Application of nanotechnology for food safety.

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NEVF
New England Vegetable and Fruit Conference

December 17-19, 2024

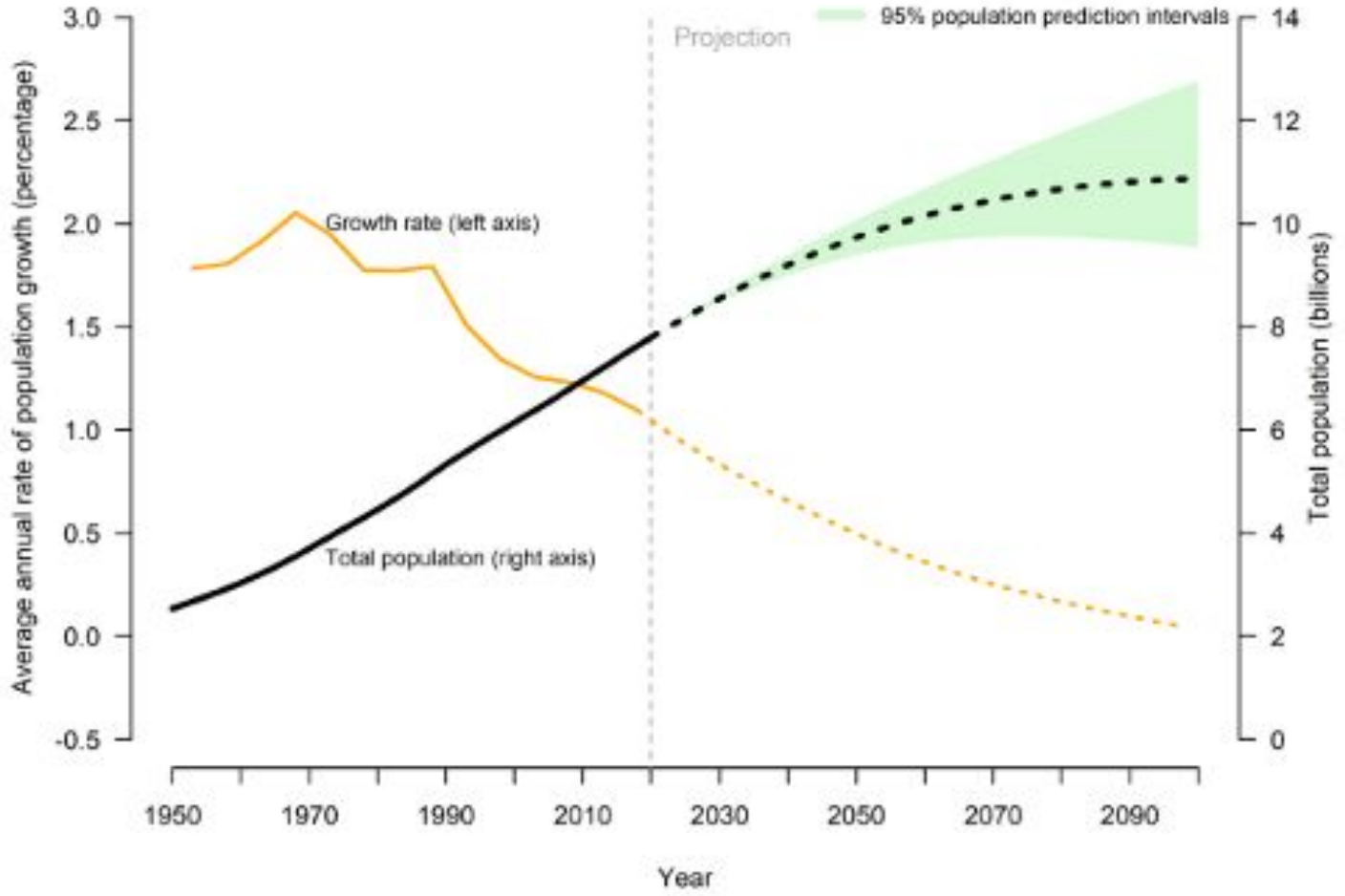
Overview

THE CHALLENGE	CURRENT PROGRAM	FUTURE IDEAS	QUESTIONS

The challenge

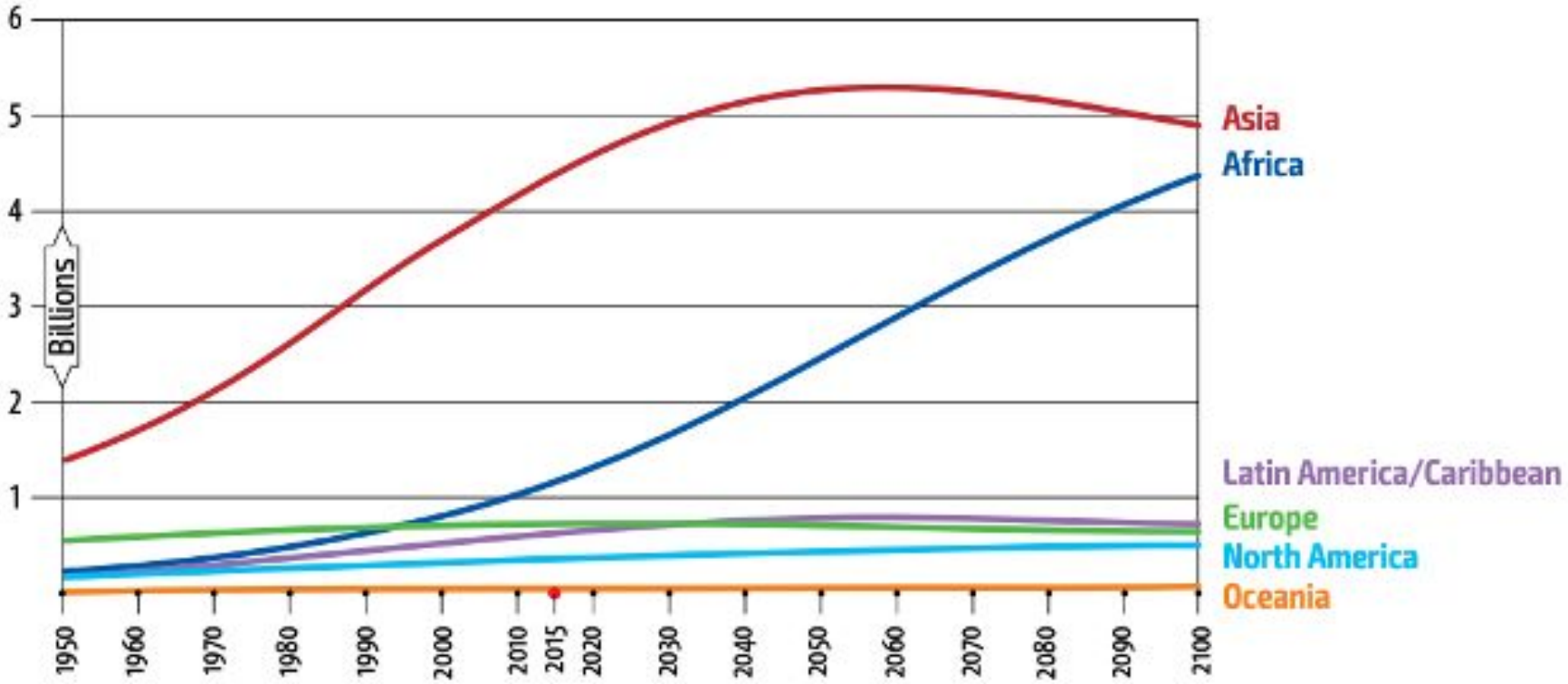
Global Population Growth

Global Population growth -1950-2100



Data source: United Nations, Department of Economic and Social Affairs, Population Division (2019). *World Population Prospects 2019.*

