Feedstuffs Reprint

Advancement in developing reduced-lignin alfalfa made

ALFALFA production in the U.S. has changed dramatically over recent decades, with a steady trend towards reduced alfalfa production and increased corn silage production.

The current alfalfa trend started in the 1990s, partly due to the corn silage shift, and accelerated downward due to increased demand for corn acres for ethanol production created by the renewable fuel standard under the Energy Policy Act of 2005.

Alfalfa production has also been affected by broad regional droughts in 2011 and 2012 that led to declining hay production and shortages that drove up hay prices. In response, acres devoted to alfalfa increased in some western states where corn is less prevalent, but not enough to offset the overall loss of alfalfa acres.

The Upper Midwest remained in an alfalfa deficit through 2013 due to winter damage and stand loss. Alfalfa production in 2013 was below trend, and hay market prices continue to be somewhat elevated.

An increase in the availability of distillers grains as a protein source — replacing alfalfa — is also a key factor in alfalfa production and utilization trends (Newell, 2014).

While alfalfa acres and dietary inclusion rates may be on the decline, alfalfa is still an important forage in dairy diets, and genetic advancements to improve alfalfa fiber digestibility are certainly a welcome technology.

Environmental challenges

Alfalfa is arguably one of the most variable feeds on many dairies. This is due to field-by-field variations in the age of the stand (grass content), harvest maturity/moisture, fiber digestibility affected by the growing environment and issues surrounding fermentation and palatability.

It is well documented that environmental factors have a smaller effect on quality than on yield and that most factors that limit plant development (e.g., lack of water, cold weather, plant diseases) tend to promote higher quality because of their effect on altering the leaf:stem ratios (Van Soest, 1996).

Nothing influences the nutritional quality of alfalfa more than the growing environment and harvest maturity. Fiber digestibility is greater under cooler temperatures, with first and fourth cuttings having the highest neutral detergent fiber digestibility (NDFD) and second and third cuttings — which are typically grown under higher heat units — displaying the lowest NDFD.

The biggest environmental factors influencing alfalfa quality are temperature, water deficiency, solar radiation and — a distant fourth — soil fertility. Growing conditions that promote the highest alfalfa quality include long day lengths, cool nights and moderately dry weather. Warm, wet weather results in the poorest-quality alfalfa. Cool, wet growing conditions produce high-quality alfalfa due to less neutral detergent fiber (NDF) and low lignification (Van Soest, 1996).

However, getting a hay crop harvested in these conditions can be problematic, with harvest delays resulting in maturity issues, in addition to the potential for higher respiration, leaching or fermentation/spoilage losses from increased exposure to soil-borne fungi and bacteria. Solar radiation (light) is the only environmental factor that promotes both yield and quality. Light promotes carbohydrate production, with every hourly increase in day length increasing digestibility by about 0.2 percentage units (Van Soest, 1996).

The shortening photoperiod in the fall has a negative effect on alfalfa digestibility but is somewhat offset by cooler temperatures. Cloudy weather reduces photosynthesis, causing low sugar and mobilization of nutrients, which results in higher proteins, both of which can be problematic for silage production (Van Soest, 1996).

Drought conditions reduce yield, but the resulting stunted yet leafy plants are generally higher in protein and digestibility due to the higher leaf:stem ratio. The digestibility advantages would be greater if they weren't somewhat offset by increased lignification from high temperatures that typically accompany drought conditions.

Temperature accelerates plant development, and warm weather accelerates NDF development and lignification. Every 1°C increase in temperature will generally de-

Bottom Line

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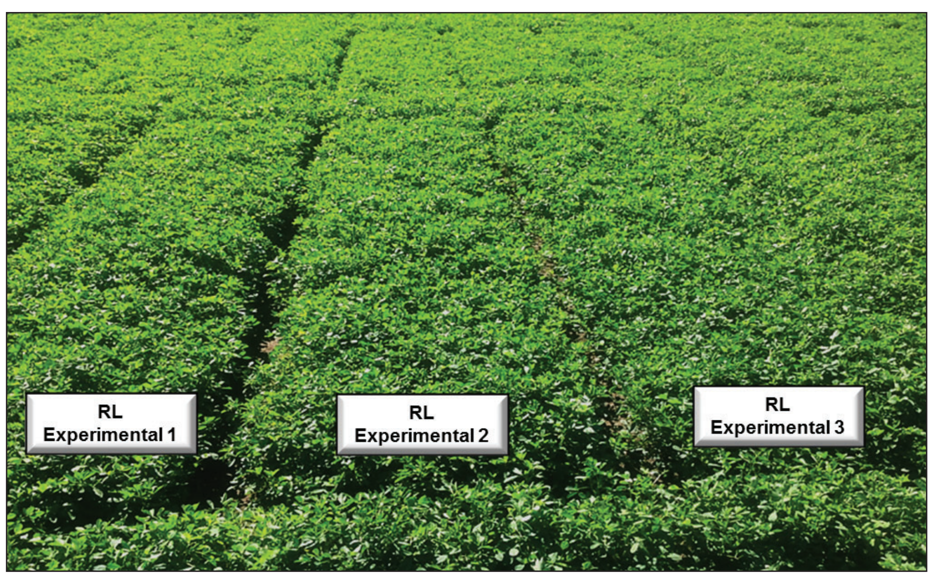

crease the digestibility of forages 0.3-0.7% units (Van Soest, 1996). This is one reason why forages produced in northern latitudes or higher elevations (cooler nights) tend to be higher quality. In the spring, light and temperature are positively correlated until June 21, when maximum day length and light occur, after which light decreases and temperature increases (bad for quality) until the fall, which is characterized by declining temperatures and decreasing day length and light (good for quality).

