4.2.3 ADVANCED AGRICULTURAL SYSTEMS FOR ENTERIC EMISSIONS REDUCTION

Technology Description

Enteric emissions of methane from animals are a byproduct of digestion that are exhaled or eructated by the animals. It is a natural process, and the amount of methane is dependent on the animal's digestive system and the amount and type of feed consumed. Any reductions in this energy loss will increase nutritional efficiency – therefore the goal of much nutrition research has been to reduce this energy loss, while increasing production or nutritional efficiency. There are a number of strategies that can be used, including increased digestibility of forages and feeds; feeding grain rather than forages; providing feed additives that may tie up hydrogen in the rumen and inhibit the formation of methane by rumen bacteria; improving production efficiency; and modification of bacteria in the rumen. Many production practices are currently used that reduce methane; when used individually or in conjunction with each other, the practices may lower the loss of methane energy up to one half. These have not only global change benefits but may have significant economic benefits as well. Most system concepts for reducing methane emissions are, however, theoretical, and considerable research and development are required.

System Concepts

- High-grain diets: Feeding of high-grain diets to reduce methane emissions and increase animal production efficiency, without contributing to the animal health problems that are typically associated with high-grain diets.
- Ruminal fermentation time: Methane is released from the rumen where feed is fermented in an aerobic environment. The shorter the period of time feed remains in the rumen, the less carbon is converted to methane. Residence time in the rumen can be shortened by increasing the digestibility of feed grains or forages and by feeding of concentrated supplements.
- Alternate hydrogen acceptors: Addition of unsaturated edible oils in feed may be used to reduce methane emissions by sequestering hydrogen making it unavailable for methanogens.
- Use of feed additives: Ionophores are feed additives that inhibit the formation of methane by rumen bacteria. Considerable research is needed in maintenance of effectiveness for long periods and for delivery systems to grazing cattle.
- Improvement in production efficiency: Any practice that increases productivity per animal reduces methane emissions. Animal technologies that increase productivity include BST to increase milk production, growth regulators for beef cattle to enhance lean and reduce fat, genetic improvement of animal performance, genetic improvement of pasture and other feedstuffs potential, improved animal feed-handling practices, improved pasture nutritional and water management, and earlier marketing of animals.
- Enhancing ruminal acetogens: Acetogens are a group of rumen microbes that produce acetic acid from hydrogen and carbon dioxide rather than methane. They exist in the rumen as a minor species, predominate in the gut of some termites, and may be important in the lower gut of several animal species. Developing methods to make them more competitive in the rumen or transferring the acetogenesis genes to already successful ruminal organisms could be very helpful to animal efficiency and the environment.
- Modification of bacteria in the rumen: Alteration of ruminal microbes may lead to significant reduction in methane emissions; however, considerable research is needed to genetically produce microbes that can compete with natural microbes for sustained periods.

Representative Technologies

- Improved feed and forage management and treatment practices to increase the digestibility and reduce residence digestion time in the rumen, such as using improved feed grains and forage, increased surface area of the feeds, addition of fiber sources, treatment of the feeds/forages to increase digestibility, and appropriate use of concentrated supplements.
- Best-management practices for increased animal reproduction efficiency.
- Use of growth promotants and other agents to improve animal efficiency and enhance lean meat production.

Technology Status/Applications

- First-generation precision agriculture technologies are available and have been used on as many as 14% of farms by 1998.

- Rapid soil characterization sensors; selected forage stress, yield, and quality sensors; integration of global positioning systems to enhance selected needed areas of forage systems for enhanced selected management; and a systematic integration of all technologies for all major pasture and forage systems are not yet at technical performance levels required for field application.
- Strong understanding of animal physiology exists in the agriculture, energy, and university research areas.
- Research is required for the development of control-release materials and biological process inhibitors.
- Extensive use is made of animal and feed technologies in dairy- and beef-feeding systems; however, adequate techniques for uniform and effective delivery systems are needed in grazing systems.
- Best-management practices are in place in many production sectors.

Current Research, Development, and Demonstration

RD&D Goals

- Precision agriculture technologies that will improve forage and feedstuffs production efficiencies and increase digestibility.
- Remote and field-deployed sensors/monitors and information management systems for accurate, real-time monitoring and analysis of forage and crops, soils, water, fertilizer, and agricultural chemical use/efficiency to improve animal production efficiency.
- Smart materials for prescription release of feed additives under pasture or grazing systems.
- Genetic improvement of forages to increase productivity and digestibility.
- Methods of manipulating ruminal microbial processes to sequester hydrogen making it unavailable to methanogens.
- Deployment of first-generation integrated system models, technology and supporting education, and extension infrastructure.
- Genetically design forages to increase digestibility, reduce fertilizer requirements, provide chemicals for increased digestibility, and provide appropriate nutrients to enhance acetogen competitiveness.
- Genetically design bacteria that can compete with natural microbes for sustained periods.
- Full utilization of best-management practices.

RD&D Challenges

- Precision agriculture requires advances in rapid, low-cost, accurate plant, soil-nutrient, and physical property characterization; real-time crop and forage water requirements characterization; real-time crop and forage yield and quality characterization; real-time insect and pest infestation characterization; autonomous control systems; and integrated physiological model and comprehensive and user-friendly data/information-management systems.
- "Smart" materials that will release chemicals and feed additive doses under special conditions.
- Improved understanding of specific rumen microbial processes is required to support development of methods for making engineered microbes competitive with natural rumen microbes.
- Models that represent accurate understanding of the relationship of animal digestion and plant physiology must be coupled with models that represent soil-plant growth relationships. These models also must consider the changing global climate.
- Genetic engineering of sustainable competitive microbes that will produce acetic acid for the reduction of CO_2 with hydrogen.
- Development of plant varieties that increase nutrient-use efficiency while enhancing digestibility.
- Conduct direct basic and applied research effort on animal physiology, sensor development, material and feed additive research, and microbial processes research.

RD&D Activities

- The principal funding for this type research comes from the USDA and the animal-support industries. Others include the EPA, universities, state agencies, commodity groups, and instrumentation developers.

Recent Progress
• High-resolution satellite imagery can be used to identify water and nutrient stress and disease in some forage systems at 1-to-2 m resolution. • Success has been observed under grazing in the use of ionophores, which are widely used in the beef industry. • Control-release formulations for fertilizers and pesticides are in use, which improve forage productivity and digestibility. • Animal productivity per unit of methane emissions has steadily increased under managed conditions in the past 30 years. • On-farm use of yield-monitoring equipment is increasing. • Commercial sensors for sensitive, precise, and rapid analysis of greenhouse gases are in development and being marketed. • Best-management practices are in place for many crops and animal-management systems and regions of the country.
Commercialization and Deployment Activities
• Global-positioning systems, geographic information system software for parameter mapping, remotely sensed imagery, selected field monitors, and selected variable rate-control systems for seed, fertilizer, and chemical applications are commercialized and in application in the United States, Canada, Australia, and Europe. All of these systems may be used for increasing productivity and digestibility of forages. • Mitigated-release fertilizers and pesticides are available commercially. • Ionophores are widely used in the beef-feeding industry to increase productivity – but better delivery systems are needed. • Current precision agriculture technology is proven to be cost effective about 50% of the time, with poor reproducibility. • The infrastructure in place for agricultural production will support economical new technologies; however, the cost to compete with traditional technologies may initially be high until technology integration is complete.