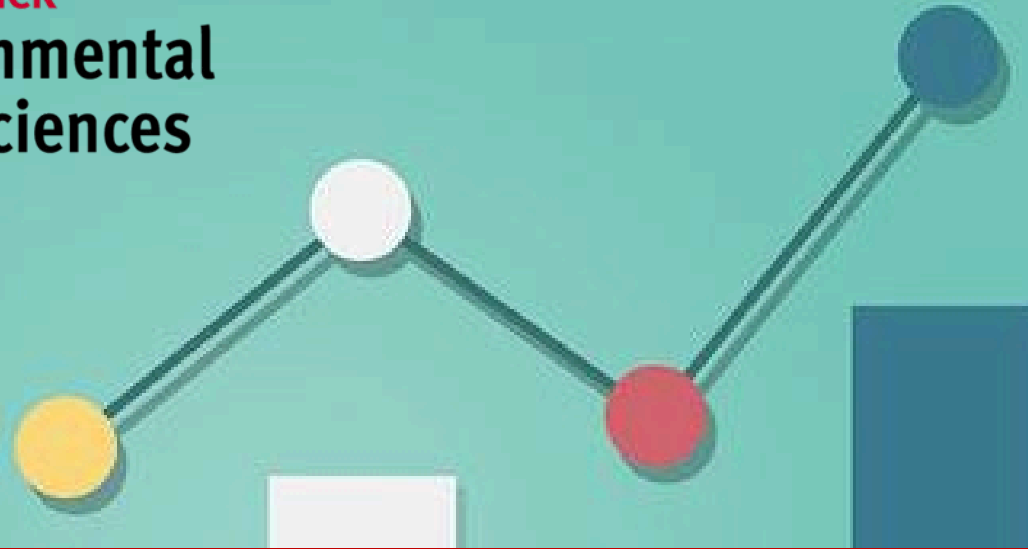




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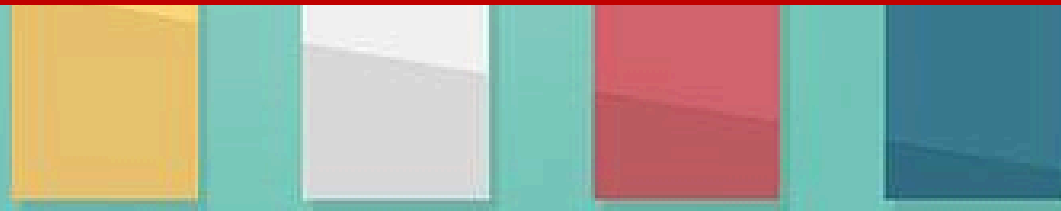


Clean AND Safe? Navigating Clean-Label Formulation Trade-Offs

Byron D. Chaves, PhD.

