PHC 4573
Foundations of Food Safety

Genetically Modified Organisms (GMOs)

Lecture 13

Lecture Objectives

- Define GMOs.
- List the types and uses of GMOs.
- Describe the advantages of using GMOs for food production, sustainability, and health.
- Explain the opposition to GMOs in foods with respect to health, the environment, and labeling.
- Recognize shortfalls in current regulation of GMO crops.

What is a GMO (Genetically Modified Organism)?

- GMO = an organism whose DNA has been altered by genetic engineering:
  - Upregulating/downregulating genes
  - Adding genes from related species
  - Adding genes from unrelated species
  - Deleting genes
  - Silencing genes
  - CRISPR
  - Etc.
- Can include all of the following:
  - Plants
  - Animals
  - Microorganisms
  - Humans

GloFish contain genes from jelly fish and other marine animals.

Genetic Modification – Plants

- Herbicide resistance:
  - Corn
  - Soy
  - Cotton
  - Canola
  - Rice
  - Alfalfa
  - Beet (sugar)
  - Flax

NOTE: Many GMOs have more than one of the above (also known as stacked technology).

- Insect resistance:
  - Corn
  - Cotton
  - Potato
  - Tomato
- Sterile pollen:
  - Corn
  - Chicory
- Virus resistant:
  - Papaya
  - Squash
  - Plum

Forbes.com

Genetic modification - Plants

- Delayed ripening:
  - Tomato
- Altered oil:
  - Canola
  - Soy
- Altered protein composition:
  - Corn
  - Wheat
- Reduced nicotine:
  - Tobacco
- Prevent bruising:
  - Potato

Dr. Francisco Barro – his laboratory used RNA silencing to produce a reduced gluten wheat.

Genetic Modification - Plants

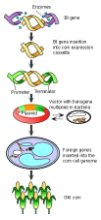
- Allergen removed/reduced:
  - Soybean
  - Tomato
  - Apple
  - Rice
  - Peanut – an allergy-free peanut is currently waiting approval.
- Toxin removed/reduced:
  - Cassava

ABCNews: 19 year old college freshman dies after eating cookie which contained trace amounts of peanut oil.

How to Make a GMO Plant??

NO!!!

YES!!!



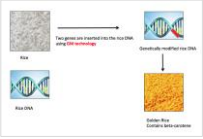
Science Creative Quarterly

Genetically Modified Corn

- Resistant to glyphosate (Roundup®) herbicide.
  - Enables farmers to kill weeds with Roundup® without killing their crops.
- Roundup® blocks an enzyme (EPSP) synthase required for growth.
  - GMO corn contains a gene to boost EPSP synthase, resulting in resistance to Roundup®.
    - The gene is usually derived from bacteria.
- The net result is that the farmer can spray crops with Roundup and kill weeds but the corn will not die.

Should we ban GM plants?

- Monsanto (aka MonSATAN) produces Roundup Ready corn.
- Do we really need more corn?



Source: Generationgreen.com

Golden Rice

- Engineered to produce β-carotene, a precursor to vitamin A.
- Vitamin A deficiency is a disease of poverty and poor diet.
  - 1.9-2.8 million preventable deaths annually
- Death is preventable by ingesting a few ounces of Golden Rice daily.
- Seeds are free of charge to resource-poor farmers.
- *Science Vol. 341 20 Sept 2013*

Golden Rice – Predicted Benefit

- Estimated worldwide welfare gains of over $15 billon per year.
  - India
  - Asia
    - Projected 2% growth in national income.
- As many as 2.8 million lives could be saved.
- "Stacked" technology would allow vaccinations to be delivered with the same rice.
- *Qaim, New Biotechnology (2010) Vol 27(5): 552-7*

Rotavirus Antibody in Rice

- Rice has been engineered to contain antibody against rotavirus.
- Rotavirus is the leading cause of severe diarrhea in infants and young children.
  - 520,000 deaths annually.
- Rice is intended to complement the vaccine which is less effective in developing countries due to weakened immune systems.
  - Rice is very stable.
- *Tokahara et al. J Clin Invest. 2013 Sep 3;123(9):3829-38*

Closer to Home – Peanut Allergies


GENETICALLY MODIFIED PEANUTS COULD SAVE LIVES

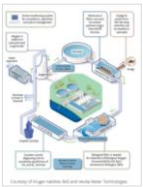
GENETICALLY ENGINEERED PEANUTS may help fight the most common cause of fatal allergic reactions to food in the United States. While the research is unlikely to result in the

Peanut Allergy

- Peanuts are the most common cause of severe or fatal food allergy:
  - 200 deaths per year in the US.
- Transgenic peanuts were produced in which the gene responsible for the allergy was silenced.
- When tested against sera from allergic patients, no reaction occurred.
- *Dodo et al. (2008). Plant Biotechnol. J. 6:135-145*

Genetically Modified - Animals

- Faster growth, longer growing season.
  - Atlantic Salmon
- Disease prevention.
  - Cows
- Disease treatment.
  - Goats
  - Rabbits
  - Chickens



Aquabounty's sustainable fish farm.

