International Association for Food Protection WEBINAR

Modernizing the Ways of Traditional Smoking: Application of Liquid and Dry Smoke in Meat, Poultry and Pet Foods

Organized by: IAFP's Meat and Poultry Quality and Safety PDG and Animal and Pet Food Safety PDG

Moderator: Saurabh Kumar, Kerry

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Webinar Housekeeping

- It is important to note that all opinions and statements are those of the individual making the presentation and not necessarily the opinion or view of IAFP.

- All attendees are muted. Questions should be submitted to the presenters during the presentation via the Questions section at the right of the screen. Questions will be answered at the end of the presentations.

- This webinar is being recorded and will be available for access by IAFP members at within one week.

Modernizing the Ways of Smoking: Application of Liquid and Dry Smoke in Meat, Poultry and Pet Foods

Joshua B. Gurtler, PhD
USDA

Surabhi Wason, PhD
Kerry

Aiswariya Deliephan, PhD
Kraft Heinz

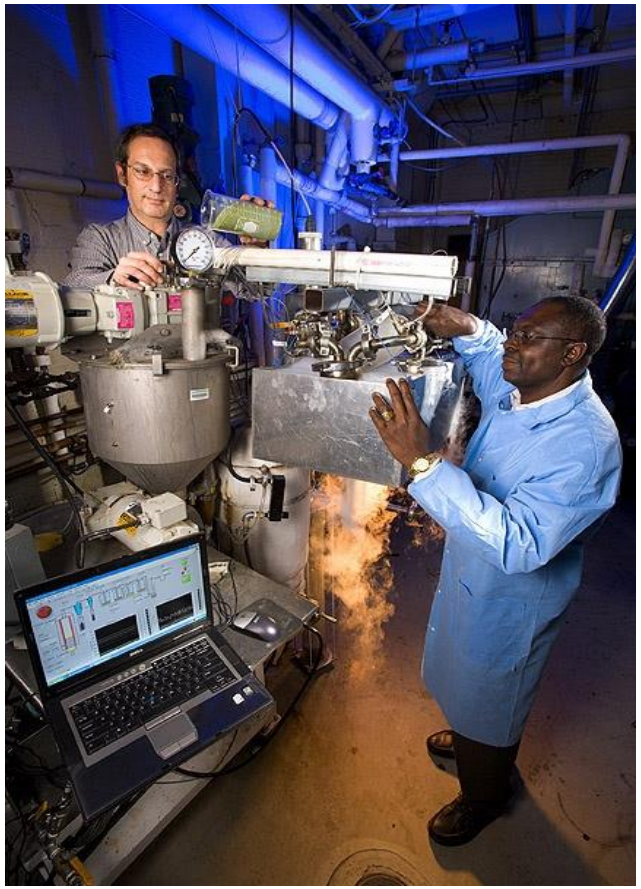
Saurabh Kumar, MS
Kerry

Title	Speakers
History, Uses, and Regulatory Status of Liquid Smoke for Food Applications	Joshua B. Gurtler, USDA
Multifunctional Smoke Systems for Antimicrobial and Antioxidant efficacy in Meat / Poultry Application	Surabhi Wason, Kerry Ingredients
Liquid Smoke as a Clean-Label Solution for Pet food Applications	Aiswariya Deliephan, Kraft Heinz

Overview of the History, Uses, and Regulatory Status of Liquid Smoke for Food Applications

Joshua Gurtler
USDA, Agricultural Research Service
Microbial and Chemical Food Safety Research Unit
Eastern Regional Research Center, Wyndmoor, PA

USDA-ARS, ERRC Bio-Energy Program
Sustainable Biofuels and Co-products Research Unit
Fast Pyrolysis Reactors



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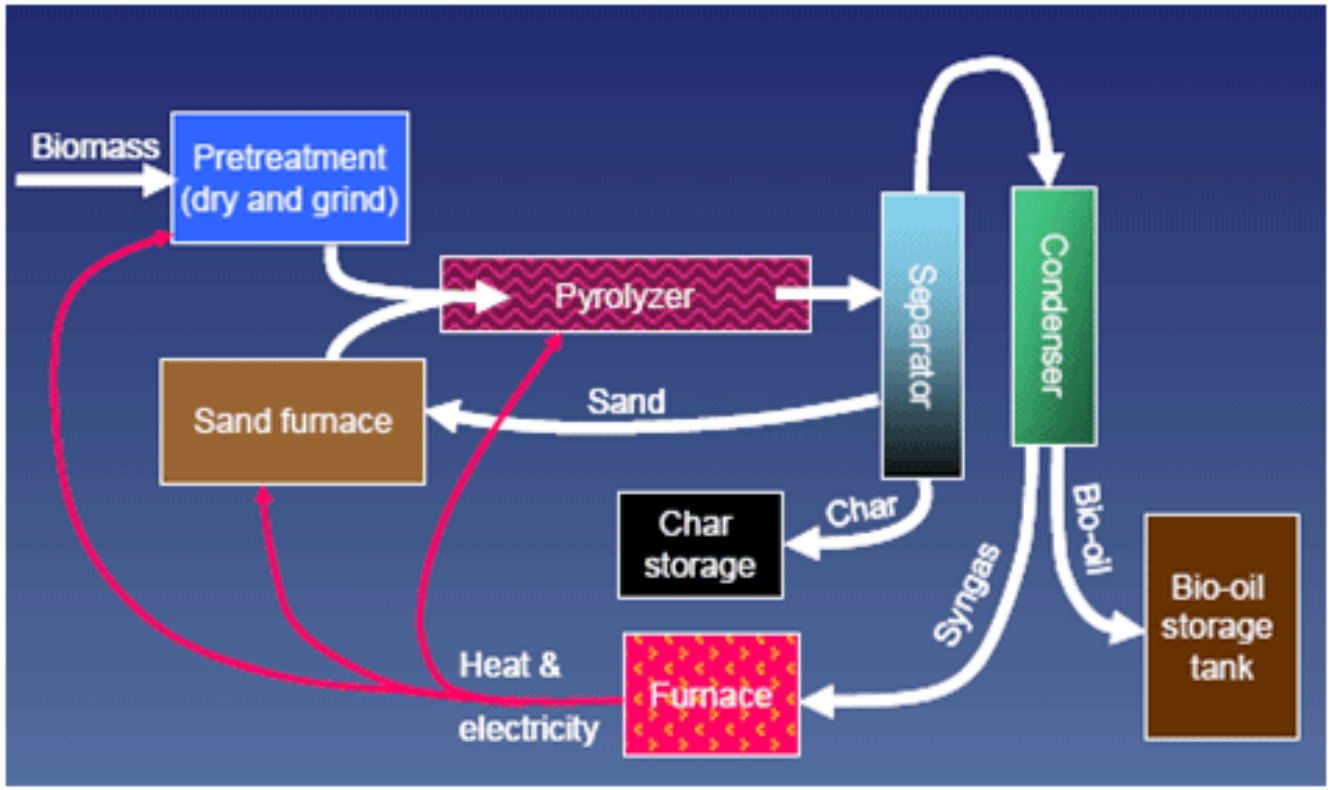
Fast Pyrolysis
Thermo-Chemical Conversion



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History of Traditionally Smoking Meats

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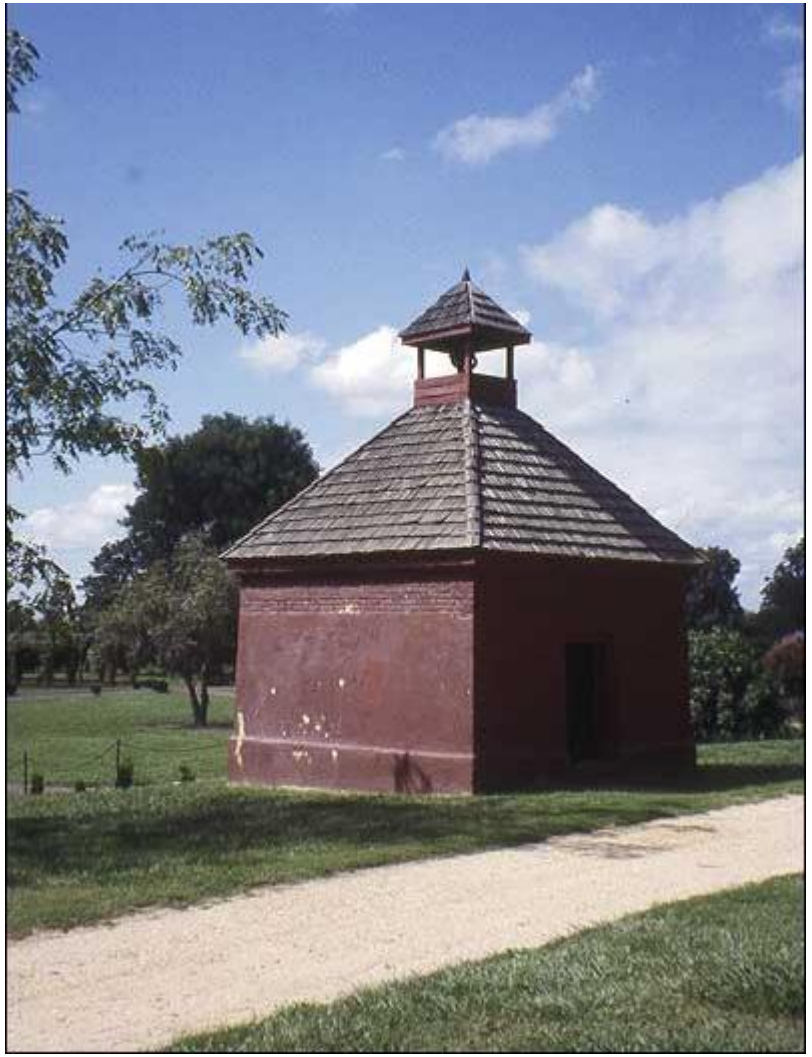
Colonial Smokehouses in Williamsburg, VA



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Colonial Smokehouses in Williamsburg, VA

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History of Traditionally Smoking Meats

- Used for centuries/millennia in cultures around the world
- Involves heating wood/sawdust or other organic feedstocks (e.g., nut shells, coconut hulls, rice husks, etc.) at temperatures and/or oxygen-limiting conditions to promote smoldering and prevent burning
- Hardwoods are favored (e.g., mesquite, maple, oak, hickory, cherry, apple, beech, pecan, etc.), while some softwoods are acceptable
- Hypoxoic fast pyrolysis being studied for its production (>100 publications)

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Benefits of Traditionally Smoking Meats

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Benefits of Traditionally Smoking Meats

- Delays microbial spoilage and pathogen growth by the production of antimicrobials
- Delays oxidative spoilage by the production of antioxidants
- Enhances color
- Enhances aroma
- Enhances flavor
- Enhances texture and promotes peeling on some meat products
- Dries/lowers a_w

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Challenges With Traditionally Smoking Meats

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Challenges With Traditionally Smoking Meats

- Natural meat smoking is not economically or logistically feasible in many locations and for many (especially small) companies
- Important employee safety/health considerations during production
- Traditional smoking imparts some metabolically toxic and potentially carcinogenic chemical byproducts to foods (e.g., PAHs [Polycyclic aromatic hydrocarbons])
  - Natural smoke extract can contain >60 different PAHs, although formation is minimized at < 400°C

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Liquid Smoke, Smoke Condensates and Smoke Extracts

aka Wood Vinegar or Pyroligneous Acid

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History of *Liquid* Smoke

https://en.wikipedia.org/wiki/Liquid_smoke

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History of *Liquid* Smoke

- Generated by capturing natural smoke condensates from heating wood or other organic feedstocks (e.g., rice husks)
- Originally known as “wood vinegar”

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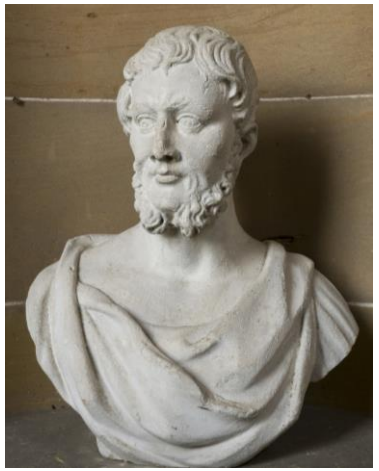
History of *Liquid* Smoke

- Generated by capturing natural smoke condensates from heating wood or other organic feedstocks (e.g., rice husks)
- Originally known as “wood vinegar”
- Roman naturalist, Pliny the Elder, recorded its use as a superior embalming agent (ca. 50 A.D.)



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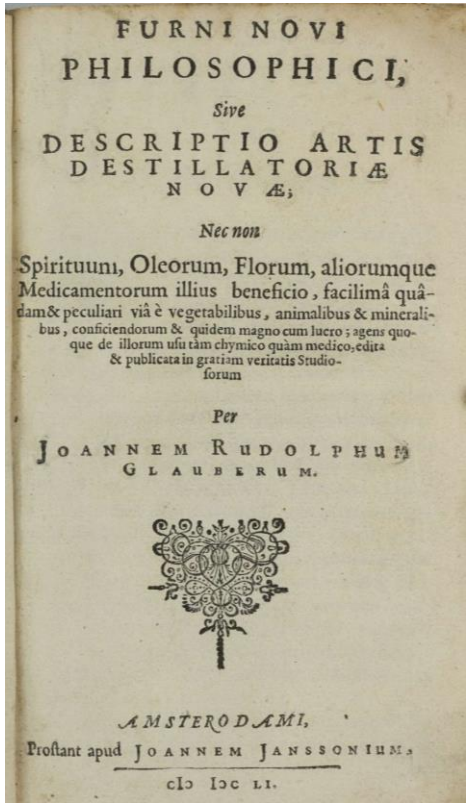
History of *Liquid* Smoke

- Production from charcoal first published by German Alchemist Johann Rudolph Glauber (1658)



FURNI NOVI
PHILOSOPHICI,
Sive
DESCRIPTIO ARTIS DESTILLATORIÆ NOVÆ;
Nec non
Spirituum, Oleorum, Florum, aliorumque Medicamentorum illius beneficio, facilimâ quâdam & peculiari viâ è vegetabilibus, animalibus & mineralibus, conficiendorum & quidem magno cum lucro; agens quoque de illorum usu tàm chymico quàm medico, edita & publicata in gratiam veritatis Studiosorum
Per
JOANNEM RUDOLPHUM GLAUBERUM.
AMSTERODAMI,
Prostant apud JOANNEM JANSSONIUM,
cIↃ IↃC LI.

