Food and Agriculture Center for Science Education

Increasing Sustainability of Beef with Genetics

Middle School, Life Sciences

Task Overview

In this task, students will use a model to predict the effects of selecting a bull to be mated with a group of cattle, given the goal of decreasing cattle carbon emissions using genetics.

- In prompt 1, students are introduced to the primary factors contributing to a hamburger patty's carbon footprint and identify which factor(s) could be influenced by cattle genetics.
- In prompt 2, students are introduced to trait heritability and make connections between trait heritability and breeding cattle to produce beef more efficiently.
- In prompt 3, students apply their understanding of traits and heritability to a basic model of a beef animal's lifecycle to identify which traits could potentially influence the model and, thus, the carbon footprint of a hamburger patty.
- In prompt 4, students are introduced to Expected Progeny Difference (EPD) statistics. They focus on the production trait of growth and compare the genetic difference between two calves based on traits ultimately impacting the animals' carbon emissions.
- In prompt 5, students use a model and EPD data to predict the effects of selecting a particular bull and its potential impacts on the carbon footprint of a hamburger patty. Additionally, they identify possible environmental factors that could alter the actual results from their predictions based on EPD data.

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Background Information

Traits passed from parent to offspring influence the efficiency of the offspring. Certain traits, such as feed efficiency, are of particular importance to a livestock producer as feed is expensive and has ecological impacts on production. Cattle that are better able to efficiently convert feed into pounds of protein (beef) for human consumption are more profitable to cattle farmers and have less of an impact on the environment. While some traits that control feed efficiency are highly heritable, others are less easily passed from generation to generation and attributed to environmental conditions where the calf was raised. So, understanding the traits that can be influenced and improved upon is essential to making more beef from fewer cattle, requiring fewer resources.

Next Generation Science Standards

Claim 1 (Prompts 1 – 4)

Modify a model—based on evidence—to match what happens when selective breeding for a particular genetic characteristic is used.

Claim 2 (Prompt 5)

Identify non-genetic factors that could cause outcomes to differ from expectations and explain how each would impact the model and, ultimately, the sustainability of the hamburger.

This task is intended to elicit student learning of the following **NGSS elements** for each of the three dimensions:

Disciplinary Core Ideas

Biological Evolution: Unity and Diversity (MS)

- *LS4.B-M2:* In artificial selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits determined by genes, which are then passed on to offspring.

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Science and Engineering Practices

Developing and Using Models (MS)

- *MOD-M2:* ~~Develop or~~ modify a model—based on evidence—to match what happens if a variable or component of a system is changed.

Constructing Explanations and Design Solutions (MS)

- *CEDS-M4:* Apply ~~scientific ideas, principals, and/or~~ evidence to construct, ~~revise and/or use~~ an explanation for real-world phenomena, examples, or events.

Crosscutting Concepts

Cause and Effect (MS)

- *CE-M2:* Cause and effect relationships may be used to predict phenomena in natural or designed systems.

New York State P-12 Standards

- *3-LS3-2:* Use evidence to support the explanation that traits can be influenced by the environment.
- *3-LS4-2:* Use evidence to construct an explanation for how the variation in characteristics among individuals of the same species may provide advantages in surviving, finding mates, and reproducing.

Suggestions for Use

This task is intended for formative assessment purposes—to identify students' strengths and needs with the above dimensions, provide feedback to students, and guide shifts in instruction.

Assumptions

This task assumes students have prior knowledge about sexual reproduction and the heritability of traits. While optional, prior experience with the carbon cycle and/or how greenhouse gases work is beneficial. Figure 1 in the student task is designed to help provide the basic necessary understanding of greenhouse gasses for students who may be unfamiliar with the concepts.

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Materials Needed

- Increasing Sustainability of Beef with Genetics Student Task Handout
- Writing utensil

Sources

Werth, Samantha. The Biogenic Carbon Cycle and Cattle. 19 February, 2020. Clarity and Leadership for Environmental Awareness and Research at UC Davis Center.

Assessment Guidance

Introduction

Hamburgers rank among America's most consumed foods. There's a long list of "hamburger" types, including turkey burgers, veggie burgers, and salmon burgers, but the most consumed type (currently and historically) is made from ground beef. According to the USDA "World Agriculture Supply and Demand Estimates," the annual consumption of beef per person in the US in 2024 was 56 lbs. That includes some steaks and roast beef, but if the average hamburger is a 1/4lb, that's a lot of hamburgers!

