

# Potential of Eggshell Nanoparticles as a Natural Pesticide Against the Red Flour Beetle

Charlie Gumienny, Audrey Empkey, Michael Aikins, Amie Norton, and Thomas Phillips  
Department of Entomology, Kansas State University, Manhattan, KS

## Background

### Background

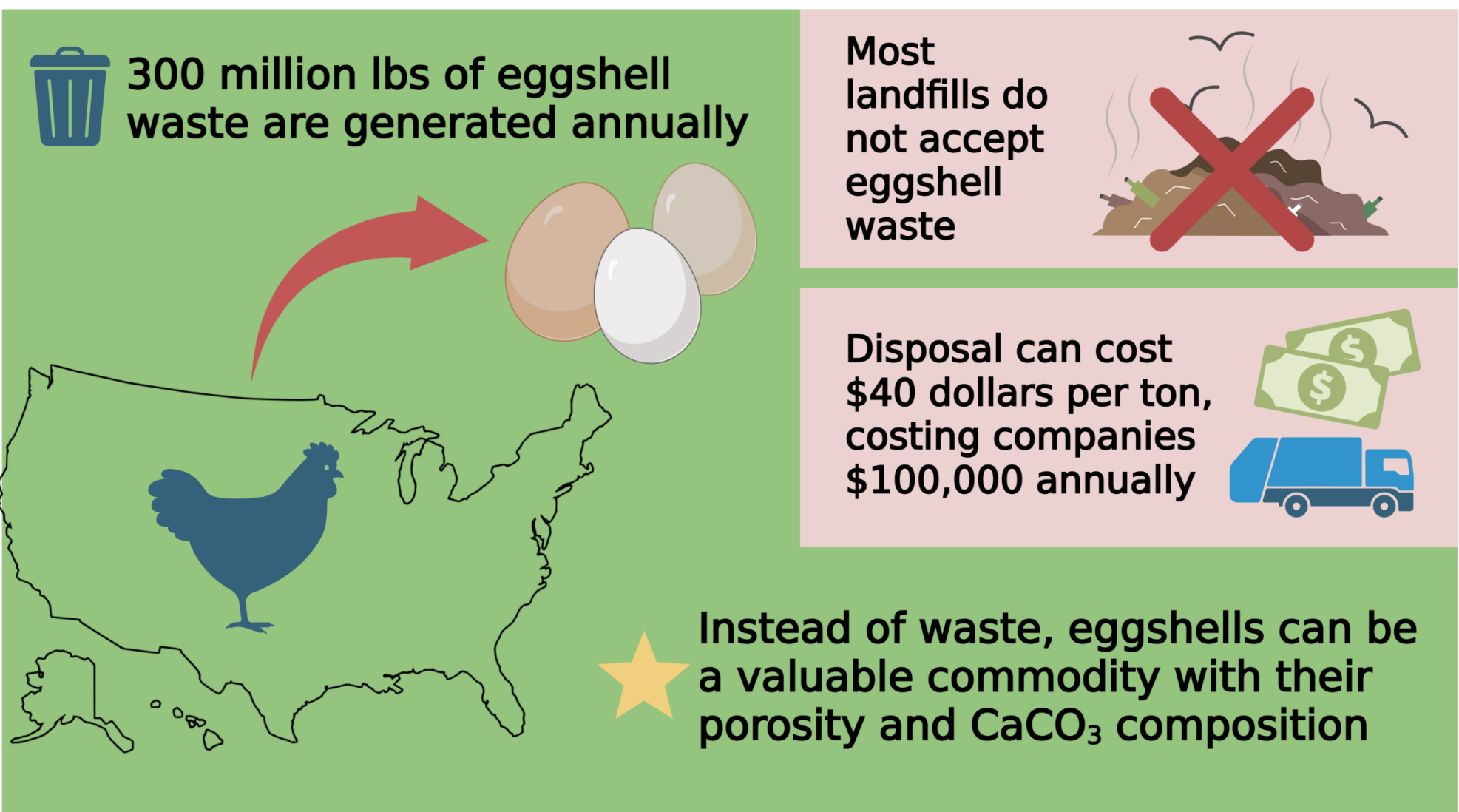
- Agricultural waste management is a growing environmental and economic challenge.
- The U.S. generates ~6 billion kg of eggshell waste annually, ranking it as the 15th most significant food-related pollutant, according to the EPA.
- Eggshells are composed primarily of calcium carbonate ( $\text{CaCO}_3$ ) — a benign, mineral-rich material ideal for recycling.
- Using nanotechnology, eggshells can be milled into  $\text{CaCO}_3$  nanoparticles with enhanced surface area, reactivity, and insecticidal potential.