Reduced-lignin alfalfa

The October 2014 World Dairy Expo in Madison, Wis., was the launch site of two new alfalfa technologies. One was a genetically modified, reduced-lignin alfalfa (HarvXtra) by Forage Genetics International (FGI) that will be licensed to a number of seed brands.

The other release was lower-lignin alfalfa from Alforex Seeds developed through conventional plant breeding. The company says the Alforex Seed products (Hi-Gest 360 and Hi-Gest 660) have 7-10% less lignin and are available in 34% coated, non-glyphosate-tolerant varieties on a limited basis for the spring 2015 planting season.

Other alfalfa breeding companies have previously released lower-lignin varieties under the guise of "high quality" through conventional breeding methods delivering at least a 5% reduction in lignin content.

HarvXtra was developed through a strategic partnership among FGI, The Samuel Roberts Noble Foundation, DuPont Pioneer and the U.S. Dairy Forage Research Center, in conjunction with Monsanto.

There are several steps in the process of lignin synthesis in alfalfa, with the lignin biosynthetic pathway involving 12 different enzymes. Each is required for a specific step in the pathway. Noble Foundation scientists identified and suppressed several lignin genes that code for specific pathway enzymes (COMT and CCOMT).

FGI scientists generated and evaluated biotechnology-derived plants with suppression of a specific lignin gene, resulting in a 10-15% decrease in lignin content and a 10-15% increase in NDFD and relative feeding quality compared to related lines without the HarvXtra trait. HarvXtra alfalfa also displays a slower change in quality with advancing maturity compared with conventional varieties yet maintains alfalfa's important agronomic characteristics, including lodging potential equal to most commercial varieties harvested at the same time. HarvXtra alfalfa will be sold in a trait stack with Genuity Roundup Ready alfalfa.

A petition to deregulate has been reviewed by the U.S. Department of Agriculture, with an anticipated limited commercial introduction in 2016 to allow growers the opportunity to realize the benefits of the technology and with 2017 as the first year of a wide-scale commercial launch (Fanta, 2014).

Lignin in alfalfa cell walls (primarily the stem) fills space between cellulose, hemicellulose and pectin molecules and cross-links to hemicellulose. It acts similarly to rebar in concrete to enhance the plant's structural integrity. Lignin also allows the plant's vascular system to transport water without leakage, sequesters atmospheric carbon and is the most slowly decomposing component of vegetation, providing the major portion of soil organic matter (Combs, 2015).

A query of the Dairyland Laboratories Inc. database showed that from 2010 to 2012, alfalfa hay averaged 7.6% lignin (in a range of 5.3-9.8%), with alfalfa silage averaging 8.4% (in a range of 6.3-10.6%). It is interesting that silage had a higher lignin content than hay, but this could be the result of fermentation, which reduces sugar and, thus, increases the concentration of lignin (Mahanna and Thomas, 2013).

These technologies should provide alfalfa producers with greater harvest flexibility when adhering to current harvest schedules and harvesting higher-relative feed quality alfalfa. They can also serve as a built-in quality buffer for weather delays or for allowing delayed harvest to capture more yield while still maintaining desirable forage quality.

In geographies that typically take four harvests, there is an opportunity to improve yields by around 15-20% by harvesting only three times while obtaining the same or better quality as a lower-yielding late-bud harvest.

The improved fiber digestibility of these varieties will likely provide the most benefits in transition and early-lactation diets, where dry matter intake is of most concern. Abstracts reporting studies with lactating dairy cows fed total mixed ration diets consisting of 50% alfalfa hay (Weakley et al., 2008) and lamb digestion studies that fed 100% alfalfa hay (Mertens et al., 2008) have shown significant improvements in both milk yield and NDFD. These studies both concluded that down-regulating COMT and CCOMT enzymes in the lignin biosynthesis pathway resulted in improved fiber digestibility and that down-regulating COMT resulted in the biggest improvement in alfalfa fiber digestibility.

Continued research will be needed to determine the desirable physically effective fiber levels in rations containing low-lignin alfalfa, especially if coupled with brown mid-rib corn silage (Mahanna and Thomas, 2013).

The Bottom Line

In recent years, alfalfa breeders have worked diligently to deliver increased yields by improving disease and pest resistance, winter hardiness and standability, along with integrating herbicide tolerance for a weed-free stand. While these are admirable advancements, it took a consortium of companies to finally deliver a significant advancement in alfalfa nutrient availability via a biotechnological approach that reduces the amount of lignin while still maintaining key agronomic characteristics desired by growers.

As alfalfa and corn geneticists develop forages with improved fiber digestibility, laboratories and nutritionists must be able to correctly analyze and combine these forages in diets that enhance the profitability of producers paying a premium for these new technologies.

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