A. Fornax cum sibi incamerato instrumento ferreo, & recipiente.
B. Artifex sinistrâ auferens operculum, dextrâ autem iniiciens materiam destillandam præparatam.
C. Forma Vasis externa.
D. Forma Vasis interna.
E. Aliud quoddam vas non incameratum, incumbens carbonibus.

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History of *Liquid* Smoke

- Wood vinegar first called pyroligneous acid in 1788
- Popularized and first marketed in the U.S. by Missouri pharmacist Ernest H. Wright in 1895 – used by farmers curing meats
- Historically applied to meat & poultry, fish & seafood, and non-meat foods (e.g., nuts, cheese, tofu, beans, pet food, etc.)
- 2023 global market value of ca. $93 million expected to reach $245 million by 2033
  https://www.futuremarketinsights.com/reports/liquid-smoke-market

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Benefits of Industrial Liquid Smoke Application

https://en.wikipedia.org/wiki/Liquid_smoke

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Benefits of Industrial Liquid Smoke Application

- Some benefits similar to traditional smoking (e.g., enhances color, aroma, and flavor, & includes antioxidants + antimicrobials to prevent microbial and oxidative spoilage)
- Toxic chemical compounds removed by refining condensates with phase separation and filtration (e.g., PAHs)

https://en.wikipedia.org/wiki/Liquid_smoke

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Benefits of Industrial Liquid Smoke Application

- Reduces harmful smoke emissions in the vicinity during application (especially urban areas)
- Reduces other employee safety/health hazards
- Reduced labor costs for food application and cleanup
- Increased throughput

https://en.wikipedia.org/wiki/Liquid_smoke

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Production of Smoke Condensates and Extracts

https://en.wikipedia.org/wiki/Liquid_smoke

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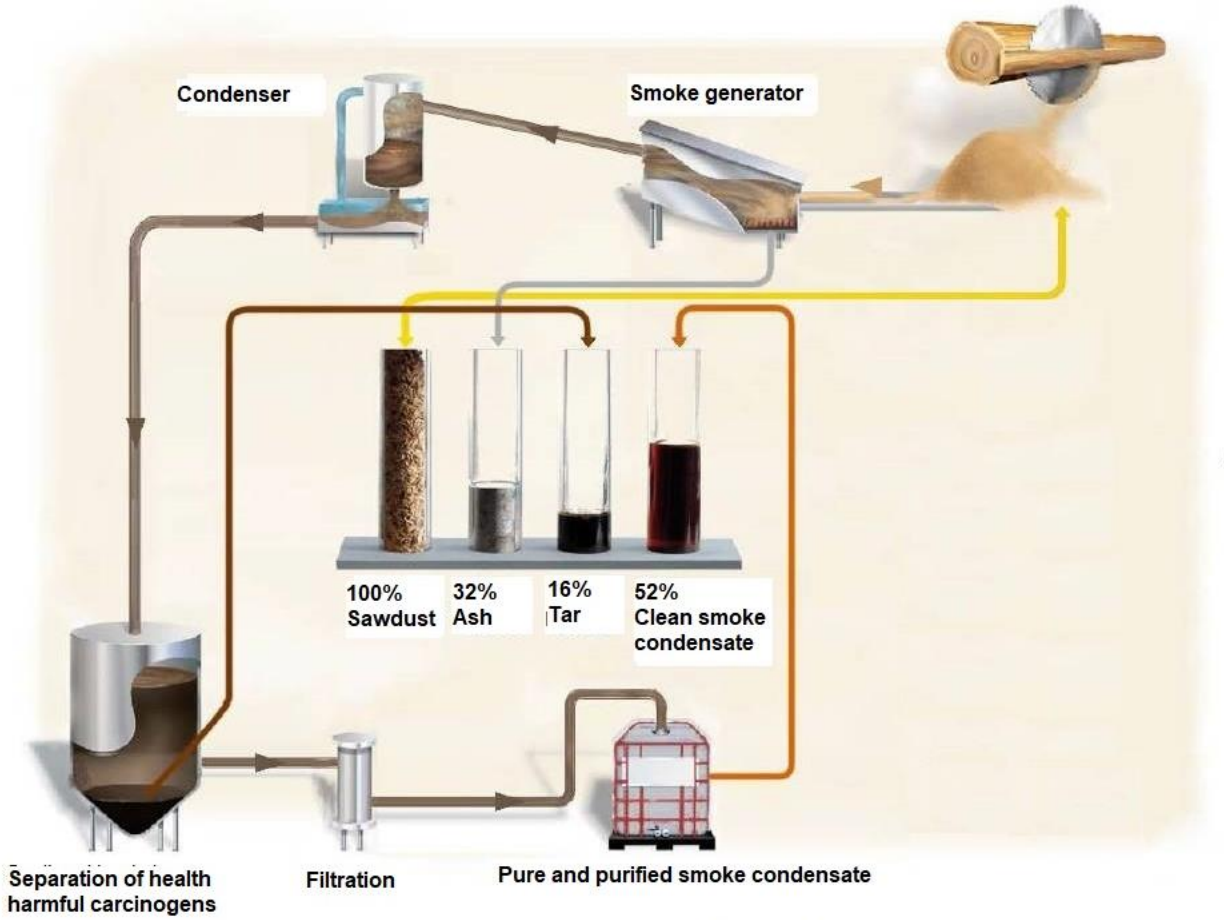
Production of Smoke Condensates and Extracts



http://smokeland.eu/EN/menu/f-a-q

https://en.wikipedia.org/wiki/Liquid_smoke

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Production of Smoke Condensates and Extracts

https://www.youtube.com/watch?reload=9&app=desktop&v=YJUGzk03qeM

https://en.wikipedia.org/wiki/Liquid_smoke

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Production of Smoke Condensates and Extracts

- Research done in 1960s and 1970s refined modern processing
- Produced by batch or continuous feed, typically at 450-500°C
- Reactors include rotary ovens, heated augers, and fluidized beds
- Condenses into an aqueous phase and an oil phase, collected by water baths, scrubbers or shell and tube heat exchangers
- Aged to increase sensory qualities
- Filtration and purification removes unwanted and harmful compounds (e.g., waxes, resins, terpenes, metals, PAHs, etc.)

https://en.wikipedia.org/wiki/Liquid_smoke

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Chemical Composition of Smoke Condensates and Extracts

https://en.wikipedia.org/wiki/Liquid_smoke

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Chemical Composition of Smoke Condensates and Extracts

- Important components include water, organic acids (e.g., acetic, propionic), carbonyls, and phenols (with other compounds, e.g. furans and furfurals), many impart tartness
- Condensate contain ca. 400 organic compounds, including ca. 85 phenols, 110 aldehydes and ketones, 65 carboxylic acids, 20 aliphatic hydrocarbons, 80 aromatic hydrocarbons, as well as alcohols, esters, etc.

https://en.wikipedia.org/wiki/Liquid_smoke

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Chemical Composition of Smoke Condensates and Extracts

- Wood to generate liquid smoke composed of cellulose, hemicellulose, and lignins
- Cellulose & hemicellulose (pyrolyze at 180-350°C) generate organic acids & carbonyls (i.e., aldehydes & ketones) - impart sweetness, color, and antimicrobials
- Lignins (pyrolyze at 300-500°C) generate phenols - impart smoky flavors, aroma, antimicrobials, and antioxidants

https://en.wikipedia.org/wiki/Liquid_smoke

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Chemical, Flavor & Aroma Profiles, and *Functionality* Affected by Various Factors During Pyrolysis

https://en.wikipedia.org/wiki/Liquid_smoke

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Chemical, Flavor & Aroma Profiles, and *Functionality* Affected by Various Factors During Pyrolysis

- Type of wood used
- Moisture content
- Particle size
- Temperature
- O_2 concentration
- Vapor residence time

https://en.wikipedia.org/wiki/Liquid_smoke

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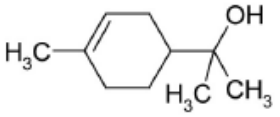
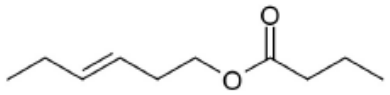
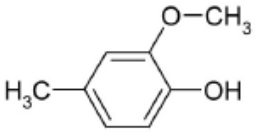
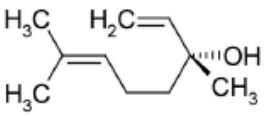
Chemical, Flavor & Aroma Profiles, and *Functionality* Affected by Various Factors During Pyrolysis

Table 2. Organoleptic compounds found in LSC [34, 42].

Compound	Structure	Flavour
α-terpineol		sweet, floral, lilac flavour
3-hexenylbutanoate		wine-like, green, cognac or brandy, slightly buttery flavour
4-methylguajacol		spicy, aromatic, sweet, smoky, caramel, vanilla-like
linalool		light lavender flavour

Simon, et al., 2005. Composition and analysis of liquid smoke flavouring primary products. *Journal of Separation Science.* 28:871-882

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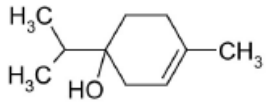
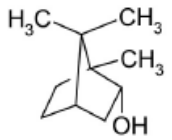
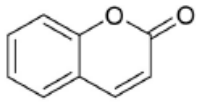
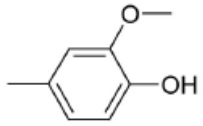
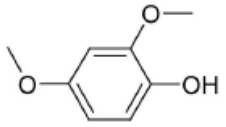
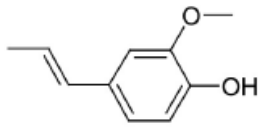
Chemical, Flavor & Aroma Profiles, and *Functionality* Affected by Various Factors During Pyrolysis

terpinen-4-ol		pepper, woody, earthy, musty
endo-borneol		camphoraceous, earthy, pine
2H-1-benzopyran-2-one		fragrant, resembling vanilla beans, burning taste
guaiacol		phenolic, spicy, peppery hot, sweet, dry, smoky
4-methoxyguajacol		phenolic, smoky, burnt, Whiskey, dry, peppery hot
i-eugenol		sweet fruity, mildly smoky, dry, peppery hot

Simon, et al., 2005. Composition and analysis of liquid smoke flavouring primary products. *Journal of Separation Science.* 28:871-882

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Commercially Marketed Condensed Liquid Smoke Preparations

https://en.wikipedia.org/wiki/Liquid_smoke

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Commercially Marketed Condensed Liquid Smoke Preparations

1. Concentrated liquids for atomizing, or smoke regeneration in smoking/cooking chambers
2. Extracts added to meat by injection or mixing
3. Water-miscible solutions for direct liquid surface applications
4. Powders added to carriers to provide smoke flavor
5. Condensates to be directly added to sauces for meat application

https://en.wikipedia.org/wiki/Liquid_smoke

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Commercial Liquid Smoke
Applications

https://en.wikipedia.org/wiki/Liquid_smoke

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Commercial Liquid Smoke
Applications

- Recirculating showers or drenches

Rozum, J. 2014. Liquid Smoke (Smoke Condensate) Application. *Encyclopedia of Meat Sciences.* Vol. 3. pp. 315-320

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Commercial Liquid Smoke *Applications*

- Recirculating showers or drenches
- Smoke regeneration (vaporization or atomization) - Recommended application rates of 1.5-3.0 kg condensate/ton meat

Rozum, J. 2014. Liquid Smoke (Smoke Condensate) Application. *Encyclopedia of Meat Sciences.* Vol. 3. pp. 315-320

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Commercial Liquid Smoke *Applications*

- Recirculating showers or drenches
- Smoke regeneration (vaporization or atomization) - Recommended application rates of 1.5-3.0 kg condensate/ton meat
- Incorporating into ingredients, breading, batters, other coatings
- Injecting
- Spraying, dipping, brining
- Impregnated into meat casings, stuffed and cooked

Rozum, J. 2014. Liquid Smoke (Smoke Condensate) Application. *Encyclopedia of Meat Sciences.* Vol. 3. pp. 315-320

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Regulatory Status of Liquid Smoke Application for Meats and Poultry

https://en.wikipedia.org/wiki/Liquid_smoke

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Regulatory Status of Liquid Smoke Application for Meats and Poultry