Producers and consumers care about how their food is grown. They want to ensure that it is safe, tastes good, and is nutritious, and they want to ensure that it is raised sustainably. Sustainable food means producing food in a way that protects the environment and natural resources. Cattle producers do many things to protect the environment and natural resources on their land. Today, we will investigate if cattle genetics can contribute to raising sustainable beef. Specifically, we will look at one aspect of sustainability: carbon emissions.

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Prompt 1

Prompt 1a: *NOT ASSESSED. This is a scaffolding prompt used to familiarize students with the context of the beef industry.*

Prompt 1b: *NOT ASSESSED. This is a scaffolding prompt used to familiarize students with the context of the beef industry.*

Prompt 2

Prompt 2a: *NOT ASSESSED. This is a scaffolding prompt used to familiarize students with common genetic traits considered in the beef industry.*

Prompt 3

Prompt 3a: *NOT ASSESSED. This is a scaffolding prompt used to familiarize students the life cycle of beef cattle.*

Prompt 4

Prompt 4a: *NOT ASSESSED. This is a scaffolding prompt used to familiarize students with genetic statistics used in the beef industry.*

Prompt 4b: *NOT ASSESSED. This is a scaffolding prompt used to familiarize students with genetic statistics used in the beef industry.*

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Describe how EPD for RSI would affect the model in Figure 6. (Include the stage(s) impacted by each and how they would change for each bull.) Use evidence to support your answers.

Prompt 4c Performance Outcome	
Modify a model—based on evidence—to match what happens when selective breeding for a particular genetic characteristic is used.	
SEP	**MOD-M2:** Develop or modify a model—based on evidence—to match what happens if a variable or component of a system is changed.
DCI	**LS4.B-M2:** In artificial selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits determined by genes, which are then passed on to offspring.
CCC	**CE-M3:** Phenomena may have more than one cause, ~~and some cause-and-effect relationships in systems can only be described using probability~~.

Prompt 4c Assessment Rubric			
	Emerging	Developing	Proficient
Sample Student Response	RSI would affect stage 3 (after the calf is weaned). The calf would not have to eat as much feed.	RSI would affect stage 3 (after the calf is weaned). If the animal is gaining more weight on the same amount of feed, it would get to market weight faster.	RSI would affect stage 3 (after the calf is weaned). If the animal is gaining more weight on the same amount of feed, it would get to market weight faster. That would mean less

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			emissions needed to grow the feed and less emissions from the animal because it would not need as many days in stage 3.
Look-Fors	• Student identifies stage 3 as the one that would be affected by RSI • Student does not accurately identify how Stage 3 would be affected • Student does not accurately identify that that the reason RSI would shorten Stage 3 is that it would take the animal less overall feed and less overall days to reach market weight therefore reducing the emissions it takes to grow feed and emissions from the cattle themselves	• Student identifies Stage 3 as the one that would be affected by RSI • Students identifies that Stage 3 would be shorter/less days/narrower • Student does not accurately identify that the reason RSI would shorten Stage 3 is because it would take the animal less overall feed and less overall days to reach market weight therefore reducing the emissions it takes to grow feed and emissions from the cattle themselves	• Student identifies Stage 3 as the one that would be affected by RSI • Student identifies that Stage 3 would be shorter/less days/narrower • Students identifies that the reason RSI would shorten Stage 3 is that it would take the animal less overall feed and less overall days to reach market weight therefore reducing the emissions it takes to grow feed and emissions from the cattle themselves

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Prompt 5

Prompt 5a: *NOT ASSESSED. This is a scaffolding prompt used to familiarize students with genetic statistics used in the beef industry.*

a. Based on your calculations in the table, explain which bull has the most genetic potential to lower the carbon footprint of a hamburger patty?
   - Use evidence from your calculations to support your answer.

Refer to the three types of emissions referenced in Figure 2. Explain which types of emissions would be impacted and how.

Prompt 5b Performance Outcome	
Using evidence, explain how the effects of selective breeding for certain characteristics could impact the sustainability of hamburger.	
SEP	**CEDS-M4:** Apply ~~scientific ideas, principals, and/or~~ evidence to construct, ~~revise and/or use~~ an explanation for real-world phenomena, examples, or events. **MOD-M2:** Develop or modify a model—based on evidence—to match what happens if a variable or component of a system is changed.
DCI	**LS4.B-M2:** In artificial selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits determined by genes, which are then passed on to offspring.
CCC	**CE-M2:** Cause and effect relationships may be used to predict phenomena in natural or designed systems.

