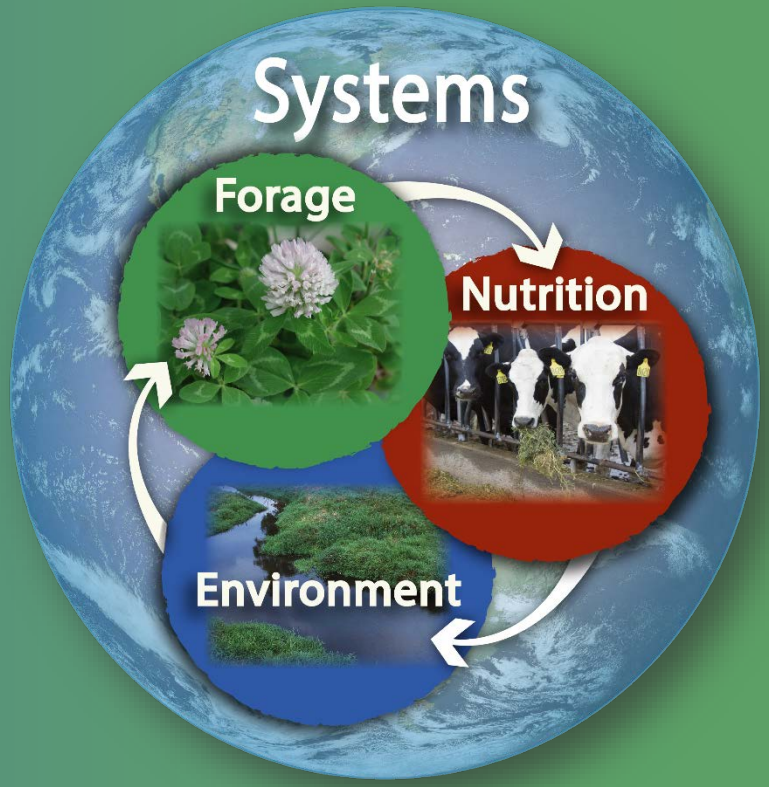
USDA
United States Department of Agriculture

Managing Fermentation with Baled Silage



World Dairy Expo 2015
September 30, 2015

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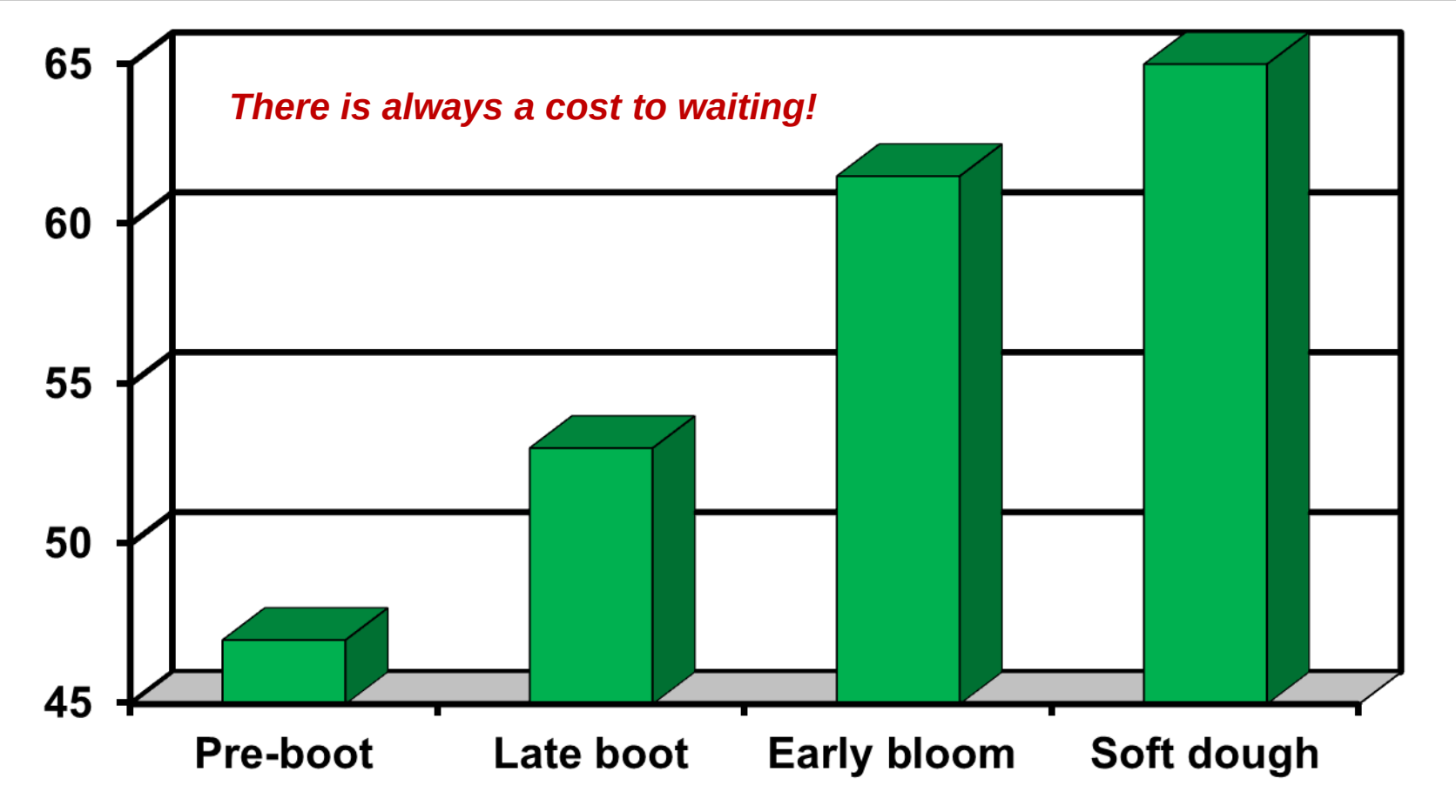
Regardless of silo type, most management principles are the same.

- ***start with high-quality forage***

Why Choose Baled Silage over Hay?

- ***well-made baled silage will often exhibit better quality characteristics than corresponding hays***
  - ***less leaf loss (legumes)***
  - ***less wilting time required***
  - ***reduced risk/exposure to rain damage***
  - ***little or no spontaneous heating***
  - ***no weathering after baling (outdoor storage)***

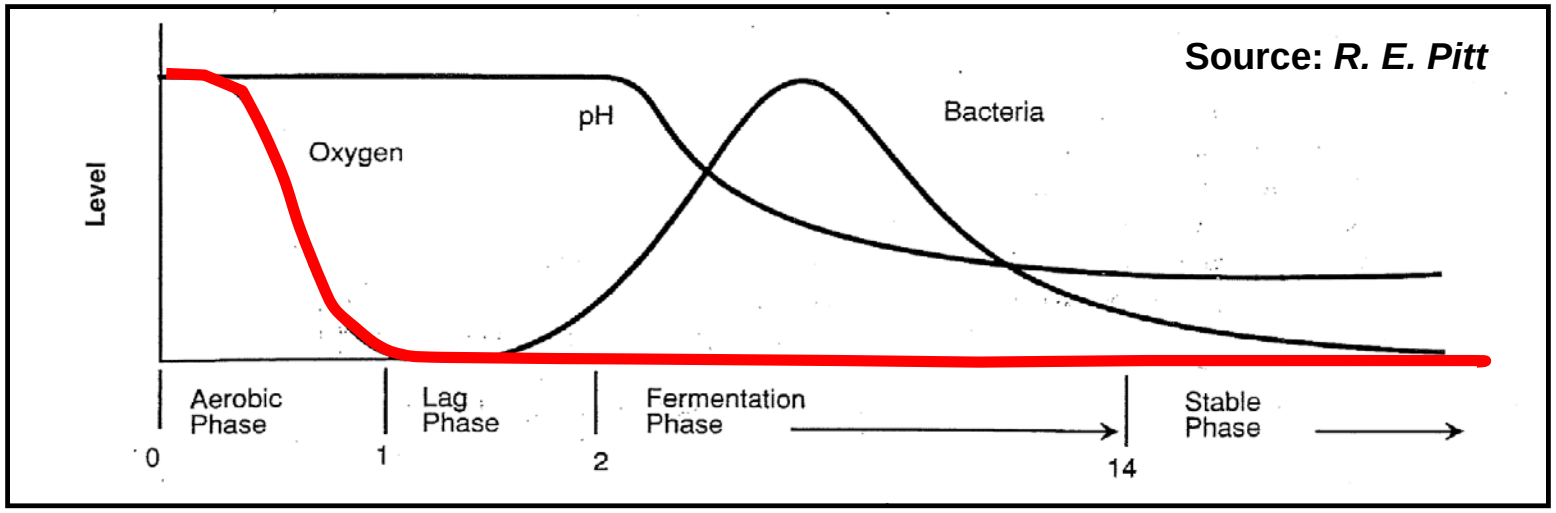
Delaying Harvest: NDF (%) within KY-31 Tall Fescue at Various Maturities