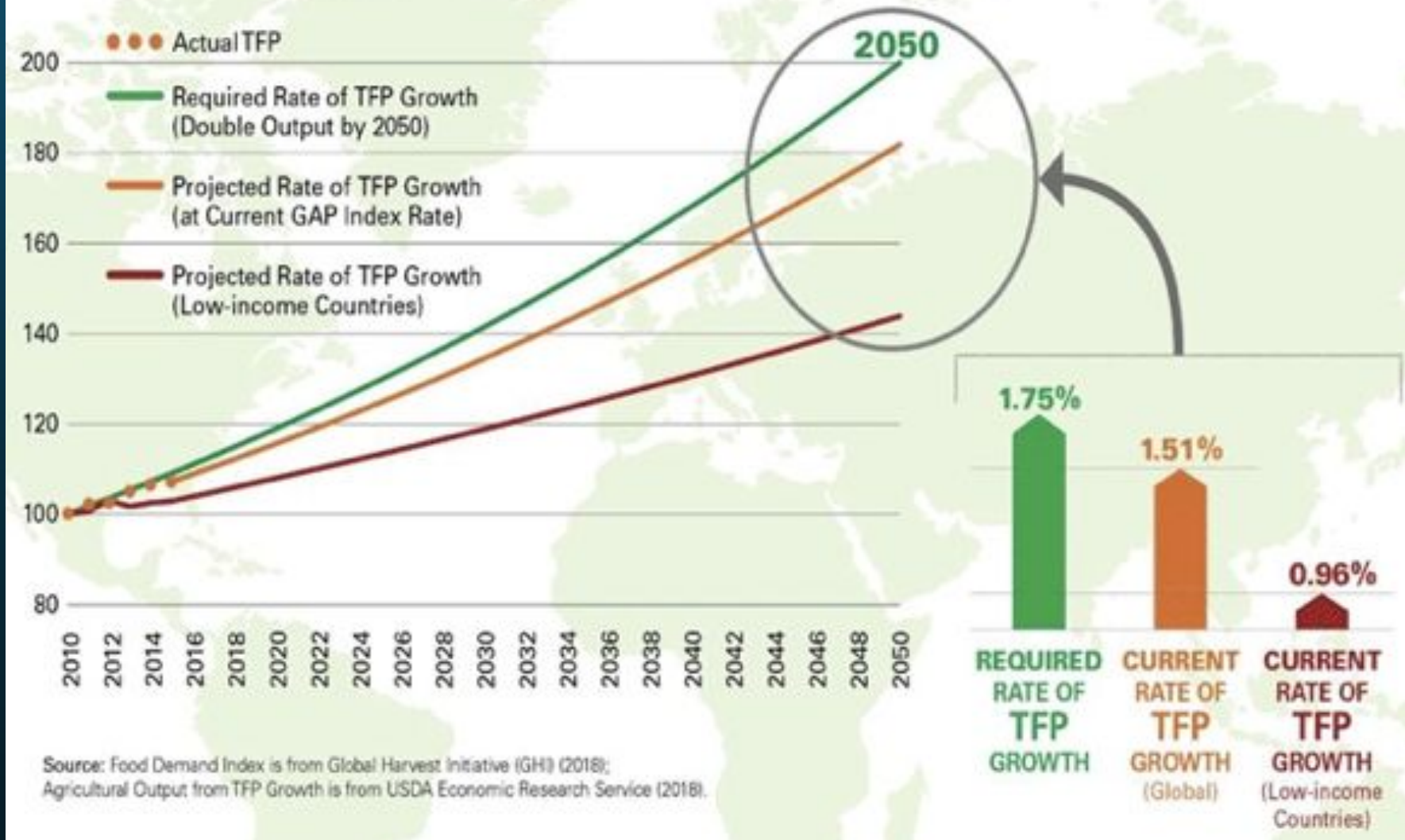
Regional Trends in Population Growth



Source: UN, 2015.

What about Food Security?

THE GLOBAL AGRICULTURAL PRODUCTIVITY (GAP) INDEX™



Source: Food Demand Index is from Global Harvest Initiative (GHI) (2018); Agricultural Output from TFP Growth is from USDA Economic Research Service (2018).

Sustainable food production requires innovations from farm to fork

Food safety: Key to Sustainability

What is food safety?

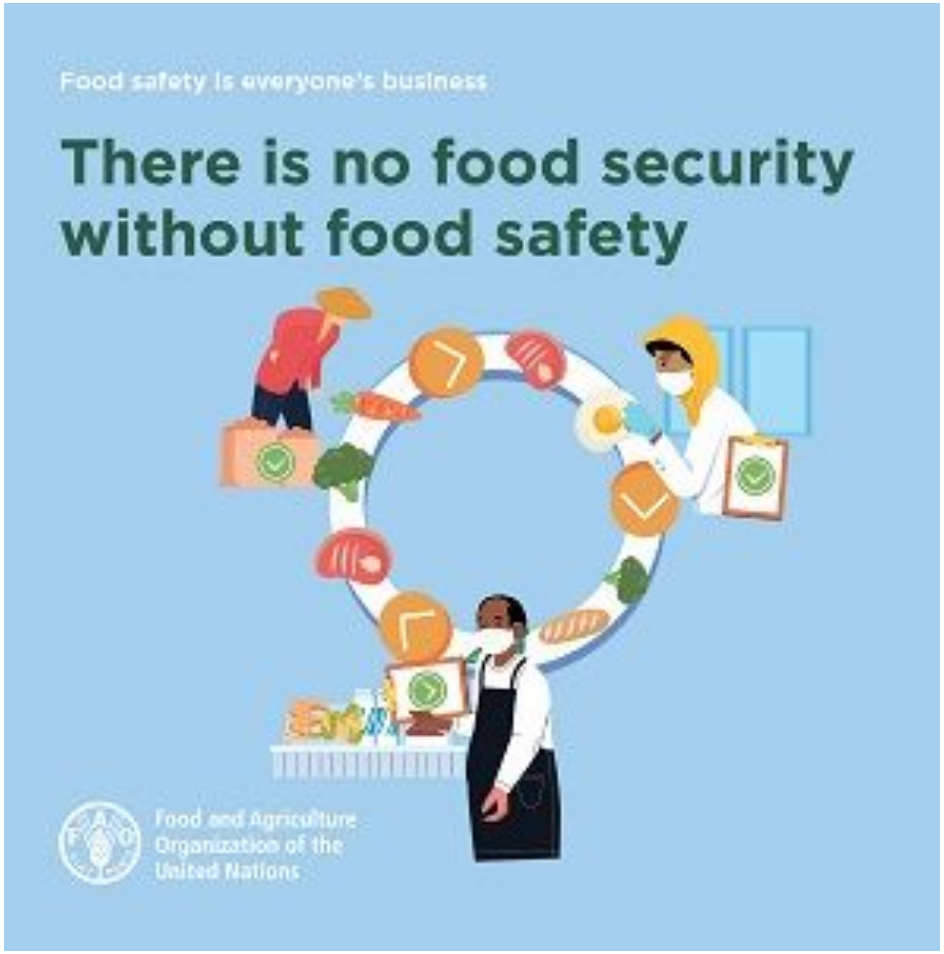
Food safety is the process or action that prevents food from containing substances that could harm a person's health.

If it is not safe, it is not food

Food and Agriculture Organization of the United Nations

World Health Organization

SUSTAINABLE DEVELOPMENT GOALS


Food safety is everyone's business
There is no food security without food safety
Food and Agriculture Organization of the United Nations

Foodborne illnesses


WHO ESTIMATES OF THE GLOBAL BURDEN OF FOODBORNE DISEASES
The burden of foodborne diseases is substantial
Every year foodborne diseases cause:
almost
in 10
people to fall ill
33 million
healthy life years lost
Foodborne diseases can be deadly, especially in children <5
420 000
deaths
Children account for
1/3
of deaths from foodborne diseases
FOODBORNE DISEASES ARE PREVENTABLE.
EVERYONE HAS A ROLE TO PLAY.
For more information: www.who.int/foodsafety
#SafeFood
Source: WHO Estimates of the Global Burden of Foodborne Diseases. 2015.
World Health Organization

AN ESTIMATED **1 in 6**

Americans get sick

FROM FOODBORNE DISEASES

every year.

DEPARTMENT OF HEALTH & HUMAN SERVICES · USA

CDC

CS331204-A

Foodborne illnesses in the USA

Each year, foodborne infections result in

- **48 million** illnesses
- **128,000** hospitalizations
- **3000** deaths[1]

Annual health care costs **~ 55-90 billion USD[2]**

1-Scallen et al. 2011; 2-Scharff, 2015

Improve Food Safety

CURRENT PROGRAM

Current research program at UConn

Developing intervention strategies for controlling foodborne pathogens at pre-harvest and post-harvest stages.

