Introduction to Safety Assessment of Foods from Genetically Engineered Plants

Jason Dietz

Office of Food Additive Safety

Center for Food Safety and Applied Nutrition

Food and Drug Administration

Conflict of Interest Statement

- As a federal employee, I have no conflicts of interest to declare.

Outline

- Background
- Producing a genetically engineered (GE) plant variety
- Whole foods as mixtures
- Safety assessment

Photo courtesy of USDA Agricultural Research Service.

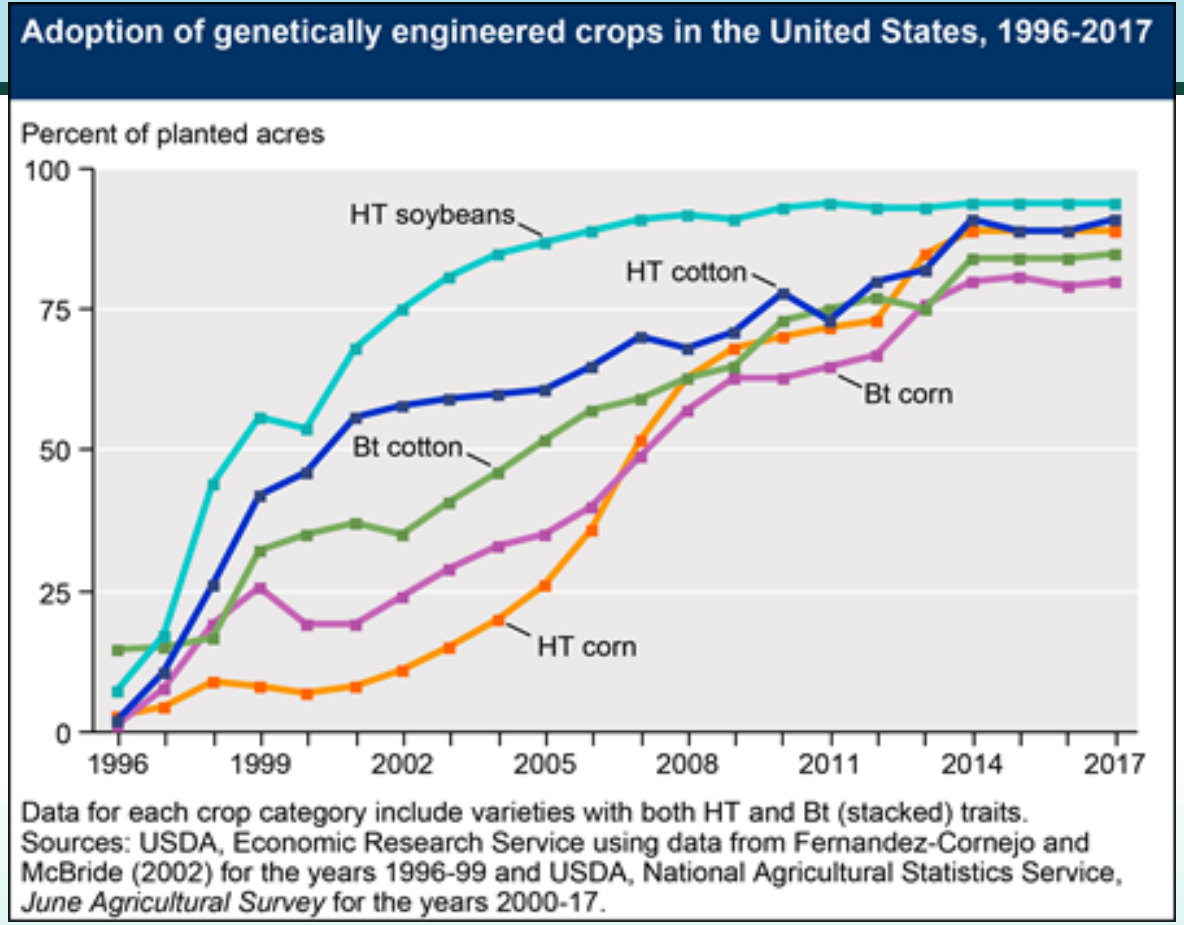
Background

Photo courtesy of USDA Agricultural Research Service.

