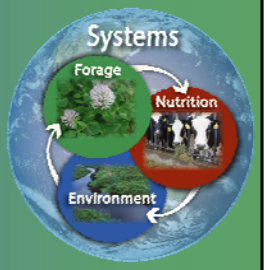
United States Department of Agriculture

Key Components of Making Baled Silage

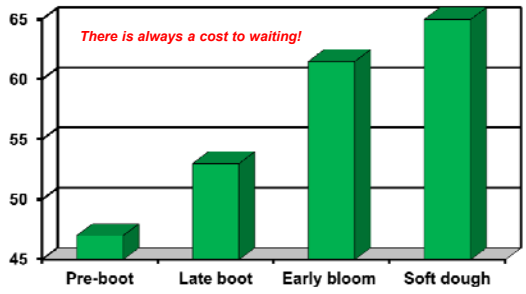


2016 Area Dairy Conferences
March 7-11, 2016

Wayne Coblentz
USDA-ARS
US Dairy Forage Research Center
Marshfield, WI

U.S. Dairy Forage Research Center, USDA Agricultural Research Service

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



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

3

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)*

2

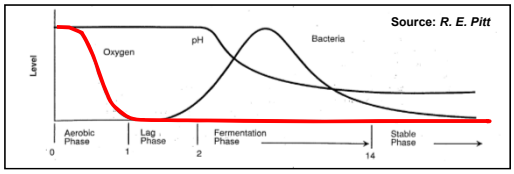
Regardless of silo type, most management principles are the same.

- *start with high-quality forage*

4

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*



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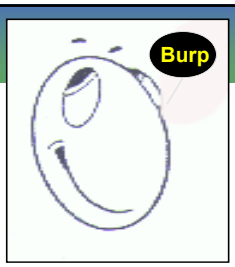


Lactic Acid, The "Good Silage" Acid

plant sugars → lactic acid

Homofermentative

glucose or fructose + 2ADP + 2 Pi → 2 lactate + 2 ATP + 2 H_2O

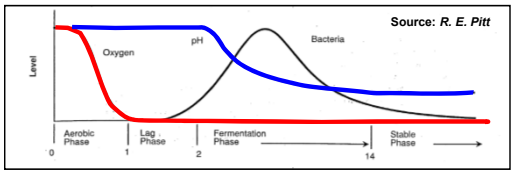
Heterofermentative (multiple pathways)

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

7

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!

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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)*

8

Baled Silage vs. Precision-Chopped Haylage
How Do They Compare?

- *silage fermentation is restricted by the lower moisture content of baled silage*
- *lack of chopping action in baled silages forces sugars to diffuse from inside the plant to reach lactic-acid producing 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 restricts availability of sugars to lactic-acid producing bacteria*

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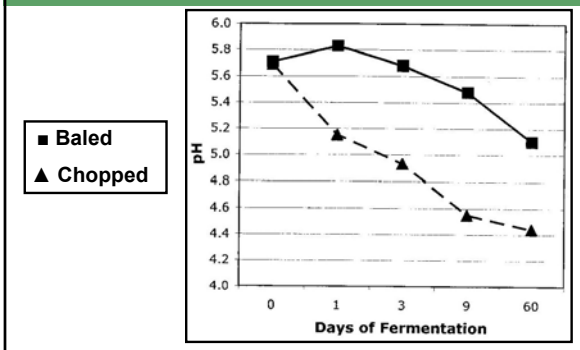
Baled vs. Precision-Chopped Silage
Alfalfa/Grass



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

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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)

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Plant Factors

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

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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

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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 14

