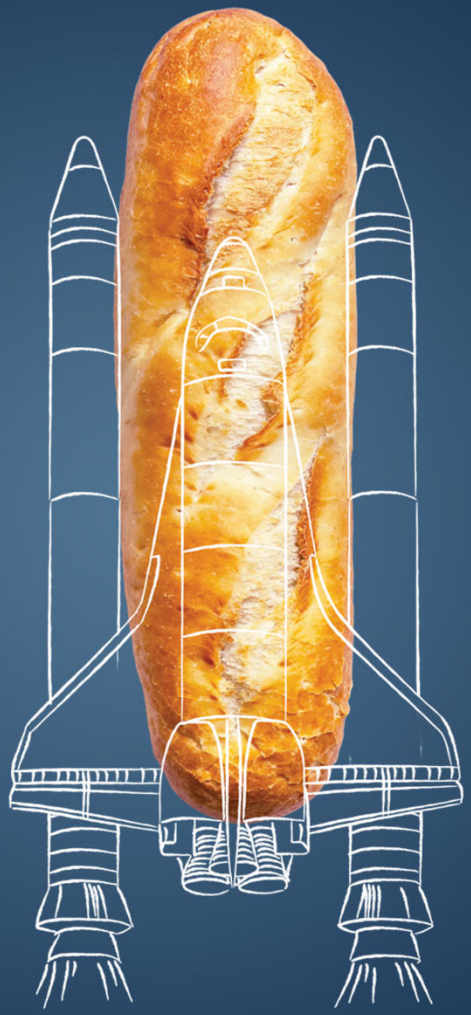
CLEAN LABEL ANTIMICROBIALS IN BAKERY

Gokila Thangavel, Ph. D
Kemin Industries



IBIE INTERNATIONAL BAKING INDUSTRY EXPOSITION
EDUCATION: SEPT. 17-21, 2022
EXPO HALL: SEPT. 18-21, 2022
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MICROBIAL SPOILAGE

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MICROBIAL SPOILAGE

- Baked goods are generally at a lower risk of causing food poisoning as compared to other food.
- However, spoilage in baked goods is a major concern.
- Estimated bakery product loss is 5% in US & 1 - 5% in Europe
- Spoilage incurs huge economic losses
- It also affects the entire food product chain

http://www.fao.org/sustainable-development-goals/overview/en/ Garcia *et al*., 2021

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MICROBES OF CONCERN

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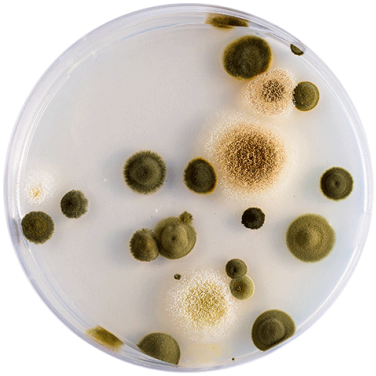
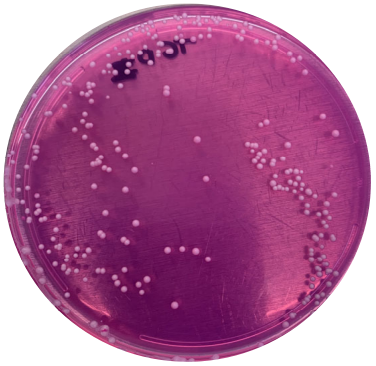
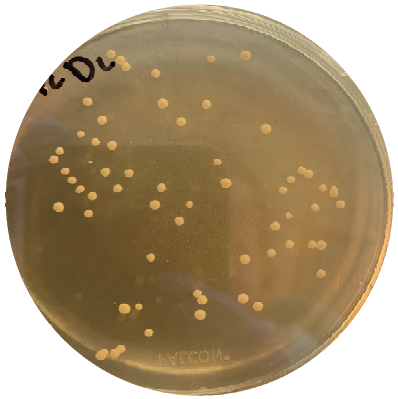
TYPES OF MICROBES



Mold



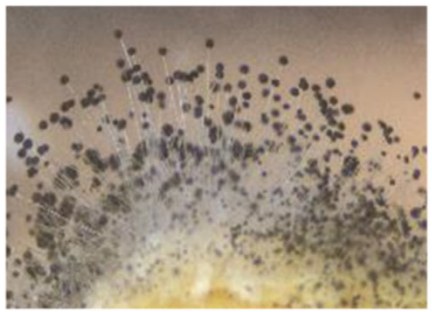
Yeast



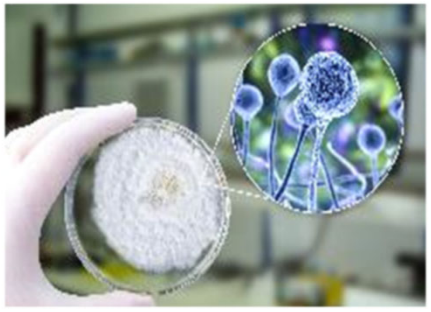
Bacteria

COMMON MICROBES IN TORTILLA

Aspergillus



Rhizopus



Mucor

Neospora

Geotrichum

Bacillus

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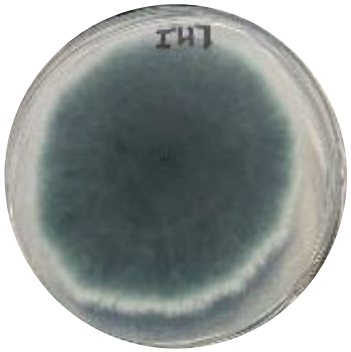
RESISTANT MOLDS

Penicillium:

- A few species are preservative resistant - e.g., *Penicillium roqueforti, P. paneum, P. carneum*.
- *P. roqueforti* a sorbate resistant mold, produces 1,3 pentadiene - kerosene smell
- *P. roqueforti* can grow under refrigerated temperature, also called “cold weather mold”



Monascus:

- Heat resistant mold
- *Monascus spp*: e.g., *Monascus ruber, M. pilosus*
- Survive kill steps e.g., pasteurization, baking
- Also called “summer month mold” or ascospores

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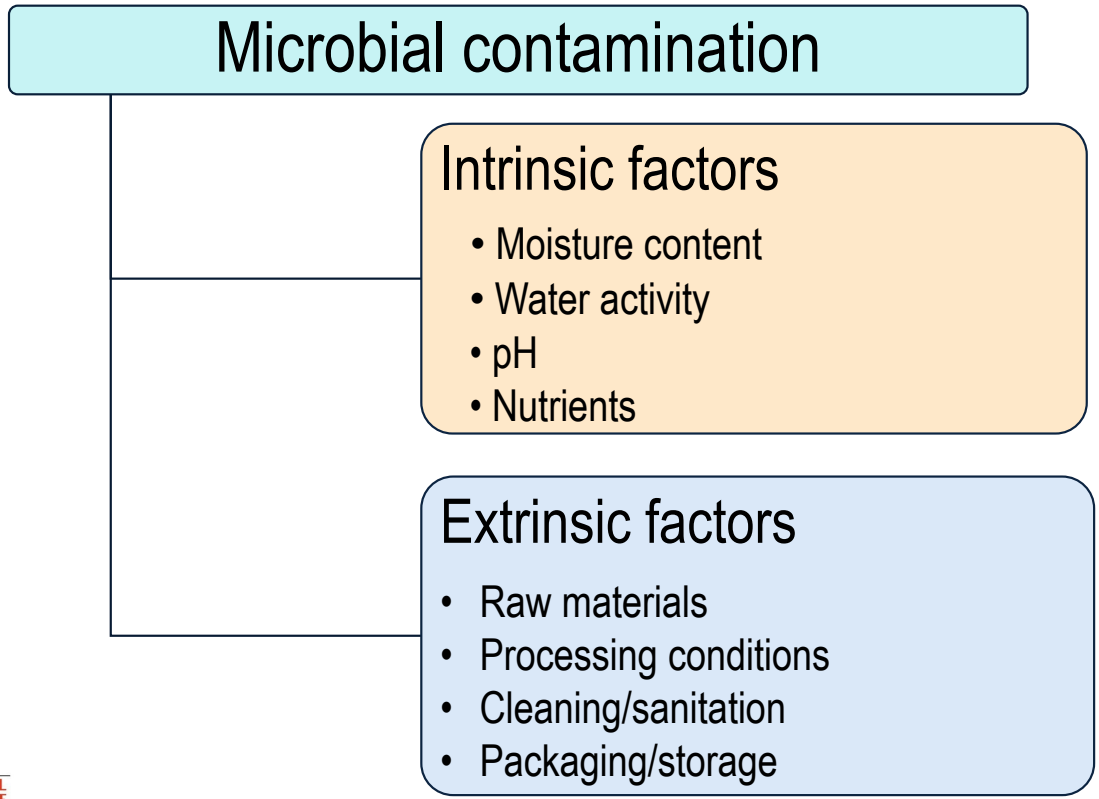
FACTORS THAT INFLUENCE MICROBIAL SPOILAGE



INTRINSIC FACTORS - MOISTURE AND WATER ACTIVITY (a_w)

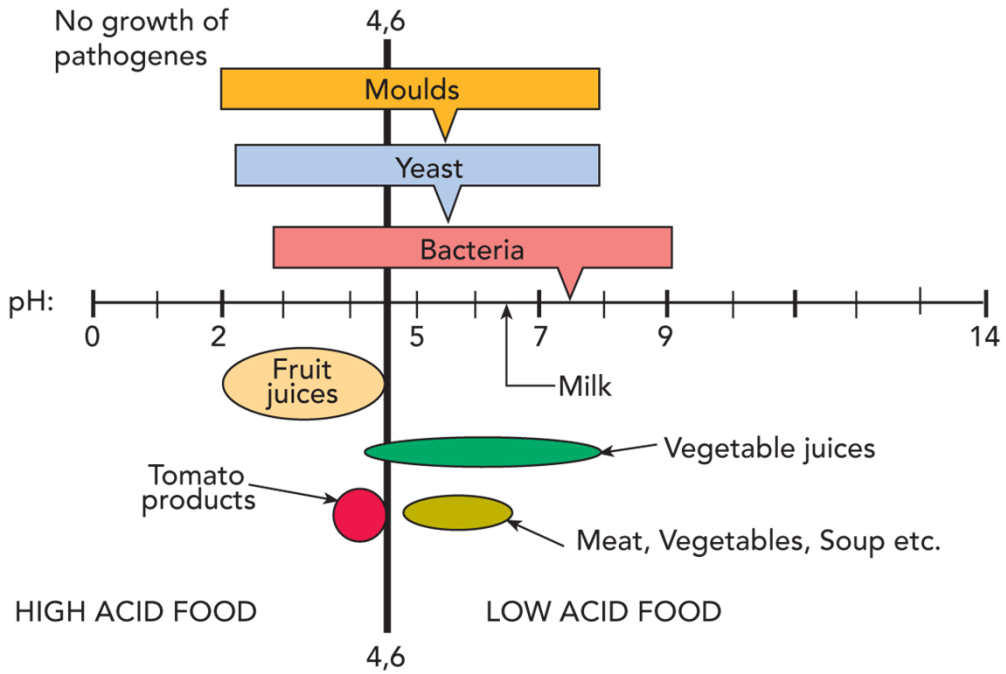
- Moisture = total moisture
- a_w = Free water available to microbes
- Tortilla has moisture = 35 – 50% and a_w of 0.8 to 0.97
- Lowering a_w can hinder microbial growth
- Solutes – salt/sugar can reduce a_w
- However, it may have an impact on the sensory and texture.

