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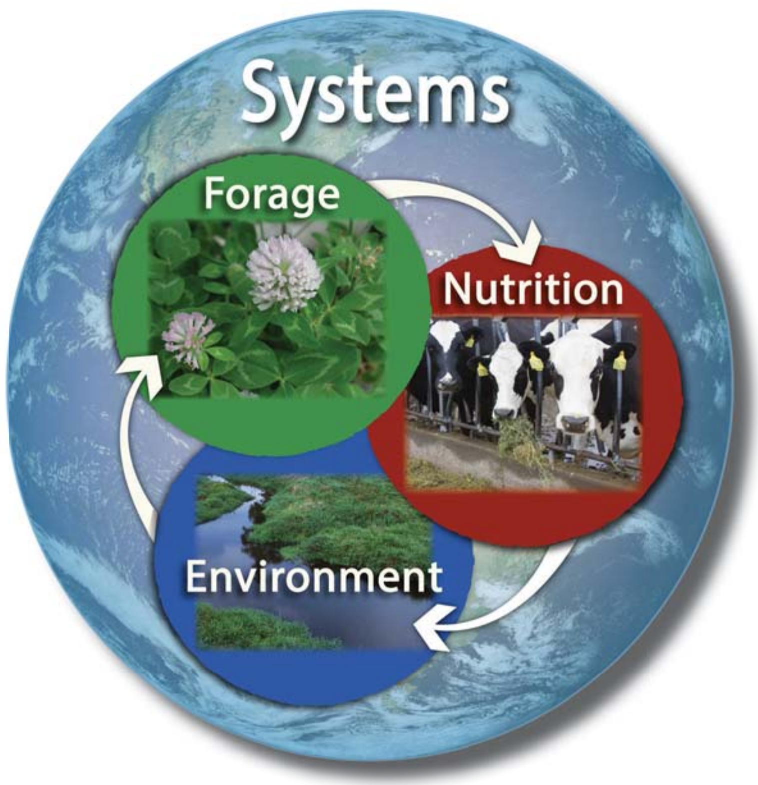
In the News



January to March, 2016

Hidden Valley meadow fescue:

The grass that won't be forgotten

by Michael Casler and Lori Ward Bocher

IT WAS a grass that time forgot — until a Wisconsin grazier rediscovered it decades later and research showed that it had great potential as a pasture grass. It was almost forgotten again when seed companies gave up on plans to take it to market because it did not grow well in the seed-producing region of western Oregon. But the grass has traits that dairy graziers *really* desire, so it was given another chance by a farmer willing to accept the challenge of seed production on his own. And if all goes well, Hidden Valley meadow fescue could be on the market by 2017 or 2018.

The story of Hidden Valley meadow fescue begins in 1990 when Charles Opitz of Mineral Point, Wis., noticed an unknown grass growing in a remnant of an ancient oak savanna ecosystem near the location for a new milking parlor. After much research at the U.S. Dairy Forage Research Center (USDA Agricultural Research Service), with assistance from several other labs around the world, we identified this grass as meadow fescue, a close relative of tall fescue and perennial ryegrass.

We believe the meadow fescue came to the unglaciated Driftless Area of Wisconsin, Minnesota and Iowa with early settlers in the 1800s and later was transported with cattle shipped from the southern U.S. Meadow fescue was a popular forage grass, but KY-31 tall fescue replaced it in the Southern states by the 1950s. We have found meadow fescue on over 300 farms in the Driftless Area, so we think that it survived the post-World War II mechanization of agriculture in oak savanna remnants that could not be plowed.

After finding it in 1990, Opitz spread this meadow fescue around his farm by feeding mature hay with ripe seeds to cattle during winter and allowing the cattle to spread the seed in manure pats. It thrived in his pastures. Hidden Valley represents this population of meadow fescue. Plants were collected from the Opitz farm and used to produce seed for testing by the U.S. Dairy Forage Research Center at the University of Wisconsin Arlington Agricultural Research Station.

Excellent forage traits

Since we first produced Hidden Valley seed at the Arlington farm, we have conducted numerous agronomic studies. We have found meadow fescue to be highly winter hardy and drought tolerant. Its adaptation region is the north central and northeastern U.S. and similar regions of Canada.

From a dairy nutrition standpoint, Hidden Valley meadow fescue has a very high fiber digestibility (see table). This translates to more predicted milk production even though lower forage yield reduces the potential stocking rate compared to other grasses. We were excited about the potential for this grass and consequently proceeded with the steps needed to help it reach market.

Seed production hurdles

When USDA research results in a new or improved plant variety, the USDA usually enters into an agreement with a commercial seed company that acquires exclusive rights to increase seed and take the variety to market. This was attempted with Hidden Valley. But due to poor seed production in Oregon, and the relatively small market for pasture grasses, any interest in the customary options for commercial seed production were eliminated.

But word of Hidden Valley's superior qualities spread. In 2013, Larry Smith volunteered to plant a Hidden Valley seed production field near Viroqua, Wis., where he runs a beef grazing operation. Shortly after that, the USDA formally released Hidden Valley to the public, meaning that anyone has the right to produce and market Hidden Valley seed without contracts or agreements with USDA or the University of Wisconsin.

Larry Smith harvested his first two crops of Hidden Valley Breeder's seed in 2014 and 2015. In spite of the fact that there can be no exclusive rights to the variety, two seed companies (Byron Seed and Allied Seed) and a Wisconsin-based dairy cooperative (Organic Valley) have requested Hidden Valley Breeder's seed from him.

Smith has produced Breeder's seed at his own expense, but is asking companies to provide research funds to Grassworks through a special agreement based on commercial seed sales. Grassworks is a Wisconsin-based organization that provides leadership and education to farmers and consumers for the advancement of managed grass-based agriculture. The U.S. Dairy Forage Research Center continues to work with Hidden Valley, conducting additional forage and livestock trials to ensure that the public has good data to make informed decisions. Very limited amounts (not enough for commercial use) of Hidden Valley seed can be obtained from the USDA Germplasm Resources Information Network (www.ars-grin.gov) or directly from the U.S. Dairy Forage Research Center (Michael Casler). Questions about its future commercial availability should be directed to the seed companies. We will be watching from the sidelines, eager to see if Hidden Valley succeeds in the marketplace, the pasture, and the dairy cow's diet. •

Forage quality and predicted milk production of four grasses

Grass species	Fiber digestibility (%)	Stocking rate (cows/acre/day)	Milk production (lb 3.5% FCM/cow/day)
Meadow fescue	74	15	59
Orchardgrass	71	13	52
Quackgrass	67	17	50
Reed canarygrass	70	18	53

Evaluated in southern and central Wisconsin (data from Geoff Brink and colleagues)

MICHAEL CASLER AND LORI WARD BOCHER

The authors are a plant geneticist and an agricultural information specialist, respectively, at the U.S. Dairy Forage Research Center, Madison, Wis.

Baleage quality hinges on fermentation

by Mike Rankin

THOUGH there is no scientific survey that documents the rising popularity of baled silage, an excursion down rural roads tells us that more and more forage is being harvested in this manner. Baled silage, or baleage as it's often called, offers the opportunity to harvest high-moisture feed at a lower cost compared to conventional silage.

"Expensive toys (equipment) are not always the answer to good baled silage," said Wayne Coblentz, a U.S. Dairy Forage Research Center scientist based in Marshfield, Wis. "The key is to start with high-quality forage. There's a cost that can't be recaptured if a hay crop is too mature." Coblentz spoke as a part of World Dairy Expo's forage seminar series last October in Madison, Wis.

Many livestock producers are shifting at least some of their dry hay production to baleage in an effort to capture a higher quality feed. According to Coblentz, baleage is an attractive alternative because the higher moisture feed allows for reduced leaf loss in legumes; there is less wilting time required, reducing the risk for rain damage; little or no spontaneous heating takes place within the bale; and there is no weathering loss after harvest if bales are stored outside.

Like conventionally chopped silage, a good fermentation is important to making high-quality, baled silage. "The first key to a good fermentation is to eliminate oxygen. This does two things: it encourages the growth of desirable lactic acid-producing bacteria and prevents further decay, losses in dry matter, energy, and possibly the production of toxic compounds," explained Coblentz. "Ideally, the goal is to establish a stable silage mass by lowering pH and maintaining anaerobic conditions."

