SILAGE FOR BEEF CATTLE | 2022 CONFERENCE

SPONSORED BY:

N EXTENSION

LALLEMAND
LALLEMAND ANIMAL NUTRITION

IOWA STATE UNIVERSITY
Extension and Outreach
Iowa Beef Center

2022 SILAGE FOR BEEF CATTLE: SMALL GRAIN SILAGE

8:30 AM — **WELCOME AND INTRODUCTIONS**
Dr. Kip Karges,
Technical Services Manager,
Lallemand Animal Nutrition

8:45 AM — **AGRONOMIC MANAGEMENT OF SMALL GRAIN FOR SILAGES**
Dr. Daren Redfearn,
Professor,
University of Nebraska-Lincoln

9:30 AM — **A BALANCING ACT: WHEN TO HARVEST SMALL GRAIN SILAGE?**
Dr. Mary Drewnoski,
Associate Professor,
University of Nebraska-Lincoln

10:15 AM — **BREAK**

10:30 AM — **SORGHUM FORAGE MANAGEMENT**
Matt Akins,
Scientist and Extension Dairy Specialist
UW-Madison Dept. of Animal and Dairy Science

11:15 AM — **WHY FERMENTATION ANALYSIS IS IMPORTANT AND WHAT IT MEANS FOR YOUR OPERATION**
Dr. John Goeser,
University of Wisconsin –
Madison & Rock River Laboratory

NOON — **LUNCH**

12:45 PM — **STEPS TO SILAGE QUALITY: DETAILS MAKE A DIFFERENCE**
Becky Arnold,
Custom Harvest Business
Development Manager,
Lallemand Animal Nutrition

1:30 PM — **INOCULANTS FOR SMALL GRAIN SILAGE: WHICH ONES, WHEN TO USE AND RETURN ON INVESTMENT**
Dr. Limin Kung,
Professor,
University of Delaware

2:15 PM — **BREAK**

2:30 PM — **ECONOMICS & ROI ON QUALITY FORAGE IN GROWER AND FINISHING BEEF RATIONS**
Dr. Jhones Sarturi,
Associate Professor,
Texas Tech University

3:15 PM — **PANEL DISCUSSION: MAKING SMALL GRAIN SILAGE WORK**
Moderated by Dr. Dan Loy,
Director of Iowa Beef Center,
and Professor, Iowa State University
Panelists: Jesse Hough, Jeremy Martin
Sean Robinson, and Jeremy Row.

3:45 PM — **ADJOURN**

2022 SILAGE FOR BEEF CATTLE: SMALL GRAIN SILAGE

AGRONOMIC MANAGEMENT OF SMALL GRAINS FOR SILAGES

Daren Redfearn, PhD
Professor of Agronomy and Nebraska Extension Forage and Crop Residue Specialist

Daren Redfearn is a Professor of Agronomy and Nebraska Extension Forage and Crop Residue Specialist. Dr. Redfearn is a member of a multidisciplinary team focused on enhancing and developing forage-based beef production systems. His research and extension program emphasizes annual and perennial grass management, converting cropland to forage production, and evaluating forages that can be integrated into economical and resilient crop-forage-bioenergy agricultural production systems. He also serves as Program Leader for the Water and Integrated Cropping Systems (WICS) Team co-leading a group of technical experts in water and cropping systems to build collaborative relationships and foster engagement that addresses complex issues in agricultural production and natural resource systems. He is a member of the American Society of Agronomy and Crop Science Society of America and served as co-editor for Volume II of Forages: The Science of Grassland Agriculture and as editor and co-editor for Crop, Forage, and Turfgrass Management. He received his Ph.D. and M.S. degrees in Agronomy from the University of Nebraska-Lincoln with B.S. degree from Texas Tech University in Animal Science.

INTRODUCTION

In regions where small grain crops and livestock are economically important, small grains forage can be grazed and harvested as either hay or silage. There are several characteristics that make the small grains suitable for forage (Table 1). All small grains are easy to establish and have rapid growth, good production potential, and high nutritional value for livestock. Recent improvements in cultivar development have allowed the small grains to be grown in a broader range of environmental conditions. Similarly, cultivar development in some small grains has improved grazing tolerance, which is important in dual-purpose systems that emphasize both grazing and grain production. It is possible that this system could be modified to substitute silage production for grain production.

Small grain crops, such as oats (Avena sativa L.), cereal rye (Secale cereale L.), triticale (×Triticosecale Wittmack), wheat (Triticum aestivum L.), and barley (Hordeum vulgare L.), all have comparable agronomic requirements and are primarily adapted to cool, humid climates. There are several management factors that can optimize forage growth potential from small grains. These include using 1) adapted species and cultivars, 2) appropriate planting dates, and 3) reasonable fertility strategies. Fall planting of small grains is a common management practice for many areas where a small grain is adapted.

SELECTION OF SPECIES AND CULTIVARS

Oats

Oat is one of the more commonly used small grain forages. It nearly always fails to survive cold temperatures in the central and northern Great Plains, so it must be planted prior to the season of intended use. For example, a late-summer planting date is needed for autumn and early winter use and a late winter or early spring planting date is needed for late spring use.

TABLE 1.

Planting dates, planting rates, and growth characteristics of common small grains used as fall and spring forage.

		Seeding rates		Growth characteristics	
Species	**Planting dates**	**Drill**	**Broadcast**	**Fall**	**Spring**
Oats	Fall Spring	80 to 100 lbs./A	100 to 120 lbs./A	Excellent fall growth; winterkill.	Excellent spring growth.
Cereal rye	Fall	60 to 120 lbs./A	90 to 150 lbs./A	Less fall growth than oats; fall growth similar to triticale.	Excellent spring growth; matures rapidly.
Triticale	Fall Spring	60 to 120 lbs./A	90 to 150 lbs./A	Less fall growth than oats; fall growth similar to cereal rye.	Excellent spring growth; 10 to 14 days later than cereal rye.
Wheat	Fall	60 to 120 lbs./A	90 to 150 lbs./A	Good fall growth; less fall growth than oats.	Excellent spring growth; later maturity than cereal rye and triticale.
Barley	Fall Spring	60 to 100 lbs./A	75 to 125 lbs./A	Good fall growth; less fall growth than oats; winterkill possible.	Excellent spring growth (with no winterkill);

Oat varieties are commonly classified as either “grain-type” or “forage-type”. This designation is related more to maturity and growth height, than intended use. Under reasonable growing conditions, both types will produce adequate forage. Major differences between the types are that grain-type varieties are usually early- to medium maturity with a short to medium plant height. The forage-type oats are usually medium- to late-maturing varieties that are taller at maturity. When oat is planted from mid- to late-July, early maturing varieties usually have a long enough growing season to produce some grain. However, the growing season will not be long enough for later maturing varieties to begin flowering. While forage yields are similar for both types, the forage quality will likely be greater in the later maturing, taller oat cultivars. Spring planted oat follows a similar growth and maturity pattern to fall-planted oats.

Cereal rye

We generally expect that most cereal rye cultivars will not winterkill in the central and northern Great Plains, regardless of whether they are they classified as a “northern type” or a “southern type”. Northern-type cereal rye cultivars are very winter hardy with longer dormant periods than the southern types. Thus, the southern types will have longer growth into the winter and are often the first of the small grains to begin growth the following spring. However, the northern types mature earlier than the southern types.

Triticale

Triticale is a hybrid small grain forage species that has both cereal rye and wheat as parents. There are spring (non-winter hardy) and winter hardy varieties of triticale, but there are few extensive evaluations forage production for either type. One of the more obvious differences between winter hardy triticale and cereal rye and wheat is that plant maturity of triticale in the spring is intermediate between the parents. Recent breeding improvement in triticale cultivars have resulted in many new cultivars that offer additional flexibility as a small grain for both fall and spring forage production.

Wheat

Traditionally, winter wheat has been the small grain of choice as a winter and spring forage and is often used as the standard to compare other small grain forages. Since most wheat is winter hardy, production of autumn forage production is lower when it is planted late in the fall. There are many varieties of wheat that are winter hardy even when planted early enough to provide fall forage growth and a harvestable forage crop in the spring when grazing is terminated before spring growth begins.

Barley

Barley is another promising small grain forage. Like triticale, there are both spring (non-winter hardy) and winter hardy varieties of barley. Even the winter hardy varieties do not consistently survive the winter in the central and northern Great Plains. Barley as a source of fall and spring forage has not been extensively evaluated although it has been used with success in some regions.

SEASONAL DIFFERENCES IN FORAGE PRODUCTION

Many seasonal differences between winter-hardy and non-winter hardy (spring) small grains are related to vernalization, or the need to go through an extended cold, winter period. In the winter-hardy small grains, this is a necessary physiological process required for stem elongation and heading. It occurs through the combination of cold temperatures coupled with short day length.

Winter-hardy small grains have a strict requirement for vernalization to initiate stem elongation and heading. Winter-hardy species planted in late summer or early fall will be vegetative only with minimal stem elongation. Forage yield may be lower, but with higher forage quality. Once they resume spring growth, stem elongation and heading occur rapidly. Late planting, such as dormant season planting, can reduce the vernalization effect on stem elongation and flowering. This could marginally affect spring forage production potential.

Non-winter hardy (spring) small grain species and cultivars do not require vernalization for stem elongation and heading. When planted in the late summer, many spring species can have significant fall growth. However, they have minimal or no winterhardiness, so when planted in the late summer through early fall, they nearly always fail to survive the winter.

We can take advantage of vernalization and winterhardiness to increase our understanding of forage production from the small grains. There are both non-winter hardy (spring) and winter-hardy (winter) varieties. Each has different forage production potential, season of production, and winterhardiness. This makes small grain species and variety selection important to help meet expectations for either fall and/or spring forage production.

AGRONOMIC PRACTICES

Planting date

Of the agronomic management practices required for small grain forage production, planting date is critically important. This is because delayed fall planting reduces not only fall forage production, but also spring forage production.

A study conducted in southcentral Nebraska evaluated cereal rye forage production planted within a three-week planting window from October 2 to October 21. In this study, fall forage production for cereal rye decreased from around 1000 pounds of forage per acre when planted on October 2 to less than 500 pounds forage per acre when planted three weeks later on October 21. Remarkably, this trend also occurred for spring forage production. In mid-April with cereal rye near the boot stage, forage production was approximately 6500 pounds forage per acre with cereal rye was planted on October 2. This contrasts with cereal rye forage production from an October 21 planting date that was around 3500 pounds of forage per acre. Spring forage production of cereal rye decreased more than 150 pounds of forage per acre for each day of lost growth.

Fall seeding dates

In the western Corn Belt, the ideal planting window for using winter-hardy small grains as a late spring-harvested forage crop is between September 1 and October 1. Ideally, non-winter hardy small grains should be planted between August 1 and September 1. In either case, minimal growth will occur after October 1, unless the fall is unusually warm and wet.

Spring seeding dates

In the western Corn Belt, the usual planting window for spring-seeded, non-winter hardy (spring) small grains is between March 15 and April 1 with an optimum planting time during the third week of March. If dry weather and above freezing temperatures occur in late February and early March, the planting date can be shifted closer to March 15. However, if conditions are wet, damp, and cold during late February and early March, then planting may be delayed until early April.

Seeding rate and depth

In much of the western Corn Belt, small grain forage growth can be improved when seed is drill-planted at seeding rates of 80 to 100 pounds of seed per acre (25 to 30 seeds/sq. ft.). In areas with lower precipitation, seeding rates from 40 to 60 pounds of seed per acre are more common (12 to 18 seeds/sq. ft.). A study conducted in Kansas examined the upper range of seeding rates for triticale. In this study, increasing triticale seeding rate above the recommended rate of 70 pounds of seed per acre did not increase forage production. In fact, triticale forage production was similar when seeding rates were reduced from 70 pounds of seed per acre to 60 pounds of seed per acre, a 25% decrease in seeding rate. At a seed cost of $0.38 per pound, this would be a savings of $3.80 per acre (Table 2).

What we are seeing is the trend for small grain breeding programs to select for increased agronomic performance including improved germination, seedling vigor, and early growth. These are all important characteristics for both forage and grain production.

TABLE 2.

Species comparison of seed weight, seed price, and seed cost per acre of common small grains used as fall and spring forage.

Species	Seed (no./lb.)	Planting rate (lbs./acre)		Seed price (per lb.)	Seed cost ($/acre)	
		Drill	Broadcast		Drill	Broadcast
Oats	13,000	70	110	0.38	26.60	41.80
Cereal rye	22,000	70	120	0.33	23.10	39.60
Triticale	16,000	70	120	0.38	26.60	45.60
Wheat	15,000	70	120	0.26	18.20	31.20
Barley	15,000	70	100	0.35	24.50	35.00

Seeding depth can be as deep as 1½ inches but planting at only ½ to ¾ inches deep will increase the rate of emergence, establishment, and forage production potential. Slightly higher seeding rates and shallower planting depth should result in faster establishment and increased growth.

ESTIMATED PRODUCTION COSTS

A small grain forage is not inexpensive to grow. At the recommended seeding rates for forage production, the establishment operation, including seed cost, can range from $40 to $50 per acre. Additionally, nitrogen fertilizer and application costs might be as low $40 to $60 per acre. In total, the costs of producing a small grain forage will likely range from round $90 to over $150 per acre, excluding land cost and overhead (Table 3).

TABLE 3.

Small grain forage production costs (University of Nebraska Custom Rates/Budgets).

	Forage production[1]		
Input	Fall	Spring	Fall + Spring
	Cost per acre ($)		
Seed costs[2]	26.60	26.60	26.60
Planting costs[3]	18.86	18.86	18.86
Fertilization[4, 5]	36.96	55.43	92.39
Application costs[6]	6.66	6.66	13.32
Total cost	89.08	107.55	151.17
Cost/ton ($)	59.39	43.02	37.79

[1] Fall-only yield (1½ tons/A); Spring-only yield 2½ tons/A); Fall + Spring (4 tons/A).
[2] 70 lbs. seed per acre @ $0.33 per lb.
[3] Average custom rate for no-till small grains.
[4] 40 lbs. N per acre (urea @ $850 per ton.
[5] 60 lbs. N per acre @ $850 per ton.
[6] Average custom rate for dry fertilizer solid broadcast, labor, and applicator.

RATE AND TIMING OF NITROGEN APPLICATION

Fall production

Forage production from fall-planted winter-hardy small grains is not as reliable as spring forage production. With adequate moisture and an extended growing season, fall forage production from winter-hardy small grains may not exceed 1500 pounds of forage per acre. When planted in late August through early September, forage production may reach 3000 pounds of forage per acre with good growing conditions that extend into the fall. In this instance, an N fertilizer rate of no more than 40 pounds actual N per acre is reasonable. For fall-planted non-winter hardy (spring) small grains, forage production could be near 2500 to 3000 pounds of forage per acre. This level of production would also require reasonable N fertilizer at no more than 40 pounds actual N per acre. However, the greatest limiting factor for fall forage growth is often amount and distribution of timely precipitation.

Spring production

Under good growing conditions, spring forage production for fall-planted winter-hardy small grains could range between 2500 to 5000 pounds of forage per acre. Based on this amount forage production, planning should include N fertilizer at a rate of 60 pounds actual N per acre after establishment but before spring growth begins.

Although not be extensively evaluated, frost-seeding legumes, such as red clover, in February through mid-March is a good option to improve forage production and quality without adding additional N fertilizer. It is important to know that small grains can produce additional tillers that compensate for reduced seeding rates. To improve the success of this practice, choosing to reduce small grain seeding rates could be an option. For example, reducing the small grain seeding rate from 60 to 70 pounds of seed per acre to 35 to 40 pounds of seed acre could reduce competition from the small grain and increase the legume establishment success from frost-seeding legumes at 4 to 8 pounds of seed per acre.

Fall Grazing Management and Spring Production

For winter-hardy small grains, conservative grazing management during winter will not greatly reduce forage production. Small grains should be a minimum of 5 to 6 inches tall before winter grazing. Typically, 40 to 60 days of growth is needed to produce sufficient grazing for late summer planted, small grains. Grazing can be delayed until a killing frost to allow for increased forage production without extensive loss of nutritional value. For example, the planting date for a November 1 grazing date would be no later than early September. It is important to keep in mind the relationship of forage production to planting date, as well as the effects of growing environment.

SUMMARY OF OPTIONS AND TRADE-OFFS

Small grain forage is not a risk-free solution for forage production. There are substantial risks involved due to weather, insects, and diseases. However, there are several options for growing small grains for use as a forage crop in the western Corn Belt. Recently, much effort has centered on including small grains as a forage resource in row crop systems (i.e., cover crops), but this has proven to be challenging.

Small grain success is greatly improved in wheat systems, but insect and disease pressure could be problematic. Since corn silage is harvested earlier than corn grain, it offers opportunities for somewhat greater success. Slightly earlier planting at increased seeding rates may support good production, especially in a fall with greater than normal precipitation and growing temperatures. The late harvest date typical for both soybean and corn limits most small grain growth to the following spring unless shorter season grain cultivars are used to extend the fall growing season for small grain forage production. In either case, spring forage production will be less than the maximum potential production. Regardless of the management, it is important to remember the carryover effects from delayed fall planting on spring growth of small grains used as forage.

