Economic Benefits of Increasing the Digestibility of Forages

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Feed costs are high, and corn prices are maintaining around the $3.65 per bushel. This equals $.0651 per pound, or $130 per ton. Dried distillers grains are currently in the price range of $110 to $140 per ton, FOB, and the prices of corn gluten feed is keeping pace on an energy and protein basis, at approximately $100 to $110 per ton, so supplemental feeds for cow-calf producers or stocker cattle operations have costs between $.05 to %.06 per pound. Therefore, forage-based operations must utilize cost effective management tools that maximize forage digestibility. However, the conversion of fibrous forages to meat and milk is not efficient, with only 10 to 35% of the energy intake being captured as net energy to the animal, because 20 to 70% of the cellulose may not be digested (Varga and Kolver, 1997). I can't imagine anyone buying grain and then throwing more than half of it away. However, we do the same thing with hay when we make it, store it, and feed it in a way that results in only a 10 to 35% digestibility (and we're not even talking about the wastage that occurs with round bales that are stored and fed improperly, resulting in spoilage!).

All nutrients (energy, protein, vitamins, minerals, and water) are used in a hierarchy that goes from maintenance > development > growth > lactation > reproduction > fattening. This means that an animal's maintenance needs must be met before any other functions can occur. For example, a cow that has calved and is in lactation will take longer to re-breed if her nutrient requirements are not being met. If she is three years old, or younger, and still growing, her nutrient requirements will be even higher than if she were mature, and not growing. The impacts of improper forage management include cows in poor body condition, delayed rebreeding times, lower conception rates, and lighter weaning weights due to cows not breeding on the first service, and then having lower milk production than they would have had if they were in better condition.

In ruminants, feed is digested in the rumen by ruminal bacteria that attach to the surface of a feed particle to digest it. In ruminants, maintaining the visceral organs (rumen, reticulum, omasum, abomasum, small intestine, and large intestine) plus the liver and kidneys can take as much as 40-50% of the energy and 30-40% of the protein consumed in a day. Forage diets that are very bulky and only 40-60% digestible. More mature, less digestible forages increase the weight of the digestive tract, because more undigested feed remains in each segment of the digestive tract, causing the visceral organs to grow.

Additionally, in contrast to cattle being fed grain-based diets, the size of the rumen limits the amount of energy that can be consumed with forage-based diets, and digestible energy intake decreases with increasing forage maturity. Combined, these factors increase an animal's maintenance energy requirements, leaving fewer nutrients for production purposes. The impacts of improper forage management include cows in poor body condition, delayed rebreeding times, lower conception rates, and lighter weaning weights due to cows not breeding on the first service, and then having lower milk production than they would have had if they were in better condition. In order to reduce an animal's maintenance requirements with forage, it is necessary to use technologies that reduce the particle size of the forage, and/or increase the rate of forage digestion.

The rate, and extent, of fiber digestion in the rumen is controlled by the amount of surface area that is available for the fiber digesting bacteria to attach. From a practical standpoint with unprocessed forages, the large size of mature forage reduces the energy available to the animal, because for digestion to occur, the microorganisms in the rumen must first be associated with the forage, and then attach to the forage. Furthermore, *digestion of the forage by the bacteria normally occurs from the inside of the forage to the outer layers*. Limitations to the speed at which this occurs include the physical and chemical properties of the forage, the moisture level of the forage, time for penetration of the waxes and cuticle layer, and the extent of lignification (Varga and Kolver, 1997). Anything that decreases the particle size of forages also increases the surface area for the bacteria to attach, and this speeds up the rate of digestion, allowing the animal to get more nutrients in a quicker time. The digestible carbohydrate portions of fiber, cellulose and hemicellulose, must be freed from the indigestible structural strengthening component, lignin, in a timely manner to allow for an adequate amount of digestible energy to be achieved. Lignin is an indigestible compound that gives the plant strength. It limits the areas of attachment of the bacteria to the digestible portions of the fiber. This is why cattle ruminate (regurgitate and re-chew their food), to create smaller particle sizes that allow more area for bacterial attachment.

The undigested forage forms a mat layer in the rumen, on the top of the rumen fluid, and this mat layer is regurgitated and re-chewed until it is either digested or reduced in particle size to a point where it can pass through the reticulum to the omasum. In many cases, the space that the mat layer takes up actually reduces an animal's feed (and energy) intake, because it takes up space that a more digestible feed could occupy. Think of 'hay belly' as a buildup of indigestible feed that must be chewed until the particle size is reduced enough for the forage to either be digested or small enough to pass on down the digestive tract. Most particles leaving the rumen are smaller than 1mm (.04 inches), although particles as large as 5 cm (2inches) may leave the rumen (Welch, 1986). It is, therefore, not hard to understand how reducing the large particle size of many mature forages to 2 to 6 inches can reduce maintenance energy expenditures due to a decrease in visceral organ mass and the reductions in energy expenditure of rumination and re-chewing. What's the particle size of first-cutting Orchardgrass or Timothy hay in a round bale....3 to 4 feet? Have you ever thought of how much energy a cow needs to expend to reduce that to 2 inches?