### Objective

- Develop and evaluate nanoparticles derived from eggshell waste as a natural, sustainable, and effective control method for red flour beetle, *Tribolium castaneum* in stored grain systems.

### Eggshell Waste

- Milling eggshells into nanoparticles transforms waste into a value-added agricultural input.
- Provides a renewable, biodegradable, and low-cost source of pest control material.

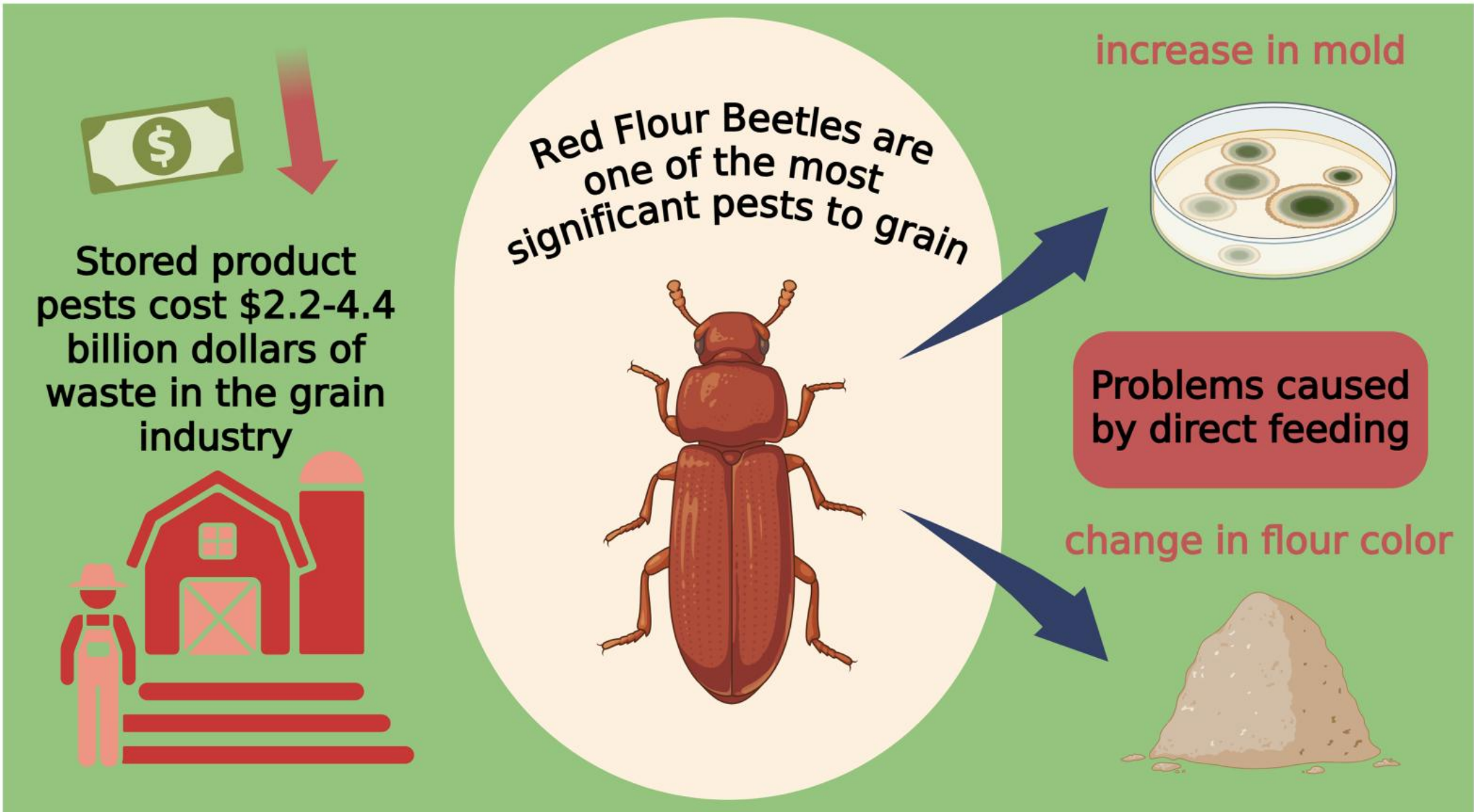


### Red Flour Beetle

- *Tribolium castaneum* is a major pest of stored grains and milled products, causing contamination, mold growth, and economic loss.
- Reliance on chemical insecticides and fumigants has led to widespread resistance in beetle populations.
- A nanoparticle-based physical control approach could provide a safer alternative for long-term pest management.