Planting simple mixtures of winter-hardy and non-winter (spring) small grain species and varieties in late summer may increase the chance of producing both fall and spring grazing. One common example that has been successful is a mixture that includes both oats and cereal rye. Using this method, oats provide much of the forage during the fall. Oats will winterkill, then the cereal rye will provide spring forage production. There could be other combinations of other small grains that are also suitable for improving seasonal distribution of forage yield. Greatest flexibility for small grain forage production is with small grains included as a component of an annual forage system.

WHEN TO HARVEST SMALL GRAIN SILAGE? A BALANCING ACT BETWEEN YIELD AND NUTRIENT CONTENT

Mary E. Drewnoski
Associate Professor and
Beef Systems Specialist
University of Nebraska

Dr. Mary Drewnoski is a Beef Systems Specialist with the University of Nebraska-Lincoln. She has spent time learning and working in cattle systems in many locations across the U.S. including: Kentucky, North Carolina, Iowa, and Idaho. She is a beef cattle nutritionist with expertise in forage production systems and is a part of an interdisciplinary team evaluating Economical Systems for Integrated Crop and Livestock Production in Nebraska. She has spent the last 8 years researching and providing education on the use of crop residues and cover crop forage for backgrounding calves and feeding beef cows. Reach Mary at (402) 472-6289 or email her at mdrewnoski2@unl.edu.

Collaborators: Graduate students -Abigail Sartin, Kallie Calus, Morgan Grabau, Alyssa Kuhn, Alexa Johnson. Faculty-Daren Redfearn, Jenny Rees, Ben Beckman, Brad Shick, Gary Lesoing, Erin Laborie, Todd Whitney, Connor Biebler.

INTRODUCTION

Winter hardy small cereal grains can be planted in fall and harvested in the spring as silage, offering the potential for a double crop system with a warm-season forage or cash crop.

Cereal rye is the most commonly planted cover crop in corn and soybean systems. Winter wheat and winter triticale are also sometime used. These species all have the potential to produce forage that can be cut for silage. This paper will describe how each species may fit into a crop rotation based on recent data from a project looking at the relative timing of maturation of each species coupled with the yield and nutritive value at various maturity stages.

EFFECT OF WINTER HARDY SPECIES AND HARVEST TIMING

Winter hardy small cereals were planted and harvested over two growing seasons. For year 1, VNS cereal rye, NT11406 triticale, and Araphoe wheat were planted on October 15, 2019. In year 2, Rymin cereal rye, NT1140 triticale, and Arapahoe wheat were planted on October 7, 2020. In the spring 60 lb/ac of nitrogen was applied. The forage was harvested at 4 different stages: boot, pollination, milk, and soft dough. Silos were left to ensile for 45 days before being opened and sampled.

Unexpectedly, there were not large differences among species in the timing of maturity. In fact, in year, the cereal rye and triticale were harvested on almost the same dates (Table 1). Wheat reached boot about 5 days later than rye and triticale but matured more quickly and reached soft dough 7 d before the other two species. In year 2, rye generally reached each stage ~7 days before triticale. Wheat reached boot, pollination, and milk at a similar time as triticale but again was harvested 7 days before triticale. It is important to note that all species matured rapidly with an average of 30 days between boot and soft dough stage. Thus it is easy to miss the target harvest stage.

From a dry matter (DM) yield perspective, triticale and rye outperformed wheat (Figure 1). Dry matter yield of rye and triticale did not differ except at soft dough stage where triticale was greater than rye. Triticale yield was greater than wheat at pollination and soft dough, with rye being greater than wheat only at soft dough. Visual observations suggest that wheat had more loss of leaf material (senescence) at soft dough than the other two species.

In terms of energy content (Figure 2A), measured as digestible organic matter (DOM) after fermentation, rye and wheat did not differ and were both greater than triticale. Across all species, boot stage had the greatest DOM concentration, followed by pollination then soft dough with milk having the lowest energy content. The 2% unit increase in the energy concentration at soft dough was due to starch being formed in the seed head. There was only a loss of about 2% units in DOM when delaying harvest from boot to pollination. Crude protein (CP) of all species decreased with increasing maturity (Figure 2B). There were minor differences in CP concentration among species, with rye being greater than triticale at boot, pollination, and soft dough but not differing from wheat. When harvested at boot stage the small cereals had CP content (17 to 18% CP) that was similar to good alfalfa and could be used as a protein supplement. There was a loss of about 3.5% units in CP when delaying from boot to pollination and an additional 2 to 3% units when delaying to milk and soft dough.

When energy and protein content were combined with dry matter yield and evaluated on a yield of DOM and CP per acre, rye and triticale had greater nutrient yields than wheat. Overall, the yield of DOM (energy) per acre continued to increase as maturity advanced (Figure 3). On average every 8 to 12 d delay in harvest increased DOM yield by around 1,000 lb/acre. The CP yield did not differ across stage of maturity. It appears that for the most part, the plants had taken up the majority of the nitrogen before the first harvest time (boot) and this nitrogen was diluted by the additional DM accumulation at later stages of maturity.

EFFECT OF MOISTURE CONTENT AT PACKING

In 2021, seventeen Nebraska producers provided small grain silage samples at harvest and again after fermentation to evaluate changes in nutrient content and the quality of the fermentation achieved. Of the samples obtained 55% were cereal rye, 25% triticale, 5% wheatlage, 5% raising oatlage, and 10% mixes. When surveyed about their production practices, 85% stated they had wilted or field dried the crop, yet 40% of those that wilted still had dry matter content lower than 30%. The plants standing in the field do tend to get dryer with maturity. Those that wilted boot, heading or pollination for 16 to 24 hr appeared to be more likely to achieve targeted DM content. For milk or soft dough 0 to 2 hr seemed to commonly result in desirable results. The average loss in the total digestible nutrients (TDN) during fermentation was 6 TDN units (Figure 4). However, the range in TDN loss was 0 to 17% units. Samples with greater TDN loss were wet at packing (less than 30% DM) and many had increased butyric acid content, suggesting fermentation by clostridial bacteria. Not only does clostridial fermentation result in loss of energy content but also reduces palatability. These data suggest that moisture management is a challenge for producers and an area that could help improve the quality of their small grain silage.

SUMMARY

It appears that triticale had slightly greater DM yield with slightly lower digestibility (energy) and protein content while rye had slightly lesser yields with slightly greater digestibility and protein content. There is likely as much variation among varieties within a species as there is among species. Thus selection should depend on quality and yield goals coupled with seed cost. For high quality forage, harvest at pollination appeared to allow for increased yield without sacrificing much nutritive value. For maximized yield, harvesting at soft dough is a better option. Regardless, of stage at harvest producers should monitor moisture and ensure that the silage is not packed when it is too wet.

Acknowledgement: The project described in this paper was partially funded by NCR-SARE.

TABLE 1.

Timing of harvest of winter hardy small cereals in Eastern Nebraska.

Year 1 (2020)			
	Rye	Wheat	Triticale
Boot	5/18	5/23	5/18
Pollination	6/1	5/28	5/29
Milk	6/9	6/8	6/9
Soft Dough	6/22	6/16	6/22
Year 2 (2021)			
	Rye	**Wheat**	**Triticale**
Boot	5/5	5/13	5/11
Pollination	5/12	5/24	5/24
Milk	6/11	6/7	6/8
Soft Dough	6/15	6/14	6/21

FIGURE 1.

Dry matter yield of cereal rye, winter triticale and wheat harvest at four stages in Eastern Nebraska.

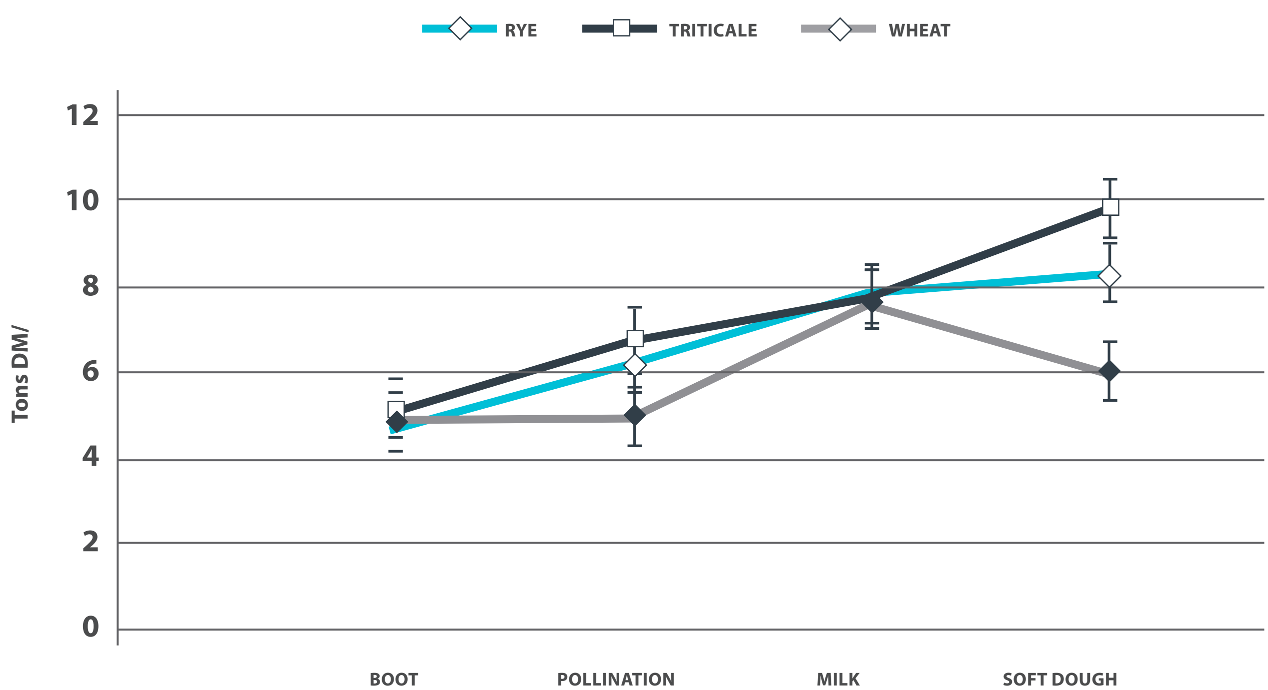


FIGURE 2.

The digestible organic matter (DOM; estimate of energy similar to TDN) and crude protein (CP) and of cereal rye, winter triticale and wheat harvest at four stages in Eastern Nebraska.

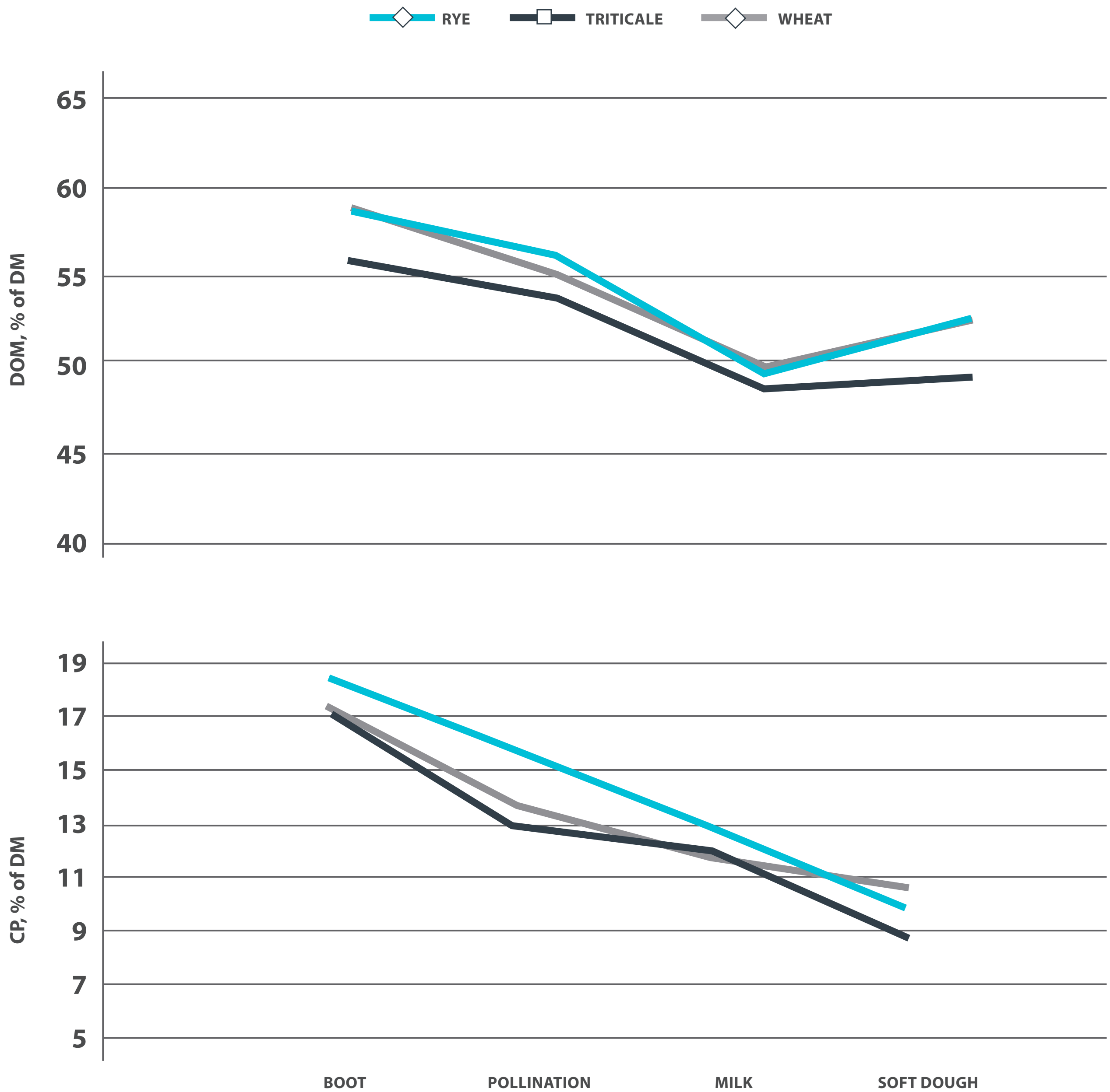


FIGURE 3.

Nutrient yield of winter hardy small cereals harvest at four stages in Eastern Nebraska. DOM = digestible organic matter (energy). CP = crude protein. .

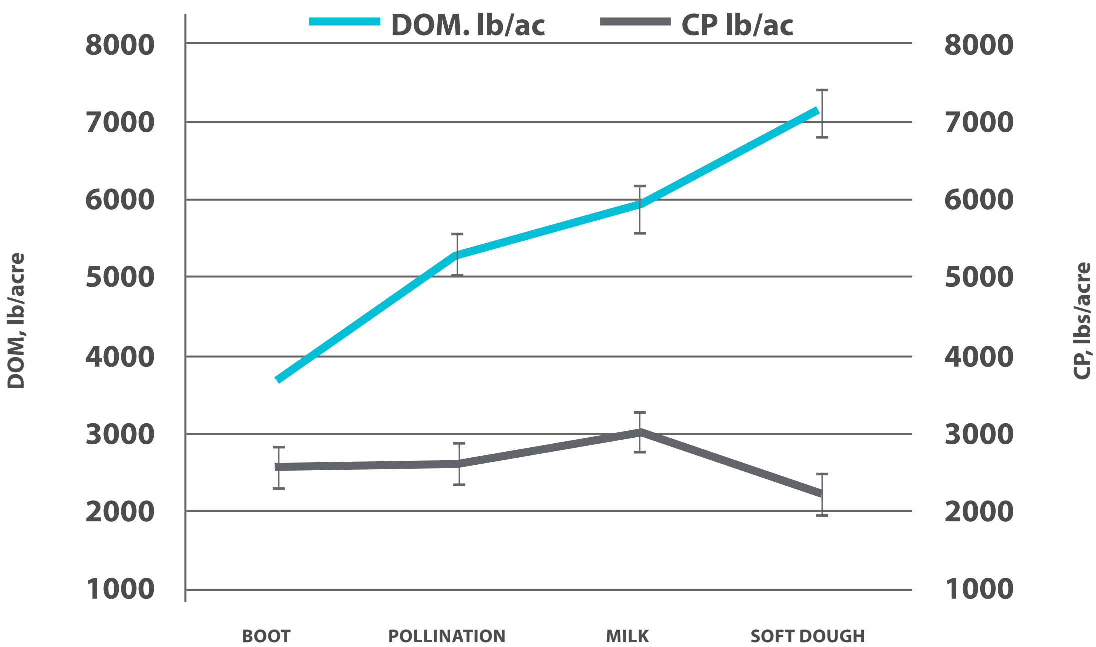
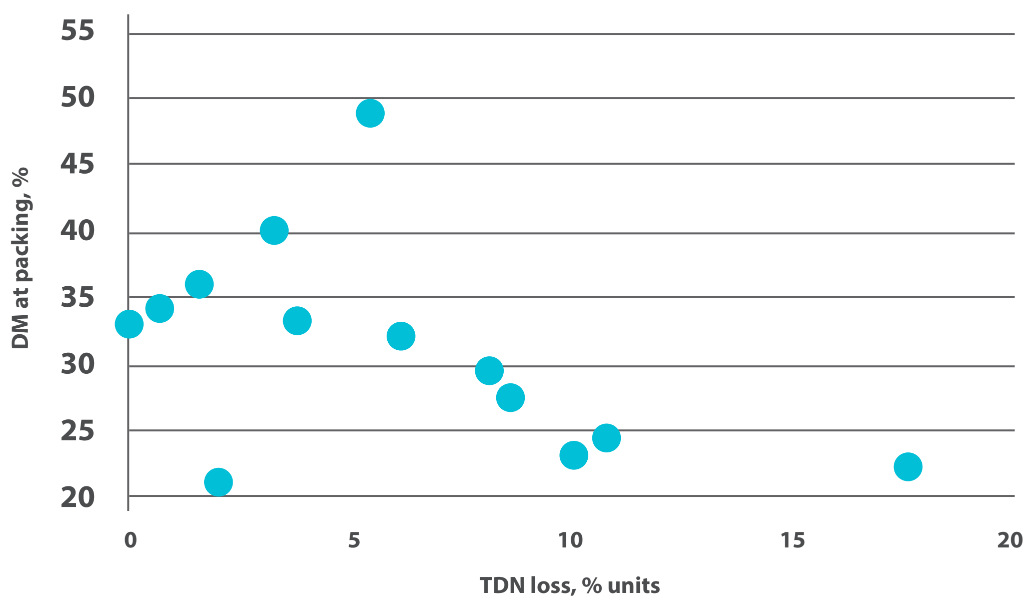


FIGURE 4.

