Unintended Effects

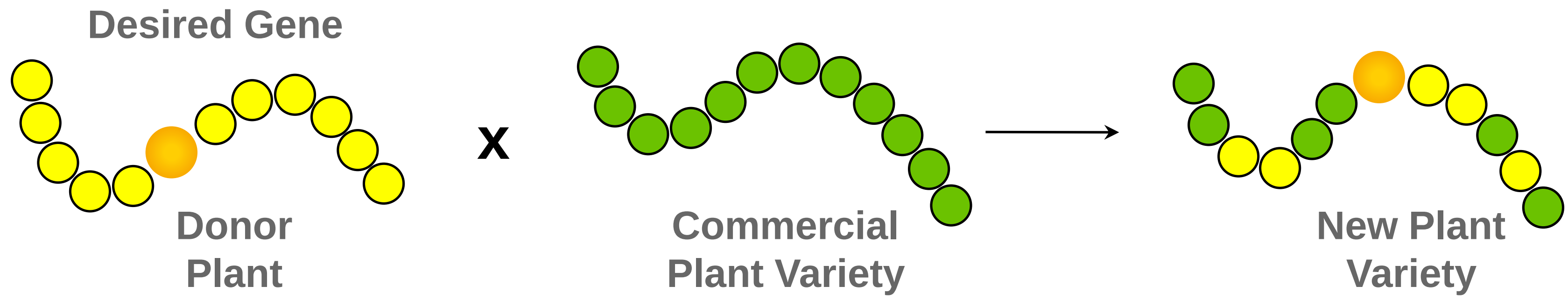
24 October, 2018

Contents

Biotechnology is an extension of traditional plant breeding

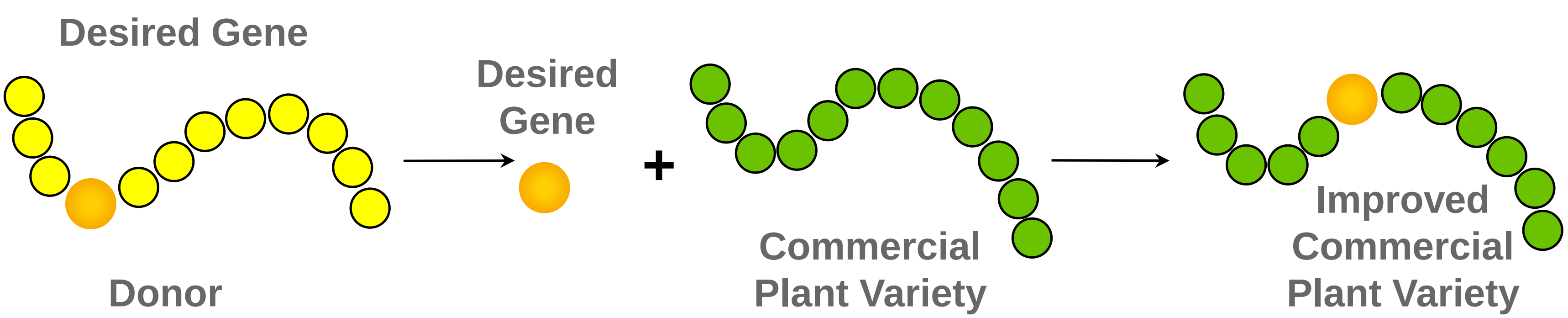
Traditional plant breeding

Many genes are transferred



Plant biotechnology

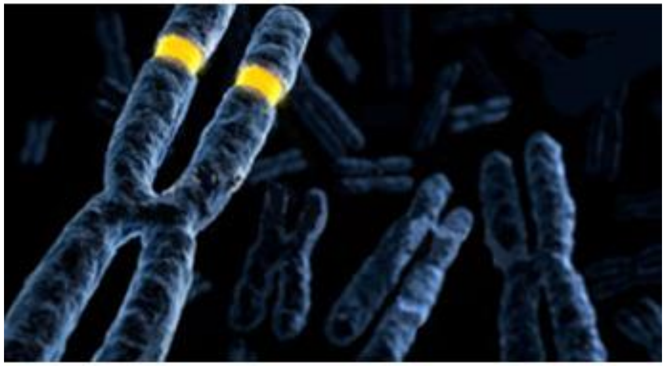
A single gene is transferred



General Unintended Effects

GM-insertional effects are assessed based on molecular information but…

insertional effects are not limited to those encountered as a result of genetic engineering and should present a similar level of risk.