Know your forage

Not all forage plants are created equal in terms of the amount of water-soluble carbohydrates (WSC) within the plant and their buffering capacity. Water-soluble carbohydrates (sugars) serve as the substrate for lactic acid-producing bacteria that drive down the silage pH for long-term preservation. Forage species vary in the amount of WSC they contain. Corn silage and sorghum species may be 10 to 20 percent WSC as a percent of dry matter. In contrast, cereal forage is 8 to 12 percent, alfalfa is 4 to 7 percent, and bermudagrass is typically 2 to 4 percent.

Coblentz noted there are several factors that impact WSC concentrations. In one study with fall-grown oats, WSC concentrations declined with increasing nitrogen fertilizer applications. As might be expected, WSC concentrations decline significantly when wilting forage is subjected to significant rainfall. Coblentz cited a study where alfalfa received 1.9 inches of rain after being cut and WSC levels dropped from near 6 percent to about 2.5 percent. In such situations, a desirable fermentation that reduces silage pH becomes more challenging.

Forage species also differ in their inherent ability to resist pH change once ensiled. This is referred to as buffering capacity. It's more difficult to lower the pH of forages with a high buffering capacity, such as alfalfa, compared to corn silage, which has a low buffering capacity. Coblentz compiled the buffering capacities of several forages and these are presented in the table. Those forages with a low level of WSC coupled with a high buffering capacity require the greatest amount of management to achieve a good fermentation.

"It's really important to wrap as soon after baling as possible," said Coblentz. While showing some of his research with alfalfa, Coblentz noted, "If the bale is allowed to heat before it gets wrapped, the buffering capacity of the forage significantly rises and this reduces your chances of a good fermentation. Strive to get bales wrapped as quickly as possible. A commonly mentioned target is within two hours of baling, but this may not always be feasible from a practical management standpoint. Research has indicated that damage is usually pretty minimal within the first eight to 12 hours."

Moisture management

"Ideally, baled silage moisture should be in the 45 to 55 percent range, with a group of bales averaging around 50 percent," said Coblentz. "The production of silage fermentation acids is positively associated with moisture concentration. As such, baled silage fermentation is at an inherent disadvantage because it's made at a lower moisture resulting in a fermentation that is slower, with a higher (less acidic) final pH."

Coblentz also cautions growers that there are problems when moisture is either too low or too high. He cites his own research where lactic acid production was near zero at moisture levels below 42 percent. Conversely, the potential for a clostridial fermentation accelerates at high moisture concentrations. The undesirable by-products of this type of fermentation are elevated levels of butyric acid and ammonia. High-protein legumes like alfalfa are especially susceptible to clostridial fermentation when moisture levels exceed 60 percent.

"Expensive toys are not always the answer to good baled silage."

According to Coblentz, the basic management principles of making baleage compared to chopped silage are similar, but there are two characteristics beyond moisture that make an optimum fermentation for baled silage more difficult. The first is the lack of chopping action, which forces sugars to diffuse from inside the plant to reach lactic acid-producing bacteria located on the outside of the forage. Furthermore, baled silage is often less dense than chopped silage. This may also restrict the availability of sugars to lactic acid bacteria. The result of these factors is that baled silage fermentations generally produce less lactic acid and have a higher pH.

Eliminate air

Air is the enemy of baled silage; whatever is done correctly prior to and during harvest can be easily erased if air enters the bale after it's dropped from the baler. Coblentz noted that the evils of air are well documented in research. When air is present, ongoing plant respiration converts plant sugars to carbon dioxide and water, while releasing heat; this reduces the pool of fermentable sugars, results in excessive dry matter loss, indirectly increases fiber levels, and decreases the energy density of the feed.

"Strive for a bale density of 10 pounds of dry matter per square foot or more," suggested Coblentz. "To hit this mark, you may have to reduce ground speed and increase PTO speed," he added. Bale density is also impacted by windrow size (smaller will increase revolutions per bale) and forage moisture (strive for about 50 percent).

"Research is clear that at least four layers, at minimum, of 1 mil stretched plastic are needed to seal the bale," said Coblentz. He added that six layers are more appropriate for long-term storage and in Southern states. "Use UV-resistant plastic and patch any holes with an approved type of tape. Duct tape doesn't fall into that category," Coblentz noted.

Once properly sealed, locate an appropriate storage site where the integrity of the plastic can be maintained. Isolate bales from cattle and place them in an area that won't invite nearby wildlife. Keep weed and grass growth under control around the storage area. Once wrapped and stored, inspect the bale plastic from time to time for holes.

For in-line wrapped bales, Coblentz emphasized the need for bale uniformity to eliminate air pockets along the row of bales.

Are inoculants needed?

Generally speaking, bacterial inoculants are used inconsistently during baled silage production, but Coblentz recommends the practice in specific situations where alfalfa is at risk for a clostridial fermentation. The first situation occurs when forage is borderline too wet (approaching or greater than 60 percent moisture). In this case, lactic acid producing bacteria will help to drive the pH down and reduce the risk for clostridial fermentation. A second situation when inoculants might be considered is when dairy slurry was applied after the previous cutting of alfalfa. Coblentz pointed to research he had done that suggested there were elevated levels of clostridial bacteria on the forage following a post-harvest liquid manure application on the previous cutting.

A final situation where inoculants are recommended is when the forage is rain damaged. Here, there are fewer WSC to act as substrate and bacterial inoculants will help support fermentation and lower the final silage pH.

Buffering capacities (mEq/kg DM) for selected forage crops

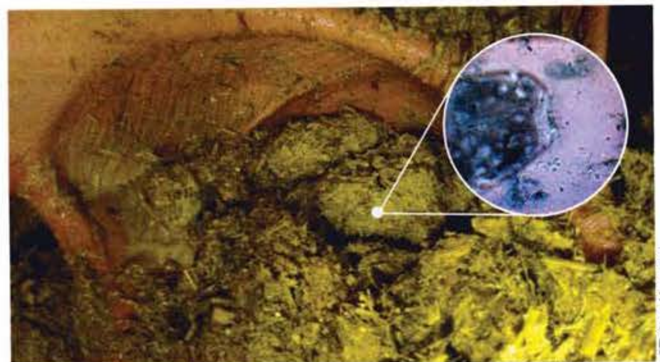
Crop/species	Range	Mean
Corn silage	149 to 225	185
Timothy	188 to 342	265
Fall oat (headed)	300 to 349	323
Orchardgrass	247 to 424	335
Red clover	—	350
Fall oat (boot)	360 to 371	366
Italian ryegrass	265 to 589	366
Alfalfa (mid-bloom)	313 to 482	370
Perennial ryegrass	257 to 558	380
Alfalfa (1/10 bloom)	367 to 508	438
Alfalfa	390 to 570	472
White clover	—	512

Compiled from various sources

by Paul Weimer and Lori Ward Bocher

Rumen microbes: A cow's best friend

THE rumen of a dairy cow is one of the richest and most productive microbial habitats on Earth. There are more than 1 trillion microbes in a mere ounce of rumen fluid; that's 135 times more than the number of people on Earth! New technologies are helping us understand more about these essential creatures, but we still have much to learn. Let's look at what we do and don't know.



PROTOZOA AND BACTERIA are among the plethora of living organisms found in the rumen. This microbial community allows ruminants to convert fiber to energy. As microbes breakdown fiber, sometimes protozoa consume bacteria as shown in the inset of this photo.

Microbes matter

Put simply, without rumen microbes, a cow's digestive system would shut down, and it would starve to death. Microbes are the nutritional foundation of all ruminant animals. They also are the reason why cows and other ruminants can eat highly fibrous feed that animals with a simple stomach, including humans, cannot digest. This advantage gives the ruminant a unique role in feeding the world — turning forages and by-products from the food, fiber and fuel industries into nutritious food for humans.

In many ways, when you feed a cow, you're really feeding the microbes in its rumen. The cow cannot directly utilize most feed components, even simple sugars. It relies on rumen microbes to convert feeds into nutrients that it can then absorb and use to make energy and milk. About two-thirds of feed digestion and 90 percent of fiber digestion takes place in the rumen — all with the aid of microbes.

More specifically, here are some of the things that microbes accomplish for the cow:

1. Convert feed carbohydrates into volatile fatty acids (VFA), the main energy source for the cow and the main source of milkfat.

2. Convert nonprotein nitrogen to high-quality microbial protein that is used by the cow. Rumen microbes are about 55 percent protein; in some rations, they provide half of the total dietary protein a cow needs. And microbial protein has almost the perfect amino acid profile for cows; it is an especially high source of lysine and methionine, two amino acids that are most difficult to supplement in dairy cattle rations.