Dry matter content at packing and resulting loss in total digestible nutrients (TDN; energy content) during fermentation.



SORGHUM FORAGE MANAGEMENT

Matt Akins
Scientist and Extension Dairy Specialist
UW-Madison Dept. of Animal and Dairy Science

Matt Akins is an Associate Scientist and Extension Dairy Specialist at the University of Wisconsin-Madison. Matt conducts research and extension on dairy heifer management to improve nutrition and dairy profitability. His research has mainly focused on evaluation of high-fiber forages for use in dairy heifer rations including straw, alfalfa stems, and sorghum forages. Matt also is evaluating grazing as a potential option to lower heifer rearing costs. His extension work has focused on collaborating with county agents to conduct surveys to estimate the cost of raising dairy heifers, on-farm testing of alternative forages, and surveys evaluating the use of dairy beef crossbreeding.

SORGHUM FORAGE MANAGEMENT

- Type of sorghum/sudangrass to use?
- Planting conditions (temp., depth, soil type/condition)
- Seeding rate and method
- Fertility needs
- Harvesting

SORGHUM TYPES

- Forage sorghum
- Sudangrass
- Sorghum-sudangrass

Possible traits:

Brown mid-rib
Photoperiod sensitive
Male sterile
Brachytic Dwarf
Dry stalk

PLANTING CONDITIONS

- Well-drained soils are ideal
- Avoid wet, lowland areas
- Soil temperature critical
- Ideal >65 °F; Minimum >60 °F
- Avoid planting before a significant rainfall, especially in tilled field
- No-till or tillage systems
- No-tilling after a cereal forage can work well
- Planting Depth: 3/4 to 1 inch; up to 1.5 inches in sandy soils
- Slow emergence if too deep

SEEDING RATE AND METHOD

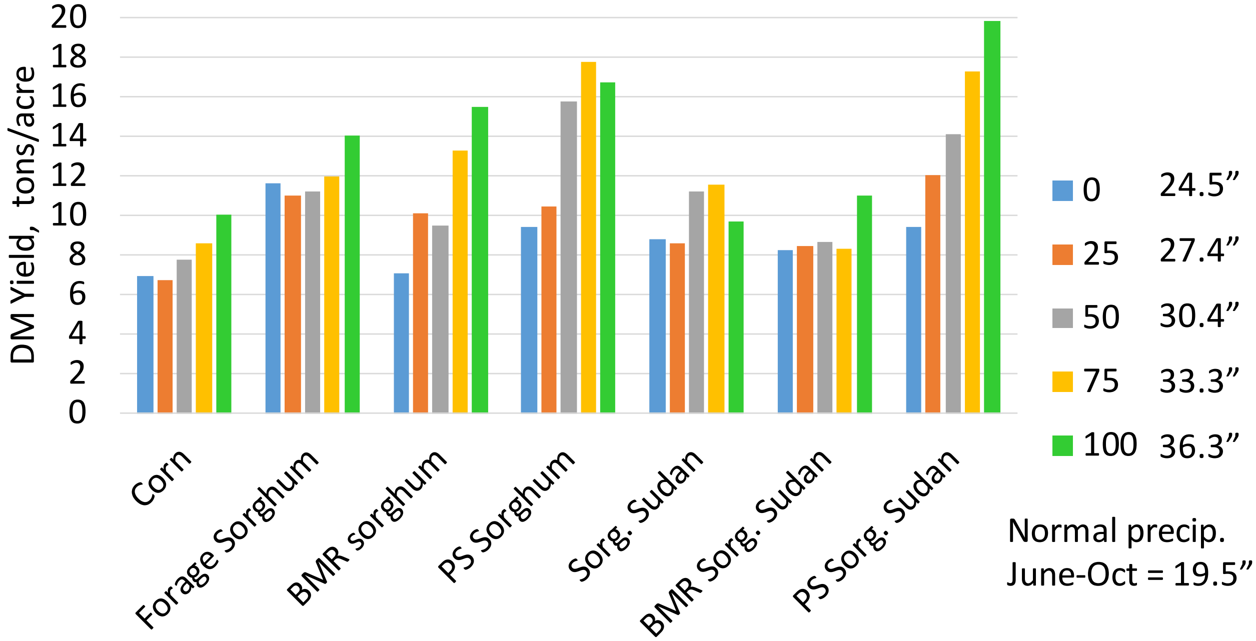
Depends on equipment and species

- **Forage Sorghum - planter or grain drill**
  - 60-80,000 seeds/acre (4-8 lb/acre)
  - Planter more precise with low populations
- **Sorghum-sudangrass – grain drill (6-18" rows)**
  - 20-30 lb/acre
- **Sudangrass**
  - 15-20 lb/acre– grain drill (6-18" rows)

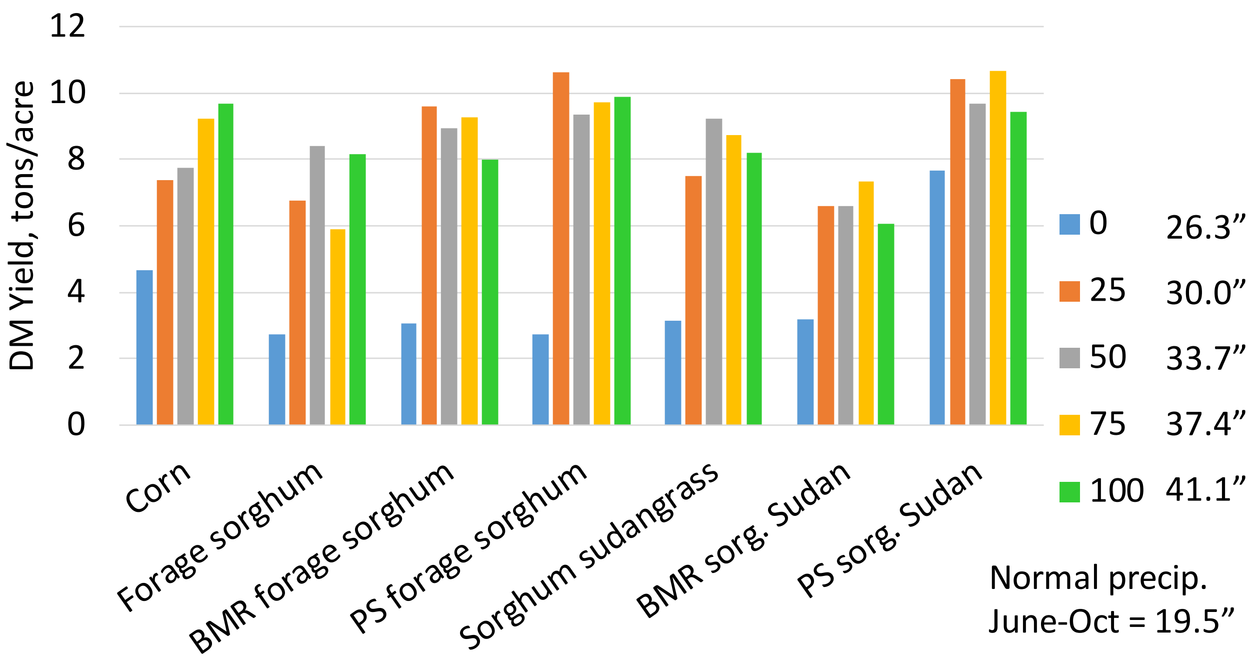
FERTILITY

- **Nutrient removal rates can be high**
- **Nitrogen: depends on yield and N credits**
  Single harvest: 100 – 150 lb N/acre pre-plant
  Multi-harvest: 40-60 lb N pre-plant and after each cutting
  Data from Cornell shows higher N rates (75-100 lb N/cutting)
  *Higher rates can lead to nitrate or prussic acid issues
- **Potassium: removal can be high (2-4% of DM)**
  K2O removal rate of 60 lbs /ton DM (2.5% K in forage)

IRRIGATION: HANCOCK, WI 2016



IRRIGATION: HANCOCK, WI 2017



HARVEST MANAGEMENT AND FEEDING

Multiple Harvest

- Higher quality forage – higher NDFD and protein
- 2 harvests most likely in Midwest (3 possible in southern areas)

1st Cutting ~ 40-45 days post-planting		2nd Cutting	
Early/Mid June	Late July (cut/wilt) 30-50" tall	**Option 1:** Mid-late Sept (cut/wilt) Plant cover crop after	**Option 2:** Mid/Late Oct (cut/chop) 7-10 days after frost

Single Harvest

- Maximizes yield of moderate quality forage
- Main option for forage sorghum (similar to corn silage)
- May need to wait for frost and allow to dry if direct harvesting

  Photosensitive varieties; late planting
- Silage harvest ideal

Early/Mid June	Mid/late September (cut/wilt)	Mid-late Oct/Early Nov (direct chop at 30-40% DM) Wait 7-10 days if frost occurs

July 18, 2018

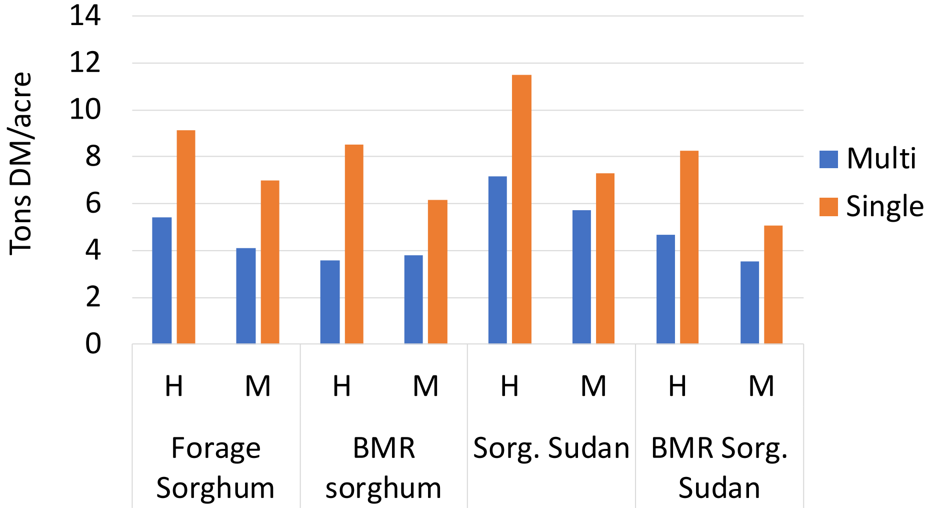
August 14, 2018

September 22, 2018

Cut September 22, 2017

Harvest September 25, 2017

- Single vs Multiple harvest



NDF (%DM) values of sorghums and whole plant corn

	2015		2016	
Forage	Multiple	Single	Multiple	Single
Whole plant corn	65.5	50.4	62.3	43.4
Forage sorghum	64.3	54.7	62.7	58.6
BMR forage sorghum	62.9	51.2	58.5	52.9
Sorghum-sudan	65.0	54.0	63.5	59.0
BMR sorghum-sudan	63.5	59.1	62.0	55.5

TDN (%DM) values of sorghums and whole plant corn

	2015		2016	
Forage	Multiple	Single	Multiple	Single
Whole plant corn	65.9	65.8	65.6	67.4
Forage sorghum	65.6	60.8	63.2	59.3
BMR forage sorghum	67.3	62.5	67.2	65.0
Sorghum-sudan	63.4	57.3	61.6	55.5
BMR sorghum-sudan	66.2	62.7	66.2	63.1

FORAGE SORGHUM SILAGE

Single harvest management similar to corn silage

- 65-70% moisture (mid to late dough stage)
- 3/8 - 1/2" chop length
- Processing needed to break apart berries
- Sugar levels can be high
- Heterofermentative inoculant may reduce feedout issues

Lower energy than corn silage

- 45-60% NDF and 15-20% starch
- BMR improves fiber digestion and lessens fill effects

USE OF SORGHUMS IN LACTATING COW DIETS

Several studies looking replacing corn silage with sorghum

2008 – Miner Institute (Dann et al.) 35-45% of diet BMR-SS

- Lower intakes for cows fed BMR sorghum-sudan,
  but higher milkfat content and similar solid corrected milk

2017 – Penn State (Harper et al.) 10% of diet Dwarf BMR FS

- Lower intake and milk protein for cows fed FS, but higher milkfat

*Balancing for starch and fiber will likely minimize changes in milk production

USE OF SORGHUMS IN BEEF CATTLE DIETS

- **Good forage source for beef cows**
  Energy may be above needs
  Protein supplement may be needed
- **Growing cattle**
  Can fit well in a high forage feeding system
  Use of BMR trait will enhance intake and growth
- **Finishing cattle**
  Potential use as forage portion of diet (10% of diet)
  Lower level of forage possible?

SPECIAL CONSIDERATIONS WITH SORGHUMS

- **Nitrates**
  Often found in drought or frosted sorghum forages
  Accumulates in lower stem and does not dissipate in field
  High in younger, vegetative forage
  Avoid excess nitrogen fertilizer
  Silage fermentation can reduce nitrates by up to 1/2
  Test before feeding (only $10-20)

NITRATE TOXICITY

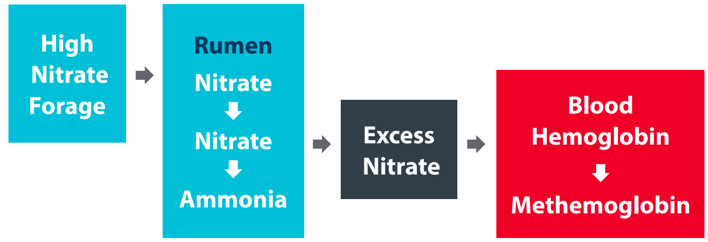


TABLE 4.

Guidelines for use of feeds with known nitrate content.

Nitrate content on 100% dry matter basis		
NO_3-N	NO_3	Comment
ppm		
<1000	<4400	Safe. A 1000-pound cow consuming 20 pounds of dry matter would consume about 9 grams of NO3-N or less than 1 gram per 100 pounds of body weight.
1000 to 2000	4400 to 8800	Generally safe when fed balanced rations. Best to limit to half of the total dry ration for pregnant animals and also be sure water is low in nitrate.
2000 to 4000	8800 to 15000	Limit amount to less than half of total dry ration. Be sure ration is well fortified with energy, minerals, vitamin A.
Over 4000	Over 15000	Potentially toxic - do not feed.

PRUSSIC ACID (HYDROGEN CYANIDE)

- Increases in young growth and leaves after frost
- Cell rupture releases cyanogenic glycoside dhurrin and is converted to HCN
- Dissipates when leaves dry and during harvesting/feeding
- Grazing poses most risk after frost event

- HCN binds hemoglobin not allowing oxygen transfer
  Difficult breathing, excess salivation, asphyxiation
  Bright, cherry red mucous membranes

** This work is partially supported by the USDA National Institute of Food and Agriculture, Hatch project 1006557 and by a grant from the Midwest Forage Association*

SILAGE FERMENTATION ANALYSIS & FEED HYGIENE

John Goeser, PhD, PAS, Dipl. ACAN
Professional Animal Scientist, Diplomate of the American College of Animal Sciences, Animal Nutrition

Goeser grew up with the dairy industry, following in his father's footsteps as a dairy nutritionist.

Goeser holds several degrees from the University of Wisconsin – Madison, including:

- B.S. degrees in Animal & Dairy Science and Agronomy
- M.S. degrees in Plant Breeding & Genetics and Animal & Dairy Science
- Ph.D. in Animal & Dairy Science

Goeser has offered agribusiness & dairy nutrition and management expertise for over a decade. He has been overseeing animal nutrition, technical support and research with Rock River Laboratory since 2012. In 2014, Goeser joined the UW-Madison Animal & Dairy Science Department as an adjunct professor, and also began privately consulting for agricultural businesses.

Goeser's focus is improving our understanding of ruminant nutrition, seed genetics and forage management, and feed hygiene in relation to feed conversion efficiency, sustainability, and agribusiness profitability.