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Prompt 5b Assessment Rubric			
	Emerging	Developing	Proficient
Sample Student Response	Bull A has the highest genetic potential to lower the carbon footprint of a hamburger patty because it would require 210.8 lbs less feed than Bull B.	Bull B has the highest genetic potential to lower the carbon footprint of a hamburger patty. Bull B's progeny would require less feed (210.8 lbs less) over their lifetime so there would be less emissions from growing feed.	Bull B has the highest genetic potential to lower the carbon footprint of a hamburger patty. Because the weaning weight is higher, the progeny would have less weight to gain to reach market weight (940 lbs vs 990 lbs). Even though Bull A would consume less feed per day, Bull B would reach market weight 20 days sooner and still consume 210.8 lbs less feed overall. That means that the animal would have 20 days less emissions and the emissions from producing the feed would be less as well.
Look-Fors	• Student may or may not identify Bull B as having the highest genetic potential for lowering the carbon footprint of a hamburger patty • Student identifies 0 – 1 of the types of emissions that would be lowered (animal and feed) but do not provide evidence for how	• Student identifies Bull B as having the highest genetic potential for lowering the carbon footprint of a hamburger patty and may or may not cite calculations from Prompt 5a • Student provides evidence for one of the two types	• Student identifies Bull B as having the highest genetic potential for lowering the carbon footprint of a hamburger patty and cites the evidence from calculations in Prompt 5a • Student provides evidence for less emissions being required to raise less feed • Student provides evidence that animal would reach market weight in less days and the animal emissions

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		of emissions o less emissions being required to raise less feed o less emissions from animal because it would reach market weight in less days	would be less

b. We know EPD data does not take environmental differences into consideration. Identify three environmental factors (non-genetic) that could potentially cause different results in progeny than expected? For each factor, identify which stage(s) of the Lifecycle model (from Figure 6) would be affected and explain how.

Prompt 5c Performance Outcome	
Identify non-genetic factors that could cause outcomes to differ from expectations and explain how each would impact the model and, ultimately, the sustainability of the hamburger.	
SEP	**MOD-M2:** Develop or modify a model—based on evidence—to match what happens if a variable or component of a system is changed.
DCI	
CCC	**CE-M2:** Cause and effect relationships may be used to predict phenomena in natural or designed systems.

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Prompt 5c Assessment Rubric			
	Emerging	Developing	Proficient
Sample Student Response	1. Disease 2. Injury 3. Not enough feed	1. A progeny could get sick, which would cause them to not eat as much and gain weight less efficiently. This could happen at stages 2 or 3. In stage 2, the calf would weigh less at the end which would mean stage 3 would take longer. If it got sick in stage 3, it would add days to stage 3. 2. The quality of the feed may influence the rate of gain and RSI for the progeny. It could be higher or lower based on the quality of feed. This would impact stage 3. If the feed was higher quality, it could potentially shorten stage 3 or if lower quality it could increase the amount of time for it.	1. A progeny could get sick, which would cause them to not each as much and gain less efficiently. This could happen at stages 2 or 3. In stage 2, the calf would weigh less at the end which would mean stage 3 would take longer. If it got sick in stage 3, it would add days to stage 3. 2. The quality of the feed may influence the rate of gain and RSI for the progeny. It could be higher or lower based on the quality of feed. This would impact stage 3. If the feed was higher quality, it could potentially shorten stage 3 or if lower quality it could increase the amount of time for it. 3. If the mother cow got sick while nursing the calf, the calf might not get as much milk or gain as much weight. This would impact stage 2 and 3. The animal would have a lower

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			weaning weight or might need to nurse longer. If the animal has a lower WW, it would day more time in stage 3 to get to market weight.
Look-Fors	• Student identifies 0 - 3 different environmental factors • Student accurately identifies impacts on the Lifecycle model for 0 – 1 of the factors	• Student identifies 2 - 3 different environmental factors • Student accurately identifies impacts on the Lifecycle model for 2 of the factors	• Student identifies 3 different environmental factors and accurately identifies the stage(s) and how they would be impacted

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