Schnell, J. et al. (2015) A comparative analysis of insertional effects in genetically engineered plants: considerations for pre-market assessments. Transgenic Res. 24, 1-17.

Table 1. Examples of naturally occurring genetic changes common in plants and the resulting characteristic.

Genetic change	Genotypic or phenotypic example	Reference
Transposable elements (transposons)	White grapes, blood oranges	Lisch (2013)
	>25,000 unique insertions detected across 31 varieties of soybean	Tian et al. (2012)
	Yellow maize	Palaisa et al. (2003)
	>50 new inserts of a transposon per rice plant per generation	Naito et al. (2006)
	Elongated tomato fruit	Xiao et al. (2008)
	Round or wrinkled peas (Mendel)	Ellis et al. (2011)
	2 million transposons exchanged between higher plants	El Baidouri et al. (2014)
Organellar DNA in nuclear DNA	Gain and loss of mitochondrial DNA common to maize inbred lines	Lough et al. (2008)
	Gain and loss of chloroplast DNA common to maize inbred lines	Roark et al. (2010)
Bacterial genes	Expression of several bacterial genes in sweet potatoes	Kyndt et al. (2015)
Crossing with wild relatives	>60 wild relatives have been used for >100 characteristics (80% involve pest or disease resistance) in 13 crops	Hajjar and Hodgkin (2007)
	Dozens of alien genes used in wheat breeding	Jones et al. (1995)
Pararetroviruses	Stable viral DNA in rice genome	Liu et al. (2012)
	Stable viral DNA in tomato (previously also seen in potato)	Staginnus et al. (2007)
Florendoviruses	Stable integrations in all plants	Geering et al. (2014)
Insertions and deletions	Submergence-tolerant rice	Xu et al. (2006)
	Dwarf sorghum	Multani et al. (2003)
	Yellow soybean seeds	Tuteja et al. (2004)
Single-nucleotide polymorphisms (SNPs)	Maize proteins (300–400 amino acids long) from 2 alleles differ by 3–4 amino acids	Tenaillon et al. (2001)
	Maize genome has 55 million SNPs	Gore et al. (2009)
	Green Revolution gene has 2 SNPs for dwarf wheat	Peng et al. (1999)
	One SNP caused loss of shattering in domestic rice	Konishi et al. (2006)
	Tall or short pea plants (Mendel)	Ellis et al. (2011)
	7 new SNPs created per meiosis per billion base pairs	Ossowski et al. (2010)
Presence, absence, or copy number of genes	856 wild-type soybean genes absent in cultivated varieties (and >186,000 DNA insertions or deletions)	Lam et al. (2010)
	$>10^6$ SNPs, 30,000 insertion or deletions, and a few large chromosomal deletions (>18 genes) in 6 elite maize varieties	Lai et al. (2010)
	Copy number variation relates to soybean cyst nematode resistance	Cook et al. (2012)
	Pinot Noir, Corvina, and Tannat wine grapes have 1873 genes not found in other wine grapes	Da Silva et al. (2013)
	Only 81% of *Brassica* genes are always present in the same number	Golicz et al. (2016)
	2500 genes found only in either B73 or PH207	Hirsch et al. (2016)
	G. soja genotypes can vary by 1000 to 3000 gene families from each other	Li et al. (2014)

Unintentional effects may occur during conventional breeding

Selected

Wild watermelon
Judging by paintings of the fruit dating to the 17th century, watermelons may have once had seeds arranged in **swirly geometric patterns.**

Modern watermelon
Over time, humans have bred watermelons to have a **bright red**, juicy interior. The **seeds are often removed** by preventing the plants from being fertilized by pollination.

Wild carrot
The first carrots were likely cultivated around the 10th century in Asia Minor and were either **white or purple** with thin, forked roots and a **strong flavor.**

Modern carrot
Carrots today are large, **bright orange,** and tasty.

Wild banana
The first bananas may have been cultivated at least **7,000 years ago** in what is now Papua New Guinea, and were **stocky and hard,** with large, tough **seeds** throughout the fruit's interior.