AGENDA

- Forage preservation options
- Fermentation process - good vs bad
- Fermentation analysis training
- Options to improve
- Other feed hygiene risk factors

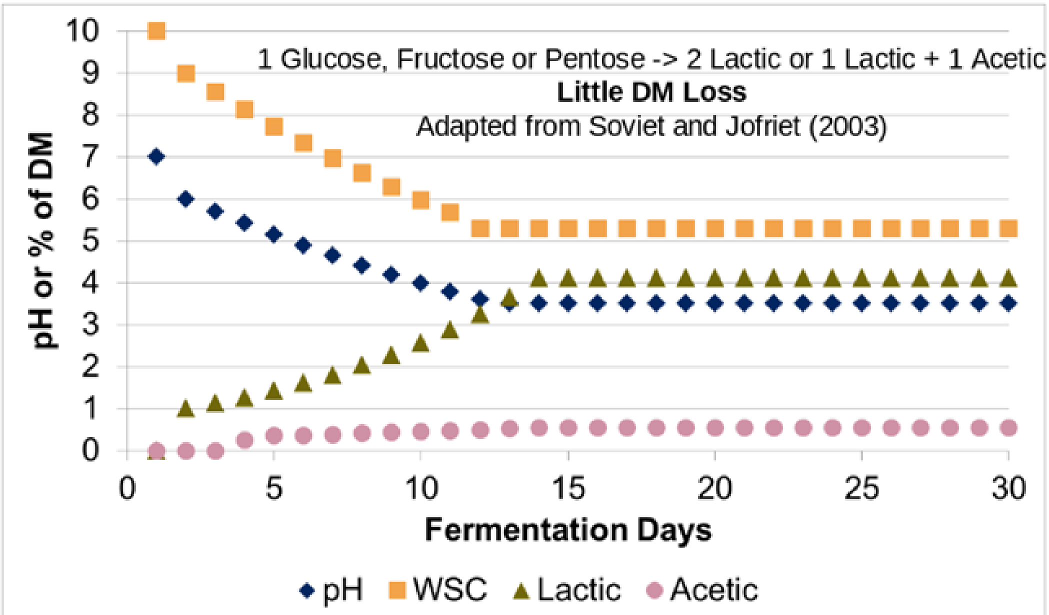
PRESERVING FORAGE

100 tons harvested, goal is to feed out close to 100 ton

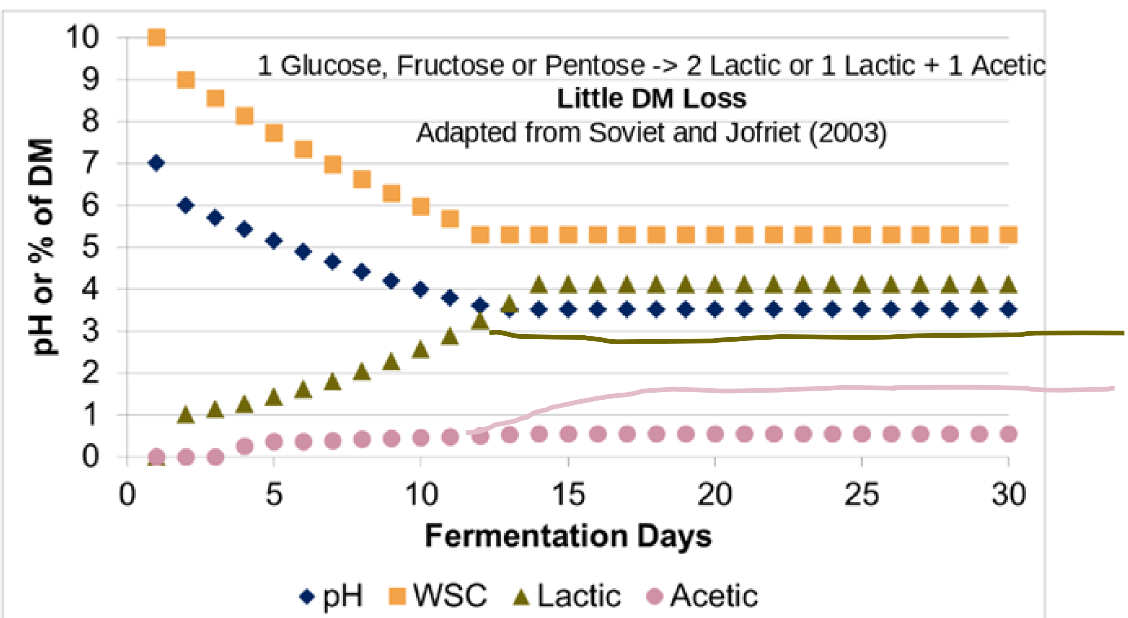
- **Dry hay?**
  Probably feed out 90 to 95 ton
  Benefit? Stable, portable
  Drawback? Weather, Covered storage, Inventory
- **Wet wrapped hay?**
  Probably feed out 85 to 95 ton
  Benefit? Stable, portable, less exposed to weather, get out of field & quicker ferment
  Drawback? Storage, bale to bale differences, fermentation can go sideways
- **Silage?**
  Feed out anywhere from 75 to 95 ton
  Benefit? Stable, can store BIG inventory, high quality and more digestible feed
  Drawback? Not portable, prone to BIG losses, increased management demand



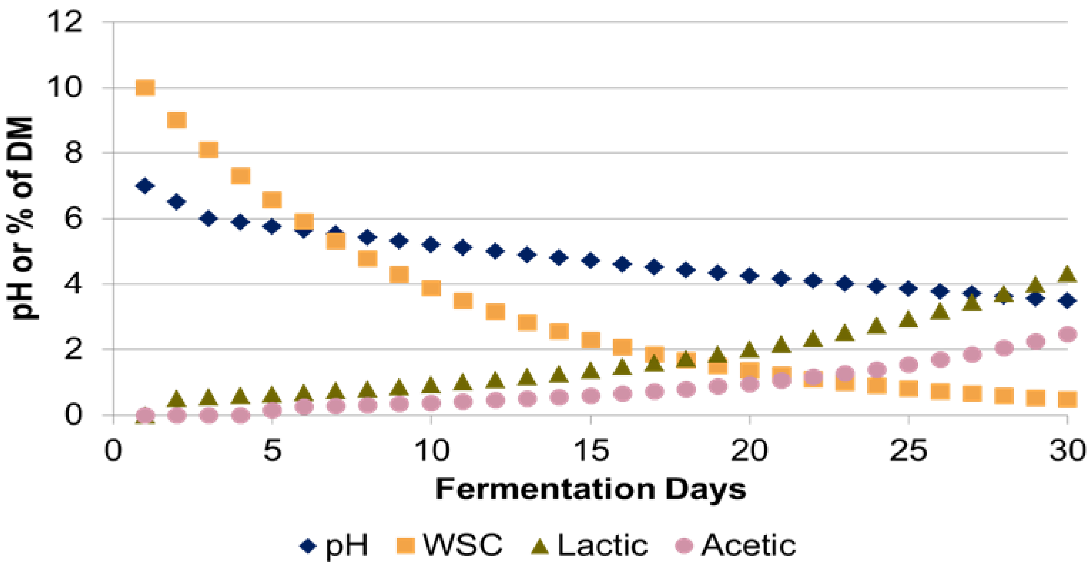

SILAGE: IDEAL PROCESS
Goal 1



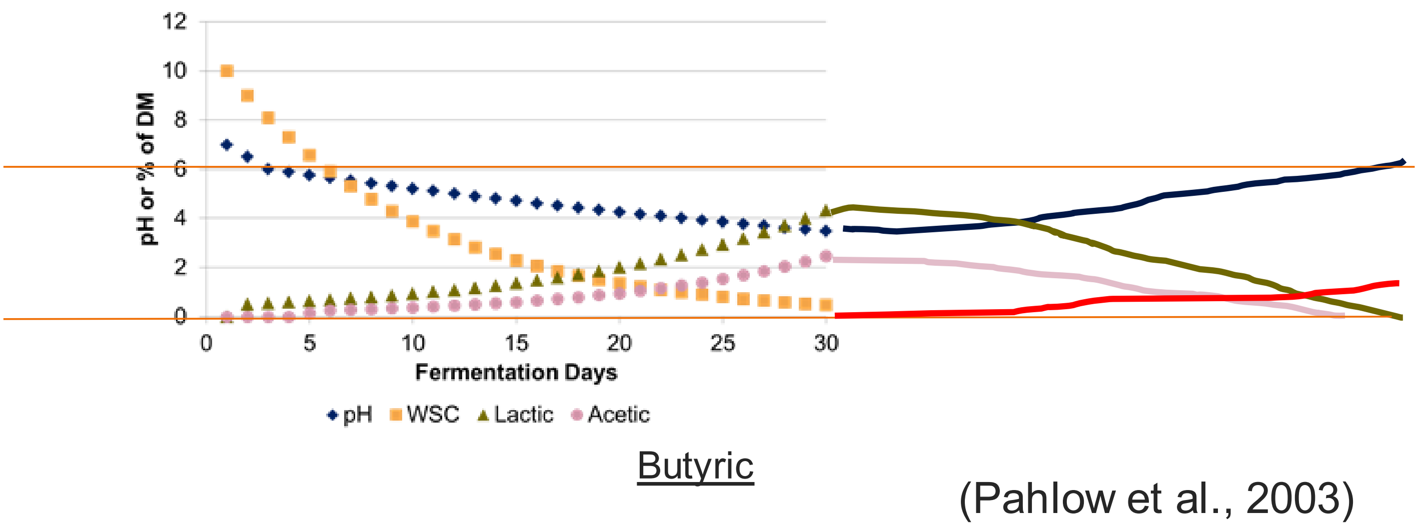
SILAGE: IDEAL PROCESS
Goal 2



LESS THAN IDEAL PROCESS



Various substrates -> Acids + Alcohols + NH3-N + Gases (CO2, H2)
Substantial Substrate Loss (~ 8 to 60% lost)
Adapted from Soviet and Jofriet (2003)



- Major challenges (Muck, 1988)
  Shrink, health & performance
- The wheels fall off...Enterobacteria!
  Butyric acid, NH_3-N, other acids, alcohols, gaseous losses, toxins

BEYOND FEED QUALITY AND VARIATION

- Harvest 100 tons? Want to feed out 100 tons!
- Best silos feed out 98 tons per 100
- Some feed out < 75 ton!!!

WHAT IS SILAGE SHRINK?

- High quality water soluble carbohydrate (sugar and starch) – some protein as well
- Must be replaced with corn or similar energy value ingredient
- 3% Shrink with 1 ton Silage = how many bushel???

  ½ Bushel Corn

Corn Silage				
Parameter, % of DM*	**Mean**	**Median**	**15th Perc.**	**85th Perc.**
pH	3.92	3.86	3.70	4.07
Lactic Acid	4.39	4.35	2.64	6.11
Acetic Acid	2.38	2.23	1.27	3.85
Lactic:Acetic ratio	2.64	1.91	1.17	3.75
Butyric Acid	0.04	0.00	0.00	0.12
Propionic Acid	0.10	0.00	0.00	0.24
Succinic Acid	0.21	0.19	0.00	0.38
Formic Acid	0.01	0.00	0.00	0.00
Total Acid	7.13	7.19	4.96	9.41
Ethanol	0.54	0.47	0.00	1.03
1,2-Propanediol	0.43	0.17	0.00	0.97
1-Propanol	0.15	0.00	0.00	0.20
2-Butanol	0.00	0.00	0.00	0.00
2,3-Butanediol	0.35	0.20	0.00	0.64
Total Alcohol	1.49	1.24	0.44	2.35

Sorghum Silage				
Parameter, % of DM*	**Mean**	**Median**	**15th Perc.**	**85th Perc.**
pH	4.50	4.12	3.79	5.80
Lactic Acid	4.34	4.56	0.03	7.80
Acetic Acid	1.73	1.53	0.00	3.22
Lactic:Acetic ratio	4.26	3.20	1.25	5.63
Butyric Acid	0.12	0.00	0.00	0.17
Propionic Acid	0.08	0.00	0.00	0.16
Succinic Acid	0.22	0.19	0.00	0.44
Formic Acid	0.02	0.00	0.00	0.00
Total Acid	6.50	7.30	0.23	10.57
Ethanol	0.56	0.37	0.00	1.25
1,2-Propanediol	0.28	0.00	0.00	0.60
1-Propanol	0.03	0.00	0.00	0.00
2-Butanol	0.00	0.00	0.00	0.00
2,3-Butanediol	0.20	0.00	0.00	0.39
Total Alcohol	1.08	0.86	0.00	2.04
NH3-N, % CP	5.89	4.79	1.23	10.00

High Moisture Shell Corn				
Parameter, % of DM*	**Mean**	**Median**	**15th Perc.**	**85th Perc.**
pH	4.45	4.18	3.98	5.21
Lactic Acid	1.25	1.29	0.48	1.90
Acetic Acid	0.38	0.25	0.08	0.72
Lactic:Acetic ratio	5.90	4.49	1.54	9.58
Butyric Acid	0.03	0.00	0.00	0.04
Propionic Acid	0.05	0.00	0.00	0.14
Succinic Acid	0.03	0.00	0.00	0.08
Formic Acid	0.00	0.00	0.00	0.00
Total Acid	1.76	1.73	0.64	2.75
Ethanol	0.25	0.20	0.00	0.48
1,2-Propanediol	0.11	0.00	0.00	0.24
1-Propanol	0.01	0.00	0.00	0.00
2-Butanol	0.00	0.00	0.00	0.00
2,3-Butanediol	0.10	0.05	0.00	0.14
Total Alcohol	0.48	0.36	0.12	0.85

Grass Haylage				
Parameter, % of DM*	**Mean**	**Median**	**15th Perc.**	**85th Perc.**
pH	4.81	4.58	4.13	5.76
Lactic Acid	3.77	3.58	0.37	6.94
Acetic Acid	1.90	1.42	0.37	3.62
Lactic:Acetic ratio	3.43	2.62	0.64	5.70
Butyric Acid	0.43	0.00	0.00	0.48
Propionic Acid	0.14	0.00	0.00	0.33
Succinic Acid	0.25	0.17	0.00	0.52
Formic Acid	0.02	0.00	0.00	0.01
Total Acid	6.51	6.73	1.98	10.39
Ethanol	0.35	0.26	0.00	0.75
1,2-Propanediol	0.16	0.00	0.00	0.34
1-Propanol	0.06	0.00	0.00	0.05
2-Butanol	0.01	0.00	0.00	0.00
2,3-Butanediol	0.31	0.12	0.00	0.66
Total Alcohol	0.89	0.68	0.15	1.58
NH3-N, % CP	9.05	7.40	4.22	13.56

Alfalfa Haylage				
Parameter, % of DM*	**Mean**	**Median**	**15th Perc.**	**85th Perc.**
pH	4.82	4.71	4.42	5.20
Lactic Acid	4.47	4.41	1.96	7.00
Acetic Acid	2.14	1.75	0.76	3.67
Lactic:Acetic ratio	3.38	2.50	1.05	4.98
Butyric Acid	0.42	0.05	0.00	0.40
Propionic Acid	0.12	0.00	0.00	0.29
Succinic Acid	0.40	0.34	0.10	0.70
Formic Acid	0.04	0.00	0.00	0.11
Total Acid	7.59	7.47	4.14	11.10
Ethanol	0.28	0.18	0.00	0.62
1,2-Propanediol	0.11	0.00	0.00	0.23
1-Propanol	0.04	0.00	0.00	0.00
2-Butanol	0.00	0.00	0.00	0.00
2,3-Butanediol	0.25	0.10	0.00	0.49
Total Alcohol	0.68	0.48	0.01	1.25
NH3-N, % CP	9.80	8.90	5.20	13.70

PRACTICALLY MANAGING SILAGE

- **Pre-season:**
  Game plan
  Soil health & fertility critical
- **In-season:**
  Grow & harvest healthy crop
  Hybrid resistance?
  Fungicide around silking
  Prof Damon Smith, Pers. Comm.
  Harvest a high quality crop &
  avoid rain

HARVEST & STORAGE

- Put a decision maker on the Pack Tractor, Silo or Bagger
  Pack it, and pack it some more
- Use a research proven inoculant
  Some produce antibacterial / mold compounds (Muck, 2013) – beyond acetic acid?!?!
  Reduced Clostridium growth (Tabacco et al., 2009)
- Chemical preservatives
  Acids? Sorbates & Benzoates? Oxygen scavengers?
- COVER IT
- Seal holes or damage quickly

STEPS TO SILAGE QUALITY:- DETAILS MAKE A DIFFERENCE

Becky Arnold
Custom Harvest Business Development Manager
Lallemand Animal Nutrition
barnold@lallemand.com

Becky Arnold is the Custom Harvest Business Development Manager for Lallemand Animal Nutrition.

Becky's passion for silage began when working for a large seed company where she spent nearly 10 years focused on agronomy, crop production, animal nutrition and forage quality. She went on to own and operate a custom harvesting business in west Texas. Her business included forage harvesting, custom farming, and manure spreading. Now at Lallemand for almost 4 years, Becky brings a unique and practical perspective, that encompasses everything from the field to feed out, helping livestock producers and harvesters to drive performance through quality management practices. Becky lives in Colorado with her dog and best friend, Ben.