MICROBES	SPECIES	MINIMUM a_w
Most spoilage bacteria		0.90-0.91
Bacteria	*Bacillus cereus*	0.92-0.95
Bacteria	*Clostridium botulinum*	0.90-0.98
Most molds		0.80-0.98
Mold	*Aspergillus spp*	0.68-0.90
Mold	*Aspergillus flavus*	0.78-0.90
Mold	*Aspergillus niger*	0.80-0.84
Mold	*Fusarium spp*	0.82-0.92
Mold	*Mucor spp*	0.80-0.93
Mold	*Penicillium spp*	0.78-0.93
Xerophilic molds		0.65
Spoilage yeasts		0.88
Yeast	*Saccharomyces bailii*	0.80
Yeast	*Saccharomyces*	0.90-0.94
Yeast	*Saccharomyces rouxii*	0.62
Osmophilic yeast		0.6

https://thefooduntold.com/blog/food-science/water-activity-aw-and-food-safety/#:~:text=To%20inhibit%20the%20growth%20of%20bacteria%2C%20the%20water,a%20water%20activity%20of%20around%200.85%20or%20below.

NUTRIENTS, pH AND OTHERS

- Excellent nutrition source
  - Carbs
  - Fat
  - Protein
  - Sugar
- pH = 4.8 – 12.0
- Typical storage = 70 – 90 °F
- Oxygen in package
- Storage time is favorable for the growth of mold



https://dairyprocessinghandbook.tetrapak.com/chapter/microbiology

EXTRINSIC FACTORS – RAW MATERIAL

Raw materials – raw agricultural commodity

- Potential source of mold, yeast and bacteria
- Spores of resistant molds - *P. roqueforti, P. paneum, P. polonicum, Monascus.*
- Flour dust carrier for spores on equipment surface/processing area

Water quality

Wooden pallets and cardboard boxes - spores to the packaging area

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EXTRINSIC FACTORS – PROCESS

Baking - temp, time

- HRM spores (ascospores) can survive baking
- Ascospores contaminate food equipment surfaces

Cooling/temperature gradient

- Water condensation
- Surfaces, walls, ceiling, overhead piping
- *Penicillium roqueforti* can grow in colder months

Recontamination post baking

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EXTRINSIC FACTORS – ENVIRONMENT/CLEANING

Air quality

- Create positive air pressure in plant
- Removal external contamination
- Filtration of incoming air – HEPA filter
- Maintain temperature and humidity

Cleaning and sanitation of equipment

Personnel hygiene – wearing gloves

EXTRINSIC FACTORS – PACKAGING/STORAGE

Packaging materials

- Vacuum packing, MAP

Storage condition

- Refrigeration, frozen, ambient

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PRESERVATION - HURDLE TECHNOLOGY

Hurdle Technology : Multiple Barriers

- a_w
- Thermal kill step-Baking
- Formulation-Preservatives/pH
- Innovative Packaging/MAP, Vacuum,O_2 Scavengers
- Storage temperature (Refrigerated/Frozen)

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SYNTHETIC PRESERVATIVES

- Antimicrobials (AM) are extensively used to inhibit microbial spoilage in tortillas
- Propionic acid is the most commonly used mold inhibitor
- Sorbic acid and benzoic acid are used as helper molecules

Antimicrobials	Spoilage microorganism		
	Mold	Yeast	Bacteria
Propionic acid	X		X
Sorbic acid	X	X	X
Acetic acid	X		X
Benzoic acid	X	X	X
Parabens	X		X

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MODE OF ACTION OF PRESERVATIVES

Propionic acid

- Undissociated acid theory/acid stress

Sorbic acid

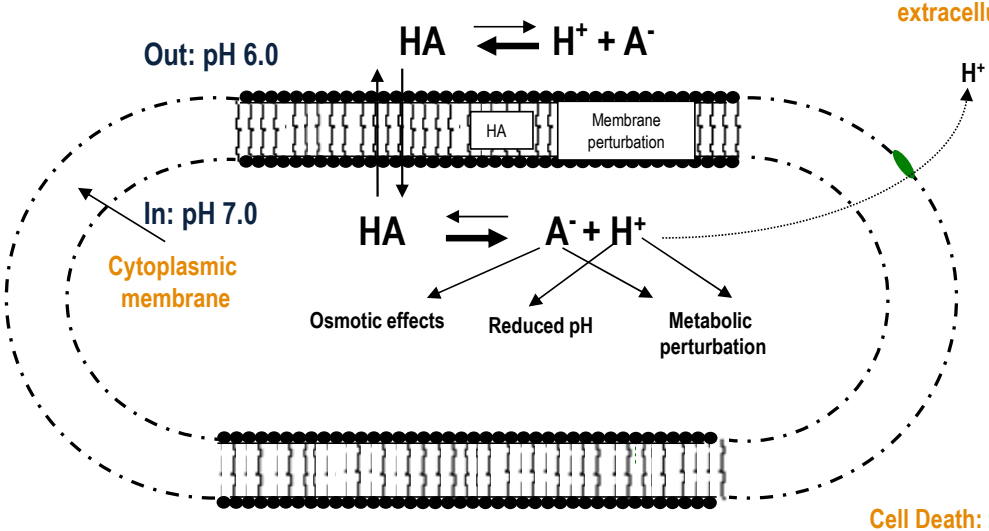
- Partly due to undissociated acid
- Loss of lipid membrane integrity
- Inhibition of enzymes required for transportation

