Curriculum development was supported by the USDA National Institute of Food and Agriculture.	Kansas Foundation for AGRICULTURE IN THE CLASSROOM (KFAC)	Curriculum Development Team Chelsea McCall Emily Duello Katie Hutchison Celsey Crabtree

Course:	Biology 9-12	**Unit:**	Vertical Gardening - Agriculture Careers
Lesson Title:	Plant genetics and biotechnology		
Estimated Time:	5 class periods of 40 minutes		

Objectives:

1) Extract plant DNA using laboratory procedures
2) Define genetic modification and biotechnology.
3) Create an infographic about GMOs

Equipment Needed:

Device to project or individual student devices to watch a 5-minute video

Supplies Needed:

Paper Copies (1 per student) of the Science Video Review
Your choice of organism to extract from
Mortar and pestle OR blender
Masking tape and markers
2 Plastic cups (150mL or more)
metal strainer (fine mesh strainer)
Rubber band
Dish detergent (Dawn)
Salt (non-iodized)
91% Isopropyl alcohol (cold)
Tray or tub of ice
Popsicle stick or coffee stir stick

Accessibility Options

Students can access information visually through online videos with subtitles and auto-translations.
Utilize Speech-to-Text and text-to-speech add-ons for reading/listening/writing support (Updated 7/17/23)

Multisensory resources: DNA extraction materials **For more suggestions, please visit:** **https://www.washington.edu/doit/equal-access-science-and-students-sensory-impairment**

Instructor Directions & Estimated Time	Procedures
Day 1 40 minute period	DNA refresher
Day 2 40 minute period	DNA Extraction
Day 3 40-minute period	National Ag in the Classroom lesson over GMO
Day 4 40 minute period	National Ag in the Classroom lesson over GMO
Day 5 (optional) 40 minute period	National Ag in the classroom CRISPR activity
Day 6 (optional) 40 minute period	National Ag in the classroom CRISPR activity

No.	9-12 Next Generation Science Standards		
HS-LS 1-1	Structure and function: Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins that carry out the essential functions of life through systems and specialized cells		
	Disciplinary Core Ideas	Science and Engineering Practices	Cross-Cutting Concepts
	LS1 .A: Structure and Function	Constructing explanations and designing solutions	Structure and function

No.	9-12 National Agriculture Literacy O

	Outcomes
T2. 9-12 b&d	b. Describe resource and conservation management practices used in agricultural systems (e.g., riparian management, rotational grazing, no-till farming, crop and variety selection, wildlife management, timber harvesting techniques) d. Discuss the value of agricultural land

Vocabulary	
Enzymes	a biological catalyst and is almost always a protein.
Detergents	a class of molecules whose unique properties enable manipulation (disruption or formation) of hydrophobic-hydrophilic interactions among molecules in biological samples.
GMOs	any organism whose genetic material has been altered using genetic engineering techniques
Mutagenesis	a method of selective breeding in plants where seeds are exposed to chemicals or radiation to promote DNA mutations that could result in developing new traits in offspring plants

Careers Mentioned	
Genetic Engineer	Responsible for conducting a thorough study of genes and living forms.

Day 1

Essential Question: What is DNA, and how is it extracted from cells?

Day 1- **Start with a refresher on DNA:**

1) Watch this 5-minute video titled "What is DNA for kids" by LearnBright.org and critique it. Do you think this is a useful resource to teach people about DNA? Why or why not? (For structured viewing, students can watch the video and complete this Science Video Review.) *The video has subtitles that can be translated into multiple languages.

2) Discuss Plant DNA extraction procedures. List materials, divide, and actively read procedures decide on group roles (Timer, Observer/Recorder, Materials Specialist, Questioner, Reader, Photographer, etc.)

Procedure options:
Option A: Extract DNA from leafy greens (Give students plant options)
Option B: Strawberry DNA Lab on National Ag in the classroom:
https://agclassroom.org/matrix/lesson/519/ (Duration: 1 hour)
Option C: Extract DNA from Canned Corn (From Seed 2 Stem
https://www.kscorn.com/wp-content/uploads/2017/09/dna-extraction-from-corn.pdf)

Review the roles of materials. For example: **Enzymes** are structures that look like______ whose purpose/function is to __________.
Detergents are structures that look like______ whose purpose/function is to __________.

For additional background information, go to
https://www.gs.washington.edu/outreach/dhillon_dnaprocedure.pdf

Day 2

Day 2- **DNA Extraction**

1) Review roles
2) Collect materials
3) Document steps (Students can take pictures or draw important steps in the process to create their recap of their technique; groups could critique each other and discuss how their results varied. Ex: Which group extracted more DNA? Why?)

Data to measure: Initial mass of greens, quantities of substances added, different types of greens

Days 3 and 4

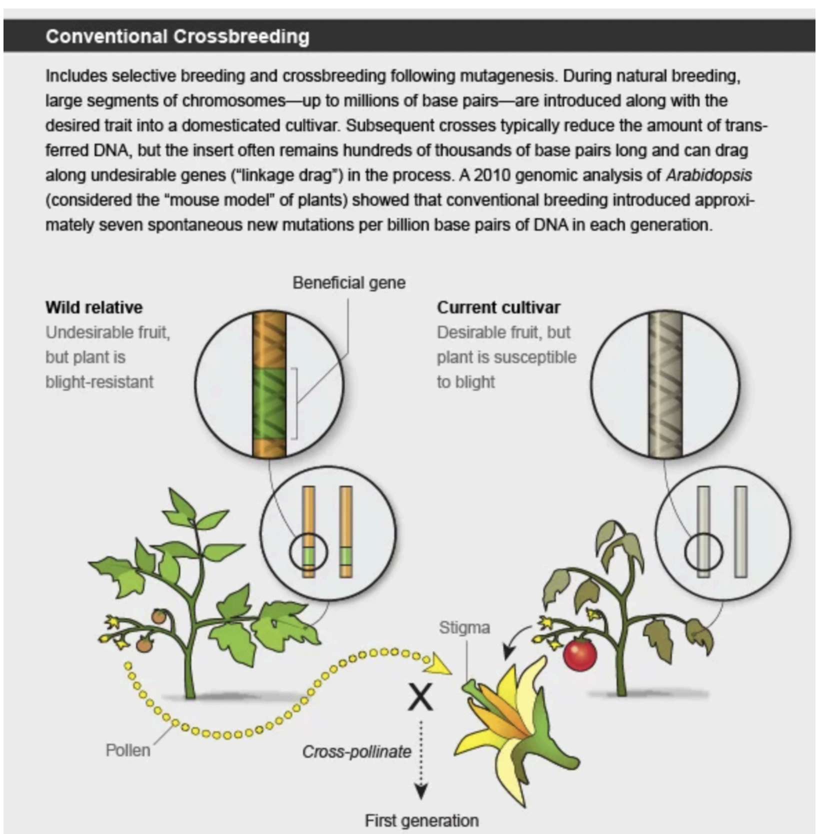
Day 3-4
Essential question: Why should we care about GMOs and biotechnology? What is safe for us to eat?
Connect back to GMOs, biotechnology (3 days)

See National Ag in the Classroom Lesson: Evaluating Perspectives about GMOs
https://agclassroom.org/matrix/lesson/86/ (The lesson is listed as 2-3 hours long. How much time do we want to spend?)