KEY POINTS THAT LEAD TO QUALITY SILAGE

- Preserving nutrients
- Harvest timing
- Fermentation Fundamentals
- Processing & Chop Length
- Pack Density

TERMINOLOGY

I want to make sure we are on the same page when referring to SHRINK VS Dry Matter Loss

SHRINK is a widely used term in the feed industry but can be quite deceptive.
Shrink is Ton in VS Ton out. If an operation keeps everything "high and tight" this number could be ZERO! (That doesn't really fly)

DM LOSS or NUTRIENT loss.
WE know that some nutrients are lost, converted or consumed in the process of fermentation

A ton of GOOD FEED weighs the same as a ton of BAD FEED!

There are four types of dry matter loss

7-46% loss opportunity

- Fermentation loss (2-6%)
- Loss from leaching "Seepage" (1%)
- Surface spoilage loss (3-24%)
- Feedout loss (15-40%)

FACTORS TO ACHIEVE AN EFFICIENT FERMENTATION:

- **Optimal Moisture:** Too wet and the process is delayed, AND can lead to unfavorable fermentation from Clostridial organisms. Too dry and it is very difficult to pack the O2 out of the pile.
- **Plant Sugars:** Lactic Acid Bacteria convert plant sugars to Lactic Acid which drives the pH down.
- **Anaerobic Environment:** Lactic Acid require a non-oxygen environment to do their job AND spoilage organisms will continue to proliferate as long as oxygen present.
- **A Quality Proven Inoculant:** Silage WILL ferment on its own, but how long will it take. We want to overwhelm the process with efficient bacteria to get the job done quickly and efficiently

Corn Maturity: Grain stage VS plant moisture

These values related plant dry down are based on a healthy plant, no drought, insect, weed pressures etc.

Growth Stage			Calendar Days to Maturity	Growing Degree Units to Maturity	% of Maximum yield		Percent Moisture	
	Kernel Stage	Milk Line			Grain	Whole Plant Corn Silage	Grain	Whole Plant Corn Silage
	Silk		40 - 45	1100 - 1200	0	50 - 55%	0	80 - 85%
	Blister		30 - 35	875 - 975	5 - 10%	55 -60%	85 - 95%	80 - 85%
Early Dent	In the Milk	Roasting Ear (all milk)	25	650 - 750	30 - 50%	65 - 75%	60 - 80%	75 - 80%
Early Dent	In the Dough	Button/Cap	20					
80-90% Dent	Hard Dough	1/8 Milk Line	15	425 - 525	60 - 75%	75 - 85%	50 - 55%	70 - 75%
80-90% Dent	Hard Starch	1/4 Milk Line	10					
	1/2 Milk Line	1/2 Milk Line	0	200 - 300	90 - 95%	100%	35 - 40%	65 - 70%

Corn matures by Growing Degree Units (GDU). It takes 900 GDU's from silk to 1/2 milk line. Calendar days are relative.

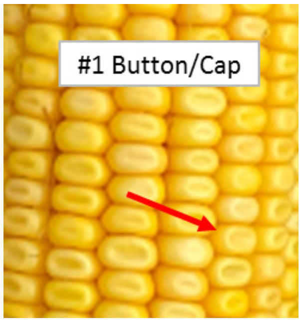
Corn Maturity: Grain stage VS plant moisture

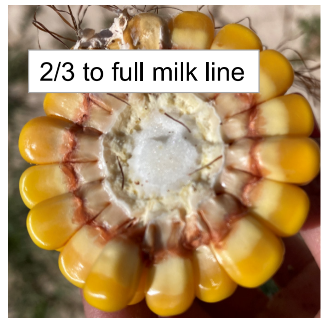
These values related plant dry down are based on a healthy plant, no drought, insect, weed pressures etc.

Growth Stage			Calendar Days to Maturity				Percent Moisture	
	Kernel Stage	Milk Line						Whole Plant Corn Silage
	Silk		40 - 45					80 - 85%
	Blister		30 - 35					80 - 85%
Early Dent		**Roasting Ear**	**25**					75 - **80%**
Early Dent		Button/Cap	20					
80-90% Dent		1/8 Milk Line	15					70 - 75%
80-90% Dent		**1/4 Milk Line**	**10**					
	1/2 Milk Line	**1/2 Milk Line**	**0**					**65 - 70%**

Corn matures by Growing Degree Units (GDU). It takes 900 GDU's from silk to 1/2 milk line. Calendar days are relative.

Milk Line





Harvesting corn for ensiling

Harvesting small grains for ensiling

- Begin in early boot
- Complete by late boot

Boot stage

- Wilt to 34-42% DM
- Earlier stage of maturity => 'protein crop'

Soft/mid dough stage

- Direct cut
- Later stage of maturity => 'energy crop'

Photo: andersonsplantnutrients.com

Photo: fao.org

Nutrient Content of Wheat Silage at Different Stages of Growth

			Energy	
Stage	Crude Protein	Digestibility	Net Energy for Milk	TDN
			Mcal / 100 lb.	*Percent*
Boot	**20.87**	89.22	76	73
Early-head	15.31	83.12	68	66
Mid-head	11.26	78.89	61	59
Late-head	10.27	67.51	46	46
Milk	8.99	64.84	49	49
Dough	**8.49**	72.07	56	55
Ripe	6.78	71.22	55	54

Source: Belyea and coworkers. 1978. University of Missouri Extension Guide Sheet 3260.

How long does the crop need to wilt

Harvesting sorghum for ensiling

Harvesting small grains for ensiling

TABLE 2.

Maturity and moisture recommendations for harvest of forage sorghums for silage.

		Percent Moisture		
Crop	**Maturity**	**Bunker**	**Stave**	**Oxygen Limiting**
Forage Sorghum	Grain- Medium to hard dough or beginning to lose color (varies by hybrid)	70-75	65-70	50-60
Sorghum-Sudangrass	3' - 4' high	70-75	65-70	50-60
Grain sorghum, whole plant	Grain - Medium to hard dough	67-72	63-68	50-60
Sorghum grain, rolled ground	Medium to hard dough	26-32	26-32	
Sorghum grain, whole	Medium to hard dough	-----	-----	22-26

Feeding Sorghum

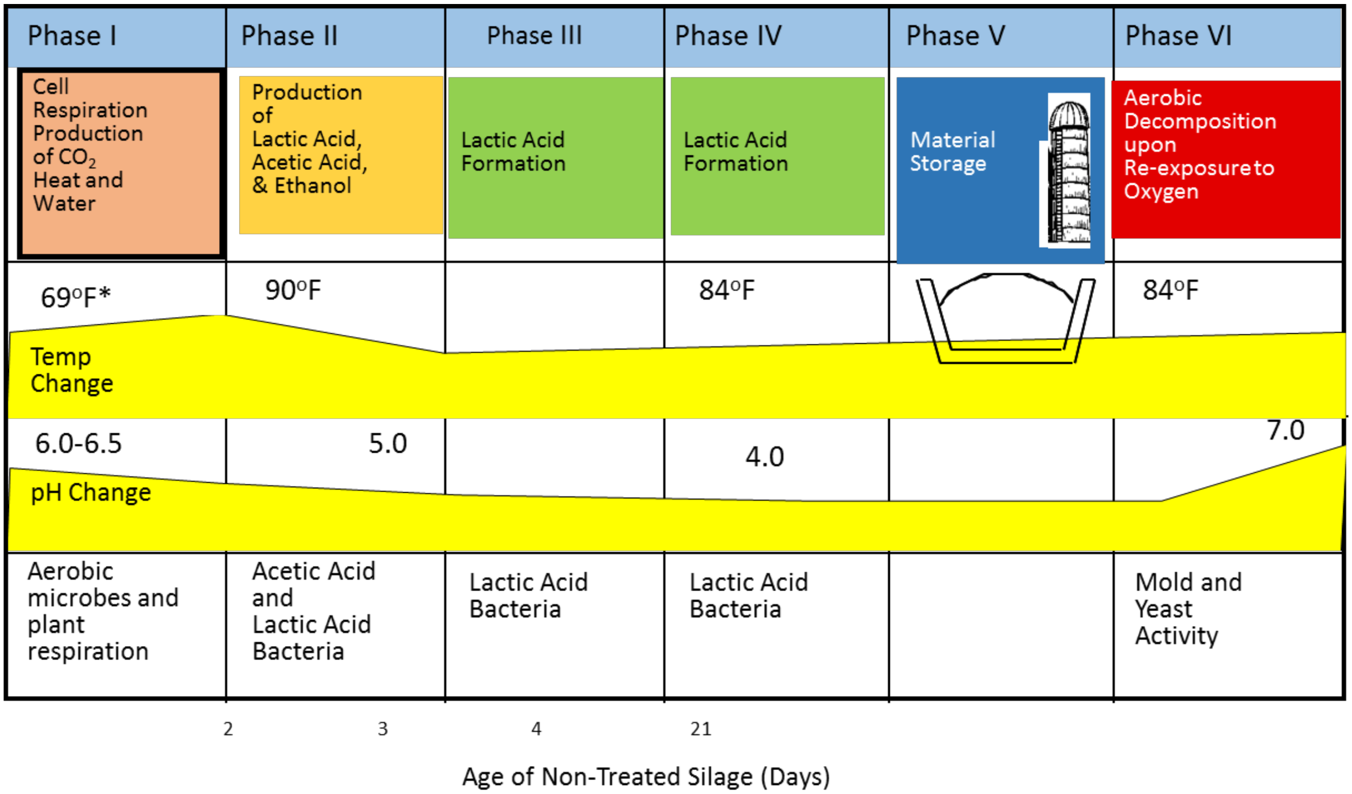
- Steam Flaking grain sorghum => increases feed value on avg 15%
- Energy is very comparable between sorghum and corn, sorghum is higher in protein & fat than corn
- High Moisture Grain => maintaining the optimal moisture at harvest is critical

Precautions

- Moisture when direct cut & secondary fermentations
- Nitrates
- Prussic Acid Poisoning

SIX PHASES OF SILAGE FERMENTATION AND STORAGE

Maturity and moisture recommendations for harvest of forage sorghums for silage.



Adapted from McCullough * Temperature dependent on ambient. Ensiling temperature generally is 15o higher than ambient.

~20° increase in temp day 2-3

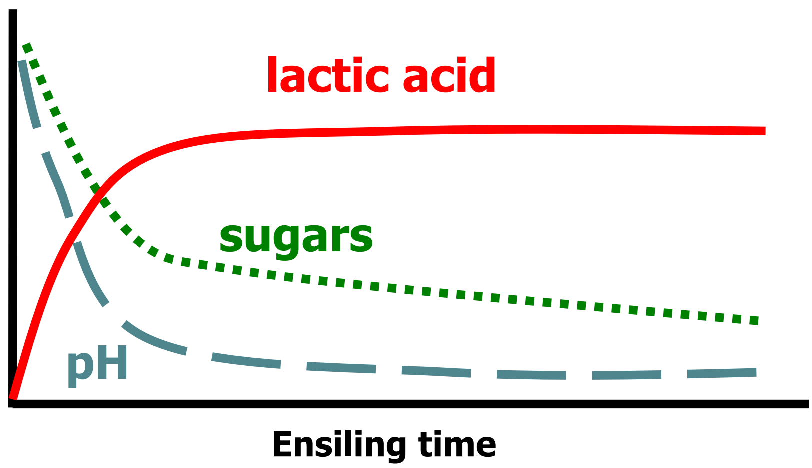
Return to w/in 10-15° of ambient temp when fermentation is complete

pH drop to 5 within 3 days and reach terminal pH of 4 or less when fermentation is complete

The field is full of (epiphytes) some are good and many are "naughty BUGS!" And they all get harvested with the crop!

- Yeast
- Mold
- Clostridia
- Bacillus

ALL of the Bugs, good & bad, are consuming nutrients in the silage… The ideal fermentation: a simple process that STOPS the consumption



Like Storming the Beaches of Normandy, we want to OVERWHELM the environment with POWERFUL soldiers

The Bugs get tucked in for a nap!

- Use an efficient Inoculant to quickly drop pH
- Pack the Oxygen out of the pile
- The bugs go down for a nap

When we open the pile to feed to the cows…

They wake up….! The disco ball comes out, the stereo gets turned up and the bugs start eating the nutrients we need to make milk and muscle

How many naughty bugs we wake up depends on if we had an efficient fermentation or not

Optimal Kernel Processing

Adequate to Poor Kernel Processing

Chop Length needs to be monitored

Factors influencing pack density

- Delivery rate
- Tractor Weight- 800 Rule
- Number of tractors
- Length and slope of fill ramp
- Packing layer thickness
- Tire Width & Pressure
- Dry Matter/Moisture
- Particle Size
- Tractor Speed
- Slope/Angles

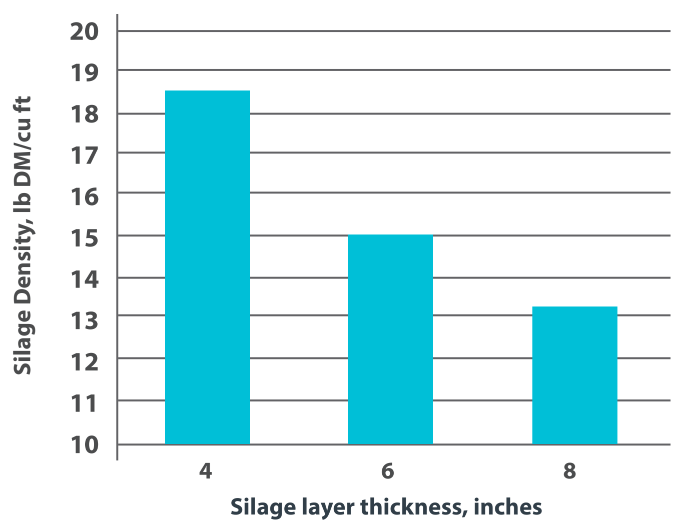
Density Pack related to layer thickness

Density decreases as the push layer thickness increases.

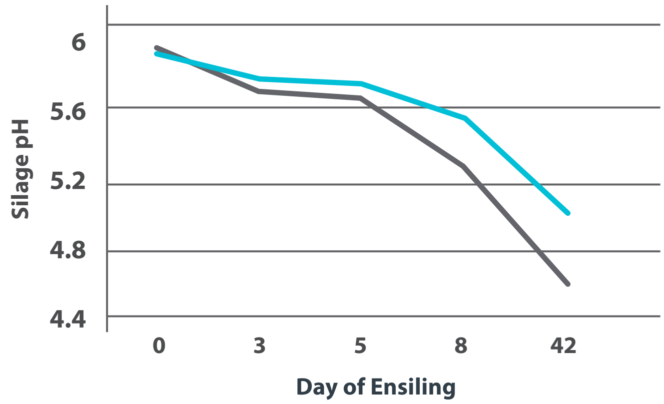
Positive correlation with

- packing time
- packing weight
- dry matter content

As each one increases, density also increases



Poor packing density => more air exposure, slowing the ensiling process and increasing yeast levels

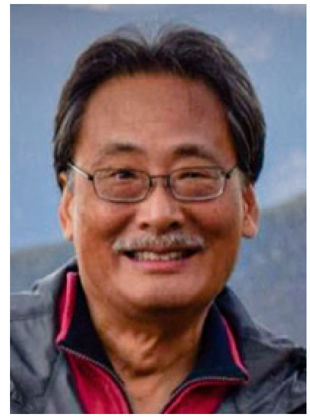


Lynch and Kung 2000

There are some things we have to do ON PURPOSE in order to efficiently preserve the crop

- Harvest timing
- Efficient Fermentation
- Monitor processing and chop length
- Pack, Pack and Pack!

USE AND MODES OF ACTION OF ADDITIVES IN SILAGE MAKING



Limin Kung, Jr., Ph.D.
S. Hallock du Pont Professor
Department of Animal and Food Sciences
University of Delaware
lksilage@udel.edu

Limin Kung, Jr. is a native of Honolulu Hawaii where he obtained his BS and MS degrees in Animal Science. He completed his PhD at Michigan State University in Dairy Science and is currently the S. Hallock du Pont Professor of Animal Sciences (endowed professorship) in the Department of Animal and Food Sciences, University of Delaware. Limin has a research, teaching and extension appointment and led the Department as Chairperson for 5 years. His research has centered on ways to improve the productive efficiency of lactating dairy cows through a better understanding of fermentation processes that occurs in silage and in the rumen of cows. His silage program has been recognized in the US and internationally and he is a sought-after speaker at dairy meetings throughout the world.

INTRODUCTION

The primary goal of making silage is to maximize the preservation of original nutrients in the forage crop for later feedings. However, undesirable silage fermentations and poor aerobic stability result in losses of energy, dry matter (DM), and overall nutritive value, ultimately compromising animal performance and net farm profits. This review will briefly discuss the processes of how bacterial inoculants and some chemical additives can improve silage fermentation and aerobic stability. This review will not cover the use of various enzymes that are sometimes added with bacterial inoculants. A more comprehensive publication of this topic can be found at Muck et al. (2018).

In order to understand how silage additives can help it is important to understand what factors can affect the silage fermentation process.

SILAGE FERMENTATION

In general, final silage quality can only be as good as the quality of the starting crop placed into the silo. Thus, it is necessary to harvest high-quality forage that is readily digestible and contains adequate amounts of fermentable carbohydrates for rumen microorganisms and the cow.