Classified as a Generally Recognized as Safe (GRAS) compound by the FDA

https://en.wikipedia.org/wiki/Liquid_smoke

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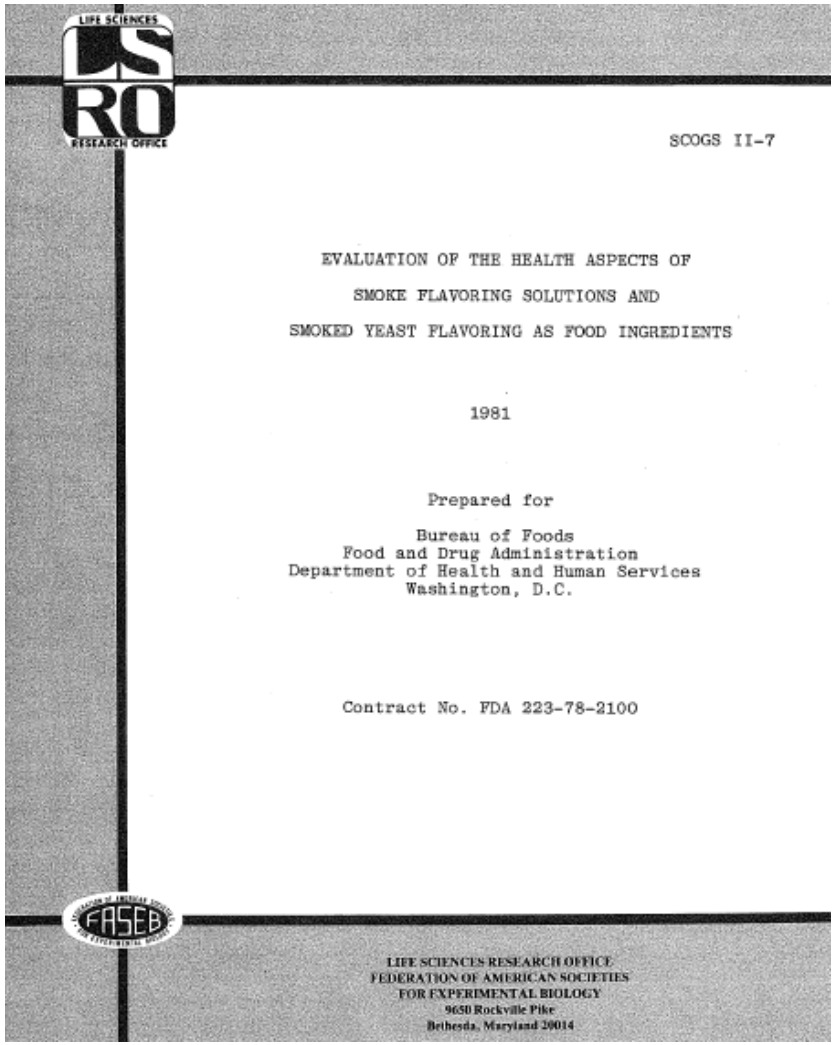
Regulatory Status of Liquid Smoke Application for Meats and Poultry



SCOGS II-7

EVALUATION OF THE HEALTH ASPECTS OF
SMOKE FLAVORING SOLUTIONS AND
SMOKED YEAST FLAVORING AS FOOD INGREDIENTS

1981

Prepared for

Bureau of Foods
Food and Drug Administration
Department of Health and Human Services
Washington, D.C.

Contract No. FDA 223-78-2100

LIFE SCIENCES RESEARCH OFFICE
FEDERATION OF AMERICAN SOCIETIES
FOR EXPERIMENTAL BIOLOGY
9650 Rockville Pike
Bethesda, Maryland 20014

https://en.wikipedia.org/wiki/Liquid_smoke

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Regulatory Status of Liquid Smoke Application for Meats and Poultry

". . . the labeling of natural smoke flavorings is covered by 9 Code of Federal Regulations 317.2 (j) (3) and 381.119 (a) and by Policy Memo 117, "Smoke Flavoring." Natural smoke flavoring may not be listed as "natural flavor" or "flavor" in the ingredients statement. It may be declared as "natural smoke flavoring" or "smoke flavoring."

https://ask.usda.gov/s/article/askFSIS-Public-Q-A-sf

https://en.wikipedia.org/wiki/Liquid_smoke

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Regulatory Status of Liquid Smoke Application for Meats and Poultry

9 CFR 317.2 (j) (3)

"When an artificial smoke flavoring or a smoke flavoring is added as an ingredient in the formula of a meat food product, as permitted in part 318 of this subchapter, there shall appear on the label, in prominent letters and contiguous to the name of the product, a statement such as "Artificial Smoke Flavoring Added" or "Smoke Flavoring Added," as may be applicable, and the ingredient statement shall identify any artificial smoke flavoring or smoke flavoring so added as an ingredient in the formula of the meat food product."

https://www.ecfr.gov/current/title-9/chapter-III/subchapter-A/part-317/subpart-A/section-317.2

https://en.wikipedia.org/wiki/Liquid_smoke

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Regulatory Status of Liquid Smoke Application for Meats and Poultry

9 CFR 317.2 (j) (3)

However. . .

https://en.wikipedia.org/wiki/Liquid_smoke

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Regulatory Status of Liquid Smoke Application for Meats and Poultry

9 CFR 317.2 (j) (3)

However. . .

"Meat or poultry products which have been exposed to natural liquid smoke flavor which has been transformed into a true gaseous state by the application of heat or transformed into vapor by mechanical means, e.g., atomization, may be labeled "Smoked.""

USDA, FSIS. 2024. Food Standards and Labeling Policy Book. https://www.fsis.usda.gov/sites/default/files/import/Labeling-Policy-Book.pdf

Rozum, J. 2014. Liquid Smoke (Smoke Condensate) Application. *Encyclopedia of Meat Sciences.* Vol. 3. pp. 315-320

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Regulatory Status of Liquid Smoke Application for Fish and Fishery Products
21 CFR 123.3 (s)

https://en.wikipedia.org/wiki/Liquid_smoke

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Regulatory Status of Liquid Smoke Application for Fish and Fishery Products
21 CFR 123.3 (s)

"Smoked or smoke-flavored fishery products means the finished food prepared by:
(1) Treating fish with salt (sodium chloride), and
(2) Subjecting it to the direct action of smoke from burning wood, sawdust, or similar material and/or imparting to it the flavor of smoke by a means such as immersing it in a solution of wood smoke."

https://www.ecfr.gov/current/title-21/chapter-I/subchapter-B/part-123

https://en.wikipedia.org/wiki/Liquid_smoke

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Thank You for Your Attention

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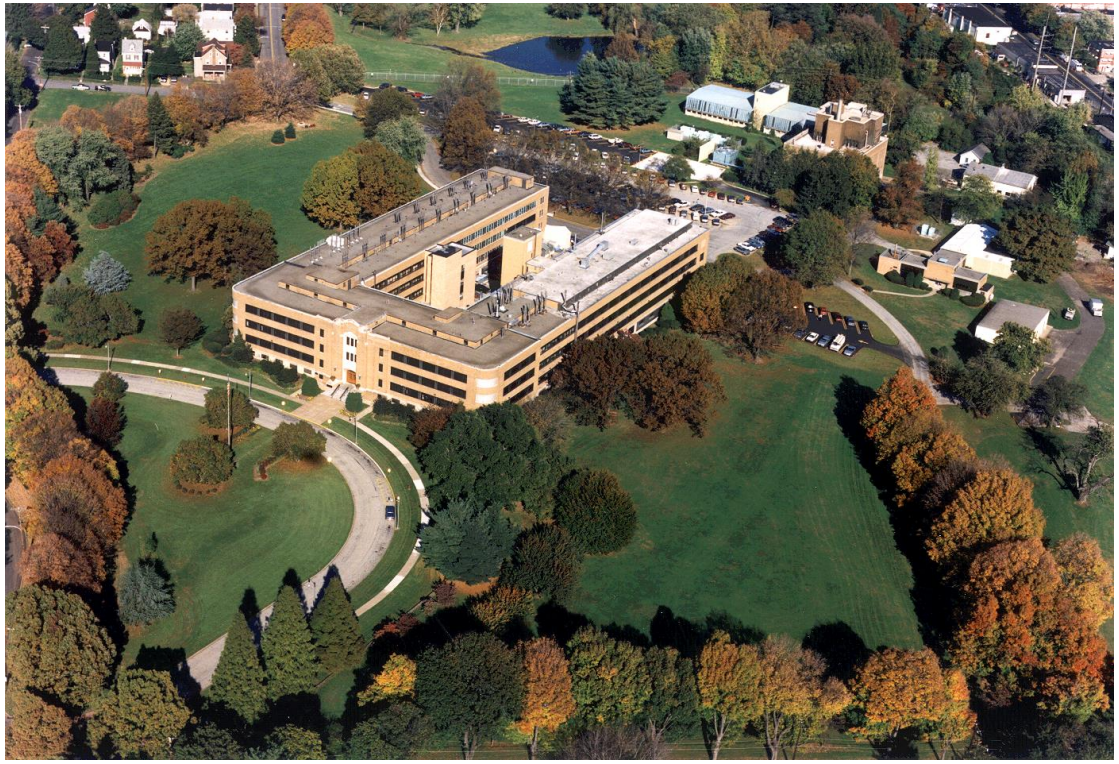
Eastern Regional Research Center • Wyndmoor, PA



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Multifunctional Smoke Systems for Antimicrobial and Antioxidant efficacy in Food Application

Revolutionizing Food Preservation With Innovative Clean Label Smoke Technology

Smoke solutions for meat and poultry preservation

Why smoke?

Issues in safety and quality of meat ?

How smoke can preserve meat?

Delaying spoilage: Fresh Poultry

Shelf-life extension and *Listeria* control: Frankfurters

Salmonella control in fresh poultry

Sensory validation

Other applications - Beverages

Bacteria impacting the meat safety and stability

Common Defects in Meat Products & Causal Bacteria

Defects	Meat product	Causative Bacteria
Slime	Meats	*Pseudomonas, Lactobacillus, Enterococcus, Weissella, Brochothrix*
H_2O_2 Greening	Meats	*Weissella, Leuconostoc, Enterococcus, Lactobacillus*
H_2S Greenin	Vacuum Packaged Meats	*Shewanella*
H_2S Production	Cured Meats	*Vibrio, Enterobacteriaceae*
Sulfide Odor	Vacuum Packaged Meats	*Clostridium, Hafnia*
Cabbage Odor	Bacon	*Providencia*
Putrefaction	Ham	*Enterobacteriaceae, Proteus*
Bone taint	Whole Meats	*Clostridium, Enterococcus*
Souring	Ham	Lactic acid bacteria, *Enterococcus, Micrococcus, Bacillus, Clostridium*

Nychas et al. (2008)

Microbial risk for meat safety

Risk	Causative Bacteria
INFECTION	*Salmonella, Campylobacter jejuni, Listeria monocytogenes*
Production of TOXINS	*Staphylococcus aureus, Bacillus cereus, Clostridium botulinum*

How to maintain food stability and food safety

Delay the growth of spoilage bacteria

Inhibit the pathogen

Food Safety first!

Control oxidation

Control Yeast & Molds

Nychas et al. (2008)

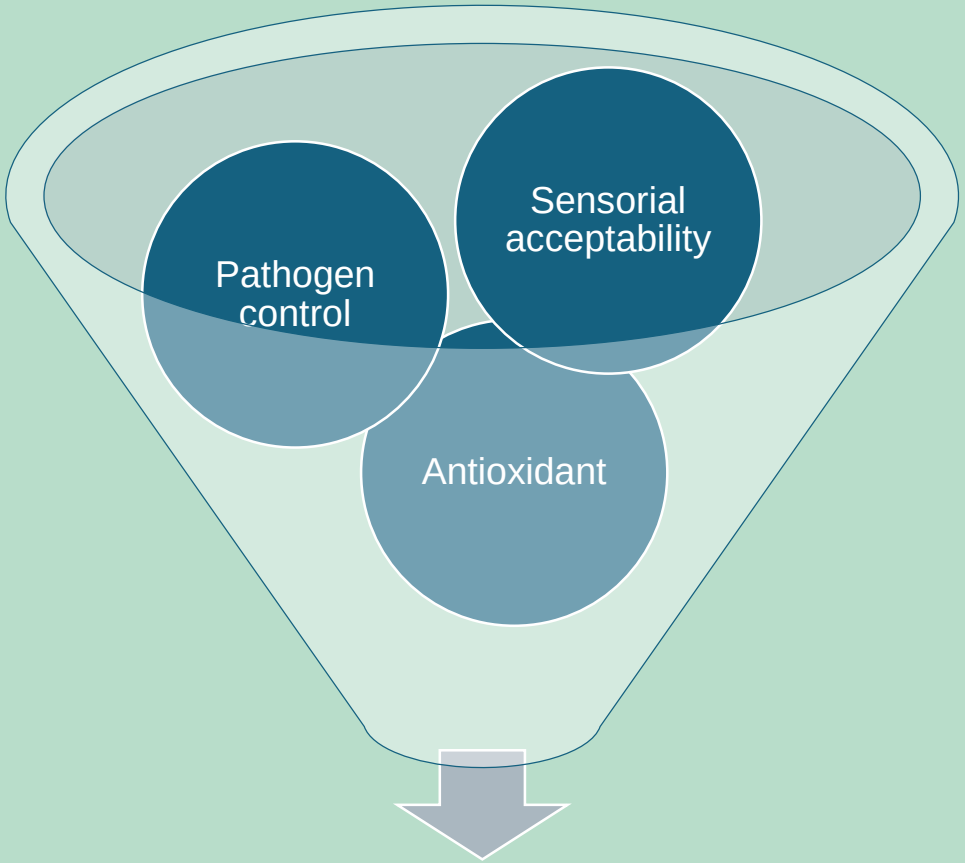
Smoking of poultry, fish and red meat has been increasing in popularity

Benefits of Liquid smoke

1. Application of liquid smoke requires less time
2. Ease of application
3. Use of liquid smoke allow the processor to control the concentration of smoke being applied – good reproducibility of desired characteristics obtained in the final product