Dr. Steven Loerch, at The Ohio State University, investigated the potential of using processing technologies to improve the utilization of prairie hay. Dr. Loerch reported that "One effective option producers rarely consider is hay chopping. Chopping hay allows the cows to eat 25-30% more energy. Costs of chopping hay (equipment, labor, etc.) should be compared to costs of purchasing supplemental energy. For some producers, this may be a cost effective option. I came to realize the potential of hay chopping from an observation at the OARDC Beef Center in Wooster. Steers fed a chopped hay based diet gained 2.5 lbs/day while those fed round baled hay (same hay source) in a rack gained less than 1.5 lbs/day." (Source: https://agnr.osu.edu/sites/agnr/files/imce/pdfs/Beef/AltFeedSuplong.pdf). This can be explained on the basis of more surface area being available for degradation, allowing for a more rapid rate of digestion; a faster rate of passage of indigestible components from the rumen allowing for an increase in feed intake, and the possibility that these factors allowed for an increase in propionate production due to a faster rate of digestion, and an increased rate of passage of indigestible components (Hintz et al., 1999). Harvesting techniques have been found to result in improvements in forage digestibility. Hintz et al. (1999) reported that maceration, an intensive forage conditioning process that shreds forage thus reducing rigidity and increases field drying rates by as much as 300% by disrupting the waxy cuticle layer of the plant and breaking open the stem, resulted in an increase in surface area available for microbial attachment in the rumen, a decreased lag time associated with NDF digestion, an increase in NDF digestion.

If feed processing is not an option on your operation, look for feed additives that increase fiber digestibility, such as Amaferm (Biozyme Incorporated, St. Joseph Misouri) or Levucell SC (Lallemand Animal Nutrition, Blagnac, France). Based on extensive research, the mode of action of Amaferm®, an all-natural fermentation extract of *Aspergillus* oryzae, (Biozyme Incorporated, St. Joseph, MO) is very well documented. Chang et al. (1999) reported that Amaferm, accelerated both the rate and extent of fiber digestion through increased growth of the rumen fungus *Neocallimastix frontalis* EB188, thus functioning like a prebiotic in stimulating the activity of fungi that break lingo-cellulose bonds leading to enhanced bacterial digestion. Furthermore, in vitro studies have shown the addition of Amaferm to increase NDF and ADF degradation of several feedstuffs (Beharka and Nagaraja, 1993). The increase in digestion of feedstuffs by Amaferm supplementation is the result of increased numbers of ruminal bacteria and the activity of the normally occurring intestinal microflora, as calves supplemented with Amaferm have been found to have higher total ruminal bacteria counts than controls (Beharka et al., 1991), increased cellulolytic bacteria counts in beef cattle supplemented with Amaferm (Kreikemeier and Varel, 1997; Beharka et al., 1991), and higher hemicellulolytic and pectinolytic bacteria counts than controls (Beharka et al., 1991).

The rumen fungi are the only rumen microorganisms capable of breaking the lingo-cellulose bonds of forages in the rumen, and Amaferm has been shown to accelerate the growth of motile zoospores of the rumen fungus *Neocallimastix frontalis* EB188, with a resulting increase of cellulase enzyme production peaking at 150% greater than controls, resulting in a 37% increase in carboxymethyl cellulase, a 261% increase in β-glucosidase, and a 407% increase in amylase, showing that the effects of Amaferm are not limited to enzymes responsible for fiber digestion, but also starch digestion (Schmidt et al., 2004). The increase in growth rate is not limited to fungi, as Amaferm® has been shown to increase the growth rate of the fiber digesting bacteria in the rumen, *Fibrobacter succinogenes* S85 and *Ruminococcus albus* 7 as well as several strains of the lactate utilizing bacteria *Megasphaera elsdenii, Selenemonas ruminantium,* and *Selenomonas lactilytica* (Beharka and Nagaraja, 1998). Additionally, Amaferm has been shown to increase fungal mass in three rumen fungi species, which can lead to more surface area being made available to bacterial attachment, as well as increasing total VFA production. (Harper et al., 1996). When a greater rate of digestion occurs, more microbial protein is produced, which leads to a greater flow of microbial protein to the small intestine. Finally, Caton et al., (1993) reported that steers grazing cool-season pastures had increased dry matter intake and fiber digestibility during July and August when pastures were dormant, when supplemented with Amaferm.

If forage is evaluated on a price per pound, rather than a price per ton, the necessity to maximize digestibility becomes apparent. If corn is $3.65 per bushel, it is $.0651 per pound. If hay is $160 per ton, it is $.08 per pound. Normally, the digestibility of corn is around 95%, but the digestibility of hay may only be 40%, so from a digestibility standpoint, the price for a pound of corn would be $.068 per pound ($.0651/.95), but the price of hay from a digestibility standpoint would be $.20 per pound ($.08/.40). The main limitation in having an efficient forage-based production is the economic understanding that forage may be 2.3 times more expensive than grain from a digestible energy standpoint. Therefore, in order for forages to be economically competitive, they must be managed, harvested, and potentially processed to their optimum digestibility. High prices for all feeds will necessitate that beef producers adopt grazing practices and forage harvesting and processing technologies that reduce the animal's energy and protein requirements through reducing visceral organ mass; increase the digestibility of forages through providing more sites for bacterial attachment; and use technologies and products that increase the microbial protein yield. If a producer could increase the digestibility of the hay from 40% to 55%, they would take the price of their hay from a digestibility standpoint from $.20 to $.145 per pound, a 27.5% decrease in price! In summary, there are several options available for producers to use in order to maximize their production in a forage based operation, both with grazed and harvested forages.

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