Days **5 and 6 (Optional)**

Day 5-6 (Optional extension based on time)
Essential Question: How can we teach the public about biotechnology?
Must know: DNA, Genes, Gene modification & biotechnology, could include heredity (link refresher resources)
Limit CRISPR and Biotech to 1-2 days
Background reading: (Scientific article CRISPR for crops:
https://www.nature.com/articles/s41438-019-0159-x
https://www.fdli.org/2021/11/the-future-of-food-crispr-edited-agriculture/#:~:text=CRISPR%20enables%20desirable%20crop%20traits,plant%20and%20related%20finished%20goods.

Bellringer: What is an infographic, and why is it useful? (Show Visual Guide to Genetic Modification from https://blogs.scientificamerican.com/sa-visual/a-visual-guide-to-genetic-modification/)



Goals:
1)Students create a PSA/infographic: What should you know about GMOs before you go to the grocery store?

2) Students will be able to explain what GMOs are, how they are related to DNA and proteins, and why they are used.

See National Ag in the Classroom lesson called “Targeted Genome Editing” (Estimated time: 2-45 minute periods) https://agclassroom.org/matrix/resource/1119/

Students will watch videos to gain a better understanding of how genome editing is done. They will discuss the characteristics of a useful infographic and create their own.

Option: Philosophical chairs- Students research a stance and share. (Could create a 1-pager or poster featuring both sides of the argument)

*Scaffold: provide evidence, students have to sort; peers critique each other., sentence frames - peer voting/polling with Google form (before and after)

Main topics teachers should know:

DNA is the molecule that contains the genetic information for all living organisms, instructing cells on how to grow, function, and reproduce. Understanding its applications through biotechnology helps us understand different problems about genetically modified organisms or GMOs and food safety. DNA is a long molecule that's tightly packed inside the nucleus of a cell. To extract DNA, scientists use a series of steps to break down the cell wall and membrane, releasing the DNA so it can be studied or used in experiments. Key components in this process include detergents and enzymes. Detergents are used to break down the cell membrane and nuclear envelope, which are composed of fats and proteins. By dissolving these layers, detergents help release the DNA into a solution. Enzymes are proteins that speed up chemical reactions. During DNA extraction, enzymes like proteases break down proteins that may be attached to DNA, ensuring the DNA is pure and free from other cellular materials. In some cases, other enzymes help break down cell walls (especially in plants), making DNA extraction more efficient. GMOs are organisms whose genetic material has been altered using biotechnology to express specific traits. GMOs are widely used in agriculture to improve crop resilience, yield, and nutritional content. However, GMOs are a topic of public debate, as people consider the benefits alongside concerns about environmental impact and food safety. Mutagenesis is the process of creating genetic mutations, which are changes in the DNA sequence of an organism. It can happen naturally through exposure to environmental factors or be induced in laboratories to create genetic variations. Mutagenesis is used in plant breeding to develop new traits, such as disease resistance or faster growth. Mutagenesis involves encouraging mutations that can be selected for desired traits. Biotechnology includes any technological applications that use biological systems or organisms to create or modify products. In agriculture and food production, biotechnology allows for advances like GMOs, mutagenesis, and even lab-grown meat. With these advancements come safety regulations, as authorities assess each modified organism for safety, environmental impact, and allergenic potential before approving it for public consumption.

Genetic engineers play a vital role in biotechnology by modifying the genetic makeup of plants to give them desirable traits. They do this by using gene editing technology and mutagenesis to develop crops to make them more resistant to pests, diseases, herbicides, and environmental stressors. This helps reduce the use of chemical herbicides and pesticides. By using this biotechnology, genetic engineers make sure these crops are safe, effective, and regulated to minimize any health concerns.

- Treatment of cells with detergent activates caspases and induces apoptotic cell death - PubMed
- GMO Crops, Animal Food, and Beyond | FDA
- Mutagenesis - an overview | ScienceDirect Topics
- Genetically Modified Organisms (GMOs): Transgenic Crops and Recombinant DNA Technology.

Suggestions for instruction:

When extracting DNA, use fresh fruits and vegetables or dried whole food products. Processed foods may be harder to extract DNA from as the DNA may have been damaged during processing. Dry beans and peas work well if you use a blender to break open cells. Cereal grains such as wheat may not work as well since they have such a high concentration of starch and require a finer grind to break open cells. In the DNA extraction, the salt helps stabilize DNA and remove proteins. The dish detergent breaks open cell membranes and the nuclear membrane so the DNA can be exposed. Any regular dish detergent will work. Do not use dishwasher detergent. Some DNA extraction protocols use meat tenderizer. Meat tenderizer can be used to break down proteins that are making the DNA less available for extraction, but in many cases it will not be necessary. The rubbing alcohol is what precipitates the DNA to make it visible. This can be purchased from any store that sells rubbing alcohol. The rubbing alcohol could be stored in a freezer or an ice water bath to make sure it is cold for the DNA extraction. Cold alcohol makes it easier to precipitate the DNA.

Biodefense Research in Kansas

National Bio & Agro-Defense Facility

The U.S. Department of Agriculture (USDA) is working with the U.S. Department of Homeland Security (DHS) to open the National Bio and Agro-Defense Facility (NBAF) in Manhattan, KS. USDA will own and operate NBAF. This state-of-the-art facility will be a national asset that helps protect the nation's agriculture, farmers, and citizens against the threat and potential impact of serious animal diseases. NBAF will replace the Plum Island Animal Disease Center (PIADC), a biosafety level-3 facility that is more than 65 years old. Currently, USDA's Agricultural Research Service (ARS) and Animal and Plant Health Inspection Service (APHIS) conduct foreign animal disease research, training and diagnostics in this facility. ARS and APHIS will transfer their missions from PIADC to NBAF and will operate the facility jointly.

Protecting livestock and agricultural interests also protects the economy. Agriculture, food, and food processing contribute more than $1.1 trillion to the U.S. economy's gross domestic product per year. In addition, 10 percent of jobs — about 20 million — have some ties to agriculture. At NBAF, USDA will conduct comprehensive research, develop vaccines and anti-virals, and provide enhanced diagnostic and training capabilities to protect the nation from animal diseases that are:

- Foreign or transboundary — those that could enter the U.S. from another country.
- Emerging — are new or not well known.
- Zoonotic — normally exists in animals but can infect humans.

According to the World Health Organization, more than 70% of new and emerging infectious diseases in humans are zoonotic. USDA will expand its scientific work at NBAF and be the first in the U.S. to provide maximum biocontainment (biosafety level-4) laboratories capable of housing large livestock to develop vaccines and diagnostics for zoonotic diseases. NBAF will be a critical component of USDA's priority to develop vaccines and countermeasures for — as well as the early detection of — diseases that threaten livestock, other animals, and food from the nation's farms and fields.