*https://www.marketreportsworld.com/enquiry/request-sample/21011034

The Power of Smoke



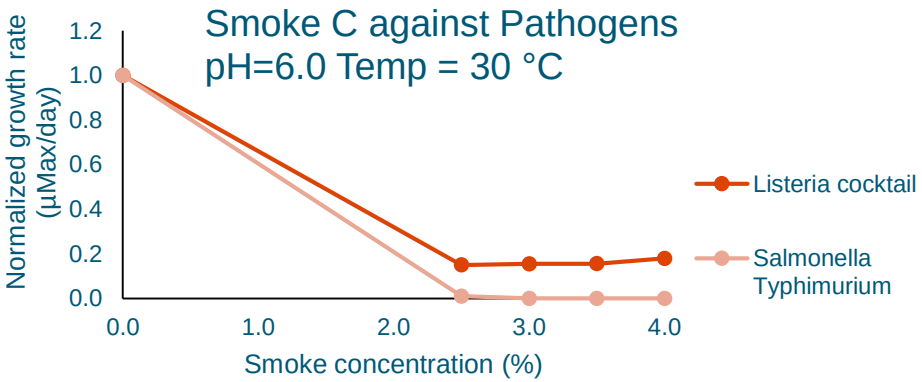
One package preservative solution

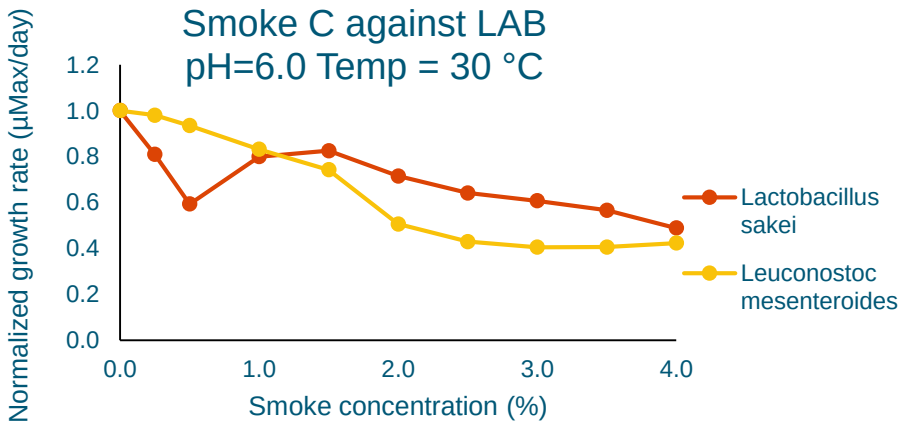
In-vitro studies

Antimicrobial efficacy in-vitro of liquid and dry smoke products

MIC % (Minimum inhibitory concentration) at pH= 6.0 and Temp= 30 °C

	Pathogenic bacteria	Smoke A (Liquid) (%)	Smoke B (Liquid) (%)	Smoke C (Liquid) (%)	Smoke D (Dry) (%)
1	*Listeria* cocktail	**0.25**	**1.0**	**>4.0**	**0.4**
2	*E. coli*	**0.20**	**1.0**	**>4.0**	**0.4**
3	*Salmonella* Typhimurium	**0.25**	**1.0**	**3.0**	**0.4**
4	*Staphylococcus aureus*	**1.50**	**1.0**	**3.0**	**0.4**
5	*Bacillus cereus*	**0.20**	**1.0**	**3.0**	**0.4**
	Lactic acid bacteria				
6	*Lactobacillus sakei*	**0.50**	**0.5**	**>4.0**	**0.1**
7	*Leuconostoc mesenteroides*	**0.25**	**0.5**	**>4.0**	**0.4**





Conclusion

Antimicrobial efficacy in-vitro of Smoke A> Smoke D> Smoke B > Smoke C

Application studies

Antimicrobial efficacy of liquid smoke against spoilage and pathogenic bacteria in meat application

Frankfurters

L. monocytogenes

Zesti Smoke @ 2.5% LS -2 log CFU/mL reduction;
5% LS -listericidal after 6 weeks;
10% LS -listericidal after 4 weeks (Morey et al., 2012)

Zesti B 100% sprayed - Undetectable
1 log -after 1 week;
2 log -after 4 weeks;
3 log -slowly increased to 3.8 logs over 10 weeks
Control -increased by 7 logs.

CharSol-10 100% dipped - 1 log reduction after 72 h (Messina et al.,1988)

Ground pork bellies

Staphylococcus aureus

Charsol Supreme @1.25% - 1.7 log reduction after 3 h (Taormina and Bartholome, 2005)

Antimicrobial efficacy of liquid smoke against spoilage and pathogenic bacteria in seafoods application

Salmon

L. monocytogenes

C10 *Staphylococcus aureus*
25% No reduction after 5 days at 25%.
50% Below detection after 5 days
75% Below detection after 3 days
100% Below detection after 3 day
(Paranjpye et al., 2004)

AM-3, AM-10 @0.9%
2 log CFU/g reduction *Listeria innocua* after 2 weeks
(Montazeri, Himelbloom et al., 2013)

CharSol Supreme 60%, 15 s dip
3 log reduction of *Listeria innocua* (Vitt et al., 2001)

Trout

Smoke fractions 100% dip, 1 min
L. monocytogenes -
L1 and L2 - below detection limit immediately;
S - below detection limit by 21 days;
L3 - no inhibitory affects (Suñen et al., 2003)

Additive Combinations for Delaying Spoilage in Fresh Poultry

Market Dynamic

Shelf life without preservation is very short, needing to be ground onsite at the retailer and often creating large quantities of retail and consumer waste.

Before
- No preservative

After
- Vinegar
- Natural (Smoke) Flavour

Approach

Focusing on spoilage, we looked for additive impact of two individual ingredients when used in combination, to further extend shelf life

Microbes of concern: Spoilage (APC)

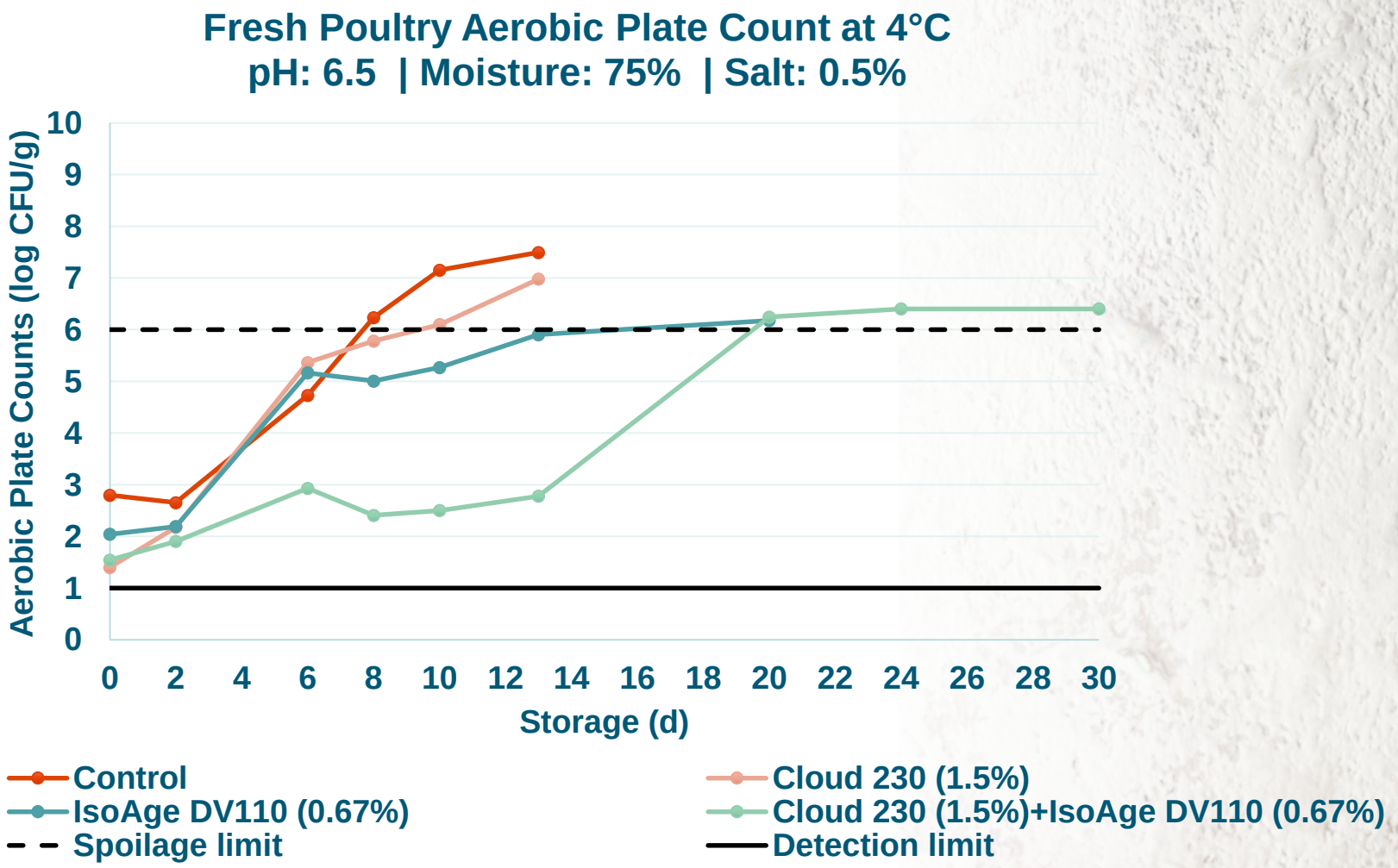
Impact

Extra Shelf-Life Days	Smoke (230)	Buffered Vinegar	Combination
Versus Negative Control (no preservatives)	3 days	5 days	13 days

*Depending on microorganisms present/of concern

13 days+ Minimum additional shelf life versus no preservatives

Refrigerated Fresh Poultry treated with Buffered Vinegar and Smoke had An Enhanced Shelf Life



The use of multifunctional ingredients to improve food safety

Clean label shelf-life extension solutions for meat applications

Combined ingredient systems are key for longer shelf life

Microbial and oxidative delay are possible with clean label ingredients

Extra shelf-life days can translate into positive environmental impact

Enhancing Sensory, Texture and Shelf Life of Hot Dogs

Market Dynamic

Hot dogs are affordable and delicious meat products, beloved around the world. They have a long shelf-life expectation from retailers and consumers alike.

Approach

Hurdle approach: Combining organic acids with an ingredient with a different mode of action can extend shelf life through additive effects.

Impact

Extra Shelf-Life Days with 1.5% Cloud 230 + 0.63% IsoAge DV100	*Listeria*	*L. sakei*
Versus Negative Control (no preservatives)	>60 days	15 days
Versus Market Solution (IsoAge DV100)	28 days	13 days

Before
- Vinegar

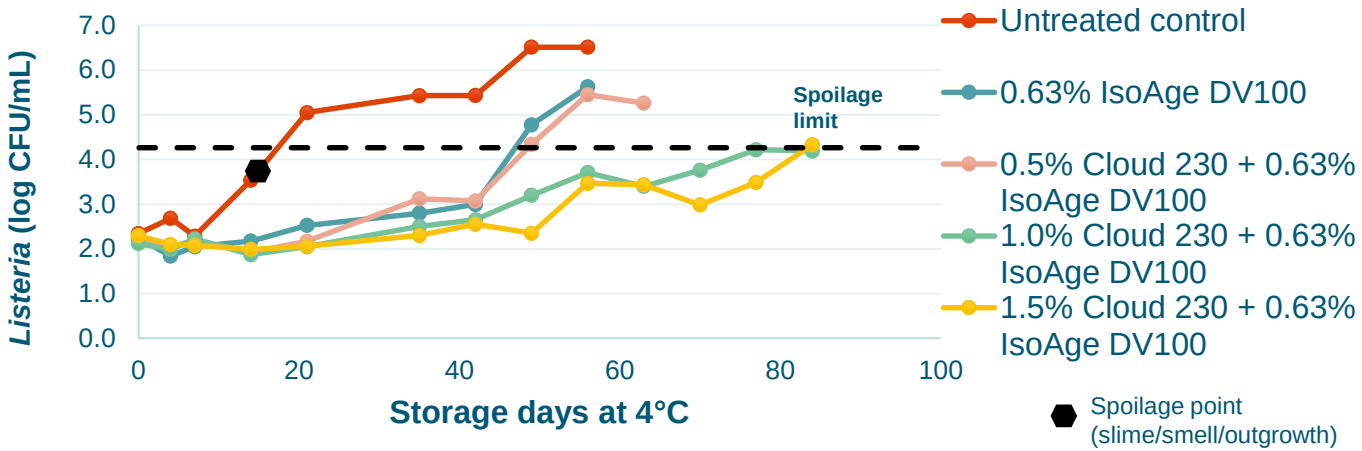
After
- Vinegar
- Natural Smoke Flavour

Microbes of concern: Pathogen (*Listeria monocytogenes cocktail*), Spoilage (*Lactobacillus sakei*)

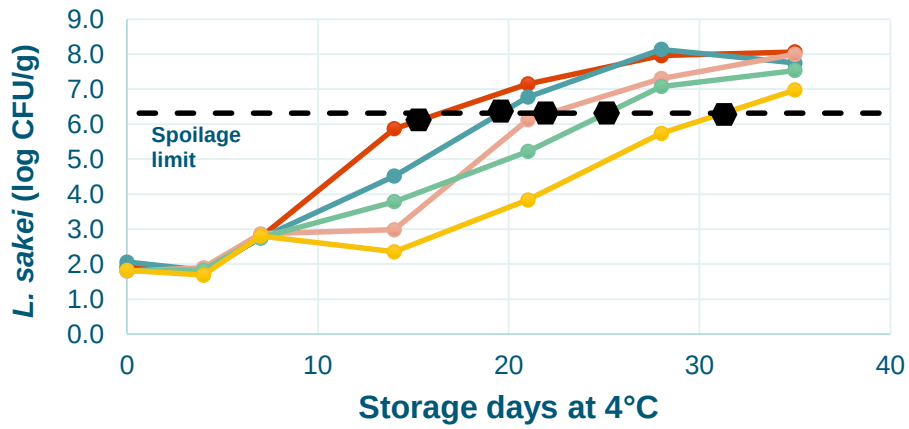
15 days+ Minimum additional shelf life versus no preservatives

Combined Efficacy of Vinegar and Smoke on Refrigerated Hot Dog Over Shelf Life

Hotdogs *Listeria* cocktail at 4°C pH: 6.7 | Moisture: 64% | Salt: 2.77%



Hotdogs *L. sakei* cocktail at 4°C pH: 6.7 | Moisture: 64% | Salt: 2.77%



Treatments	*Listeria monocytogenes* (Days to ≥2 log outgrowth)
Control – no preservatives	17
0.63% IsoAge DV100	49
0.5% Cloud 230 + 0.63% IsoAge DV100	50
1.0% Cloud 230 + 0.63% IsoAge DV100	77
1.5% Cloud 230 + 0.63% IsoAge DV100	84

Addition of Cloud 230 enhances Umami and Bite

Treatments	*L. sakei* (Days to 7 log CFU/g)
Control – no preservatives	15 (smell) 20 (7 log)
0.63% IsoAge DV100	22
0.5% Cloud 230 + 0.63% IsoAge DV100	25
1.0% Cloud 230 + 0.63% IsoAge DV100	28
1.5% Cloud 230 + 0.63% IsoAge DV100	35

Conclusion: Hot Dogs treated with IsoAge DV100 in combination with Cloud 230 have been found to have a longer shelf life - stored at 4°C.