Rutgers University

byron.chaves@rutgers.edu

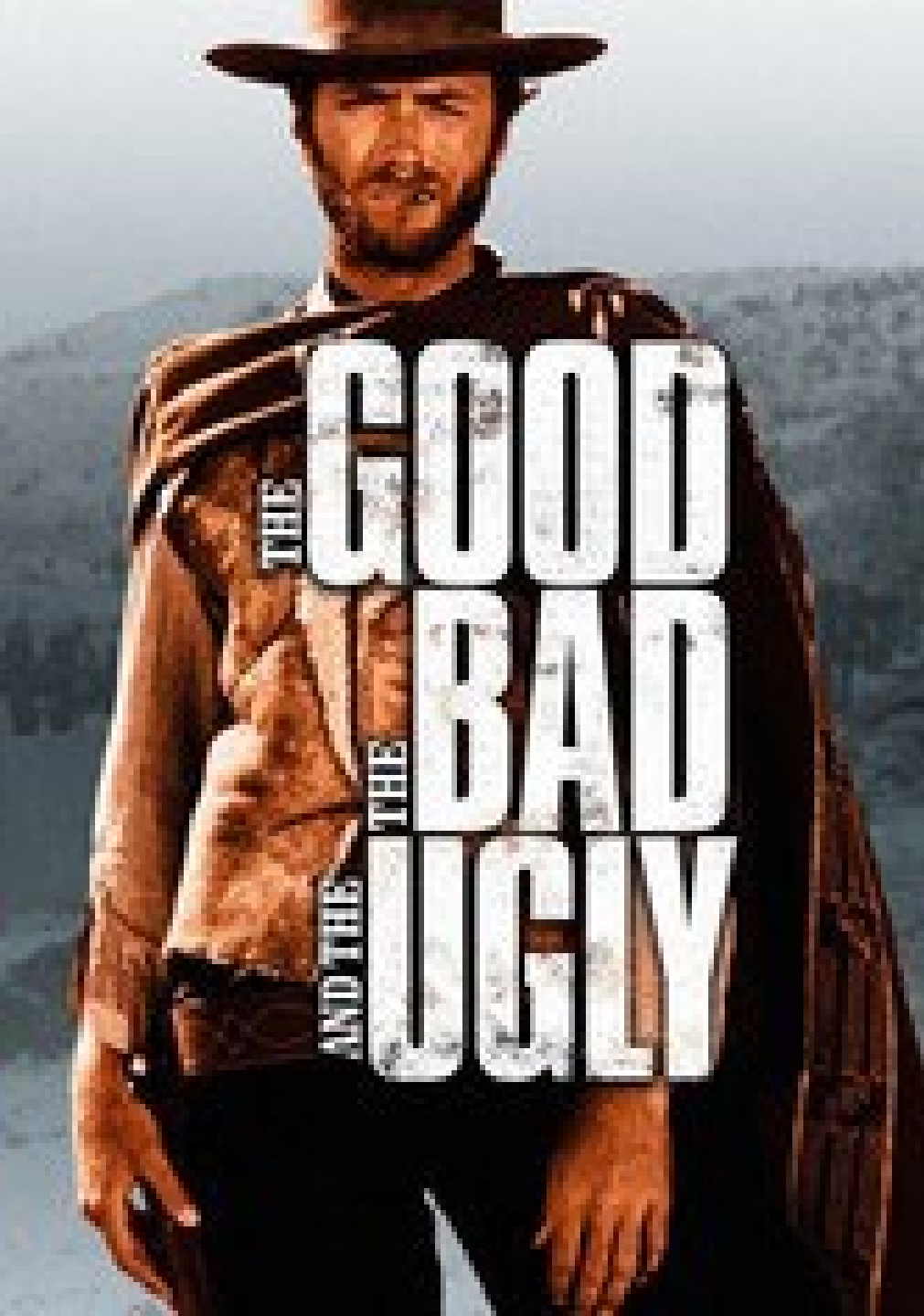


No Artificial Colors, Flavors, or Preservatives

Consumer perception has shifted

- Over the last 15-20 years, consumers have increasingly associated:
 - Short ingredient statements with higher quality
 - Familiar ingredients with safety and transparency
 - Chemical-sounding names with "artificial" or "unhealthy" products

Consumers often perceive synthetic ingredients as less desirable, regardless of toxicological evidence supporting their safety.



Traditional preservative

Potassium sorbate

Sodium benzoate

Propionates

Sodium nitrite

Synthetic antioxidants

Common clean-label alternative

Vinegar-based systems

Fermentation-derived ingredients

Cultured flour ingredients

Vegetable-derived nitrate/nitrite systems

Rosemary or green tea extracts



Animal-derived



Examples:



- Lysozyme
- Lactoferrin
- Lactoperoxidase

Applications:



- Dairy
- Certain processed foods



Microbial-derived



Examples:



- Nisin
- Natamycin
- Other bacteriocins

Applications:



- Dairy
- Processed foods
- RTE products



Plant-derived



Examples:



- Rosemary extract
- Oregano extract
- Thyme extract
- Green tea extract
- Cinnamon compounds
- Garlic compounds

Applications:



- Meat
- Poultry
- Sauces
- Bakery
- Produce



FERMENTATES

Microbial metabolites delivered directly



Examples

Cultured sugar, cultured milk, fermentation-derived metabolites



Advantages

- Broad antimicrobial activity
- Can replace traditional preservatives
- Often accepted as “natural”
- Familiar labeling



Why important

More predictable, consistent performance across food matrices



PROTECTIVE CULTURES

Living microorganisms that produce antimicrobials



Intentionally added microorganisms



Produce antimicrobial metabolites in food



Usually minimal impact on sensory properties



Inhibit pathogens

Listeria monocytogenes
Staphylococcus aureus

Key distinction

Require growth in the food system



ESSENTIAL OILS & PLANT EXTRACTS

Botanical antimicrobials with multiple benefits



Examples

Oregano, Thyme, Rosemary, Cinnamon, Black cumin



Applications

Listeria control, *E. coli* O157:H7 control, Yeast & mold inhibition, Antioxidant activity



Limitations

Food matrix interactions, Flavor & aroma impacts, Reduced efficacy in foods vs. laboratory systems

Promising, but context-dependent



ORGANIC ACIDS (DELIVERY SYSTEMS)

Trusted antimicrobials in natural forms



Key acids

- Lactic acid
- Acetic acid
- Propionic acid



Natural sources

- Vinegar
- Lemon juice
- Fermentation products
- Cultured ingredients



What doesn't change

Same antimicrobial mechanisms, different ingredient declaration

Same efficacy, cleaner label

Efficacy of Natural Antimicrobials

- Many natural antimicrobials show excellent *in vitro* performance but effectiveness can change drastically depending on:
 - Does it control the target organism?
 - Under what conditions?
 - At what concentration?
 - Throughout the entire shelf life?
 - Across manufacturing variability?

Natural ingredient = different ingredient requiring the same scientific validation.



Step 1

Ingredient selection



Step 2

In vitro screening

- MIC
- MLC
- Growth inhibition



Step 3

Exploratory challenge studies



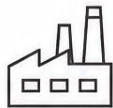
Step 4

Finished-product challenge studies



Step 5

Shelf-life validation



Step 6

Commercial implementation

The success of novel antimicrobials should not be measured by how "natural" they sound on a label, but by their ability to consistently deliver food safety, quality, and shelf-life outcomes in validated commercial systems.