After chopping, plant matter is still alive, respiration continues for several hours (and perhaps days if silage is poorly packed), and plant enzymes (e.g., proteases) are active until the air is eliminated and the pH declines. Excessive respiration leads to a decline in fermentable nutrients. A rapid removal of air prevents the growth of unwanted aerobic bacteria that also add to excessive respiration, which can compete with beneficial lactic acid bacteria (LAB) for fermentable substrates. If air is not removed quickly, high temperatures and prolonged heating lead to losses of energy and DM. Air can be eliminated by wilting plant material to recommended DM for the specific crop and storage structure, chopping forage to a correct length, quick packing, obtaining good bulk densities, and even distributing forage in the storage structure immediately sealing with good tarps and weights. Bulk densities should target a minimum of 44 lb of wet forage per ft3 (Holmes and Muck, 2020).

During active fermentation, LAB utilize water-soluble carbohydrates (WSC) to produce lactic acid, which is primarily responsible for increasing the acidity and decreasing the pH in silage. A quick reduction in silage pH helps minimize the unwanted breakdown of protein in the silo by plant proteases. In addition, it inhibits the growth of undesirable anaerobic microorganisms such as enterobacteria and clostridia that are intolerant of low pH. Eventually, the continued production of lactic acid and a decrease in pH inhibits the growth of most microorganisms in the silo. Depending on the crop, the fresh plant material in the field can range from a pH of about 5 to 6 and decrease to a pH of 3.7 to 4.5 (depending on the crop and DM) when fermentation is complete.

Although the ensiling process appears quite simple, many factors can affect what type of fermentation takes place in a silo and, thus, the mixture of end products (Figure 1). For example, because of the high buffering content of most legumes, more acid production is needed to lower the pH in alfalfa than in corn silage, resulting in the former being more challenging to ensile. The DM content of the forage can also have significant effects on the ensiling process via different mechanisms. First, drier silages do not pack well, and thus it is more difficult to exclude air from the forage mass. Second, as the DM content increases more than 35-40%, LAB growth is reduced, acidification occurs slower, and the amount of total acid produced is low. Thirdly, undesirable bacteria such as clostridia tend to thrive in very wet silages (< 30% DM) and can result in excessive protein degradation, DM loss, and production of biogenic amines. When weather permits, wilting forage above 30-35% DM before ensiling can reduce the incidence of clostridia because these organisms are not very osmotolerant (they do not like dry conditions). Another factor affecting the ensiling process is the concentration of WSC present for good fermentation. Hirsch and Kung (unpublished data, University of Delaware) showed that WSC dramatically decreased, and DM losses increased when corn forage was not immediately packed into silos after chopping (Figure 2). The types and numbers of bacteria on the plant also have profound effects on silage fermentation. Natural populations of LAB on plant material are often low in number and heterofermentative (produce multiple end products). Theoretical recoveries of DM and energy from the fermentation of sugars are shown in Table 1. Lactic acid fermentations are more desirable than other types of fermentation because the recovery of DM and energy is highest. Additionally, highly wet silages tend to have high levels of acetic acid because Enterobacteria often dominate the fermentation, resulting in significant losses of DM and poor intakes.

THE AEROBIC STABILITY OF SILAGES

When silage fermentation is complete and kept away from air, silages can remain relatively stable for extended periods (years). However, if silage is exposed to air during storage (e.g., leaky silos, holes in bag silos, poorly packed silage) or at feed out, lactate utilizing yeasts may initiate aerobic spoilage. The succession of events is a) silage is exposed to air-> b) yeasts degrade lactic acid-> c) production of heat occurs via respiration-> d) the pH increases-> e) molds and aerobic organisms further the deterioration. Aerobic stability is a term used to define the length of time that silage remains stable and does not spoil after exposure to air. Silages that are aerobically stable are desirable because air often penetrates the silage mass during storage, and during feed out, air can penetrate more than 1 m into the feeding face. In general, silages that have high numbers of yeasts (>100,000 to 1,000,000 yeast per gram of wet silage) have the potential to spoil very quickly aerobically; those with low levels of yeasts (less than 1,000 to 10,000 yeast) often remain stable for prolonged periods. Because air fuels yeast growth, minimizing their numbers and minimizing exposure to air in silage is a fundamental goal in silage making. Spoiled or spoiling silage is undesirable as it represents a loss of DM and energy, reducing intake and animal production. For example, Windle and Kung (2013) fed a fresh and spoiling TMR containing corn silage to heifers. The temperature of the spoiling TMR ranged from 90 to 120°F at feeding. The fresh TMR contained about 110,000 yeasts per gm, whereas the spoiling TMR contained about 66,000,000 yeasts per gm of fresh weight. Heifers fed the spoiling TMR ate about 12% less DM. Poor aerobic stability is often worse in crops with a high DM content. Poor aerobic stability is also more common in high moisture corn, whole plant corn silage, and some small grain silages than alfalfa silage.

IMPROVING SILAGE FERMENTATION WITH ADDITIVES

Microbial and chemical-based silage additives should not be used in place of good management. However, they have been shown to improve DM and nutrient recovery, produce silages that remain fresh for extended periods (good aerobic stability), and prevent poor fermentations that could negatively affect intake or production.

Lactic acid bacteria to improve the initial fermentation process. The concept of adding a microbial inoculant to silage was to add fast-growing homofermentative LAB (hoLAB) to the forage mass to dominate the fermentation and suppress the growth of naturally occurring undesirable microbes on the plant. The result would be high DM and nutrient recovery (Table 1). This general concept of using "good" bacteria to combat "bad bacteria" has since become mainstream in human nutrition and is often known as "probiotic" therapy. Some of the more common hoLAB used in silage inoculants include Pediococcus acidilactici, P. pentosaceus, and Enterococcus faecium (Kung et al., 2003). Lactobacillus plantarum is also commonly used as a silage inoculant. It is technically now classified as a facultative heterofermentative LAB species rather than an hoLAB species, but it is still practically grouped with hoLAB.

Microbial inoculants can contain one or more bacteria; the rationale for multiple organisms comes from potential synergistic actions with combined organisms. For example, the growth rate is faster in Enterococcus > Pediococcus > Lactobacillus. In addition, some Pediococcus strains are more tolerant of high DM conditions than are Lactobacilli and have a broader range of optimal temperature and pH for growth (they grow better in cool conditions found in late Fall and early Spring). In contrast, the actions of Enterococcus and Pediococcus tend to subside earlier than many strains of Lactobacillus plantarum which, is a "strong finisher" in the fermentation process. The use of a sole type of bacteria or combination varies with formulations from the various companies selling inoculants.

Legumes, grasses, and small cereal grain crops have responded well to microbial inoculation with hoLAB. This is especially so because a rapid drop in pH inhibits the growth of undesirable microbes. However, holAB microbial inoculation of corn silage has resulted in less consistent results probably because the pH drop of corn silage occurs very quickly. Compared to untreated silages, silages treated with adequate numbers of a viable hoLAB should be lower in pH, acetic acid, butyric acid, and ammonia-N but higher in lactic acid content. When effective, microbial inoculation with hoLAB might also be expected to improve DM recovery by 3-5% and prevent a clostridial fermentation.

Whereas as hoLAB can stimulate the early phases of ensiling, one drawback of using only these types of bacteria is that in many instances, they have no effect on improving aerobic stability and often can make aerobic stability worse (Muck and Kung, 1997). This is probably due to a lower content of acetic acid and other potential antifungal end products. This finding is highly ironic because many producers use microbial inoculants based only on hoLAB because they perceive an improvement in aerobic stability. Thus, it is now commonly accepted that there needs to be a compromise in silage fermentation end products such that recovery of nutrients is maximized with improved stability when exposed to air.

Use of Lactobacillus buchneri type of bacteria to improve aerobic stability. Muck (1996) suggested that Lactobacillus buchneri, a heterofermentative LAB, could improve the aerobic stability of silages. In contrast to hoLAB, this organism does not improve the speed of fermentation. However, it anaerobically converts moderate amounts of lactic acid to acetic acid (Oude-Elferink et al., 2001), which has good antifungal characteristics and decreases the numbers of yeasts in silage thus improving stability. There have been numerous studies on a wide variety of crops (e.g., corn silage, high moisture corn, sorghum silage, barley silage, grass silages) to support this claim (Kleinschmit and Kung, 2006; Arriola et al., 2021). Combination inoculants containing hoLAB and L. buchneri are available to improve the initial fermentation and provide good aerobic stability. Several bacteria similar to L. buchneri and in its' family, have been research on their effects to improve aerobic stability (e.g., L. brevis, L. hilgardii, and L. diolivorans). The largest body of independently published studies documents the success of the specific strain of L. buchneri 40788 to improve stability.

Organic acids to improve aerobic stability. Various organic acids, including potassium sorbate, sodium benzoate, and propionic that inhibit yeasts, have been used to enhance the aerobic stability of silages but are by far less popular than using bacterial inoculants. This is probably because compared to using a microbial inoculant containing L. buchneri, the addition of organic acids is usually more expensive and requires more significant volumes of liquid application than ultra-low volume applicators commonly used for microbial inoculants. However, in their favor, the activity of the acids does not require a microorganism to grow and dominate the fermentation process and produce an active end-product. Chemical additives are also relatively more stable and have longer shelf lives than their live microbial counterparts.

It is the undissociated form of organic acids that have potent antifungal properties and is dependent on pH. If added to a fresh crop with a pH of 6, only about 1% of these acids would be in the undissociated form and would thus be inactive. Whereas at a pH of 3.5, about +90% of the acids would be undissociated and active. Thus, these acids should be used in forages with low pH to be the most effective. Additives containing potassium sorbate and sodium benzoate (Auerbach and Nadeau, 2013) have proven effective in improving aerobic stability in various crops.

General management of additives. Microbial inoculants are can be applied in a dry form and are often mixed with calcium carbonate (limestone), dried skim milk, sucrose, or other carriers. These products are best applied by some type of solid metering devices (e.g., Gandy applicator) as per the manufacturer's recommendations. For large operations, dried inoculant powders are mixed with water just before use. (Using chlorinated water may be detrimental to the inoculant if levels exceed more than 1.5 to 2 PPM.) The application can be made with a metered liquid sprayer to disperse the water-inoculant mixture on the forage evenly.

The temperature of the water in the application tank of bacterial inoculants can affect the viability of your inoculant. Research from our lab (Windle and Kung, 2016) has confirmed that lactic acid bacteria used in inoculants are less likely to remain viable when the temperature of water is above 95 to 100°F. In applicator tanks sampled in the field, the amount of expected viable bacteria sampled from tanks with temperatures about 100°F was only 50% of the required viable bacteria needed to meet the recommended application rate. When the water temperature in tanks was greater than 110°F, they contained only 10% of required live bacteria. Of more than 50 application tanks that were sampled, about 22% of them had water temperatures of 90°F or greater. The most common reason for high water temperatures in applicator tanks was due to gaining heat from the engine or exhaust of the chopper. Users are encouraged to monitor the temperature of water in their tanks and if they are found to be high, to take appropriate measures to correct the problem. If moving the tank is not an option, ice packs can be used to cool the water. Microbial inoculants that sit in applicators for dry applications (e.g., a Gandy applicator) also most likely lose viability if they become over heated and if storage is longer than a few days.

On average, bacteria mixed in water are stable for about 48 h. Anything that was mixed and unused after 3 days should probably be discarded. If you notice foul smells or slime in the tanks, discard this material and thoroughly clean the tank and lines before reusing. Cleaning should include the use of a mild cleaning agent but thorough rinsing is required to avoid any detrimental effects of a cleaning agent on the viability of the inoculants.

Microbial inoculants and chemical additives can be applied to the forage at a variety of locations. However, application to forage at the chopper is highly recommended to maximize the time that microorganisms contact fermentable substrates. Application at the chopper is more critical if silage is stored in a bunk or pile because it is difficult to achieve good distribution onto the chopped material from a forage wagon. Distribution of additives is less of a problem if applied at the blower of an upright silo or the bagger. Throwing a can of dry inoculant onto a load of forage and hoping for even distribution is not an acceptable practice.

Storage is an essential aspect of a high-quality inoculant that contains live microorganisms. Some inoculants require refrigeration or freezing for optimum storage. Those that do not require cold temperatures for storage should still be kept in cool, dry areas away from direct sunlight. Moisture, oxygen, and sunlight can decrease inoculants' stability, resulting in lower viable counts and a product that does not meet label guarantees. Opened bags of inoculants should be used as soon as possible and, if not ultimately used, not carried over into the next season. Inoculants mixed in water are usually stable for 1 to 2 days but probably should not be kept past this time. If there are instances where inoculant tanks become slimy and smell "off', they should be cleaned prior to use.

EXAMPLES OF WHAT TYPE OF BACTERIAL INOCULANT TO USE

Here are a few examples of how to choose the best type of additive based on some specific situations:

Situation 1: **Silage is always fresh and never or seldom has issues with a heating TMR even in warm weather.**

Type of silage inoculant to consider: Use a homolactic acid based inoculant

Reasoning: Silage fermentation can still be improved with preservation of 2 to 4 more units of total dry matter by using a good homolactic acid inoculant.

Situation 2: **Large bunker or pile silo with a face that may be too wide that causes a slow rate of feed out and silage is hot when comes out of the silo.**

Type of silage inoculant to consider: Use an inoculant with L. buchneri (with homolactic acid bacteria as an option).

Reasoning: Silage treated with L. buchneri will have a better ability to withstand the stress of aerobic exposure.

Situation 3: **Silage that is sold and/or left on intermediate feeding piles for several days (especially in warm weather) or silage that will be moved from one silo to another.**

Type of silage inoculant to consider: Use an inoculant with L. buchneri (with homolactic acid bacteria as an option).

Reasoning: Silage treated with L. buchneri will have better stability when sitting in the pile exposed to air.

Situation 4: **One silo will be fed out during cold winter months but another silo will be fed out in the hot summer and there are issues with heating of the TMR with the summer fed silage.**

Type of silage inoculant to consider: For the winter silo, treat with a homolactic acid inoculant. For the summer silo, treat with an inoculant with L. buchneri (with homolactic acid bacteria as an option).

Reasoning: Silage fed in the winter usually does not spoil as rapidly when exposed to air, but this silage can still be improved with a good homolactic inoculant. Silage fed in the summer tends to spoil rapidly when exposed to air. Silage treated with L. buchneri may improve stability for this situation.

Situation 5: **A portion of the silo is fed out in the winter (e.g. top of a tower silo), whereas another portion (e.g., bottom of a tower silo) is fed out during the summer.**

Type of silage inoculant to consider: Treat the top with a good homolactic acid bacteria-based inoculant, treat the bottom with L. buchneri (with homolactic acid bacteria as an option), as an option treat the whole silo with a L. buchneri + homolactic acid bacterial inoculant.

Reasoning: See Situation 4

Situation 6: Grass or legume forages ensiled at relatively high moisture contents (> 65-70% moisture or less than 30-35% DM).

Type of inoculant to consider: Consider using a homolactic acid-based inoculant.

Reasoning: When these forages are wet, the conditions often favor the growth of clostridia that produce butyric acid and may excessively degrade proteins. Homolactic acid inoculants drop the pH fast and can inhibit the growth of clostridia.

Situation 7: Corn silage or alfalfa/grass haylage harvested at a relatively high DM (> 40 % DM).

Type of silage inoculant to consider: Use an inoculant with L. buchneri with homolactic acid bacteria.

Reasoning: High DM silages are often more prone to aerobic spoilage than wetter silages. High DM silages ensile slower than wetter silages. An inoculant with L. buchneri may help to improve aerobic stability and the homolactic acid bacteria will drop the pH fast.

Situation 8: Silage in storage structures that are "oxygen limiting".

Type of silage inoculant to consider: Use a homolactic acid based inoculant.

Reasoning: Even if oxygen is limiting, a homolactic acid inoculant can improve the efficiency of fermentation.

Situation 9: Corn plants are harvested when they are frozen, or the ambient temperature is freezing and it is expected to remain very cold.

Type of silage inoculant to consider: Consider still using a good homolactic acid based inoculant but if the crop is dry (>40% DM) consider using a combination product with L. buchneri and a homolactic acid bacteria.

Reasoning: Frozen forage will not ensile but when the ambient temperature rises and warms the forage mass, fermentation may proceed if air is excluded from the mass. The biggest issue that may prevent this scenario from happening is that it will take sustained high ambient temperatures to warm forage up in very large silos. If a silo is opened before the mass has ensiled, the aerobic conditions at the face will most likely result in forage that spoils before it ensiles unless the rate of feed out is extremely fast.

Situation 10: Ensiling HMC, snaplage, or earlage

Type of silage inoculant to consider: Consider using a L. buchneri type of additive.

Reasoning: Aerobic instability or spoilage is usually the biggest challenge for high moisture grain crops. Thus, controlling yeasts is of the utmost importance. (Remember that inoculants with L. buchneri tend to inhibit the growth of yeasts that cause aerobic spoilage.)

CONCLUSIONS

Silage fermentation is often an uncontrolled process, but the goal is to maximize the recovery of DM and nutrients and produce a stable crop during storage and feed out. Poor fermentations and aerobic stability will result in losses of nutrients, animal productivity, and farm profits. Quick and low drops in pH and minimizing the number of lactate-utilizing yeasts aid in insuring a good fermentation. Recommended management practices for harvesting, filling of silos, and silo coverings should be followed. Various silage additives can be effective in helping to achieve a high-quality fermentation of forage crops, but they should not be substitutes for good silo management.

