Feeding Transgenic Feedstuffs to Cattle

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Introduction

Science and technology have been part of agriculture's foundation in enhancing productivity for over the last 50 years. Much progress has been made in the past but utilization of existing tools alone will not be adequate to meet the future demands. Smart and wise use of existing technologies along with the creation and development of new ones will need to occur in order to grow sufficient quantities and quality of grain, oilseeds, forages, and other food and feed products to meet the demand.

How are crops traditionally modified?

Plants can be modified by a variety of means including conventional as well as genetic engineering. Traditional plant breeders modify plants by selecting parental lines for a desired trait and cross-fertilizing them to produce offspring with the more desirable agronomic trait and/or nutritional value. Conventional plant breeders who produce new and improved varieties may depend on mutations that happen naturally or they may create mutations by using irradiation or other methods. The UN Food and Agriculture Organization (FAO) and the International Atomic Energy Agency maintain a database (http://www-infocris.iaea.org/MVD/) which lists 2543 known plant varieties developed through mutagenesis, including many common crop plants. Breeders can hybridize crop plants with related species; however, since this does not happen naturally in the wild, specialized laboratory techniques may be needed to make these crosses. For more information on the use of mutation techniques for gene discovery and crop improvement see Shu and Lagoda (2007). Marker-assisted breeding is a relatively new technology for improving the rate of gain for yield and associated traits. Marker-assisted selection (MAS) is the most promising marker-assisted breeding tool. MAS uses DNA markers that are tightly-linked to target loci (position of a gene on a chromosome) as a substitute for or to assist phenotypic screening. By determining the allele (one of several possible mutational forms of a gene at a given genetic locus) of a DNA marker, plants that possess particular genes or quantitative trait loci (QTLs) may be identified based on their genotype rather than their phenotype. The fundamental advantages of MAS compared to conventional phenotypic selection include: 1) simpler compared to phenotypic screening; 2) selection may be carried out at seedling stage; and 3) single plants may be selected with high reliability (http://www.knowledgebank.irri.org/ricebreedingcourse/Marker_assisted_breeding.htm).

What are genetically modified (GM) plants?

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Biotechnology can be used as a more predictable, precise and faster way to select specific native plant or exogenous genes that provide the plant with new genetic capabilities to tolerate herbicides, protect against insects and viruses, and enhance nutritional and health components. Biotechnology is defined as the application of (i) in vitro nucleic acid techniques, including recombinant deoxyribonucleic acid (DNA) and direct injection of nucleic acid into cells or organelles, or (ii) fusion of cells beyond the taxonomic family, that overcome natural physiological reproductive or recombination barriers and that are not techniques used in traditional breeding and selection. Genetically modified plants as used in this paper is defined as those plants derived from the use of biotechnology. Corn is a nice example of the progress in enhancing yield using various technologies. Little progress was made in the enhancement of corn yield using open pollination in the United States until about 1929 when double crossing was adopted. There were steady increases in corn yield to 1959 when it was further increased as result of the adoption of single crossing. The advances up to this point in time were primarily due to traditional breeding. The rate of yield gain was then accelerated in 1996 with the adoption of genetically modified (GM) corn (Troyer, 2006). These significant step changes in yield will need to continue not only for corn but for other feed grains, oilseeds, and forages as well utilizing a combination of technologies such as traditional breeding, marker-assisted breeding, biotechnology, no/reduced-till and other agronomic practices.

What commercial biotech crops are in the U.S.?

With a global market share of 50%, the United States is the largest producer of biotech crops in the world (James, 2008). In 2008, 154.4 million acres of biotech corn, soybeans, cotton, canola, sugar beet, alfalfa, papaya and squash were grown in the US. The increase in biotech acres of 11.9 million between 2007 and 2008 was the largest among the 25 countries growing biotech crops. The US again demonstrated its leadership by being the first country to commercialize biotech sugar beets in 2008 on approximately 0.6 million acres.

In the United States, commercialized biotech crops include: herbicide-tolerant and/or insect-protected corn, cotton (87% of the upland cotton acreage), and potato,; herbicide-tolerant soybeans (>90% of the acreage) , canola (> 90% of the acreage), alfalfa (~5% of the acreage) and sugar beet (~59% of the acreage); and virus-resistant squash and papaya (James, 2008). In 2008, Roundup Ready® sugar beets were first introduced into the US with a rapid adoption rate of an estimated 59%. Biotech crops are being offered with multiple traits to cover the tolerance to various herbicides and key economically significant insect pests. These traits include herbicide tolerance, various insect tolerance based on the insect of interest (European corn borer, ear worm, corn rootworm, etc.). Farmers have readily adopted the biotech crops with the stacked traits. As compared to 2007, in 2008 single traits in corn decreased from 37% to 22%, double traits decreased from 35% to 30% and triple traits increased from 28% to 48% of the biotech corn acres. In cotton, 75% of the cotton biotech acres were planted in the stacked herbicide-tolerant and Bt (insect-protected) trait, 23% in the herbicide-tolerant trait and 2% in the single Bt trait (James, 2008).