Clean Label Processing and Packaging

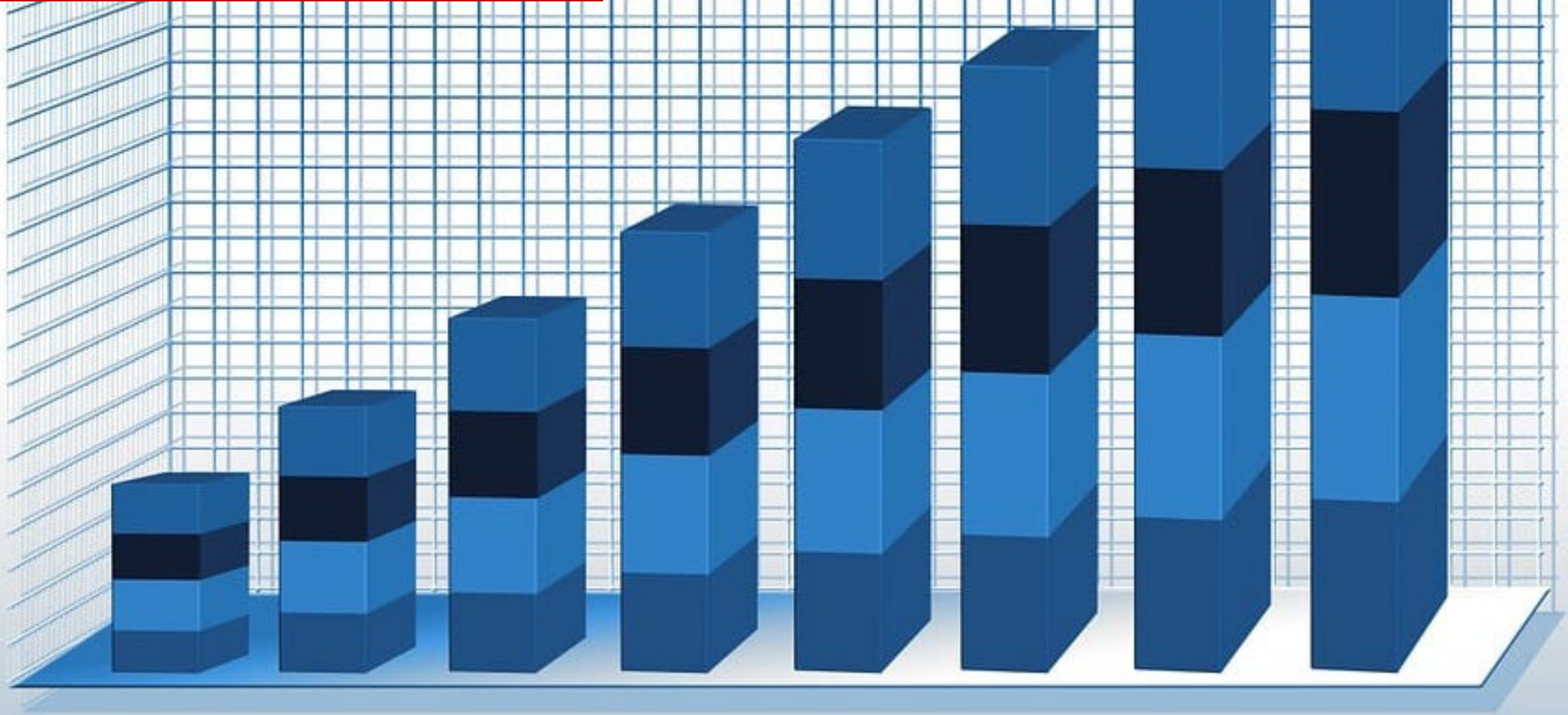
- Clean label is evolving from "what is in the food" to "how the food is produced."
- Packaging:
 - Nitrogen flushing, CO₂ atmospheres, oxygen scavengers, ethylene scavengers, barrier technologies, controlled atmosphere storage
- Processing:
 - High Pressure Processing (HPP) as a clean label enabler

Clean-label products rarely eliminate preservation systems; they redistribute preservation across ingredients, processing, and packaging technologies.

Key Messages

- Clean label is a consumer expectation, not a scientific definition.
- Removing conventional preservatives does not remove microbial risk.
- Preservation systems must integrate packaging and processing.
- Food manufacturers are replacing preservation systems, not simply replacing ingredients.
- The challenge is achieving equivalent performance with non-conventional ingredients.
- The ultimate measure of a clean-label preservative is validated performance in food.
- **So, validation is critical.**