Sensory Analysis

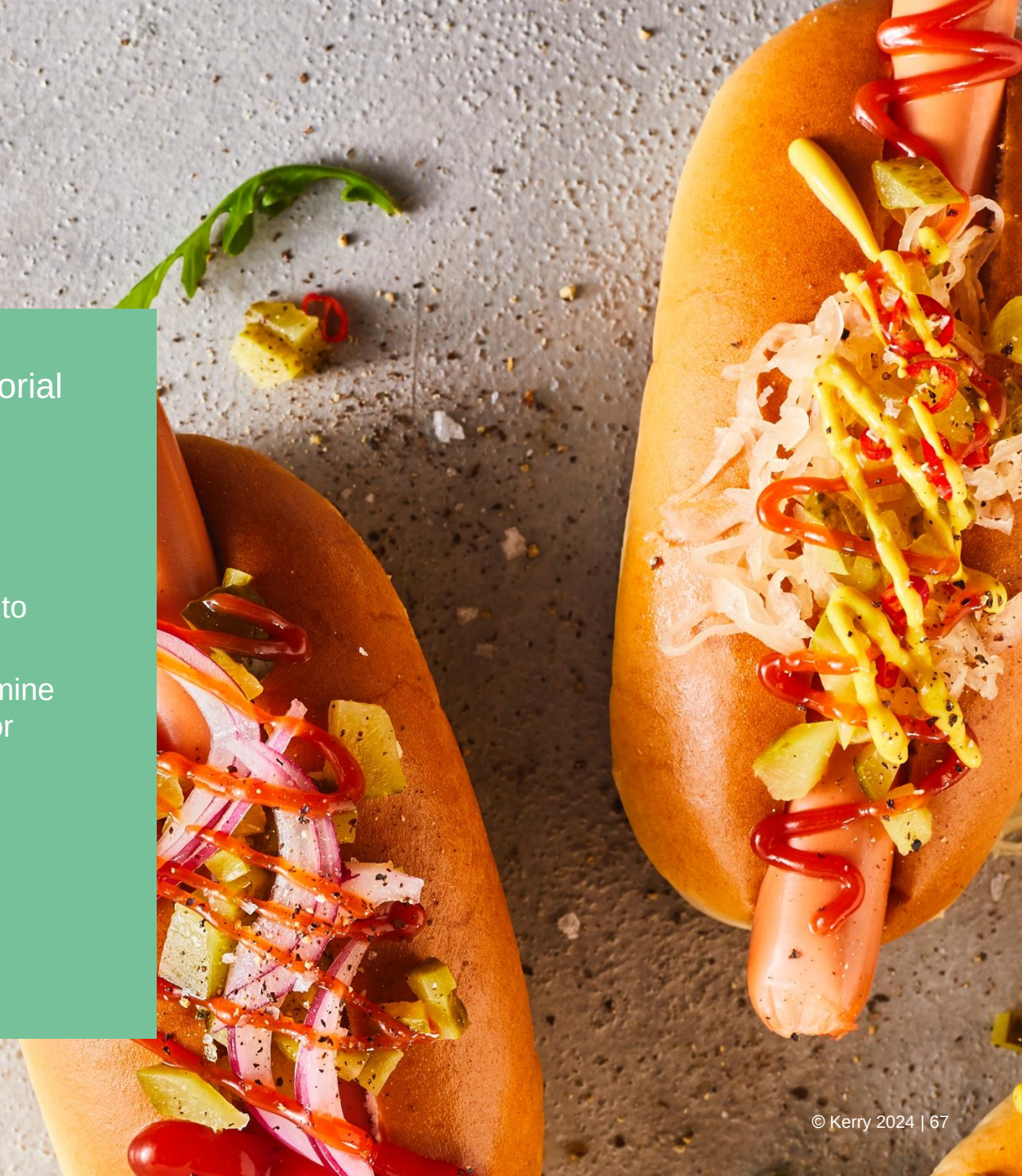
Sensory analysis was conducted to determine the sensorial impact of the Cloud 230 at three usage levels on key frankfurter attributes.

Methods:

- Samples were blinded with three-digit codes and compared to reference (0.63% IsoAge DV100).
- Panelists used a 9-point relative to reference scale to determine how different and the directionality of that difference (more or less) for key attributes.

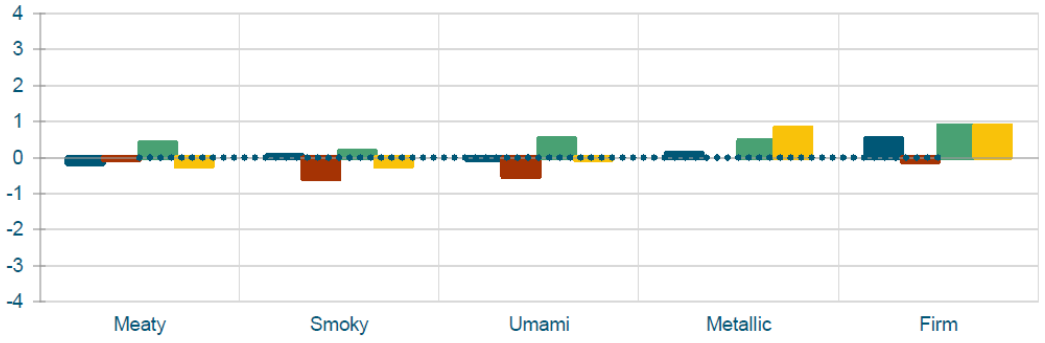
Data Analysis:

The data was collected using EyeQuestion version 5.07.15 and analyzed and charted using the Kerry Data Analysis Software.

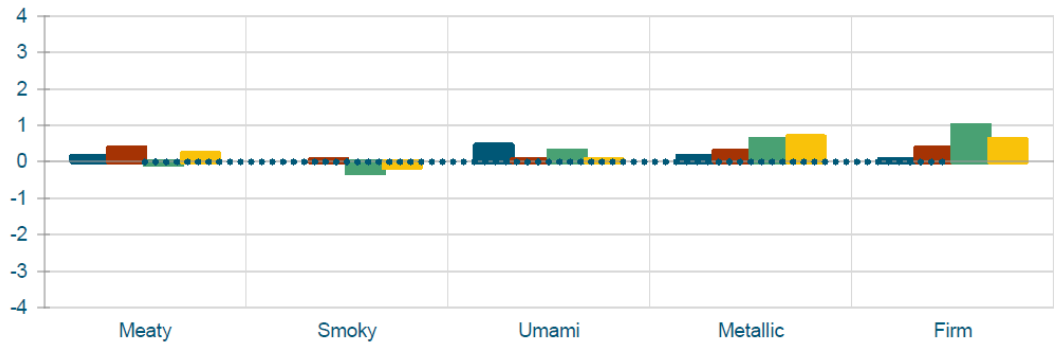


Addition of Cloud 230 enhances Umami and Bite

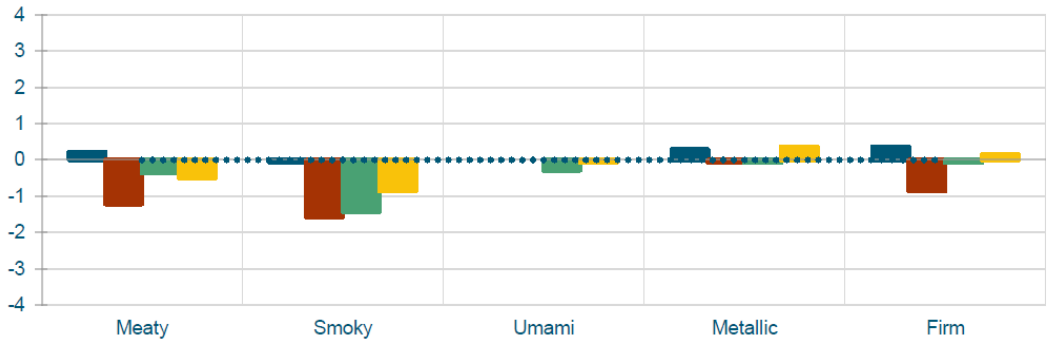
Day 7



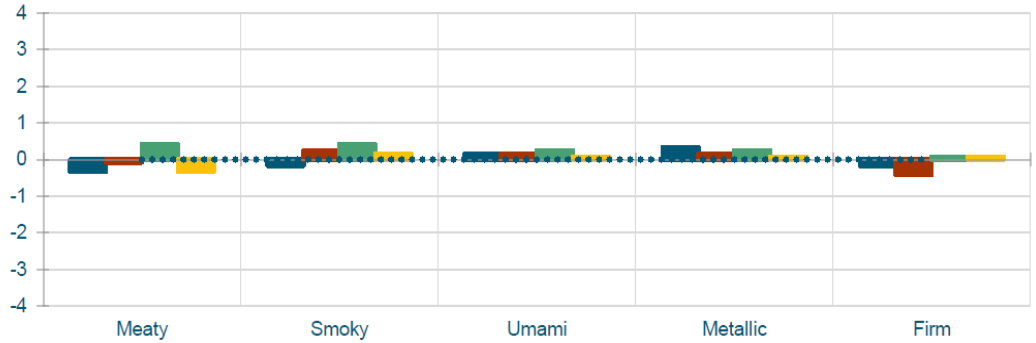
Day 14



Day 30



Day 60



(Blind) 0.63% IsoAge DV100

0.63% IsoAge DV100+ 0.5% Cloud 230

0.63% IsoAge DV100+ 1.0% Cloud 230

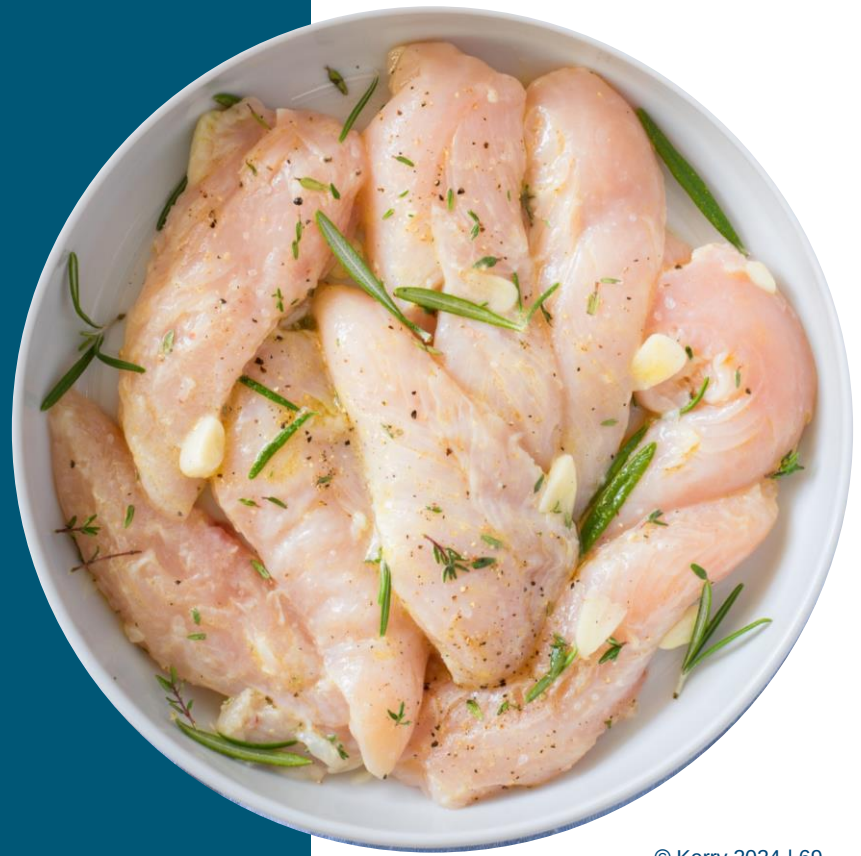
0.63% IsoAge DV100+ 1.5% Cloud 230

Salmonella Inhibition in Fresh Chicken

Market Dynamic

- *Salmonella* -10 large-scale recalls in the US in 5 years
  (Source: USDA FSIS 2019 – 2024).
- About 1.35 million cases of salmonellosis, with 26,500 hospitalizations and 420 deaths
  (Source: Centers for Disease Control and Prevention (CDC).
- There are limited ingredients today that will protect food in the event of a *Salmonella* contamination.

