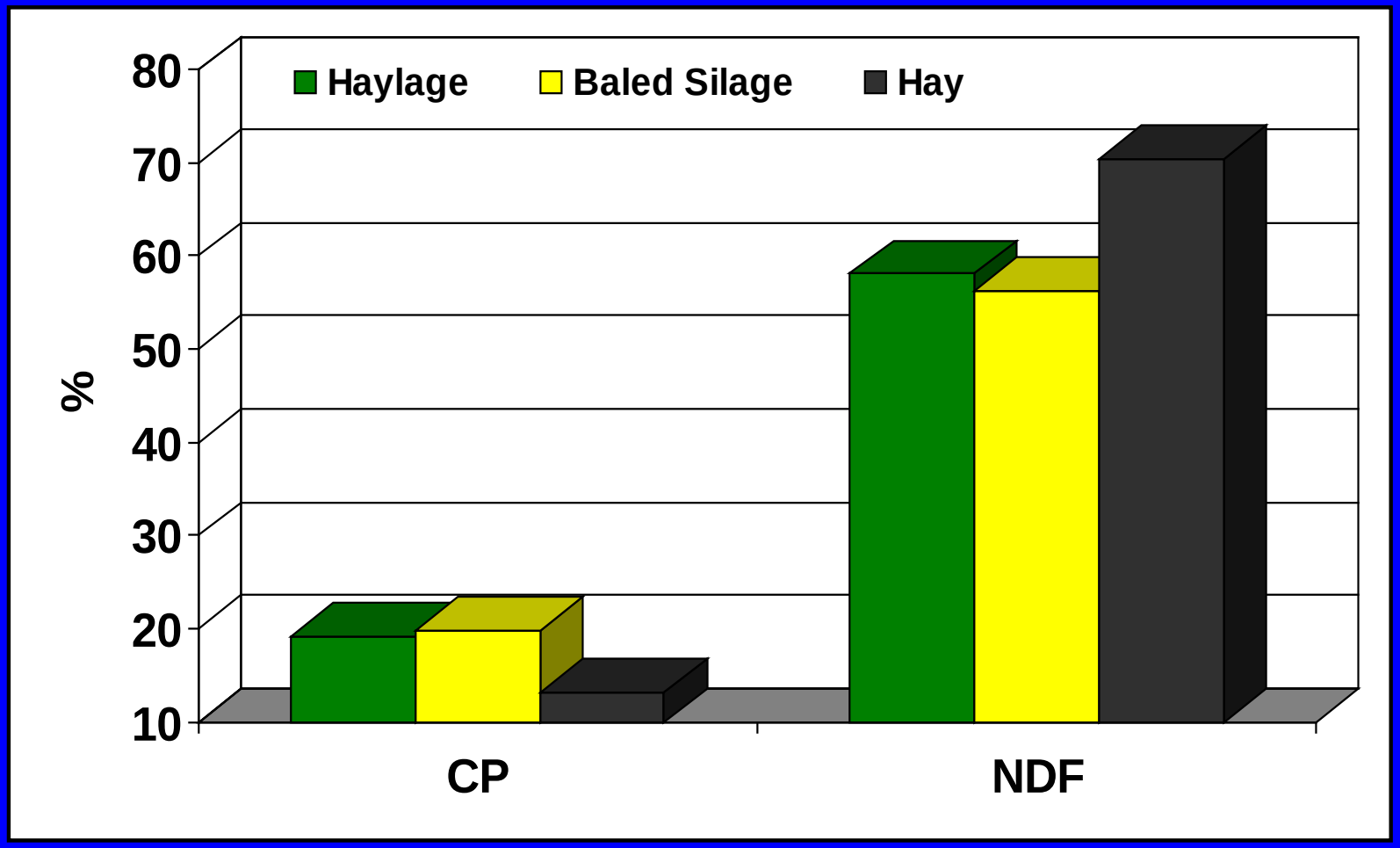
Delaying Harvest: NDF (%) within KY-31 Tall Fescue at Various Maturities



Source: C.S. Hoveland and N.S. Hill, University of Georgia

Delaying Haying for Favorable Weather

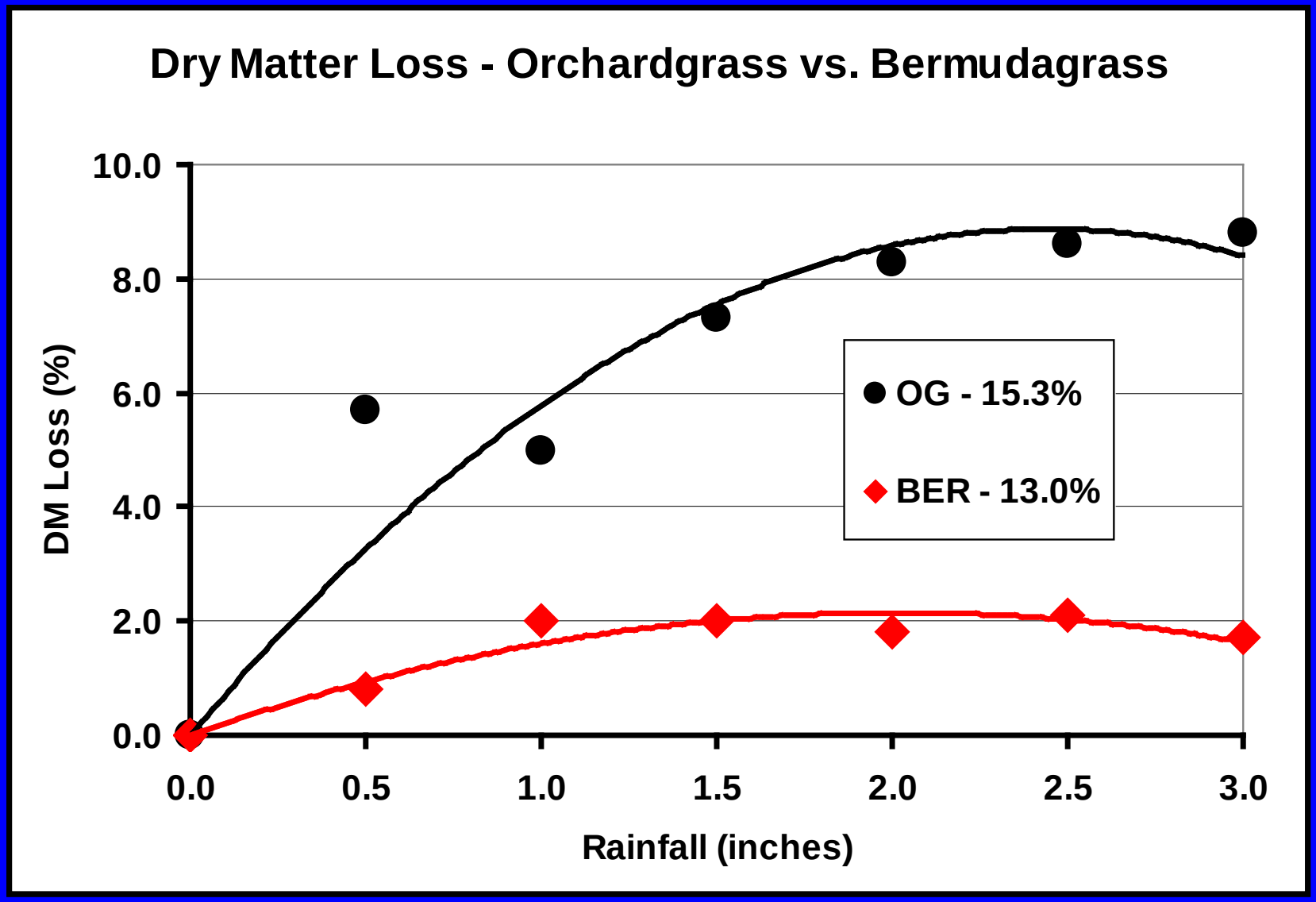
Annual Ryegrass



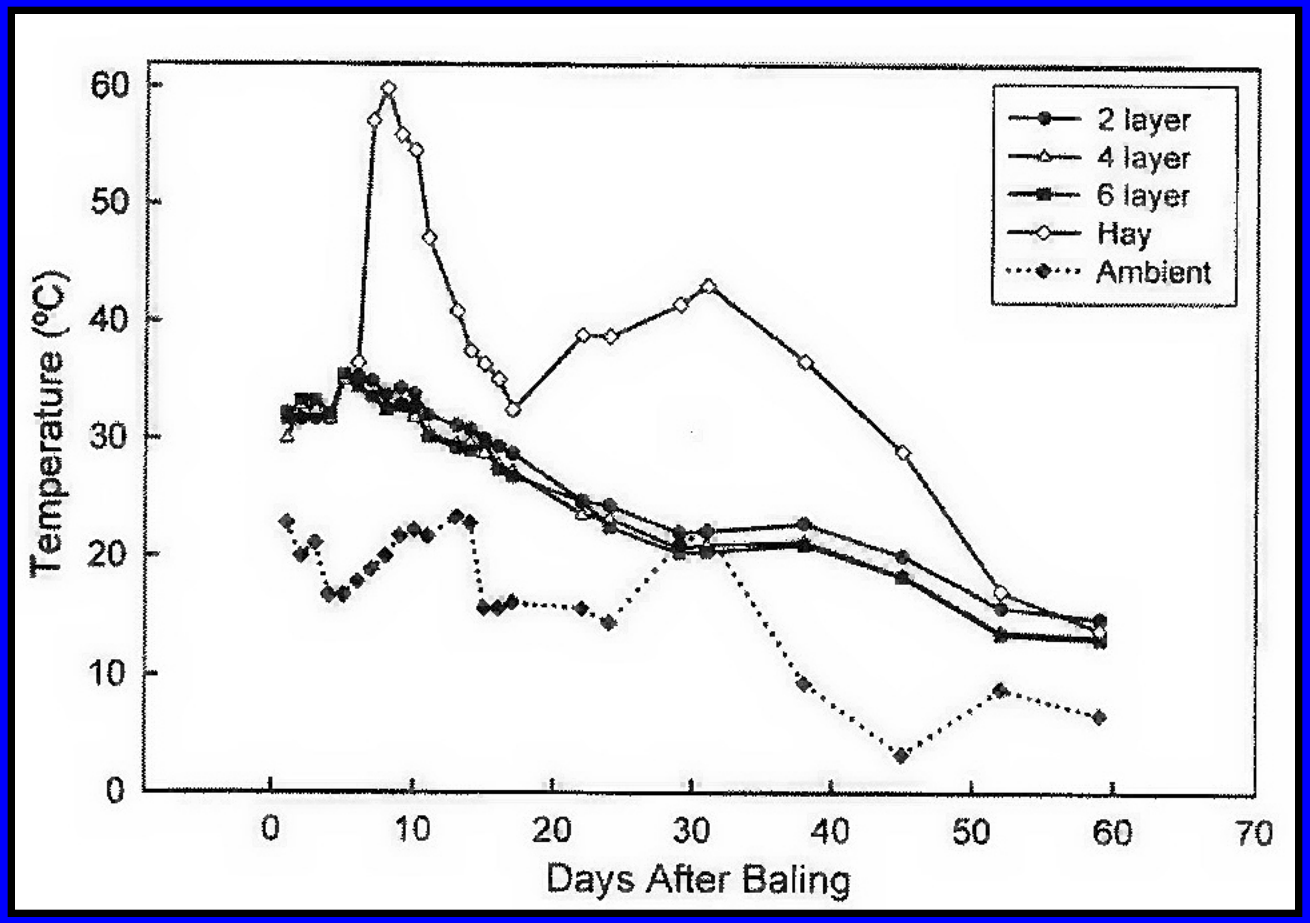
McCormick et al. (1998): ***annual ryegrass (1993-94); silages harvested mid-April, hay in early May***