Benzoic acid

- Alter membrane fluidity - disruption of membrane trafficking and dynamics

Undissociated prop. acid can penetrate the cell membrane

Presence of organic acids in undissociated form at lower extracellular pH



Cell Death: Dissociation of organic acids into protons and anion

Adapted from Hirshfield *et. al*, 2003
Busta *et. al*., 1986

pH ROLE IN PRESERVATIVE ACTION

Undissociated propionic acid (%)	pH
99	2.87
95	**3.59**
90	3.92
80	4.27
70	4.50
60	4.69
50 (pK_a)	**4.87**
40	5.05
30	5.24
20	5.47
10	5.82
1	**6.87**
0.5	7.17

Acidulants

- Lower the pH of finished product
- Improve the efficiency of preservatives
- Disadvantage: affect the after taste of product

pK_a = pH when concentration of acid is equal to its conjugate base i.e., acid is 50% dissociated

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CLEAN-LABEL ANTIMICROBIALS

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CLEAN-LABEL ANTIMICROBIALS

- Source – naturally driven
- No synthetic ingredients
- Fermented products
  - ✓ Cultured dextrose
  - ✓ Cultured wheat/whey
  - ✓ Cultured feedstock
- Essential oils
- Plant extracts – herbal, berry extracts

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ACTIVE INGREDIENTS – FERMENTED PRODUCTS

Typical actives include

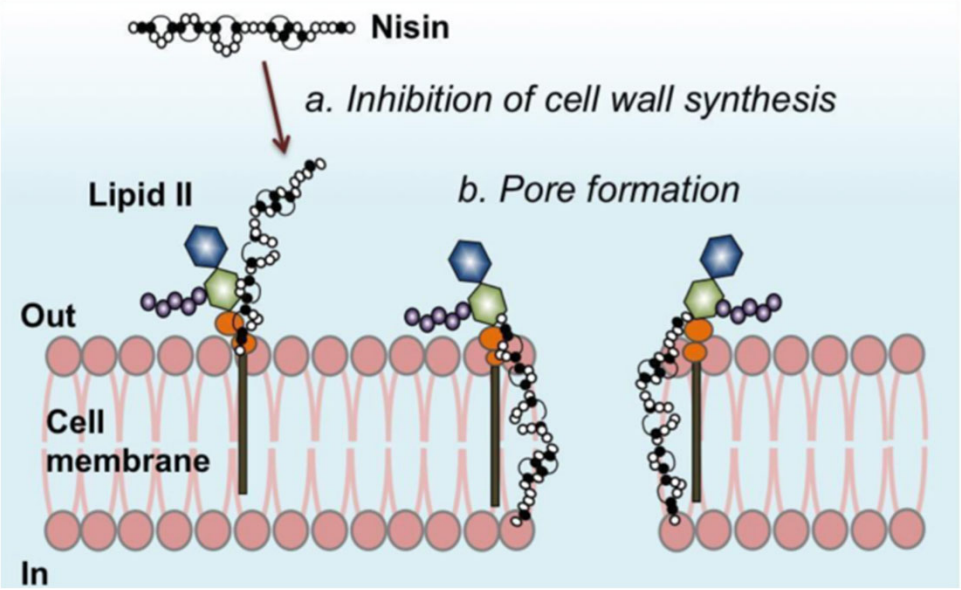
- Short chain fatty acids
- Microbial peptides - bacteriocins

Fatty acids in fermented products

- Propionic acid, acetic acid, lactic acid
- Valeric acid, butyric acid, hexanoic acid and heptanoic acid

Mode of action of fatty acids are similar to synthetic.

Mode of action of peptides



Perez *et al,* 2015. Bacteriocins from Lactic Acid Bacteria: A Review of Biosynthesis, Mode of Action, Fermentative Production, Uses, and Prospects.

PRODUCTION OF FERMENTED PRODUCTS

- Use of microbial strains
- Fermentation of different feedstocks
- Production of organic acids and other antimicrobial compounds during the growth of the microbes
- Concentration varies
- May be dried

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PRODUCTS AVAILABLE

Based on the microbe used and the process, the products available in the market can vary to a great extend in

- Efficacy due to the different active molecule and active level – based on process – concentration
- Sensory – based on the feedstock used and downstream process to remove impurities
- Cost/cost-in-use – vary based on manufacturing cost as well as the active concentration (dosage)

LIMITATIONS

- Typical level of actives is low – ranging from 0 – 80%, higher dosage to be used based on the product.
- Consistency due to the variability in the fermentation process – if the actives are not standardized.
- Impact on color due to the fermented product.
- Other sugars and ingredients present in the dried – causing sensory impact.
- Cost of cultured dextrose - $3.0 to 15.0/lb.
- May have an impact on the texture of the finished product.