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

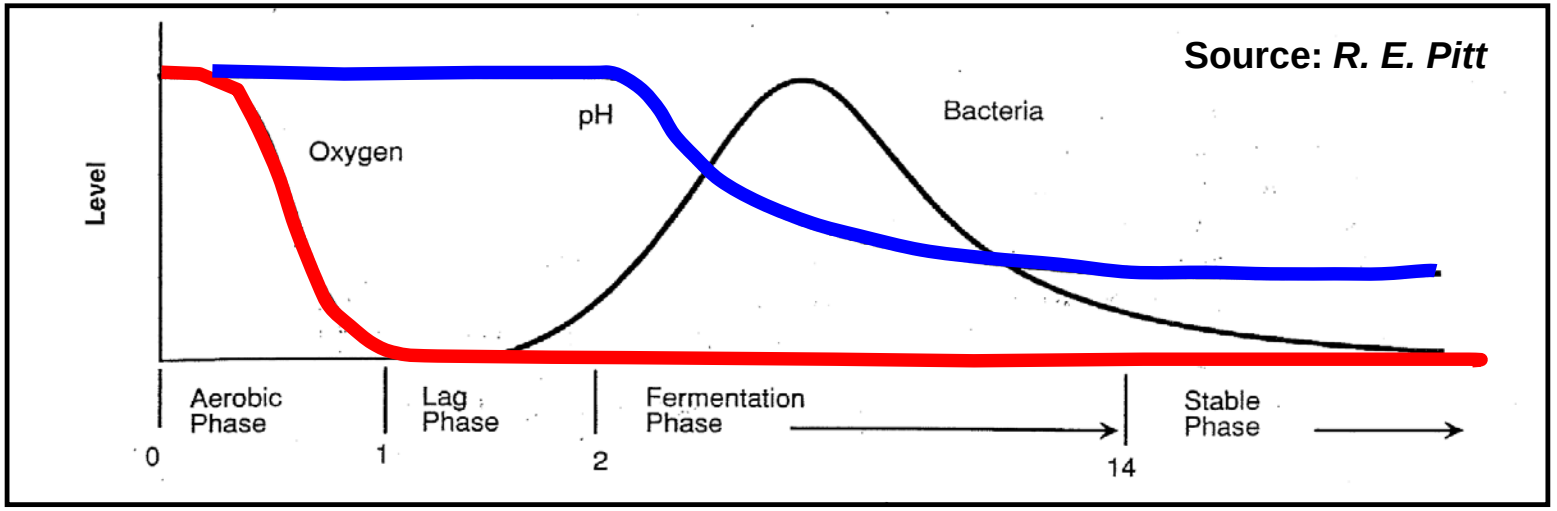
Goal: Silage Preservation

- ***Establish anaerobiosis (no oxygen)***
  - ***trapped oxygen is removed through respiration of still-functioning plant cells***
  - ***sealing prevents air from re-entering and circulating throughout the silo, thereby preventing decay, losses of DM and energy, and (possibly) production of toxic products***

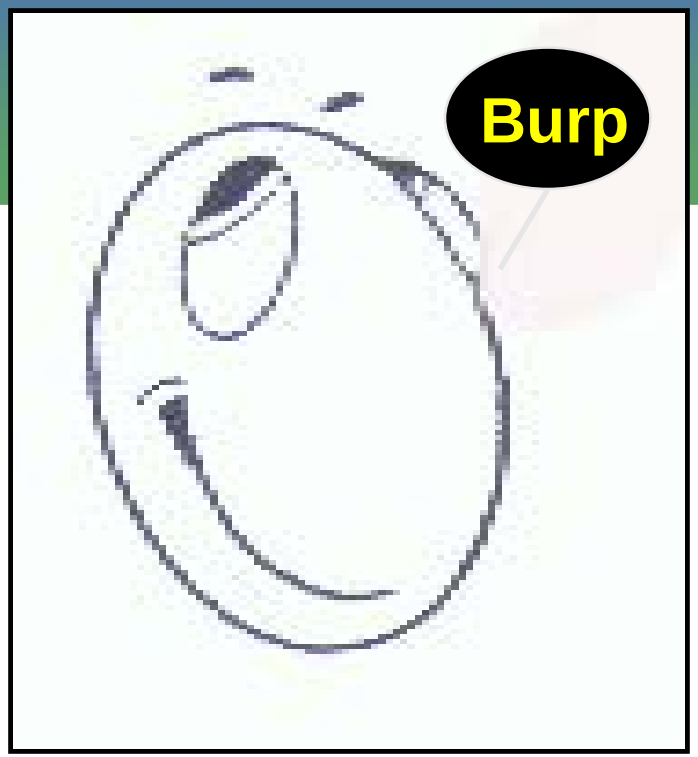


Goal: Silage Preservation

- ***Establish conditions that encourage proliferation of desirable microorganisms, but discourage undesirable ones***
  - ***desirable (lactic-acid bacteria)***
  - ***undesirable (clostridia, enterobacteria)***



Ideally, the goal is to establish a stable silage mass by lowering pH and maintaining anaerobic conditions!



Lactic Acid, The "Good Silage" Acid

plant sugars → lactic acid

Homofermentative

glucose or fructose + 2ADP + 2 Pi → <u>2 lactate</u> + 2 ATP + 2 H_2O

Heterofermentative (multiple pathways)

glucose or fructose + ADP + Pi → <u>lactate</u>, acetate, ethanol, mannitol, ATP, H_2O, and CO_2

Typical Characteristics of Chopped Grass Silages in Northern Europe from Different Fermentation Types

Item	Lactic Acid	*Wilted*	*Clostridial*	Acetic Acid	Sterilized
DM, %	19.0	*30.8*	*17.0*	17.6	21.2
pH	3.9	*4.2*	*5.2*	4.8	5.1
Protein N, % of N	23.5	*28.9*	*35.3*	44.0	74.0
Ammonia N, % of N	7.8	*8.3*	*24.6*	12.8	3.0
Lactic Acid, %	10.2	*5.9*	*0.1*	3.4	2.6
Acetic Acid, %	3.6	*2.4*	*2.4*	9.7	1.0
Butyric Acid, %	0.1	*0.1*	*3.5*	0.2	0.1
WSC, %	1.0	*4.8*	*0.6*	0.3	13.3

adapted from *McDonald and Edwards (1976)*

Plant Factors

- ***Water Soluble Carbohydrates (WSC)***
- ***Buffering Capacity***

Fermentable Sugars
Water-Soluble Carbohydrates (WSC)

Sources of Variation for WSC

Species

Cultivar Within Species

Stage of Growth

Time of Day

Climate

Drought

Frost Events

N Fertilization

Rain

Poor/Extended Wilting Conditions

Management

Lactic Acid,
The "Good Silage" Acid

plant sugars → lactic acid

Water Soluble Carbohydrates (WSC) for Selected Forage Crops

Crop/Species	WSC, % of DM
Corn Silage	10 - 20
Forage Sorghum	10 - 20
Sudan, Sorghum-Sudan, Millet	10 - 15
Rye, Oat, Wheat, Triticale	8 - 12
Ryegrass	8 - 12
Alfalfa	4 - 7
Bermudagrass, Stargrass	2 - 4
Bahiagrass	< 5
Limpograss	< 5
Perennial Peanut	1 - 4

Adesogan and Newman, 2013

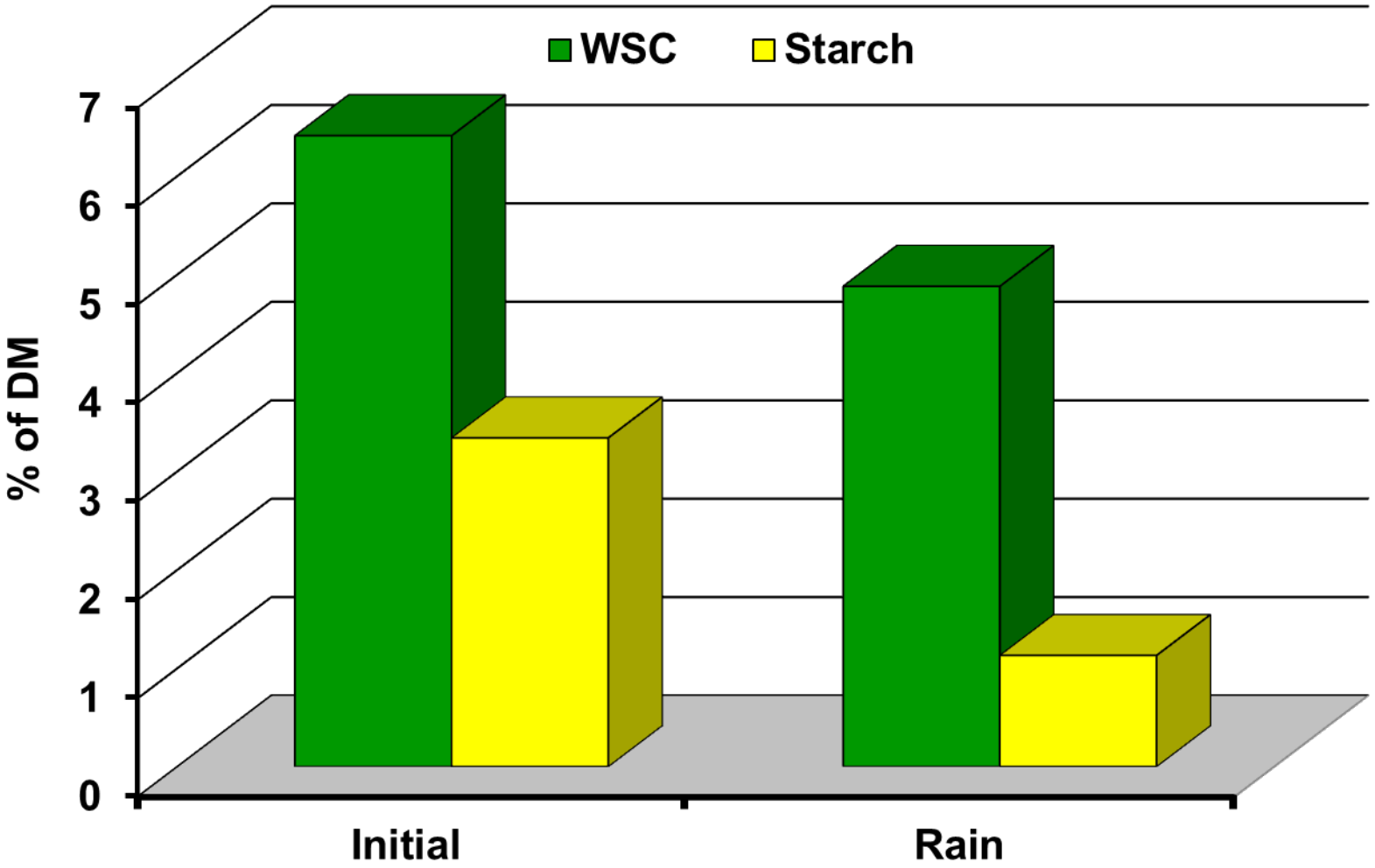
Water Soluble Carbohydrates (WSC) for Fall-Grown Oat as Affected by N Fertilization Rate