Some foods from genetically engineered plants commonplace in the US food supply:

Corn	Soy
Canola	Cotton (cottonseed oil)
Sugar beets	Papaya
Potatoes	Apple
Squash	Alfalfa

Background

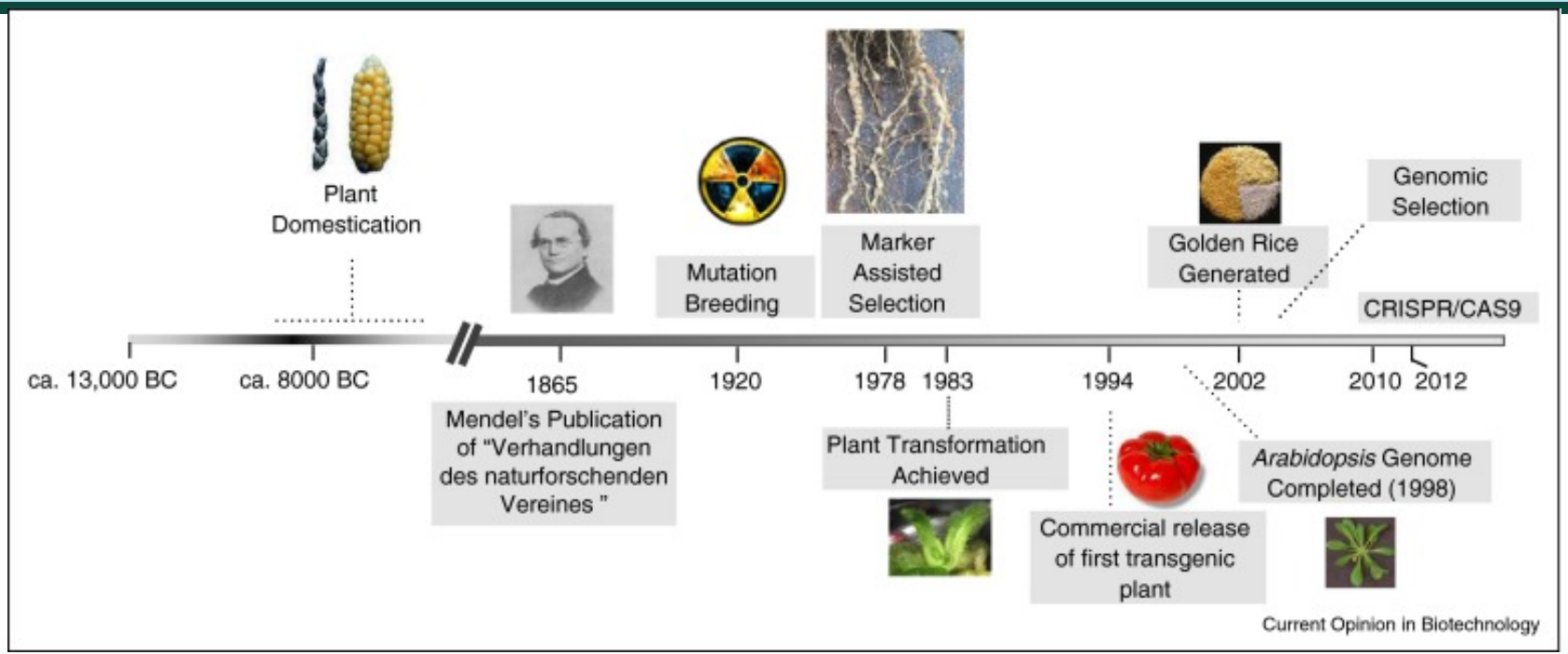


https://www.ers.usda.gov/data-products/adoption-of-genetically-engineered-crops-in-the-us/recent-trends-in-ge-adoption/

Producing a GE Plant Variety

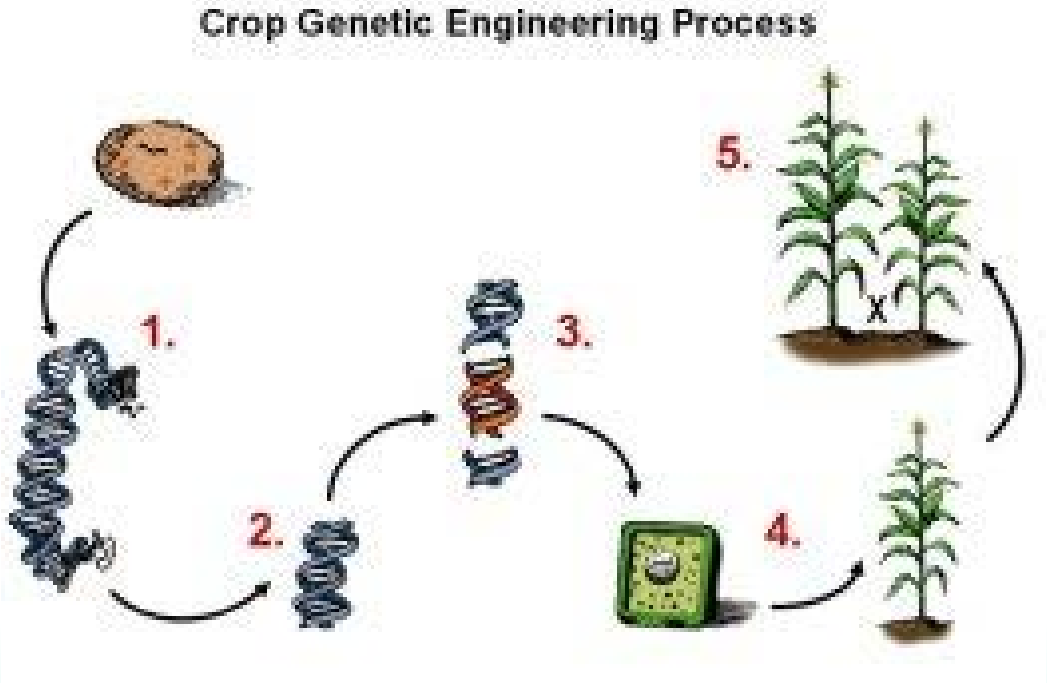
Photo courtesy of USDA Agricultural Research Service.