Pre-harvest Food Safety

Post-harvest Food Safety

Intervention strategies

Phytochemicals

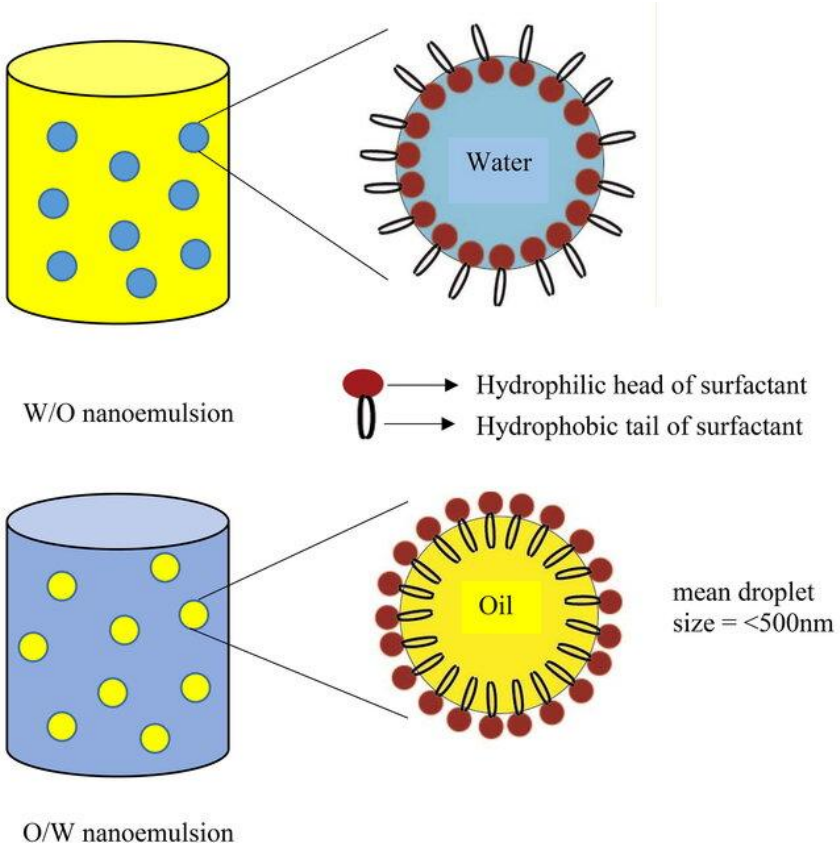
Antimicrobial gases

Phytochemical Nanoemulsions

Ultra-fine bubbles

Nanoemulsions

- Colloidal dispersion systems composed of two or more immiscible phases, consisting of oil, aqueous phase and an emulsifier to form a single phase.
- Could be oil-in-water (o/w) and water-in-oil (w/o)



Reference: DOI: 10.1080/13102818.2021.1915869; https://doi.org/10.3389/fsufs.2019.00095

Phytochemical nanoemulsions

Trans-cinnamaldehyde

Caprylic acid

Eugenol

Development and characterization of Trans-cinnamaldehyde & Caprylic acid nanoemulsions

Stirred for 30 min, Water added

Sonication (High energy method)

Zetasizer Nano ZS

TCNE & CANE : 4 % Gum Arabic & Lecithin and 1.25 % TC or CA

(Bhargava *et al;* 2015)

Rationale for using Gum Arabic & Lecithin

Gum Arabic
(21 CFR 184.1330)

Lecithin
(21 CFR 184.1400)

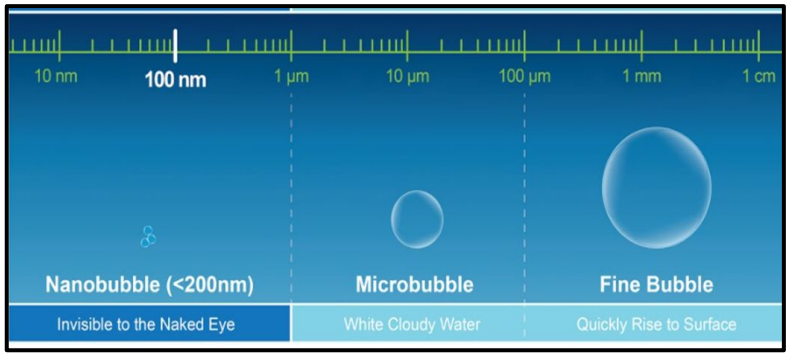
- ✔ Natural emulsifiers
- ✔ Food grade
- ✔ Mixture of polysaccharide and phospholipid provides good emulsification properties
- ✔ Increased stability of nanoemulsion

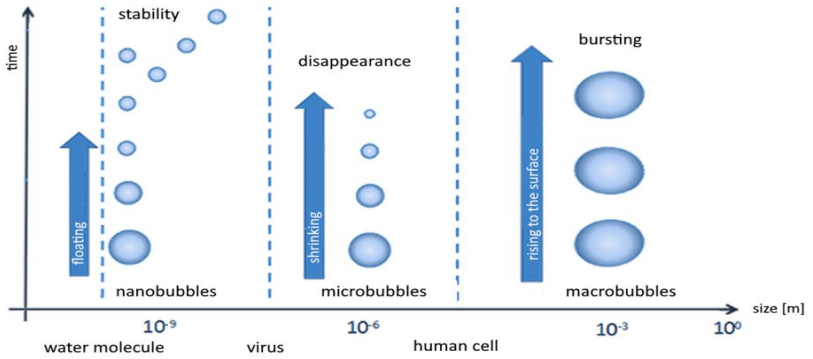
(Dammak et al., 2020)


Ultra-fine bubble technology
www.deseoaprender.com

Ultrafine bubbles technology

- ✔ High stability and longevity in solution,
- ✔ Ability to penetrate deeply into liquids and interact with surfaces effectively.
- ✔ These bubbles can carry gases, such as oxygen or ozone, in high concentrations, enabling various beneficial effects in different applications.





Application of Ultrafine bubbles technology

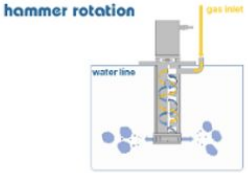


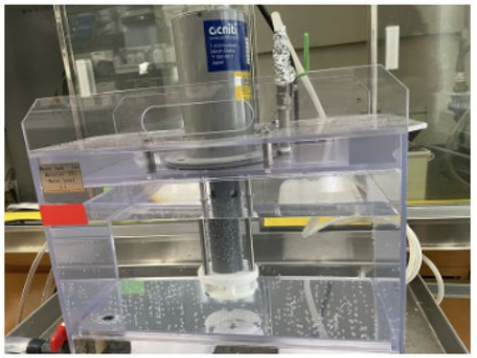



Production of Ultra-fine ozone bubbles in water.

Oxygen concentrator

Ozone generator





Ultra fine bubble generator

Zetasizer (Size, PDI, zeta potential)

Ultrafine bubble monitoring machine

Farm to fork food safety: Hurdle approach

Challenge area # 1

Gut colonization

↓

Challenge area # 2

Persistence in processing environment

↓

Challenge area # 3

Post-harvest contamination

↓

Challenge area # 4

Human infections

Challenge area # 1

Reducing colonization of foodborne pathogens in poultry

Major Results

- Trans-cinnamaldehyde, Eugenol and Caprylic acid nanoemulsions are effective in reducing ***Salmonella* Enteritidis** and ***Campylobacter jejuni*** colonization in broiler chickens.
- No change in production parameters.

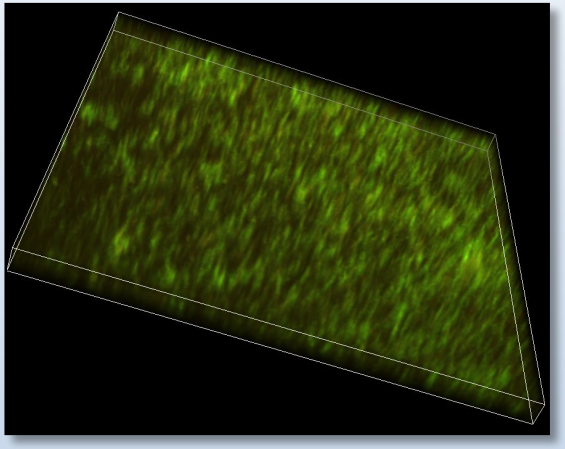
Future Ideas

- Efficacy of therapeutic supplementation strategies.
- Market age and combination studies.
- Effect on meat quality and taste.
- Research in other poultry-Layer birds, Turkeys.