Risks of Rain Damage in Hay Production

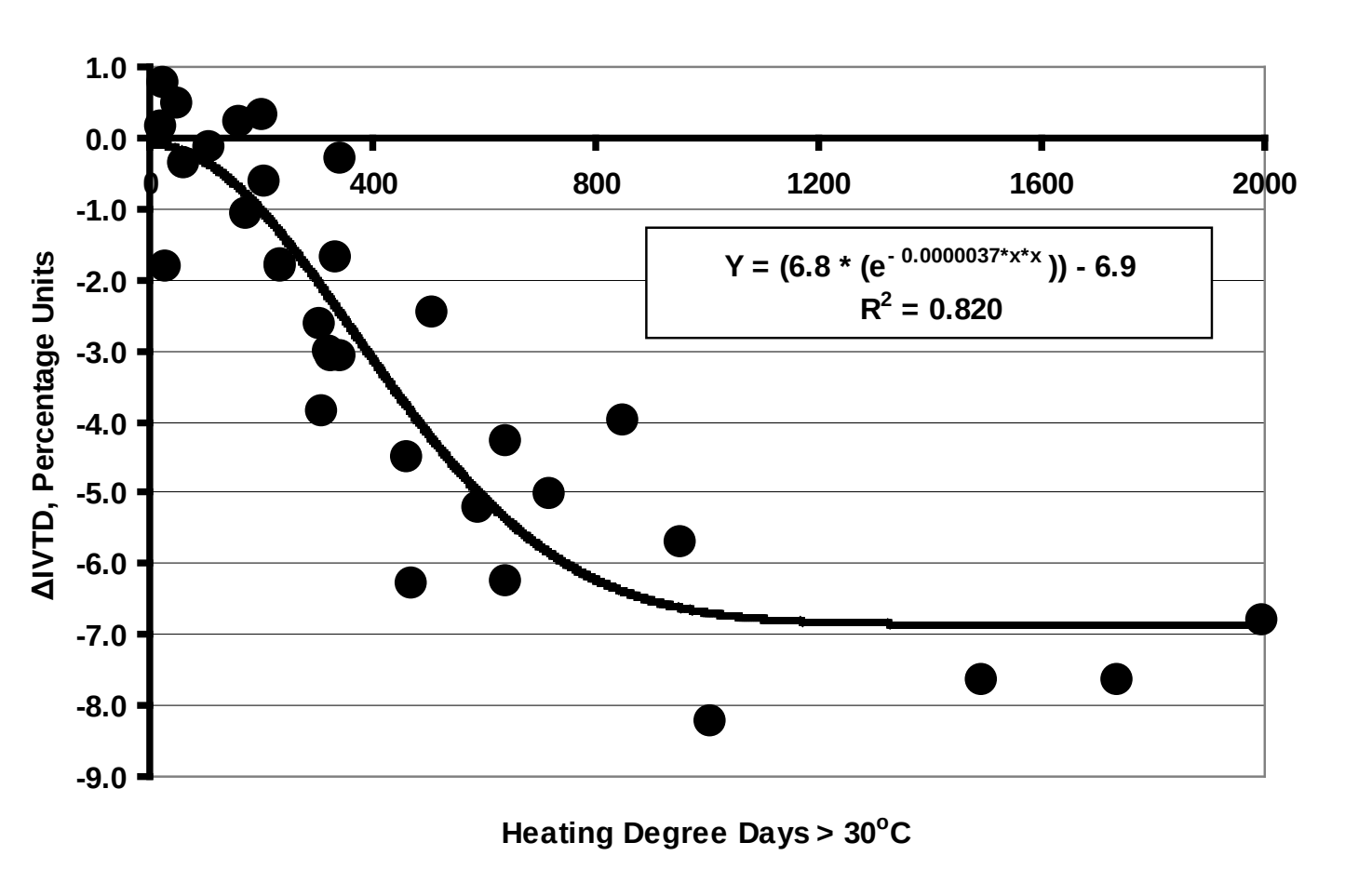
(Scarbrough et al., 2005)



Spontaneous Heating in Alfalfa Hay vs. Baled Silage



Hancock and Collins (2006): ***alfalfa harvested at mid-bud stage of maturity; hay baled at 19.8% moisture and stored outside, uncovered; hay received two rainfall events totaling 0.6 inches prior to baling.***



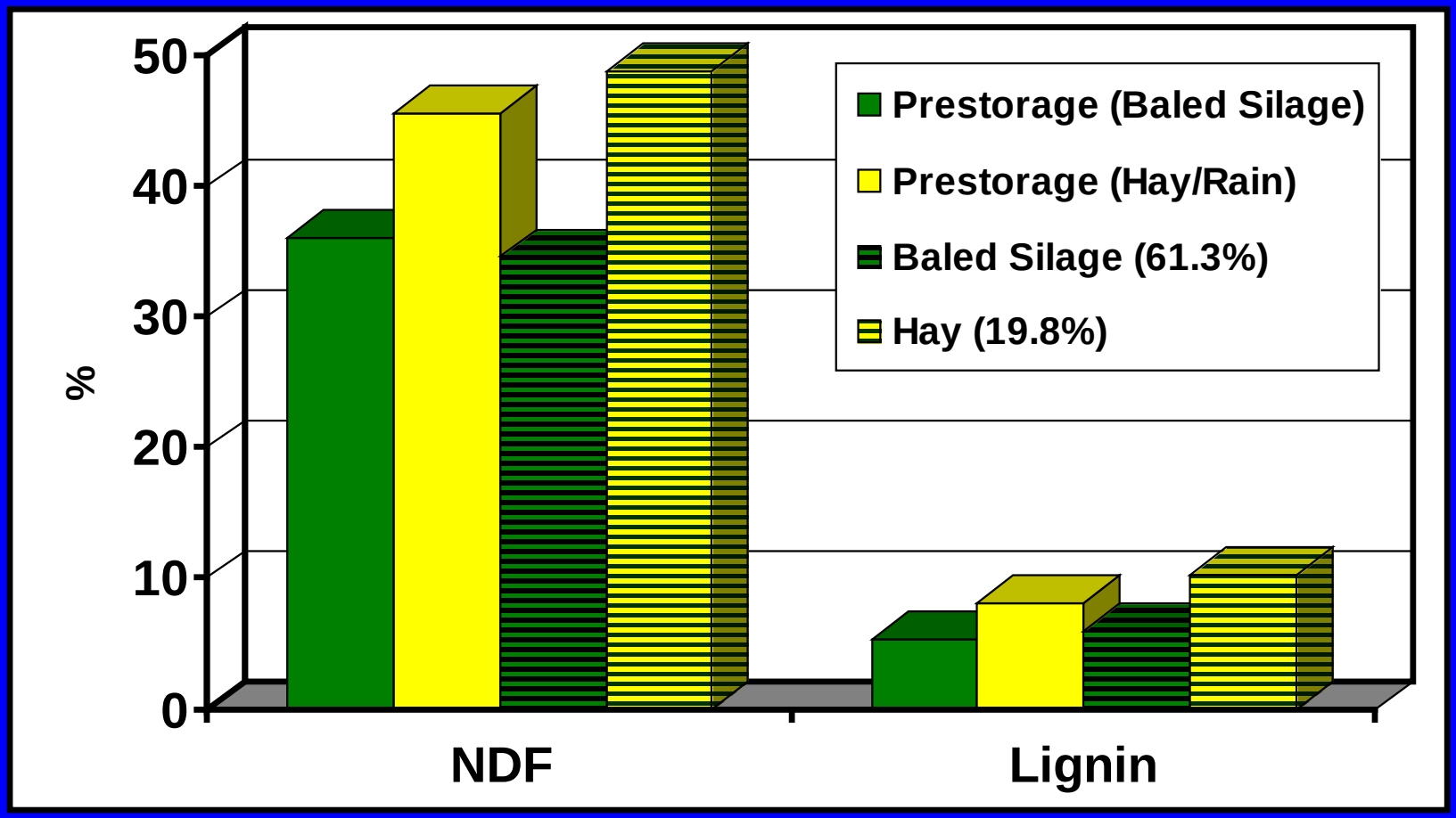
In Vitro True Digestibility

N = 32 baling treatments

Initial = 77.2%, which corresponds generally to ΔIVTD = 0 on the y-axis

Wisconsin Round Bale Study
Heat-Damaged Hay
(2006-07)

Combined Effects of Rain Damage and Modest Spontaneous Heating



Hancock and Collins (2006): ***alfalfa harvested at mid-bud stage of maturity; hay baled at 19.8% moisture and stored outside, uncovered; hay received two rainfall events totaling 0.6 inches prior to baling.***