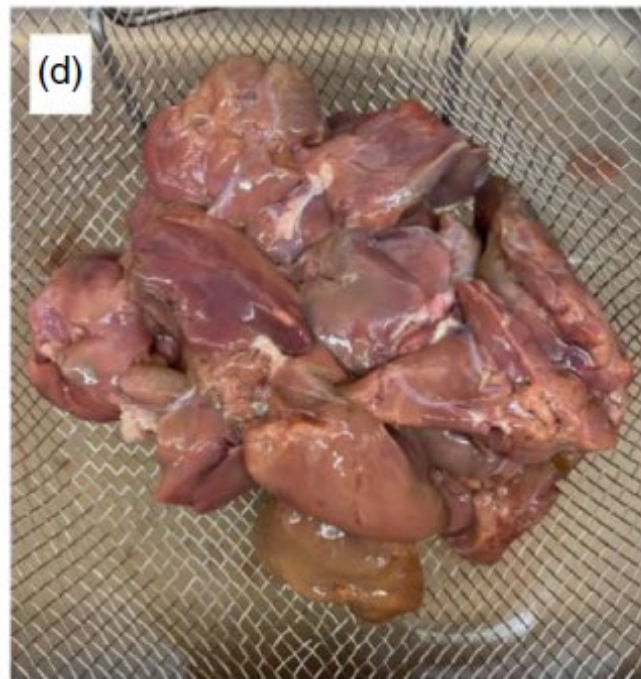
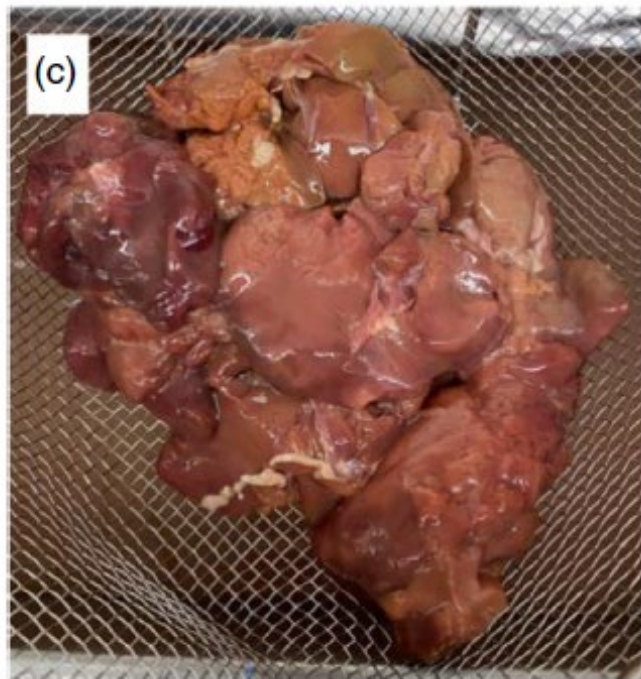
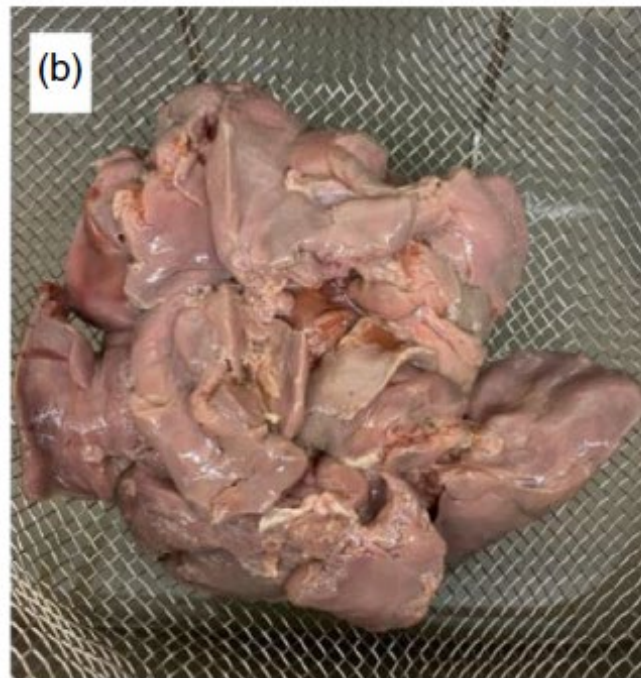
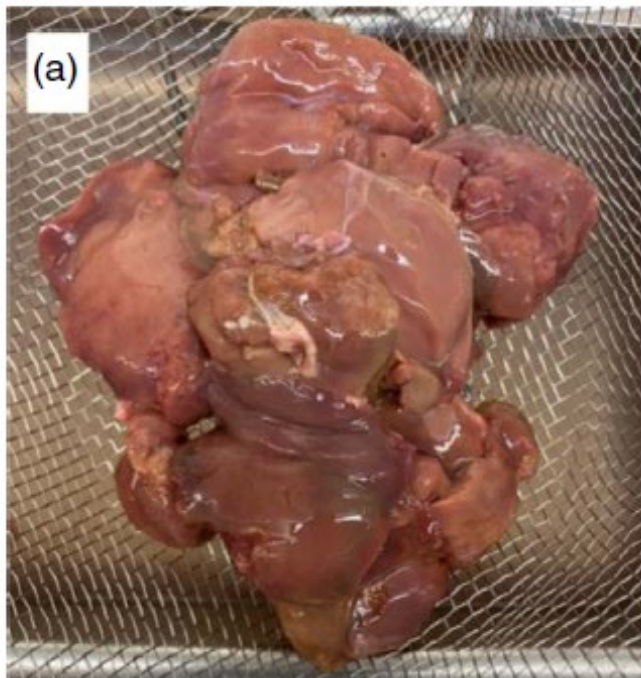
WHAT TYPE OF DATA DO WE NEED TO MAKE A DECISION?



