



Feeds from Genetically Engineered Plants – Results and Future Challenges

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The cultivation of genetically engineered plants (GEP) increased worldwide during the last 10 years, up to about 100 million ha yearly. Soybean, maize, rapeseed, and cotton are the predominant crops. These plants, the so-called first generation GEP, are characterized by input traits such as tolerance to pesticides or herbicides, or resistance against insects. They are considered substantially equivalent to their isogenic counterparts because they do not exhibit substantial differences in their composition or their nutritional value.

Second generation GEP are characterized by their output traits, such as an increase in valuable compounds (nutrient precursors, amino acids, fatty acids, vitamins, enzymes, etc.), an improved availability of nutrients, or a decreased concentration of undesirable substances (e.g., phytate, lignin, allergenic substances, etc.).

Nutritional and safety assessment of second generation GEP presents a formidable challenge for animal nutritionists. This article reviews the nutritional and safety assessment of feeds from first generation GEP, and comments on the parameters for assessing second generation GEP.

Feeds from GEP with input traits (first generation)

Most GEP currently under cultivation are first generation, i.e., varieties without substantial changes in composition or nutritive value. Numerous scientific associations and expert panels have proposed guidelines for the nutritional and safety assessment of feeds from first generation GEP (e.g., EFSA 2004, ILSI 2003). Based on these recommendations, nutritional studies with first generation GEP feeds have been undertaken worldwide.

Since 1997, 16 studies were performed at the Institute of Animal Nutrition of the German Federal Agricultural Research Centre (FAL) in Braunschweig to determine the effect of first generation GEP feeds on the nutrition of dairy cows, growing bulls, growing and finishing pigs, laying hens, and chickens for finishing, as well as on the growth and laying characteristics of quail. This research was recently summarized by Flachowsky et al. (2007).

The majority of feeds tested in the studies (e.g., Bt-maize, Pat-maize, and Pat-sugar beet) were grown under conditions similar to their isogenic counterparts in fields at FAL. The composition of feeds was analysed, and animal studies were used to assess nutritional qualities, including parameters such as digestibility, feed intake, health and performance of target animal species, and effects on food quality derived from the animals. Reproduction was also considered in generation studies with quail (20 generations are now completed) and laying hens (4 generations).

Both chemical analyses and the animal studies reveal no significant differences between GEP feeds and their isogenic counterparts (reviewed in **Table 1**) and hence strongly support their substantial equivalence. Our results agree with more than 100 studies published in the literature and reviewed recently (**Table 2**).

Mycotoxin contamination of some GE crops is lower than non-GE, which may be one exception to their substantial equivalence. For example, Bt maize is less severely attacked and weakened by the corn borer and hence might have a greater resistance to field infections, particularly by *Fusarium* fungi, which produce mycotoxins. Evidence of reduced mycotoxin contamination in GE crops has been demonstrated in some but not all cases, as summarized by Flachowsky et al. (2005). In long-term studies, numerous researchers investigated the influence of levels of corn borer infestation of isogenic and Bt hybrids on mycotoxin contamination. Most researchers concluded that a lower level of mycotoxin contamination was observed in the transgenic hybrids, despite the considerable geographical and temporal variation observed.



Table 1: Analyses of feeds from first generation GE crops (Federal Agricultural Research Centre; Flachowsky et al. 2007)

GMP	Analytical measurements	Animal Species/categories	Type of Study	Animal number (isogen/transgene)	Duration (days)	Results (comparison to isogenic plants)			
						Composition of GM-feeds	Digestibility	Zootechnical parameters	Further measurements
Bt-maize Grain	Crude nutrients, Amino acids, Fatty acids, NSP, Minerals	Growing and fattening pigs	Digestibility	3 times: 6/6	14	NS	NS	-	-
	Mycotoxins		Growing/fattening	12/36	91	NS	-	NS	Slaughtering data, Fate of DNA
	Crude nutrients	Growing pigs	Digestibility	5/5	14	NS	NS	-	-
	Crude nutrients, Starch, NSP, Amino acids, Fatty acids, Minerals	Laying hens	Digestibility, measuring of performance	6/6	10	NS	NS	NS	Fate of DNA
	Crude nutrients	Broilers	Digestibility	6/6	5	NS	NS	-	-
	Crude nutrients	Broilers	Growing	9/27	35	NS	-	NS	Fate of DNA
	Crude nutrients, Starch, Amino acids, Fatty acids	Growing and laying hens	10 generations (growing, laying) presently 20th generation	Growers 140/140	10 times: 42	NS	-	NS	Reproduction, Fate of DNA
			Layers 32/32	42	NS	-	NS		
	Crude nutrients, Starch, Amino acids, Fatty acids	Growing and laying hens	4 generations (growing, laying)	Growers 200/200	4 times: 126	NS	-	NS	Reproduction
Layers 32/32			91	NS	-	NS			
Bt-maize Silage	Crude nutrients	Growing and fattening bulls	Growing/fattening	20/20	246	NS	-	NS	Slaughtering data, Fate of DNA
	Crude nutrients	Sheep	Digestibility	4/4	24	NS	NS	-	-
Bt-potatoes	Crude nutrients	Broilers	Growing	9/18	21	NS	-	NS	Fate of DNA
Pat-maize	Crude nutrients, Starch, Sugar, NSP, Amino acids, Fatty acid	Pigs	Digestibility	5/5	14	NS	NS	-	-
Pat Sugar beets	Crude nutrients, Sugar	Sheep	Digestibility	4/4	24	NS	NS	-	-
		Pigs	Digestibility	5/5	14	NS	NS	-	-
	Crude nutrients, Sugar	Sheep	Digestibility	4/4	24	NS	NS	-	-
Roundup Ready soybeans	Crude nutrients, Starch, Amino acid Fatty acids, Minerals	Pigs	Growing/fattening	12/36	40	NS	-	NS	Slaughtering data, Fate of DNA