For a current listing of commercialized agricultural biotech products, the Biotechnology Industry Organization website should be viewed (http://www.biotradestatus.com/). This site allows a search for all commercialized products by crop, event name, trait provider (company) and country. Once the event is known the specific gene that was inserted in the crop can be identified at the Biosafety Clearin-House link (http://bch.cbd.int/database/organisms/uniqueidentifiers/) or at the GM crop database at Agbios (http://www.agbios.com/dbase.php?action=ShowForm).

Are the commercial genetically modified feedstuffs safe?

Government and international scientific organizations including the Food and Agricultural Organization/World Health Organization of United Nations (FAO/WHO, 1991), Food and Drug Administration (FDA, 1992), Organization for Economic Co-operation Development (OECD, 1993), French Academy of Science (ADSF, 2002), and Society of Toxicology (SQT, 2003) have concluded that plant biotechnology does not pose any unique risk compared with other production methods. As with human food safety assessment, the safety assessment of livestock feed derived from a GM crop looks at the compositional, toxicological, and nutritional characteristics of the biotech feed in comparison with its conventional counterpart. This assessment includes the source of the gene, molecular characterization of the inserted DNA; history and safe use of the expressed protein, as well as its function, concentration, toxicology and mode of action; crop agronomic characteristics; and composition. All commercialized GM crops have been assessed to be as safe as their conventional counterparts. The assessment process for determining food and feed safety has been reviewed (Chassy et al., 2004). They concluded routine feeding studies with multiple species generally add little to the nutritional and safety assessment of GM crops when there are no intentional compositional changes. However, animal studies may play a role in testing the nutritional value of crops with enhanced nutritional traits.

Consumer groups have asked whether direct human consumption of the DNA or protein in plant biotech products impacts human health and whether human consumption of animal products (e.g. meat, milk or eggs) from farm animals fed the biotech crops are safe. The United Nations FAO and WHO (1991), US FDA (1992) and EPA (2000) have each stated very clearly that the consumption of DNA from all sources (including plants improved through biotechnology) is safe, given the long history of safe consumption of DNA. Beever and Kemp (2000), Beever and Phipps (2001) and Jonas et al. (2001) have discussed the *in vivo* fate of DNA and concluded that there is a growing body of scientifically valid information available indicating no significant risk associated with the consumption of DNA or expressed proteins associated with GM crops. Even though DNA (plant, animal, microbial, etc.) has been consumed from the beginning of mankind without any adverse consequences, studies were conducted in an attempt to detect fragments of the transgenic DNA in milk, meat and eggs from animals that had been fed GM crops. Also, measurement of transgenic protein was attempted in these same tissues in spite of data showing the rapid digestion of these proteins in simulated gastric conditions. To date, all studies have shown that transgenic proteins and DNA have not been detected in meat, milk or eggs from animals fed GM crops

(CAST, 2006). A task force commissioned by the Council for Agricultural Science and Technology (CAST, 2006) to examine the safety of meat, milk and eggs from animals fed crops derived from plant biotechnology concluded the following:

"*The regulatory processes in place to assess the safety of biotechnology-derived crops have been effective in safeguarding public health. To date, there has been no authenticated case of an adverse health-related incident associated with the consumption of food or feed derived from modern biotechnology. The review of the currently available data concludes that meat, milk, and eggs produced by farm animals fed biotechnology-derived crops are as wholesome, safe, and nutritious as similar products derived from animals fed conventional crops."*

Is cattle performance and the quality of milk and/or meat different?