2. Baled Silage vs. Precision-Chopped Haylage

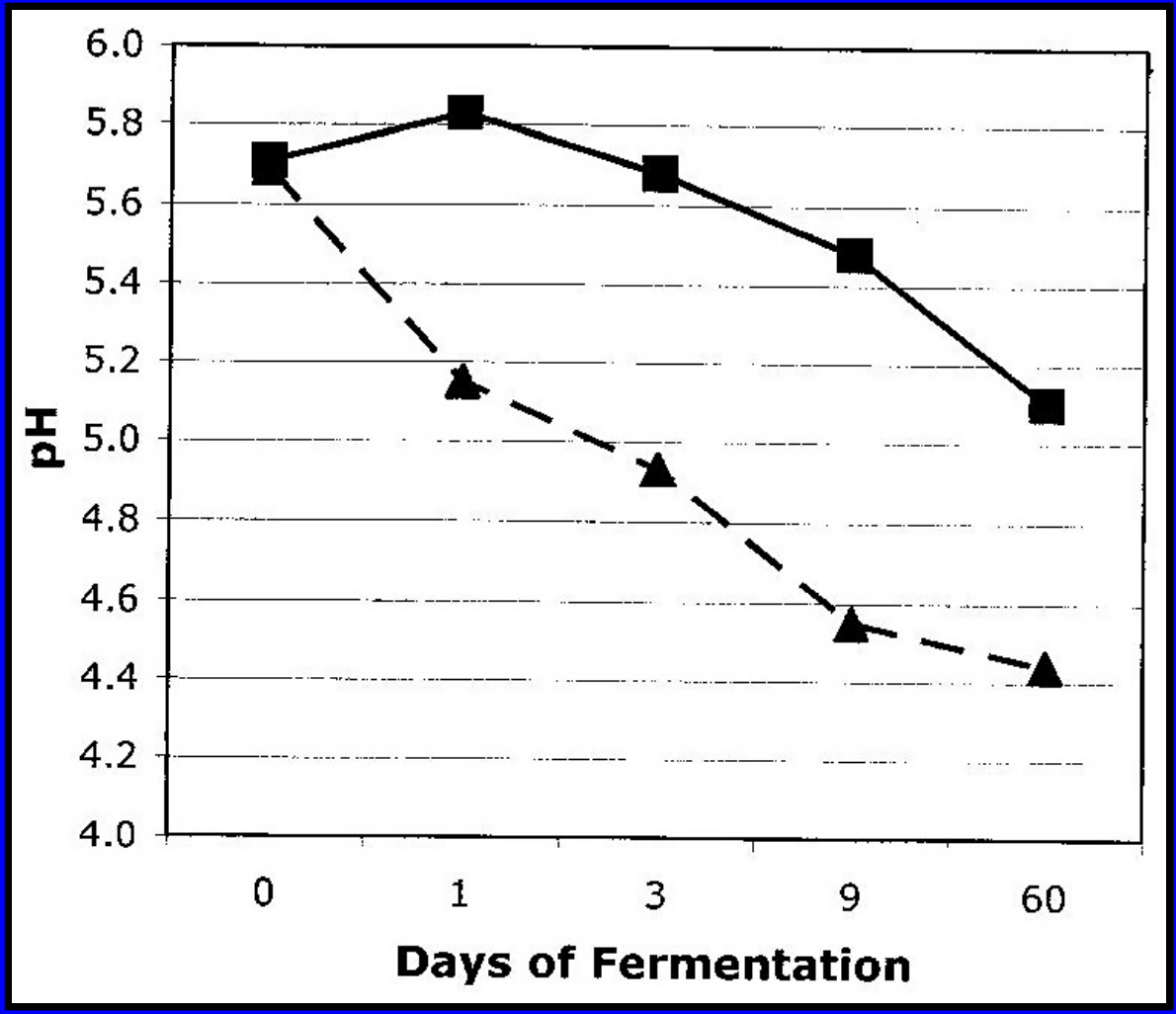
How Do They Compare?

- *lack of chopping action forces sugars to diffuse from inside the plant to reach lactic-acid bacteria located on the outside of the forage*
- *although dependent on many factors, baled silage may be less dense (DM/ft^3) than some other (chopped) silo types, which also may restrict availability of sugars to lactic acid bacteria*
- *lower bale density, and greater ratio of surface area to forage DM, potentially make baled silage more susceptible to entrapment and/or penetration by O_2*
- *recommendations for the moisture content of baled silage are 5 to 20 percentage units lower than for chopped forages; this alone will restrict fermentation*

Baled vs. Precision-Chopped Silage Alfalfa/Grass

■ **Baled**

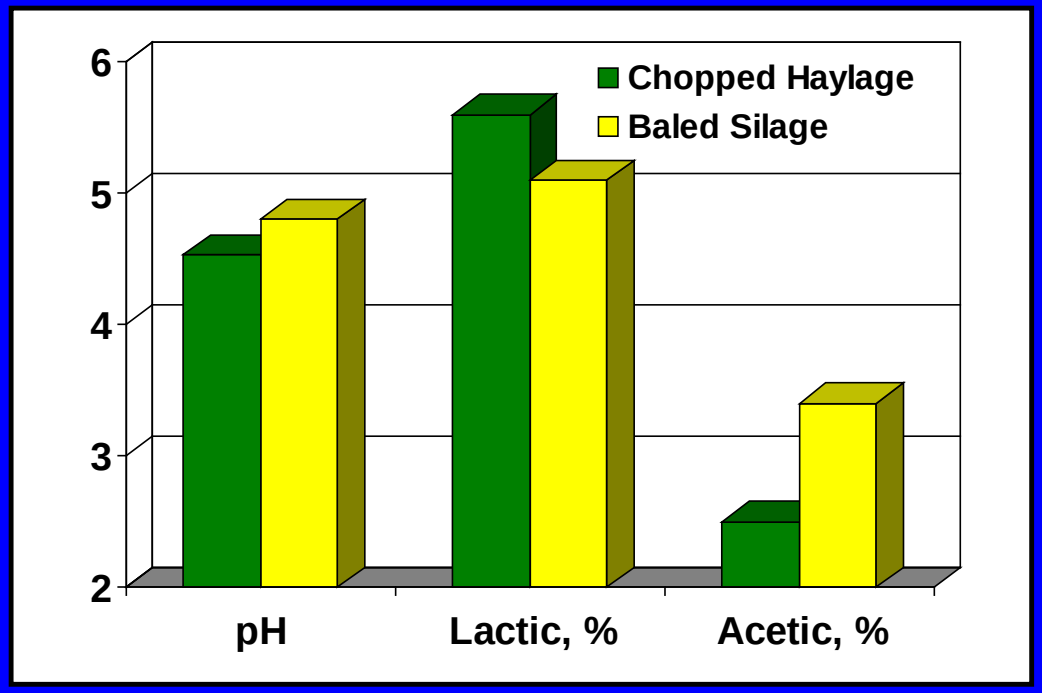
▲ **Chopped**

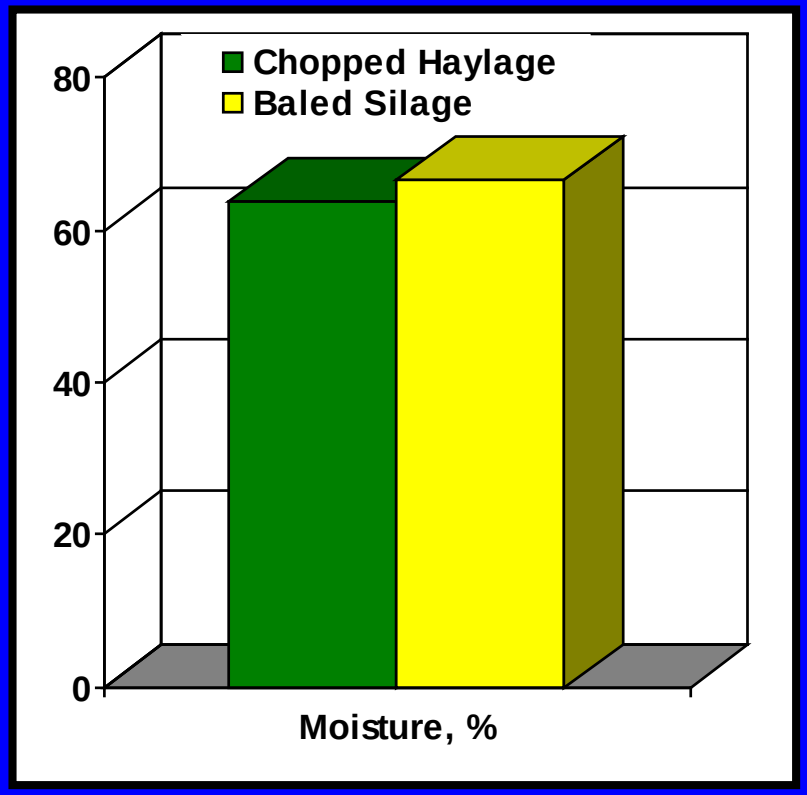


Muck (2006) – adapted from Nicholson et al. 1991; average moisture content of silages was 61%

Fermentation Characteristics Chopped Haylage vs. Baled Silage

McCormick et al. (1998)