N Fertilization Rate	2011	2012
lbs N/acre	---------- % of DM ----------	
0	12.4	19.3
22	12.3	17.4
45	11.5	17.4
67	10.0	16.5
90	10.1	16.3
SEM	0.76	0.53
Contrast	---------- *P* > *F* ----------	
Linear	0.004	< 0.001
Quadratic	ns	ns
Cubic	ns	ns

[1] ns, non-significant (*P* > 0.05)

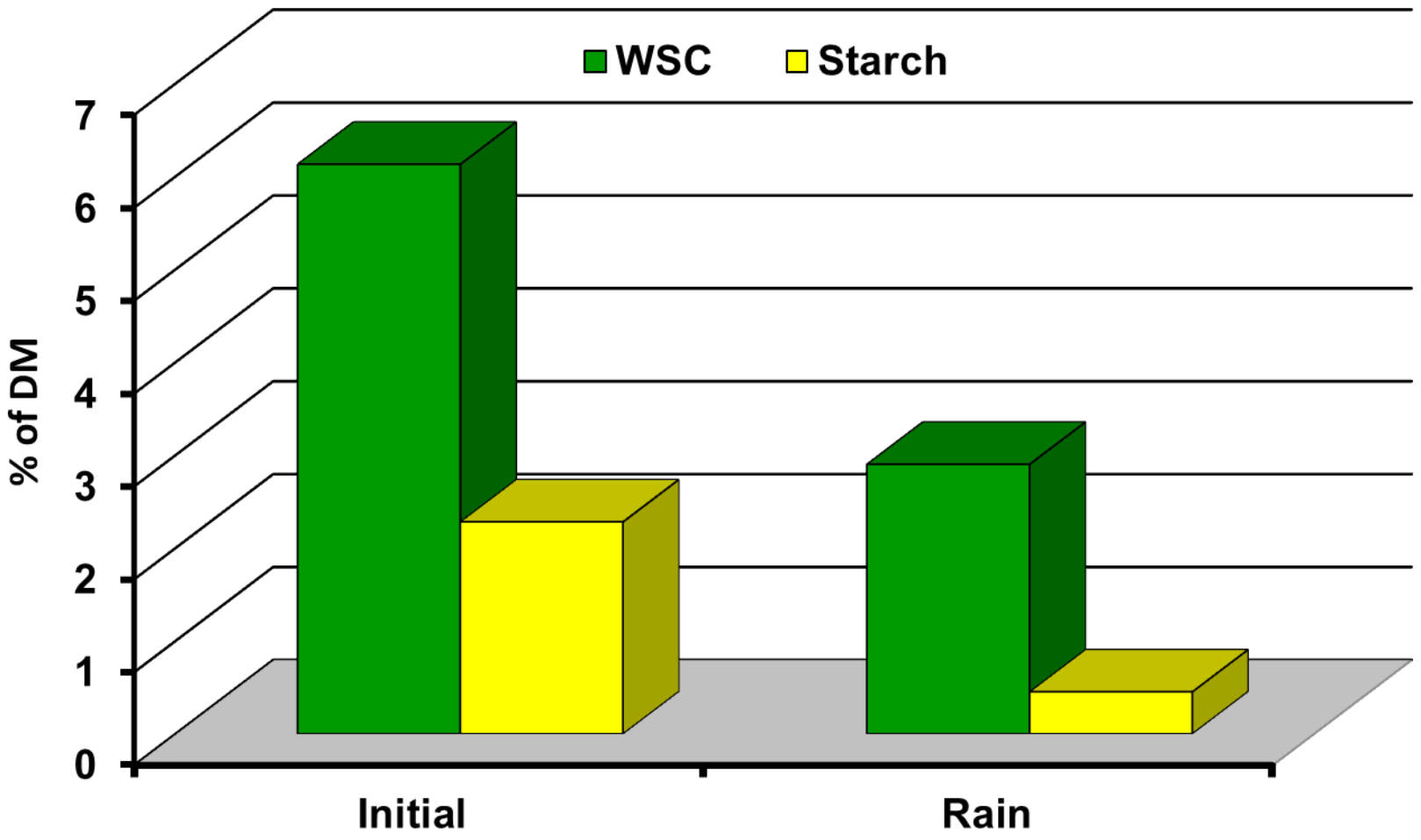
Coblentz et al. (2014)

WSC and Starch in Rain-Damaged Alfalfa (1.1 inches)



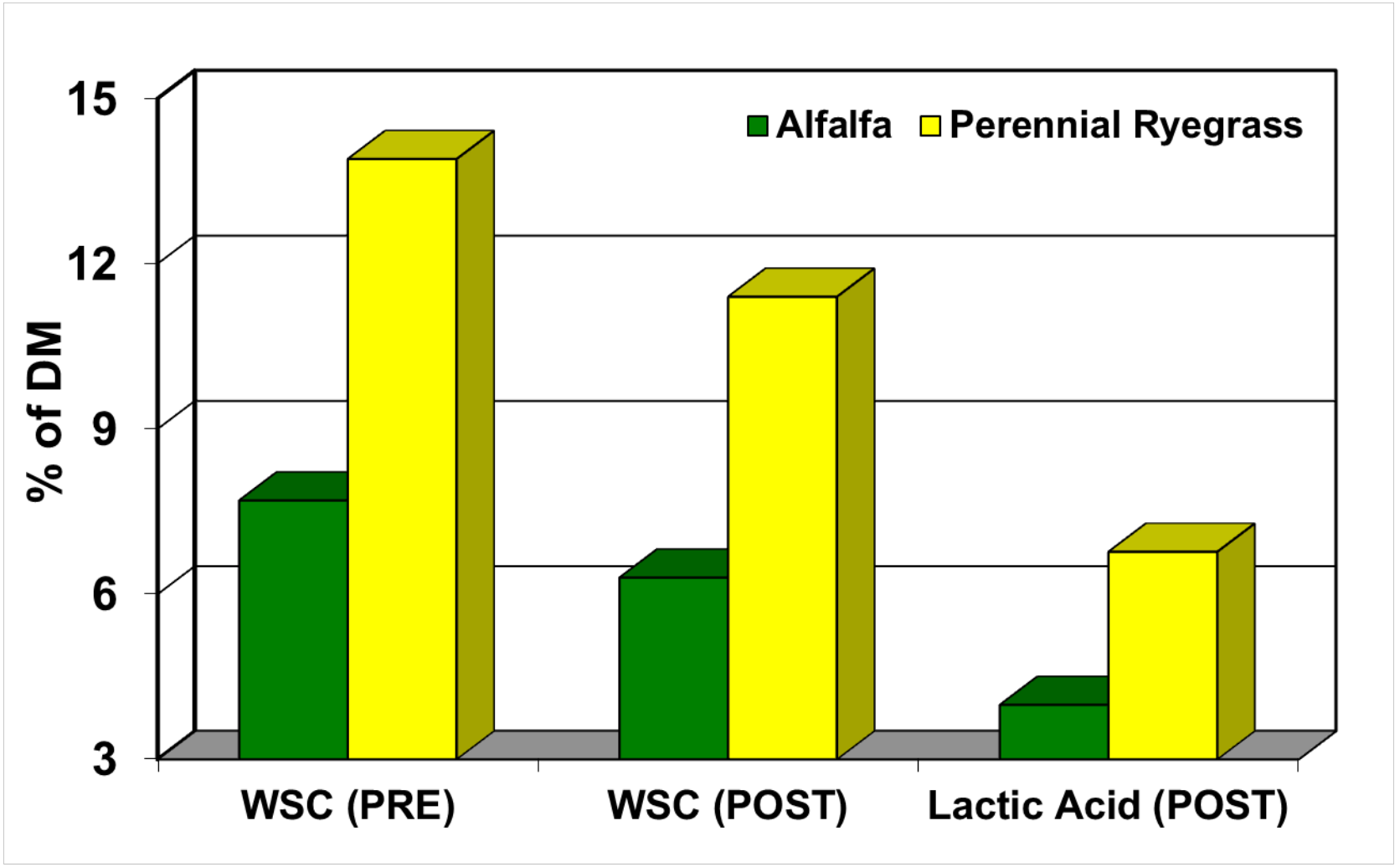
Coblentz and Muck, 2012

WSC and Starch in Rain-Damaged Alfalfa (1.9 inches)