Numerous cattle feeding studies have been conducted to demonstrate that genetically modified crops are as nutritious and wholesome as compared to their conventional counterparts (Clark and Ipharraguerre, 2004; Flachowsky et al., 2005). A comprehensive listing of references is posted on the FASS website (http://www.fass.org/page.asp?pageID=43). No biological relevant differences in animal performance, health, or animal product (meat and milk) composition were observed. Table 1 provides a description of studies where GM crops were fed to dairy cattle. The GM crops included corn, corn silage, soybeans, soybean meal, cottonseed, fodder beets, eggplants, and alfalfa. The GM traits included a variety of insect-protected and herbicide-tolerant traits or a combination of them. Researchers have fed herbicide-tolerant and insect-protected corn, corn silage, and corn residues to beef cattle (http://www.fass.org/page.asp?pageID=43). Overall, no significant differences in gain, intake, and feed conversion were reported. Since the GM crop's composition is not different from its conventional counterpart [except for the introduced transgene(s) and expressed protein(s)] and the expressed transgenic protein is rapidly digested in the digestive system, one would not expect any unintended effects.

What are the benefits to the producer?

Supply – cost of ingredients. Since 1996 the average yield impact across the total area planted to the biotech traits over the 12 year period has been +6.1% for corn traits and +13.4% for cotton traits (Brookes and Barfoot, 2009). In 2007, world production levels of soybeans, corn, cotton lint and canola were +6.5%, +1.9%, +7.7% and +1.1%, respectively, higher than if farmers had not used biotech traits. The increase in yield results in a positive economic effect on the livestock producers buying and growing these crops for their livestock enterprises. Adoption of biotechnology has had a significant impact on farm income (Brookes and Barfoot, 2009). In 2007, the increase in farm income was US$10.1 billion (herbicide-tolerant soybeans, US$3.9 billion; herbicide-tolerant corn, US$0.442 billion; herbicide-tolerant cotton, US$0.025 billion; herbicide-tolerant canola, US$0.346 billion; insect-protected corn, US$2.075 billion; insect-protected cotton, US$3.20 billion; other, US$0.05 billion)(Brookes and Barfoot, 2009). For the period of 1996-2007 the increase in farm income totaled US$44 billion of which 44% were due to substantial yield gains and 56% due to cost savings (James, 2008). The development of drought-tolerance, virus-resistant, and other traits, will enable more food and feed to be produced in a more environmentally friendly and sustainable manner.

Quality – less weeds and weeds seeds, even safer. With the adoption of herbicide-tolerant crops, the quality of the grain and forage has been enhanced due to less weeds and weed seeds. With herbicide-tolerant alfalfa, there is less chance of noxious plants growing and being harvested along with the alfalfa. Economic losses to mycotoxin contaminated corn can be substantial (Wu, 2006). In corn, fumonisin has been shown to be reduced as result of less insect damage (Munkvold et al., 1999). Combining insect-protection traits having different modes of action into corn may help in reducing other mycotoxins as well. Based on the assumption that Bt corn was planted in 17% of the corn area in the US and Bt corn is partly effective in reducing aflatoxin, an additional benefit from aflatoxin reduction was calculated to be US$14 million (Wu, 2006).

Environmental. Animal consumption of forages is a major contributor to green house gas production in agriculture. Therefore, targeting a more efficient digestion of the forage where less methane is produced would be a significant benefit. Biotech tools are available to up-regulate, down-regulate or knock-out certain key enzymes in a metabolic pathway, insert new pathways, etc. through genetic manipulation. However, every metabolic alteration has consequences that need to be understood. If carbon is diverted towards the production of more starch, then there is less carbon for oil and protein production (e.g. corn plant). An understanding of the key metabolic pathways in plants and the genetic components that control and influence them will be crucial in developing improved forages. Using the tools of biotechnology it may be possible to reduce or alter lignin for enhanced fiber digestibility; alter carbohydrates for improved microbial efficiency in the rumen and reduce its impact on fiber digestibility and ruminal pH; increase protein content, quality and amino acid balance; enhance digestible biomass; and incorporate rate limiting digestive enzymes in the plant. The key is to identify those targets that will have the biggest economic impact to the livestock enterprise without sacrificing any of the key agronomic traits (Hartnell et al., 2005).

Conclusion

The adoption of biotech crops has proven to be effective in deriving socio-economic and environmental benefits to the producer and consumer. Commercialized biotech crops with insect-protected and herbicide-tolerant traits have been shown to be safe, nutritionally equivalent, and wholesome to their conventional counterparts when fed to animals. Now and in the future, the use of biotechnology in agriculture will be crucial in providing cost-effective, high quality feed ingredients and to contribute to the sustainability of the livestock enterprise in an environmentally friendly way.