Careers:

Genetic Engineer

Description: A genetic engineer is professionally responsible for conducting a thorough study of genes and living forms – human beings, plants, animals, and even microorganisms, in which they are contained. The study of genetic engineering comprises of identification of gene patterns, DNA structure, cell nature and types, gene content, traits of heredity, etc. The engineer has to keep track of the latest advancements in genetic engineering and studies being conducted as research work in a particular field. The duties and responsibilities of a genetic engineer include: needs to be thoroughly aware of the concepts of the subject and its present as well as prospects, proper care of the living organisms being engineered for genetic purposes or those upon whom some laboratory research work or study is being conducted, properly assessment of environmental conditions often serve as important factors to determine the results of various genetic engineering tests; hence the natural issues such as temperature, heat, pressure, water content, etc., keep tabs on the advancements in the concerned field by various firms and beyond national boundaries as well; by maintaining interactive sessions, reading journals and published materials, etc., and a genetic engineer may have to do more than just fieldwork – presentation of ideas before a large group of people within the place of work or at other places.

Education: A genetic engineer must fulfill the following education and qualification requirements: bachelor's and master's degree in Genetic engineering or related fields, a doctoral degree [PhD] is necessary for appearing anywhere as a genetic engineer, and a certification by State bodies and licensure are required to be an authentic genetic engineer.

Salary: The average Genetic Engineer salary in the United States is $101,564 as of July 25, 2023, but the salary range typically falls between $90,092 and $114,776.

Links:
https://careers.stateuniversity.com/pages/402/Genetic-Engineering-Research-Scientist.html

https://www.salary.com/research/salary/posting/genetic-engineer-salary

Take a look at the Career Glossary to find other related careers!

DNA: Advanced lesson. Learn Bright. (2022, September 22). https://learnbright.org/lessons/science/dna/

Enzyme. Genome.gov. (n.d.). https://www.genome.gov/genetics-glossary/Enzyme#:~:text=An%20enzyme%20is%20a%20biological,is%20used%20over%20and%20over.

Falcone, C., Ingram, E., & Brandt, M. (n.d.). *Strawberry breeding and Genetics*. National Agriculture in the Classroom. https://agclassroom.org/matrix/lesson/519/

FDA Center for Food Safety and Applied Nutrition. (n.d.). *Targeted Genome Editing*. National Agriculture in the Classroom. https://agclassroom.org/matrix/resource/1119/

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Montañez, A. (2024, February 20). *A visual guide to genetic modification*. Scientific American. https://blogs.scientificamerican.com/sa-visual/a-visual-guide-to-genetic-modification/

Sweeney, D. (n.d.). *DNA Isolation from Strawberries*. UW Genome Sciences. https://www.gs.washington.edu/outreach/dhillon_dnaprocedure.pdf

Walker, K. (2022, March 28). *The Future of Food? CRISPR-edited Agriculture*. Food and Drug Law Institute (FDLI). https://www.fdli.org/2021/11/the-future-of-food-crispr-edited-agriculture/#:~:text=CRISPR%20enables%20desirable%20crop%20traits,plant%20and%20related%20finished%20goods

Wang, T., Zhang, H., & Zhu, H. (2019, June 15). *CRISPR Technology is Revolutionizing the Improvement of Tomato and Other Fruit Crops*. Nature News. https://www.nature.com/articles/s41438-019-0159-x

Full lesson

https://agclassroom.org/matrix/lesson/86/

Evaluating Perspectives About GMOs

Grade Level

9 - 12

Purpose

While many view bioengineered crops (GMOs) as a promising innovation, there is controversy about their use. This lesson provides students with a brief overview of the technology, equipping them with the ability to evaluate the social, environmental, and economic arguments for and against boengineered crops (GMOs). This lesson covers a socioscientific issue and aims to provide students with tools to evaluate science within the context of social and economic points of view. Grades 9-12

Estimated Time

2-3 hours

Materials Needed

Engage and Activity 1: Bioengineering and Me

- Internet and video projection capability
- Bioengineering PowerPoint
- Food Label Cards, 1 set per group
- Critically Thinking Bioengineering handout, 1 per student (this handout will be used throughout the lesson)

Activity 2: **Assessing the Risks and Benefits of GMO Crops**

- Bioengineering Fact or Fiction PowerPoint or Kahoot app and electronic devices

Activity 3: How Genetic Engineering is Used in the Production of our Food

- Ball (8" or larger plastic ball or an inflatable beach ball)
- Crop Supply and Demand Challenge Cards, 1 copy per class

Vocabulary

acrylamide: a chemical substance which forms in starchy foods after high-temperature cooking processes such as frying, roasting, and baking

crossbreeding: selectively breeding two plants or animals of different breeds or cultivars to produce a superior offspring sometimes called a hybrid

gene: a unit of heredity that is transferred from a parent to offspring and is held to determine some characteristic of the offspring

genetic engineering: the process of directly modifying an organism's genes using biotechnology to produce desired traits

genetically modified organism (GMO): any organism whose genetic material has been altered using genetic engineering techniques

hybrid: the offspring of two plants or animals of different species or varieties

inbreeding: selectively breeding closely related plants or animals in an effort to isolate and perpetuate a desired trait

mutagenesis: a method of selective breeding in plants where seeds are exposed to chemicals or radiation to promote DNA mutations that could result in developing new traits in offspring plants

selective breeding: process by which humans control the breeding of plants or animals in order to exhibit or eliminate a particular characteristic

transgenic: containing a gene that has been transferred from one organism to another and acts as a synonym for genetically modified

Full Lesson
https://agclassroom.org/matrix/lesson/124/

Design 'Y'er Genes

Grade Level

9 - 12

Purpose

This lesson introduces students to the relationships between chromosomes, genes, and DNA molecules. Using the example of a strawberry, it also provides activities that clearly show how changes in the DNA of an organism, either naturally or artificially, can cause changes. Grades 9-12

Estimated Time

Five 45-minute sessions

Materials Needed

Activity 1: Building a Strawberry DNA Molecule

- Design Y'er Genes Part 1 worksheet
- Where Do Genes Come From? chart
- Fresh strawberries, 1 per student
- Envelopes or plastic bags
- Glue or tape
- Colored markers or pencils
- Scissors

Activity 2: Genetic Mutations

- Design 'Y'er Genes Part 2 worksheet

Activity 3: Genetic Engineering

- Phosphate, Sugar, and Base Pair cut-out sheets (1 set per team)
- Design 'Y'er Genes Part 3 worksheet
- DNA Gene Cut-Out Models (1 set per team)
- Colored markers or pencils
- DNA Gene Cut-Out Models (1 set per team)
- "Design Yer Genes" Lab Sheets Parts 1, 2, & 3 (one set per team)
- Envelopes or plastic bags
- Fresh strawberries
- Glue or tape
- Phosphate, Sugar, and Base Pair cut-out sheets (1 set per team)
- Scissors, tape and glue

Essential Files

- Design 'Yer' Genes Part 1 Lab Sheet
- Design 'Yer' Genes Part 2 Lab Sheet
- Design 'Yer' Genes Part 3 Lab Sheet & DNA Cut-out Models
- Where Do Genes Come From? chart

Vocabulary

chromosome: a threadlike structure of nucleic acids and protein found in the nucleus of most living cells, carrying genetic information in the form of genes

codon: a series of three specific nucleotides of a base that specify the cell to make a particular amino acid

gene: a unit of heredity that is transferred from a parent to offspring and is held to determine some characteristic of the offspring

genotype: the genetic makeup of an organism

mutation: changes in the genetic sequence that lead to new traits and diversity in offspring; often in a single generation

phenotype: the set of observable characteristics of an organism resulting from the interaction of its genotype with the environment

Name Date Class

Science Video Review

Part 1: Video Information

Title: Audience: Children/Teenagers/Adults
Source (website link): Duration (minutes):
Speaker/Publisher: Language:

Part 2: Important information (Listen, record 5+ important pieces of information and underline keywords.)

