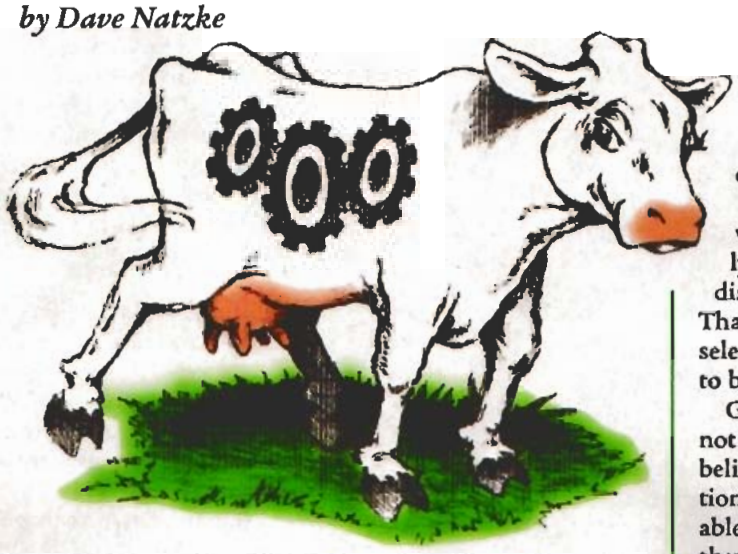
Unlocking bovine genome creates new horizons

Once breaking technology, artificial insemination and embryo transfer have helped boost average annual milk production per cow from 11,890 lbs. in 1980 to 19,560 lbs. in 2005. Unlocking the cattle genome will create new horizons.

by Dave Natzke



Increased genetic selection intensity through artificial insemination (AI) and embryo transfer (ET) has led to production and financial advances in dairy, building and propagating elite cow families that will serve as the genetic base for dairy herds to come. Improving that genetic base through these "traditional" methods has resulted in milk production increases per cow of about 1.5% to 2% annually, said Bob Collier, dairy scientist at the University of Arizona.

Those tools will continue to be useful in developing cows that can produce and stand up to the rigors of increasing demands for production. However, unlocking the bovine genetic code – called genomics – will create new horizons for dairy geneticists and producers alike, further impacting management and profitably.

Detecting problems

DNA technology has already allowed for the detection and prediction of genetic defects, where scientists can discover an undesirable recessive gene like bovine leukocyte adhesion deficiency (BLAD) or complex vertebral malformation (CVM), then develop and use a DNA test on AI sires and young sires, making genetic selection based on those tests. Although these defects may never be completely eliminated, the technology could reduce the frequency of these recessive genetic defects to less than 5% in the population, according to Kent Weigel, University of Wisconsin-Madison dairy geneticist.

"In the next five years, we'll see massive developments in the area of DNA-based (genomic) selection, due mainly to the invention of high-throughput genotyping systems," Weigel said. "We'll know exactly which areas of the genome were inherited by each offspring of a mating of an elite cow and a top AI bull, and we can then determine which has inherited the best sample of genes from its parents. Vast quantities of genetic information will be generated and, while it will take a few years to learn how to interpret it and use it effectively, it will make a major change in the way we look at animal breeding."

In addition to genetic defects, identifying genomes will identify animals susceptible to diseases that currently have huge negative financial impacts, such a Johne's disease, mastitis or bovine spongiform encephalopathy. That knowledge will allow geneticists and producers to select away from that vulnerability, or come up with a way to block it.

Genomics will also allow for selection based on positives, not just as a way to avoid negatives. Like Weigel, Collier believes production markers will become standard information for future bull proofs. Using indexes, producers will be able to make breeding decisions based on the relative value they place on specific markers matched to their management needs.

Three major areas

Collier identifies three areas where genomics – identifying genes affecting a particular trait – will aid dairy producers:

1 ***Milk composition,*** including everything from quantity and quality to levels of components and the development of nutraceuticals

2 ***Cow health,*** by identifying disease susceptibility and resistance.

3 ***Reproduction.***

"Genomics will have its biggest impact on milk composition and animal health," said Collier, who predicted unlocking the bovine genome will also yield rapid progress on disease issues, including mastitis resistance. "Milk composition will get a lot of scrutiny. Protein will continue to be extremely important, but also lipid composition."

Turning attention to animal health, progress will come not only in detecting resistance, but also through new information on the organism and treatment of the disease – viral and bacterial.