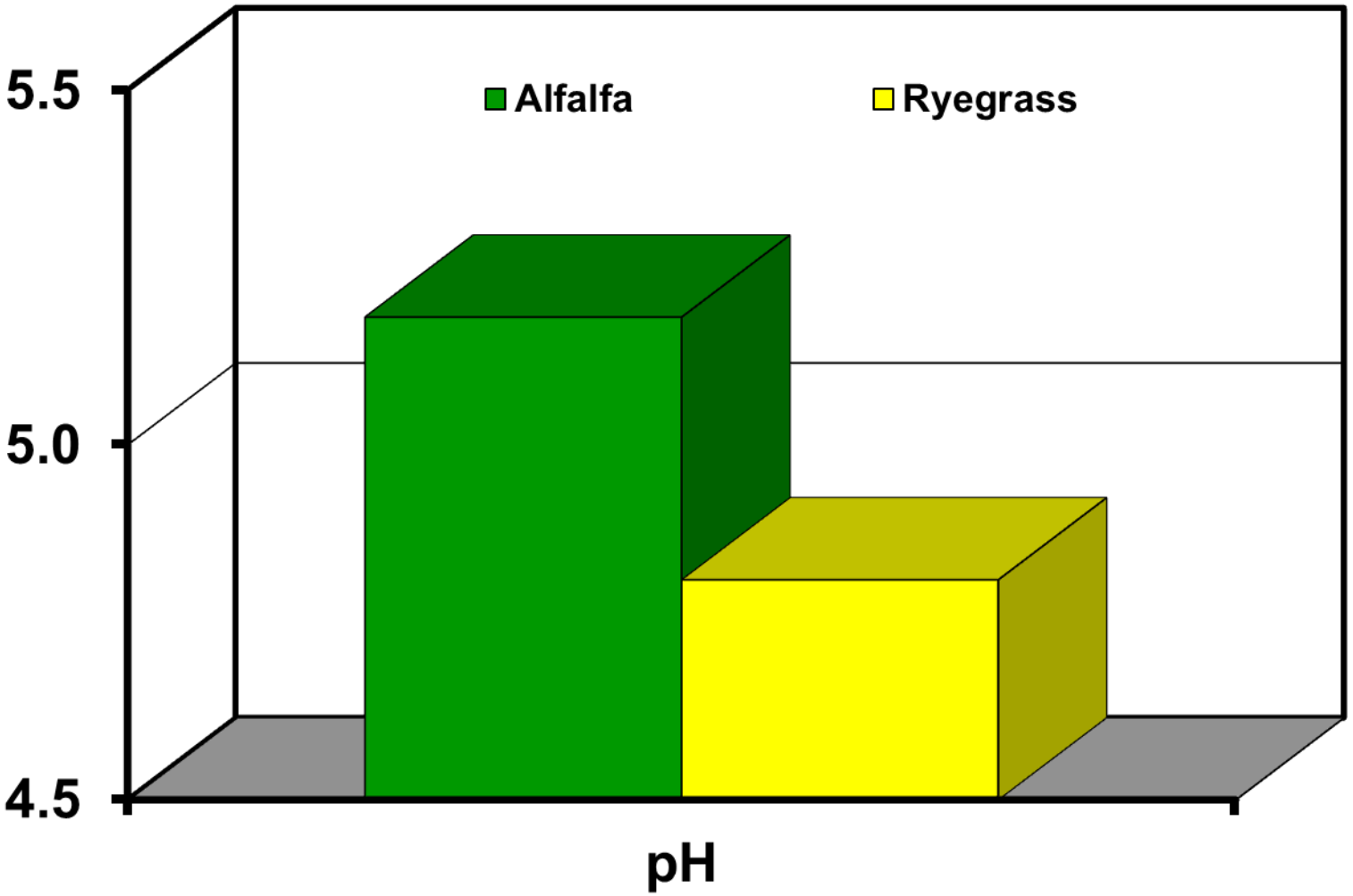
Coblentz and Muck, 2012

How Does WSC Affect Silage Fermentation?



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

How Does WSC Affect Silage Fermentation?



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

Ethanol-Dominated Fermentation in Highly Sugared Forage Crops[1]

Treatment	Bale Moisture	WSC	Lactic Acid	Ethanol	pH	NDF	CP	TDN
		---------- % of DM ---------				----- % of DM ------		
Boot Stage								
Initial	67.6	22.6	. . .	. . .	6.90	40.3	13.7	71.4
Final	74.0	17.8	4.82	5.82	4.61	47.0	17.9	67.8
Early Heading Stage								
Initial	63.7	21.0	. . .	. . .	6.94	46.9	14.6	69.7
Final	67.3	11.9	1.63	4.85	5.71	55.0	16.0	60.9

[1] *'Vista' fall-grown oat.*

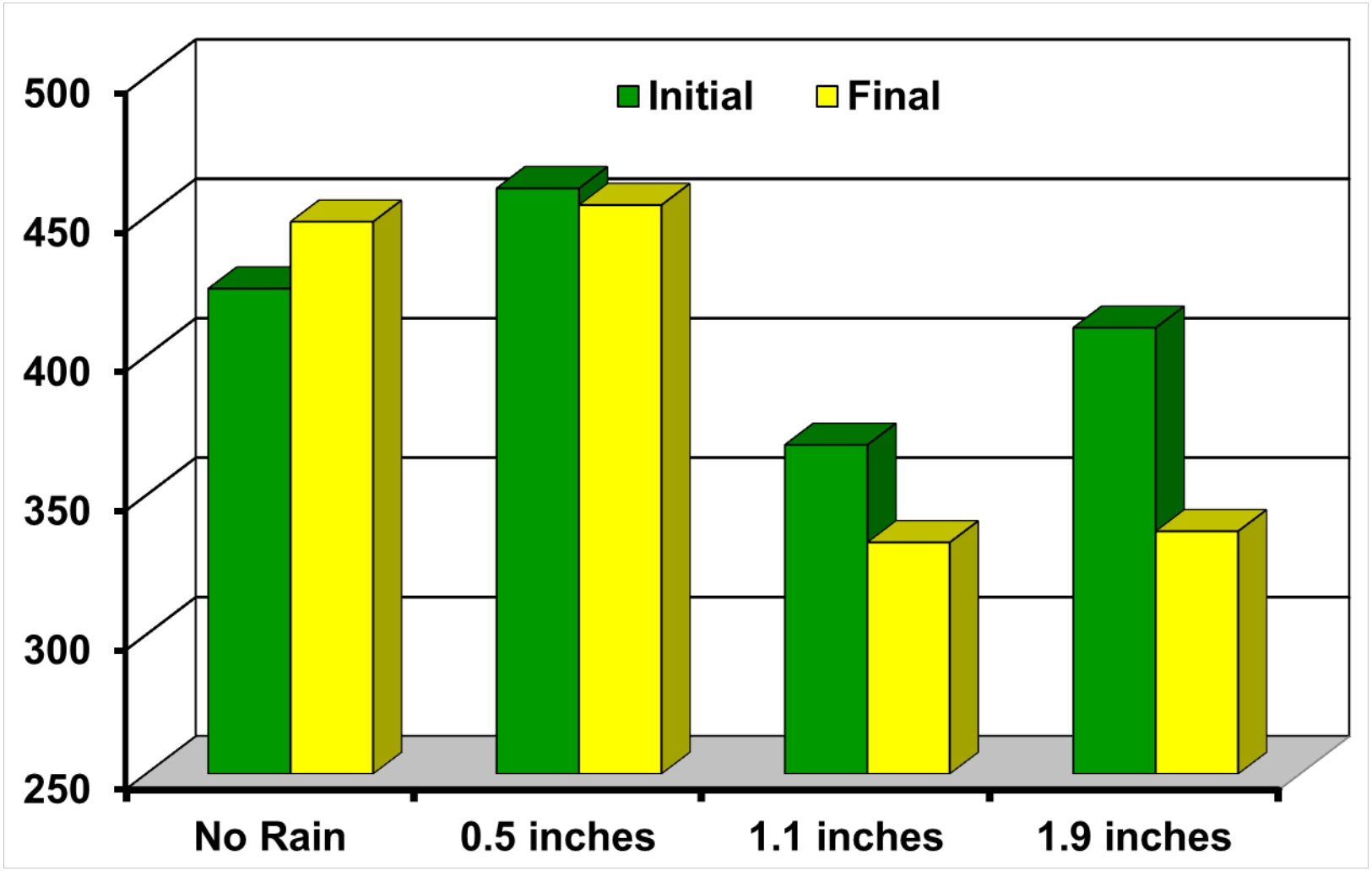
Coblentz et al. (2015)

Buffering Capacities (mEq/kg DM) for Selected Forage Crops

Crop/Species	Range	Mean
Corn Silage	149-225	185
Timothy	188-342	265
Fall Oat (Headed)	300-349	323
Orchardgrass	247-424	335
Red Clover	. . .	350
Fall Oat (Boot)	360-371	366
Italian Ryegrass	265-589	366
Alfalfa (mid-bloom)	313-482	370
Perennial Ryegrass	257-558	380
Alfalfa (1/10 bloom)	367-508	438
Alfalfa	390-570	472
White Clover	. . .	512