EFFICACY STUDIES IN FOOD

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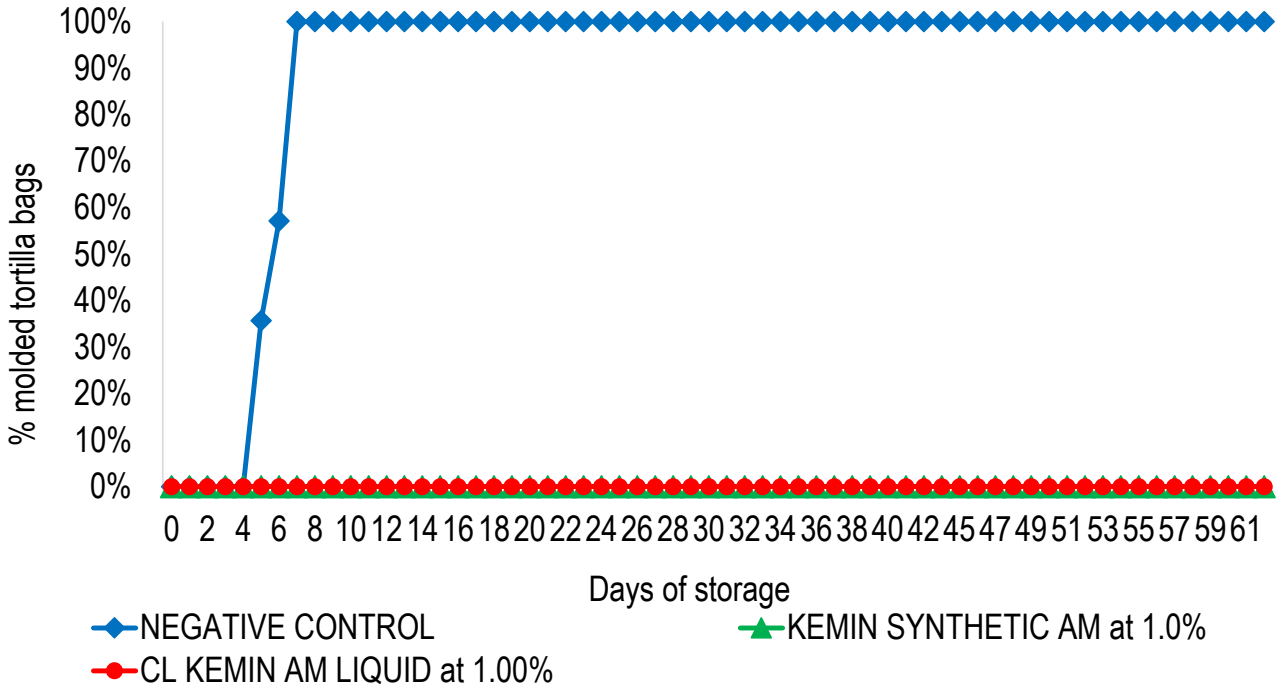
EFFICACY IN TORTILLAS



Sensory

Groups	Hedonic score
Kemin synthetic AM at 1.0%	7.17 ± 0.75
CL Kemin AM Liquid at 1.0%	6.50 ± 0.54

Cultured dextrose based product was similar to synthetic product at equal concentration

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Negative control – no antimicrobial, Kemin synthetic AM – contains propionic acid and benzoic acid, CL Kemin AM liquid – cultured dextrose based product

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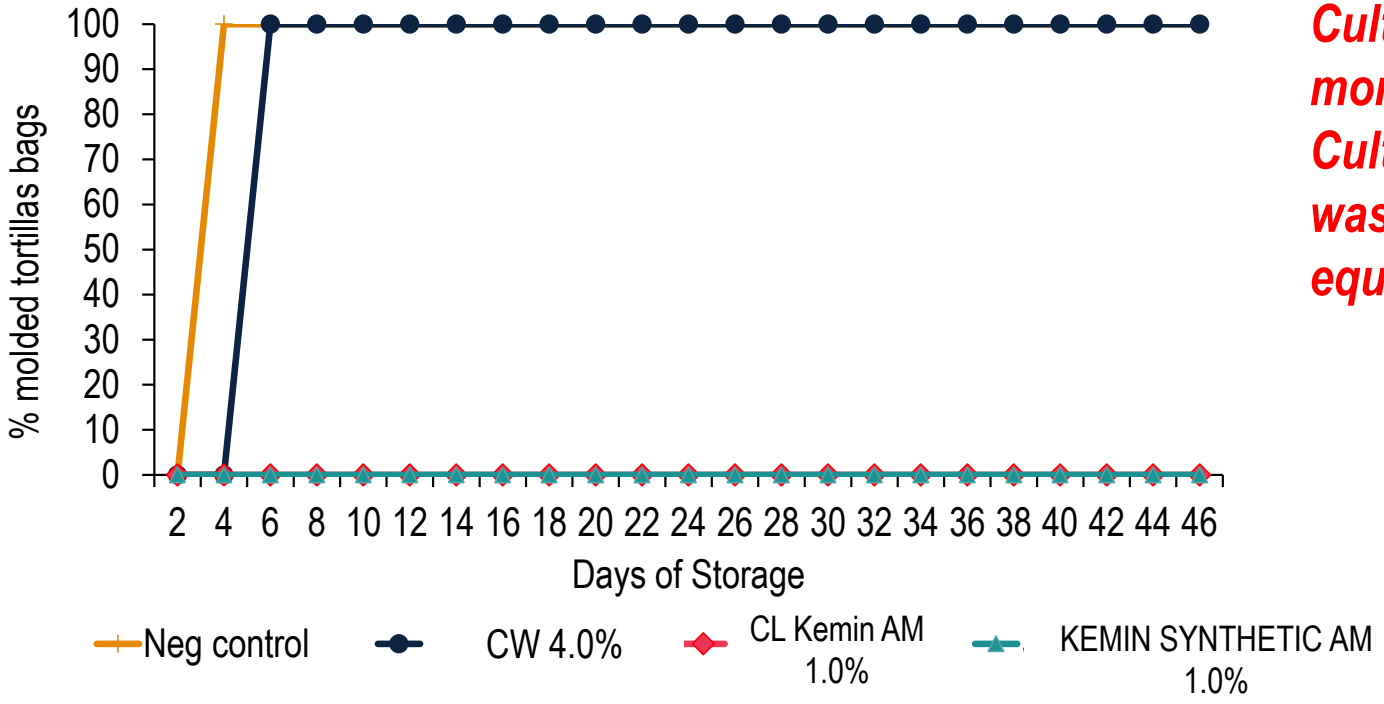
EFFICACY IN TORTILLAS