Good quality tests to pick up animals with susceptibility to diseases will provide an immediate payout to put an eradication program in place. The bull population (bull studs) will see the initial genetic testing for health issues, but Collier foresees the day when producers will conduct genetic tests on their cows. That's because, like any technology, developing and perfecting genomic selection will bring costs down, and virtually every young bull (and many elite young heifers) will have their genome "scanned" to provide a complete DNA fingerprint.

In addition to lower costs, paybacks will come in other forms. Known genomics could increase the value of embryos, for example.

Addressing reproduction

Reproductive performance is a challenge to most dairy producers, and there won't be quick answers. More rapid progress in reproduction research will require additional and more controversial technology - cloning - to reduce generation intervals, Collier said.

"It will take a lot of work to make progress on reproduction," Collier said. "Reproductive performance heritability is 5% or less. If there's not a lot of progress, at least we should see a slowdown in the current decline in reproductive efficiency."

Commercial availability

Some commercial "production markers" are already available. For example, Igenity, a subsidiary of Merial, now offers a series of genetic tests for cattle, using hair follicles, blood or semen, to identify genotypes to detect:

- **Leptin,** a protein that regulates appetite and energy balance in dairy cattle, enabling producers to select for higher feed intake and, consequently, greater milk production.
- **DGAT1,** a gene responsible for encoding an enzyme that is important in intestinal fat absorption, energy storage, milk production and egg production, potentially enabling producers to select for higher milk yield without sacrificing fertility.
- **A natural variation** in the bovine growth hormone (somatotropin) receptor (BGHR) gene, allowing producers to make mating decisions to improve milk component levels without a significant negative effect on milk yield, fat, fat percentage, somatic cell score, productive life or pregnancy rates.
- **Parentage identification,** enabling producers to validate parentage or match sires from AI, single-sire or multisire mating situations.
- **A DNA-based identification** system that ensures traceability of an animal throughout the entire production chain.

Management required

Understanding and managing the information gained through genomics will take technology in other areas.

"One thing we need to make genetic progress is good records," Collier said. "Current databases, such as bull studs, will have to be matched with good herd health records. We'll improve that information as we improve parameters for animal identification and health. We don't have a good national database on animal health compared to some other countries. Genetic progress will come with identification accuracy of the marker. We're going to need to improve the accuracy by getting more information, and then increasing the use of that information."

How that information is eventually utilized on the dairy will be up to the producer. Regardless of the technology, success always comes back to management.

"Some people place more value on disease resistance than on production, so they will be looking for specific breeding values in that area," Collier continued. "Information will continue to grow. We'll get more precise information about genes - desirable and undesirable. For now, though, it isn't the most important thing on the dairy. Attention to management is."

Genomics, heat stress and tropical cows

Genomics holds the potential to address other challenges facing dairy producers. Take, for example, heat stress.

"Right now we force the cow to adapt to every environment and we try to manage the environment," said Wayne Weiland, technical service specialist with Monsanto, Waunakee, Wis. "Maybe we'll be able to adapt the cow to fit the environment. What if we can isolate the gene that helps cows tolerate heat stress? There's a real possibility dairies could have a cow that could stand up to heat stress."

Jack Rutledge, professor of animal science at the University of Wisconsin-Madison, College of Agricultural and Life Sciences, is researching development and refinement of a low-cost method to generate embryos that, when implanted into native tropical cows, will grow into milk-producing cows capable of surviving the tropical climate. That has implications not only for tropical countries, where milk is scarce, but also in U.S. climates where heat stress is a concern.

Many previous attempts to import high-producing cows into tropical climates have failed because cattle from temperate climates are not accustomed to tropical heat, humidity, bacteria, parasites and low-nutrient forages. Subsequent efforts to create high milk-producing cows for the tropics focused on mating temperate dairy cattle with tropically adapted cattle, in hopes of producing a new hybrid breed with characteristics of both parent species. The first generation of offspring (the F1 generation) shows both traits for milk production and adaptation to the tropical climate. However, the F1 hybrids are unable to establish a sustainable, successful breed, even though scores of attempts have been made.

By creating hybrid embryos in the laboratory by combining oocytes collected from Wisconsin dairy cows and imported semen from tropically adapted bulls, he hopes to overcome this impasse.

University of Arizona dairy scientist Bob Collier is also researching heat stress. "We're looking at the animal's ability to cool itself," he said. "Particularly among Holsteins, there's a wide variation in sweating rate, and we think it determines their ability to withstand thermal stress."

He cautioned, however, that selecting cattle for heat stress resistance may come at a cost to production.

"When animals adapt to heat stress, they divert nutrients away from production to maintenance," he explained. "We may make some progress by improving things like sweating rate in cattle, but I think it will still be desirable to manage the environment around the animals, rather than the genetics." ■