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Table 1. Effect of Feeding Transgenic Crops to Lactating Dairy Cattle on Performance and Milk Quality

Author	Crop Fed	Transgenic Event/protein[1]	Results
(Barrière et al., 2001)	Corn Silage	IP: Bt176 /Cry 1Ab	No significant differences in milk yield, composition , and efficiency
(Brouk et al., 2008)	Corn grain & silage	IP:DAS 59122/ Cry34/35Ab1 HT: PAT protein	No significant differences in milk yield, composition and efficiency
(Calsamiglia et al., 2007)	Corn silage	IP: MON 810/Cry1Ab HT: GA21/mEPSPS	No significant differences in milk yield and composition except % milk protein, lactose and SNF were increased in the milk from cows fed the genetically modified corn. No Cry1Ab of EPSPS was detected in the milk.
(Donkin et al., 2003)	Corn grain & silage	IP: MON 810/Cry1Ab	No differences in milk yield composition, and efficiency
(Faust and Miller, 1997)	Chopped corn plant	IP: Bt (Syngenta)/ Cry1Ab	No differences in milk yield No Cry1Ab detected in the milk
(Faust et al., 2007)	Corn grain & silage	IP: TC1507/Cry1F	No significant differences in milk yield, composition and efficiency, health and blood profiles
(Folmer et al., 2002)	Corn grain & silage	IP:Bt11/Cry1Ab	No significant differences in milk yield, composition, efficiency and ruminal VFA's
(Grant et al., 2003)	Corn grain & silage	IP: MON 863/Cry3Bb1 HT: NK603/ CP4 EPSPS	IP: No significant differences in milk yield, composition, and efficiency HT: Milk yield was significantly lower in the NK603 fed cows. This corn was harvested last and had more dry down than the other corn so the DM of this silage was much higher than the others contributing to a poorer quality. Milk composition and efficiency were not significantly different.
(Hammond et al., 1996)	Soybeans	HT: GTS-40-3-2/ CP4 EPSPS	No significant differences in milk yield, composition, Dm digestibility, ruminal VFA's, N balance, DM intake. FCM was increased in the HT soybean fed cows.
(Mayer and Rutzmoser, 1999)	Corn silage	IP: Bt(Syngenta)/ Cry1Ab	No significant differences in milk yield and composition
(Phipps et al., 2003)	Soybean meal	HT: GTS-40-3-2/ CP4 EPSPS	No detection of Cp4 EPSPS in milk or blood
(Yonemochi et al., 2003)	Corn grain	IP: CBH351/Cry9c	No significant differences in blood profiles, milk yield. No detection of Cry9c in milk, blood, liver and muscle

Table 1. Effect of Feeding Transgenic Crops to Lactating Dairy Cattle on Performance and Milk Quality (continued)

Author	Crop Fed	Transgenic Event/protein[1]	Results
(Ipharraguerre et al., 2003)	Corn & Corn silage	HT: NK603/ CP4 EPSPS	No significant differences in milk yield, FCM, and composition
(Phipps et al., 2005)	Corn silage	HT: Liberty Link/PAT	No significant differences in milk yield and composition. No detectable PAT protein in milk.
(Paul et al., 2009)	Corn grain & silage	IP: MON 810/ Cry1Ab	Extensive degradation of Cry1Ab in the digestive tract
(Steinke et al., 2009)	Corn grain & silage	IP: MON 810/Cry1Ab	No significant differences in milk yield and composition
(Castillo et al., 2004)	Cottonseed	IP: Cry1Ac IP: Cry1Ac + Cry2Ab Ht: CP4 EPSPS	No significant differences in milk yield and composition. No detectable transgenic protein in milk.
(Singhal, 2006)	Cottonseed	P: Cry1Ac	No significant differences in milk yield and composition. No detectable transgenic protein in milk.
(Singhal et al., 2006)	Cottonseed	IP: Cry1Ac + Cry2Ab	No significant differences in milk yield and composition. No detectable transgenic protein in milk.
(Weisbjerg et al., 2001)	Fodder beets	HT: CP4 EPSPS	No significant differences in milk yield, composition and mitogenic activity in milk and blood
(Combs and Hartnell, 2008)	Alfalfa	HT: CP4 EPSPS	No significant differences in milk yield and composition.
(Weakley et al., 2008)	Alfalfa	Low lignin	No negative effects on milk yield and composition.
(Tiwari et al., 2007a)	Brinjal fruit (eggplant)	IP: Cry1Ac	No significant differences in milk yield and composition. No detectable transgenic protein in milk.
(Tiwari et al., 2007b)	Brinjal fruit (eggplant)	IP: Cry1Ac	No significant differences in milk yield and composition. No detectable transgenic protein in milk.

[1] IP = Insect Protection; HT = Herbicide Tolerant

SESSION NOTES