Part 3: Find or draw a picture related to the video and write a 1-2 sentence description using keywords.

Part 4: Critique- answer the questions below.

1) Was this video educational (did it teach you something useful)? Why or why not?

2) Was this video interesting (would other teenagers like it)? Why or why not?

DNA Extraction Procedure

Materials:

- ☐ Organism sample that contains DNA. Every living thing contains DNA. Examples that work well for DNA extraction:
  - Spinach
  - Split green peas
  - Chicken liver
  - Strawberries
  - Broccoli
- ☐ Water
- ☐ Table Salt
- ☐ Liquid dish detergent (Dawn dish soap works well)
- ☐ Meat tenderizer (optional)
- ☐ 70-95% isopropyl or ethyl alcohol (rubbing alcohol), cooled in a freezer or ice bath
- ☐ Blender or mortar and pestle
- ☐ Measuring cup
- ☐ Measuring spoons
- ☐ Test tubes or small clear plastic cups
- ☐ Cotton swabs or Q-tips

Procedure:

1. Place in a blender*:
   - ½ cup of organism sample for DNA extraction
   - ⅛ teaspoon table salt
   - 1 cup cold water

2. Blend contents on high for 15 seconds.

3. Strain chunks from the liquid using a fine mesh strainer. Reserve the liquid for your DNA extraction.

4. Add 2 tablespoons liquid dish detergent to your reserved liquid. Swirl to mix, being careful not to create bubbles.

5. Let the mixture sit for 5 to 10 minutes.

6. Carefully pour the liquid mixture into test tubes or a plastic cup, again being careful not to create bubbles. Fill the containers about ⅓ full with liquid.

7. Optional Step: Add a pinch of meat tenderizer and stir gently. Do not stir too much or the DNA may be broken up and harder to see.
   - This step is not always necessary. Try your DNA extraction with and without meat tenderizer with your chosen organism sample to see which yields the best DNA extraction results.

Adapted from:
Genetic Science Learning Center. (2018, October 23) How To Extract DNA From Anything Living. Retrieved August 15, 2023, from https://learn.genetics.utah.edu/content/labs/extraction/howto/

8. Tilt your test tube or cup at an angle and slowly pour down the side of the container the chilled alcohol until you have approximately the same volume of alcohol as DNA extraction mixture. The alcohol should float on top of the DNA extraction mixture.

9. White stringy strands of DNA should begin to appear between the DNA extraction liquid and alcohol. Some of the DNA may begin to float to the top of the alcohol layer. Use a cotton swab, skewer, or coffee stir rod to gently collect your DNA. Place on a paper towel or in a container of alcohol for further inspection of your extracted DNA.

*Note: you can also grind the sample with a mortar and pestle and then mix in the water and salt rather than using a blender to make your DNA extraction liquid.

Adapted from:
Genetic Science Learning Center. (2018, October 23) How To Extract DNA From Anything Living. Retrieved August 15, 2023, from https://learn.genetics.utah.edu/content/labs/extraction/howto/

Alaska Agriculture in the Classroom

AITC Lesson Plan

Title: Genetically Modified Crops versus Other Methods of Changing Food

Author: Barbara Ross

Grade Level(s): 6-8

Class Time Suggested to Complete: 4 days

Lesson Focus: Where does our food come from? What does it mean to be genetically modified? What are other ways foods can be modified? Why would we want to modify our food?

Standards Covered: Processes of Science; Genetics; Scientific Knowledge and Technology

Rationale: Students will learn about the reasons for modifying food for human consumption. They will learn how this is done and explore if it is a good idea or not.

Assessment: There is a Pre-Test, which is also the Post Test.

Prior Knowledge: Students will have a general understanding of genetics.

Student Learning Objectives: Students will be more aware of the sources of the food they eat.

Materials/ Preparation for Teaching: See attached pages.

https://search.yahoo.com/yhs/search?p=youtube+gmo+foods&ei=UTF-8&hspart=mozilla&hsimp=yhs-001 (You Tube video about genetically modified foods; about 7 minutes)

https://search.yahoo.com/yhs/search?p=youtube+gmo+foods&ei=UTF-8&hspart=mozilla&hsimp=yhs-001 (You Tube video; The Eyes of Nye: Genetically Modified Foods; by Bill Nye; about 25 minutes) https://search.yahoo.com/yhs/search?p=youtube+gmo+foods&ei=UTF-8&hspart=mozilla&hsimp=yhs-001 (You Tube video: What is a Genetically Modified Food; Instant Egghead #45; Scientific American; a little over 3 minutes)

Differentiated Instruction: The material provided is for 6-8 use as appropriate.

Lessons:

1. Pre-Test
2. Play the game: **Farm to Cart** (Note: this game was created for lower elementary students but middle school students should do OK with it.) This is an overview as to where our food comes from.
3. Watch the 3 You Tube videos for an introduction to GMO's.
4. Discuss why farmers have tried to change the foods we eat over time. Use the articles on Golden Rice, the Arctic Apple, Transgenic Salmon, Seedless Watermelon and Seedless Oranges. Which of these are not genetically modified? How do you know? What are the concerns?
5. Discuss Traditional Plant Breeding vs. Genetic Engineering using the chart:

Traditional Plant Breeding	**Genetic Engineering**
Combine DNA from plants of the same species	Can combine DNA from different species
Select plants that have desirable traits and cross them	Select a desirable trait from another species and isolate the gene
Large parts of genome changed	Can select a single gene
Genes introduced via pollination	Genes introduced via a plasmid

6. Look up and discuss other genetically modified foods. In pairs, students will look up a GMO and report back to the class on their findings. They should include pros and cons for their particular organism.
7. Take Post Test

References:

http://www.agfoundation.org/resources/farm-to-cart-a-downloadable-board-game
http://pioneerio.hubpages.com/hub/geneticallymodifiedfood
http://www.healthline.com/health/gmos-pros-and-cons#1
http://www.geneticallymodifiedfoods.co.uk/what-are-common-gm-foods.html
http://www.foodpyramid.com/what-is-golden-rice/
www.arcticapples.com/arctic-apples-story/how-we-keep-apples-from-turning-brown
http://www.nature.com/polopoly_fs/1.12903!/menu/main/topColumns/topLeftColumn/pdf/497017a.pdf
http://www.washingtonpost.com/wp-dyn/content/article/2010/08/31/AR2010083102643.html
http://www.ehow.com/info_8058700_oranges-seedless.html

Vocabulary

Agrobacterium: A bacteria that is a natural plant pathogen, able to transfer genes to plants by invading through wounds and inserting DNA into the chromosomes. This is used in genetic engineering to get the gene of interest into the target organism

Backcross: The process of breeding genetically modified plants that contain the gene of interest with plants that have other desirable traits, such as high yields.

cisgenic: Transferring genes from the same organism or a plant containing no foreign genes.