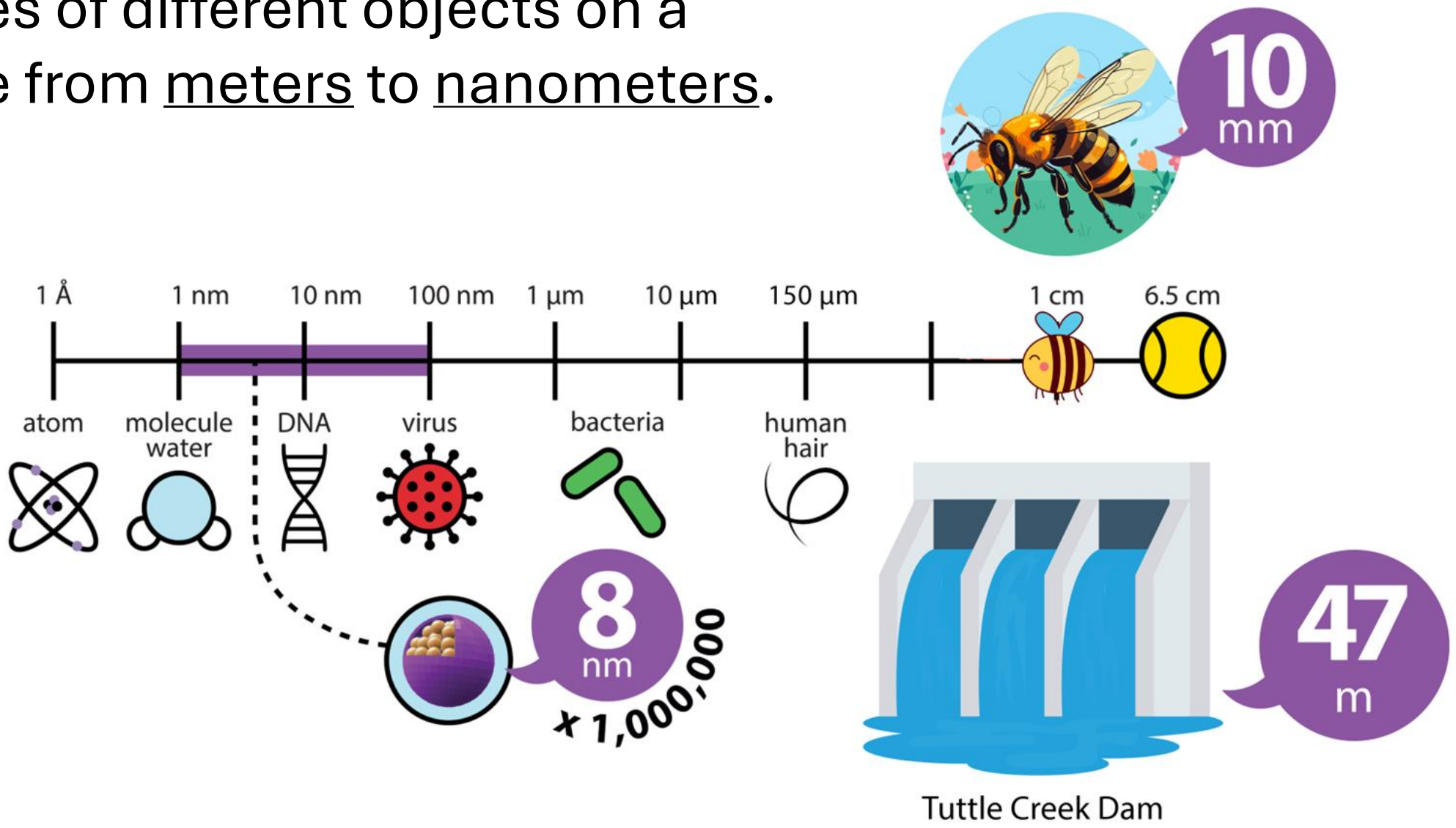
### Impact and Application

- Converts waste into a functional nanomaterial with agricultural and environmental benefits.
- $\text{CaCO}_3$  nanoparticles offer abrasive and biochemical effects that can reduce pest survival without toxic residues.
- Promotes circular economic principles by reusing waste and reducing chemical inputs.
- A scalable, eco-friendly strategy for protecting stored grains and food security.