Producing a GE Plant Variety



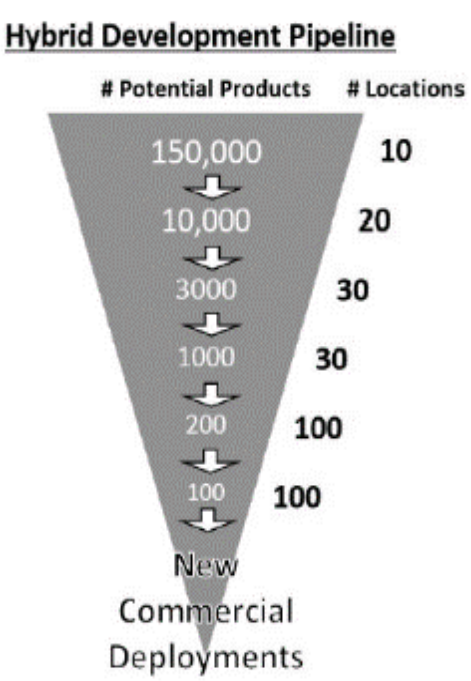
Reprinted from *Current Opinion in Biotechnology,* 44, Francis, D., Finer, J. J. and Grotewold, E., "Challenges and opportunities for improving food quality and nutrition through plant biotechnology," 124-129, Copyright 2017, with permission from Elsevier.

Producing a GE Plant Variety



https://cropwatch.unl.edu/biotechnology/makinggmo

Producing a GE Plant Variety



Young Plant

Percent emergence
First leaf shape
Plant vigor[1]
Seedling height
Seedling color

During Pollination

Pre-anthesis brittle snap
Pre-anthesis root lodging
Density of spikelets
Glume color
Anther color
Leaf color
Silk color
Days to pollen shed[2]
Days to silking[2]

Post Pollination

Brace root color
Stalk anthocyanin
Internode direction
Internode length
Leaf sheath pubescence
Husk color fresh
Plant height
Ear height
Stalk diameter
Nodes with brace roots
Leaf angle
Upper leaf number
Ear leaf length
Ear leaf width
Tassel length
Tassel spike length
Tassel peduncle length
Tassel branch number
Ear position
Ears per stalk
Days to husk opening[2]
Husk color dry
Husk cover
Husk length

At Harvest

Ear length
Ear shape
Ear weight
kernel rows
kernels per row longitudinally
Ear diameter
Cob diameter
Cob color
Kernel length
Kernel width
Kernel thickness
Kernel row direction
Kernel type
Kernel cap color
Kernel side color
Endosperm color
Endosperm type
100 kernel weight

Glenn et. al., (2017) *Crop Science, "Bringing New Plant Varieties to Market: Plant Breeding and Selection Practices Advance Beneficial Characteristics while Minimizing Unintended Changes"* 57:2906-2921.

Assessing the Safety of Whole Foods

Photo courtesy of USDA Agricultural Research Service.

Whole Foods are Mixtures

- Whole foods are complex mixtures.
  - Thousands of compounds
    - Structural compounds
    - Energy use and storage
    - Defense against pests
    - Abiotic stress response
  - Variation with growth stage, environment, weather conditions, genetic background, etc.

Photo courtesy of USDA Agricultural Research Service.

Whole Foods are Mixtures

- Over millennia humans have identified plants that are safe to eat and those that are not.
  - While there may be varietal changes in foods, such changes typically have not resulted in food safety or nutritional concerns.

Photo courtesy of USDA Agricultural Research Service.

Whole Foods are Mixtures

- When foods have characteristics of concern they are generally well known and well managed.
  - Glycoalkaloids in potatoes
  - Lectins in soybeans
  - Cyanogenic glycosides in cassava
  - Erucic acid in canola
  - Cucurbitacins in squash

Photo courtesy of USDA Agricultural Research Service.

Whole Foods are Mixtures

- Plant breeding and food processing interventions can mitigate these concerns.
  - For example:
    - Plant breeders screen potato cultivars to assess glycoalkaloid levels.
    - Cassava is routinely cooked before consumption.
    - Lima beans are soaked before cooking.