Clone: To isolate and make copies of a single gene, such as the gene for Cry protein.

Enzyme: Protein that catalyzes a biochemical reaction. In genetic engineering, enzymes are used to cut DNA, allowing scientists to isolate the gene they would like to insert into another organism.

Gene: A region of the DNA that encodes a protein or part of a protein.

Genetic Engineering (GE)/ Genetic Modification (GM): The process of directly modifying an organism's genes using biotechnology to produce desired traits.

GMO: Genetically modified organism

Grafting: Horticulture.

1. a bud, shoot, or scion of a plant inserted in a groove, slit, or the like in a stem or stock of another plant in which it continues to grow.
2. the plant resulting from such an operation; the united stock and scion.

Herbicide: a substance or preparation for killing plants, especially weeds.

Hybrid: the offspring of two animals or plants of different breeds, varieties, species, or genera, especially as produced through human manipulation for specific genetic characteristics.

Plasmid: a segment of DNA independent of the chromosomes and capable of replication, occurring in bacteria and yeast: used in recombinant DNA procedures to transfer genetic material from one cell to another.

Pesticide: a chemical preparation for destroying plant, fungal, or animal pests.

Scion: a shoot or twig, especially one cut for grafting or planting; a cutting.

Transformation: When foreign DNA is inserted into the host, such as the Bt Cry protein gene into the corn DNA.

Transgenic: Containing a gene that has been transferred from one organism to another. A synonym for genetically modified.

Pre/Post Test

1. What is a GMO?

2. What is a hybrid?

3. What has been added to tomato plants to keep them from freezing?

4. What is an Arctic Apple?

5. Why would you want a seedless watermelon?

6. For what reason would scientists want to genetically engineer a salmon?

7. Golden Rice is a fairly new product. What gives it the golden color? Why has it been added?

8. How do we get seedless oranges?

9. Name 3 genetically modified foods.

10. What is the difference between transgenic and cisgenic?

Pre/Post Test (KEY)

1. What is a GMO?
   A GMO IS AN ORGANISM THAT HAS BEEN GENETICALLY MODIFIED.

2. What is a hybrid?
   A hybrid is the offspring of two animals or plants of different breeds, varieties, species, or genera, especially as produced through human manipulation for specific genetic characteristics.

3. What has been added to tomato plants to keep them from freezing?
   Genes from an arctic fish have been added.

4. What is an Arctic Apple?
   It is a variety of apple that does not brown quickly when cut. It also does not bruise easily.

5. Why would you want a seedless watermelon?
   They are easier to eat. Also there is less chance of children choking to death on the seeds.

6. For what reason would scientists want to genetically engineer a salmon?
   They do this so the salmon could grow twice as fast as salmon in the wild.

7. Golden Rice is a fairly new product. What gives it the golden color? Why has it been added?
   Genes from a daffodil plant give it the yellow color. This has been added for the Vitamin A, which helps prevent blindness in those with a Vitamin A deficiency.

8. How do we get seedless oranges?
   We get seedless oranges by grafting.

9. Name 3 genetically modified foods.
   Some examples of genetically modified foods are corn, tomatoes, golden rice, salmon, soybeans, sugar beets, potatoes and squash.

10. What is the difference between transgenic and cisgenic?
    Transgenic transfers genes from one organism to another while cisgenic means the organism has no foreign genes.

Golden Rice:
http://www.foodpyramid.com/what-is-golden-rice/

What is Golden Rice?

Image of Golden rice

Golden rice is a form of rice with biosynthesis of beta-carotene (a form of vitamin A). In other words, golden rice is produced through genetic engineering. Beta-carotene gives golden rice its “golden” or “yellow” coloring. White rice, on the other hand, does not contain carotenoids (i.e. beta carotene) and therefore lacks that “golden” coloring. When you consume golden rice, the beta-carotene either accumulates in your fatty tissues or is transformed into vitamin A.

Carotenoids, like beta-carotene, are the colorful plant pigments normally found in a variety of fruits and vegetables (carrots, tomatoes, broccoli, cantaloupe, sweet potatoes, etc.). It is important to note that plants lack the direct form of vitamin A, but do contain beta-carotene, a form of vitamin A. Moreover, your body metabolizes vitamin A when you consume foods rich in beta-carotene. Vibrant fruits and vegetables, along with meats contain vitamin A. If you adhere to a poor diet, you have an increased risk of life-threatening medical conditions and diseases associated with a vitamin A deficiency.

Golden rice is rich in beta-carotene. It is also easily processed by your digestive system. In fact, the natural fatty lipids in golden rice aid in the absorption of beta-carotene, even when little or no oil is added to it. When oil is added to rice it helps your body absorb the carotenoids in it, but in the case of golden rice oil is not necessary to reap the benefits. Other benefits of golden rice include: increased energy (which comes from the starch located within the rice) and a low fat content.

Golden Rice History

Golden rice was invented in 1999 by **Peter Beyer**, professor at the University of Freiburg, Germany in the Centre for Applied Biosciences and **Ingo Potrykus**, professor at the Swiss Federal Institute of Technology at the Institute for Plant Sciences. Golden rice was originally produced in 1982 as an initiative for the Rockefeller Foundation. In 1992, a group of research experts and scientists met to perform studies on golden rice pros and cons. Beyer and Potrykus developed a rather complex biosynthetic crop that could be altered to produce healthier and more abundant grains like rice.

Peter Beyer and Ingo Potrykus

Golden Rice and Vitamin A

It is important to understand that golden rice is considered a type of genetically modified rice (GMO). It is a fortified food that is produced to combat a vitamin A deficiency in areas where this vitamin is scarce. More and more people are being diagnosed with a vitamin A deficiency. In fact, young children are the most vulnerable to vitamin-related deficiencies. Approximately 1 million children die of a vitamin A deficiency each year.

A vitamin A deficiency can severely affect a child's eyesight; weaken his/her immune system function and increase his/her risk of chronic conditions. Moreover, in underdeveloped countries, approximately half-a-million people, mostly children, develop blindness, associated with a vitamin A deficiency. Approximately 50% of those diagnosed with this type of deficiency-related blindness die a year or two after becoming blind (Wright, Hinchliffe & Adams, 2005). To make matters worse, approximately 10 million children suffer from malnutrition every year. In severe cases, the malnutrition turns deadly (Wright, Hinchliffe & Adams, 2005).

Low levels of vitamin A can also negatively affect your immune system and cause serious illnesses and/or death. In the last few years, an increase in child deaths (under the age of five) has been linked to deficiencies in vitamin A, protein and zinc. The newest form of golden rice varies from the original strain through the addition of three new beta-carotene genes.

In addition, this newest form of golden rice (invented in 2005) is referred to as Golden Rice 2 because it contains higher levels of beta-carotene then the original golden rice. Golden rice was originally developed, with the support of environmental activists, to improve, enrich, support and enhance health and well-being and it has accomplished its goals. The invention of golden rice has lowered the risk of a variety of health conditions and ailments. Golden rice has been tested in the Philippines for over two seasons on two different locations in 2012.