Microbe of concern:
Salmonella



Evaluation of Smoke as an Intervention for *Salmonella spp.* in Ground Chicken

Methodology

1

Chicken breasts were cut into
4IN X 4IN SQUARES
100gr

Placed on a disinfected tray

25 pieces per tray

2

Chicken pieces were inoculated with 1ml of a diluted cocktail

Diluted cocktail
2-3 LogCFU/ml
enteritidis/infantis/typhimurium

3

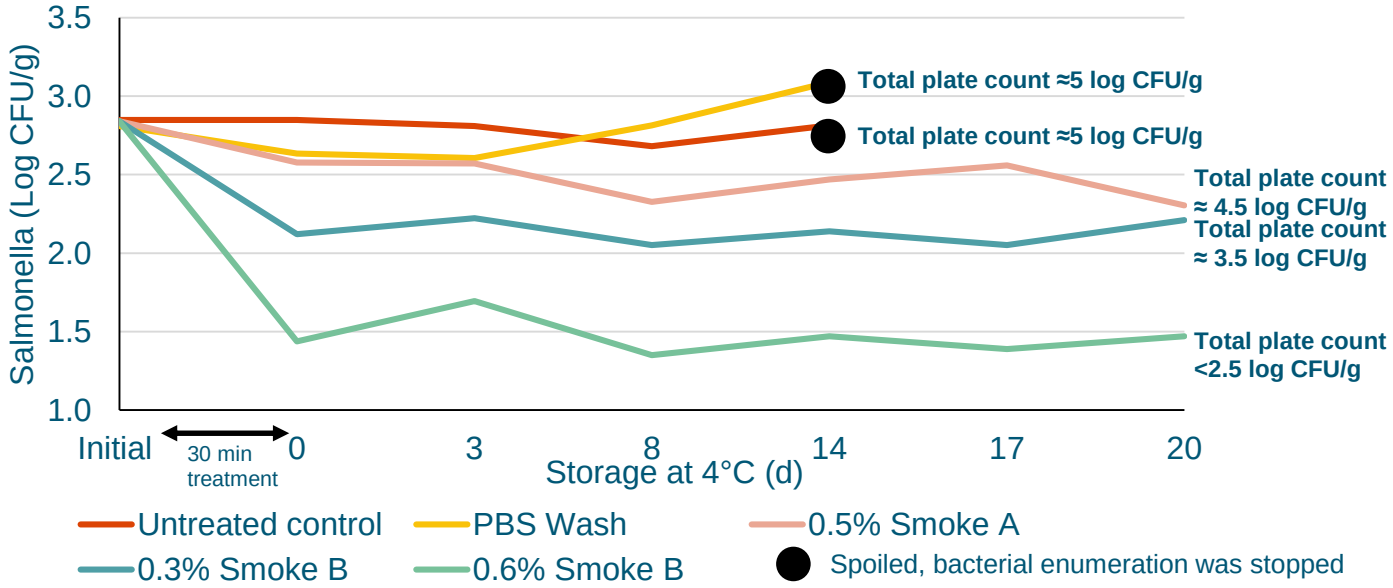
Before the respective intervention pieces were left for 1 h for bacterial attachment and sprayed with smoke solutions

After intervention
Pieces were grinded

50 g samples and packaged until further processing.

Challenge Study:
Log Reduction of *Salmonella* in Various Fresh Poultry Formulations

Fresh poultry: Effect of Smoke A and Smoke B against Salmonella
pH= 6.0; aw =0.962; Temp =4°C; MAP packaging (30% carbon dioxide and 70% nitrogen)



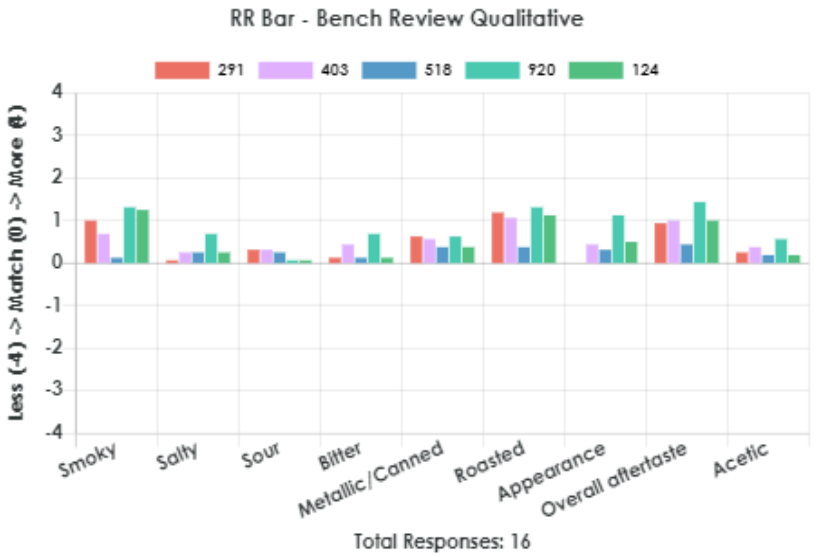
Treatments	Total *Salmonella* reduction (Log CFU/g) on day 0
Untreated control	No reduction observed
PBS wash	0.2
0.5% Smoke A	0.3
0.3% Smoke B	0.6
0.6% Smoke B	1.4

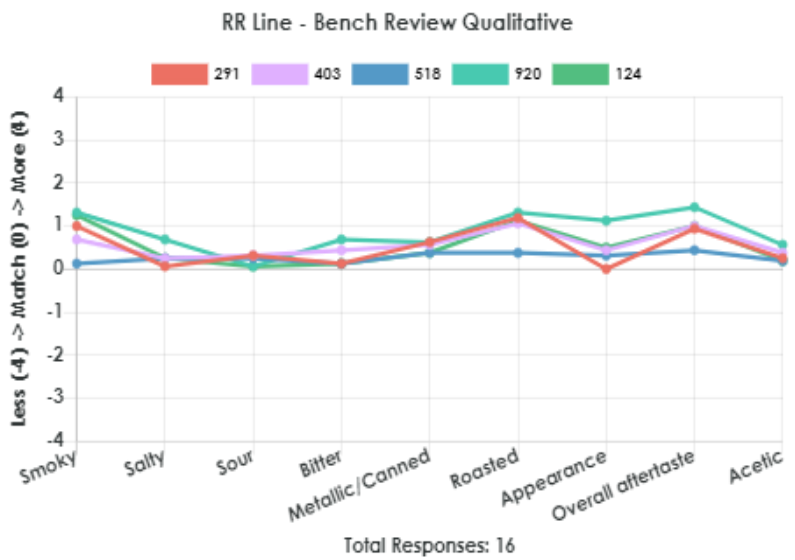
Conclusion

1. 0.3% Smoke B provided 0.6 log reduction maintained throughout storage.
2. 0.5% Smoke A achieved 0.3 log CFU/g reduction of *Salmonella* cocktail in ground poultry which remained stable throughout storage.
3. 0.6% Smoke B achieved 1.40 log CFU/g reduction of *Salmonella* cocktail in ground poultry which remained stable throughout storage. This treatment could impart smoky flavor and color so advantageous for applications such as smoked sausages.

Sensory Validation of Various Ground Poultry Concepts Containing Smoke and Vinegar

Kerry Bench Review (KBR) system was used to evaluate the sensory characteristics by 17 panelists.
Attributes evaluated: Acetic, Smoky, salty, sour, sweet, meaty, roasted, texture, appearance, and overall aftertaste.



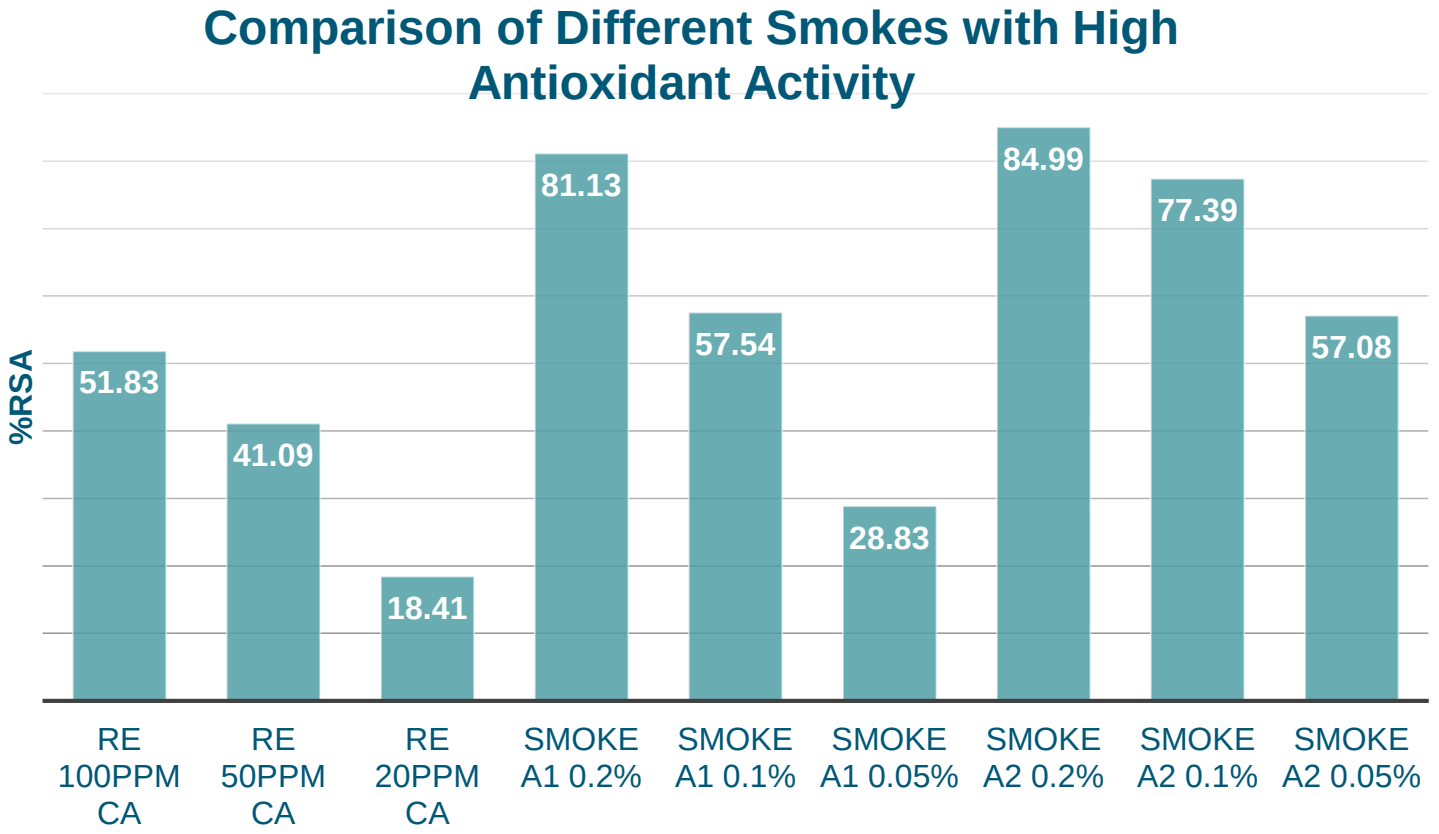


Sensory codes	Treatment
291	0.5% Smoke A
403	0.3% Smoke B
518	Untreated control
920	0.3% Smoke B + 0.19% Vinegar
124	0.3% Smoke A + 0.19% Vinegar

Conclusion

1. Overall, there is an increased perception of smoky, roasted, acetic, and overall aftertaste with inclusion of 0.5% Smoke A and 0.3% Smoke B.
2. Metallic/Canned perception of samples with smoke were not significant different as compared to control.
3. 0.3% Smoke B imparted slightly bitter taste as compared to 0.5% Smoke A.
4. Addition of vinegar did not impact the sensory perception. Combination of smokes and vinegar at 0.49% can be used for ground chicken application.

Antioxidant Analysis of smoke fractions (In vitro) via DPPH



Several smoke fractions were evaluated for radical scavenging capacity and found to have moderate to excellent antioxidant capabilities.




Potential of Smoke in diverse food matrices



Yeast and Mold inhibition in Beverages, Supplements, Plant Based and Dairy

Carbonated Beverage: *Yeast* Challenge Study

Aim

To evaluate efficacy of Flavoset 5400L in carbonated beverage against Yeast.

Trial Conditions

- Products prepared in commercial trial
- 100 mL aliquoted into crimp top vials with rubber stopper (3 samples/treatment)
- Treatments inoculated with yeast cocktail at 2-4 log CFU/mL, mixed gently to attain uniform dispersion of inoculum
- Samples stored at 25 °C throughout the study.

Microbiological analysis – Tested in Triplicate

- Yeast and Mold on PDA incubate at 25 °C for 4-7 days.