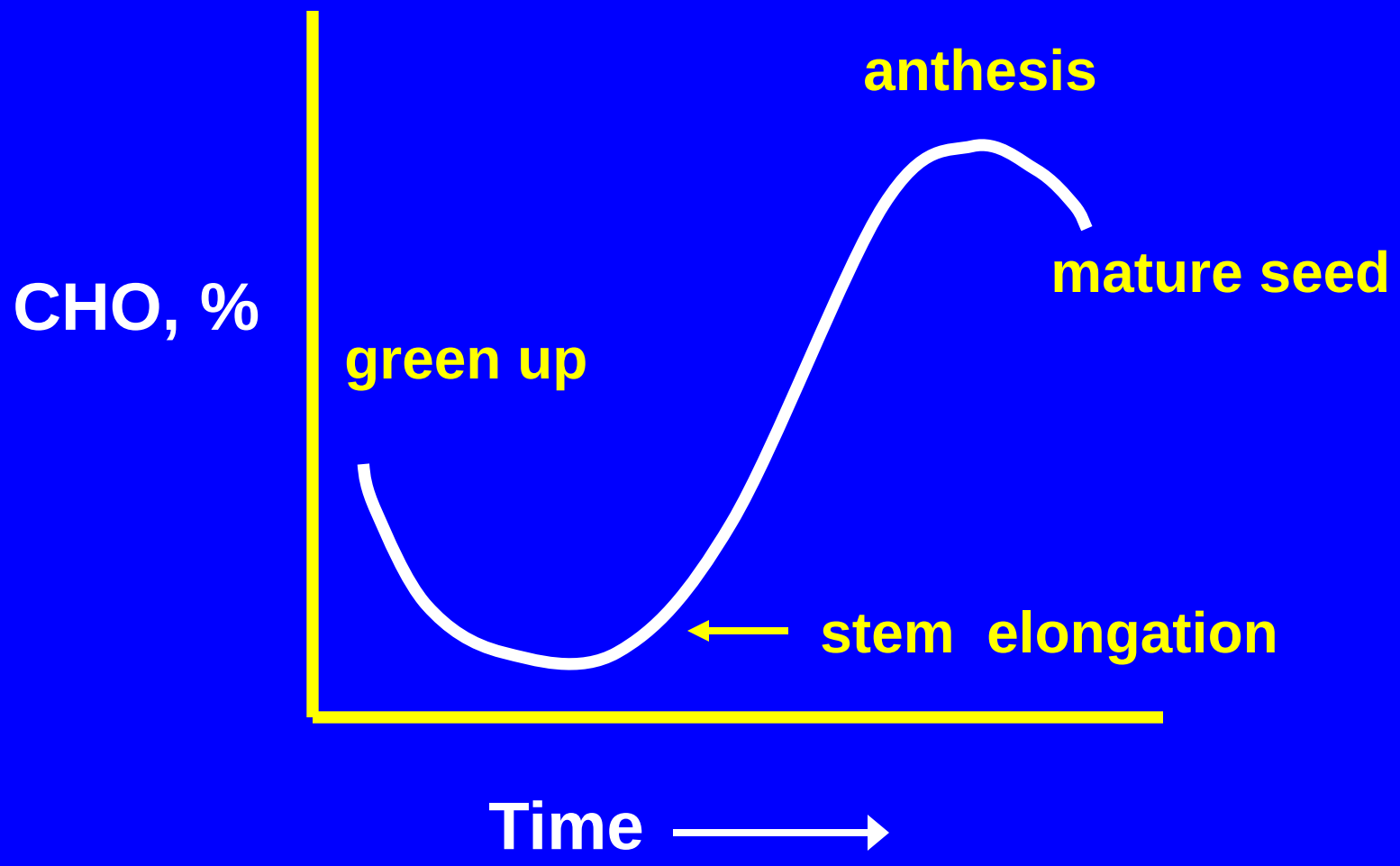
- *annual ryegrass (1993-94)*
- *4 x 4 bales*
- *silages harvested mid-April in southeast Louisiana*

3. Effects of Crop Factors on Baled Silage

- ***harvest high-quality forages – expensive equipment generally will not improve forage quality***
- ***damaged, or mismanaged forages that ferment poorly in conventional silo types also are likely to make poor baled silage***
- ***harvest at proper growth stage (sugar status)***
- ***remember that forage species are inherently different***
  - ***legumes ≠ cool-season (cs) grasses***
  - ***cs grasses ≠ warm-season (ws) grasses***
  - ***ws annuals ≠ ws perennials***

Crop Factors

Sugar Status: Nonstructural CHO in Stem Bases of Perennial Cool-Season Grasses

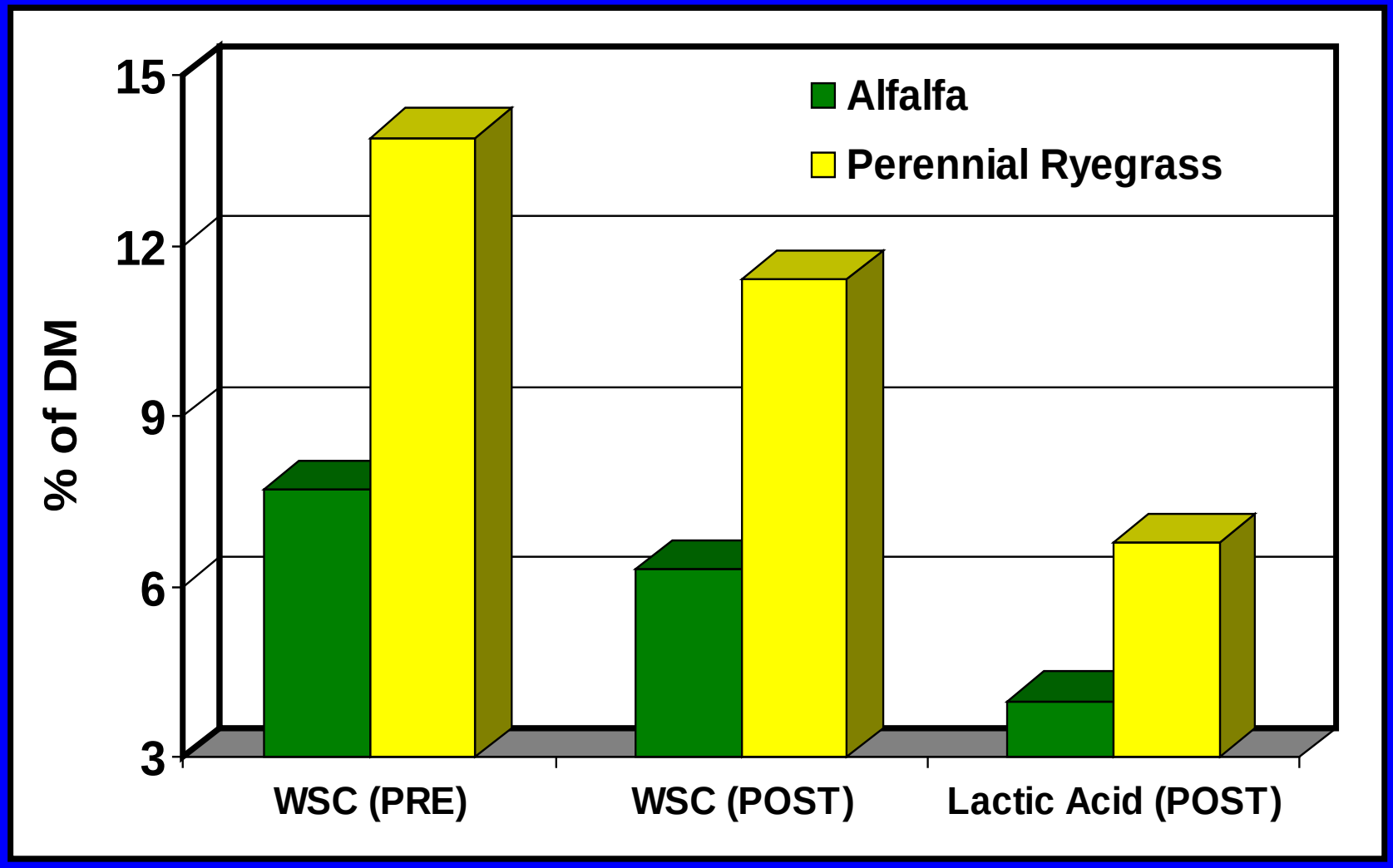


Concentrations of CHO in Orchardgrass

Plant Part	Proportion of Plant Weight	Reducing Sugars	Sucrose	Fructan
	%	---------- % of DM ----------		
Leaf – top 2/3	14.0	1.4	8.4	7.6
Leaf – lower 1/3	12.1	1.2	5.8	22.0
Tiller base (upper)	9.4	1.9	3.6	23.7
Tiller base (lower)	23.6	0.7	2.6	36.2
Roots	40.9	1.2	8.9	8.2

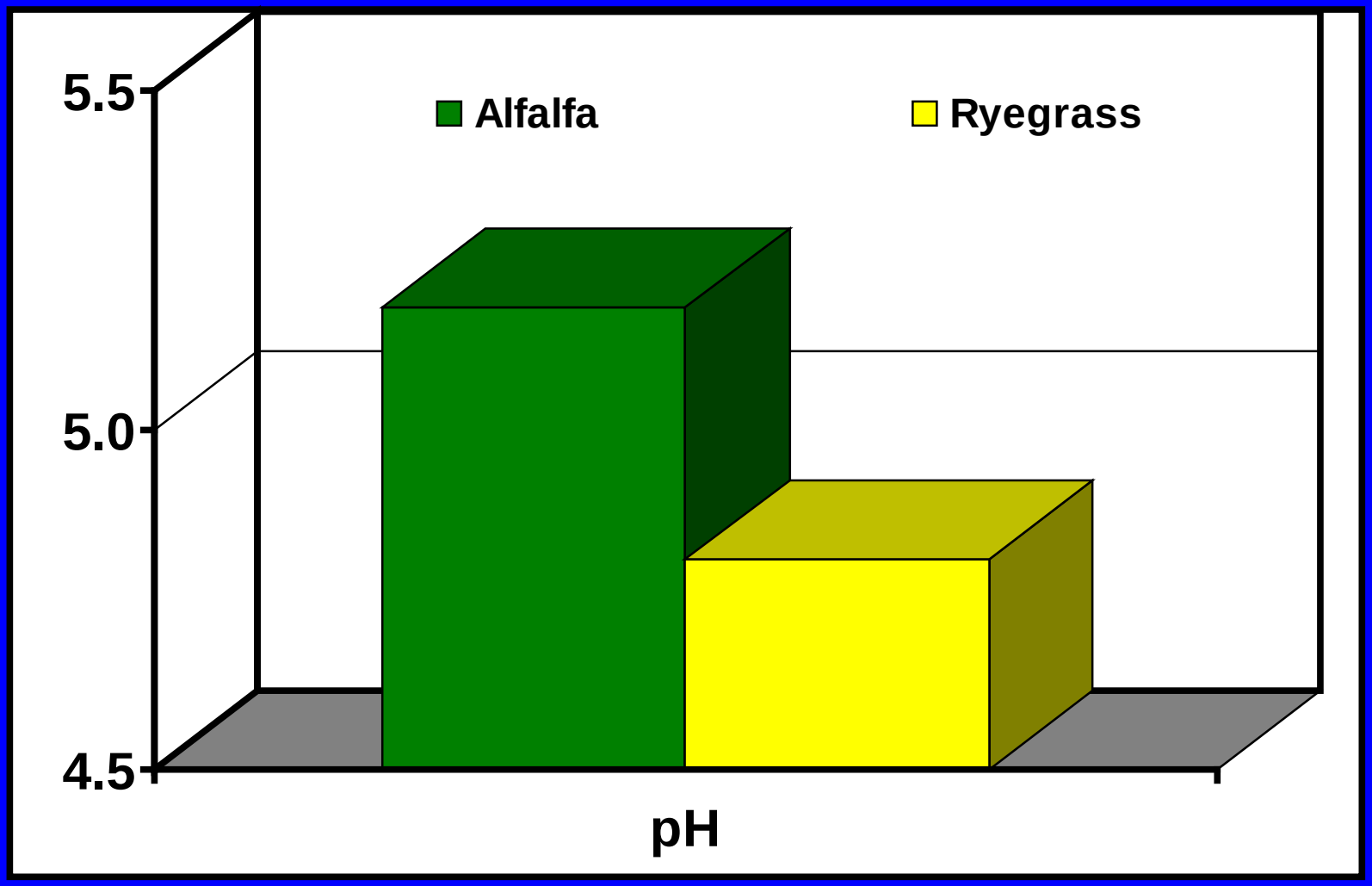
Sprague and Sullivan (1950)