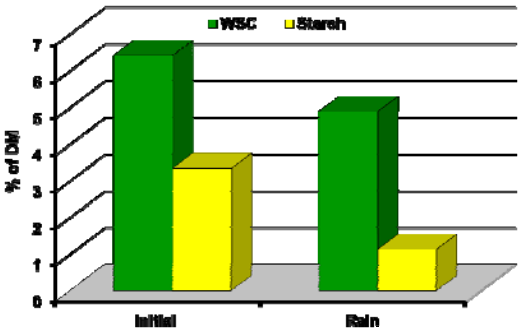
Water Soluble Carbohydrates (WSC) for Fall-Grown Oat as Affected by N Fertilization Rate

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 ($P > 0.05$)

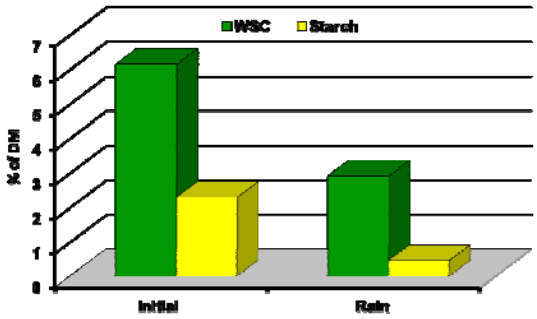
Coblentz et al. (2014) 15

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



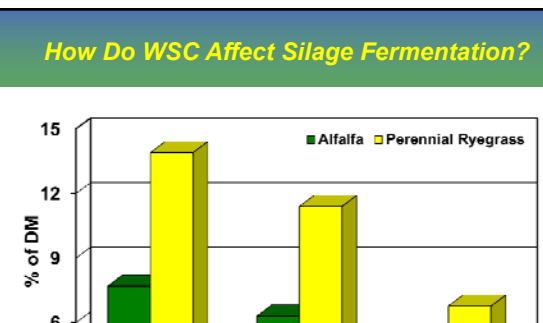
Coblentz and Muck, 2012 16

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



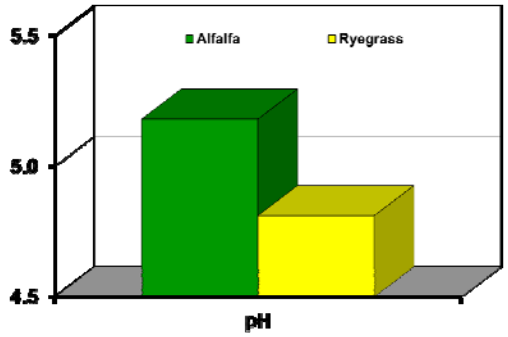
Coblentz and Muck, 2012 17

How Do WSC Affect Silage Fermentation?



Han et al. (2006): mean of ideal (48.8%) and low (29.5%) moisture bales 18

How Do WSC Affect Silage Fermentation?



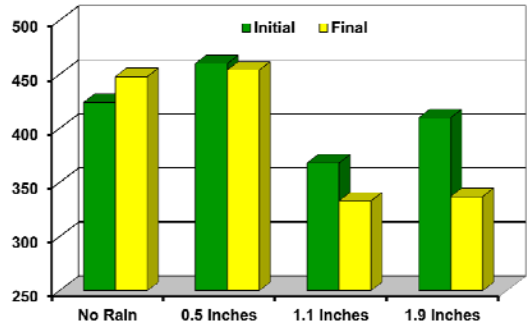
Han et al. (2006): mean of ideal (48.8%) and low (29.5%) moisture bales 19

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 20

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



Coblentz and Muck, 2012 21

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) 23

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%.