White rice vs Golden Rice

Golden Rice Benefits

- Lowers Risk of Blindness, Infections, Cancers and Diseases

Golden rice has the ability to lower your risk of blindness, infections, cancers and diseases. A vitamin A deficiency can increase your risk of vision impairments, age-related macular degeneration and blindness. It can also worsen infections (measles, HIV, AIDS, chicken pox, etc.), especially in children. Approximately 125 million children, worldwide, exhibit chronically low levels of vitamin A (Wright, Hinchliffe & Adams, 2005). The carotenoids found in golden rice can combat adult degenerative diseases. Other benefits of golden rice include: a lower risk of both a variety of heart diseases and prostate, breast and skin cancers.

- Reduces Gastrointestinal Distress

Another one of the benefits of golden rice is that it can reduce gastrointestinal distress. In fact, it is considered a beneficial food to eat following an episode of diarrhea, regardless of the cause. Golden rice behaves like a mild astringent in your gastrointestinal system, which supports easy digestion and restores your intestinal mucus following an episode of gastroenteritis and colitis.

- Reduces High Blood Pressure and High Cholesterol

Golden rice is a low-fat and low-sodium food; therefore it is especially beneficial for lowering high blood pressure and cholesterol. High levels of sodium, a mineral, can lead to fluid accumulation, edema (fluid retention) and a spike in blood volume. The excess fluid can increase your risk of high blood pressure. In other words, the more sodium you consume, the higher your blood pressure may soar. Moreover, one of the most valuable benefits of golden rice is that it prevents fiber-related biliary acids from accumulating in your intestines. Biliary acids found in the liver and transported to your intestines, aid cholesterol production. Golden rice contains no fat (i.e. no cholesterol); therefore it has the ability to regulate your unhealthy blood cholesterol levels.

Problems with Golden Rice

Controversy has surrounded the production of golden rice because it is considered **genetically modified rice** (GMO). Critics have raised concerns of using genetically engineered foods to combat vitamin deficiencies like vitamin A. One of the main problems with the original form of golden rice was that it did not contain enough vitamin A to be beneficially for reducing disease risks. This problem was rectified when the new form of golden rice, Golden Rice 2 was developed in 2005. Critics continue to not only question the effectiveness of using genetically modified rice to improve health, but also the degree to which the nutrients persist once the rice has been cooked.

In a recent study (2009), it was found that golden rice was just as beneficial and effective as supplementing with vitamin A (Tang, Qin, Dolnikowski, Russell & Grusak, 2009). An organization called Greenpeace, vehemently opposes the production and use of golden rice citing this GMO will encourage the development of more GMOs in the future. Anti-GMO activists argue that an increase in GMOs will cause the degradation of foods to the point where everything that we eat will be artificial and genetically engineered. In the long run these types of non-natural foods will cause a variety of health problems (Tang, Qin, Dolnikowski, Russell & Grusak, 2009).

These activists also argue that a balanced diet that contains beta-carotene (kale, mustard, greens, carrots, broccoli, sweet potatoes, etc.) provides an adequate amount of vitamin A and should therefore be utilized first and foremost. Supporters of GMOs argue that although it would be nice if everyone could adhere to a balanced diet rich in vitamin A, it just is not possible for some people. These supporters cite a lack of available resources and poverty as two of the main reasons why some people have developed nutritional deficiencies. They state that it is important to have alternative food sources to eliminate vitamin deficiencies and improve health and well-being. More research is needed to get a full understanding of golden rice pros and cons.

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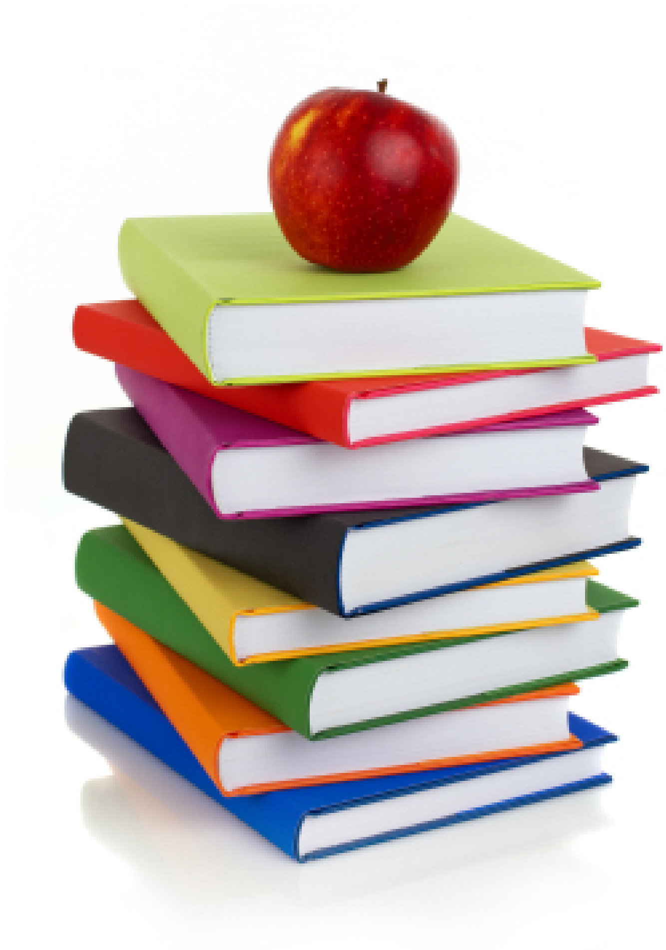
www.arcticapples.com/arctic-apples-story/how-we-keep-apples-from-turning-brown

How'd we do that?

So how'd we "make" nonbrowning Arctic® apples? This modern marriage of nature and science is simpler than you may think.



Browning 101

Enzymatic browning is the primary type of apple browning. It is caused by the apple's chemical reaction after cell injury, such as by bruising, biting or cutting the apple. Enzymatic browning is a predominant cause of apple browning due to handling, for example in your kitchen. Arctic apples don't undergo enzymatic browning. (Let any food get old enough, such as leaving it in the fridge too long, and any apple – including Arctic apples – will eventually suffer other types of browning.)

Meet the PPO gene family

When you bruise, bite, slice or dice an apple, rupturing the apple cells' walls, a chemical reaction is triggered between the apple's polyphenol oxidase (PPO) and phenolics that turns the apple flesh brown. And unfortunately, that reaction burns up the apple's health-promoting phenolics in the process. Read more here. A family of four genes controls the majority of PPO production.

Apple-to-apple transformation

To scientifically breed Arctic apples, Okanagan Specialty Fruits' science team turns down the expression of the apple PPO genes in a process called gene silencing, which utilizes low-PPO genes from other apples.

Gene silencing is a natural process that all plants (and animals too) use to control expression of their genes. This apple-to-apple transformation is aided by time-proven biotechnology tools. In the end, Arctic apples produce too little PPO to brown. (For an even more detailed description of Arctic apple science, visit the OSF website.)

No frankenfood here, folks – just apples, now with suppressed PPO to stop enzymatic browning.