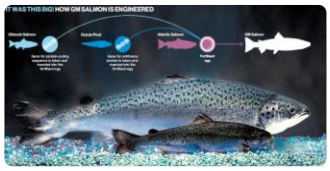
AquAdvantage Salmon

- Atlantic salmon were genetically modified to produce fish that reach market size in 16-18 months rather than 3 years.
- Genes from other fish are inserted to modify a growth hormone, resulting in faster growth.
- These fish are exclusively farmed.

How to make GM Salmon

NO!!!

YES!!!



Independent.co.uk

Genetically Modified Cows

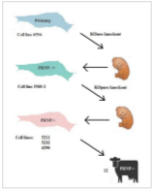
- These cows are deficient in PrP^C
- In short, they cannot get mad cow disease.
- This was done the hard way, by deleting genes.
- These cows are not in the food supply, but they could be if mad cow were to become a worldwide problem.

Richt et al. Nature Biotechnology. Vol. 25(1). 2007.

How to make genetically modified cows.

NO!!!

Source: Thebullvine.com



YES!!!!

Should we ban GM animals?

- Do we really need salmon and beef to survive?
- Wouldn't the environment be better off without both?

Source: Genetic Literacy Project

Genetically Modified Goats

- In 2009, the first drug made from a GE animal was approved.
- This drug, ATryn, is an anticoagulant used for the prevention of blood clots in patients with a rare disease known as hereditary antithrombin (AT) deficiency.
- The gene for antithrombin is inserted into the goat genome and is produced in milk.
- It is then just a matter of isolating antitrombin from the goat's milk.

Genetically Modified Rabbits

- The U.S. Food and Drug Administration approved Ruconest, for the treatment of acute attacks in adult and adolescent patients with hereditary angioedema (HAE).
  - People with HAE can develop rapid swelling of the hands, feet, limbs, face, intestinal tract, or airway. Swelling of the airway is potentially fatal without immediate treatment (FDA.gov)
- The C1 esterase inhibitor gene is engineered into rabbits who then produce the inhibitor in their milk.

Genetically Modified Chickens

- In late 2015, the FDA approved the drug Kanuma to treat a rare condition known as lysosomal acid lipase deficiency:
  - Results in fat accumulation in the liver, spleen, and vasculature and is quickly fatal to infants.
- Chickens are genetically engineered to produce a recombinant form of human lysosomal acid lipase (rhLAL) protein in their egg whites.

Genetically Modified Mosquitoes

NO!!!!

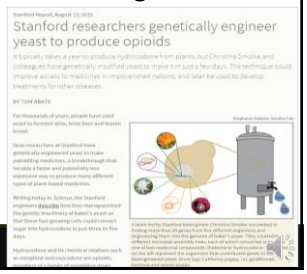
Source: Fox News via Facebook

Source: NPR.org

YES!!!!

Genetically Modified - Microorganisms

- Work in microorganisms paved the way to the use of genetic engineering in plants, animals, etc.
- The use of genetic engineering in microorganisms is beyond the scope of this lecture but a few examples are given.



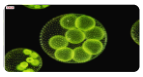
Genetically Engineered - Vaccines

- Hepatitis B vaccine – plasmid containing genes for HBsAg inserted into baker's yeast.
- Human papillomavirus vaccine – recombinant DNA technology produces the L1 major capsid protein of HPV which then self-assembles into a virus-like particle.
- Rotavirus vaccine – contains 5 reassortant rotaviruses developed from human and bovine parent rotavirus strains.

Source: Dailykos.com

Genetically Engineered Biofuels

- Algae can be genetically engineered to produce a variety of products, including biofuels.
- Biofuels are one of the hottest research topics at the moment and they have shown promise as a replacement for petroleum-based fuel.
- Researchers here at USF are using genetically engineered algae to produce biofuels.



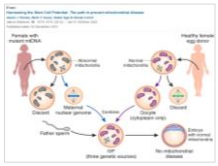
Genetically Modified Humans?

How to Make Genetically Modified Humans

http://blogs.discovermagazine.com/sciencenoiction/2011/07/23/captain-america-gets-enhancement-right/#WAJsEIMrKUk

While Captain America is fiction, the movie touched on a few real and important issues surrounding genetic modification:

1. It was intentional and not accidental (directed change).
2. Consent - the participant (Steve Rogers, AKA Captain America) consented to the treatment.



YES!!

NO!!!

This procedure was performed in Mexico as congressional action currently prohibits mitochondrial DNA replacement therapies in the US.