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

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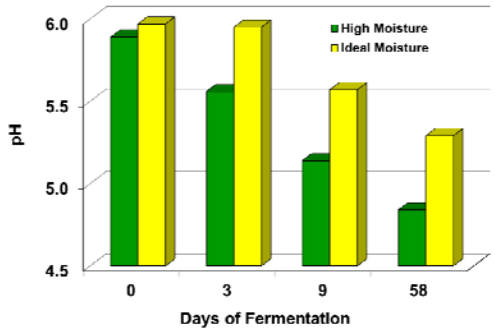
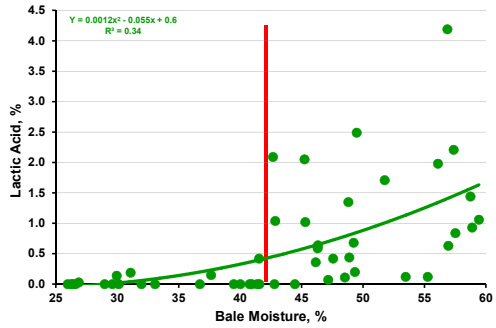
Fermentation Characteristics of Alfalfa Forages Ensiled in Large-Round Bales at High (60 to 65%) or Ideal (49 to 54%) Moisture



Nicholson et al. (1991) 24

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



Coblentz et al. (2014)

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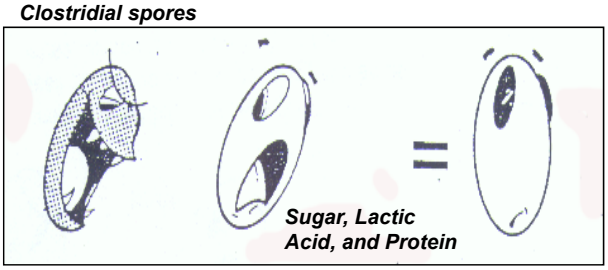
Clostridial Fermentations

Clostridial spores



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

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So Why Not Bale Forage Wetter?

- *Safety*
- *Equipment/Baler*
- *Clostridial Fermentations*

Coblentz et al. (2014)

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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.

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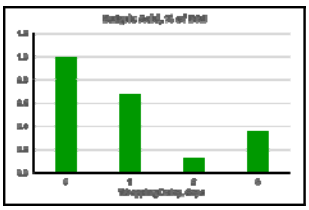
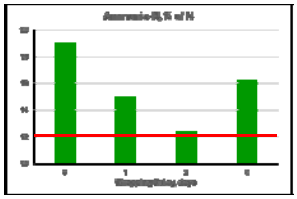
Butyric Acid and Ammonia In Alfalfa Round Bale Silage (59% Moisture)





Coblentz et al. (2016) 28

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)

Coblentz et al. (2014) 30

Physical Characteristics and Composition of Dairy Slurry

Application rates were determined from slurry density and weight difference before and after slurry application to each plot (± 5 lbs).

Item	Mean	SD
Density, lbs/gal	8.93	0.525
Rate, gal/acre	4503	439.7
DM, %	5.7	1.84
N, % of DM	3.9	0.52
NH_4, % of DM	1.7	0.32
P, % of DM	0.77	0.105
K, % of DM	4.1	0.92
S, % of DM	0.30	0.026
Ash, % of DM	36.1	6.56
C:N Ratio	9.7	1.02
Clostridial Cluster 1[1,2]	6.89	0.181

[1] *Expressed log_{10} genomic copies/g.*
[2] *Clostridium tyrobutyricum was not detected.*

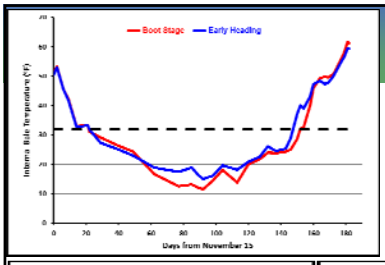
Coblentz et al. (2014) 29

Weather Factors

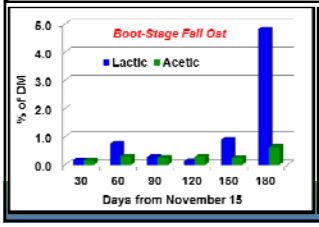
Temperature

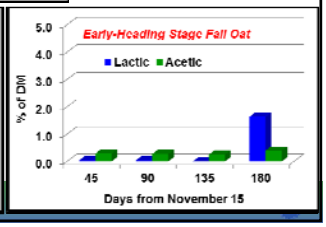
31

Effects of Cold Weather on Fermentation of Fall-Grown Oat



Coblentz et al. (2015)