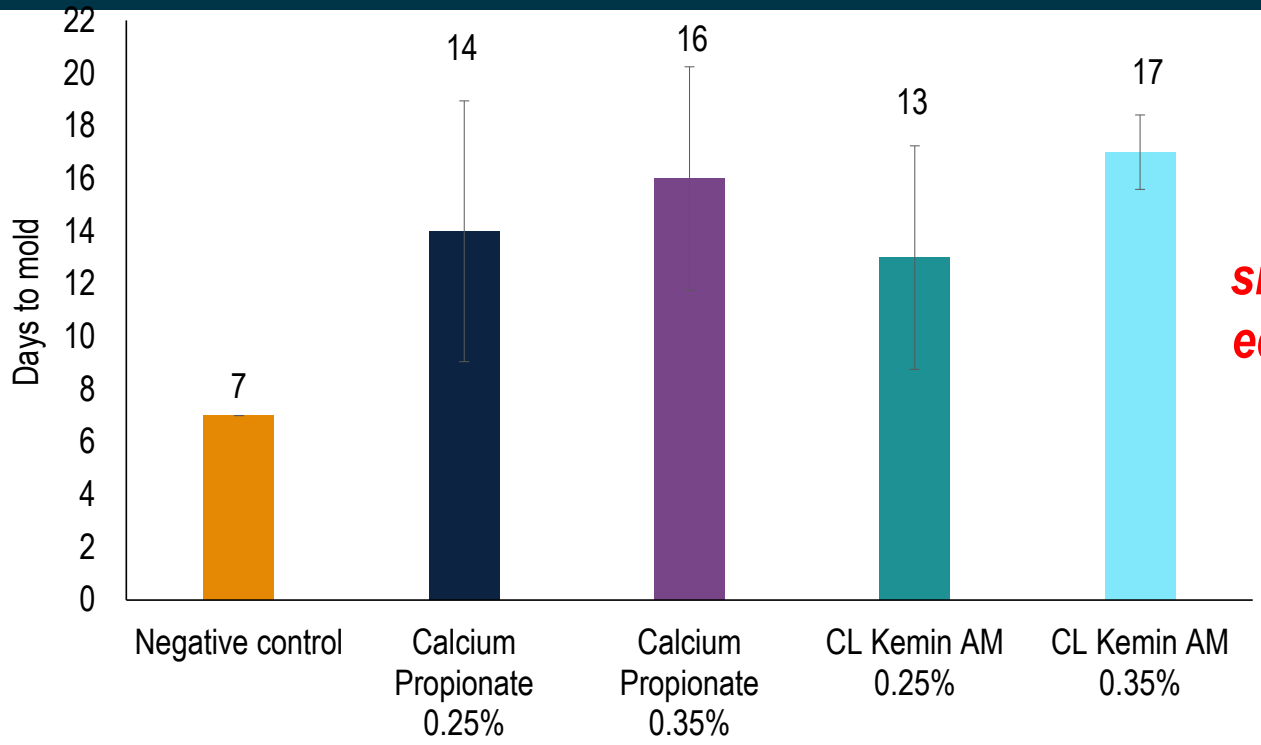


Cultured wheat provided only 2 more days of shelf life.

Cultured dextrose based product was similar to synthetic product at equal concentration

Negative control – no antimicrobial, CW – cultured wheat, CL Kemin AM liquid – cultured dextrose based product, Kemin synthetic AM – contain prop and benzoic acid

EFFICACY IN BREAD



Cultured dextrose based product was similar to synthetic calcium propionate at equal concentration. Sensory was similar between the groups

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Negative control – no antimicrobial, CL Kemin AM – cultured dextrose based product, calcium propionate – synthetic calcium propionate