Challenge area # 2

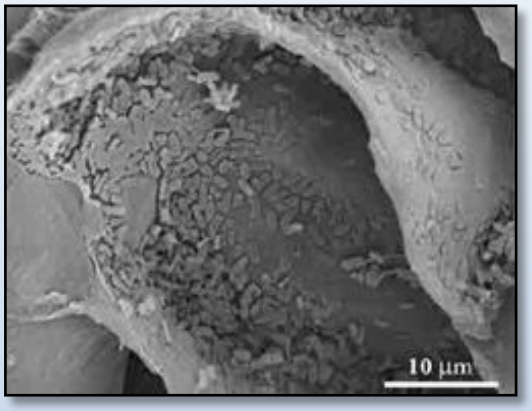
Reducing persistence of foodborne pathogens in environment

Bacterial biofilms

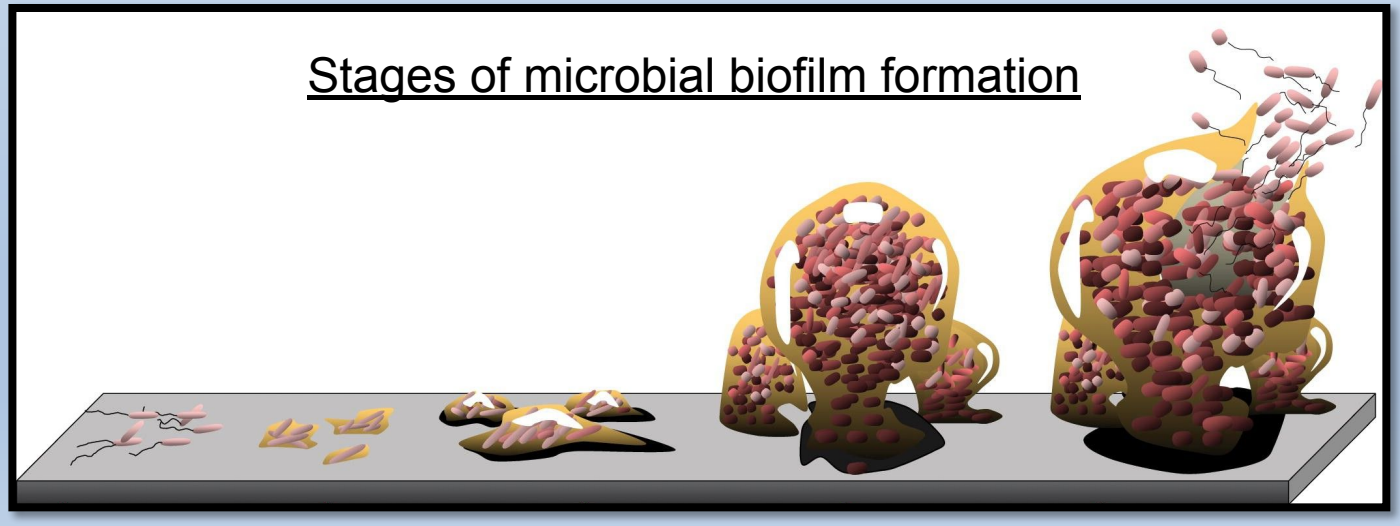


Upadhyay et al., 2013;
Food Microbiology, 36, 79-89

Organized microbial system associated with surfaces.



Annous et al 2009, Journal of Food Science, 74(1), R24–R37



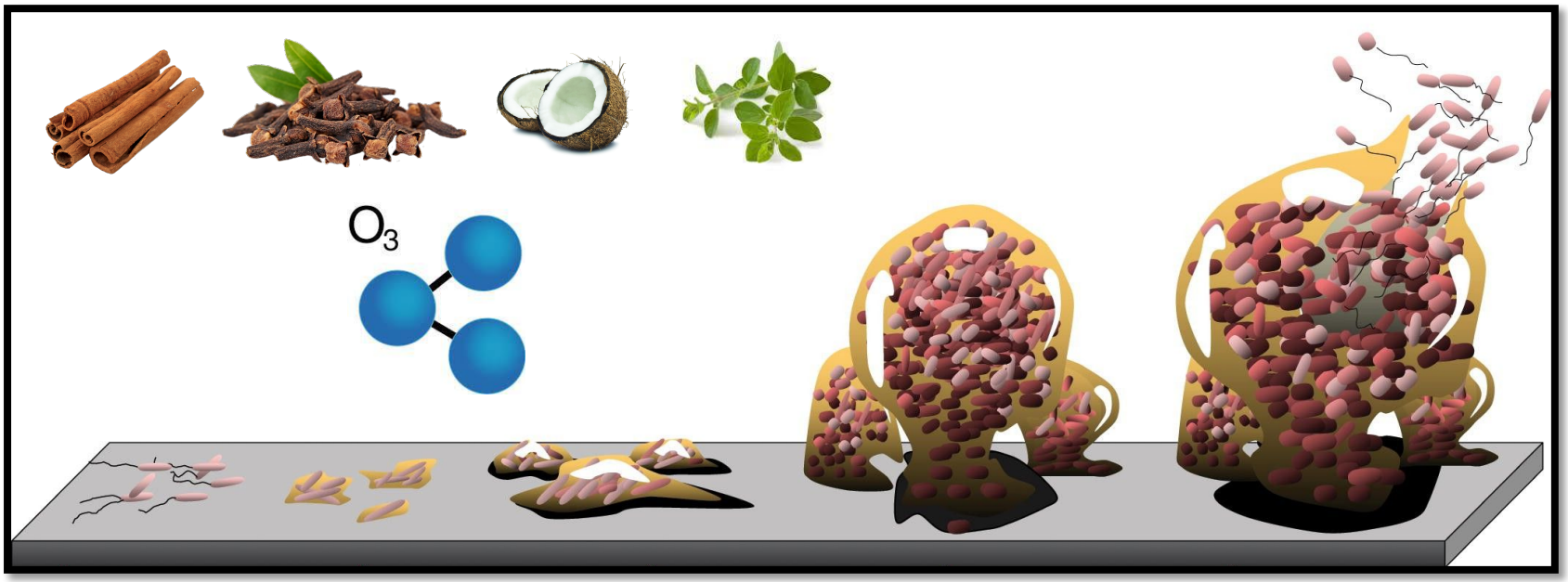
Unosson, E., 2015. *Antibacterial strategies for titanium biomaterials* (Doctoral dissertation, Acta Universitatis Upsaliensis).

Hall-Stoodley, et al.,2004. Bacterial biofilms: from the natural environment to infectious diseases. *Nature reviews microbiology*, *2*(2), pp.95-108.

Major Results

Nanoemulsions of Eugenol, Carvacrol, Caprylic acid and **Trans-cinnamaldehyde** are effective in controlling biofilms of *L. monocytogenes* and S. Enteritidis.

Ultra-fine ozone bubbles are effective in inactivating mature *L. monocytogenes* biofilms.



frontiers | Frontiers in Sustainable Food Systems

TYPE Original Research
PUBLISHED 27 October 2023
DOI 10.3389/fsufs.2023.1272373

OPEN ACCESS

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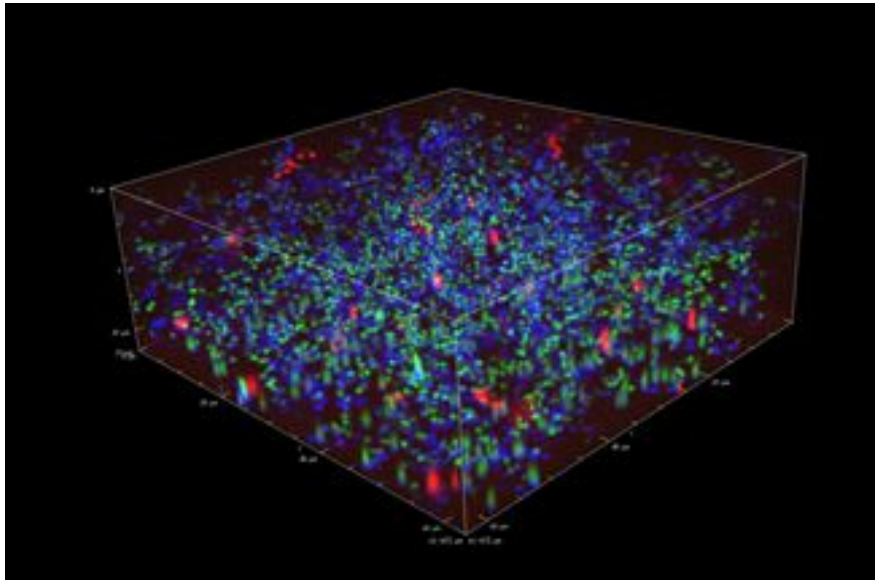
Eugenol nanoemulsion reduces *Listeria monocytogenes* biofilm by modulating motility, quorum sensing, and biofilm architecture

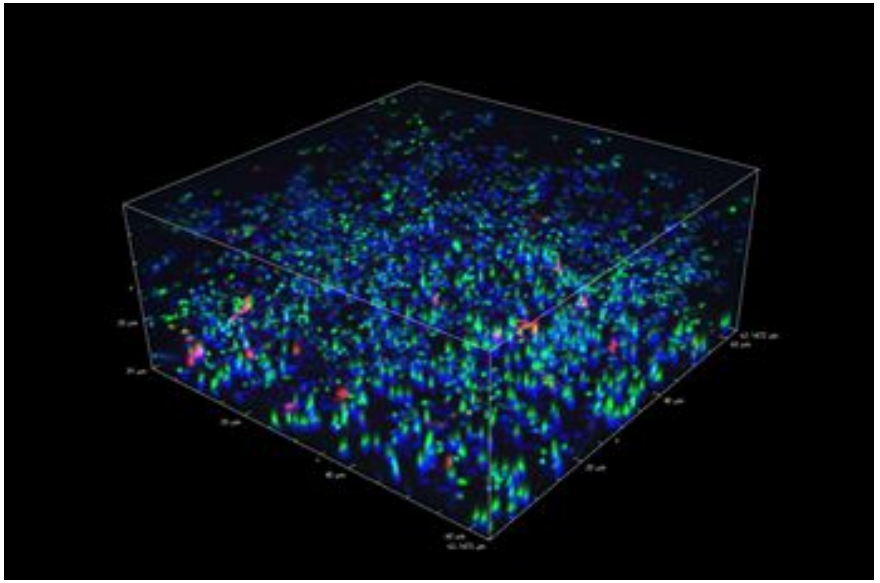
Brindhalakshmi Balasubramanian[1], Jingyi Xue[2], Yangchao Luo[2] and Abhinav Upadhyay[1]*