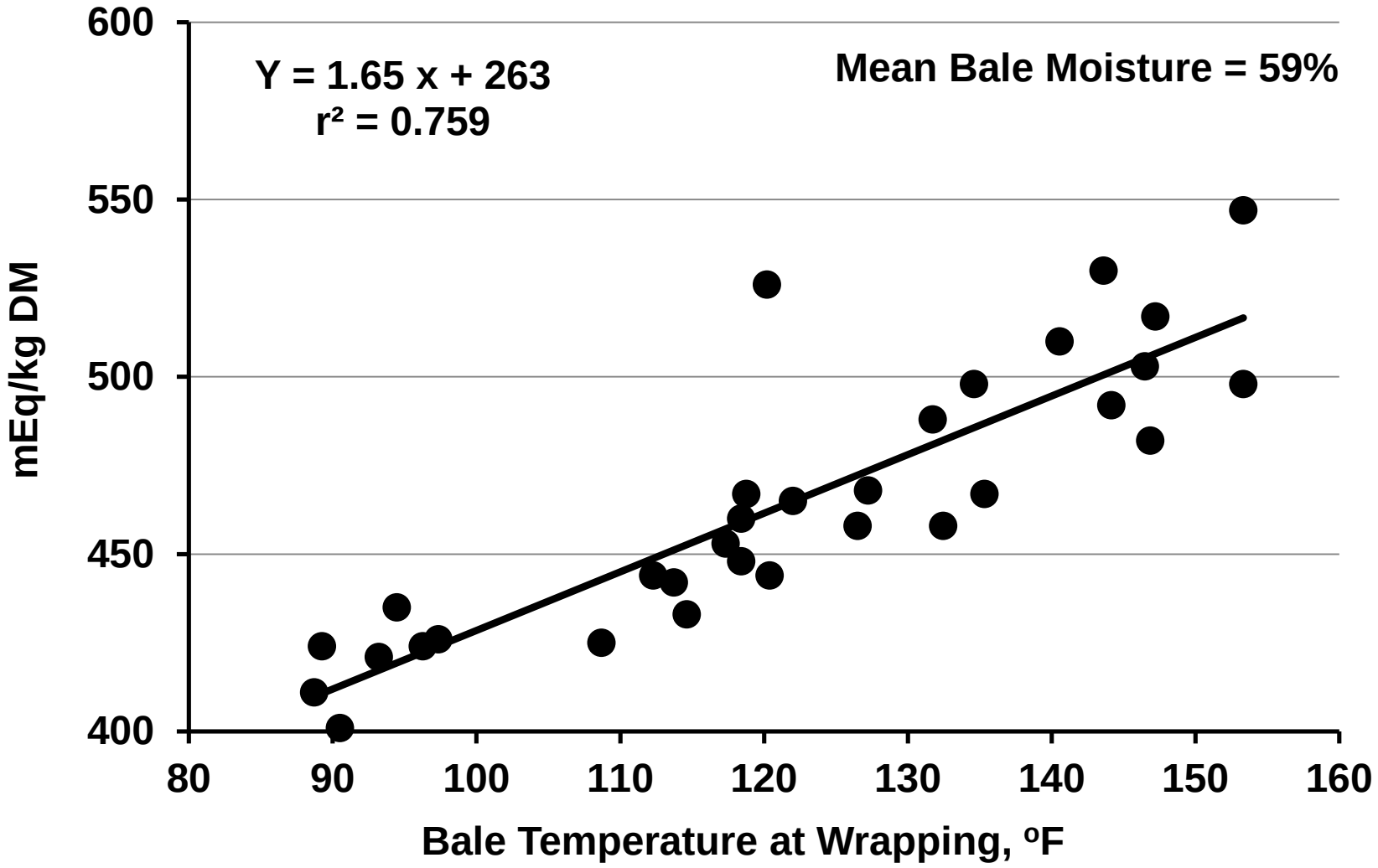
Compiled from Various Sources

Buffering Capacity (mEq/kg DM) of Wilting Alfalfa Forages as Affected by Natural Rainfall



Coblentz and Muck, 2012

Buffering Capacity of Alfalfa Forage as Affected by Internal Bale Temperature before Wrapping

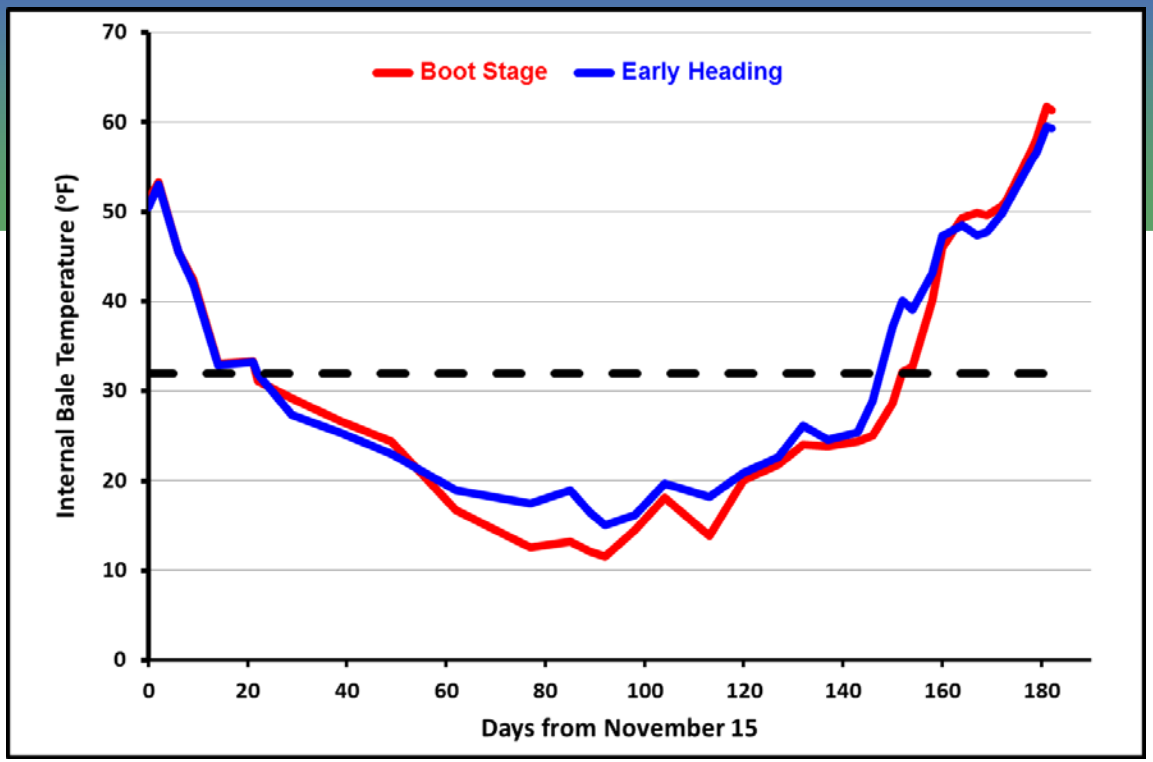


Coblentz et al. (unpublished)

