Does the Feeding of Biotechnology-Derived Crops Affect the Wholesomeness and Nutritional Value of Pork Products?

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Author
Marjorie A. Faust, Iowa State University

Reviewer
Eric Decker, University of Massachusetts

Introduction

Consumer confidence is critical for maintaining high demand and profitability in the pork industry. Consequently, the industry is responsible directly to produce pork products that are wholesome, nutritious, and appealing to consumers. Many factors including genetics, health, biosecurity, management, and nutrition and feeding influence pork products and ultimately, consumer demand and appeal for pork.

Biotechnology-derived crops represent an increasingly larger proportion of feeds for swine and other livestock in the US. For those who produce grains, the currently available biotechnology-derived crops offer advantages such as increased yields, insect resistance, and herbicide tolerance. Future products are expected to include a wide array of biotechnology-derived crops that benefit livestock producers directly, including products with enhanced nutrient content and nutrient availability. These new crops have the potential to further environmental stewardship, reduce ration costs, and improve health and nutrition for livestock. However, the implications of biotechnology-derived crops for producing quality pork are not immediately evident, and the current dialog on biotechnology-derived crops will determine market acceptance for today's crops and shape the future for new products that promise to confer more direct benefits to the livestock industries. In fact, some have questioned whether transgenic proteins and deoxyribonucleic acid (DNA) can be detected in animal products (meat, milk, and eggs) from livestock fed biotechnology-derived crops. Thus, it is important for those in the pork and other livestock industries to understand and to make informed discussions about biotechnology-derived crops as feeds for livestock.

Background on Biotechnology-Derived Crops

Biotechnology-derived crops were introduced into the US marketplace beginning in 1995. By 2002, important biotechnology-derived feed crops included insect-protected corn varieties such as *Bt* corn and cotton and herbicide-tolerant varieties of corn, soybeans, cotton, sugar beets, and canola (rape). A few specialty biotechnology-derived crops have altered nutritional value, and it is expected that new varieties of crops with enhanced nutritional value and other beneficial attributes will become increasingly more available as feeds for livestock.

Biotechnology-derived crops have been developed using techniques of modern agricultural biotechnology such as gene transfer, and as a result, these crops contain a novel segment of DNA that confers on the plants unique traits such as insect resistance and herbicide tolerance. For example, *Bt* corn contains a genetic element from the naturally occurring soil bacterium, *Bacillus thuringiensis (Bt)*. This genetic element ultimately is responsible for the resistance of *Bt* corn to European corn borers and several other corn pests.

Because biotechnology-derived crops contain these novel genetic elements, they are subject to safety reviews by US federal regulatory agencies including the Environmental Protection Agency (EPA) for pest protected crops only, the US Department of Agriculture (USDA), and Food and Drug Administration (FDA). Safety testing conducted for the US regulatory review process is product-specific and as a result, testing for individual products is determined wholly by the potential risks identified for these products. Factors evaluated for biotechnology-derived feed crops that have received US regulatory approval have included those listed in Figure 1.

Crops and products that fail to meet necessary safety criteria of FDA and other criteria outlined by the other regulatory agencies (USDA and EPA when applicable) are not acceptable, and so cannot be commercialized. Thus as part of the regulatory review process, it is the direct responsibility of these federal agencies to review data that are submitted for assessing the safety of biotechnology-derived crops for the environment and as foods and feeds.

Gene(s)
- Source(s)
- Molecular characterization
- Gene insert, copy number, and integrity

Protein(s)
- History of safe use and consumption
- Function, specificity, and mode of action
  - Levels
- Toxicology and/or allergenicity testing

Crop Characteristics
- Morphology
- Yield

Food/Feed Composition
- Proximate analysis
- Key nutrients
- Key anti-nutrients

Environmental Safety (examples shown for insect protected corn)
- Speed of soil degradation
- Impact on soil invertebrates (i.e. Earthworms)
- Impact on aquatic invertebrates (i.e. Daphnia)
- Impact on beneficial insects (i.e. Ladybugs, parasitic wasps, honeybees, and lacewings)
- Impact on fish (i.e. Trout)
- Impact on birds (i.e. Quail)
- Impact on mammals (i.e. Mice)
- Insect resistance management

Figure 1. Factors evaluated for biotechnology-derived feed crops that have received US regulatory approval

One important element of safety testing for the currently available biotechnology-derived crops is toxicological testing, and testing for commercially available crops has shown no detrimental effects to animals. For example, no oral toxicity effects were found for mice that were dosed with as much as 4000 mg/kg of bodyweight of purified Cry1Ab core protein (insecticidal protein in one type of insect protected *Bt* corn) in a single dosing. This mouse dosing with no effects represents a consumption level for the introduced protein that is 200 to 1000% of typical exposure levels for this type of *Bt* corn (AGBIOS, Inc., 2001a). Other studies have reported no deleterious effects from acute oral toxicity studies when purified transgenic proteins were ingested at levels that exceed expected human consumption levels by as much as 1,000,000 times (AGBIOS, Inc. 2001b).