Modern banana
Today's tastier bananas are **hybrids** of two wild banana varieties, **Musa acuminata** and **Musa balbisiana.**

Unintended

Changes in Composition of Maize

420 M.P. SCOTT, J.W. EDWARDS, C.P. BELL, J.R. SCHUSSLER, J.S. SMITH

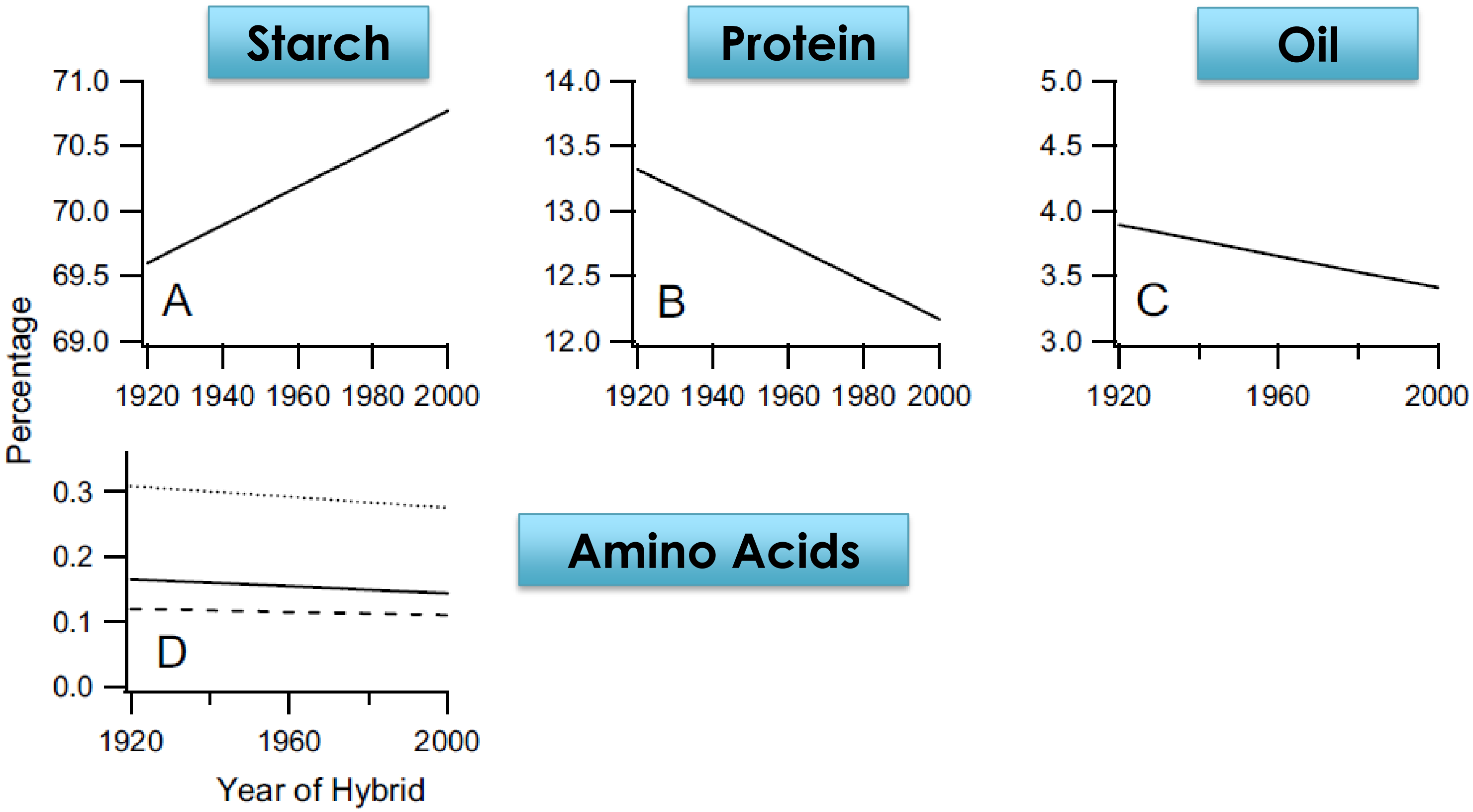
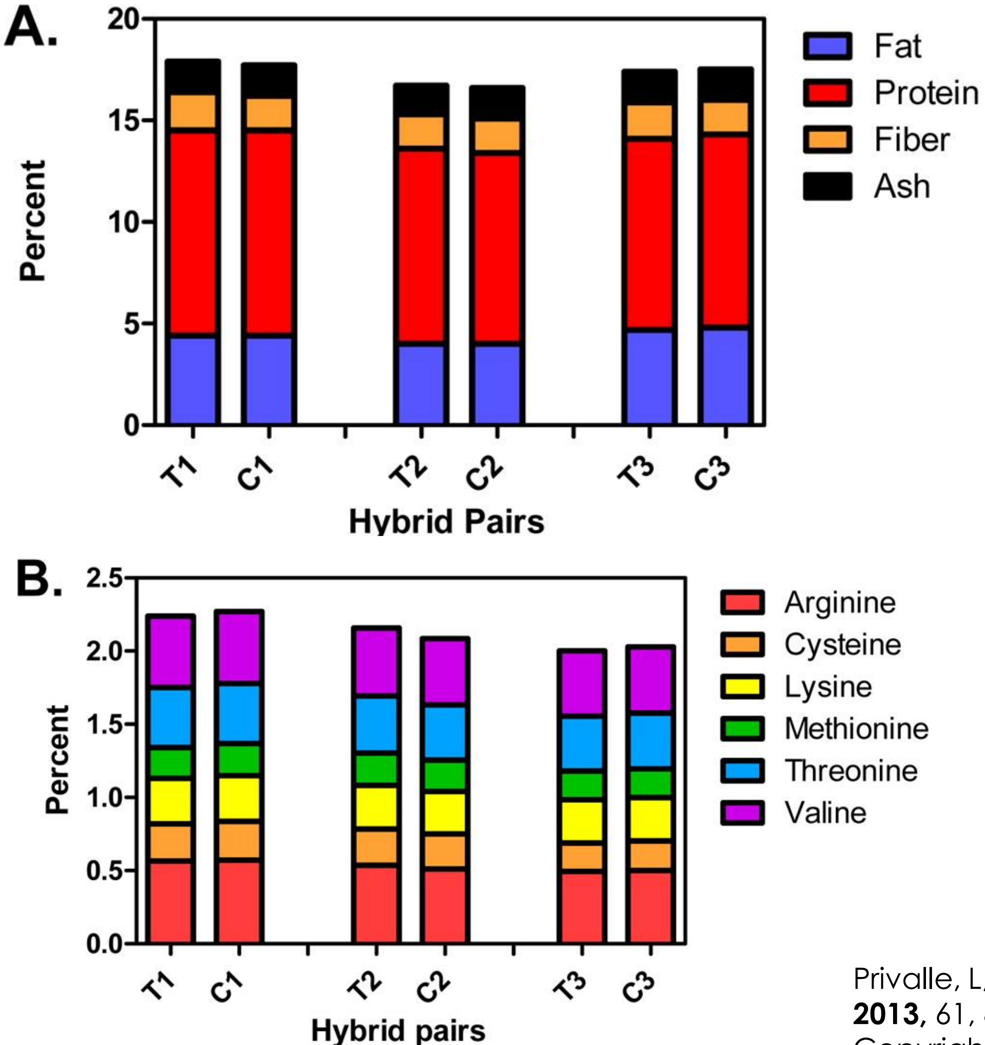