3. Metabolize some plant toxins. For example, oxalate (abundant in open-range forages in the western U.S.) and mimosine (abundant in the tropical legume Leucaena) both can cause severe toxicoses in ruminants. Microbiologists have identified ruminants resistant to each compound and traced the resistance to previously unknown species of bacteria in the rumen. These new species can actually be transferred to sensitive animals that then acquire resistance to the toxins.

Ruminants and microbes have a symbiotic relationship. The cow consumes the feed and water that the microbes need for survival. Cows also perform rumination (cud chewing) to grind feed particles to a smaller size so that the microbes can attack a larger surface area of the feed. In addition, the rumen environment is favorable for microbes: it is anaerobic (no oxygen), the temperature is near the microbial optimum of 102°F, and the pH generally ranges from 5.5 to 6.8, also in the optimum range for microbial growth.

Cows also remove fermentation products to allow further microbial growth. For example, cows absorb volatile fatty acids through the rumen wall for use in energy and milk production, and they recycle bicarbonate to help prevent acidosis. They also remove fermentation gases through belching.

Bacteria lead the list

Rumen microbes are mostly bacteria, but other forms of microorganisms are also present, including archaea, protozoa and fungi (table).

In a way, there are "good" and "bad" microbes. We think of "good bugs" as those that digest fiber, ferment carbohydrates, degrade lactic acid and detoxify toxins. Microbes that produce methane, ammonia and other undesirable products of fermentation are considered "bad bugs," along with protozoa which eat the "good" bacteria. However, because the microbes function as an interactive community, some seemingly "bad bugs" are still necessary for proper rumen function.

Two centuries of study

The first indication that microbes existed in the rumen came in 1831 when it was noted that plant fiber was converted to acetic and butyric acids. Protozoa, the largest of the rumen microbes, were first observed in 1843. And in 1879, it was determined that the production of volatile fatty acids and gas in the rumen were due to microbial fermentation.

In 1948, Robert Hungate, University of California at Davis, developed methods for cultivating rumen microbes in the laboratory which improved our ability to study them. However, understanding microbial activities required the laborious isolation of pure cultures under anaerobic conditions.

With these limited techniques, only about two dozen species were isolated and their metabolic activities characterized. But this limited knowledge led scientists to determine that rumen microbes participate in all of the important nutrient transformations in the rumen, including carbohydrate and protein fermentation, methane and carbon dioxide production and protein synthesis.

The techniques of molecular biology have opened new doors for microbiologists. Whole-genome sequencing allows us to study the metabolic capabilities of individual species. And community fingerprinting methods, quantitative PCR (polymerase chain reaction) and

Diversity persists in the rumen

Microbial group	% of cell numbers	% of microbial weight	What they do
Bacteria	~98%	~60%	Ferment fiber, starch, sugars, protein and more
Archaea	1%	<1%	Produce methane gas
Protozoa	1%	~40%	Eat bacteria, ferment starch
Fungi	<1%	1-3%	Help break down fiber

The authors are a rumen microbiologist and an agricultural information specialist, respectively, at the U.S. Dairy Forage Research Center, USDA Agricultural Research Service, Madison, Wis.

metagenomic sequencing allow us to determine species composition and abundance within the rumen itself. Microbiologists now have the ability to track specific populations within the rumen and determine how these are impacted by feeding and management and how they relate to animal performance.

Each rumen contains a community of several hundred or more bacterial species, along with dozens of species of other microbes. The two dozen bacterial species in the rumen that were originally identified and cultured in the lab represent less than 10 percent of the bacterial species in the rumen. Work continues to identify more species and determine their roles in the community.

Microbiologists have determined that there is a small set of microbial species, known as the "core microbiome," that is present in every cow. But the overall microbial community is unique to each individual animal, similar to fingerprints in humans. A cow and her rumen microbes are well-matched partners. The microbial community is very dynamic, with changes within and across daily feeding cycles. And it is surprisingly resilient when changes are introduced. But overall, each cow's community is relatively specific to them.

We demonstrated this with an experiment at the U.S. Dairy Forage Research Center a few years ago. We identified two cannulated cows (fitted with a permanent access port in the rumen) that had very different microbial communities; they were consuming the same diet and were in the same stage of lactation. We emptied nearly all of the contents of each rumen and then switched the rumen contents between cows. Within two to nine weeks, each cow's rumen microbial population reverted back to what it had been before the contents were switched.

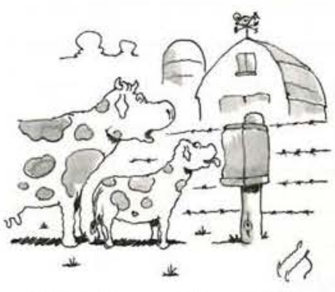
We're still learning

Rumen microbiologists are linking specific members of the rumen community to nutritional outcomes such as feed efficiency, milkfat production and rumen acidosis. They are also searching for new ways to control undesirable microbial activity, such as methane production. And they are evaluating the role of the rumen community in affecting the health and immune response of dairy cattle.

More than 100 years ago the founder of this magazine, W.D. Hoard, wrote: "I have given years of study to the dairy cow, and I believe I know a good deal about her, but more and more I am convinced that the darkest place in the world is the inside of a dairy cow. Chemists have their laboratory, mechanics may have their machines, but no man knows how the dairy cow transforms the hay and grain she eats into milk."

We know much more today about the rumen, but we still have much to learn. For example, what exactly are those other 90 percent of rumen microbes doing? Can we dictate rumen community compositions by how we feed and raise the calf or heifer? Can we, or how can we, get probiotic strains to persist in the rumen? Can rapid testing of the rumen microbial community guide us to feeding cows more intelligently?

To help a cow's rumen microbes work better, you should avoid sudden changes in rumen conditions. Introduce new feed sources and rations gradually over the course of several feedings. Avoid pushing rumen temperatures outside the comfort zone of the microbes; don't feed frozen silage or extremely cold water; and mitigate heat stress (the rumen temperature always runs slightly higher than the cow's core body temperature). Also, recognize that the microbial communities of individual cows will respond differently to the same feeding and management; there is no "one size fits all" response.



"When I was a kid we didn't have salted caramel licks."

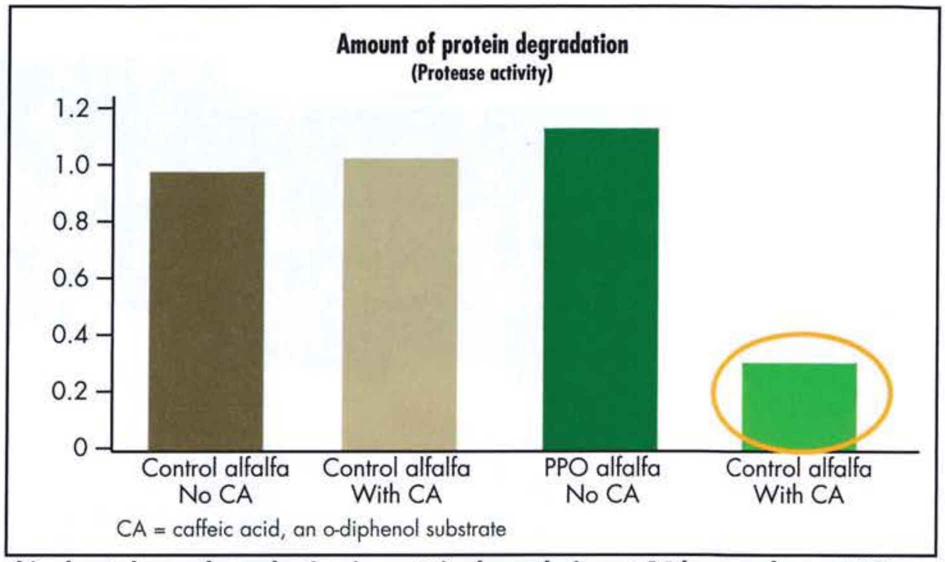
Redesigning alfalfa for improved protein utilization

by Lori Ward Bocher

ALFALFA is the most widely used perennial forage in the U.S. due to its high digestibility, its ability to fix nitrogen, and its high protein content. But much of that protein is degraded during ensiling and in the cow's rumen — as much as 80 percent is under poor ensiling conditions. Protein degraded during ensiling is poorly utilized by the cow, and much of the nitrogen in that protein is excreted in manure and lost to the environment. If researchers could redesign alfalfa to improve its protein utilization, the economic and environmental payback would be substantial.

How substantial? Different estimates show that a redesigned alfalfa with a 25 to 40 percent decrease in protein degradation during ensiling and ruminal digestion would save an estimated $100 to $300 million per year for the U.S. dairy industry by reducing the amount of protein supplements purchased. In addition, with more protein utilized by the cow, there would be substantial reductions in manure nitrogen excretions and subsequent nitrogen losses as ammonia, nitrous oxide (the most potent agricultural greenhouse gas) and nitrate.