Biotechnology-Derived Crops as Feeds for Livestock

Despite the extensive regulatory reviews conducted for biotechnology-derived crops, some have questioned whether products such as meat, milk, and eggs from livestock fed these crops can be differentiated from products derived from animals fed conventional non biotechnology-derived feedstuffs. Product differentiation is critical for those wishing to capitalize on many specialty markets for their pork and other livestock products. For example, in the future new biotechnology-derived crops may promise to enhance the nutritional value of pork from pigs fed these crops, and for these situations, product differentiation will be necessary to capture added value from these specialty feeds.

However, for biotechnology-derived crops such as *Bt* corn and herbicide-tolerant soybeans, nutritional value is not different from conventional counterparts. Thus when pigs and other livestock are fed biotechnology-derived and conventional crops, animal performance, health, and animal product composition are not expected to differ. In fact, approximately 50 independent research studies have been conducted worldwide to assess the effects of biotechnology-derived crops for animal performance. The overall conclusion for these studies is that when livestock are fed biotechnology-derived crops, animal performance and product composition are at least as good as when livestock are fed feeds containing conventional crops. Studies were conducted for swine, beef cattle, dairy cattle, sheep, broilers, catfish, and laying hens (see reviews by Aumaitre et al., 2002; Clark and Ipharraguerre, 2001; Faust, 2002; Faust and Glenn, 2002 for more in-depth discussion of these studies). Further, studies indicate that pork and other livestock products from animals fed biotechnology-derived and conventional crops cannot be differentiated based on composition.

Bt Corn and Mycotoxins

Mycotoxins in corn and other crops are a health concern worldwide. The detrimental effects of mycotoxins can be severe and even fatal for pigs and other livestock and can range from nervous symptom disorders to gangrene in extremities to immune suppression to liver toxicity. Chronic feeding of fumonisins was reported to produce liver and kidney cancer in experimental animals (Munkvold and Desjardins, 1997; US FDA, 2001). However, results from studies have indicated that the use of *Bt* corn for livestock feed may lower exposure of livestock to certain mycotoxins.

Environmental factors such as temperature, humidity, drought stress, and rainfall during pre-harvest and harvest periods influence fungal diseases and mycotoxin contamination in plants (US FDA, 2001). Another factor that contributes to the development of fungal diseases is damage to plants by insect pests. On the other hand, corn that is protected against insect damage, such as varieties of *Bt* corn that express *Bt* protein in kernels, has been shown to have lower levels of mycotoxin-producing fungi such as *Fusarium* and the fumonisin mycotoxins that they produce (Munkvold et al., 1997 1999; Munkvold and Hellmich, 1999). Average fumonisin concentrations for *Bt* varieties were 78-87% lower than levels for conventional genetic counterpart varieties when plants were exposed to high populations of European corn borer larvae (Munkvold et al., 1999). Similarly for fumonisins and other potentially detrimental mycotoxins, researchers in Europe reported that levels of fumonisin, ergosterol, deoxynivalenol and zearalenone were lowest in corn grain from *Bt* as compared to non-*Bt* varieties when plants were exposed to high levels of European corn borer pests (as reviewed in Aumaitre et al., 2002).

Slight advantages for swine and poultry growth performance were reported for several studies when animals were fed *Bt* as compared to non-*Bt* counterpart corn hybrids (Piva et al., 2001a; 2001b). These scientists attributed the performance advantages for animals fed *Bt* crops to the lower levels of mycotoxins detected in the *Bt* corn. In fact, Munkvold and Desjardins (1997) concluded that agricultural biotechnology appears to be the “most attractive” alternative to reduce fumonisin levels in corn. Under conditions that favor mycotoxin development, lower levels of mycotoxins for pest-protected *Bt* crops may be an added health and performance benefit when these grains are fed to livestock.

Are Transgenic Proteins/DNA from Biotechnology-Derived Crops Detected in Pork and Other Animal Products?

Additionally, some have considered whether detection of transgenic proteins and/or DNA in pork and other livestock products from animals fed biotechnology-derived crops will allow them to differentiate these products from similar ones produced by livestock fed conventional crops. Scientifically, detection of these macromolecules is not expected. Studies to investigate these questions have been completed, and the results are that no transgenic proteins or DNA from biotechnology-derived crops have been detected in animal products. To understand clearly these study results and why detection is not expected, it is important to describe the digestive process for proteins and DNA and also to provide details for specific studies that have been completed.

Digestive fate of ingested proteins and DNA

Proteins and DNA are components of virtually all feedstuffs and foods. The DNA comprises the genetic code and so, is found in virtually every cell in plants and animals. Further, DNA in plants and animals universally is comprised of the same four basic units called nucleotides. Thus, the digestive fate of dietary sources of DNA such as naturally occurring DNA from plants, animals, and other organisms and the introduced DNA in biotechnology-derived crops are similar. Further, the United Nations Food and Agriculture Organization, the World Health Organization, and the US Food and Drug Administration have stated that the consumption of DNA from all sources including introduced DNA in biotechnology-derived crops presents no health or safety concerns (FAO/WHO, 1991; US FDA, 1992). These conclusions are based on the long history of safety associated with the consumption of DNA by farm animals and humans.