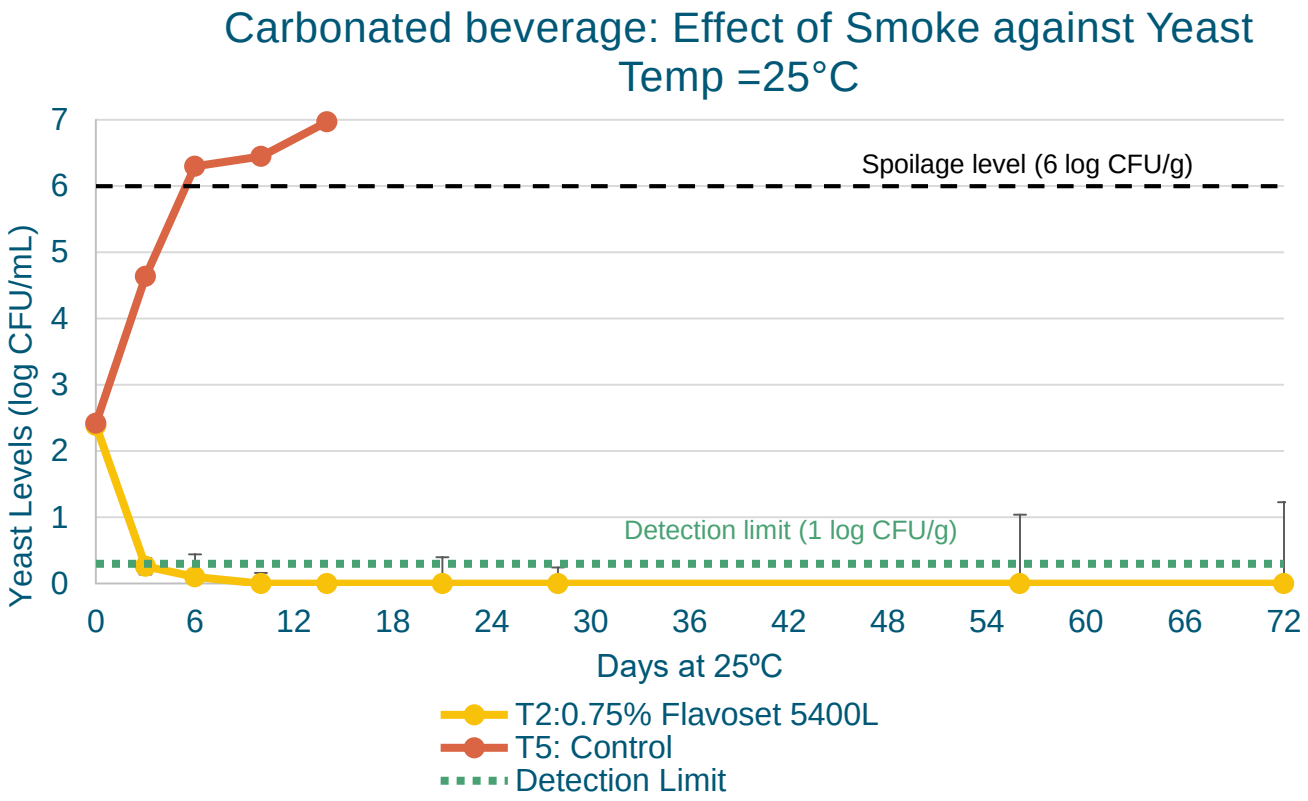
Product Characteristics & Sensory

- pH, water activity (aw), colour

S. No.	Strain name
1	***Zygosaccharomyces bailii***
2	***Saccharomyces cerevisiae***
3	***Candida tropicalis***
4	***Dekkera bruxellensis***
5	***Brettanomyces naardensis***

S.no.	Treatments	Smoke %
1	Untreated Control	-
2	Flavoset 5400L	0.75

Carbonated Beverage - Antimicrobial Screening



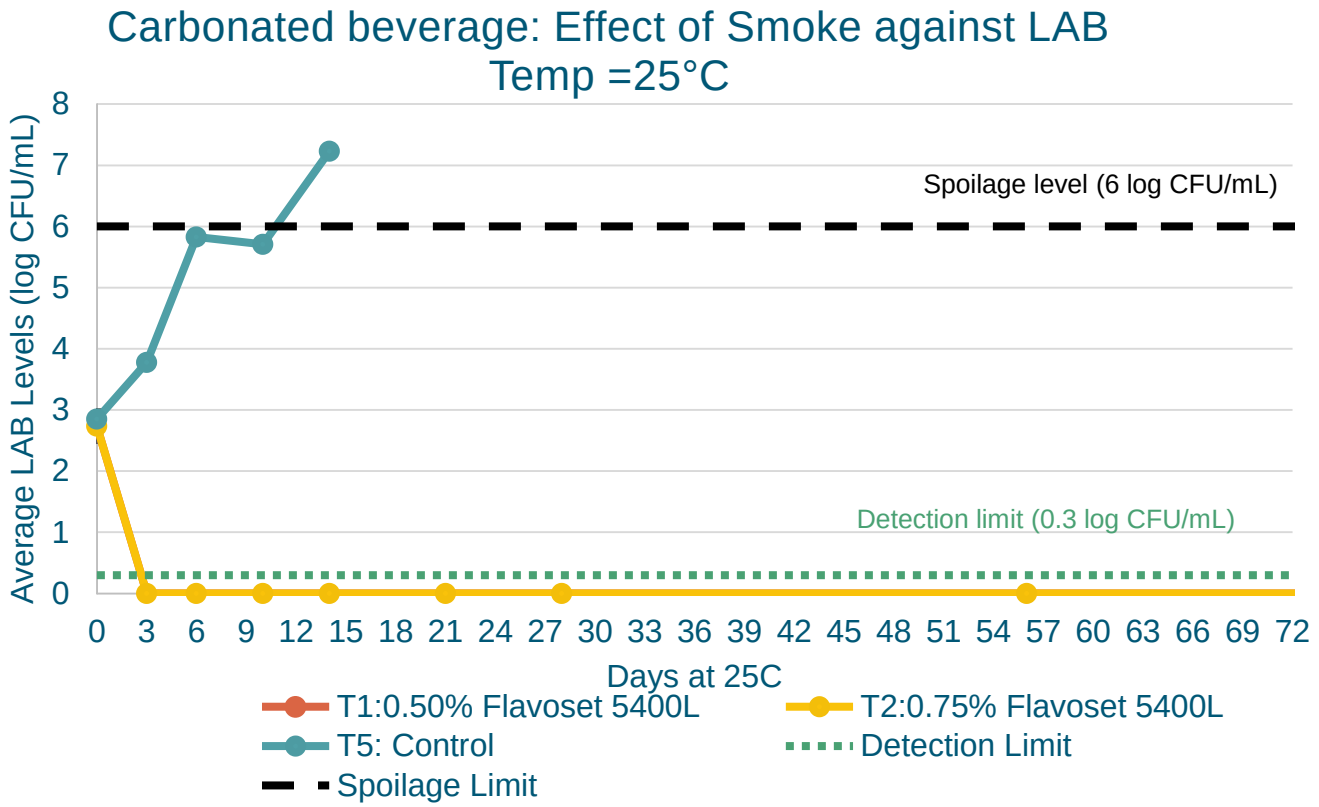
Product characteristics

S. no.	Treatment	pH	Aw	Brix
1	T2:0.75% Flavoset 5400L	3.42	0.9390	2.38
2	T5: Control	3.52	0.9488	2.18

Conclusion

1. T5 (no antimicrobial control) reached spoilage limit around day 6
2. Yeast levels in T2: 0.75% Flavoset 5400L below detection limit post day 3 timepoint and continued to be below detection limit for >72 days.

Carbonated Beverage - Antimicrobial Screening



Product characteristics

S. no.	Treatment	pH	Aw	Brix
1	T2:0.75% Flavoset 5400L	3.42	0.9390	2.38
2	T5: Control	3.52	0.9488	2.18

Conclusion

1. T5 (no antimicrobial control) reached spoilage limit around day 10
2. LAB levels dropped below detection limit in T2, on day 3 and continued to be below detection limit for >72 days

Smoke shows **potential efficacy** in a variety of applications

RTD alcoholic beverage

- 4.0 - 7.9% ABV
- pH 2.9 - 4.0
- Brix 2.0 - 7.5

10 months challenge study – data available

BFY prebiotic soda

- pH 3.3 - 3.6
- Brix 2.0 - 2.5

12 weeks challenge study – data available

Beverage Concentrates

- pH 2.3 - 3.5
- Brix 5 -70

8 weeks challenge study – data available

RTD tea-based drinks

- pH 3.5 - 4.5
- Brix 4 - 8

21 days challenge study – data available

Cloud Smokes key takeaways

1) Cloud smokes provide a broad-spectrum antimicrobial efficacy.
2) Clean label preservative solution for wide variety of food products.
3) Smoke based solutions were effective in inhibiting and controlling the growth of *Salmonella* in fresh poultry.
4) Smoke solutions did not impact the sensory perception.
5) Multifunctional Systems- Combined technologies / products are more effective to meet specific goals.

Cloud Smokes

Label Friendly

Natural smoke enables consumer-friendly flavor labelling.

Product Quality

Smoke attributes inherently maintain quality over shelf life.

Sustainable

Captures the best of the smoking process and removes and repurposes undesirable fractions.

IAFP WEBINAR

Modernizing the Ways of Traditional Smoking: Application of Liquid and Dry Smoke in Meat, Poultry and Pet foods

APPLICATION OF LIQUID SMOKE IN THE MITIGATION OF MOLDS AND MITES IN A SEMI-MOIST PET FOOD MODEL

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Senior Scientist, Kraft Heinz

September 30, 2024

Outline

- Introduction to intermediate moisture/semi-moist pet foods
- Spoilage & food safety issues
- Current challenges with conventional additives
- Liquid smoke: What we know/do not know
- Case studies:
  - Liquid smoke as an **acaricide** to control mite infestation in semi-moist pet food
  - Liquid smoke as an **antimycotic** to control mold spoilage in semi-moist pet food

Introduction

- Semi-moist pet food
  - A popular **intermediate moisture food** in the pet food category
  - Current worldwide revenue of $2.65 billion out of a total $70 billion revenue from pet foods
  - Primarily contains meat and grain-based ingredients, fat, **20-30% moisture**, with **0.76 a_w** Example: Chewy dog treats

Semi-moist pet food - Dog Treats

Mold infected pet food

- Spoilage & food safety issues in semi-moist pet food
  - Baked/formed (no kill step)
  - High moisture & a_w ; rich in proteins & fats
  - Very conducive for storage **mold** and **mite** infestation
    - ***Tyrophagus putrescentiae*** (cheese mite, ham mite or mold mite)
    - ***Aspergillus flavus, Fusarium graminearum*** (storage molds)
    - **Mycotoxins** like aflatoxin, zearalenone, DON
    - **Wild-type mold** (environmental/mixed molds)

Mite infested pet food

Pet food industry challenges with conventional additives

Additive	Advantages	Challenges
Propylene glycol	✓ Humectant (controls a_w) ✓ Used in dog food ✓ Keeps mites away	× **Synthetic** (confused with anti-freeze 'ethylene glycol') × **Toxic to cats** (Heinz body formation in blood)
Glycerin	✓ Natural ✓ Humectant (controls a_w) ✓ Used in dog & cat foods	× **Favorable for mites**
Potassium sorbate	✓ Mold inhibitor	× **Synthetic**

<u>Solution</u>: A NATURAL, FOOD-SAFE additive with MULTI-functionality

Liquid smoke

Liquid smoke

- Produced by condensing wood smoke created by pyrolysis of sawdust or wood chips followed by removal of carcinogenic hydrocarbons
- Contains carbonyls, phenols & organic acids in various proportions
- Natural, GRAS
- Color & flavor additive
- Antimicrobial

Liquid smoke

Liquid smoke production

Liquid smoke as an acaricide & antimycotic

What we know	What we do not know
Wood smoke from different plants used to control '**bee mites**' in apiaries[1].	**Can liquid smoke be effective against stored food mites?**
Liquid smoke (phenolic fraction) is effective against pathogenic bacteria like ***Listeria*, *E.coli*, *Staphylococcus*** in some meat products[2,3].	**What will be the effects of liquid smoke fractions against storage molds?** **How can it affect mold growth pattern & shelf life in a food substrate?**
Liquid smoke is effective against the mold ***Aspergillus niger*** in a **nutrient broth** assay[4].	

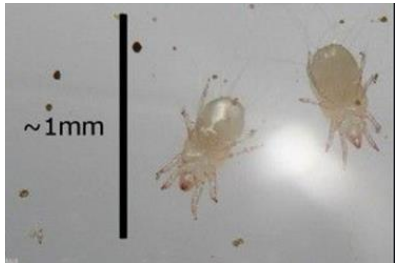
References: 1. Eischen et al., 2004; 2. Sunen et al., 2003; 3. Lingbeck et al., 2014; 4. Milly et al., 2005

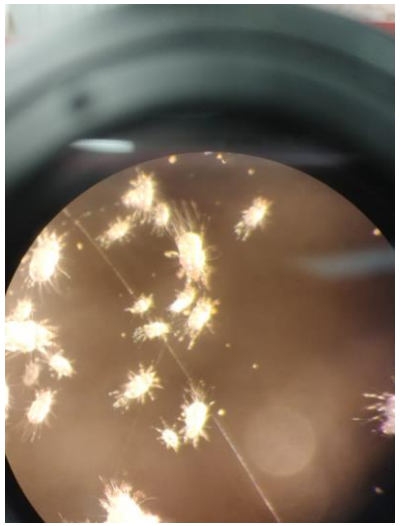
Case Study 1:

Liquid smoke as an acaricide in semi-moist pet food

Background

- ***Tyrophagus putrescentiae* (cheese mite or mold mite)**
  - Cosmopolitan stored-product mite species of the food industry including pet foods
  - Cause allergic asthma and rhinitis among food industrial workers
  - Cause allergy in dogs with atopic dermatitis; acute enteritis in humans on ingestion of mite-infested product
  - Vector for transmission of pathogens
- Isolated from pet food industry locations[5], and sealed commercial dog food bags[6]
- Current mitigation strategy – fumigation & pesticides (DEET); unsafe for the environment and human workers
- <u>Liquid smoke can be a natural alternative</u>





Mites under a microscope (used in this study)

References: 5. Thind, 2005; 6. Brazis et al., 2008

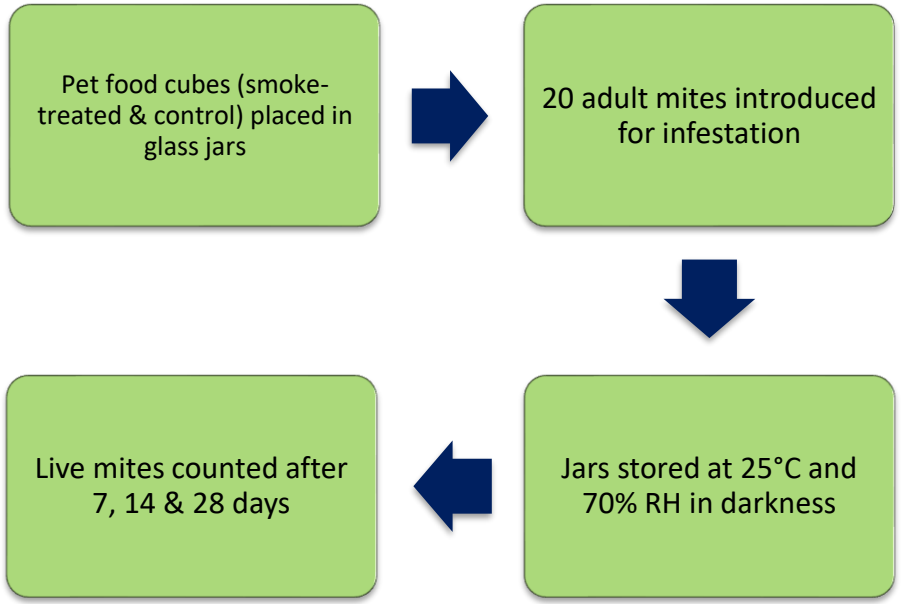
Liquid smoke fractions used in the study