EPIDEMIOLOGICAL - REGULATORY/LEGAL - EXPERIMENTAL/COMPUTATIONAL - OPERATIONAL

Cancio et al. (2023). Evaluation of Peroxyacetic Acid, Liquid Buffered Vinegar, and Cultured Dextrose Fermentate as Potential Antimicrobial Interventions For Raw Chicken Livers. *Journal of Food Safety*. <https://doi.org/10.1111/jfs.13054>

- Clean-label antimicrobials do not automatically outperform conventional interventions
- CDF showed only modest control of *Salmonella* and was the least effective treatment at suppressing background microbial growth during storage.
- Buffered vinegar did not substantially improve *Salmonella* control, but it was the most effective treatment for delaying growth of aerobic spoilage organisms and extending microbiological shelf life.
- Shelf-life extension may be easier than pathogen control



Formulating Without Nitrites: Cooked, Uncured Turkey Sausages

Li, Sullivan, Wang, and Chaves. In preparation.

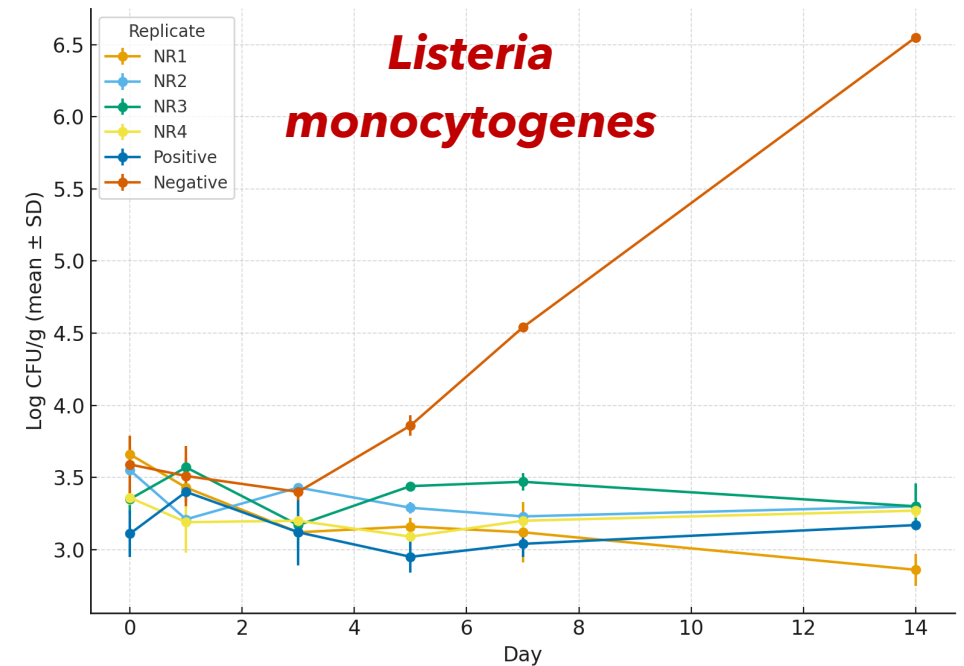
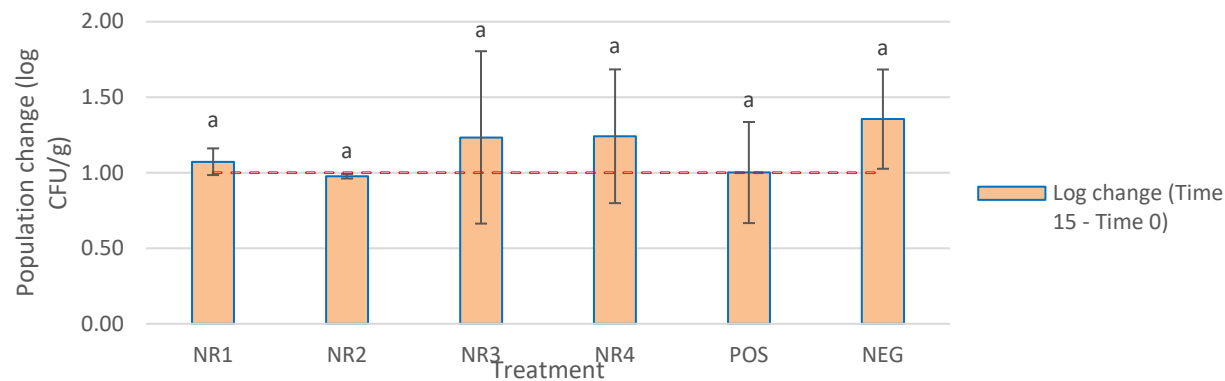
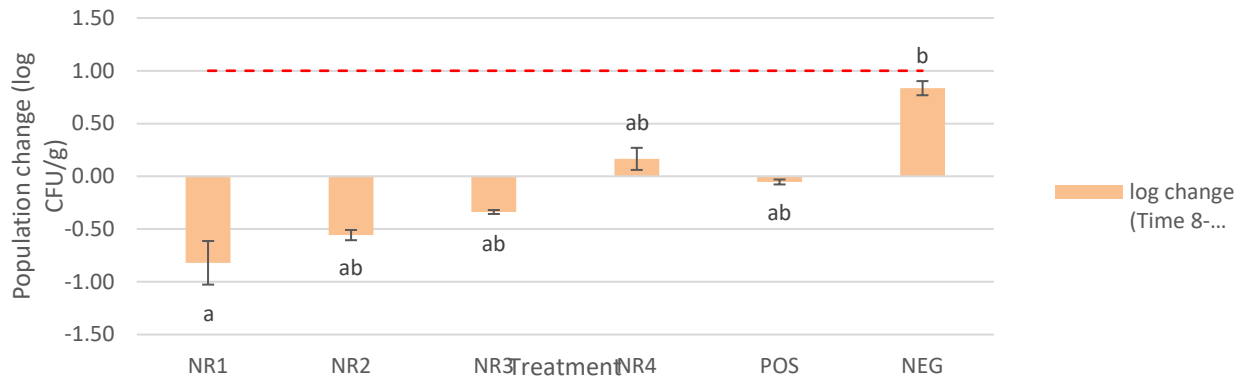
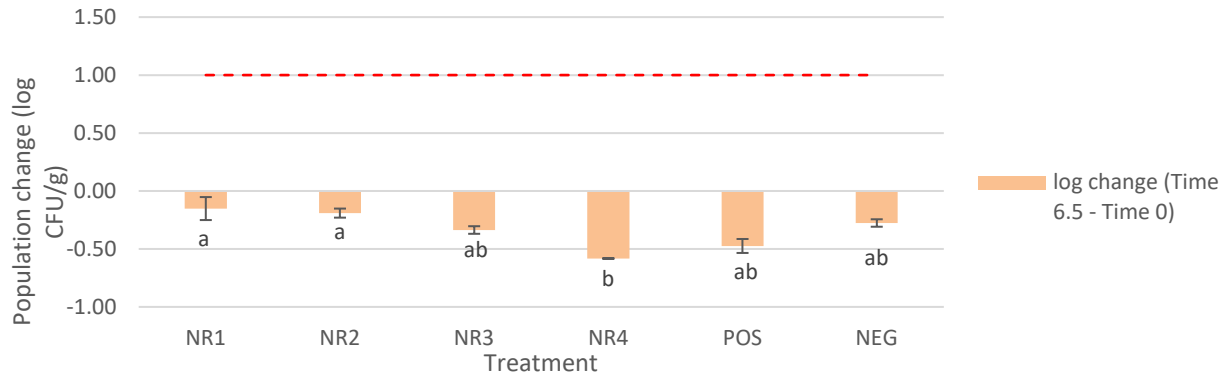
- Compared to pork-based models, growth in turkey sausage was slower (0.6325 log CFU/h), likely due to differences in fat content and pH.
- Higher salt concentration inhibits growth of *C. perfringens*, with 1.5-2% preventing typical sigmoidal growth patterns during cooling.
- Sodium bicarbonate increases growth by raising pH closer to the optimal range for *C. perfringens* (6.15 → 6.79), supporting faster outgrowth.
- The predictive cardinal temperature values resulted in $T_{\min} = 13.7$ °C.
- Temperature was the dominant factor governing outgrowth, more so than intrinsic formulation variables under dynamic cooling.