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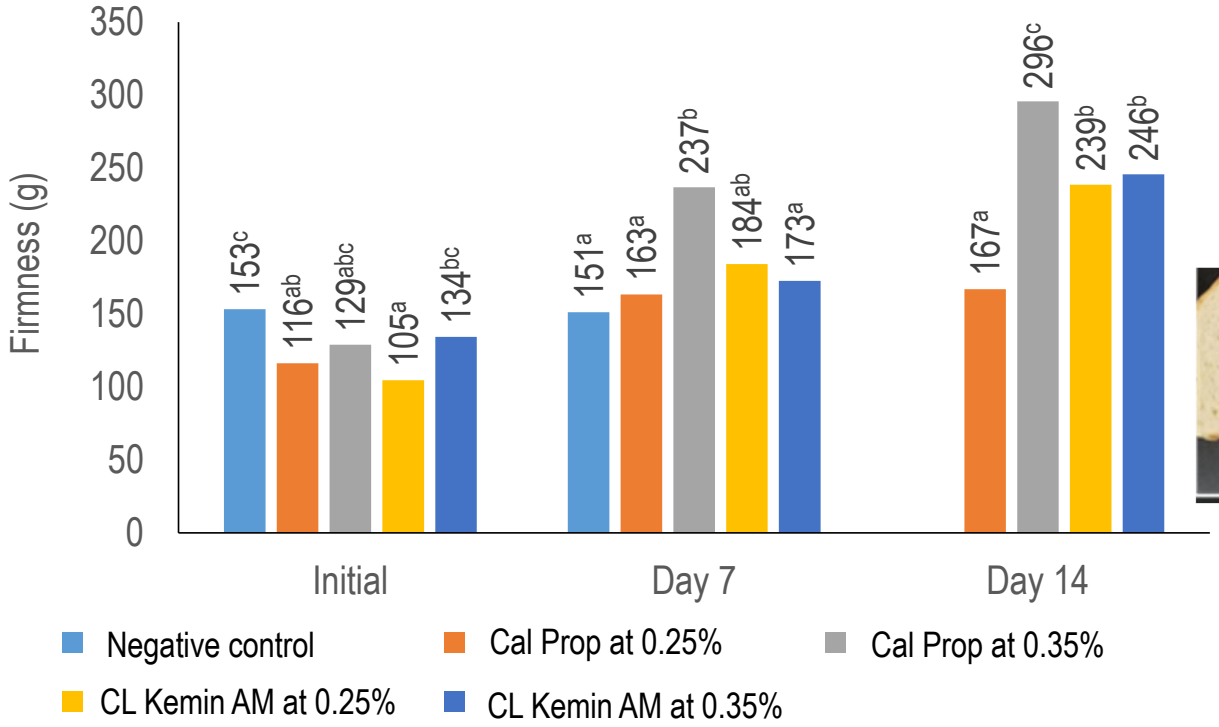
EFFICACY IN BREAD



Cultured dextrose based product was better or similar to synthetic calcium propionate in texture.

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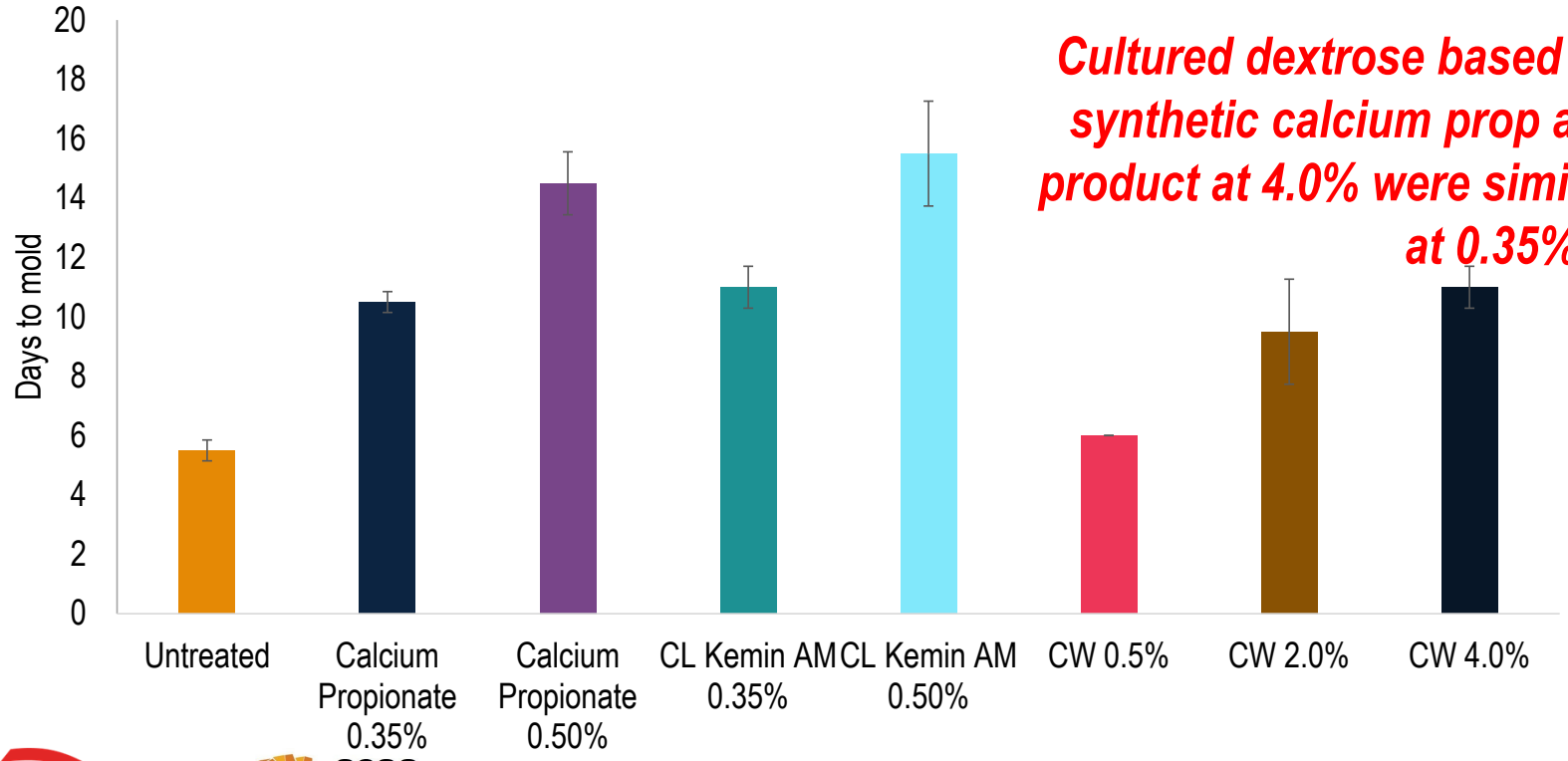
EFFICACY IN BREAD



Cultured dextrose based product similar to synthetic calcium prop at equal dose. CW product at 4.0% were similar to calcium prop at 0.35%.

