Antimicrobial packaging to improving the safety, shelf life and waste reduction of various types of food

Tony Jin, PhD.
Eastern Regional Research Center
Tony.Jin@usda.gov
Why Antimicrobial Packaging

• Antimicrobial packaging is one of multiple interventions to enhance microbial safety, quality, and shelf-life of foods

• When microorganisms attach to food, they may survive after pasteurization/sanitizing steps. Under suitable conditions, they may grow during storage, transportation and marketing before home consumption.

• Antimicrobial packaging provides a final defense system to kill or inhibit pathogenic and spoilage microorganisms in foods
Prototypes Developed and Evaluated in My Lab

- Antimicrobial bottles for liquid food
- Antimicrobial solutions for food surface coating
- Antimicrobial films (bag/pouch) for film packaging
- Antimicrobial patches for releasing gaseous antimicrobials
- Containers with antimicrobial surface
- Antimicrobial packaging + other technologies
Foods Evaluated

- **Juice/beverage:**
  - Fruit juice/puree
  - Liquid egg
  - Milk

- **Produce:**
  - Apple
  - Banana
  - Cantaloupe
  - Orange
  - Tomato
  - Strawberry
  - Blueberry
  - Spinach
  - Lettuce
  - Broccoli

- **Poultry and meat:**
  - Shell egg
  - Read-to-eat deli meat
  - Roast beef

- **Seafood**
  - Raw and RTE Shrimp

- **Dessert**
  - Cake

- **Dairy**
  - Cheese
Inactivation of pathogens in bottled juices and beverages

**L. monocytogenes** in milk

- **Salmonella** in liquid egg white

**E. coli O157:H7** in strawberry puree

- **E. coli O157:H7** in orange juice
Antimicrobial composite films

Inactivation of *L. monocogenes* on RTE meat by composite film

![Graph showing inactivation of *L. monocogenes*](image)

Inactivation of *L. innocua* on RTE meat by composite film

![Graph showing inactivation of *L. innocua*](image)
Antimicrobial coated pouch

Inactivation of *L. monocytogenes* in RTE meat by coated pouch

- Log CFU/cm²
- Days at 10°C

Inactivation of *S. Typhimurium* in RTE meat by coated pouch

- Log CFU/cm²
- Days at 10°C
Antimicrobial solutions used for coating or marinate for beef

Effects of different concentrations of antimicrobial solution on *Listeria* cocktail on roast beef

Survived *Escherichia coli* O157:H7 cocktail after raw beef being marinated by antimicrobial solution

Edible and non-edible food surface coatings (direct coating)
Survival of *Salmonella* on cantaloupe surfaces as affected by the application of antimicrobial coatings.
Inactivation of *Salmonella* stanley on apple surface by antimicrobial PLA coating

**Graph Description:**
- **Y-axis:** Log CFU/cm²
- **X-axis:** Storage days at 4°C
- **Legend:**
  - Control
  - SB
  - SB+LA
  - SB+LA+EDTA

**Legend Notes:**
- SB: Sodium benzoate
- LA: Lactic acid
Coating Treatment of Apples and Stored at Room Temperature

4 Mons

Control without solvent

7 Mons

PLA + solvent coating only
Coating Treatment of Banana and Stored at Room Temperature

0 week

1 week

2 weeks

Control; solvent; PLA+solvent
Coating Treatment of Orange & Stored at Room Temperature

Control; PLA+solvent; PLA+solvent+sodium benzoate
Antimicrobial coating keeps fresh-cut apple fresher and safer.

Survival of Salmonella on apple slices after treatments

T1: Control; T2: Coating 1; T3: Coating 2; T4: Coating 3; T5: Commercial product

Survival of Salmonella on apple slide during storage at 4C

Mold and yeast on apple slide during storage at 4C

Storage (days)

Storage days
Another Challenge

• Although surface coating is better than liquid washing, there are some limits, such as product shape, product type, or crack and crevice, causing slow penetration and lower efficacy.
Approach 2: Gaseous Sanitizers

• Gaseous/volatile antimicrobials have rapid penetration and penetrate/diffuse to any hole or pore in food, not limited to product shape or product type.
Self release antimicrobial Film

PLA+AIT film

Inactivation of *E. coli* on greens

Days at 4°C

Log CFU/g

Control

Film treatment

Self release film for deli meat

Appearance changes of deli meat in boxes with antimicrobial films after 14 days at room temperature
Self release film for fresh-cut cantaloupe

**Mold and Yeast in Cantaloupe**

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Film 1/4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microbial counts (Log CFU)</td>
<td>6</td>
<td>0</td>
</tr>
</tbody>
</table>

After 10 days at 10°C. A: Film 1/4; B: Control.

**Salmonella spp on Cantaloupe**

<table>
<thead>
<tr>
<th></th>
<th>Antimicrobial Film 3/4</th>
<th>Antimicrobial Film 3/8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microbial Reduction (Log CFU)</td>
<td>-0.80</td>
<td>-0.70</td>
</tr>
</tbody>
</table>
Self release antimicrobial film for cake

- Appearance changes of cake in boxes with antimicrobial films after 17 days at room temperature. A: Film 1/4; B: Control; C: in cake box
Self activated antimicrobial film – trigged by food

Inactivation of *Listeria* on tomato stem scar

<table>
<thead>
<tr>
<th>Hours at 10C</th>
<th>Control</th>
<th>Film treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>48</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

Inactivation of *E. coli* on tomato stem scar

<table>
<thead>
<tr>
<th>Hours at 10C</th>
<th>Control</th>
<th>Film treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>48</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

(after 60 days at 4C)
Inactivation of E. coli in broccoli

![Image of broccoli samples](image1)

**Inactivation of E. coli in broccoli**

- **Control**
- **Film treatment**

![Graph showing inactivation of E. coli in broccoli](image2)

- **Log CFU/g**
- **Hours at 10°C**
- **24**
- **48**
Package Materials with Antimicrobial Surface

Polylactic acid (PLA) films with TiO2 nanoparticles had significantly lower survivals of Listeria and E.coli cells on the surfaces than those without TiO2 nanoparticles.
Integration of Antimicrobial Packaging with Other Technologies
Combination of pulsed electric field processing and antimicrobial bottle - pomegranate juice

Lab Scale

Pilot Scale

total aerobic bacteria

molds and yeasts

UT: untreated; UT+AB: untreated and packaged in antimicrobial bottle; PEF: PEF processed; PEF+AB: PEF processed and packaged in antimicrobial bottle
Combination of antimicrobial coating (AC) and washing (AW) on survival of E.coli O157:H7 and Salmonella on strawberries
Combinations of antimicrobial coating (CT) with Ozone (OT) and Cryogenic freeze (FT) on *L. innocua* in shrimp
Antimicrobial Packaging

• Increase of antimicrobial efficacy by
  – increasing relative higher concentration on food surface
  – keeping constant concentration of antimicrobials on surface by controlled release
  – increasing surface contact time

• Use of less amount of antimicrobials to achieve the same effect, or

• Use of the same amount of antimicrobials to achieve better effect
Summary and Conclusion

• Multiple prototypes developed for various food
  – Simple and easy to use
  – For homes, stores, warehouses, manufacturers, etc.

• Antimicrobial packaging/container is an unique and effective approach to:
  – reduce foodborne pathogens
  – Extend shelf life
  – Reduce waste
  – Maintain quality
THANK YOU!