$$\mu = 0.549335 - 0.209093 \text{ NaCl} + 0.2235 \text{ NaHCO}_3$$

Clean Labels Formulations: Cooked Pork Sausages + Nitrite Removers

Biswas, Sullivan, Wang, and Chaves*. In preparation.

Clostridium perfringens



Microbial Growth and Survival in Foods

1. Physicochemical properties of the food matrix

Intrinsic Factors - a_w , chemical composition, pH

2. Conditions of the packaging and storage environment

Extrinsic factors - temperature, gaseous atmosphere, RH

3. Microbial phenotypes and ecological interactions

Implicit factors - physiological state, microbial communities

4. Antimicrobial and other interventions

Process factors - physical and chemical antimicrobial treatments

**IS CLEAN LABEL A FOOD SAFETY STRATEGY OR A
MARKETING STRATEGY?**

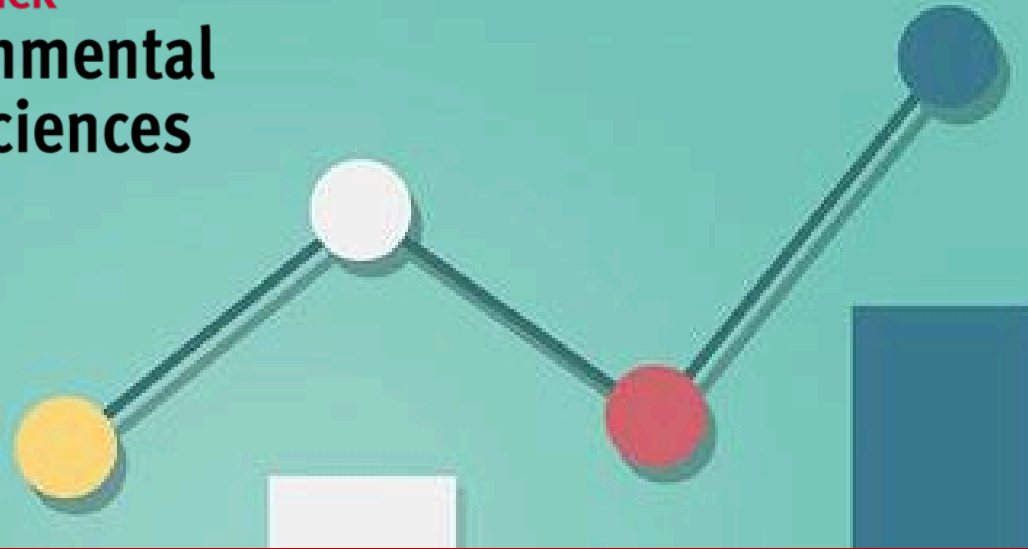
**CAN A PRODUCT BE TRULY "CLEAN LABEL" IF IT
REQUIRES MORE PROCESSING TO REMAIN SAFE?**

**WHICH IS MORE IMPORTANT: INGREDIENT
TRANSPARENCY OR INGREDIENT REMOVAL?**



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