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Negative control – no antimicrobial, CL Kemin AM – cultured dextrose based product, calcium propionate – synthetic calcium propionate, CW – cultured wheat

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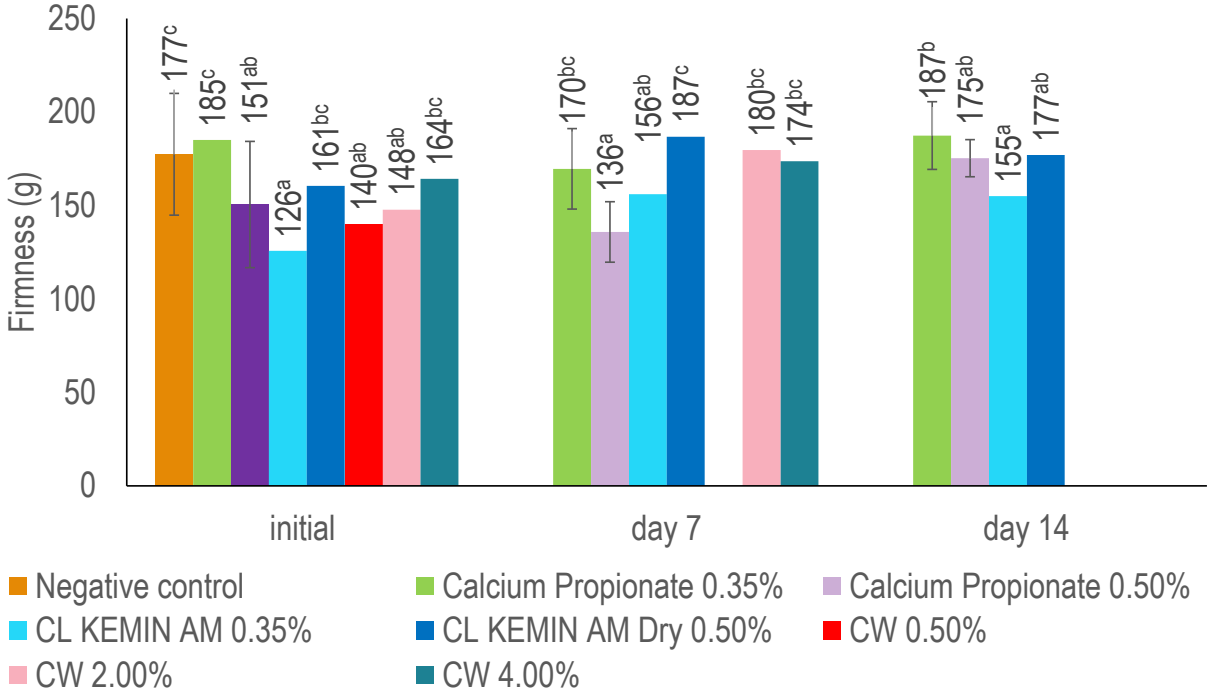
EFFICACY IN BREAD



No significant difference in texture and sensory.

Negative control – no antimicrobial, CL Kemin AM – cultured dextrose based product, calcium propionate – synthetic calcium propionate, CW – cultured wheat. CW group molded by day 7 so they were not tested for texture on day 7 and 14.

CONCLUSIONS

- Clean label antimicrobials available – fermented products have limitations.
- The available products vary hugely on efficacy, cost and sensory impact
- However, efficient products with high active content, no sensory or textural impact are available.
- Appropriate selection and testing required to choose the best suitable product for your matrix.

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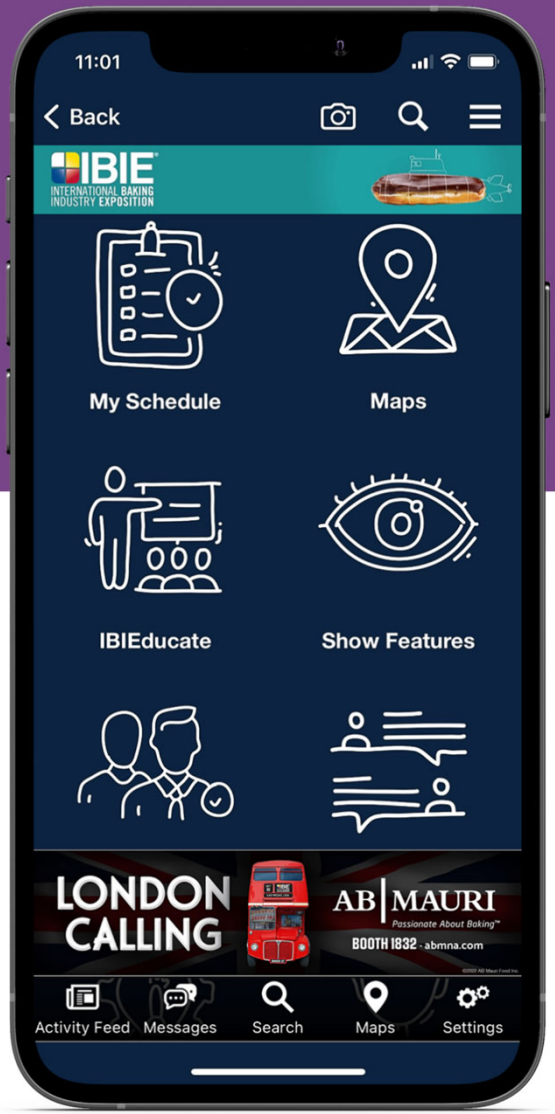
Acknowledgement : Dan Ryan, Cody Dakan and Joan Randall

QUESTIONS?



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