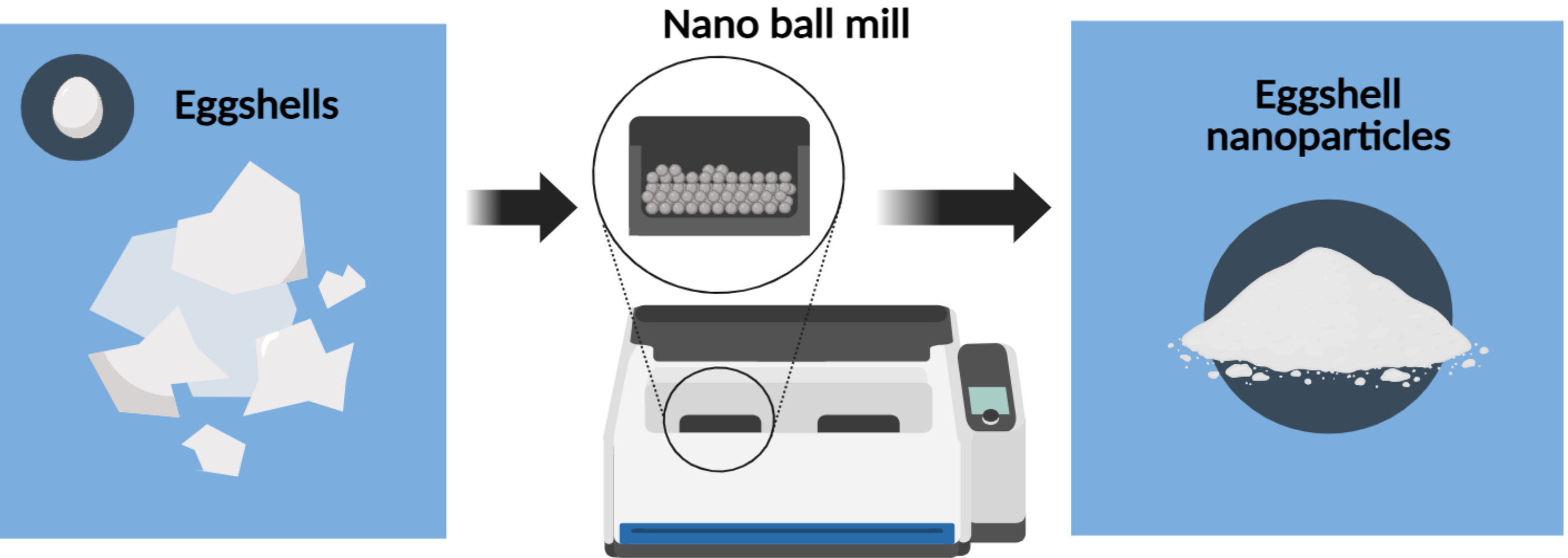


## Nano Scale

Relative sizes of different objects on a metric scale from meters to nanometers.



## Ball Mill Grinding of Eggshells



Eggshells (0.5g) were placed in a Nano mill (Retsch Co., Newton, PA) in a 50 mL stainless steel container with 50 (5 mm dia.) stainless steel balls. The eggshells were milled for 30 minutes at 15 Hz, and the powder was collected upon completion.

## Bioassay Procedures

### Red Flour Beetles Exposed to Eggshells in Flour

Week 1	Weighed 1.5, 2.5, and 5.0 g of nano-eggshells into 10 mL tubes, m=5 reps each) and dried at 60 °C for 3 days.
Week 2	Measured 50 g flour into each of 20 glass jars, mixed in the pre-weighed eggshells, n=5 reps, added 25 RFB per jar, and incubated all samples at 28°C .
Week 3	Recorded adult mortality before transferring surviving adults to new jars with flour; then continued to count mortality over weeks 3–8 and surviving larvae were checked over 4 additional weeks.

### RFBs Exposed to Eggshells, $\text{CaCO}_3$ and Organic Eggshells with no Flour Added

Step 1	Milled eggshells (organic and commercially available), and $\text{CaCO}_3$ into nanoparticles, weighed 10 mg into labeled glass vials, and had a set of reps with no treatment for the control. Added 10 RFB per vial, covered with breathable caps, and incubated. The experiment included 10 reps for each treatment.
Step 2	After 7 days, removed cells from incubator, transferred treatments to clean flour vials, allowed 3-day recovery, recorded mortality, and stored samples for imaging.
Step 3	Treatments were imaged using the SEM