Scientists at the U.S. Dairy Forage Research Center (USDA Agricultural Research Service) are working on two long-term projects to potentially develop an alfalfa with improved protein utilization. One approach uses condensed tannins, the other uses an enzyme and its substrate. It's interesting to note that both approaches are based on compounds found in other legumes but not in the alfalfa plant.



This chart shows the reduction in protein degradation at 24 hours when a PPO alfalfa is ensiled with its substrate, o-diphenols, in the form of caffeic acid (CA). The presence of PPO alone or CA alone did not reduce protein degradation.

Why protein is lost

When a forage is harvested, the plant releases proteases, a broad term for enzymes that break down protein into nonprotein nitrogen products. With silage, these proteases keep breaking down plant protein until the silage pH drops below 5. This is one reason ensiling practices emphasize the need to rapidly decrease silage pH. Losses of "true protein" in alfalfa during ensiling can reach as high as 80 percent. Although a portion of this nonprotein nitrogen can be converted to nutritionally valuable microbial protein in the rumen, excessive levels are converted to urea and excreted in urine.

In the rumen, reducing protein degradation means that more feed protein "escapes" the rumen and moves into the hindgut where it can be digested, absorbed, and used to make milk and keep the cow healthy.

Enter red clover

When studying protein degradation among various legume forages several years ago, USDFRC researchers noticed that red clover, even under poor ensiling conditions, typically has minimal degradation, maintaining 70 to 80 percent of its protein intact. Further research discovered that red clover has an enzyme, polyphenol oxidase (PPO), along with its substrates — special chemicals called o-diphenols. When PPO acts on the o-diphenols, o-quinones are produced. The highly reactive o-quinones bind with protein and prevent the proteases from degrading protein.

But red clover lacks many other qualities compared to alfalfa. So the next research question became, "Can the PPO system that works so well in red clover be transferred to alfalfa?" First, the scientists conducted an extensive survey of alfalfa germplasm and found no natural variants that contained active PPO in the vegetative portions of the plant. Therefore, a precision breeding approach was used to insert the red clover PPO gene into alfalfa. This process was quite successful, and alfalfa plants expressing the red clover gene can inhibit protein degradation when appropriate o-diphenols are added as a substrate.

The next step is to find a way to supply alfalfa with o-diphenols since alfalfa currently does not produce this substrate upon which the PPO can act to produce the o-quinones. The

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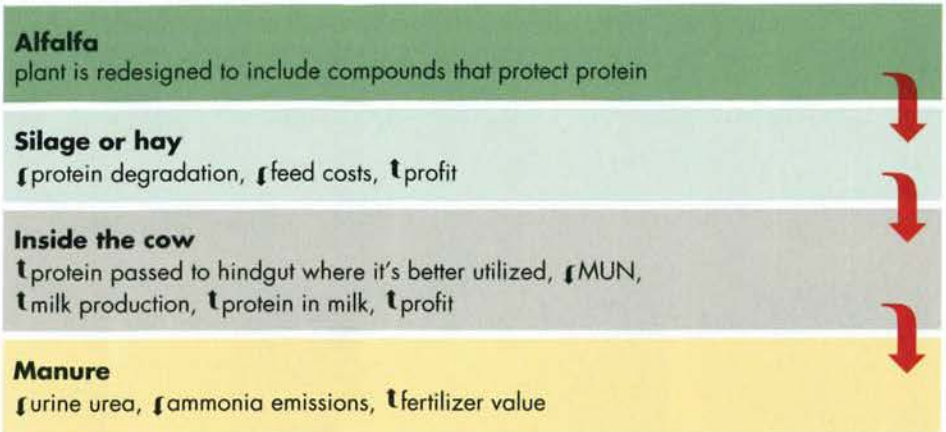


A redesigned alfalfa with protein protecting characteristics would improve farm profits and nitrogen use efficiency, and it would reduce the amount of nitrogen lost to the environment.

In small-scale ensiling experiments, the PPO-alfalfa on the right turned brown and had reduced protein degradation because an o-diphenol substrate was added. The silage on the left was not treated with the o-diphenol.

most desirable approach would be to have alfalfa synthesize the o-diphenol substrate, and USDFRC scientists are currently working on ways to introduce the necessary genes into alfalfa.

An alternative approach would be to add external sources of o-diphenols (abundant in many plants such as potato peels, coffee grounds, and forages like timothy) to alfalfa at the time of ensiling. And a third approach is to co-ensile the PPO-modified alfalfa with other plant materials or extracts that contain o-diphenols.

Condensed tannins

Tannins, as a general definition, are a subclass of compounds (called polyphenols) that are produced by plants and are distinguished from other polyphenols by their ability to bind to proteins. Condensed tannins have been found to reduce protein degradation in forages. The exact mechanism is not known, but it is thought to be accomplished when tannins form complexes with forage protein during the ensiling process and during rumen digestion, thereby preventing the proteases present from doing their job of breaking down protein.

Condensed tannins are produced naturally in forages such as birdsfoot trefoil; but, in alfalfa, it is only found in the seed. USDFRC scientists are now assisting scientists from Forage Genetics International in analyzing alfalfa plants whose genetics have been altered to produce condensed tannins in edible portions of the alfalfa plant. This research is in its preliminary stages of development.

It will be several years before alfalfa redesigned to reduce protein degradation reaches the market. But researchers believe the economic and environmental paybacks make it worth the effort. ●

by Mary Beth Hall

Forage "quality" makes or breaks rations

RUMINANTS were designed to use forages. Forage is the base that dairy rations are built on to have productive, healthy, efficient and profitable performance in a herd. It's not overstating the matter to say that forage quality makes or breaks rations — the composition, digestibility and physical form set the cow's performance limits.

Forage quality dictates how much you can include and how much of other feedstuffs need to be supplemented. But "quality" is not something that exists by itself; it has to be judged in the context of the ration in which it is included and how well it supports animal performance. In this discussion, the focus composition, digestibility and effective fiber value of forages integrate to affect the way we need to work with forages in dairy rations.

First we have to measure it

The first thing to do in working with forage composition and digestibility is to get accurate numbers to work with. Get a good sample that represents the feed the cows will be eating. Otherwise, the composition and digestibility analyses won't be useful.

Neutral detergent fiber represents the part of the forage that has the physical form to encourage rumination and is the most slowly digesting part of the forage. Fiber digestibility (NDFD) measures provide a means to determine the potential for the fiber in feed to help meet a cow's nutrient needs. This key measurement helps us evaluate how well microbes may ferment NDF to produce nutrients for the cow and how much forage we can feed without filling up the rumen with slowly digested fiber (talk to your nutritionist for his or her goals with NDFD). More on NDFD and "quality" in a minute.

Something to know about NDFD: it is not a very precise value. NDFD is measured in an assay with multiple steps and includes fermentation by rumen microbes, so it is more variable than an assay like crude protein, which has just one direct chemical measurement on the feed. We have found that, on average in a given lab, 95 percent of the measured 30-hour NDFD values for a forage sample fell between +/-4.9 percentage units from the mean (think for a sample NDFD averaging 50 percent, the range of values from a lab will be from 45 to 55 percent). Individual labs can vary somewhat. If a sample is run in different labs, the range is +/-6.6 percent from the mean.

The labs did a good job of ranking forages in order of NDFD, so NDFD is useful for comparing forages. For the best consistency, stick with one lab for NDFD analysis, pay attention to how feeds rank relative to one another and recognize that NDFD is useful but not an extremely precise value.

There's debate about what time point measure to use for neutral detergent fiber (NDF) in vitro digestibility (NDFD): 24, 30 or 48 hours. The 24- and 30-hour time points are early enough in the fermentation that differences in how rapidly the fiber is digesting may be detected, but there is also more variability in the measures for any given sample at these hours. Changes in the rate of fermentation will translate into differences between samples in the earlier hours of fermentation.

Forty-eight hours is the NDFD time point listed in the National Research Council *Nutrient Requirements of Dairy Cattle* (2001) for estimating energy derived from NDF. By 48 hours, results show less variation. You can detect which forage has a relatively greater extent of digestion than another, but you can't tell the route by which feeds got there — did one just ferment faster than another?

Another important part of forages are the nonfiber carbohydrates (NFC) are estimated to be 98 percent digestible. That may be largely true of the water soluble carbohydrates (sugars, oligosaccharides, fructans) but not necessarily for starch. Starch digestion is affected by degree of feed grinding, fermentation and protein matrix binding. Present starch digestibility assays include a seven-hour in vitro fermentation of slightly more coarsely ground samples (to retain the effect of structure on starch degradation).