Species Differences: Fermentation Characteristics



Han et al. (2006): mean of ideal (48.8%) and low (29.5%) moisture bales

Species Differences: Effects on pH



Han et al. (2006): mean of ideal (48.8%) and low (29.5%) moisture bales

4. Moisture Management for Baled Silage

- ***Generally, baled silage should be packaged at 40 to 60% moisture; the average for the whole field or group of bales should be about 50%.***
- ***Bale weight can be a safety/equipment issue.***
- ***Systems for baled silage will generally accommodate excessively dry forages better than excessively wet ones.***

  - clostridial fermentations (wet)

  - bale deformation, tensile stress on plastic (wet)

  - migration/concentration of water

- ***moisture in the plant ≠ moisture on the plant***

Typical Compositions of Grass Silages Produced by Five Different Types of Fermentation.

	---------- Silage type ----------				
Item	LAC	BUT	ACE	WILT	STER
Dry matter, %	19.0	17.0	17.6	30.8	21.2
pH	3.9	5.2	4.8	4.2	5.1
Protein N, % of N	23.5	35.3	44.0	28.9	74.0
Ammonia N, % of N	7.8	24.6	12.8	8.3	3.0
Lactic acid, %	10.2	0.1	3.4	5.9	2.6
Acetic acid, %	3.6	2.4	9.7	2.4	1.0
Butyric acid, %	0.1	3.5	0.2	0.1	0.1
WSC, %	1.0	0.6	0.3	4.8	13.3

Source: McDonald and Edwards (1976)

Moisture Management
(Clostridial Fermentations)

Some Characteristics of High-Risk Forages

- *high moisture content (after ensiling)*
- *direct cut*
- *immature, rapidly growing*
- *highly contaminated with dirt, especially if manured*
- *low sugar*
- *high buffering capacity*
- *high protein*
- *leguminous*
- *non-homogenous forages (baled silage)*
- *anything that slows or limits pH decline in wet forages*

Moisture Management
(Clostridial Fermentations)

Principle Fermentation Products/Characteristics

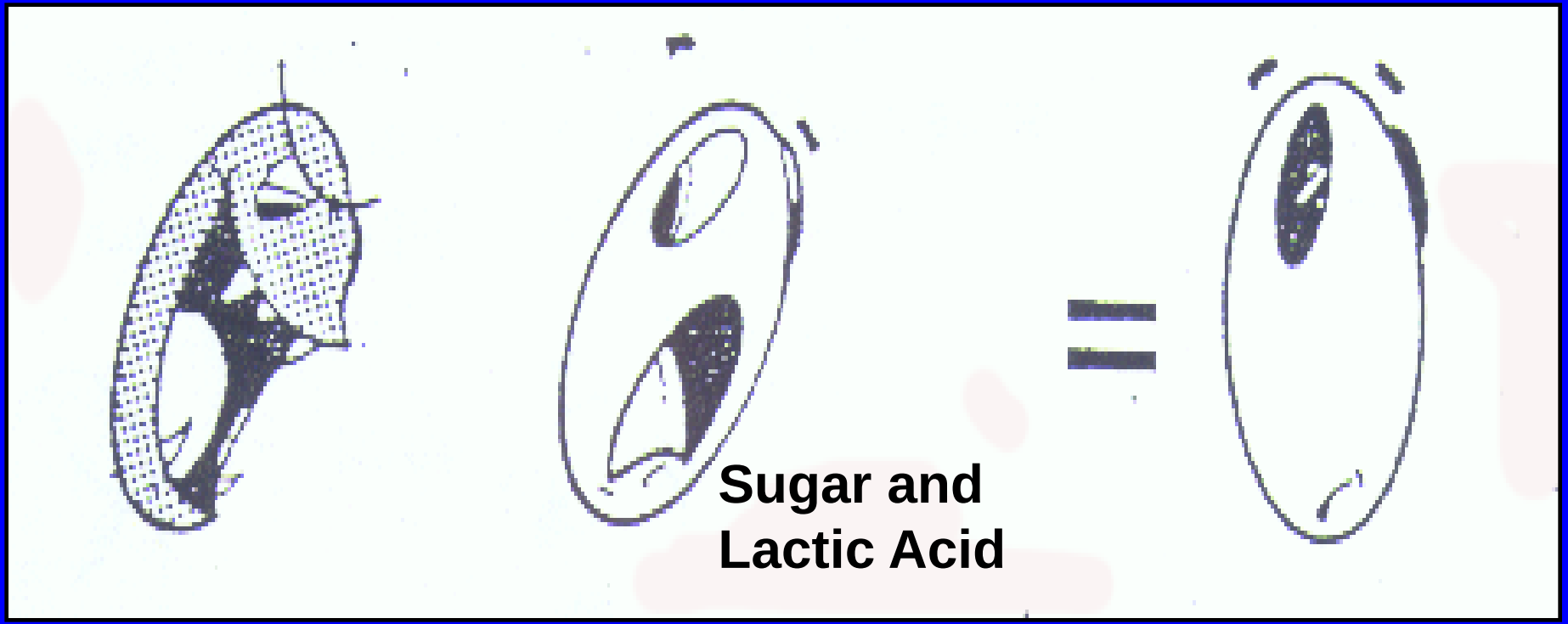
- *ammonia*
- *amines*
- *butyric acid*
- *high pH*
- *low lactic acid*
- *high DM losses*
- *poor intake by cattle*

Solutions/Prevention

- *wilt at risk forages to <65% moisture (<60% for baled silage)*
- *avoid soil contamination, especially if soil is manured*
- *optimize fermentation/pH decline*