## Surviving Adults

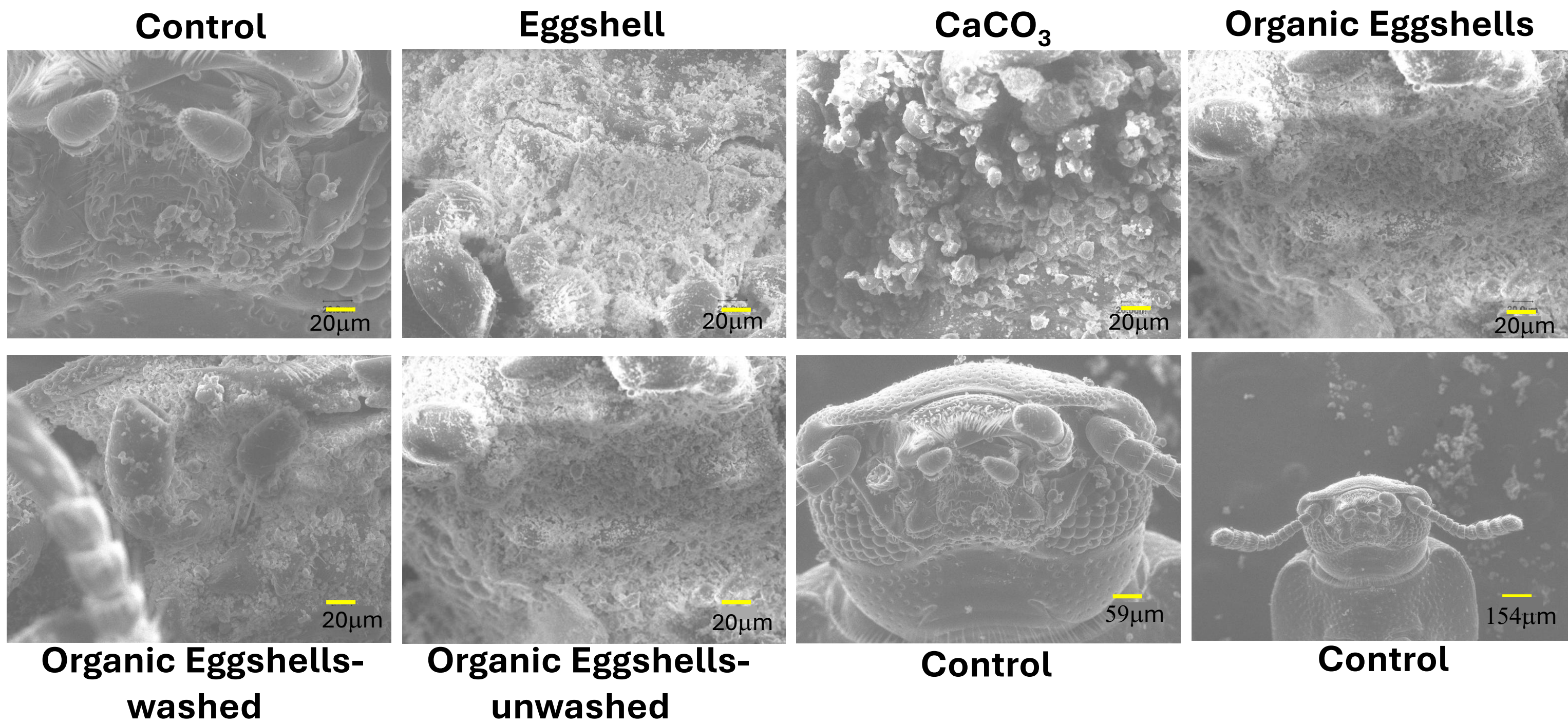
### Red Flour Beetles Exposed to Eggshells in Flour over 3 Weeks

Treatment	Time (days)			
	0	7	14	21
0g	25±0	23.2±1.3	21.8±2.3	21.6±2.3
1.5g	25±0	22.2±0.8	21.4±0.5	21.2±0.4
2.5g	25±0	22.2±1.3	21.4±1.1	20.4±1.1
5g	25±0	21.8±1.3	20.8±0.8	20.8±0.8

### Red Flour Beetles Surviving after 7 Days Exposed to Eggshells, $\text{CaCO}_3$ and Organic Eggshells with No Flour

Treatment	Average
Control	7.5±1.6
Eggshell	0±0
$\text{CaCO}_3$	0±0
Organic Eggshell	0±0

## Images of RFB in Different Treatments



Scanning Electron Microscopy images of a beetle exposed to no treatment, Eggshells,  $\text{CaCO}_3$ , and Organic Eggshells were collected to observe differences between treatments. While differences were observed between the control and treatments, no differences were observed between the treatments themselves. Attempts were made to wash the treatment off the red flour beetle to observe any abrasions underneath the treatment. However, the treatments would not wash or brush off the red flour beetles. Right center and Right images are lower magnification of the control sample's mouthparts for anatomical reference.

## Conclusions

The Eggshells,  $\text{CaCO}_3$ , and Organic eggshells all killed RFB adults after seven days when no food was present. When flour was present RFB survival was not affected when treated with eggshells. The nanoparticles appeared to be imbedded in the adults' mouthparts at high concentrations.

## Acknowledgements

Kansas Water Institution, Kansas State University, Department of Entomology, BioRender