[1]Department of Animal Science, University of Connecticut, Storrs, CT, United States, [2]Department of Nutritional Sciences, University of Connecticut, Storrs, CT, United States

Effect of eugenol nanoemulsion on eDNA in *L. monocytogenes* biofilms



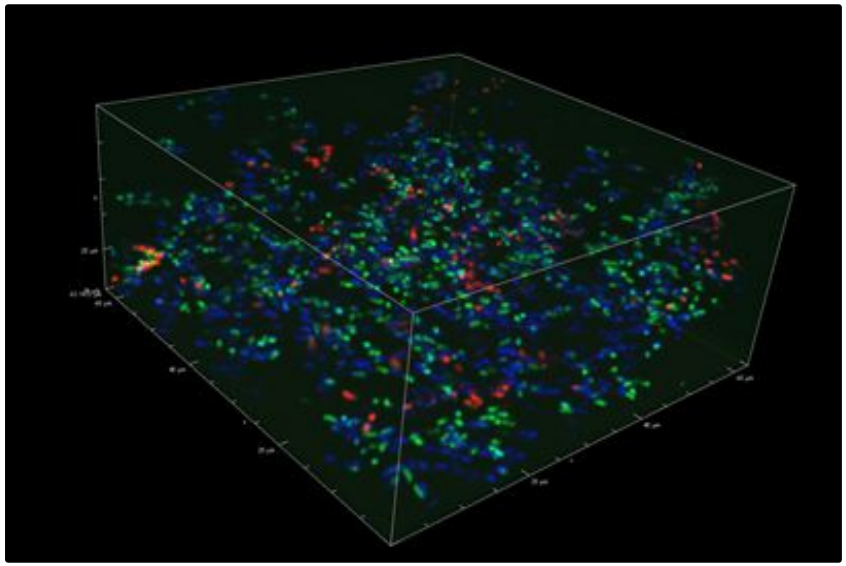
Control



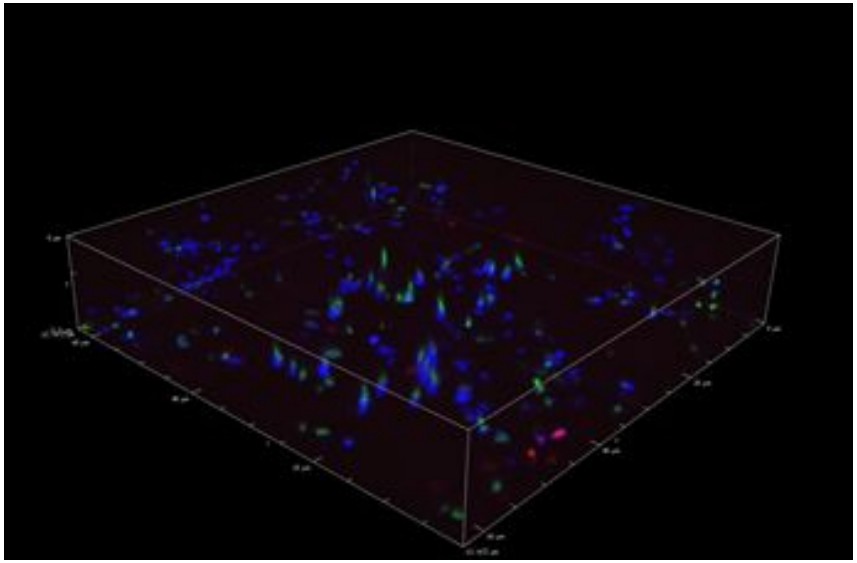
Ethanol control

Green – Live cells
Red – Dead cells
Blue – extracellular DNA (eDNA)

Effect of eugenol nanoemulsion on eDNA in *L. monocytogenes* biofilms



EG 700ppm



EGNE 700ppm

Green – Live cells
Red – Dead cells
Blue – extracellular DNA (eDNA)

Future Ideas

- Develop a natural disinfectant/ foam-based spray for controlling processing plant contamination.
- Understand how exposure to phytochemicals/nanoemulsions affect microbial physiology- in the biofilm matrix.

Challenge area # 3

Reducing post-harvest contamination of food products

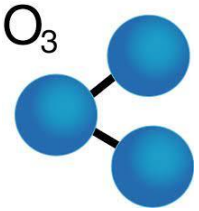
Post-harvest control of foodborne pathogens in food products

Antimicrobial wash

Cantaloupes

Lettuce and spinach

Poultry carcass



Nanoemulsions of Trans-cinnamaldehyde, Eugenol, Carvacrol and **Ultrafine ozone bubbles** are effective in reducing *L. monocytogenes*, S. Enteritidis and *E. coli* O157:H7 on fresh produce and poultry products.