FIGURE 1 - Grain composition of the era hybrids produced averaged across environments and plant densities. Lines are fit to data plotted as percentage of the tissue mass of each component. A. Starch; B. Protein; C. Oil; D. Amino acids; dotted line, lysine; solid line, tryptophan; dashed line, methionine. Slopes and standard errors for these data are presented in Table 3.L.

Maydica (2006) 51: 417-423

Impact of Germplasm Background
1 event, 1 location



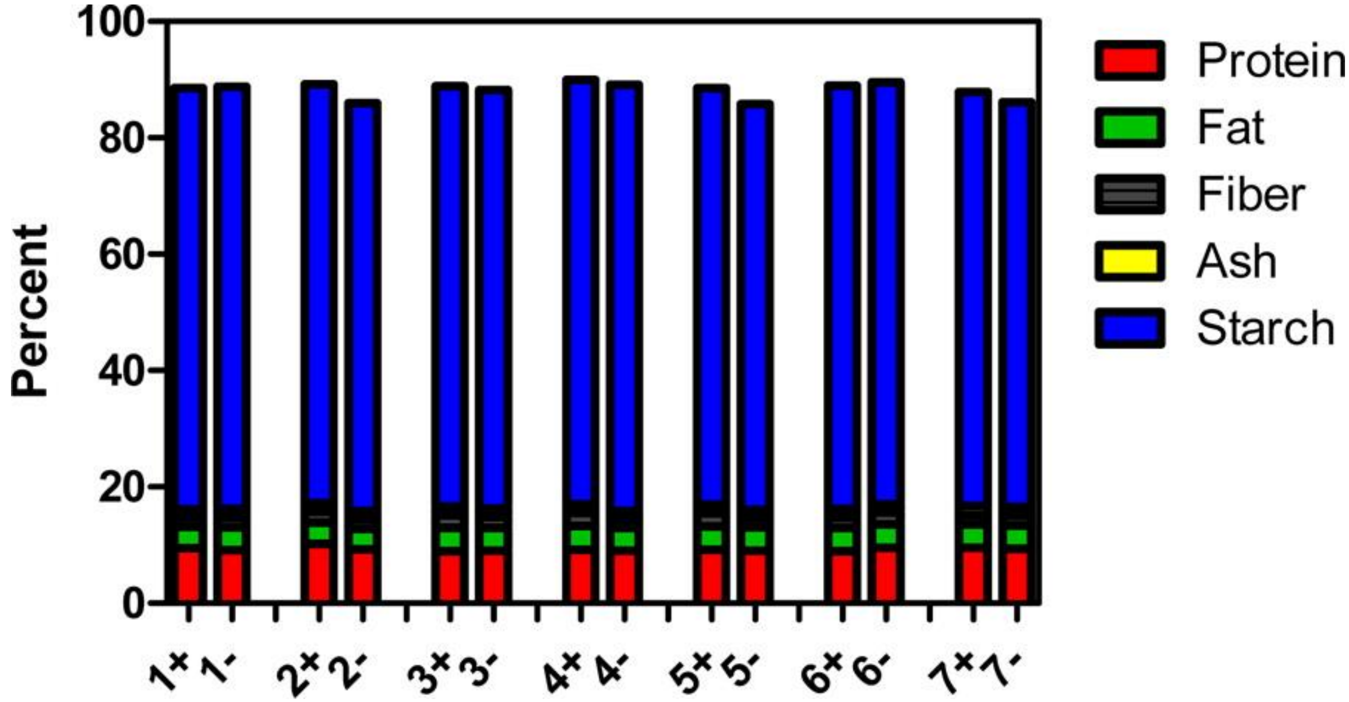
Variations in composition related to germplasm background and **NOT** to transgensis

Privalle, L, Gillikin, N, Wandelt, C. *J. Agric. Food Chem.* **2013**, 61, 8260-8266.DOI: 10.1021/jf400185q

Impact on Proximate/Fiber

Multiple Events Same Construct

1 location



No impact related to gene regardless of insertion site

ILSI Research Foundation

ILSI Crop Composition Database

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Version 1 released in 2003

Version 6 current version released in 2016, Version 7 EOY 2018

Publicly available

972,000 data points. 195 analytes

Only **Conventional** data included

8 crops (maize, soybean, cotton, potato, canola, sorghum, sweet corn, rice)

Searchable

	Endpoint	Paoletti et al.	CCDB
Maize	Amino acids	1997	6567
Soybean	Amino acids	1655	5025

History of Safe Use

- How long is long enough?
- What is the main use of these crops?

ANIMAL FEEDING

Commercial cultivation of genetically modified (GM) plants has been conducted for more than 20 yr. Over this period of time, studies on the feeding of GM crops to animals were also conducted to evaluate the potential impact. The evidence revealed that animal studies feeding GM crops did not present adverse effects.

Flachowsky (2017) Future challenges feeding transgenic plants. Animal Frontiers 7, 15-23




History of Safe Use – Over 20 years

Table 3. Estimated cumulative number of livestock raised in the United States during the period from 2000 to 2011

Industry[1]	United States
Broilers	94,683,600,000
Layer Hens	3,722,708,000
Turkeys	2,733,500,000
Beef cattle	339,350,000
Dairy Cows	33,550,000
Hogs	1,219,460,000
Total	102,732,168,000

[1]Numbers for broilers, hogs (barrows and gilts), and beef cattle (steers) are for slaughtered animals during calendar year. Dairy animals are number of dairy cows in a calendar year divided by 3 to account for 3 lactations per animal.