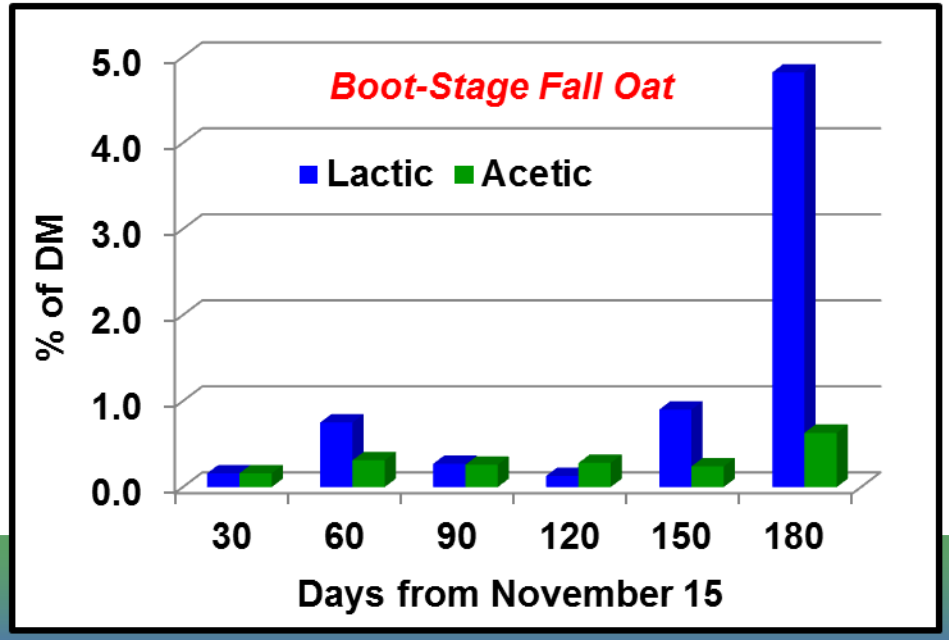
Weather Factors

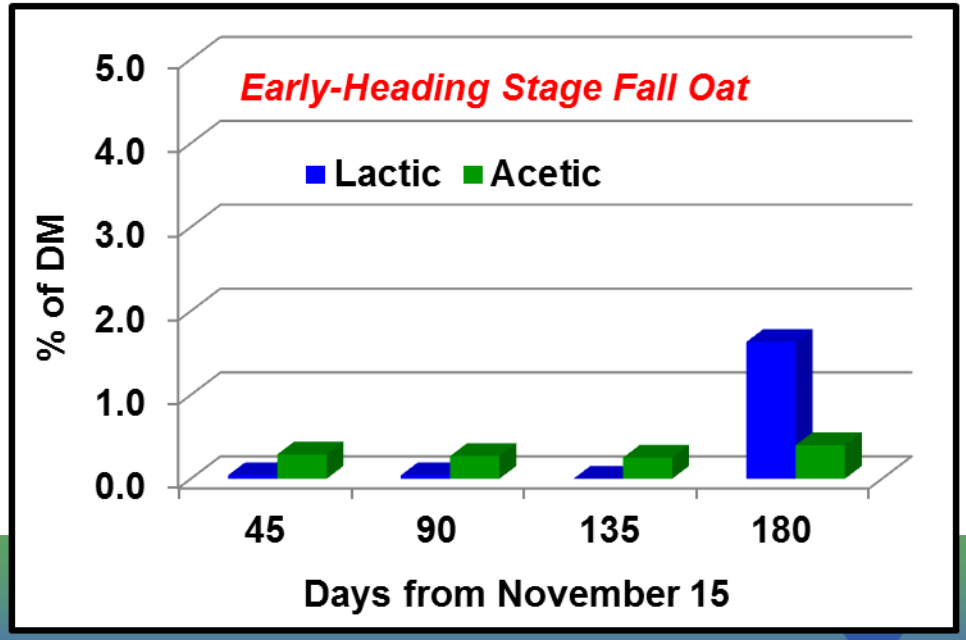
Temperature

Coblentz et al. (2015)



Effects of Cold Weather on Fermentation of Fall-Grown Oat





Moisture Management for Baled Silage

Generally, baled silage should be packaged at 45 to 55% moisture (Shinners, 2003); the average for the whole field or group of bales should be about 50%.

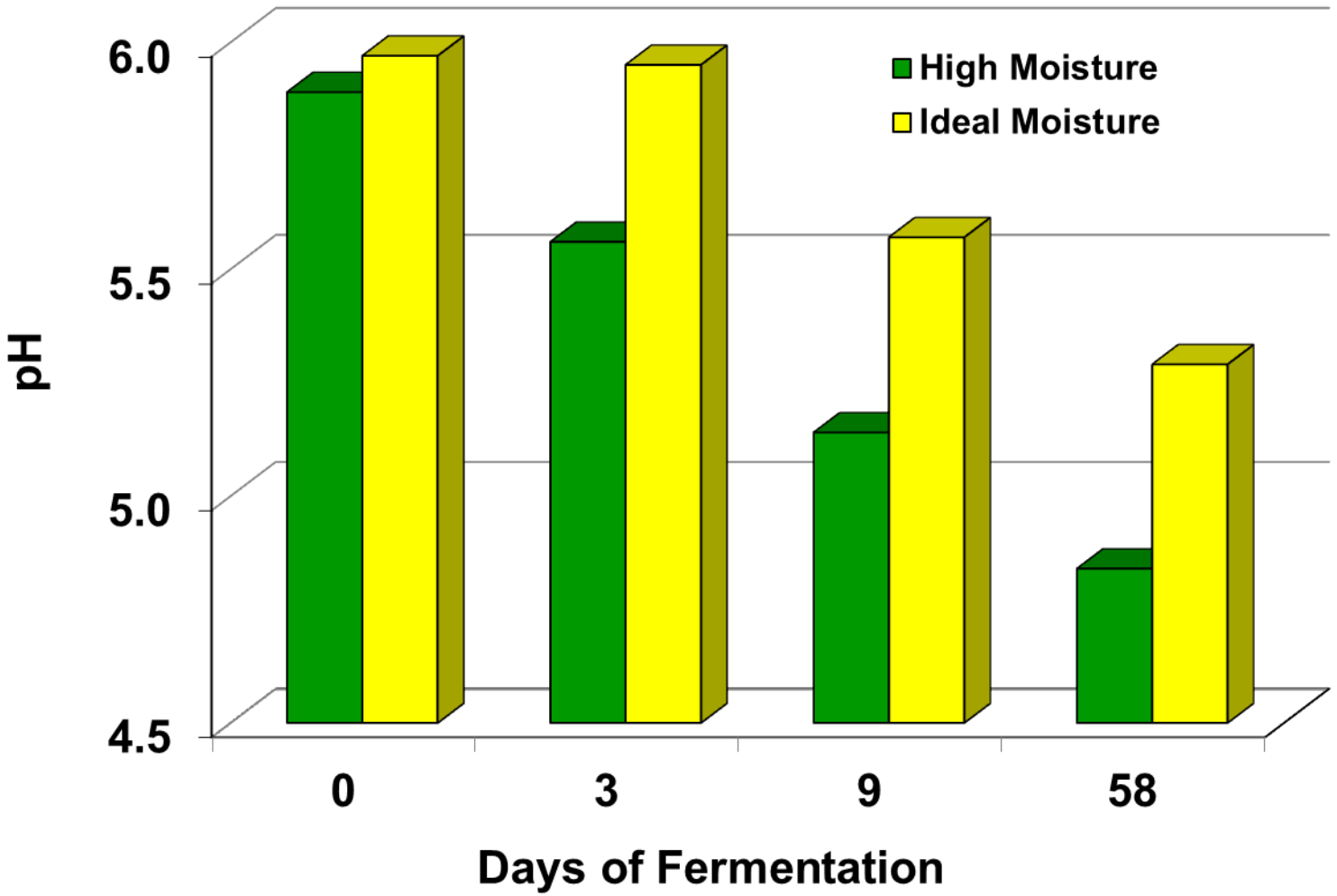
- ***production of silage fermentation acids is positively associated with moisture concentration***
- ***moisture recommendations for chopped silages are < 70%***
- ***as a result, baled silage fermentation is inherently restricted, resulting in a slower fermentation, and a greater (less-acidic) final pH***

Fermentation Characteristics of Alfalfa Ensiled in Large-Round Bales at High (60 to 65%) or Ideal (49 to 54%) Moisture

		---------- Day of Fermentation ----------			
Item	Moisture	0	3	9	58
Lactic Acid, %	High	0.40	1.63	2.45	3.80
	Ideal	0.40	0.65	1.05	2.84
Acetic Acid, %	High	1.02	1.30	1.55	1.78
	Ideal	0.89	0.91	1.09	1.16
Total Acids, %	High	1.68	3.34	4.35	5.99
	Ideal	1.55	1.87	2.45	4.37

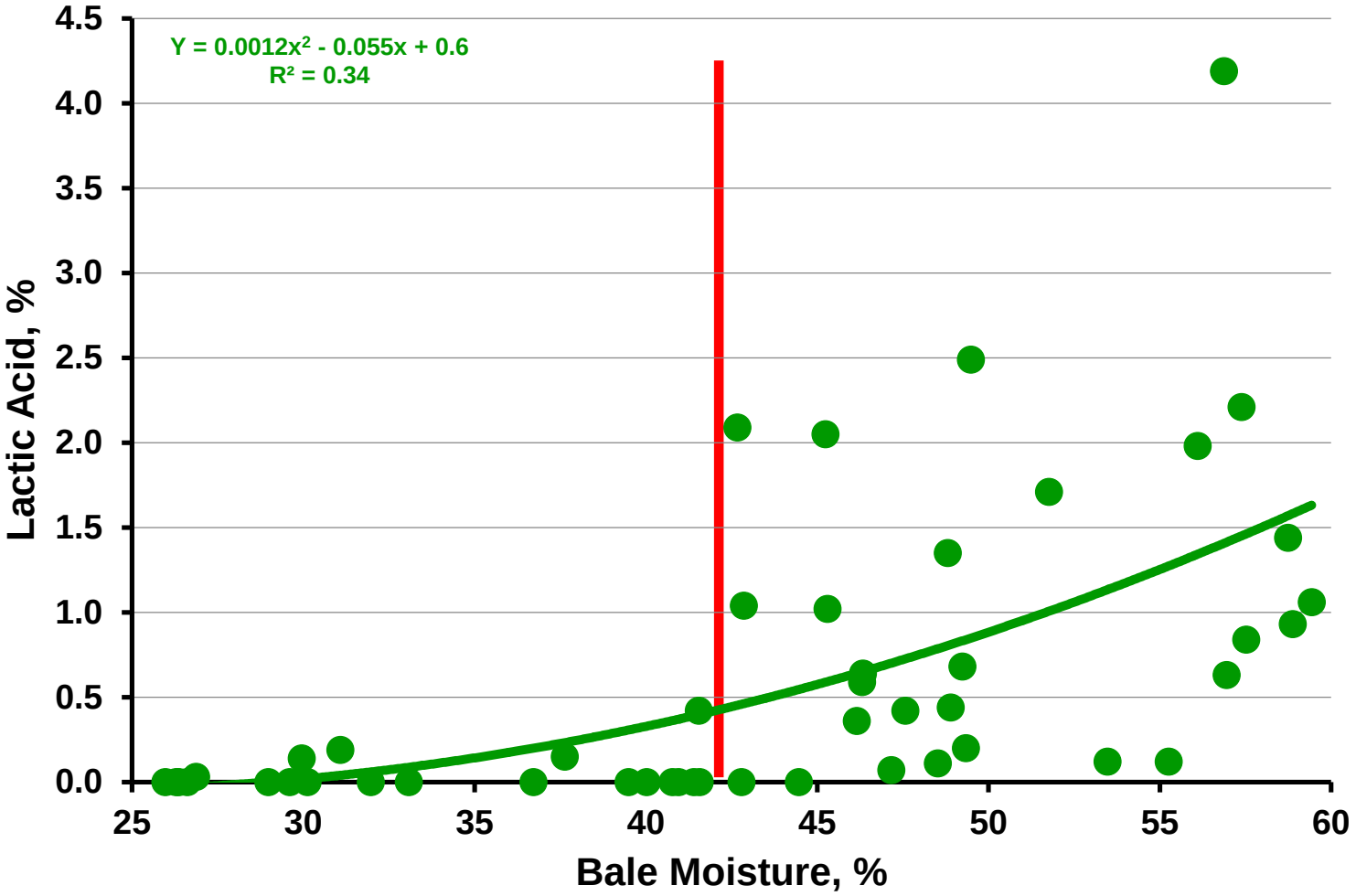
Nicholson et al. (1991)