Eggs

Major Results

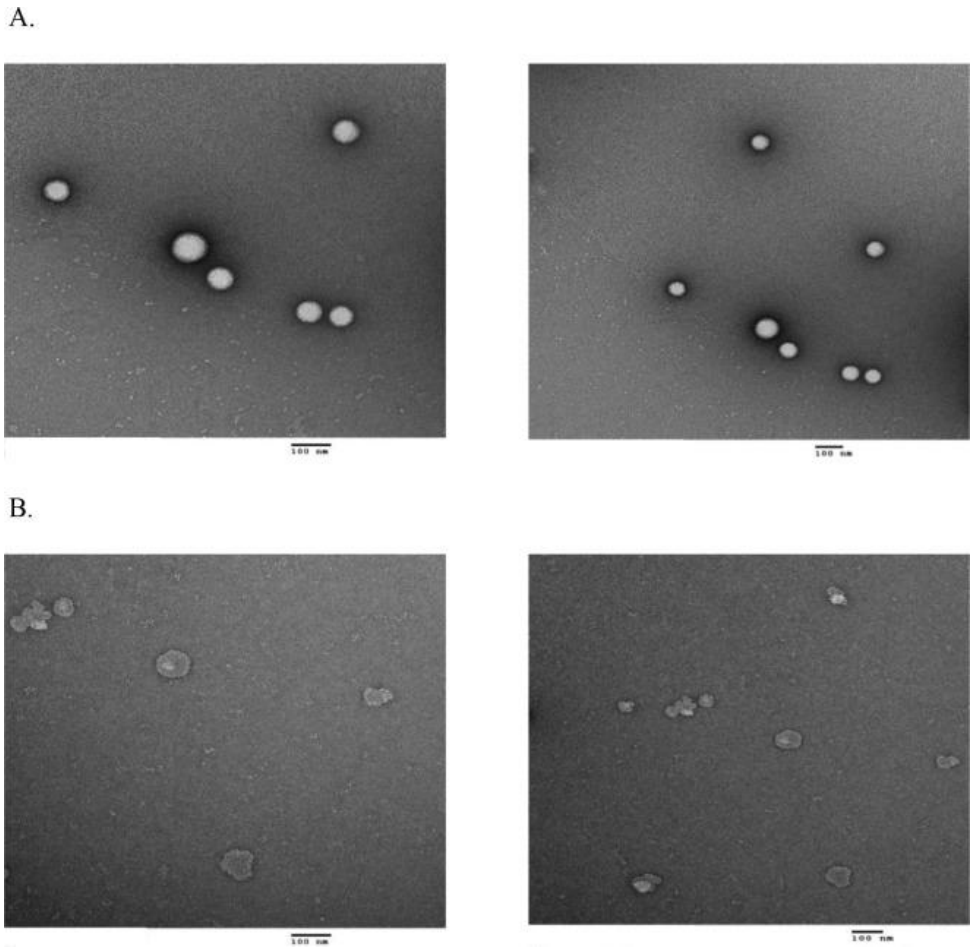
Poultry Science

Volume 102, Issue 4, April 2023, 102523

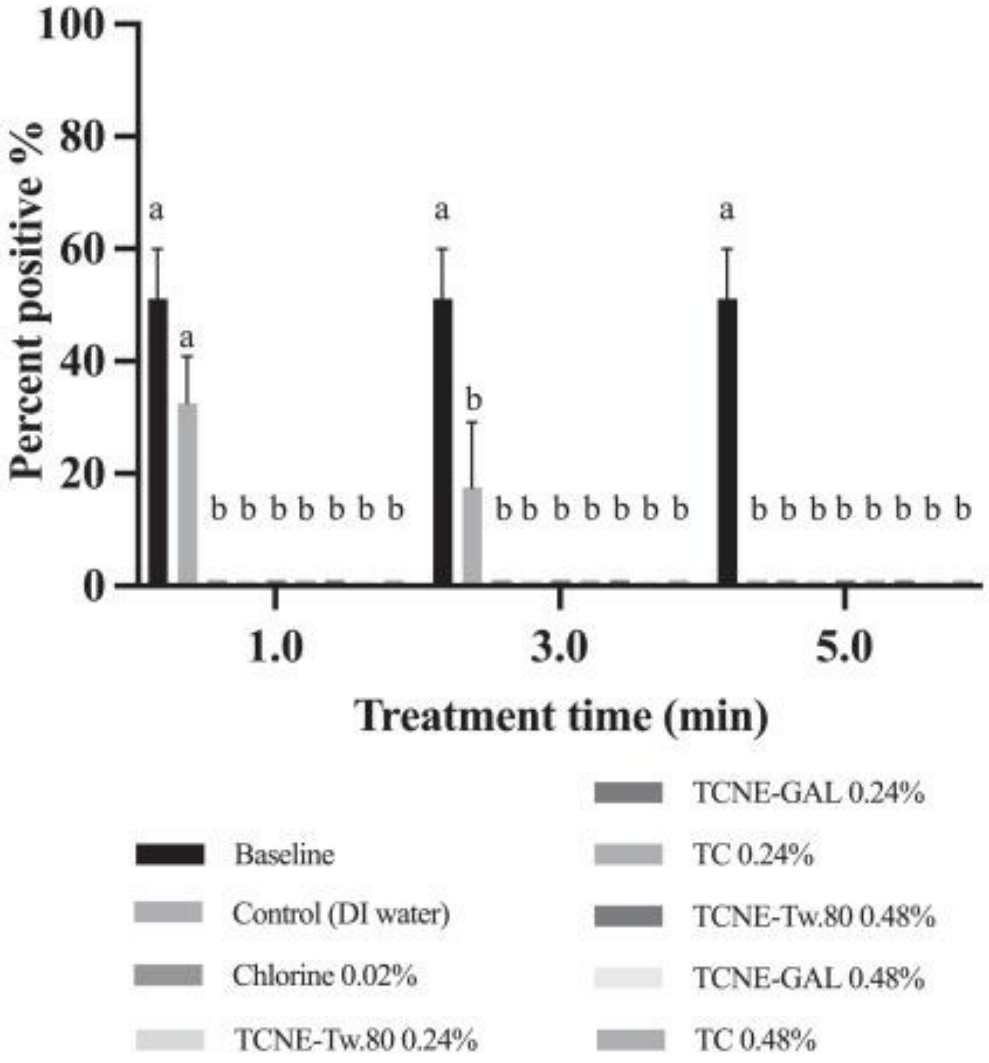
Trans-cinnamaldehyde nanoemulsion wash inactivates *Salmonella* Enteritidis on shelled eggs without affecting egg color

J. Allen *, B. Balasubramanian *, K. Rankin *, T. Shah *, A.M. Donoghue †, I. Upadhyaya ‡, B. Sartini ʃ, Y. Luo ¶, A. Upadhyay *

Transmission electron microscopy (TEM) images depicting morphology of nanoparticles of Tween 80 prepared *Trans*-cinnamaldehyde nanoemulsion (A) or Gum Arabic and lecithin *Trans*-cinnamaldehyde nanoemulsion (B).



Effect of *Trans*-cinnamaldehyde nanoemulsion (TCNE) wash on trans-shell migration of *S.* Enteritidis.



ELSEVIER

Poultry Science

Volume 102, Issue 8, August 2023, 102812

Effect of *trans*-cinnamaldehyde nanoemulsion wash on chicken embryo development in fertilized eggs

J. Allen *, B. Balasubramanian *, A.M. Donoghue † [1], I. Upadhyaya ‡, Y. Luo §, A. Upadhyay *

No impact on fertility rate by TCNE wash treatments.

frontiers | Frontiers in Sustainable Food Systems

TYPE Original Research
PUBLISHED 07 September 2022
DOI 10.3389/fsufs.2022.984391

OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to
Agro-Food Safety,
a section of the journal
Frontiers in Sustainable Food Systems

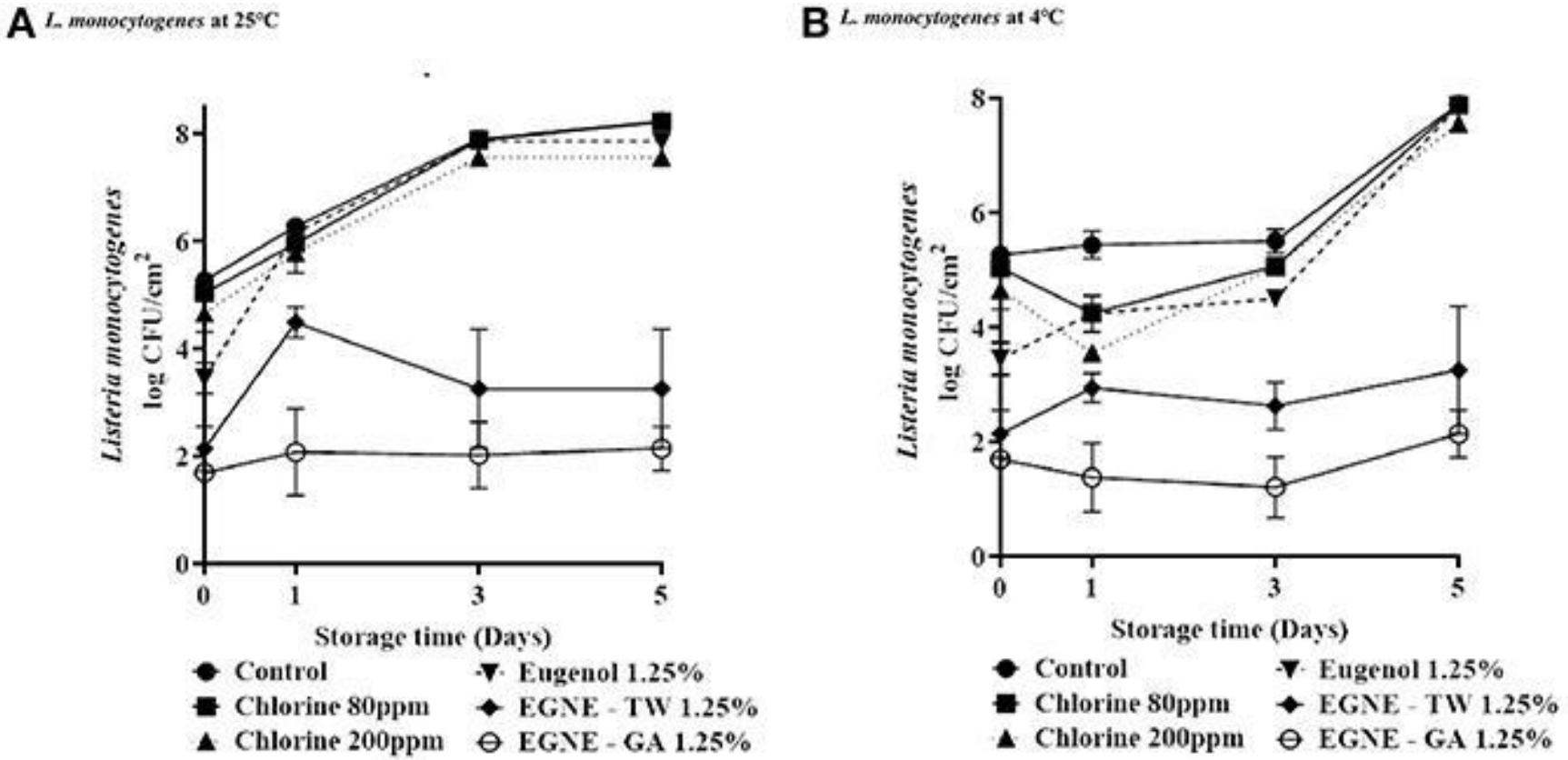
RECEIVED 02 July 2022
ACCEPTED 15 August 2022
PUBLISHED 07 September 2022