Digestibility and performance

In the grand scheme of things, cows need:

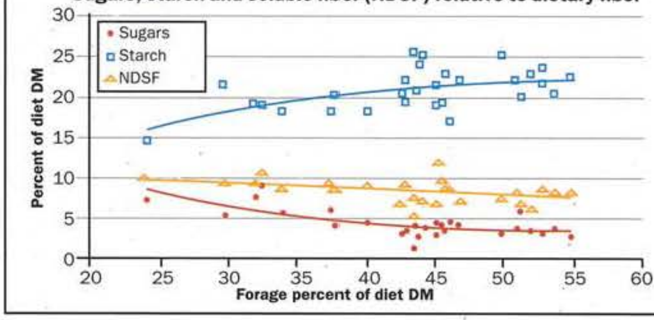
- Digestible feedstuffs to provide needed nutrients
- Effective fiber that has the structure to maintain rumen function and protect against ruminal acidosis and
- Some feed fractions that are indigestible enough to get digesta to pass from the rumen for digestion further down the tract

Furthermore, we also need to provide forage within the limitations set by physical fill (bulk that takes up space in the rumen), preventing reductions in intake but providing enough fiber to maintain rumen function and animal health.

The 2001 Dairy NRC attempted to address all of this with recommendations for NDF, forage NDF and nonfiber carbohydrates (see table). However, the amount of forage or fiber needed to maintain good productivity in herds also varies with the type of NFC fed (see figure).

The relationship between starch and forage in the figure echoes the recommendations for NFC and NDF feeding offered by the 2001 Dairy NRC. As NDF from forage increases, more NFC or starch can be included

Sugars, starch and soluble fiber (NDSF) relative to dietary fiber



in the ration. If conditions are such that animals consume large meals of grain, sort their feed, slug feed, suffer from heat stress or consume starch sources with very rapid rates of fermentation (high-moisture shell corn, finely ground barley or wheat), it might be a good idea to include more NDF and less NFC as a matter of "risk management" to prevent digestive problems.

How do these recommendations play out in a real herd of cows?

A Wisconsin herd that averaged 94 pounds of milk, 3.9 percent butterfat and 3.2 percent protein had a ration that was (on a dry matter basis) 52 percent forage, 27 percent overall ration NDF, 21 percent forage NDF, 28 percent starch and 44 percent NFC. The 30-hour NDFD was 48 percent for the total diet forage. The 30-hour forage NDFD averaged 45 percent, and nonforage 30-hour NDFD averaged 55 percent. Forage NDF was 78 percent of total NDF, and at a dry matter intake of 60.7 pounds is 0.9 percent of cow body weight.

The ration is roughly in line with the NRC recommendations. It illustrates targets that can be considered when formulating for forage NDF amount and digestibility:

1. Forage NDF should typically make up about 75 percent of total NDF.

2. Forage NDF should be set at 0.8 to 1 percent of body weight.

3. If aiming for a total dietary NDFD to provide nutrients, you will need to balance between the digestibility of the forage, how much forage NDF you can feed without limiting intake, and how much nonforage NDF to supplement to provide digestible NDF and keep starch intake within acceptable bounds.

2001 Dairy NRC recommendations for NDF and NFC formulation

Minimum NDF from forage, %	Minimum NDF in ration, %	Maximum NFC in ration, %	Minimum ADF in ration, %
19	25	44	17
18	27	42	18
17	29	40	19
16	31	38	20
15	33	36	21

NDF = neutral detergent fiber, NFC = nonfiber carbohydrates

The amount of forage NDF to include in diets is a proxy for making sure that cows get sufficient physically effective fiber to maintain rumen function and rumination to balance the fermentation of the starch and other NFC. However, if fiber is fermented (rapidly, extensively) or is reduced in size and passes, it's no longer present in the rumen to be effective. Conversely, if forage fiber is very slowly fermented, it can stay in the rumen longer to be effective.

A feed that may demonstrate the effect of digestibility on effectiveness of fiber is brown midrib corn silage (BMR). Feeding BMR did not increase total tract fiber digestibility to the degree that laboratory NDFD measurements suggested it could, but dry matter intake and rumen turnover of NDF were increased. An explanation for these results is that the more digestible BMR corn fragmented and passed more rapidly from the rumen before it was completely fermented.

As we formulate to meet nutrient requirements based on feed composition and digestibility, there is no absolute way to predetermine whether the combinations of forage NDF and digestibility will allow for excessive, adequate or insufficient effective fiber. You still will need to go look at the cows. The cows are the sole authority for accurately measuring effective fiber in the diet. Sufficient effective fiber will have at least 50 percent of the cows ruminating if they are not sleeping, eating, drinking or in heat. Among those cows, only about 5 percent of the cows may have manure that does not look normal and like the rest of the herd's (assuming no disease issues and no sorting of feed), and typically there will be limited amounts of loose manure or long fiber (greater than 1-inch long) in the manure.

Starch degradability has been shown to improve the longer that corn grain is ensiled. So, starch degradability analyses of corn silage should be performed over time to monitor the change. The challenge this presents to formulation is that starch digestibility in silage or high-moisture corn is a moving target. By the time corn

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silage made at the appropriate moisture content (32 to 35 percent) has been in the silo an entire winter, the fermentability of the starch may have risen appreciably.

It may be necessary to limit inclusion of the more rapidly fermentable starch to avoid digestive upset. This can be problematic if corn silage is high in starch (greater than 30 percent of dry matter), and corn silage accounts for most of the forage in a ration.

Right, not High, quality

We talk about feeding high-quality forage, but "right" quality is what we need to focus on. Right quality describes the forage that can be fed in adequate quantities to meet animal nutrient and effective fiber requirements without tempting people to break ration formulation guidelines.

Forages too high or low in NDFD can both be challenges. When NDF increases, fiber digestibility typically lowers. There are usually limits on the amount of such forages you can feed without limiting intake and digestible nutrient consumption. But, if there are limits on the amount of high NDF/low digestibility forage you can feed, what do you fill in the rest of the space with and not go over 25 to 28 percent starch?

This can be where fat or fermentable fiber sources such as soy hulls can be used to add digestible feedstuffs without exceeding limits for starch. Overfeeding starch will not necessarily make up the energy the cow needs, and it can readily make matters worse as the herd deals with digestive upset while performance, digestibility, feed efficiency and income suffer.

Providing adequate amounts of effective fiber and avoiding ruminal acidosis are the main issues with highly digestible forage. Forage that has very high fiber digestibility also can be low in NDF. Can you feed enough of it to meet effective fiber needs, balance the ration and have the forage inventory you need to cover the year? If the inventory answer is "no," this is where bringing in grass (silage or chopped hay) or several pounds of chopped wheat straw can be useful effective fiber supplements to amend the ration. These need to be fed in a moist ration that the cow cannot sort.

In the high digestibility category, we can also include corn silages that have more than 30 percent starch. Having seen corn silage that was nearly 40 percent starch, how do you formulate with it as your main forage? Carefully. If 60 percent of the ration is corn silage, and you limit starch to 25 percent of diet dry matter from this rapidly fermenting source, the corn silage leaves room for supplementing 1 percent more starch. Then you need to select lower starch feedstuffs to fill the remaining 40 percent of the ration. And you still need to verify that the cows are getting adequate amounts of effective fiber.

The right quality forage provides the cow with needed nutrients and effective fiber to enhance the digestibility of the entire ration. The wrong quality forage does the opposite.

Progressive Dairyman, February 2016

Canola meal edges soybean meal as dairy cow protein source

Glen Broderick for *Progressive Dairyman*

There has been some discussion as to whether canola meal outperforms soybean meal in dairy diets, and further, whether heat-treated canola is more advantageous than non-heated meal. A new study provides insights. Photo courtesy of Glen Broderick.

Increasing demand for canola oil has greatly increased canola cultivation. In Canada alone, canola production has grown from about 3 million tons in 1991 to nearly 18 million tons in 2013. This has resulted in greater availability of canola meal and made it a viable alternative to soybean meal as a protein source for livestock.

During the past few years, we conducted several feeding trials at the U.S. Dairy Forage Research Center in Madison, Wisconsin, comparing the yields of milk and milk components from lactating dairy cows supplemented with either canola meal or soybean meal. In the first of these studies, cows received basal diets containing alfalfa and corn silages plus high-moisture shelled corn but supplemented with equal crude protein equivalent from urea, cottonseed meal, soybean meal or canola meal.