Elimination of Air

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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)

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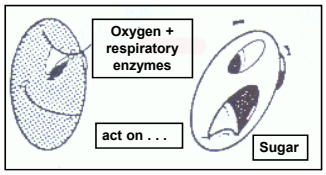
Consequences of Air Access! (Mostly Before Sealing)



- *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*

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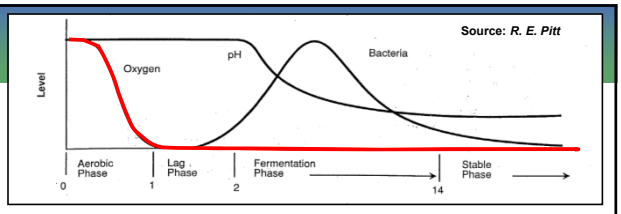

bulk density >10 lbs DM/ft³

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

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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
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)

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Sealing the Bale

- *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*
- *patch holes with appropriate tape*
- *do not puncture plastic - isolate from cattle, pets, and vermin*

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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)

39

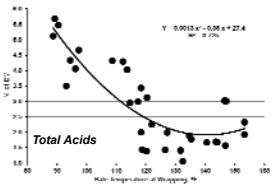
Fermentation Characteristics of Alfalfa Ensiled in Large-Round Bales as Affected by Wrapping Delays[1]

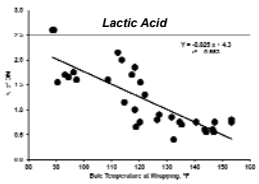
Item	Wrapping Delay, hours 0	24	48	72
Bale Temperature, °F				
at wrapping	95	117	128	147
maximum	101	121	139	152
WSC (pre-storage), %	5.3	4.6	4.5	4.0
Lactic Acid, %	1.88	1.59	0.73	0.67
Acetic Acid, %	1.47	0.77	0.61	0.91
Total Acids, %	4.63	3.19	1.77	2.21
pH	5.70	5.68	5.78	5.89

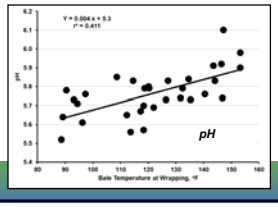
[1] Mean moisture concentration = 59%.

Coblentz et al. (2016) 40

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

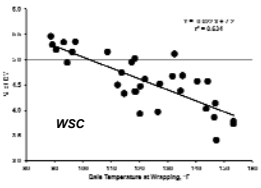


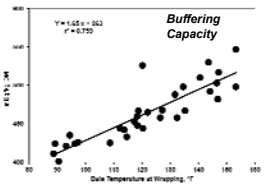




Coblentz et al. (2016) 42

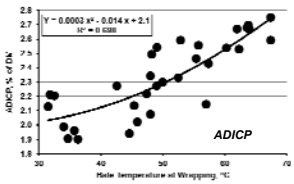
Fermentation Characteristics of Alfalfa Ensiled in Large-Round Bales as Affected by Wrapping Delays

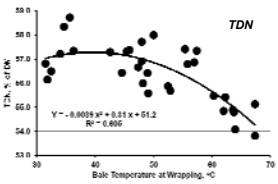




Coblentz et al. (2016) 41

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





Coblentz et al. (2016) 42

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.*

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QUESTIONS?

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Summary

- *Fermentation may occur at a slower rate for baled silage because forages are:*
  - *ensiled on a whole-plant basis*
  - *usually drier than chopped silages*
- *As a result, producers should diligently address other management details:*
  - *maximize bale density*
  - *apply plastic wrap promptly and properly*
  - *protect the wrapped product until feeding*
  - *stabilize your investment by excluding air!*

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