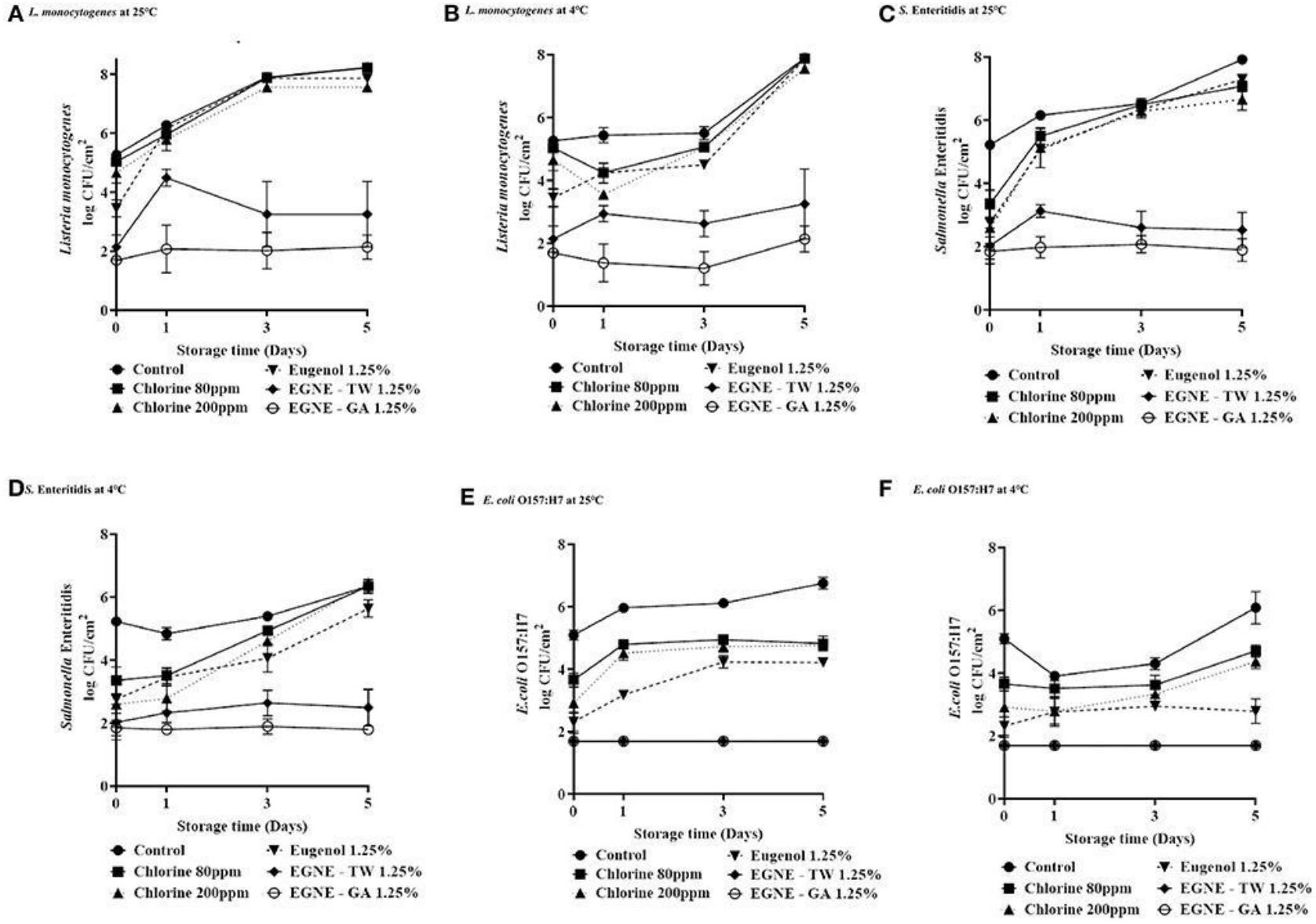
Eugenol nanoemulsion inactivates *Listeria monocytogenes, Salmonella* Enteritidis, and *Escherichia coli* O157:H7 on cantaloupes without affecting rind color

Brindhalakshmi Balasubramanian[1], Trushenkumar Shah[1], Jodie Allen[1], Kimberly Rankin[1], Jingyi Xue[2], Yangchao Luo[2], Richard Mancini[1] and Abhinav Upadhyay[1]*

[1]Department of Animal Science, University of Connecticut, Storrs, CT, United States, [2]Department of Nutritional Sciences, University of Connecticut, Storrs, CT, United States

Survival of *L. monocytogenes* (log CFU/cm^2) on cantaloupe washed with eugenol nanoemulsions during the 5-day storage at 25 (A) and 4°C (B).




A L. monocytogenes at 25°C
B L. monocytogenes at 4°C
C S. Enteritidis at 25°C
D S. Enteritidis at 4°C
E E. coli O157:H7 at 25°C
F E. coli O157:H7 at 4°C
Listeria monocytogenes log CFU/cm2
Salmonella Enteritidis log CFU/cm2
E.coli O157:H7 log CFU/cm2
Storage time (Days)
Control
Chlorine 80ppm
Chlorine 200ppm
Eugenol 1.25%
EGNE - TW 1.25%
EGNE - GA 1.25%

Inactivation of *Listeria monocytogenes* on apples, celery and lettuce at 25 or 4°C by UFO bubble wash.

Spot inoculated with *L. monocytogenes* (200 ul; ~5.5 log CFU/sample).

Washed with UFO bubble water for 1,3,5 min at 25 or 4°C.

Enumeration of surviving *L. monocytogenes*

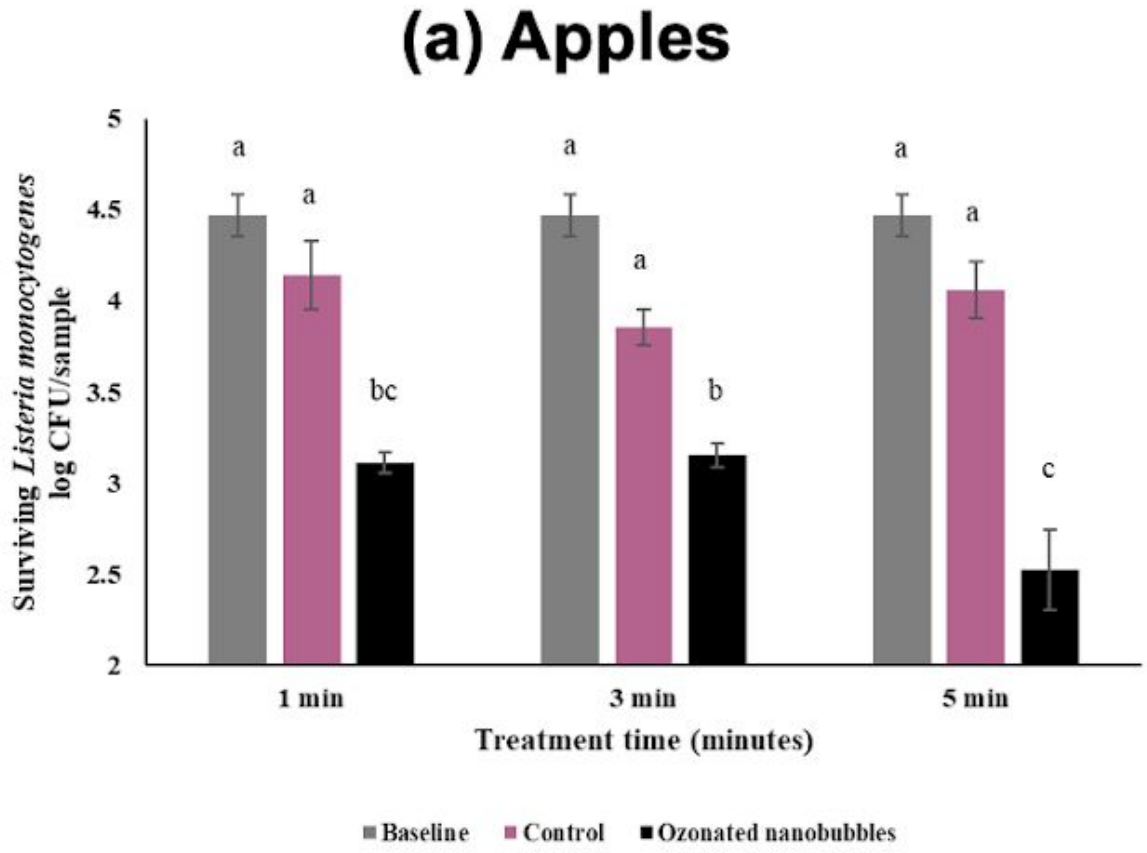
Effect of UFO bubble wash on color of apples, celery and lettuce during refrigerated storage.

Washed with UFO bubble water for 1,3,5 min at 25 or 4°C.