REFERENCES

Arriola, K. G., A. S. Oliveira, Y. Jiang, D. Kim, H. M. Silva, S. C. Kim, F. X. Amaro, I. M. Ogunade, H. Sultana, A. A. P. Cervantes, and L. F. Ferraretto. 2021. Meta-analysis of effects of inoculation with Lactobacillus buchneri, with or without other bacteria, on silage fermentation, aerobic stability, and performance of dairy cows. J. Dairy Sci. https://doi.org/10.3168/jds.2020-19647

Auerbach H., and E. M. G. Nadeau. 2019. Chemical additives for silages: When to use it, and what are the options? Pages 49-88 in Proc. VI Int. Silage Conf., Piracicaba, Brazil, November 7-8th. L. G. Nussio, E. B. da Silva, K. S. Oliveira, V. C. Gritti, P. A. R. Salvo, G. G. S. Salvati, and O. S. Dannylo eds. ESALQ, Piracicaba, Brazil.

Holmes, B.J., and R. E. Muck. 2020. Pile Silo Silage Density Calculator. https://fyi.extension.wisc.edu/forage/files/2020/05/Documentation-Pile-Density-Calculator-5-11-20.doc

Kleinschmit, D. H., and L. Kung, Jr. 2006. A meta-analysis of the effects of Lactobacillus buchneri on the fermentation and aerobic stability of corn, grass, and small grain silages. J. Dairy Sci. 89:4005-4013.

Muck, R. E., E. M. G. Nadeau, T. A. McAllister, F. E. Contreras-Govea, M. C. Santos, and L. Kung, Jr. 2018. Silage review: recent advances and future uses of silage additives. J. Dairy Sci. 101:3980-4000.

Oude Elferink, S. J. W. H., J. Krooneman, J. C. Gottschal, S. F. Spoelstra, F. Faber, and F. Driehuis. 2001. Anaerobic conversion of lactic acid to acetic acid and 1,2-propanediol by Lactobacillus buchneri. Appl. Environ. Micro. 67:125-132.

Reich, L. J., and L. Kung, Jr. 2010. Effects of combining Lactobacillus buchneri 40788 with various lactic acid bacteria on the fermentation and aerobic stability of corn silage. Anim. Feed Sci. Tech. 159:105-109.

Windle, M. C., and L. Kung, Jr. 2013. The effect of a feed additive on the feeding value of a silage-based TMR exposed to air. J. Dairy Sci. 91(E-Suppl. 1):16.

Windle, M. C., and L. Kung, Jr. 2016. Factors impacting the numbers of expected viable lactic acid bacteria in inoculant applicator tanks. J. Dairy Sci. 99:9334–9338.

FIGURE 1.

The factors that can affect the silage fermentation process.

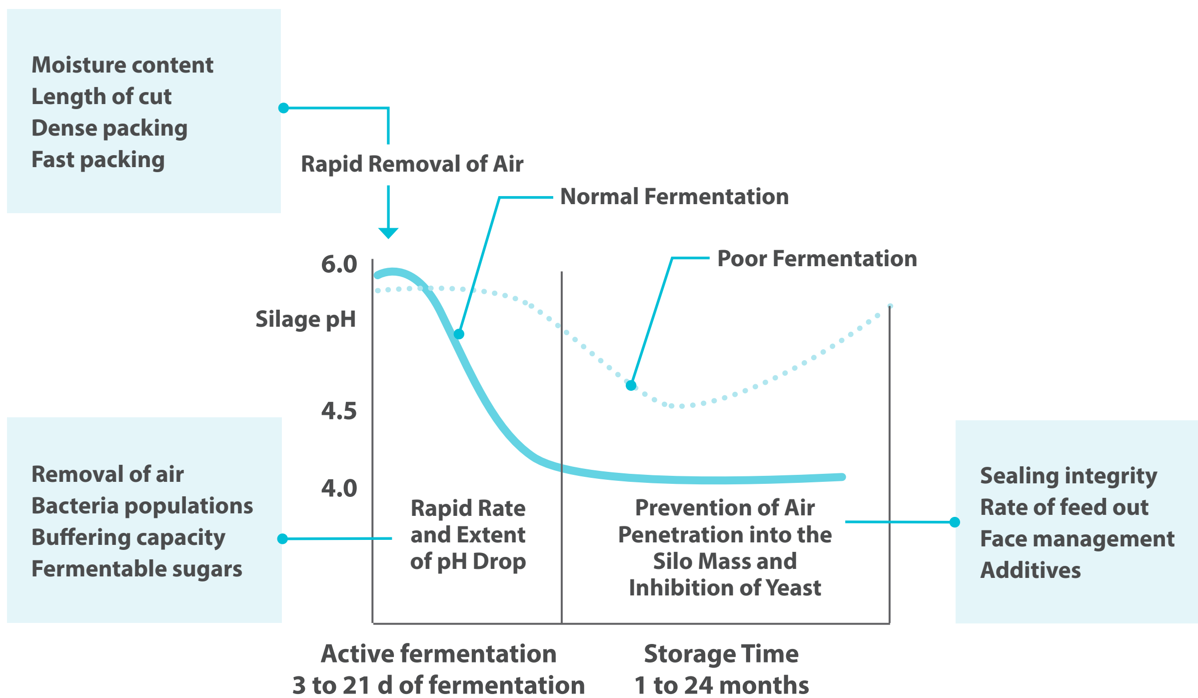


FIGURE 2.

Effect of the delayed filling (chopped forage sitting in a forage wagon for various lengths of time) on (A) water-soluble carbohydrates (WSC) and (B) Dry matter (DM) loss in corn forage. Hirsch and Kung, Univ. of Delaware, unpublished data.

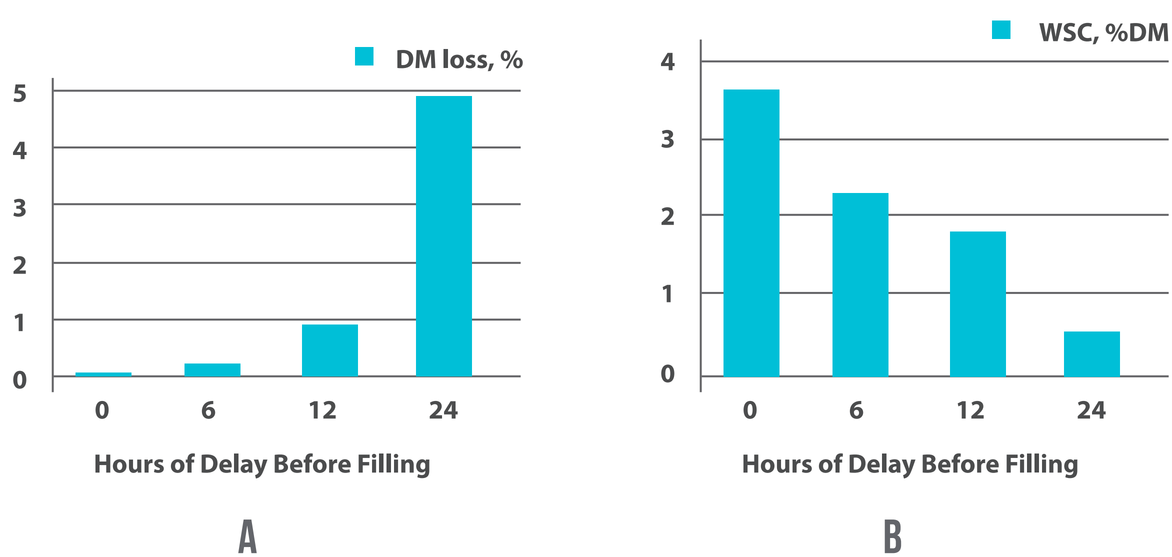


TABLE 1.

Predominant fermentation pathways.

Type of fermentation	End-products	Theoretical DM recovery, %	Theoretical energy recovery, %
Homolactic (glucose)	lactic acid	100	99
Heterolactic (glucose)	lactic acid, ethanol, CO_2	76	98
Heterolactic (fructose)	lactic acid, acetate, mannitol, CO_2	95	99
Yeast (glucose)	ethanol, CO_2	51	99
Enterobacteria (glucose)	acetic acid, ethanol, NH_3, CO_2	95	83
Clostridia (glucose and lactate)	butyric acid, NH_3, CO_2	49	82

ECONOMICS OF QUALITY FORAGE IN GROWER AND FINISHER DIETS

Jhones O. Sarturi, Ph.D.
Associate Professor
Beef Cattle Nutrition and Metabolism

Graduate student collaborators: *Alejandra M. Lopez, Barbara M. Rodrigues, Kaliu S. Silva, and Camron J. Rush*

Dr. Jhones O. Sarturi is a tenured Associate Professor of Beef Cattle Nutrition and Rumen Metabolism in the Department of Animal and Food Sciences at Texas Tech University, Lubbock-TX since early 2013. He received a D.V.M. from the University for the Development of Pantanal – Brazil, a M.S. degree in Agronomy from the University of Sao Paulo – Brazil, and a Ph.D. in Animal Science from the University of Nebraska Lincoln. During 2012, he worked as a Post-Doctoral Research Associate at the Texas A&M AgriLife Research, Amarillo-TX. Dr. Sarturi's research focus has been on the development of strategies to improve, evaluate, and better utilize byproducts, forages, and grains in ruminant diets. As the manager for the Ruminant Nutrition Laboratory and the Ruminant Nutrition Center (cattle metabolism area), Dr. Sarturi fosters basic and applied research, empowers undergrad and graduate students, as well as strives to serve society with excellence. He currently resides in Lubbock-TX, and can be contacted: j.sarturi@ttu.edu

INTRODUCTION

Beef cattle grower and finisher diets will inevitably have a unique make-up depending on animal nutrient requirements, time of the year, location, ingredient availability, equipment/feeding logistics, size of operation, ingredient market, cattle market, and wiliness of nutritionists to be creative. Though, one theme that relates to any scenario is the fact that raising feed costs certainly attracts the interest for strategies or technologies that induce a more efficient animal nutrient utilization. The costs associated with such improvements come to be more justifiable (less restrictive) as more expensive ingredients become. Other than economic attractiveness, it might be pertinent to highlight that the use of such implementations by the cattle industry will positively affect the utilization of available resources and strive for a more sustainable agriculture. Thus, in the long run, positively influences the continuous and restorative nutrients cycle in the planet.

Current proceedings will develop the concept of forage quality by targeting the amount of additional energy released by forages and roughages when the digestibility of its major nutrient fraction (fiber, represented by the neutral detergent fiber/NDF) is improved. The model included published data from our research team to provide examples of high/low-quality forage grower and finisher diets. Equations were also used to estimate energy content generated by improvements in forage-NDF digestibility in such scenarios and potential animal growth responses. Lastly, the potential financial savings connected with the animal response induced by a greater energy content, as well as the influence that diet cost magnitude has on such response were modeled.

USING QUALITY OF FORAGE TO MODEL FINANCIAL RETURNS

It is intrinsic that losses involved with forage utilization may affect profitability of the system using such type of ingredients. Losses during harvest, transportation, processing, fermentation process, storage, post-opening of the silo (aerobic stability), and shrink can be very detrimental. However, other than the amount of dry matter recovered, the quality of the material recovered will be a crucial factor dictating the amount of energy recovered and consequently potential animal growth performance. A similar concept can be applied to any other forage utilized in beef cattle grower and finisher diets, especially when greater forage inclusions are used. Improvement in quality will be then herein defined as a greater amount of energy allowing cattle body weight gain or improved gain efficiency (G:F).

The Beef Cattle Nutrient Required Model (BCNRM) released by the National Academies of Science Engineer and Medicine (NASEM, 2016) was used to model beef cattle growth performance. The assessment assumed animals offered either grower or finisher diets conditioned to fiber digestibility improvements induced on the major forage ingredients of the diets only. Such exercise to predict cattle additional growth when offered forages with improved quality may be applied to scenarios in which an investment is made to improve forage quality. The return on investment (ROI) might be then adjusted to a situation in which feed ingredients are of more or less value ($/ton of DM).

It is expected that improvements in forage quality will induce a greater rate of gain and/or gain efficiency. Thus, modeling such improvements may be the key to decide how much additional cost can be afforded to cover expenses induced by such forage quality investment.

Several scenarios were analyzed, including improvements in dietary energy induced by increases (10, 20, and 30%) in fiber (NDF) digestibility of low-quality forages (cotton burrs and corn stalks) and high-quality forages (corn silage and alfalfa hay) offered to beef cattle grower diets. In addition, finisher diets containing 20% inclusion (DM basis) of either corn silage or sorghum silage were also evaluated (Table 1). The following assumptions were used for the assessment: BCNRM empirical solution type; growing calves from 500 to 800 lb of unshrunk body weight (grower diet) or 800 to 1400 lb (finisher diet); mature live body weight (1,300 lb); reference animal's empty body fat (28%); straightbred Angus calves; DE to ME efficiency, as well as conversion from ME to NEm and NEg as described by Galyean et al. (2016); animals receiving ionophore (monensin) and implant; and with no adverse environmental conditions.

FORAGE AS SOURCE OF NUTRIENTS

Although our main goal is to discuss forage quality, which comprehends multiple fractions of the forage composition, notably fiber content herein defined by the NDF content will be the fraction with the greatest potential to be improved. During a Spring/semester of my Ph.D. program in 2009, while attending a class taught by Dr. Terry Klopfenstein, I had the opportunity to hear about one of his greatest analogies to teach students about plant fractions and their effects on forage quality: "The Hotel Theory". The analogy would frame the more available nutrients from plants associated cellular content (organic acids, water soluble carbohydrates, starch, and neutral detergent soluble components: pectic substances, galactans, and β-glucans) as being the "furniture inside the rooms of a hotel", while the "hotel structure" would represent primarily fiber carbohydrates (NDF fraction). The more easily "breakable" portions of such structure (walls) would represent the content of potentially degradable fractions (cellulose and hemicellulose), while finally, the "pillars" of the structure would represent phenolic compounds (lignin) complexes with fiber providing ultimate strength for the plant, which represent the indigestible fraction of the forage. So, such analogy was used multiple times (and I continue to convey it along to my undergraduate and graduate students) to help us understand changes in plant morphology throughout the growing seasons and the potential effects on the nutritive value of plants enduring such natural maturity process (Dhakal et al., 2020).

With that said, the concentration of readily available fractions related to the cell content of plants (100 - NDF) will positively affect the quality of forages. For instance, the concentration of organic acids from plant metabolism or as products of silage fermentation such as lactic, acetic, propionic, and butyric acids (Cherney and Cherney, 2003), soluble fiber (Hall, 2003), water soluble carbohydrates (Hall, 2014), and starch (Van Soest, 1994) will represent approximately 10 to 50% of forages depending on the maturity, plant species, and degree of processing of such materials. Thus, nutrient analyses screening (to identify the content of such non-cell wall components), plant harvesting/

grazing time and techniques used, processing, storage, and delivery method all play a role to influence the quantity of available nutrients or nutrient properties (energy) when forages are offered to ruminants. On the other hand, the potentially degradable fraction of forages, represented by the NDF content is very unique, since only ruminants can effectively and efficiently use such fraction as a source of energy to produce edibles and other goods. Other than directly increasing starch (by adding cereal grains) or other cell content components into diets, improvements in forage quality as defined by a raise in NDF digestibility is one of the upmost ways to positively affect the net energy content of beef cattle diets, regardless if using a low or high-quality forage, or if offered to growing or finishing cattle. Assuming animal's nutrient requirements have been met (NASEM, 2016), cattle will positively respond to increases in dietary energy, which will be proportional to level of digestion improvement induced in the forage NDF fraction, and consequent effects on available NEm (net energy used for maintenance) and NEg (net energy used for growth) of such ingredients affecting the overall energy level of the diet (Table 2).

EFFECTS ON OVERALL DIETARY ENERGY AND ANIMAL RESPONSE

For instance, the raise in diet NE (% increase) induced by improvements of 10, 20, and 30% on forage-NDF digestibility in the diet is presented in Table 2. As expected, beef cattle grower diets, especially the ones with low-quality forages, will be the ones to benefit the most from such improvements, followed by high-quality forage grower diets, low-quality forage finisher diet, and high-quality forage finisher diet, respectively. Several factors may influence such pattern, but we may possibly narrow down to 2 main ones: 1) forage-NDF improvement in digestibility; and 2) representation of such content in the overall diet (dietary forage-NDF content, DM basis). The relationship between both factors aforementioned helps to exemplify why low-quality forage grower diets are the ones to potentially receive the best benefits from improved forage-NDF digestibility, once the forage-NDF content in that mixture represented roughly 30% of the diet, while the high-quality forage grower diet contained roughly 22%, followed by 10 and approximately 9% for low and high-quality forage finisher diets, respectively. Conversely, it is interesting to observe that even high-concentrate beef cattle finisher diets may potentially respond to improvements in forage-NDF digestibility. Such improvement in G:F for finisher diets (Table 3) were not to the same extent as the 4 to 11% increase in G:F predicted for the feeder cattle offered low-quality forage grower diets, or 3 to 8% increase in G:F for those receiving high-quality forage grower diets, but ranged from 1 to 3%, regardless if those diets included a high or a low forage quality (Table 3).