Fermentation Characteristics of Alfalfa Forages Ensiled in Large-Round Bales at High (60 to 65%) or Ideal (49 to 54%) Moisture



Nicholson et al. (1991)

Lactic Acid Production in Alfalfa Silages Packaged in Large-Rectangular Bales



Coblentz et al. (2014)

Clostridial Fermentations
(Products: Butyric Acid, Ammonia)

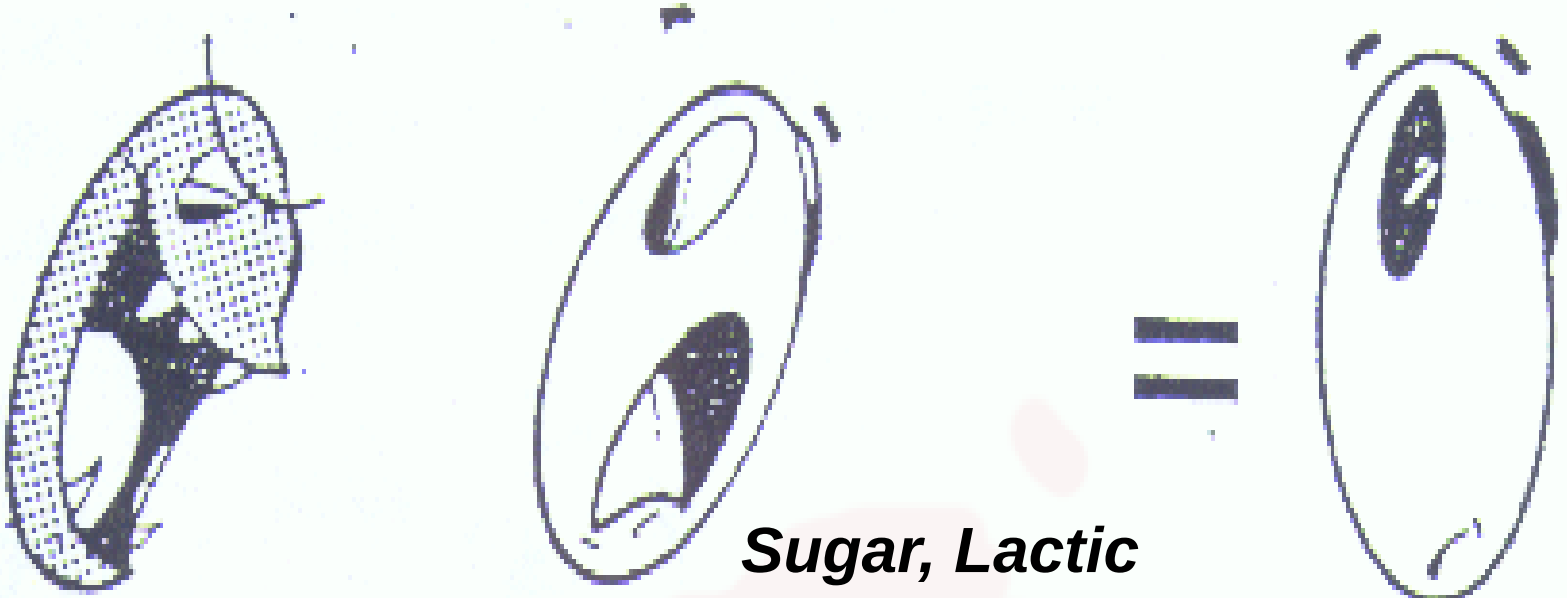
Some Characteristics of High-Risk Forages

- *high moisture concentration*
- *direct cut forages*
- *immature, rapidly growing forages*
- *highly contaminated with dirt, manure, or both*
- *low sugar*
- *high buffering capacity*
- *high protein*
- *leguminous*
- *non-homogenous forages (baled silage)*

The best prevention is to wilt the forage prior to ensiling! As such, baled silage is generally at low risk.

Clostridial Fermentations

Clostridial spores



Butyric Acid, Ammonia
"Bad, Evil-Smelling Silage"

Clostridial Counts (log_{10} genomic copies/g) for Pre-Ensiled and Post-Ensiled Alfalfa Forages Following Applications of Dairy Slurry Using qPCR Methods[1]

	Harvest 1		Harvest 2	
Treatment	**Pre**	**Post**	**Pre**	**Post**
Slurry Application				
No slurry	**3.29**	**4.26**	**3.88**	**4.21**
Stubble	**4.10**	**5.17**	**5.06**	**5.28**
1 week	**4.48**	**5.41**	**4.85**	**5.45**
2 weeks	**4.75**	**5.61**	**5.06**	**6.23**
SEM	**0.198**	**0.095**	**0.178**	**0.074**
Contrasts	----------	***P > F***	----------	
No Slurry vs. Slurry	**0.002**	**< 0.001**	**< 0.001**	**< 0.001**
Stubble vs. Delayed	**ns**[2]	**0.018**	**ns**	**< 0.001**
1 vs. 2 weeks	**ns**	**ns**	**ns**	**< 0.001**

[1] ***Clostridium tyrobutyricum*** **was not detected in dairy slurry or any forage/silage.**
[2] **ns, non-signficant (*P* > 0.05)**

Baled Silage vs. Precision-Chopped Haylage

How Do They Compare?

- *moisture effects (discussed previously)*

- *for baled silage, 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*

Fermentation Characteristics of Alfalfa Forages Ensiled as Large-Round Bales or as Precision-Chopped Silages[1]

		---------- Day of Fermentation ----------			
Item	Type	0	3	9	58
Lactic Acid, %	Baled	0.20	0.31	1.14	1.85
	Chopped	0.26	1.73	2.83	4.97
Acetic Acid, %	Baled	0.65	0.69	0.79	1.12
	Chopped	0.68	1.20	1.52	1.83
Total Acids, %	Baled	0.51	1.43	2.61	3.61
	Chopped	0.44	3.63	4.90	7.30

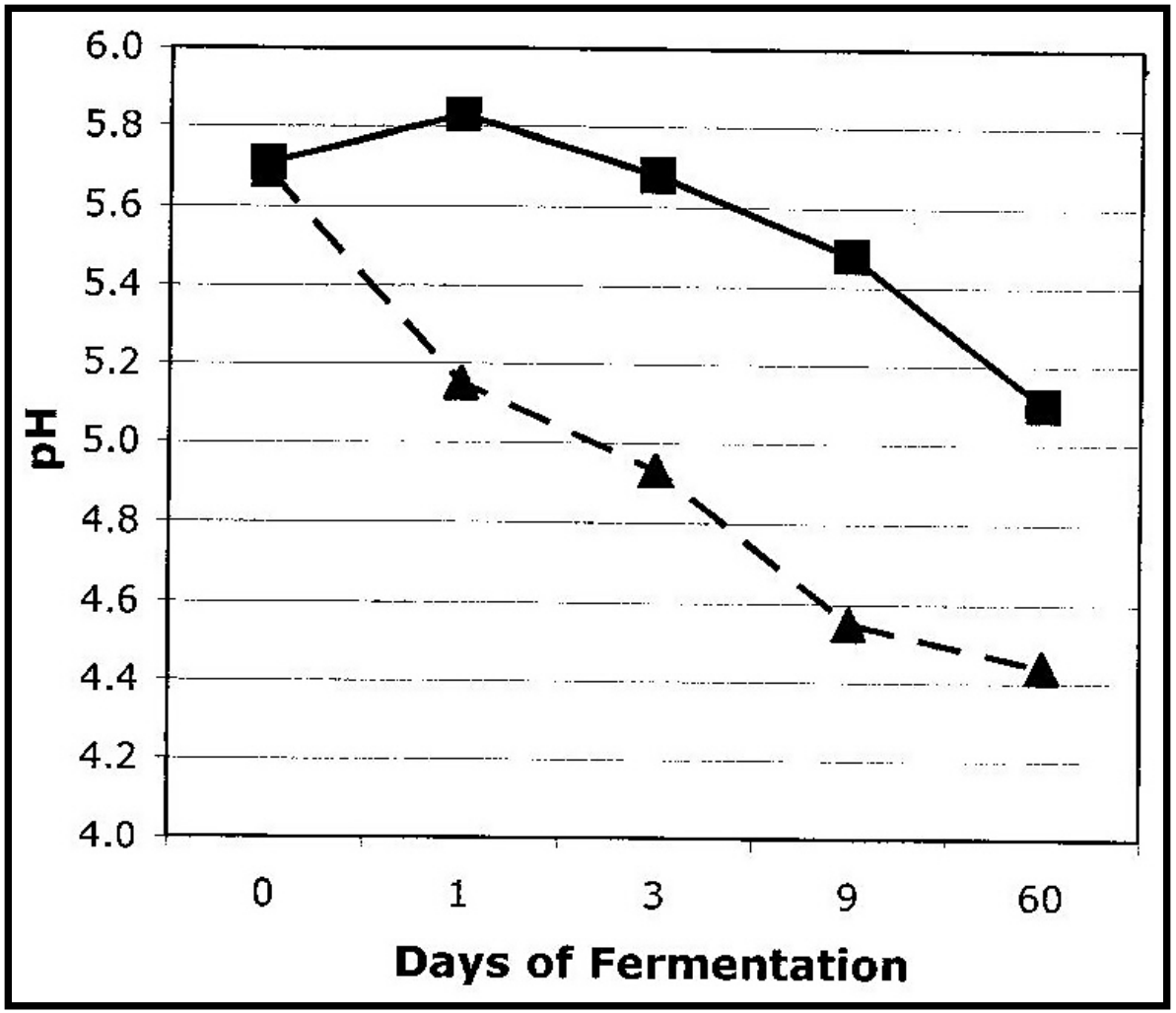
[1] Mean moisture concentration = 61%.