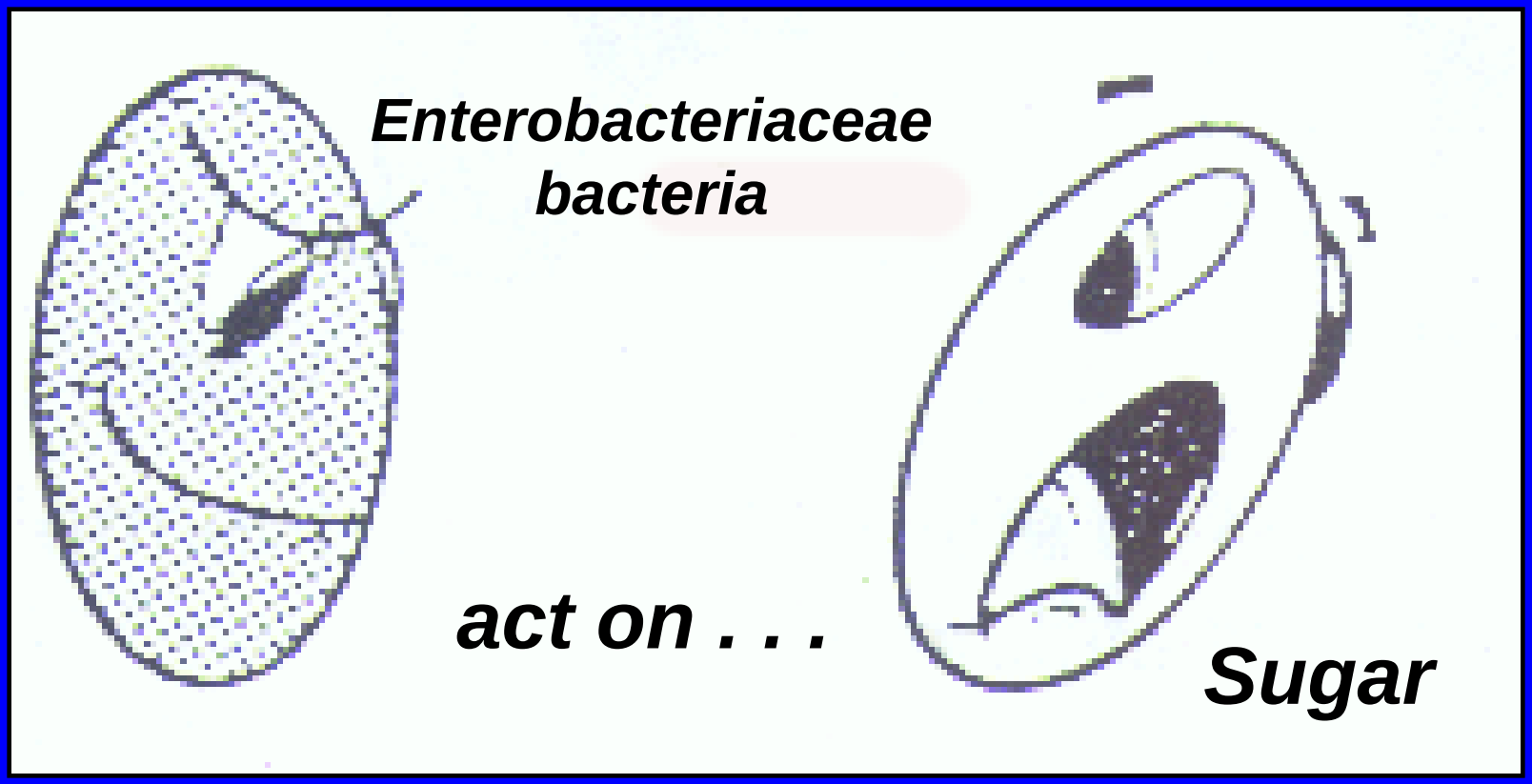
Clostridial Fermentations

Clostridial spores

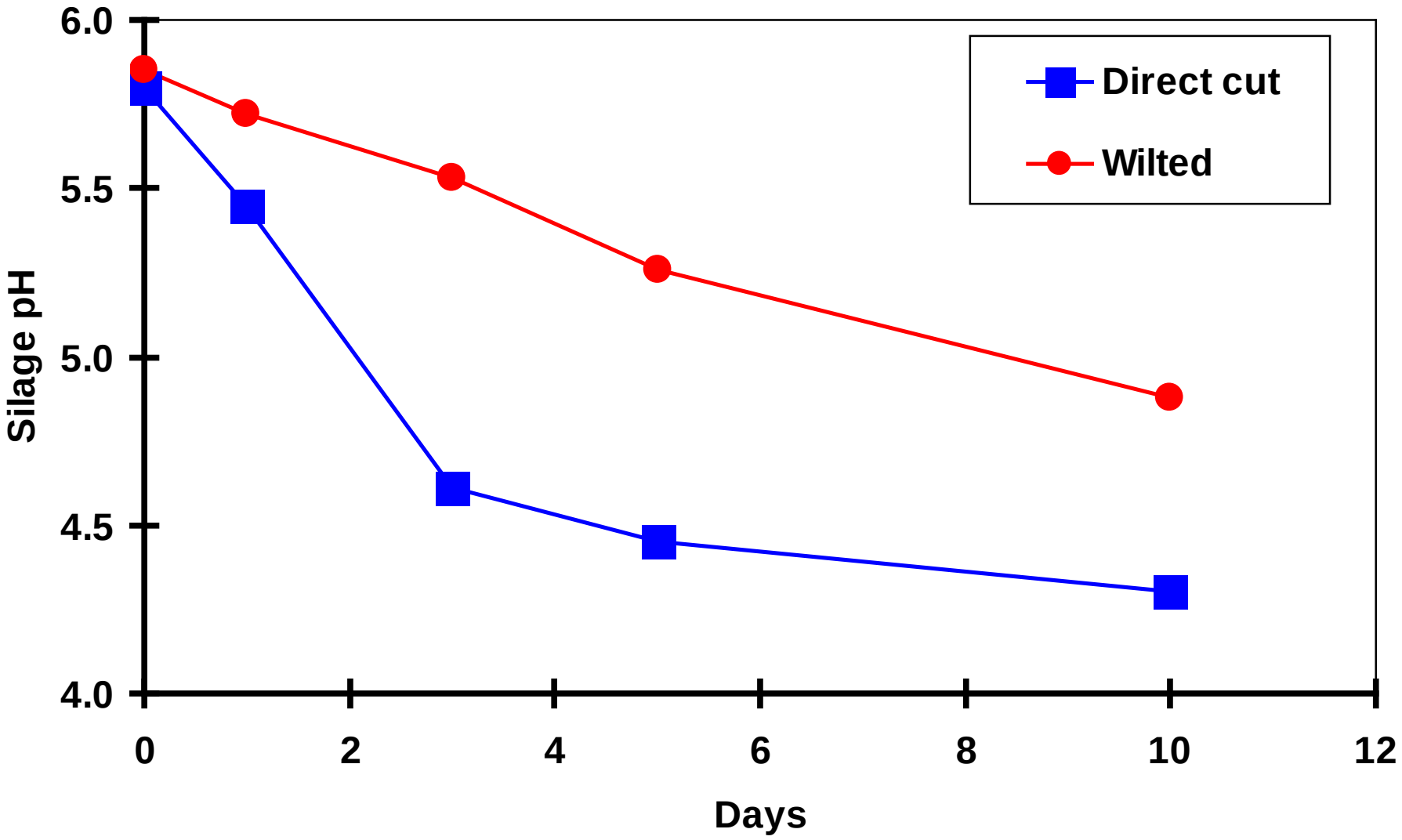


Butyric Acid
"Bad, Evil-Smelling Silage"