Table 2: Experiments comparing first generation GE feeds with isogenic counterparts (adapted by Flachowsky et al. 2005)

Animal (Species/categories)	Number of experiments	Nutritional assessment
Ruminants		No unintended effects in composition (except lower mycotoxins concentration in Bt plants)
Dairy cows	23	
Beef cattle	14	
Others	10	
Pigs	21	No significant differences in digestibility and animal health as well as no unintended effects on performances of animals and composition of food of animal origin
Poultry		
Laying hens	3	
Broilers	28	
Others (Fish, rabbits etc.)	8	

Feeds from GEP with output traits (second generation)

Second generation GEP are characterized by either:

an *increased* content of desirable/valuable traits, such as

- Nutrient precursors (e.g., β -carotene)
- Nutrients (amino acids, fatty acids, vitamins, minerals, etc.)
- Substances which may improve nutrient digestibility (e.g., enzymes)
- Substances with surplus effects (e.g., prebiotics)
- Improved sensory properties/palatability (e.g., essential oils, aromas)

or a *decreased* content of undesirable substances, such as

- Inhibiting substances (e.g., lignin, phytate)
- Toxic substances (e.g., alkaloids, glucosinolates, mycotoxins).

At present, detailed standardized test procedures are not generally available to analyze feeds from second generation GEP. Possible approaches for testing those feeds were recently reviewed by Flachowsky and Böhme (2005). Recommendations for nutritional and safety assessment of feeds from second generation GEP are being developed by EFSA and ILSI.

The following points should be considered when making a nutritional assessment of second generation GEP feeds. Feeds with intended beneficial physiological properties relating to amino acids, fatty acids, minerals, vitamins, and other substances may contribute to higher feed intake of animals and/or improved conversion of feed/nutrients into food of animal origin. Furthermore, the excretion of nitrogen, phosphorus, and other nutrients may be reduced. Consequently, depending on the claimed difference due to the genetic modification, the experiment must be designed to demonstrate these effects. Specific, targeted experimental designs are necessary to show the efficiency of the following altered nutrient constituents:

- Bioavailability or conversion of nutrient precursors into nutrients (e.g., β -carotene).
- Digestibility/bioavailability of nutrients (e.g., amino acids, fatty acids, vitamins).
- Efficiency of substances which may improve digestibility/availability (e.g., enzymes, reduced phytate).
- Utilization of substances with surplus effects (e.g., prebiotics).
- Improvement of sensory properties/palatability of feed (e.g., essential oils, aromas).
- Lower content of undesirable substances should be demonstrated in animal health and/or performance.

Genetic modifications may be associated with side effects (Cellini et al. 2004), and the larger the modification, the greater the chance of inducing secondary changes. As the basis for comparative approaches, special animal studies seem to be necessary to examine these questions. Therefore the nutritional and safety assessment of feeds from second generation GEP is a significant challenge for animal nutritionists.

The fate of transgenic DNA and transgenic proteins

The consumption of feeds from GEP results in the intake of transgenic DNA and proteins; therefore, studies were conducted on their fate within the gastrointestinal tract of animals, and the potential to which extent transgenes or their products may be incorporated into animal tissues. Studies in this area were excellently reviewed recently by Alexander et al. (2007).

Results on the fate of transgenic DNA in feeds can be summarized as followed:

- DNA is a permanent part of food/feed
(daily intake: human: 0.1 – 1 g; pig: 0.5-4 g; cow: 40-60 g).



- Transgenic (t) DNA intake amounted to ≈ 0.005 % of total DNA-intake, if 50 % of the diet comes from GE crops.
- DNA is mostly degraded during conservation (silage making) and industrial processing, as well as in the digestive tract (pH, enzymes).
- Small fragments of DNA may pass through the mucosa and may be detected in some body tissues (especially leucocytes, liver, and spleen).
- Fragments of high-copy number genes from plants have been detected in animal tissues to a higher extent than from low-copy numbers.
- No data exists showing that tDNA is characterized by unique behavior compared to native plant-DNA during feed treatment and in animals.

The fate of novel proteins in feed from GEP consumed by animals has also generated interest arising from consumers questions. Results from studies can be summarized as follows (see also Alexander et al., 2007):

- In ruminant feed, proteins are mostly degraded in the rumen, and microbial and by-pass proteins are degraded by enzymes in the smaller intestine, similar to non-ruminants.
- The chemical and physiological properties (including microbial and enzymatic degradation) of novel proteins have been intensively tested.
- Intact novel proteins have not been detected outside of the digestive tract in target animals (also not in animal tissues and products).
- There is no evidence that novel proteins are characterized by unusual chemical/physical properties distinct from native protein.

Conclusions

From the data presented above, the following conclusions can be drawn:

- Presently, over 500 million hectares of GE crops have been cultivated worldwide.
- Most animal studies have been done using first generation GE crops.
- No unintended effects in composition (except lower mycotoxins) or nutritional assessment of feeds from first generation GE crops were registered in any of the more than 100 studies with food producing animals.
- Novel experimental designs are necessary for the nutritional and safety assessment of feeds from second generation GE crops.
- Transgenic DNA and novel protein do not demonstrate unique properties during feed treatment or in animals.
- Case by case studies are necessary to answer open questions.

References

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