As expected, cows fed the urea diet did not perform nearly as well as those supplemented with one of the three true proteins: Dry matter intakes were 4.6 to 6.2 pounds per day lower, while milk yields were depressed by 16 to 18 pounds per day.

But an additional finding was that milk protein on the cottonseed meal diet was 0.2 pounds per day less than that on canola meal, while protein yield on soybean meal was intermediate between canola meal and cottonseed meal. That canola meal could outperform soybean meal was surprising because the NRC-2001 dairy nutrition bulletin, which is widely used in formulating dairy rations, indicated metabolizable protein supply – the protein directly available to the cow after accounting for microbial action in the rumen – should have been greater on soybean meal.

These findings stimulated our interest in running an experiment designed to see how canola meal stacked up directly against soybean meal. Results from that trial, which were published recently, showed a production advantage to canola meal versus soybean meal (**Table 1**): Cows ate 0.9 pounds more dry matter per day and secreted 2.2 pounds more milk per day containing 0.11 pounds more fat and 0.07 pounds more true protein per day.

Additionally, the study showed the canola meal advantage over soybean meal held up at both 15 and 17 percent dietary crude protein. Milk urea is elevated when protein efficiency declines; milk urea concentration was lower on canola meal versus soybean meal. Examining Table 1 also shows that, aside from somewhat higher fat yield, the major effect of increasing crude protein from 15 to 17 percent was to elevate milk urea and nitrogen excretion in the urine, a direct indication of reduced protein efficiency.

The main thing that happened with feeding more protein in this trial was for the cows to excrete more urinary nitrogen. Although these data are not in Table 1, two other findings were notable in this experiment: A 50-50 protein mixture from canola meal plus soybean meal performed about as well as canola meal alone, and supplementing the rumen-protected amino acids methionine plus lysine had no effect.

Feeding rumen-protected methionine alone has given small boosts to milk and protein yield in a number of other studies, particularly when soybean meal was the major supplemental protein. That response was not seen here for either canola meal or soybean meal.

We have recently completed a second feeding study comparing canola meal to soybean meal in cows fed diets containing various ratios of alfalfa silage to corn silage. Results from this experiment are not yet published but, again, about 2 pounds per day more milk were produced on canola meal.

There are also quite a few other reports in the literature comparing these two protein sources. Researchers in 2013 summarized literature data from 27 feeding trials comparing canola meal with soybean meal and a number of other supplemental proteins and found that protein yield was greater on canola meal, but that there was no difference for milk yield.

In an even larger literature study, researchers in 2011 summarized results from more than 100 mostly European experiments in which dairy cows were fed soybean meal, canola meal or canola meal that was heat-treated to increase its content of rumen-undegraded protein (RUP). The researchers found that canola meal improved feed intake plus yield of milk and milk components versus soybean meal, but heat-treated canola meal performed about the same as conventional canola meal.

There is a clear advantage to heating soybean meal to increase its RUP content, and a number of excellent heat-treated products, such as expeller soybean meal, are available in the marketplace. All of our trials, and virtually all of the literature comparisons, have compared solvent-extracted forms of canola meal and soybean meal, which are subjected to very little heating during processing. Despite this, we found lower rumen concentrations of ammonia and branched-chain volatile fatty acids, both of which are formed from protein degradation in the rumen, when canola meal rather than soybean meal was fed. Some of our colleagues from Sweden and Finland, who have had longer experience feeding canola meal, doubt that heating would improve the usefulness of canola meal protein; this is consistent with findings of researchers in 2011.

Nevertheless, our rumen in vitro studies (in which rumen fluid from cannulated cows is incubated with canola meal to test protein degradability) indicated small but consistent differences in RUP contents of canola meal from different Canadian processing plants. At the University of Nevada, professor Antonio Faciola and his graduate students are evaluating heat-treated canola meal to see if it will provide more metabolizable protein than conventional canola meal.

So canola meal appears to be a somewhat more effective protein supplement than soybean meal, possibly because it has more RUP with more of the essential amino acid methionine. However, farmers must adjust for composition differences when replacing part or all of the dietary soybean meal with canola meal. **Table 2** shows mean nutrient contents of these meals from our second trial.

Because of its lower protein content, about 1.3 pounds of canola meal must be fed to replace 1 pound of soybean meal. This extra space in the ration will likely come at the expense of corn or other grain, slightly lowering energy density. Although canola meal has a little more digestible energy as oil, it is also substantially higher in fiber content, which will also dilute dietary net energy of lactation. When price is about equal per unit of crude protein, canola meal is a slightly better buy than soybean meal.

Table 1 Production and nitrogen efficiency of cows fed either soybean meal or canola meal at 15 or 17 percent dietary crude protein (Broderick et al., 2015)

Item	Protein source			Dietary crude protein		
	SBM	CM	Prob.[1]	15%	17%	Prob.
Dry matter intake, lbs/day	54.7	55.6	0.05	54.9	55.1	0.47
Weight gain, lbs/day	0.8	1.0	0.32	0.9	1.0	0.67
Milk yield, lbs/day	86.6	88.8	< 0.01	87.1	88.4	0.07
Milk/DMI	1.59	1.60	0.11	1.59	1.60	0.14
Milk fat, %	3.99	4.02	0.49	3.99	4.02	0.50
Milk fat	3.4	3.5	0.06	3.4	3.5	0.05
Milk true protein, %	3.04	3.06	0.51	3.05	3.05	0.80
Milk true protein, lbs/day	2.6	2.7	0.02	2.6	2.7	0.14
Solids not fat, %	8.81	8.81	1.00	8.85	8.77	0.18
Solids not fat, lbs/day	7.6	7.8	0.07	7.7	7.7	0.39
Milk urea, mg N/100 ml	11.5	10.3	< 0.01	9.3	12.5	< 0.01
Milk-N/N-intake[2], %	30	31	< 0.01	32	29	< 0.01
Total urinary nitrogen, g/day	229	206	< 0.01	180	254	< 0.01

[1]Probability of a statistically significant effect; a probability less than 0.05 is "significant" and can be accepted as a meaningful difference.
[2]Percentage of dietary nitrogen (crude protein) that was secreted in the form of milk protein.

Table 2 Composition of soybean meal and canola meal (Broderick et al., 2015)

Component	Soybean meal		Canola meal	
	Mean	SEM[1]	Mean	SEM
Crude protein, % of dry matter	53.6	0.5	40.6	0.2
Organic matter, % of dry matter	92.4	0.1	91.0	0.1
Neutral detergent fiber, % of dry matter	7.0	0.3	29.9	0.3
Acid detergent fiber, % of dry matter	4.2	0.2	18.2	0.2
Neutral detergent insoluble N, % of total N	7.3	0.3	26.9	0.9
Acid detergent insoluble N, % of total N	1.6	0.2	6.2	0.1
Fraction B3[2], % of total N	5.8	0.2	20.7	0.8
Ether extract (oil), % of dry matter	1.7	0.1	3.0	0.1

[1]Standard error of the mean, a measure of variation in composition.
[2]Fraction B3 = Neutral detergent insoluble N – acid detergent insoluble N, which may be related to rumen-undegraded protein (RUP).

Summary

We compared feeding equal crude protein from different dietary sources in dairy cows fed typical Midwestern diets; several of these studies have directly compared canola meal to soybean meal. Milk yield was greater by about 2 pounds per day and protein yield by about 0.07 pounds per day – the protein equivalent of 2 pounds of milk – when canola meal replaced soybean meal. These responses occurred in three different trials and were observed on diets containing either 15 or 17 percent crude protein.

Supplementing with canola meal rather than soybean meal also increased dry matter intake by about 0.8 pounds per day and reduced milk urea content and urinary nitrogen excretion, indicating improved protein efficiency. These findings were confirmed in literature reviews evaluating milk production response to canola meal and soybean meal. Because of its lower protein and greater fiber contents, dairy farmers will need to rebalance their rations when replacing dietary soybean meal with canola meal. **PD**

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"Supplementing with canola meal rather than soybean meal also increased dry matter intake by about 0.8 pounds per day and reduced milk urea content and urinary nitrogen excretion, indicating improved protein efficiency."

EXPENSES DRIVE BREAK-EVEN POINTS

Although income is an important element of successful farms, income alone did not equate to lower break-even points for Pennsylvania farms, according to research compiled by the Penn State Dairy Team. In 2015, the average break-even point for the 107 farms included in data collection was between $19 and $20 per hundredweight. The farms ranged from break-even points at less than $16 per hundredweight to more than $22 per hundredweight, a spread of $1,500 to $1,800 per cow, reported Penn State's Timothy Beck.