The transformed Arctic apple plantlets are grafted onto rootstock and grow in a tree nursery until they are ready to be transplanted to an orchard, just as other commercial apple tree seedlings are propagated.*

One small, significant difference

Arctic apple trees behave in the orchard just as other apple trees do – they grow, flower and fruit the same way, and react to pests and weather the same way. And Arctic fruits grow, are harvested, packed, stored and shipped just as other apples are.

In other words, Arctic apple trees and fruits are identical to their conventional counterparts in every way – until you bite, cut or bruise the fruit, that is. That’s when the handiwork of their silenced PPO genes becomes evident. No PPO, no browning. No enzymatic browning, no “yuck” factor to discourage you from enjoying that delicious apple.

http://www.nature.com/polopoly_fs/1.12903!/menu/main/topColumns/topLeftColumn/pdf/497017a.pdf

AquaBounty

A genetically engineered salmon (top) grows twice as fast as its wild counterpart (bottom).

In the remote highlands of Panama, in tanks protected by netting, barbed wire and guard dogs, swim the world’s most expensive and scrutinized fish. These swift-growing salmon have been at the centre of a 18-year, US$60-million battle to bring the first genetically modified (GM) animal to US dinner tables — a struggle that may be nearing its end.

Last week marked the end of the public’s opportunity to weigh in on a US Food and Drug Administration (FDA) draft assessment of the salmon. Genetically engineered to grow twice as fast as their unaltered brethren, the fish pose no significant environmental threat to the United States when grown in landlocked tanks, says the FDA. The agency needs only to finalize that assessment before deciding whether to approve the fish for human consumption. The number of opportunities for a surprise delay — a recurring theme in

Wthe history of these salmon — is dwindling (see ‘Against the current’).
The US Food and Drug Administration (FDA) has been slow to approve a genetically modified (GM) salmon made by AquaBounty of Maynard, Massachusetts. The fish would be the first GM animal authorized for human consumption.

1989 Canadian researchers engineer wild Atlantic salmon to overexpress growth hormone.

1995 AquaBounty files an Investigational New Animal Drug application with the FDA.

2001 AquaBounty submits its first regulatory study to the FDA.

2009 The FDA releases guidance for its evaluation of genetically engineered animals as veterinary drugs; AquaBounty completes its FDA submission.

2010 The FDA says that GM salmon is safe to eat.

2012 The FDA completes its draft environmental assessment in May, but does not release it to the public until December.

2013 The public-comment period for the draft environmental assessment is extended by two months and concludes on 26 April.

Environmental groups are preparing to take the battle to consumers by fighting the sale of the fish in grocery stores across the country. Others point out that it will be years before the salmon are anything more than a curiosity. At full capacity, the Panama facility can produce only about 100 tonnes of salmon a year, says Gregory Jaffe, director of biotechnology at the Center for Science in the Public Interest, a consumer group in Washington DC that monitors the regulation of GM foods. That amount is a trifle compared to the roughly 230,000 tonnes of farmed Atlantic salmon that the United States imported in 2012. “You’d have to try hard to eat it,” says Jaffe. “It won’t be as hard as winning the lottery, but it will be close.”

For the firm that developed the fish, AquaBounty Technologies of Maynard, Massachusetts, those 100 tonnes are a hard-won prize. In 1989, the salmon were engineered to overexpress a growth-hormone gene. The result: ‘AquAdvantage’ fish that grew to full size in around 18 months rather than the usual 3 years. The company applied for FDA approval in 1995 and has been stuck in regulatory limbo ever since. AquaBounty has had to demonstrate the food’s safety, and gauge the environmental risk of the sterile fish escaping its tanks and successfully mating with wild salmon. By contrast, the FDA approved the first GM crop for human consumption — the Flavr Savr tomato — after just three years of regulatory consideration.

The uncertainty has taken its toll. To save money, AquaBounty has reduced its staff by more than half. Last year, the company sold off its research and development arm and lost one of its biggest investors. In March, AquaBounty came within a week of running out of cash, says chief executive Ronald Stotish. The firm was saved by last-minute refinancing and fresh investment from Intrexon, a synthetic-biology company based in Blacksburg, Virginia.

At first glance, the Panama facility hardly seems to be the key to financial prosperity. With salmon selling for around $6.50 per kilogram, AquaBounty would make less than $1 million each year from the salmon. It would take decades for the company to make back its $60-million investment if it relied solely on the Panama farm.

Stotish says that the company must expand. Following FDA approval, AquaBounty hopes to sell its salmon eggs to farmers and expand to markets in Argentina, Canada, Chile and China.

To sell AquAdvantage fish in the United States, each farm would require separate FDA approval, but because the food safety of the fish has already been vetted, the approval process would require only an environmental evaluation, says Jaffe.

Yet even with regulatory approval, the battle over AquaBounty’s salmon will be far from over. In March, several speciality grocery stores, including Whole Foods, an international chain based in Austin, Texas, said that they would not sell AquAdvantage fish. Lawmakers in Alaska and Oregon, which both export wild salmon, have repeatedly tried to block the GM fish because they fear contamination of the wild stock and worry that it could drive down the price of farmed salmon.

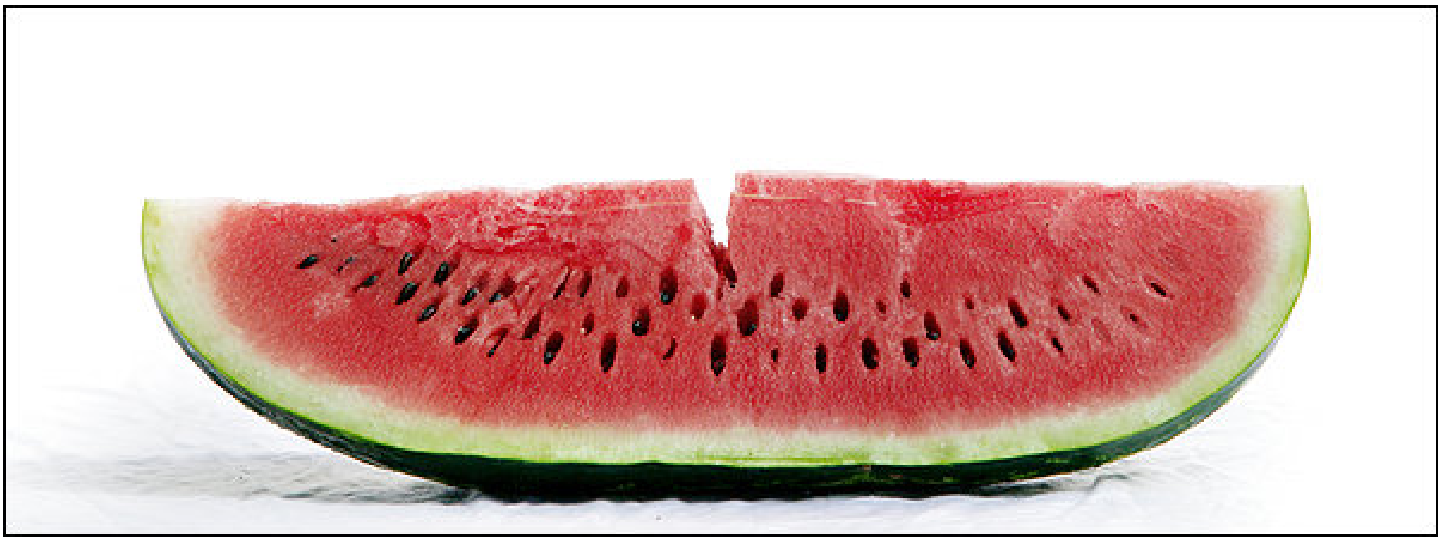
AquaBounty’s long struggle has discouraged other US companies from producing GM animals for food. Mark Walton, chief marketing officer at Recombinetics, an animal-biotechnology company in St Paul, Minnesota, says that his company will focus initially on medical applications — using modified farm animals as disease models, for example — rather than on livestock for food. Medical applications of GM