Interestingly, the potential improvements in G:F shown in Table 3, are induced by different factors depending if animals are on a grower or a finisher diet. Steers offered grower diets while developing (500 to 800 lb of body weight, BW) seem to benefit from the improvement of forage-NDF digestibility by increasing both, rate of body tissue deposition (average daily gain, ADG) and while only enduring subtle decreases in dry matter intake (DMI). However, during the growing phase, it is actually not uncommon to observe increases in DMI when dietary NDF digestibility is raised (Kondratovich et al., 2019). Potential improvements in ADG when NDF digestibility is raised may be simply indicating that the grower diets offered might not be achieving the maximum capability of nutrient digestion and assimilation by the animal. Conversely, when finisher diets are offered to cattle (800 to 1400 lb of BW), the already great inclusion of concentrate ingredients (such as highly-processed cereal grains) will be heavily contributing with the energy content of such diets. In that situation, it is very likely that the ability of the animal to assimilate and convert such energy into body tissue components might be maximized, not allowing any additional body weight increments (ADG), although still may allow additional body energy deposition (adipose tissue). When such metabolic situation is reached, a decrease in DMI is traditionally observed (Table 3) once animal chemiotactic control of intake (mediated by natural anorexigenic metabolic signals) is triggered.

FINANCIAL RETURN OF FORAGE QUALITY IMPROVEMENT

By this point of the current document, perhaps as a reader you might be wondering why the tittle starts with the term "economics", but you have not seen yet any mention of such topic! It is evident that the financial stimulus may be inflated when situations related with limited resources is aggravated. However, the assessment of effects involving improvements on forage quality on several dietary options, the prediction of mainly NE fluctuations induced by such improvements, and the disclosure of a method/model to evaluate such improvements may also yield you some extra tools to assist during the decision-making process, or to take advantage of unexplored or rather not fully explored opportunities.

The financial return model used in current comparisons is based on two main fundamentals: a) the improvement (%) on the predicted G:F when dietary forage-NDF digestibility raises; and b) three potential scenarios for diet cost ($/ton of DM) for grower (150, 200, and 250) and finisher (200, 250, and 300) diets (Table 4). Economical relevance of savings induced by improved quality of forages increases as with cost of diets. The savings are directly affected by the improvement in cattle G:F induced by more available nutrients and energy. However, other potential benefits (not considered in current assessment) would also indirectly benefit the evaluation, such as a decrease in days on feed, a decrease on expenses related with interest charges when capital or operational loans are paid sooner, a decrease on ownership risk by selling animals sooner, potential market advantage opportunities that can be predicted and logistically planned to enjoy less use of resources or less time owning a set of cattle, or even potential improvements in carcass characteristics.

With that said, as indicated by the predicted NE raise (Table 2) and animals' response (Table 3), animals consuming low-quality forage diets improved by greater forage-NDF digestibility may experience additional savings, ranging from $6-27/ton of diet DM, followed by high-quality forage grower diets ($4-19/ton of diet DM). The current assessment assumes that grower diets will be less expensive than finisher diets due to the lesser inclusion of cereal grains and current price for commodities like corn grain. When assessing finisher diets [forage-NDF content ranging from 8 to

10% only (DM basis)], savings ranged from $2-9 for low-quality, to $2-8 per/ton of DM for high-quality forage finisher diets. Note that it has been assumed a lower forage/roughage inclusion for beef cattle finisher diets (Table 1). Although in situations in which cattle are offered greater inclusions of forages during the finisher phase (for example corn silage included at rates greater than 20%, DM basis), such benefits may considerably escalate.

In addition, depending on the strategy or technology implemented to improve forage quality by raising forage-NDF digestibility, it is intrinsic to remember that other dietary components may also potentially benefit from advances. For instance, modern diets including byproducts rich in fibrous components can potentially also be targeted. If such approach is considered, it is also intrinsic to consider the real potential for improvement in NDF digestibility of such ingredients. Given the nature of alternative ingredients, some may have great NDF digestibility to begin with, while others may be embedded with elevated content of lignin or crystalline fiber structure, and therefore may requiring a more aggressive or strategic approach.

CONCLUSIONS

Improvements in forage quality as defined by a raise in NDF digestibility may positively affect the net energy content of beef cattle diets, regardless if low or high quality, or if offered to growing or finishing cattle. Such buster in dietary energy will be proportional to the level of digestion improvement and seems to be more related to improvements in NEg available in forage/roughage ingredients than NEm(a). However, it is expected that grower diets may proportionate a greater potential for improvements, simply because it will likely have more forage-NDF content compared to finisher diets, and animals will be enduring a distinct profile of tissue deposition compared to those on a finisher diet. Improvements in NDF digestibility of major forage/roughage ingredients in the diet may induce greater rates of body weight gain (especially in low-quality forage grower diets), however the most prominent effect might be related with an improved gain efficiency brought by a potential reduced feed intake. Effects on animal feed consumption are complex and can be also affected by other fundamentals. The financial return induced by an improved forage quality measured by the amount of currency savings is positively related to the price of cattle diets. The greater fiber content of grower diets may condition a greater predicted financial return induced by improvements in forage-NDF digestibility compared to finisher diets. The costs for the implementation of such strategy or technology shall not surpass the predicted financial benefit. The presence of scientific evidence denoting an improvement in NDF digestibility can be combined with mathematical models available to assist in decision making. Lastly, although the focus of current report was on the improvement of forage/roughage quality, it is imperative to highlight that other dietary ingredients may also contain NDF. Holistic approaches aiming to increase dietary NDF digestibility rather than forage-NDF may only be considered, especially on so called “modern diets” that may include multiple sources of byproducts. Such approach would also open more opportunities of improvement for finisher diets.

TABLE 1.

Dietary ingredient inclusions used to support the assessment of potential effects of NDF digestibility improvement on dietary energy changes and subsequent impacts on beef cattle growth performance when offered high/low quality forage grower and finisher diets

Item	Grower diet[1]		Finisher diet[2]	
	Low-quality	High-quality	Low-quality	High-quality
Ingredient Inclusion, % DM				
Corn Silage	-	36	-	20
Sorghum silage	-	-	20	-
Alfalfa Hay, Early Vegetative	-	15	-	-
Cotton burrs	20	-	-	-
Corn Stalks, hay	25	-	-	-
Urea	0.7	-	0.84	0.87
Cane Molasses	5	-	-	-
Steam-Flaked Corn	26.75	26.6	55.68	55.57
Wet Corn Gluten Feed	15	15	15	15
Cottonseed Meal	4	4	1.2	1.2
Yellow Grease	1	0.4	3.5	3.5
Limestone	0.55	1	1.78	1.86
Supplement	2	2	2	2
Analyzed Nutritional Composition, DM basis				
Starch, %	28.34	36.89	47.9	50.9
Crude Protein, %	14.18	14.62	14.1	13.4
Neutral Detergent Fiber, %	38.47	27.60	20.0	17.4
Acid Detergent Fiber, %	21.84	13.51	10.6	7.9
Ether Extract, %	3.02	3.06	6.36	6.70
Ca, %	0.75	0.75	0.75	0.77
P, %	0.37	0.45	0.38	0.38
K, %	1.41	1.13	0.85	0.74
Mg, %	0.19	0.29	0.23	0.20
S, %	0.18	0.2	0.162	0.158

[1] Published by Kondratovich et al. (2019).

[2] Published by Campanili et al. (2017 and 2018).

TABLE 2.

Assessment of potential effects of NDF digestibility improvement on dietary net energy raise (%) of beef cattle offered high/low quality forage grower and finisher diets

		Improvement in NDF digestibility of major forage ingredients only, %			
		0	10	20	30
Low-quality forage grower-diet	Diet [1]NEm raised, %	-	2.3	4.3	5.9
[2]Diet forage-NDF, 29.9% (DM basis)	Diet NEg raised, %	-	4.7	7.9	10.2
500-800 lb Full BW	Diet NE raised, %	-	7.0	12.2	16.1
		Improvement in NDF digestibility of major forage ingredients only, %			
		0	10	20	30
High-quality forage grower-diet	Diet NEm raised, %	-	0.9	1.8	2.6
Diet forage-NDF, 21.7% (DM basis)	Diet NEg raised, %	-	1.3	1.6	3.5
500-800 lb Full BW	Diet NE raised, %	-	2.3	3.4	6.1
		Improvement in NDF digestibility of major forage ingredients only, %			
		0	10	20	30
Low-quality forage finisher-diet	Diet NEm raised, %	-	0.5	1.0	1.4
Diet forage-NDF, 9.8% (DM basis)	Diet NEg raised, %	-	0.9	1.6	2.2
800-1400 lb Full BW	Diet NE raised, %	-	1.4	2.6	3.6
		Improvement in NDF digestibility of major forage ingredients only, %			
		0	10	20	30
High-quality forage finisher-diet	Diet NEm raised, %	-	0.4	0.8	1.1
Diet forage-NDF, 8.6% (DM basis)	Diet NEg raised, %	-	0.6	1.1	1.5
800-1400 lb Full BW	Diet NE raised, %	-	1.0	1.8	2.6

[1]Using NEm(a) and NEg(a) equations published by Galyean et al. (2016).

[2]High/low quality forage grower/finisher diets used for current assessment were published by Campanili et al. (2017 and 2018), and Kondratovich et al. (2019).

TABLE 3.

Assessment of potential effects of NDF digestibility improvement on subsequent impacts on beef cattle growth performance when offered high/low forage quality grower and finisher diets

		Improvement in NDF digestibility of major forage ingredients only, %			
		0	10	20	30
Low-quality forage grower-diet[2]	**ADG[3], lb**	2.37	2.45	2.53	2.61
Diet forage-NDF, 29.9% (DM basis)	**DMI, lb**	14.83	14.74	14.64	14.54
500-800 lb Full BW	**G:F**	0.160	0.166	0.173	0.180
			3.9	**7.5**	**11.0**
			Improvement[4] in G:F, %		
		Improvement in NDF digestibility of major forage ingredients only, %			
		0	10	20	30
High-quality forage grower-diet	**ADG, lb**	2.91	2.95	2.99	3.01
Diet forage-NDF, 21.7% (DM basis)	**DMI, lb**	13.79	13.6	13.4	13.2
500-800 lb Full BW	**G:F**	0.211	0.217	0.223	0.228
			2.7	**5.4**	**7.5**
			Improvement in G:F, %		
		Improvement in NDF digestibility of major forage ingredients only, %			
		0	10	20	30
Low-quality forage finisher-diet	**ADG, lb**	3.72	3.74	3.75	3.77
Diet forage-NDF, 9.8% (DM basis)	**DMI, lb**	22.73	22.6	22.48	22.34
800-1400 lb Full BW	**G:F**	0.164	0.165	0.167	0.169
			1.1	**1.9**	**3.0**
			Improvement in G:F, %		
		Improvement in NDF digestibility of major forage ingredients only, %			
		0	10	20	30
High-quality forage finisher-diet	**ADG, lb**	3.78	3.79	3.8	3.81
Diet forage-NDF, 8.6% (DM basis)	**DMI, lb**	22.26	22.11	21.96	21.81
800-1400 lb Full BW	**G:F**	0.170	0.171	0.173	0.175
			0.9	**1.9**	**2.8**
			Improvement in G:F, %		

[1]Improvements in digestibility (10, 20, and 30%) of major forage/roughage ingredients in the diet were used to adjust the digestible NDF content of the TDN equation proposed by Weiss (1992). The inputs needed for the equation (NDFN-free, CP, EE, ADICP, lignin, and ash) were extracted and/or calculated from the Standard Feed Library content of the BCNRM (NASEM, 2016).

[2]High/low quality grower/finisher forage diets used for current assessment were published by Campanili et al. (2017 and 2018), and Kondratovich et al. (2019).

[3]Beef cattle growth performance data were predicted by the BCNRM (NASEM, 2016) after adjustments of TDN being performed on major forage/roughage components in the diets (corn stalks, cotton burrs, corn silage, alfalfa hay, and sorghum silage).

[4]Percentual increment in body weight gain efficiency (G:F) of each NDF digestibility improvement (10, 20, or 30%) compared to the "zero" NDF improvement (first column) of each graph.

TABLE 4.

Financial return represented by savings ($/ton of diet DM) induced by potential improvements in NDF digestibility accounting for three levels of dietary prices

		Improvement in NDF digestibility of major forage ingredients only, %			
		0	10	20	30
Low-quality forage grower-diet	**$150[1]/ton of DM**	-	5.78	11.29	16.46
Diet forage-NDF, 29.9% (DM basis)	**$200/ton of DM**	-	7.70	15.05	21.94
500-800 lb Full BW	**$250/ton of DM**	-	9.63	18.81	27.43
		Savings[2], $/ton of diet dry matter			

		Improvement in NDF digestibility of major forage ingredients only, %			
		0	10	20	30
High-quality forage grower-diet	**$150/ton of DM**	-	4.07	8.14	11.19
Diet forage-NDF, 21.7% (DM basis)	**$200/ton of DM**	-	5.43	10.86	14.92
500-800 lb Full BW	**$250/ton of DM**	-	6.79	13.57	18.65
		Savings, $/ton of diet dry matter			

		Improvement in NDF digestibility of major forage ingredients only, %			
		0	10	20	30
Low-quality forage finisher-diet	**$200/ton of DM**	-	2.21	3.78	6.04
Diet forage-NDF, 9.8% (DM basis)	**$250/ton of DM**	-	2.76	4.73	7.55
800-1400 lb Full BW	**$300/ton of DM**	-	3.31	5.67	9.06
		Savings, $/ton of diet dry matter			

		Improvement in NDF digestibility of major forage ingredients only, %			
		0	10	20	30
High-quality forage finisher-diet	**$200/ton of DM**	-	1.87	3.73	5.59
Diet forage-NDF, 8.6% (DM basis)	**$250/ton of DM**	-	2.34	4.67	6.98
800-1400 lb Full BW	**$300/ton of DM**	-	2.81	5.60	8.38
		Savings, $/ton of diet dry matter			

[1]Set of three prices predicted for beef cattle growing (150, 200, and $250/ton of DM) and finisher diets (200, 250, and $300/ton of DM).
[2]Savings calculated by multiplying the decimal of the "Improvement in G:F, %" presented in Table-3 with each of the dietary cost scenario inside the table (grower or finisher diet).

REFERENCES

Campanili, P. R. B., J. O. Sarturi, M. A. Ballou, S. J. Trojan, L. Ovinge, A. Alrumaih, L. Pellarin, J. Sugg, A. Hoffman. 2017. Effects of silage type and inclusion level on ruminal characteristics and feeding behavior of steers fed finishing diets. Journal of Animal Science. 95. DOI: 10.2527/jas2017.1510

Campanili P.R., J. O. Sarturi, S. J. Trojan, M. A. Ballou, J. D. Sugg, L. A. Ovinge, and B. J. Lemos. 2018. Growing System Effects on Silage Type Selection for the Finishing Phase of Beef Steers: Feedlot Growth Performance, Carcass Characteristics, Nutrient Digestibility, and Feeding Behavior. Journal of Veterinary Science and Medicine. 6 (2): 10. DOI: 10.13188/2325-4645.1000036

Cherney, J. H., and D. J. R. Cherney. 2003. Assessing silage quality. Pp. 141-198 in Silage Science and Technology. Madison, WI. American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America.

Dhakal M., C.P. West, C. Villalobos, J. O. Sarturi, S.K. Deb. 2020. Trade-off between nutritive value improvement and crop water use for an alfalfa–grass system. Crop Science. 1–13. DOI: 10.1002/csc2.20159. 2021 Outstanding Papers in Forage and Grazing lands Award. The C-6 Division of the Crop Science Society of America.

Galyean, M. L., N. A. Cole, L. O. Tedeschi, M. E. Branine. 2016. BOARD-INVITED REVIEW: Efficiency of converting digestible energy to metabolizable energy and reevaluation of the California Net Energy System maintenance requirements and equations for predicting dietary net energy values for beef cattle, Journal of Animal Science. 94: 1329–1341. DOI: 10.2527/jas.2015-0223

Hall, M. B. 2003. Challenges with non-fiber carbohydrate methods. Journal of Animal Science. 81: 3226–3232. DOI:10.2527/2003.81123226x

Hall, M. B. 2014. Selection of an empirical detection method for determination of water-soluble carbohydrates in feedstuffs for application in ruminant nutrition. Animal Feed Science and Technology. 198:28-37. DOI: 10.1016/j.anifeedsci.2014.08.009

Kondratovich, L. B., J. O. Sarturi, M. A. Ballou, S. J. Trojan, C. Hoffmman, and P. R. B. Campanili. 2019. Effects of fibrolytic enzyme on ruminal fermentation characteristics of beef steers fed high-and low-quality growing diets. Journal of Animal Science. 97:3089–3102 DOI: 10.1093/jas/skz165

National Academies of Sciences, Engineering, and Medicine. 2016. Nutrient Requirements of Beef Cattle: Eighth Revised Edition. Washington, DC: The National Academies Press. DOI: 10.17226/19014

Van Soest, P. J. 1994. Nutritional Ecology of the Ruminant. 2nd ed. Cornell University Press, Ithaca, NY.

Weiss, W.P., H.R. Conrad, N.R. St. Pierre. 1992. A theoretically-based model for predicting total digestible nutrient values of forages and concentrates. Animal Feed Science and Technology. 39: 95-110. DOI: 10.1016/0377-8401(92)90034-4