Income per cow was stable in all break-even point brackets except for those farms that required more than $22 per hundredweight. These operations showed serious milk production issues that prevented them from achieving the milk sales needed to buoy expenses.

The two biggest expense categories found to contribute to high break-even levels were feed costs and overhead costs such as fuel, repairs, hired labor, insurance, real estate taxes, utilities, and building and machinery leases. These two areas were responsible for approximately $1,100 of variation in per-cow costs between low break-even herds and high. Other factors that were correlated with variation in break-even levels included owner withdrawal and loan payments.

VACCINATIONS PAIR WELL WITH GOOD COLOSTRUM

Vaccinations are designed to stimulate the immune system. They aren't cures, but tools to help the calf defend its body from viruses, bacteria and parasites. By understanding immunity, producers can help calves reach their potential.

At birth, calves have no immunity, and that's why colostrum is so important. The valuable antibodies it supplies set the stage for health, growth and, later, milk production. But colostrum alone is not enough.

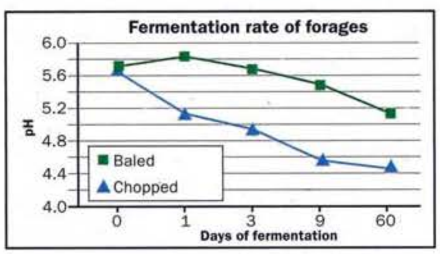
Amelia Woolums, D.V.M., Mississippi State University, presented the February webinar titled, "Getting the most bang for your vaccination dollar." She explained that vaccination is especially helpful to calves that don't receive enough colostrum since it triggers the production of additional B and T cells. When a calf is vaccinated and later exposed to the same infectious agent, it recognizes the invader and is ready.

Vaccinations can be ineffective due to poor handling, light exposure, a sick calf, overcrowding, inadequate diet, poor ventilation and improper timing of administration. Vaccines should be given at least two weeks prior to an anticipated stressful event, such as weaning, transportation or being moved to group pens.

Watch the webinar at on.hoards.com/WB_020816.

FERMENTATION IS DIFFERENT FOR BALED SILAGES

Similar to chopped silages, baled silage depends on many factors to achieve adequate fermentation. However, as shown in the graph, baled silages are naturally slower to ferment.



According to Wayne Coblentz of the USDA Dairy Forage Research Center, baled silage depends on a good anaerobic environment to convert sugars, grow lactic acid-producing bacteria and avoid dry matter loss. He recommends packaging baled silage at 45 to 55 percent moisture and applying six to eight layers of plastic within four hours of baling for optimum conditions.

Plant species factors should be carefully considered before baling and wrapping silages. Sugar levels necessary to produce lactic acid differ greatly depending on plant species, cultivar, growth stage, climate and fertilization to name a few. Additionally, buffering capacity affects fermentation ease, noted Coblentz in writing for the December issue of *Forage Focus*.

Additional differences exist between baled and chopped silages, including particle length. The longer stemmed forages more common in baled silages limit the rate and extent of fermentation because the reduced surface area makes it more difficult for plant sugars to encounter lactic acid-producing bacteria. For this reason, scientists recommend a 10-pound DM/ft^3 target density threshold when baling. The compaction of the forage will help speed fermentation.

MILKOUT DOESN'T MEAN EMPTY

Completely milking out cows is important for attaining milk production goals and also in preventing mastitis. However, the definition of completely milked out doesn't mean empty. According to Graeme Mein and Ian Ohnstad who wrote an article in the National Mastitis Council newsletter, four main guidelines exist to determine if your milking process is getting cows milked out.

1. Milk all cows out as evenly as possible. This allows for any milk left in the lower ducts and udder cisterns to be distributed evenly. If not done correctly, quarters can be overmilked or left with excess residue.

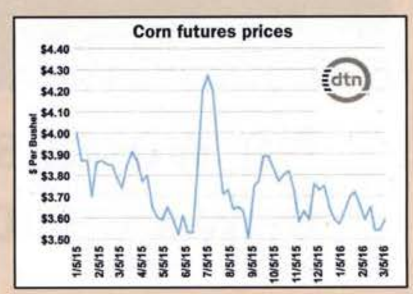
2. Ensure the milk cluster is correctly applied. Following a preparation stage that has adequately stimulated the udder, the cluster should be attached to the udder taking care not to pinch or fold any teats.

3. Milk most cows as completely as possible. This consideration denotes most rather than all, acknowledging that timeliness of milk parlor throughput is important. The article suggests a maximum detacher threshold setting of 0.9 pound per minute.

4. Less complete milkout is necessary for herds milking three or four times per day. The maximum detacher threshold setting can be moved to as high as 2.2 pounds per minute in herds milking more often.

CORN PRICES ESTABLISH SIX-MONTH LOW

Front-month futures prices held at $3.54 per bushel through the last two weeks of February, creating underlying support at that level. The availability of corn in the market and potential to get the 2016 crop into the ground in a timely manner looks encouraging at this point, creating further stability in market prices through much of the spring and summer.



This makes forward contracting and risk-management decisions for dairy producers even more challenging. For now, producers are encouraged to make hand-to-mouth buying decisions, but closely monitor long-term market and weather situations.

—Rick Kment, DTN Dairy Analyst

CANOLA BOOSTS MILK PRODUCTION LEVELS

Soybean meal and canola are common protein options for dairies looking to supplement their rations. A recent study conducted by USDA's Agricultural Research Service found canola meal supplement equated to 3 percent more milk on average than soybean meal. The researchers divided 50 cows into five ration groups — high soybean meal ration, low soybean meal ration, high canola meal ration, low canola meal ration, and a mixed soybean meal and canola meal ration.

Cows on the canola meal ration averaged 88.8 pounds of milk per day, while cows on the soybean meal supplementation averaged 86.6 pounds of milk per day. A similar influx in milk protein levels was detected.

A SNAPSHOT OF HEALTH AND WELFARE ON LARGE DAIRIES

Health and welfare is top of the mind for dairy consumers, and the industry is taking note. Recent research done by the University of Minnesota analyzed data from 15 dairies with more than 2,500 cows in Minnesota, Wisconsin, South Dakota and Iowa.

They found these dairies showed average to low rates of lameness — 16.7 percent. Additionally, the prevalence of hock lesions was 22.8 percent and hygiene scores averaged 2.5. The researchers, led by Marcia Endres, concluded cow welfare is not compromised on larger dairies in the Upper Midwest.

As a group, these herds averaged 4,972 cows and daily milk production per cow of 70.3 pounds with 3.85 percent fat and 3.15 percent protein. Bulk tank somatic cell count was 190,000.

The Soil Ramifications of Continuous Corn Silage

Mark Boggess, U.S. Dairy Forage Research Center

As most dairy and forage farmers know, the industry is coming under increasing pressure to address comprehensive environmental concerns. These challenges to the industry are further complicated by the increasing use of corn silage and other annuals at the expense of perennial crops and the resulting loss of soil and soil quality.

One indication of the urgency surrounding these issues is the cover of the December 3, 2015, edition of *Nature* magazine reading: "SAVE OUR SOILS." In this issue, four feature articles highlight soil ecology as a reemerging area of high priority for researchers, policy makers, and the agricultural industries. Of particular note is that only one of these articles was written by authors with any connection to agriculture, meaning soil and agriculture/food production are being influenced by an ever-increasing community of stakeholders, including politicians and regulators.

Loss of Soil and Organic Matter

Unfortunately, we are still losing too much soil. Current estimates place the annual soil erosion loss to wind, water, and agriculture at over 75 billion tons. This rate of soil loss is unsustainable given current production demands, let alone the demands of the future. Additional pressures are mounting due to the negative impact of soil erosion and nutrient losses on water quality, from contaminated well water in Wisconsin to the hypoxic area (dead zone) in the Gulf of Mexico.

Soil quality, which is most often defined by soil organic matter (SOM), is also declining. SOM is an easy-to-use indicator of soil carbon content, water holding capacity, nitrogen availability, and overall fertility. In general, increased SOM means better fertility and water holding capacity (drought resistance); fewer fertilizer inputs; improved resiliency and long-term sustainability; and more farm profit. Long-term sustainability of dairy forage production systems can only be realized by systems improving SOM over time.

Forage use varies widely across the dairy industry, but overall use of corn silage for dairy has increased significantly and continues to grow. Corn silage is the dairy farmer's forage of choice for many reasons including: yield; quality and consistency; ease of use in dairy rations; production and labor costs; and access to equipment, information, and local infrastructure. As dairy farmers have increased forage contents in rations, corn silage has led the way.