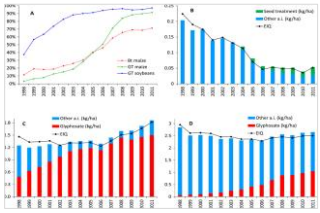
Sustainability - Bt-cotton in India

- 90% of cotton grown in India is Bt-cotton.
- 41% decrease in use of insecticide:
  - Cost
  - Benefit to environment
  - Benefit to farmers' health
- 30-45% higher yield in crops.
- **89% increase in profits.**
- *Qaim, New Biotechnology (2010) Vol 27(5): 552-7*

Source: Wikipedia

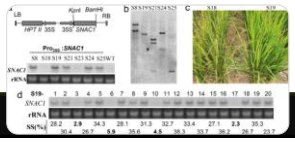
Sustainability – No Till agriculture

Sustainability – Pesticide Use



A. Uptake of GM Crops
B. Insecticide use in maize
C. Herbicide use in soybeans
D. Herbicide use in corn

Sustainability - Examples



Sustainability - Examples

Source: Delish.com

Major Concern – Health

- The effect of GMOs on health of humans and animals is usually the number one concern of consumers regarding GMOs.
- National and international treaties prevent experimentation on humans so how do you test the safety of GMOs?
  - Animal studies number in the 1000s, none of which demonstrate disease/illness.
- GM corn has been in the food supply for 10 years with no known detrimental health effect.
- Recent meta-analyses of over 1700 papers found no ill effects of GM foods on animals or humans
  - *Nicolia et al. Critical Reviews in Biotechnology. March 2014, Vol. 34, No. 1 , Pages 77-88.*

Major Concern – Environmental Impact

- Genetically altered seeds and pollen can be spread by wind, birds, bugs, etc.
  - Studies too numerous to list here have demonstrated the spread of GM crops to nearby conventional crops does occur:
  - Litigation is possible (GM crops are patented)
    - Famous case of Percy Schmeiser.
  - Labeling concerns (identify which foods are GM)
  - GMs are prohibited in certain areas (organic farming)
- Environmental effects may take decades to occur.
- Early detection of environmental effects may be impossible.

Major Concern – Environmental Impact (continued)

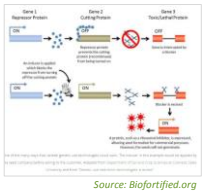
- Genetic engineering can save threatened species and environments.
- Previously unusable lands can be used for farming, etc.
  - Low water tolerant GMs
  - Herbicide/pesticide resistance
  - Salt resistance GMs
- Genetic engineering for a desired trait is no different from breeding.
- Crops can be engineered with sterile pollen to prevent unwanted spread.
- GM crops are not new (depending on your definition) some have been used commercially since 1994 with no known ill effects.

Major Concern – Environmental (continued)

- The spread of engineered organisms cannot be undone unlike other types of pollution.
- Pests and diseases can adapt to overtake genetically identical organisms.
  - In other words, GM crops are monocultures.
- Some GM crops can outgrow conventional crops and replace them.
- Genes from GM crops could spread to other organisms.

Major Concern – Environmental Impact (continued)

- Organisms are engineered to benefit the environment, not to do harm.
- GMOs are created that are resistant to pests and diseases.
  - New changes can always be made to maintain diversity.
    - This is in defense of GM crops being monocultures.
    - Another point here is that conventional and organic crops can also be monocultures.
- Sterile pollen can be engineered to prevent cross-breeding of GM and conventional crops.



Source: Biofortified.org

Major Concern - Labeling

- There are now requirements to label GMOs with QR codes or phone numbers, however most consumers will not notice those types of labels.
- Without labeling, the consumer cannot refuse to consume GMOs.
- Without labeling, GMO foods cannot be excluded.
- Many countries require GMOs to be labeled.

The Center for Environmental Health would like to see labels on GMO fish. Less clear is exactly how that label would remain attached.

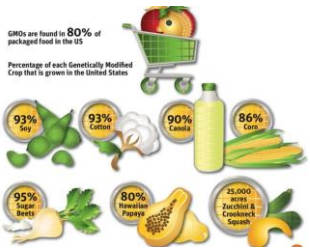
Major Concerns – Labeling (continued)

- Issues defining "GMO Foods" – in other words, what percentage of the food can come from GMO.
  - For reference, a food can be labeled Organic if it is 95% organic.
  - Should an animal that is fed GM corn be considered GMO food?
- Biotechnology firms and food producers oppose (and fund opposition to) labeling GMO foods:
  - Lack of data demonstrating health risks associated with GMOs.
  - Loss of profits
  - Costs associated with regulating labeling.
- Cross pollination of conventional crops can occur.
  - A farmer could unwittingly produce a GM product.
- Current mandatory labeling laws are for nutrition and safety, "contains GMOs" does not fall under nutrition or safety guidelines.
- Organic foods do not contain engineered organisms, consumers can avoid GM by buying organic.

NPR.org – at right is a QR code.

Regulation Loopholes

- FDA regulates substances added to food products as additives:
  - Must differ significantly from what is already present in foods.
  - If no new substance is introduced, pre-market testing is not required.
- Products genetically engineered for pesticide/herbicide production are regulated by EPA:
  - Low production of toxins by GM products generally leads to their approval.
- USDA regulates GM crops only if DNA from pathogens is utilized.
- Regulations have not caught up to the technologies with potential uses for GM foods – RNA silencing, CRISPR, etc.



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Conclusions

- Genetic engineering can be used to create new varieties of plants, animals, microorganisms, and even humans.
- Genetic engineering has the potential to contribute to health, sustainability, and of course profits.
- Concerns surrounding health effects of GMOs are unfounded.
- Environmental and regulatory concerns should be addressed further.

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