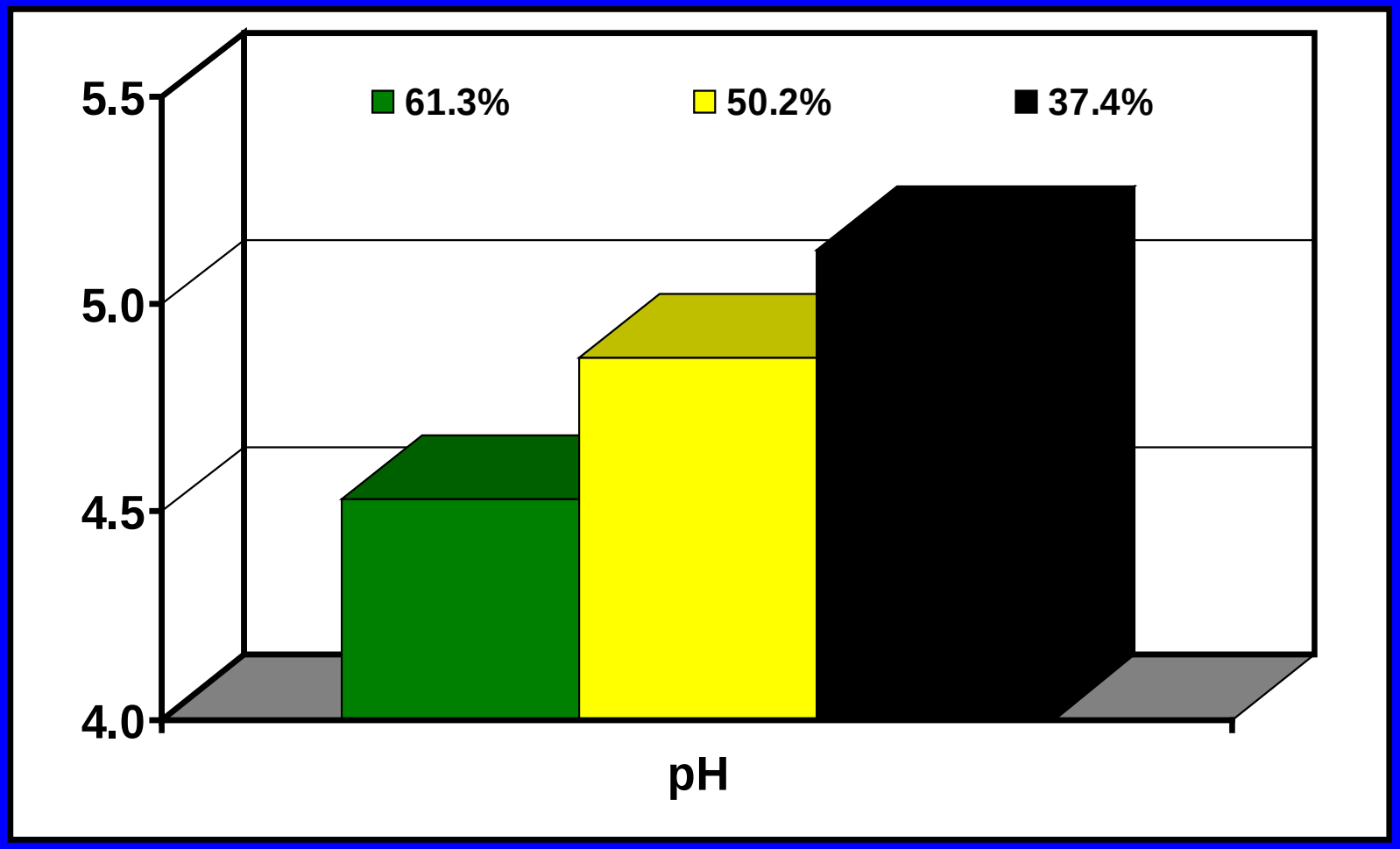
Enterobacteriaceae



Results = acetate, CO_2, lactate, ethanol, and H_2

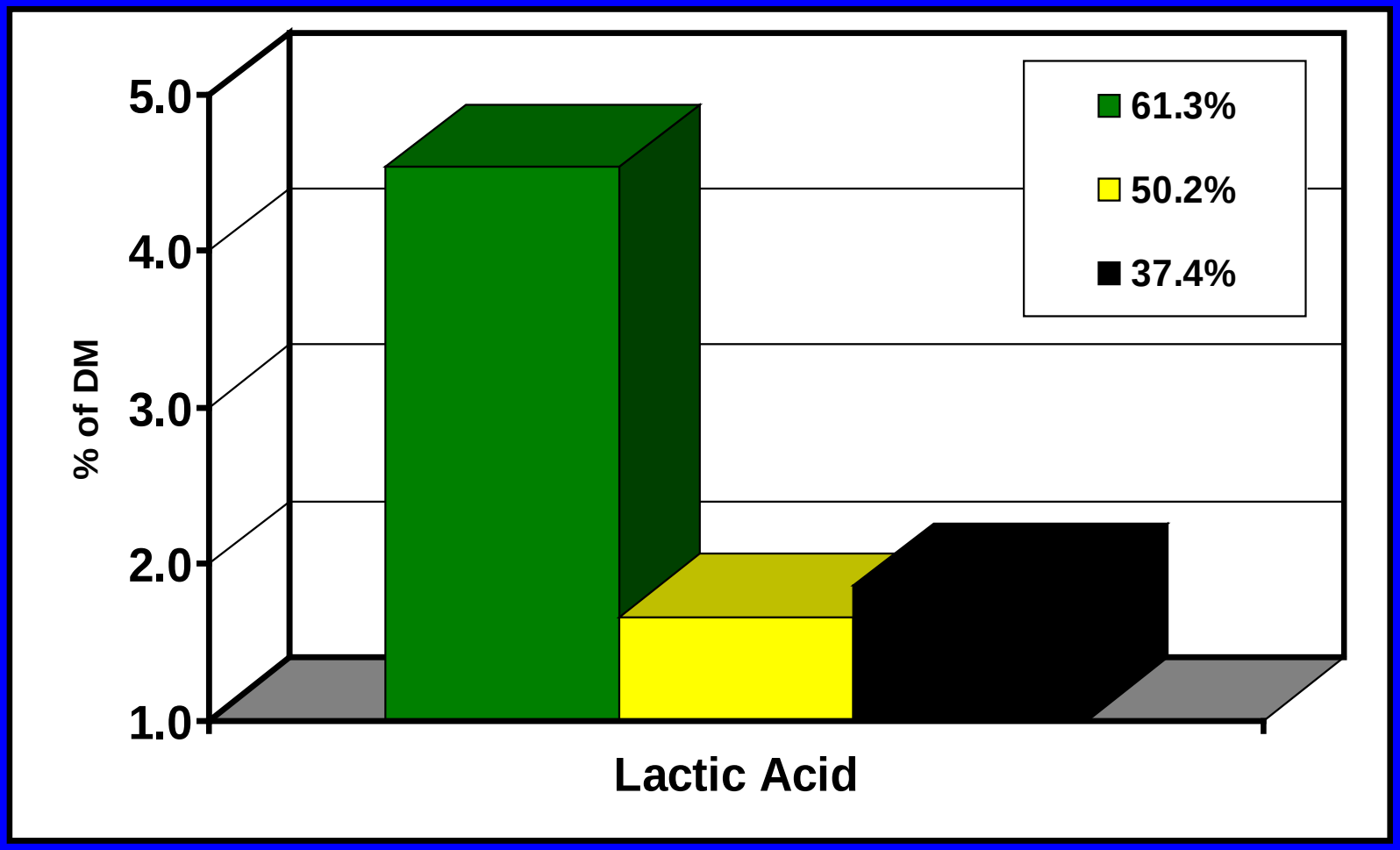

Direct (62.8%) and Wilted (47.4%) Late-Harvested
Eastern Gamagrass Silage (July 1995; Manhattan, KS)
Silage pH
6.0
5.5
5.0
4.5
4.0
0
2
4
6
8
10
12
Days
Direct cut
Wilted

Effects of Moisture Content on Silage pH



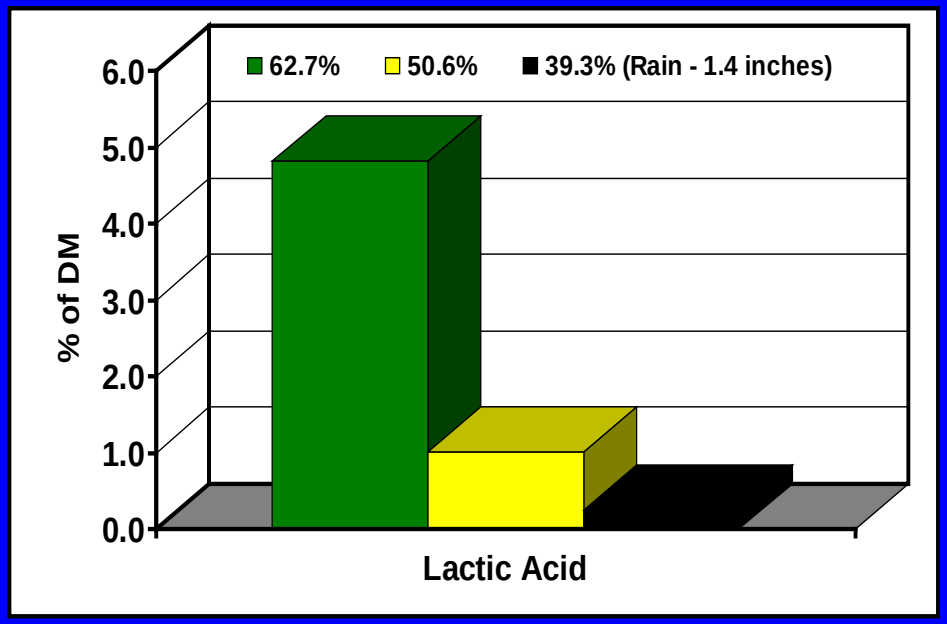
Hancock and Collins (2006): ***combined data from two trials; alfalfa harvested at mid-bud stage of maturity***

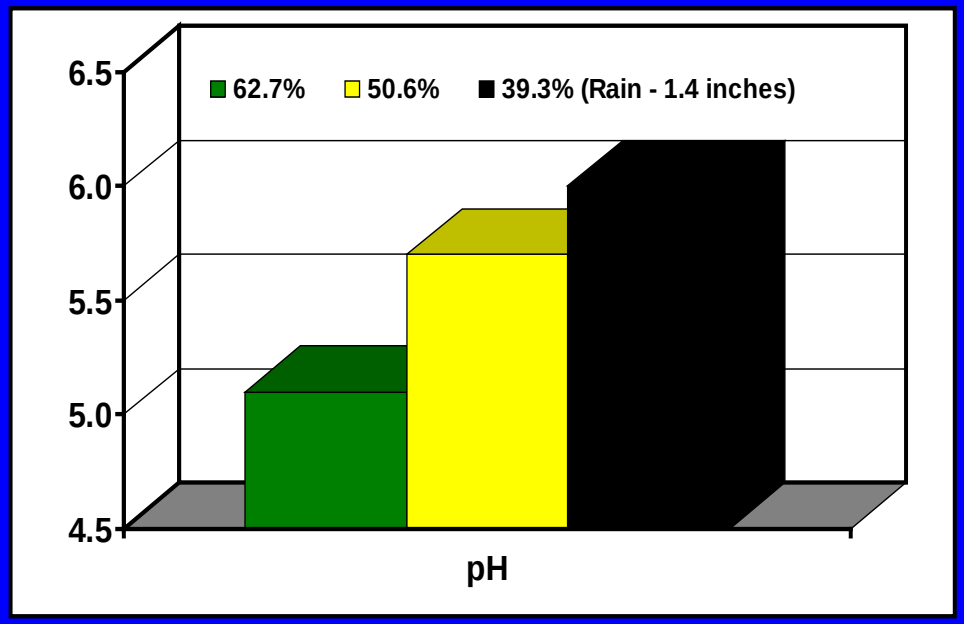
Effects of Moisture Content on Lactic Acid



Hancock and Collins (2006): ***combined data from two trials; alfalfa harvested at mid-bud stage of maturity***

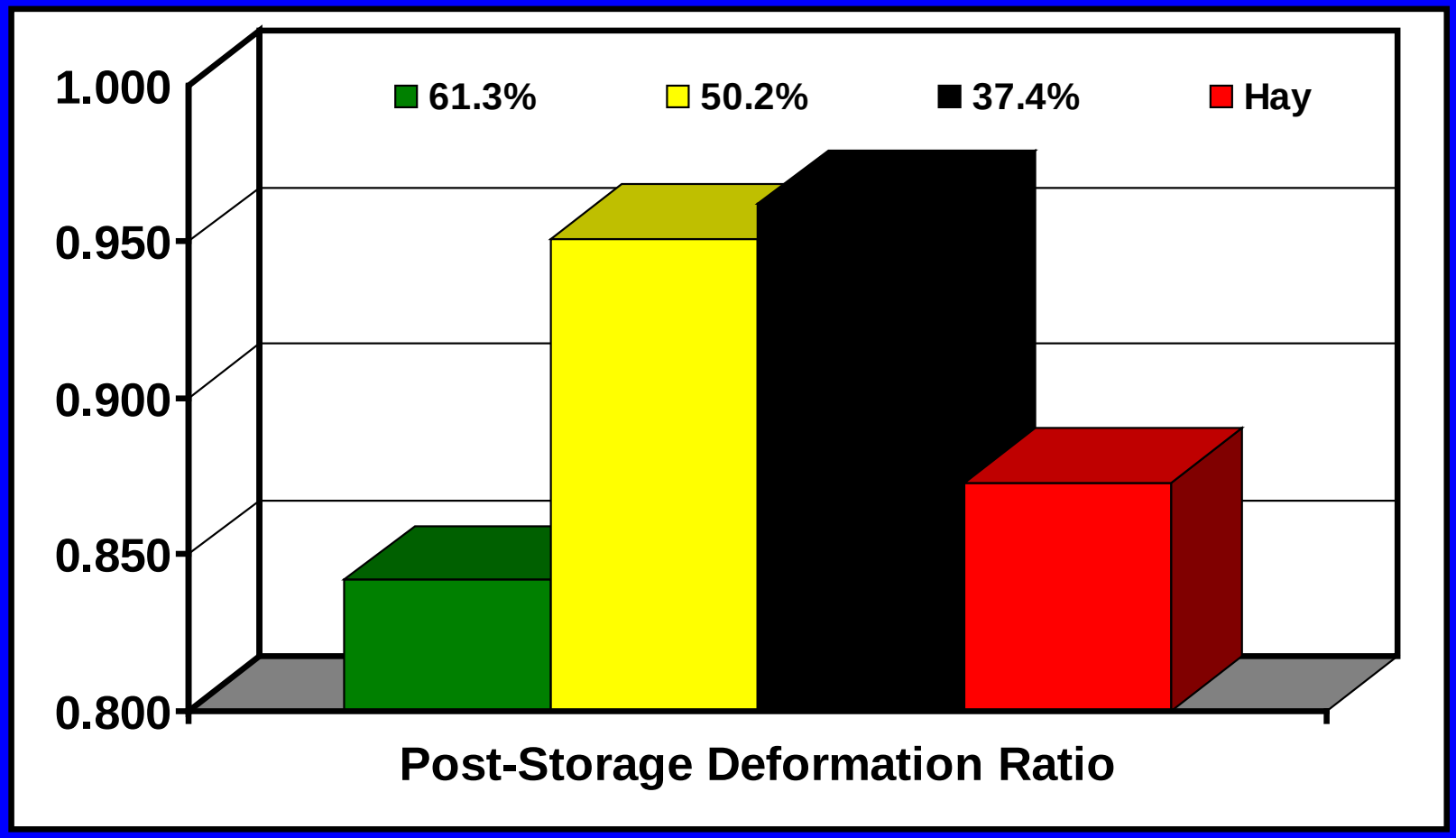
Effects of Moisture Content and Rain-Damage on Fermentation