Ramifications in the Field

Unfortunately, the benefits of feeding more and more corn silage across the dairy industry come with a cost. All current conventional cropping systems significantly reduce soil organic matter over time. But monocultures, like continuous corn silage and annual crop rotations, produce more severe losses. Crop rotations using perennials such as alfalfa, and the application of manure as a soil amendment, slow the rate of loss of SOM but do not usually improve it.

An additional concern for crop production systems which feature corn silage is annual erosion losses. Current estimates place the average annual soil erosion losses for all corn acres in the U.S. at one pound of soil lost for every pound of corn grain produced. Soil erosion losses are even higher for corn silage acres and other annual crops.

Finally, climate change adds an additional layer to challenges facing the dairy and forage industries. These include more extreme weather events – rainfall, drought, heat, and cold – as well as changing growing seasons and increasing weed and pest problems. These variables will also dictate how soil ecology changes and what management responses can be taken.

Opportunities Going Forward

The good news is soil science is undergoing a renaissance with a renewed focus on better understanding complex soils systems. We are now beginning to better see the extraordinary complexity of soil quality, health, and resiliency with respect to fertility, drought tolerance, moisture holding capacity, and pests and pathogens, all of which will lead to better management practices to improve SOM and the long-term sustainability of soils and cropping systems.

Farmers must also renew their focus on soil. Aggressively manage wind and water soil erosion and rate of soil loss on farm – no excuses. Employ filter strips, terracing, improved crop rotations, more sensible cropping strategies, and cover crops. If you can see your soil, it is vulnerable to erosion losses and is most likely not actively promoting the biological activities improving soil quality. Soil quality and security are important and need constant attention, vigilance, and new ideas.

In addition, options are emerging, including new alfalfa varieties, which promise to produce improved yields of high-quality forage for dairies while reducing costs. These varieties, and others on the horizon, may provide options for dairy and forage farmers producing excellent forage and milk production while better maintaining soil quality and sustainability.

Summary Points

- Corn silage works on today's dairies and can be managed well in high forage rations for the cow and dairy operation.
- But, soil quality and security are critically important and are being compromised.
  - Corn silage production is not optimal for long-term soil health and sustainability – production systems must evolve.
  - Current excessive soil erosion rates must no longer be tolerated.
  - New farming strategies are needed to improve SOM and long-term sustainability of crop and dairy production across landscapes.
- Climate change is further increasing the need to improve soil security and resiliency.
- Alfalfa and other high-quality forages are being improved to provide dairy farmers greater options for forages they grow and feed.

Researchers strive for a better red clover

by Heathcliffe Riday

THE USE of red clover in the U.S., as measured by seed production, is only about 10 percent of what it was at its peak around 1950. But since 1990, red clover seed production has stabilized at about 10 million pounds of seed produced each year (see figure) compared to 57 million pounds for alfalfa. There is a dedicated niche market for red clover but a limited amount of research to improve red clover options. Recent research has improved the persistence of red clover, and current research is trying to develop varieties that are tolerant of commonly used broadleaf herbicides.

The rise and fall of red clover

Red clover has a long history of use in agriculture and is associated with agricultural intensification starting in the 1500s. Initially, it was used in cropping rotations as a nitrogen fertilizer source. However, starting in the 1950s, there was a large drop in red clover usage until about 1990. This decline in red clover usage is mirrored by an increase in synthetic fertilizer usage. It is interesting to note that during a recent spike in nitrogen fertilizer prices, there was a spike in red clover seed production, indicating that, to some extent, producers will revert to red clover usage to achieve nitrogen fertilization.

The USDA National Agricultural Statistics Service (NASS) does not keep records on red clover acreage, but it does keep records for seed production. It is estimated that 80 to 90 percent of red clover seed is produced in Oregon. Assuming that most of the seed produced in the U.S. enters U.S. markets, there would be an estimated 3 to 6 million acres of land planted with red clover (compared to 18.2 million acres for alfalfa). Much of this acreage is likely in mixed grass/legume pasture. As in the past, current producers still look to red clover to supply nitrogen fertility to their systems and to enhance feed quality. The estimated value of red clover is shown in the table.

The red clover niche

Today, red clover is used in very diverse management systems including: as a summer or winter annual cover crop or hay/silage crop; as a

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companion with a small grain crop; in a pure stand for hay or silage; in a pasture mixture; or overseeded into existing pasture to improve pasture quality. Red clover has excellent establishment ability and is very shade tolerant, allowing it to be used in a range of management systems. Red clover's major weakness is its shorter life span, although newer, improved red clover varieties can persist for three to four years. Due to a scarcity of breeders and resources, breeding targets remain to improve plant persistence and enhance forage yields in diverse management systems.

From a management perspective, one reason for red clover's shorter stand life could be insufficient seeding rates. Currently, there is little consensus in recommended red clover seeding rates. An internet search revealed a range of 8 to 20 pounds per acre for pure-stand establishment, and a range of 3 to 14 pounds per acre for overseeding existing pastures or establishing red clover as part of a mixture. Such hugely variable seeding rates likely have a major impact on red clover stand life. Clearly, more research needs to be done to clarify red clover seeding rates, particularly when considering the use of new and improved red clover varieties.

There are about five organizations actively engaged in red clover breeding in the U.S. and Canada, including the U.S. Dairy Forage Research Center. These breeders are striving to improve red clover for use in very diverse environments from subtropical Florida to cool temperate climates in Canada.

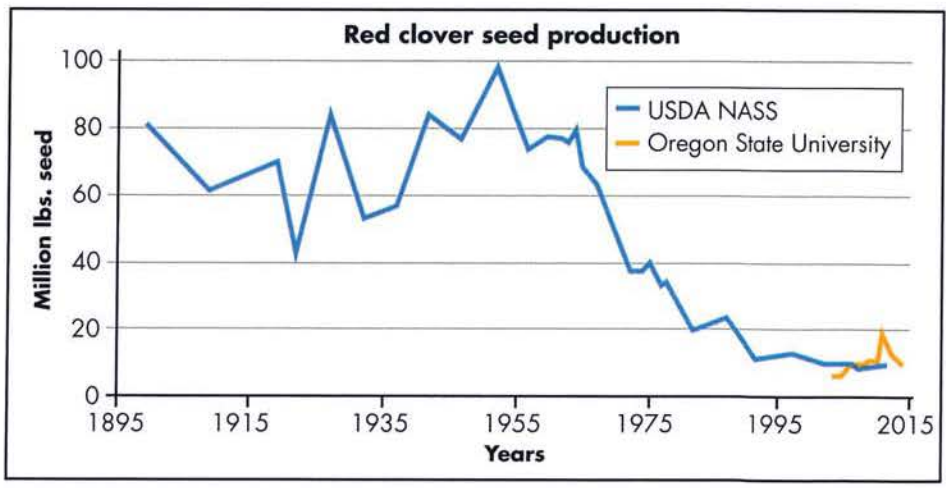
One new variety developed at the U.S. Dairy Forage Research Center is FF 9615; it became commercially available through forage seed vendors in 2015. This variety has significantly improved persistence and yield and is expected to improve red clover productivity in the cool-humid regions of the U.S.

Herbicide tolerance

Producers using red clover in pasture mixtures with grass have limited herbicide weed management options if they want to retain forage legumes in their stands. Producers would benefit by having red clover varieties that are tolerant of commonly used broadleaf herbicides such as 2,4-D. Work to develop such red clover material was initiated in the 1980s at the University of Florida using a traditional breeding approach. Recently, researchers at the University of Florida and the U.S. Dairy Forage Research Center have revisited this material to develop it further to create varieties for use by producers.

The University of Florida released a variety called FL24D that is not yet commercially available. The U.S. Dairy Forage Research Center has transferred the Floridian 2,4-D tolerance into red clover germplasm that is better adapted to the northern U.S., and they have also selected for increased 2,4-D resistance. In field tests, this red clover tolerated standard 2,4-D application with no plant death and some initial plant injury followed by plant recovery. Currently, experimental varieties from this material are being developed and tested with a focus on improved agronomic performance in northern U.S. growing conditions.

FF 9615 red clover (outlined in yellow) as seen in the third year of a variety trial, showing superior persistence compared to the other varieties.



Estimated retail value of red clover seed and its value-added products

Measure	Value (million $ per year)
Red clover seed	$29
Nitrogen fertilizer	$215
If all red clover sold as hay	$1,340
If all red clover converted to milk	$6,900
If all red clover converted to beef	$4,400