In general, the digestive tract provides a strong barrier to the absorption of macromolecules such as intact proteins and long strands of DNA. For example, when humans were given specified amounts of the protein ovalbumin, only 0.0007-0.0008% of the administered protein was detectable in their circulation (Tsume et al., 1996). The remainder of the administered ovalbumin was broken down in the digestive tract into small fragments prior to absorption and so, was not identifiable as originating from ovalbumin or from any other protein consumed in the diet. In fact, novel proteins in commercially available biotechnology-derived crops are digested relatively rapidly; for example, stability in a simulated gastric environment was only 30 seconds for the novel protein found in many varieties of *Bt* corn and less than 15 seconds for many other novel proteins in biotechnology-derived crops (AGBIOS, Inc., 2001).

Similarly, digestive enzymes in the digestive tract break down ingested DNA into small fragments prior to absorption. As a result of the digestive process, it is unlikely that transgenic proteins and DNA that are present in biotechnology-derived plants can be detected in blood, tissues, and products when livestock are fed these feeds. Results from several studies conducted in the US, Europe, and Pacific Rim countries for swine, beef cattle, dairy cattle, and poultry confirm this assertion.

Results from livestock studies

When growing swine were fed *Bt* corn (Weber and Richert, 2001) and herbicide-tolerant corn (Cromwell et al., 2001), no biotechnology-derived proteins were detected in samples from loin tissue. Similar results were reported for other livestock species, namely that no biotechnology-derived proteins were detected in milk samples from dairy cows fed green chop *Bt* corn (Faust and Miller, 1997; Faust, 2000) or in samples of blood, liver, and muscle from broilers fed one variety of stacked *Bt* and herbicide-tolerant corn (Anonymous, 2001). When laying hens were fed soybean meal from herbicide-tolerant soybeans, no biotechnology-derived proteins were detected in samples of whole egg, egg white, liver, and feces (Ash et al., 2000).

For transgenic DNA, Weber and Richert (2001) evaluated loin samples from pigs fed Bt corn and reported finding no biotechnology-derived DNA fragments in these meat samples. Similarly, no biotechnology-derived DNA fragments were detected in tissue and fluid samples from growing bulls fed Bt corn (Einspanier et al., 2001) or in tissue samples from broilers fed herbicide tolerant soybean meal (Khumnirdpetch et al., 2001) or stacked Bt and herbicide-tolerant corn (Anonymous, 2001). When dairy cows were fed Bt corn, no transgenic DNA was detected in their milk (Einspanier et al., 2001; Faust and Miller, 1997; Faust, 2000; Phipps et al., 2001) or in other tissue and fluid samples from these cows (Einspanier et al., 2001). Other researchers (Phipps et al., 2002; Klotz and Einspanier, 1998) reported finding no biotechnology-derived DNA in blood, leukocytes, and milk samples when cows were fed herbicide-tolerant soybean meal. In addition, no biotechnology-derived DNA fragments were detected in muscle, liver, spleen, and kidney tissue samples from hens fed Bt corn (Einspanier et al., 2001). Additional details for these studies are provided in several reviews (Aumaitre et al., 2002; Faust, 2002; 2001; Faust and Glenn, 2002; Glenn, 2001).

The overall conclusion from these studies is that no biotechnology-derived DNA or proteins have been detected in pork or other livestock products, tissues, or fluids. Detection methods used for these studies are extremely sensitive; for example, detection limits for one study was 50 ppb for the transgenic protein and approximately 0.000003 ppb for a 210 base pair fragment of the transgenic DNA (Glenn, 2001). However, this same author suggested that the highly sensitive methods used today may be too insensitive to detect levels of these transgenic proteins and DNA that may be present in animal products as estimated from studies using different (naturally occurring) plant source proteins and DNA. Despite the fact that new and more sensitive techniques may yield different results, researchers have stressed that approved biotechnology-derived crops are as safe as conventional crops as a result of the extensive safety testing required for their approval (Beever and Kemp, 2000).

Summary and Implications

The FDA, EPA, and USDA evaluate safety for biotechnology-derived crops as food and feeds in the US. For producing high quality pork, current biotechnology-derived crops are compositionally and nutritionally comparable to non-biotechnology derived counterparts. Further, research studies conducted in the US and worldwide have indicated that performance of swine and other livestock fed biotechnology-derived and conventional crops is not different, and that products of these livestock cannot be differentiated based on compositional and quality measures. Proteins and DNA from feeds including those from biotechnology-derived crops are broken down relatively rapidly in the digestive tract. Furthermore, transgenic proteins and DNA found in biotechnology-derived plants have not been detected in products and tissues from swine and other livestock fed these crops. Thus at this time, pork from swine fed biotechnology-derived

Bt and herbicide-tolerant crops cannot be differentiated from pork produced when pigs are fed conventional crops. In addition, under conditions that favor mycotoxin development, lower levels of mycotoxins for pest-protected *Bt* crops may be an added health and performance benefit when these grains are fed to livestock. Meat, milk, and eggs from swine and other livestock fed biotechnology-derived crops are as wholesome and nutritious as their counterparts when livestock are fed non-biotechnology derived crops.

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