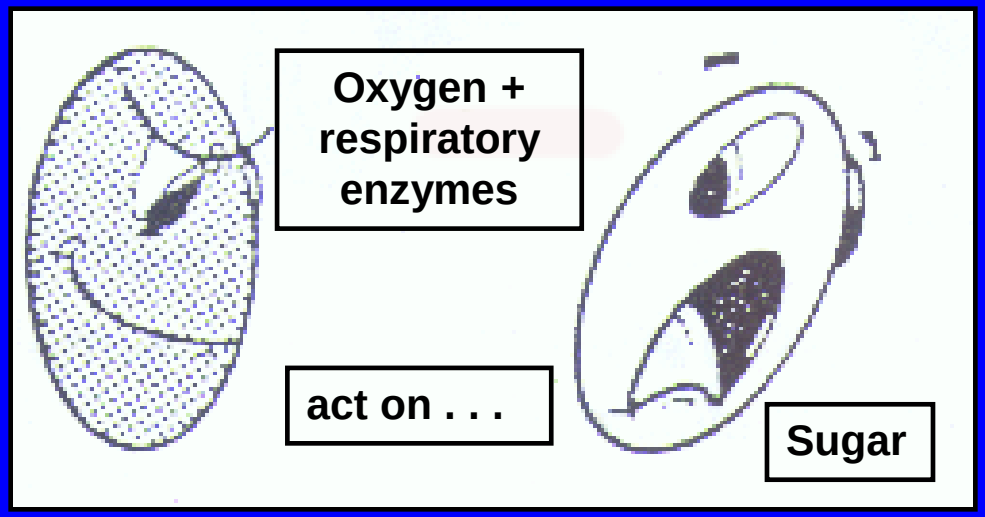
Borreani and Tabacco (2006)

Effects of Moisture Content on Bale Deformation (ft vertical/ft horizontal)



Hancock and Collins (2006): ***combined data from two trials; alfalfa harvested at mid-bud stage of maturity; estimate for hay is mean of bales made at 16.6 and 19.8% moisture, and stored outdoors, uncovered.***

5. Elimination of Air



- *causes respiration of plant sugars to CO_2, water, and heat*
- *reduces pool of fermentable CHO (sugars)*
- *dry matter loss*
- *increases (indirectly) fiber content of the silage*
- *decreases energy density of silage*
- *heat damage to silage proteins*

bulk density >10 lbs DM/ft^3

- ***reduce ground speed***
- ***increase PTO speed***
- ***thinner windrows will increase revolutions/bale***
- ***manage moisture appropriately (≈ 50%)***
- ***maintain constant bale size***
- ***baler/operator experience***

Effects of Bale Density on Fermentation

Moisture	------- 58.7% ------		------- 52.4% -------	
Density, lbs/ft^3	12.9	10.9	12.4	10.4
pH	*4.7*	4.9	*4.8*	5.1
lactic acid, %	*7.0*	6.5	*7.1*	6.3
acetic acid, %	2.4	3.8	3.3	2.0
max temp, ^{o}F	107	109	108	106
DM REC, %	98.6	98.6	97.8	98.3

Han et al. (2004): high density bales created at 842 x 10^3 Pa of chamber pressure; lower density bales made at 421 x 10^3 Pa.

Sealing the Bale

- *lack of uniformity will create air pockets for in-line wrapped bales*
- *use UV-resistant plastic*
- *wrap as quickly as possible after baling (within 2 hours is ideal)*
- *use (at least) four layers of stretched plastic (six for long-term storage and/or in southern states)*
- *storage site selection/maintenance is important*
- *do not puncture plastic - isolate from cattle, pets, and vermin*
- *patch holes with appropriate tape*

Hydraulic Bale Grapple

Effects of Delaying Wrapping on Internal Bale Temperature (63% Moisture)

Wrap Delay	At Wrapping	Day 1*	Day 2	Day 4	Day 6	Day 14
h	----------	----------	ºF	----------	----------	----------
No wrap	99	121	127	150	145	135
0	91	93	95	89	84	76
24	110	119	114	101	92	75
48	136	142	130	109	95	72
96	147	145	133	110	92	73

Vough et al. (2006): data adapted from Undersander et al. (2003); all square bales of alfalfa wrapped with eight mils of plastic film.

* Denotes days from wrapping.

Effects of Wrapping Layers on Fermentation and Alfalfa Forage Quality

Trial	Moisture	Plastic	NDF	ADF	Lactic Acid	pH
#	%	layers	----------	%	----------	#
1	50.2	2	*42.6*	*32.2*	*1.33*	*4.80*
		4	38.9	30.1	1.96	4.88
		6	39.8	30.4	1.68	4.93
	37.4	2	*43.3*	*31.5*	*2.56*	*5.81*
		4	39.2	29.7	1.50	4.60
		6	39.6	30.2	1.51	4.98
2	61.3	2	35.9	24.3	4.52	4.49
		4	34.5	23.0	4.47	4.48
		6	33.3	24.0	4.64	4.62

Hancock and Collins (2006)

6. Feedout Management

Aerobic Stability of Wheat and Orchardgrass Baled Silage

Wheat

- harvested at milk stage

- 37.6% moisture

- 11.1 lbs DM/ft^3

Orchardgrass

- harvested at heading stage

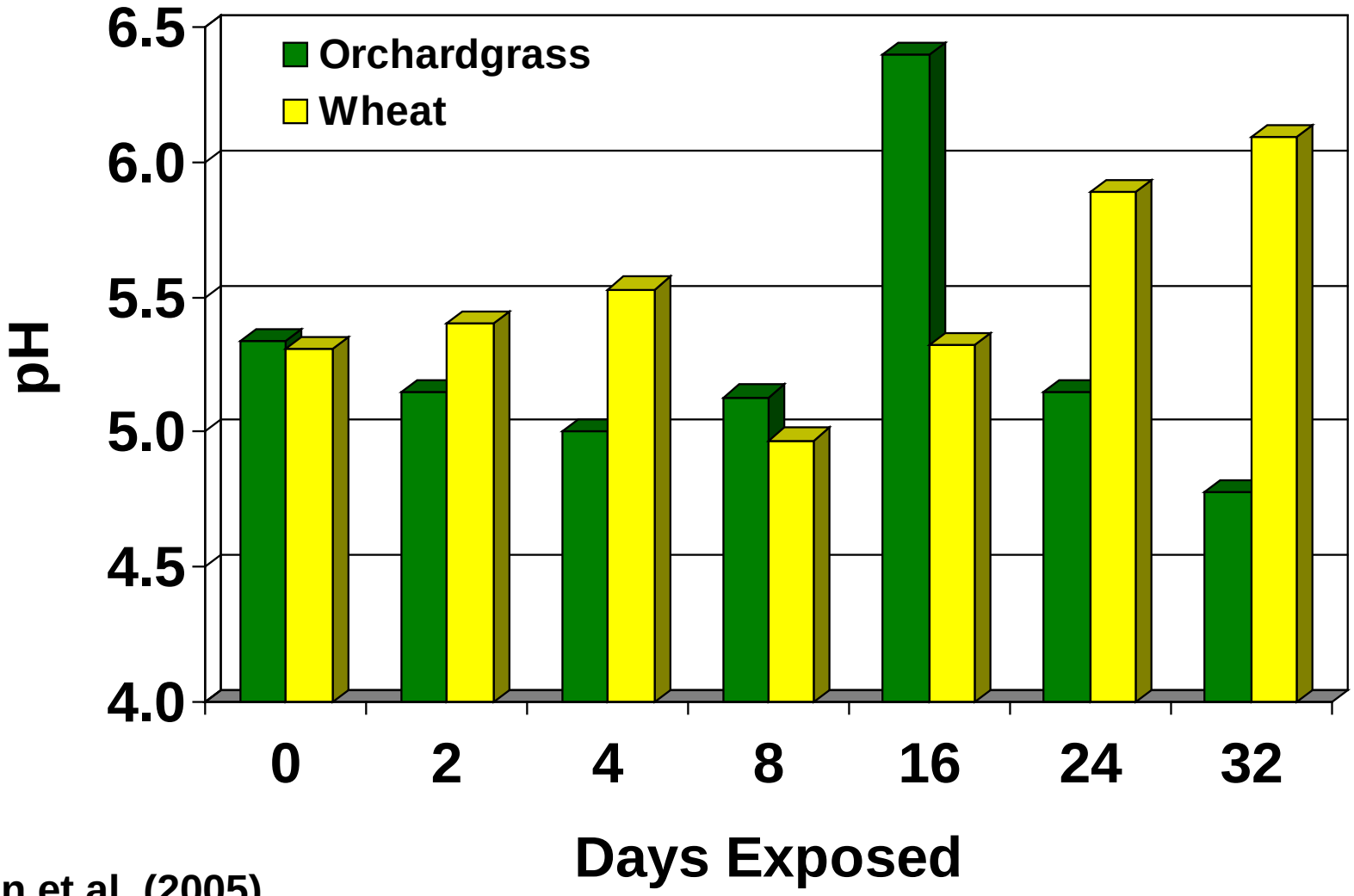
- 45.6% moisture

- 13.6 lbs DM/ft^3

Rhein et al. (2005)

University of Arkansas

Surface pH after Exposure



Rhein et al. (2005)

Comparisons of Stable and Reactor Wheat Baled Silage

Treatment	DM Recovery	Visual Score	Final pH	MAX Temp
	%			°F
Surface				
Stable	- - -	1.00	4.81	52.0
Reactor	- - -	4.00	7.91	139.4
Center				
Stable	100.0	- - -	5.02	47.8
Reactor	92.8	- - -	5.49	85.3

Rhein et al. (2005)

Summary

- Producers can make good silage using proper baling and wrapping techniques.
- Most principles of management for conventional chopped silage still apply to baled silage.
- Moisture management is critical; baled silage techniques will accommodate drier (<50%) forages much better than relatively wet (>65%) ones.

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Summary

- *Fermentation may occur at a slower rate for baled silage because forages are ensiled on a whole-plant basis, and are usually drier at harvest.*
- *As a result, producers should diligently address other management details, such as maximizing bale density, applying plastic wrap promptly and properly, and protecting the wrapped product from damage until feeding.*

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