Enumeration of color of apples, celery or lettuce

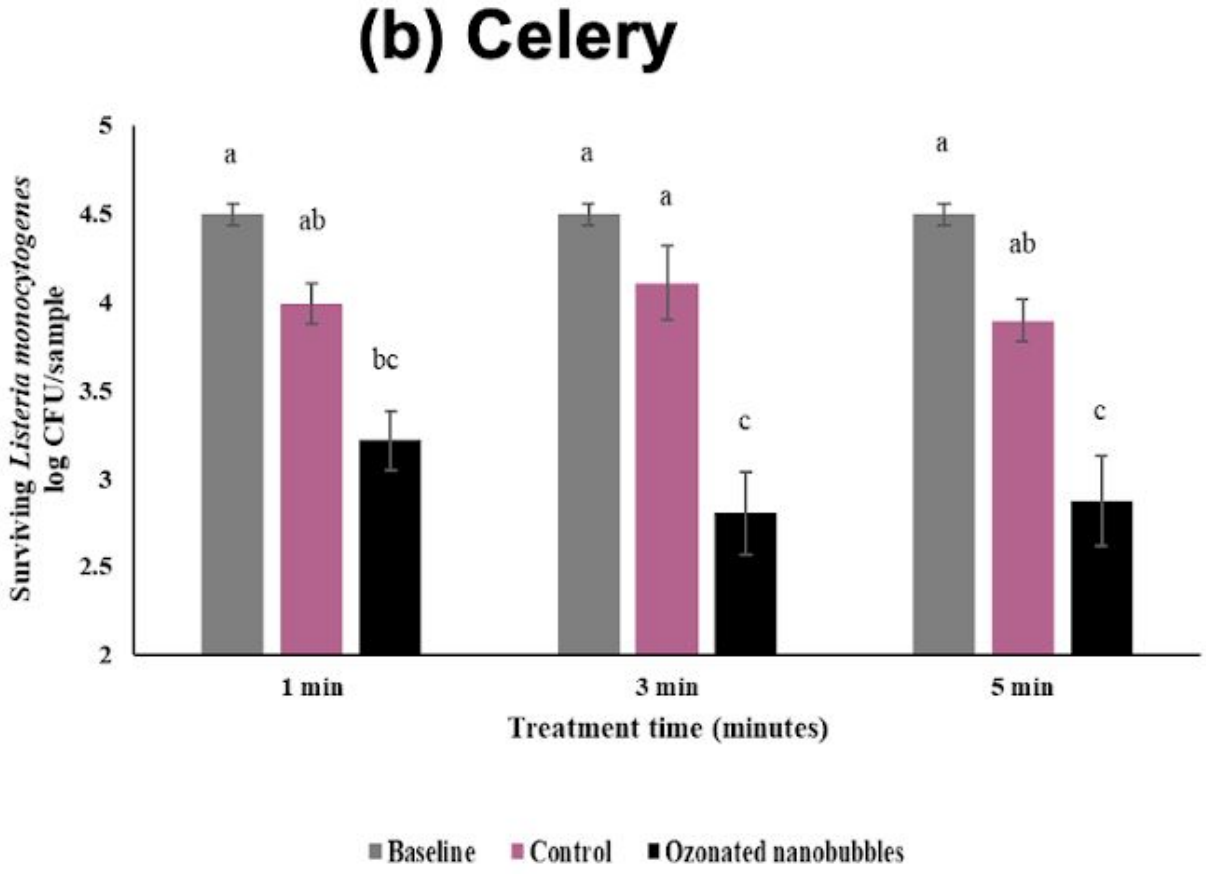
HunterLab colorimeter
L* - lightness, **a*** - red/green, **b*** - blue/yellow

Inactivation of *Listeria monocytogenes* on Apples, Celery and Lettuce by UFO bubble wash (5 ppm) at 4C.



UFO wash treatments did not impact produce color.

Inactivation of *Listeria monocytogenes* on Apples, Celery and Lettuce by UFO bubble wash (5 ppm) at 4C.



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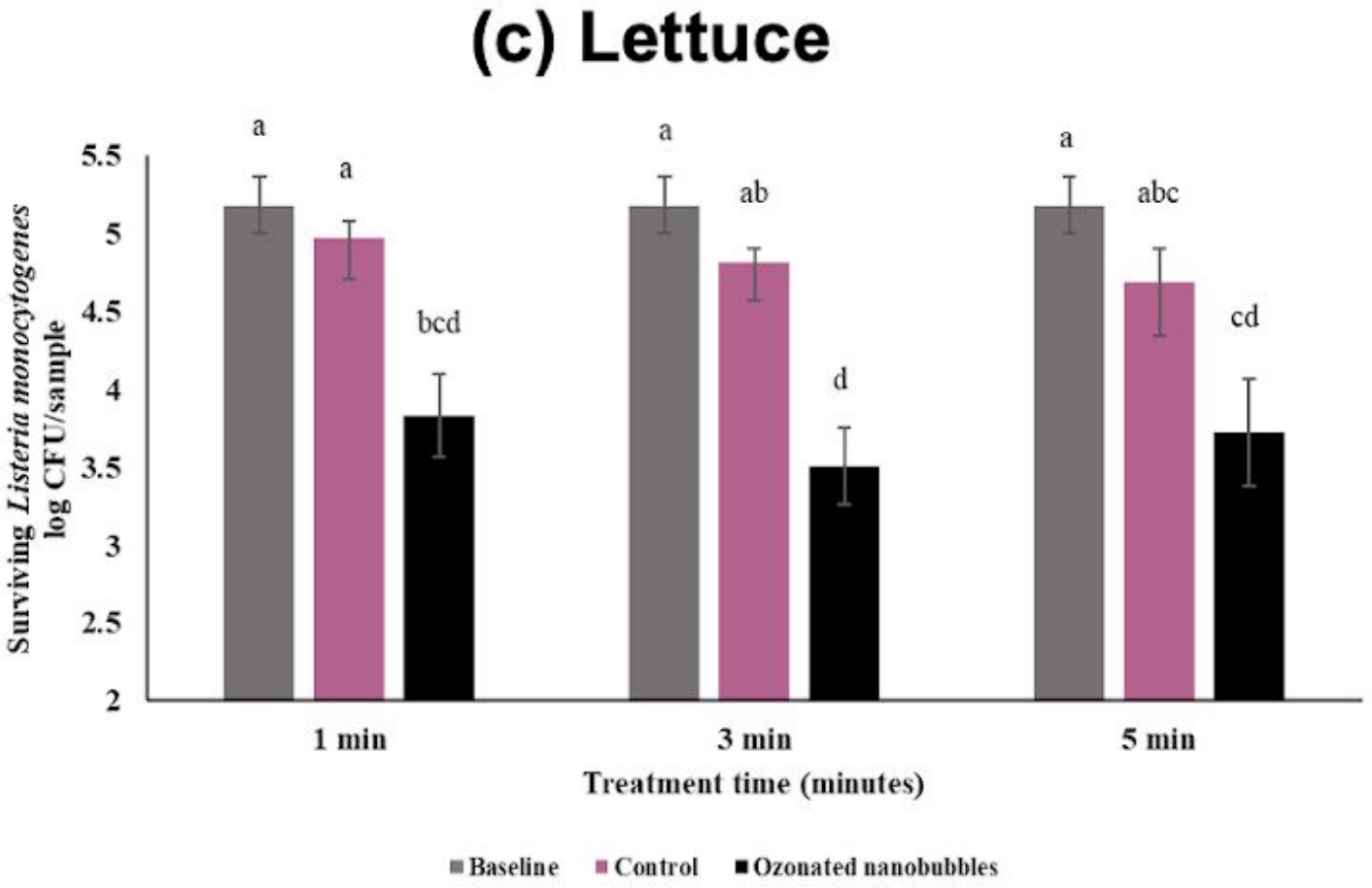

UFO wash treatments did not impact produce color.

Future Ideas

- Application of phytochemical nanoemulsions or UFO bubbles in combination with other intervention technologies for reducing pathogens in food products.
- Organoleptic investigations.
- Studies in industry settings.

S.M.A.R.T. Solutions for Food Safety

S.M.A.R.T. Solutions for Food Safety

Stakeholder-Centered Program: Supporting producers, industry, and regulators.

Modern Approaches: Developing user-friendly, economical, organic solutions for food safety and production.

Advancing Workforce: Training the next generation of academic scholars and industry leaders.

Real-World Applications: Providing solutions for both small and large-scale producers.

Targeting Global Impact: Creating national and international collaborations to drive global change in sustainable food production.

TEAM-Together Everyone Achieves More.

This work was supported by Center for Produce Safety (#2021-44), NE-SARE (#2019-38640-29877) and USDA-NIFA AFRI (# 2020-69006-31684) grant programs.