Nicholson et al. (1991)

Baled vs. Precision-Chopped Silage Alfalfa/Grass

■ Baled

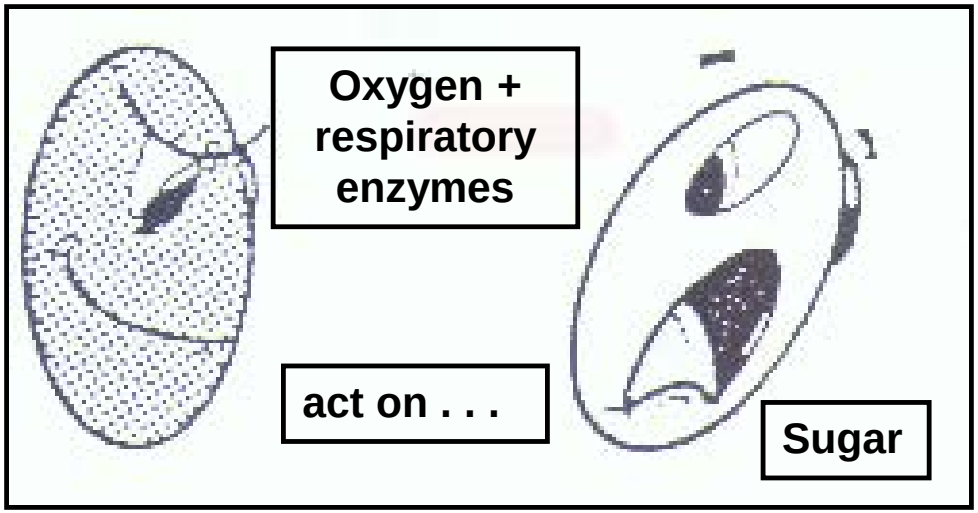
▲ Chopped



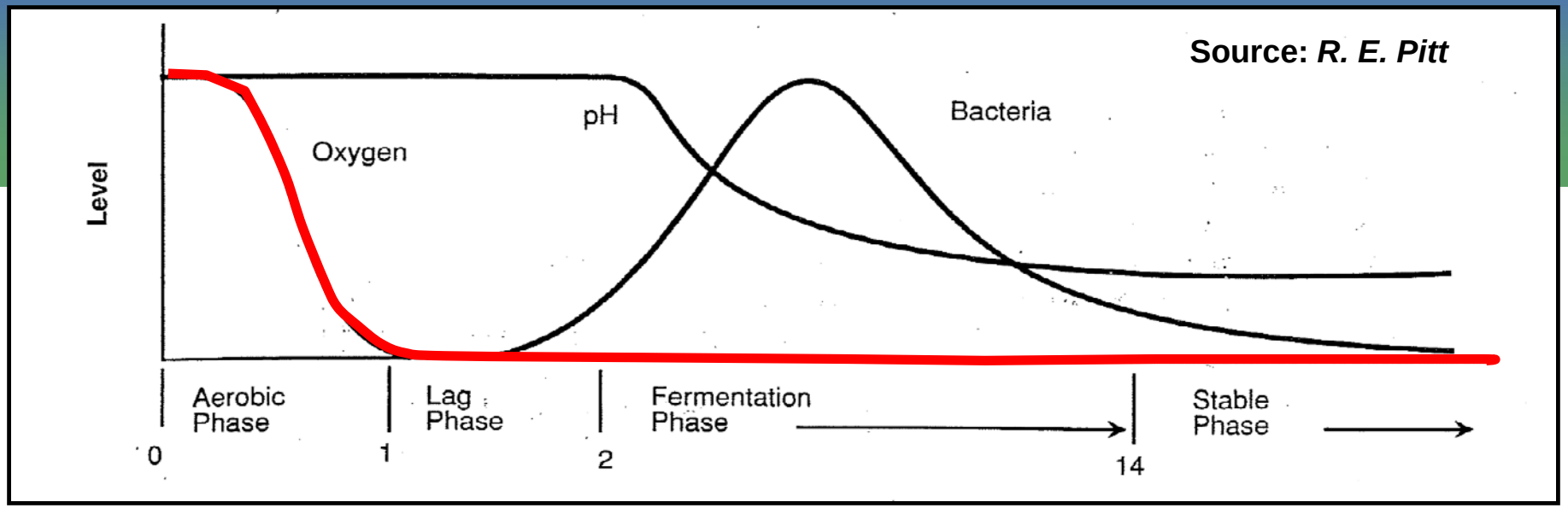
Muck (2006) – adapted from *Nicholson et al. (1991)*; moisture concentration was 61%

Elimination of Air

Consequences of Air Access!



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



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*

Sealing the Bale

- *lack of bale uniformity will create air pockets for in-line wrapped bales*
- *use UV-resistant plastic; patch holes with appropriate tape*
- *wrap as quickly as possible after baling (within 2 hours is ideal)*
- *use (at least) four layers (1 mil or 25 microns) of stretched plastic (at least 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*

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)

Fermentation Characteristics of Barley Ensiled in Large-Round Bales as Affected by Wrapping Delays[1]

	---------- Wrapping Delay, hours ----------		
Item	**2**	**10**	**19**
pH	**5.7**	**5.6**	**6.1**
Lactic Acid, %	**1.25**	**1.70**	**0.82**
Acetic Acid, %	**0.33**	**0.38**	**0.47**
Butyric Acid, %	**trace**	**trace**	**trace**
Total Acids, %	**1.63**	**2.15**	**1.35**

[1] **Barley forage baled at 53% moisture.**

Moshtaghi Nia and Whittenburg (2000)

Fermentation Characteristics of Alfalfa Ensiled in Large-Round Bales as Affected by Wrapping Delays[1]

Item	Wrapping Delay, hours 0	24	48	72
Bale Temperature, ºF				
at wrapping	95	117	128	147
maximum	101	121	139	152
WSC (pre-storage), %	5.3	4.6	4.5	4.0
WSC (post-storage), %	2.8	3.0	3.6	3.3
Lactic Acid, %	1.88	1.59	0.73	0.67
Acetic Acid, %	1.47	0.77	0.61	0.91
Butyric Acid, %	0.99	0.67	0.12	0.35
NH_3-N, % of N	19.0	15.0	12.4	16.2
Total Acids, %	4.63	3.19	1.77	2.21
pH	5.70	5.68	5.78	5.89

[1] Mean moisture concentration = 59%.

Coblentz et al. (unpublished)

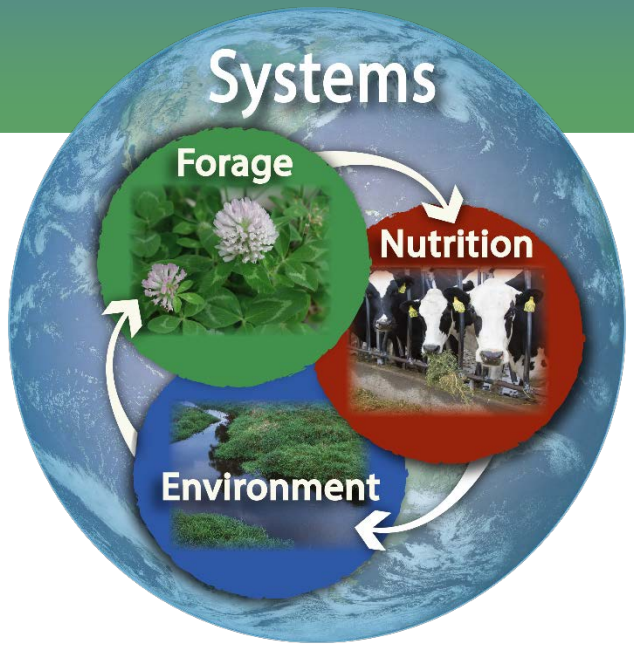
Summary

- ***Forage crops differ; learn their characteristics.***
- ***Most principles of management for conventional chopped silage still apply to baled silage.***
- ***Moisture management is critical; generally, baled silage techniques will accommodate drier (<50%) forages better than relatively wet (>60%) ones.***

Summary

- ***Fermentation may occur at a slower rate for baled silage because forages are ensiled on a whole-plant basis, and the forage is usually drier than chopped silages.***
- ***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 until feeding.***

QUESTIONS?



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