technology do not stir consumer passions in the same way as GM foods, and there is a regulatory precedent: in 2009, the FDA approved a goat that makes an anti-clotting drug in its milk. If Recombinetics invests in agricultural products, Walton adds, the items will probably be marketed outside the United States first. “The AquaBounty example has [made] the company very sceptical about how much investment to pour into the US regulatory process,” he says.
Yet Stotish says that GM animal products will inevitably find their way to grocery stores. He points to heavy investment in the technology in China, where dozens of GM farm animals are in development. “I think we will end up eating genetically modified animals of a variety of species,” says Stotish. “But they’ll come from other countries.”

http://www.washingtonpost.com/wp-dyn/content/article/2010/08/31/AR2010083102643.html

Watermelons: What happened to the seeds?

Watermelons with seeds are not as popular with consumers, so producers are growing more of the seedless fruits. (Deb Lindsey for The Washington Post)



By Jane Black
Washington Post Staff Writer
Tuesday, August 31, 2010; 11:35 AM

In 1995, Jason Schayot set the world record for spitting a watermelon seed when he shot his tiny black bullet a whopping 75 feet, 2 inches, almost a quarter of a football field. It's a record that would be hard to beat. But Schayot might not have much competition anyway. Within a generation, most Americans won't even know that watermelons have seeds, let alone how to spit them.
According to the National Watermelon Promotion Board, only 16 percent of watermelons sold in grocery stores have seeds, down from 42 percent in 2003. In California and the mid-South, home to the country's biggest watermelon farms, the latest figures are 8 and 13 percent, respectively. The numbers seem destined to tumble. Recently developed hybrids do not need seeded melons for pollination - more on that later - which liberates farmers from growing melons with spit-worthy seeds.
The iconic, black-studded watermelon wedge appears destined to become a slice of vanished Americana. If that sounds alarmist, try to remember the last time you had to spit out a grape seed.

The sea change is all in the service of convenience. "People don't eat watermelon out of hand like they used to. They like to eat it in fruit salads," said Robert Schueller, the public relations director for Melissa's Produce, a California distributor that sells only 10 percent of its watermelons with seeds. "It's a question of ease, time, and there's the safety factor. Kids could choke on the seeds."

You can't blame producers for giving people what they want, though as far as I can tell, childhood mortality rates remain unaffected by the type of watermelons for sale. Nor should we let nostalgia be an obstacle to progress. Seedless watermelons are easier to eat, and it's not only harried soccer moms who prefer them. Chefs such as Eric Ziebold at CityZen and Todd Gray of Equinox, both usually vocal proponents of heritage varietals, prefer seedless watermelons because they are more easily transformed into elegant cubes and fine dices.

Still, as the end of summer looms, I can't help but mourn the inevitable disappearance of the black-dotted red watermelon. In part, it is a wistfulness for a classic American fruit and its traditions. Without seeds, there can be no seed-spitting contests such as the one in Luling, Tex., home to an iconic watermelon water tower, or the one in Pardeeville, Wis., where the rules are strictly enforced: No professional tobacco spitters. Denture wearers must abide by the judge's decision if their teeth go farther than the seed.

Though there is some debate about it, the flavor of old-time watermelons might also be in jeopardy. And what a flavor to lose! In "Pudd'nhead Wilson," Mark Twain described the true Southern watermelon as "a boon apart . . . when one has tasted it, he knows what the angels eat." Convenience, whether it's a smaller size, a fruit without seeds or year-round availability, always seems to extract a price. And if that sounds alarmist, try to remember the last great tomato you bought at a supermarket.

The watermelon, or *Citrullus lanatus*, belongs to a family of climbing vines that include cucumbers and gourds. And like all fruits, they naturally have seeds. The seedless versions are not genetically modified, as some might assume, but are hybrids that have been grown in the United States since the middle of the 20th century. Breeders match the pollen from a diploid plant, one that contains 22 chromosomes per cell, and the flower of a tetraploid plant, which contains 44 chromosomes per cell. The result is a triploid with 33 chromosomes that is incapable of producing seeds. (The tiny white ones you sometimes find are seed coats, where a seed did not mature.) Breeders call it the mule of the watermelon world.

When farmers first began growing seedless watermelons, they still needed seeded varieties to pollinate them. But that has changed, says Mark Arney, president of the watermelon board, who, for the record, has never spit a watermelon seed farther than 20 feet. Over the past five or six years, the same period when the share of seeded watermelons began to drop precipitously at grocery stores, farmers began using so-called non-bearing pollinators. In other words, instead of planting a percentage of their fields with old-fashioned watermelons to pollinate, they plant another hybrid that produces the flowers that bees need but no actual fruit.

I see the trend at local grocery stores. I haven't found any seeded melons at my local Safeway this summer or at the nearby Whole Foods Market, though a staff member there told me that they sometimes carry organic watermelons with seeds.

The most reliable place to find old-school watermelons is the farmers market. That is not because of any bias in favor of old-fashioned varieties. It's because seedless watermelons are more difficult and expensive to grow. Their seeds are most successful when germinated in a greenhouse rather than outdoors, and farmers must buy hybrid seeds for the pollinator plants. More than half of the watermelons grown at Montross, Va.-based Garner Produce, a regular at Washington markets, are seeded. At Spring Valley Farm and Orchard in Morgan, W.Va., 60 percent of the melons have seeds. "It's easier," said Joe Heischman, a co-manager of the farm. "But I think the seeded ones also taste better. When we put out samples of both, people always say the seeded ones are sweeter."

http://www.ehow.com/info_8058700_oranges-seedless.html

Which Oranges Are Seedless?

In the U.S., oranges are considered to be seedless if they have from zero to six seeds, according to Purdue University's Horticulture and Landscape Architecture website. Because we view seeds as a nuisance when eating fresh oranges, breeders in the 1800s developed trees producing seedless varieties. These varieties are propagated by taking cuttings from a tree and grafting them onto root stock. A seedless orange is produced when the flowers from which the fruit develop are not pollinated, as the anthers do not develop pollen. The most popular varieties of seedless oranges for eating fresh are naval, Valencia and Jaffa.The Tarocco is Italy's favorite seedless orange.

Farm to Cart Game can be downloaded at:

http://www.agfoundation.org/files/Farm_to_Cart_Final_Game.pdf