Whole Foods are Mixtures

- How do we assess the safety of new food varieties while leveraging centuries of experience developing varieties that produce safe food?

Comparative Approach

- A comparative approach is used to assess the safety of foods from genetically engineered (GE) plants.
- This approach involves comparing safety-related aspects of food from a GE plant to those of a non-GE (conventional) counterpart.
  - “a long history of use is a reassuring and practical starting point’’ for evaluating the safety of a novel food (OECD, 1999).

OECD, 1999. “GM Food, Regulation and Consumer Trust.” OECD Observer No. 216. Organisation for Economic Co-operation and Development, Paris, p. 21.

Comparative Approach

- A comparative approach is used because traditional toxicology studies in animals are not readily applicable to whole foods.
  - Whole foods are complex mixtures.
  - Because of their bulk and satiety they can only be fed to laboratory animals at low multiples of amounts present in the diet.
    - Bulk may make it difficult to obtain a nutritionally balanced lab diet.
  - Detecting effects and attributing them to a particular component of food is difficult.

Comparative Approach

- The comparative approach is widely accepted.
  - In 2003, Codex Alimentarius adopted “Guideline for the Conduct of Food Safety Assessment of Foods Derived from Recombinant-DNA Plants CAC/GL 45-2003” (Codex Plant Guideline) which is based on the comparative approach.
    - Annexes 2 and 3 were adopted in 2008.

Comparative Approach

- Differences identified during comparison of the GE food with its conventional counterpart are evaluated for their importance in terms of food safety and/or nutrition.
  - Consideration of these differences may lead to additional studies or analyses to address food safety or nutritional concerns associated with such differences.
- The comparative approach results in an assessment of whether food from the new variety is *as safe and nutritious as* food that has historically been safely consumed.
  - Recognizing that no food is absolutely safe.

Data and Information Typically Considered in a Safety Assessment

- Safety assessment components
  - Molecular characterization
  - Safety of newly expressed substances
  - Levels of key nutrients, anti-nutrients, and toxicants in food from the plant
    - Assessment of unintended effects relevant to food safety or nutrition

Molecular Characterization

- Molecular characterization provides data and information about the newly inserted DNA and characterizes any products expressed from the inserted DNA.
- Molecular characterization typically considers questions such as:
  - What DNA has been inserted?
  - What are the sources, identities and functions of the inserted DNA?
  - What products are expressed from the inserted DNA?

Molecular Characterization

- Is the inserted DNA stable across multiple generations?
  - Is its molecular organization maintained across generations?
  - Is it inherited in a predictable fashion (e.g., Mendelian inheritance)?
- Information gained through molecular characterization can help guide subsequent steps in the safety assessment. This information can help focus the assessment of the newly expressed substance(s) and analyses for unintended effects related to food safety or nutrition.

Safety of the Newly Expressed Substances

- Safety assessments consider the potential for toxicity and allergenicity of the proteins encoded from the inserted DNA and any secondary products.
  - For example, if the expressed substance(s) is an enzyme, the assessment considers the safety of the enzyme(s) and its reaction product(s).

Levels of Key Nutrients, Anti-nutrients and Toxicants in the Food

- What are the key nutrients, anti-nutrients and toxicants in the food being evaluated?
  - The key nutrients, anti-nutrients and toxicants depend upon the specific food being considered.
- Have the levels of these substances been changed in a way that would make the food less safe or less nutritious than comparable food?
- Any other information relevant to the safety and nutritional assessment of the food.

New Techniques

- New chemistry-based techniques have been proposed for use as part of the food safety assessment.
  - Modern chemical techniques can simultaneously measure the levels of many metabolites in a sample (metabolomics).
- Some have suggested that this could become a component of the food safety assessment.

New Techniques

- What would use of metabolomic techniques mean for food safety assessment?
  - What kinds of considerations would be important when considering their use and data derived from them?
  - Would they routinely add meaningful value to the assessment?

Our Next Speakers

1. How much do plants vary naturally in terms of their composition?
2. What is metabolomics and how has it been used and what are some factors to consider?
3. What would metabolomic data add to the food safety assessment as currently performed? How would such data be used?

References

- Codex Alimentarius Commission (2003) “Guideline for the Conduct of Food Safety Assessment of Foods Derived from Recombinant-DNA Plants CAC/GL 45-2003.” Updated in 2008.
- Francis et al., (2017) “Challenges and opportunities for improving food quality and nutrition through plant biotechnology.” *Current Opinion in Biotechnology,* 44:124-129.
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- Organisation for Economic Co-Operation and Development (OECD), 1999. “GM Food, Regulation and Consumer Trust.” *OECD Observer* No. 216, p. 21. Paris.