Van Eenennaam, A. L. and Young, A. E. Prevalance and impacts of genetically engineered feedstuffs on livestock populations J. Animal Science (2014) 92:4255-4278

Broiler Production Statistics

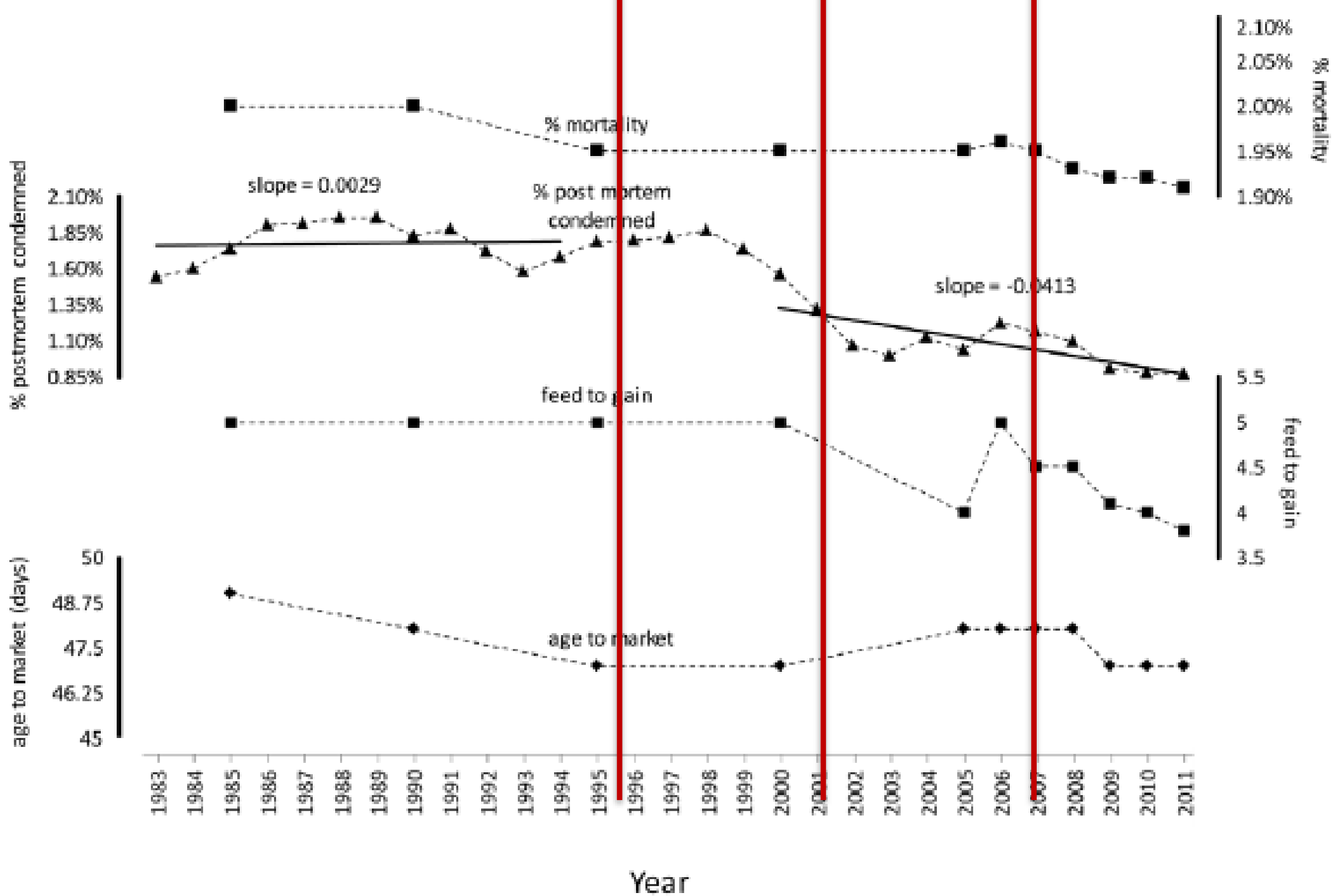

Figure 2. United States broiler statistics before and after the introduction of genetically engineered crops in 1996. Sources: USDA National Agricultural Statistics Service, 2013; National Chicken Council, 2011. Slope differs between time periods 1983 through 1994 and 2000 through 2011 ($^*P < 0.05$).

Important Animal Statistics

- All health parameters have improved in both dairy, cattle and poultry industries since the introduction of biotech products
- An estimated 24 consecutive generations of broilers have been consuming biotech feed 2000 -2011
- Through 2017 it is now **38** consecutive generations

Learnings

- Selection is a key step in both conventional and GM crop breeding
  - The plant genome is dynamic – there is extensive documentation of changes occurring in nonGM plants
- No adverse unintended impacts of GM crops due to the transformation process have been observed.
- >20 years of animal feeding on agbiotech crops no negative impact on animal production statistics

Can we build on what we've learned and focus on relevant endpoints?