SMOKE	NAME	DESCRIPTION
S1	P-1720	Buffered Low Phenol Smoke, Medium Carbonyl
S2	Cloud S-5	Buffered pH, Low Acid, Low Carbonyl, No Phenol
S3	Cloud S-C100	**Carbonyl Preparation**: High Carbonyl, Low Acid, Very Low Phenol
S4	Black deli	Basic pH Smoke, Zero Carbonyls, Organic Acid Salts, Phenols
S5	Hickory OS 1473	**Phenol Preparation**: High Phenol, Low Acid, No Carbonyl
S6	Code 10	**Base Smoke**: Organic Acid/Carbonyls/Phenols
S7	Code V	**Organic Acid Preparation**: Low pH, Medium Acid, Medium Carbonyl, Low Phenol
S8	Cloud S-AC15	High Buffered Organic Acid + Medium Carbonyl Preparation

Experiment 1: Mite reproduction & survivability assay

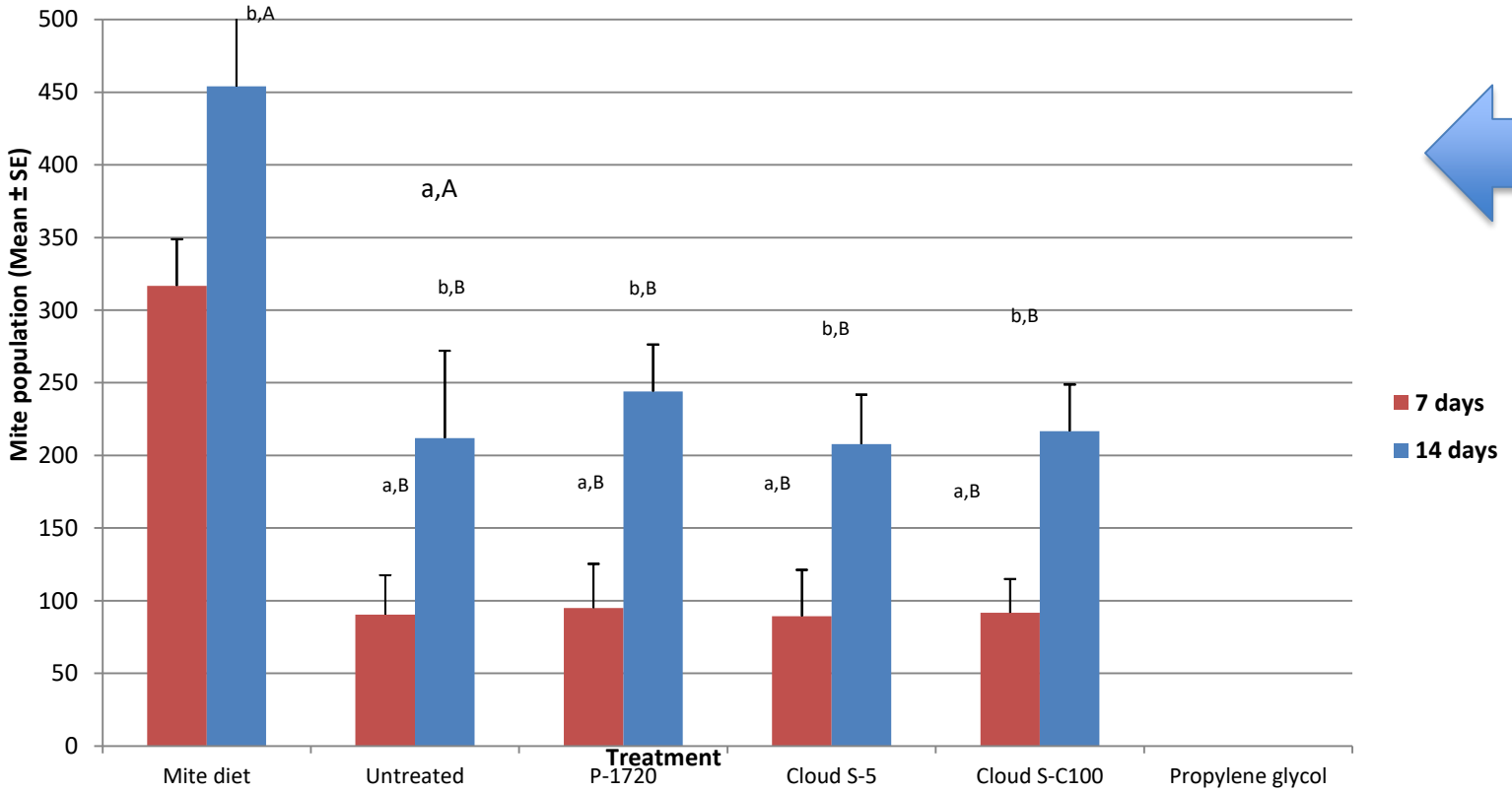
Semi-moist pet food

Procedure:



Mites observed in the assay

Mean mite population growth at 7 and 14 days on semi-moist pet food treatments with inclusion of liquid smoke preparations P-1720, Cloud S-5 and Cloud S-C100 at 0.3% w/w, in comparison to the untreated (0% smoke) and mite rearing diet. The positive control (propylene glycol treatment) did not show mite population growth.



Liquid smoke **did not kill the mites** or inhibited their population growth when included in food formulation.

Each mean is based on *n* = 3 replications. Means among treatments across **day 7 and day 14** followed by different letters in **lower case** are significantly different (***P*<0.05, Tukey's test**). Means among **treatments within each time period** of 7 or 14 days followed by different letters in **upper case** are significantly different (***P*<0.05, Tukey's test**).

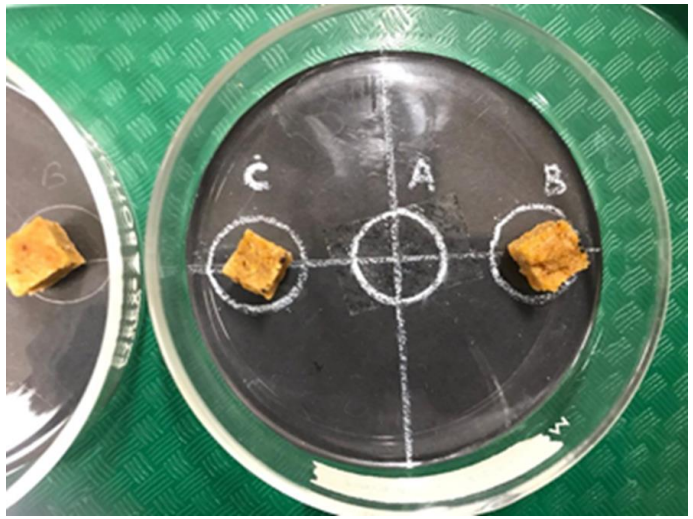
Experiment 2: Mite orientation behavior assay (attraction/repellency)

Procedure:

- Two-choice behavioral assays with mites in bio-assay arenas
- A ‘treated’ and a ‘control’ pet food cube placed in each of the circle **B** and **C**
- 20 adult mites released into middle circle **A**
- Arenas placed in darkness at 25°C and 70% RH
- Mites that oriented towards each of the pet food cubes within the circles counted after 1, 8 and 24 h
- Attraction or repulsion of mites quantified as Repellency Index (RI)

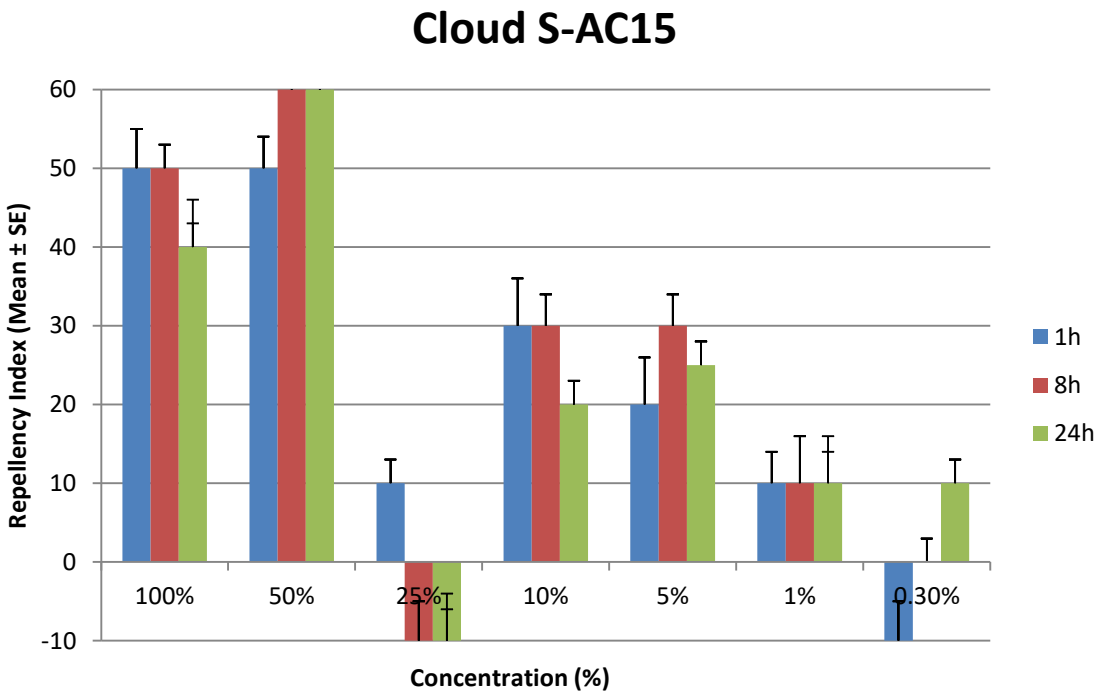
$$\mathbf{RI = (N_c - N_t)/T \times 100}$$

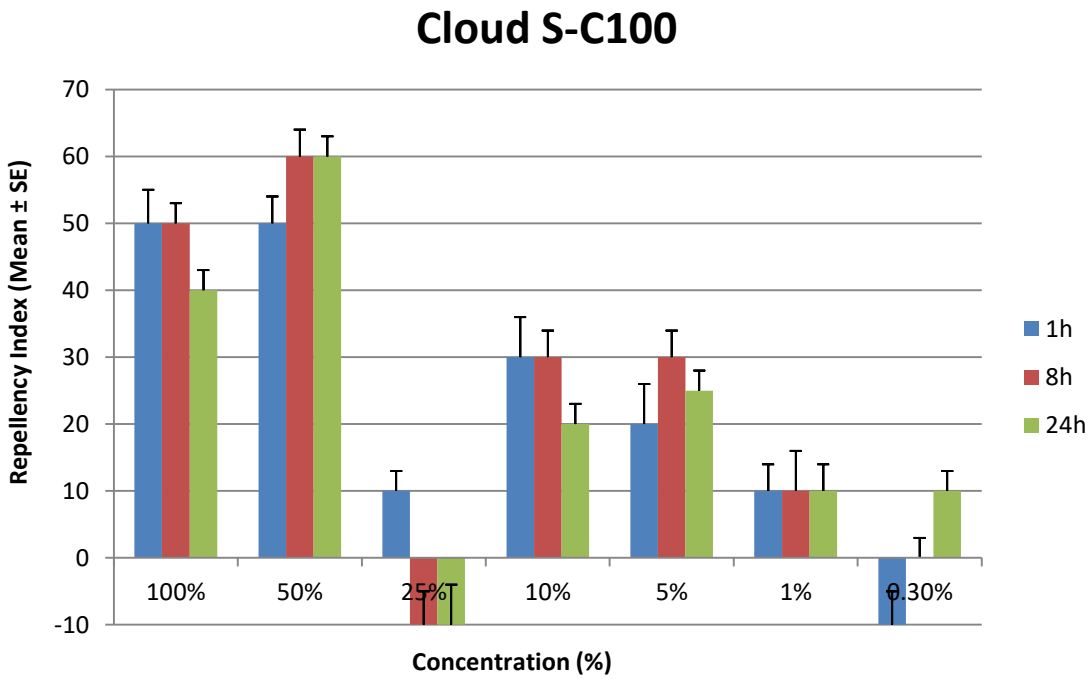
where N_c = no. of mites on control; N_t = no. of mites on treated;
T = total number of mites released (T=20)



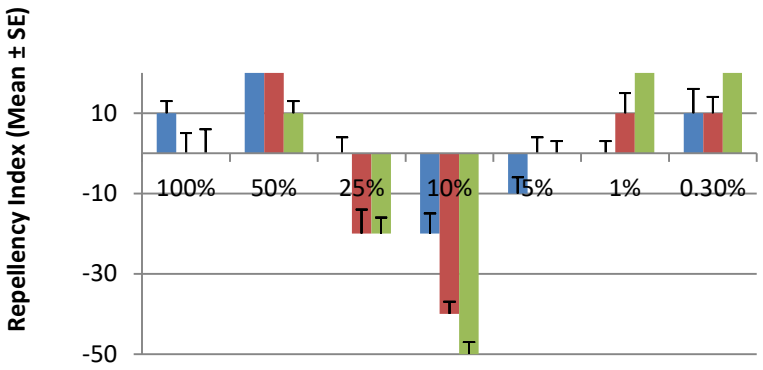
Bioassay arena for two-choice behavioral assay of mites

Mean mite repellency indices (RI) for liquid smoke preparations at 100%, 50%, 25%, 10%, 5%, 1% and 0.3%, coated on semi-moist pet food at enumeration time points 1 h, 8 h, and 24 h. Positive control (propylene glycol treatment) showed 100% repellency. RI values which are "+" indicate repellency and "–" indicate attraction.

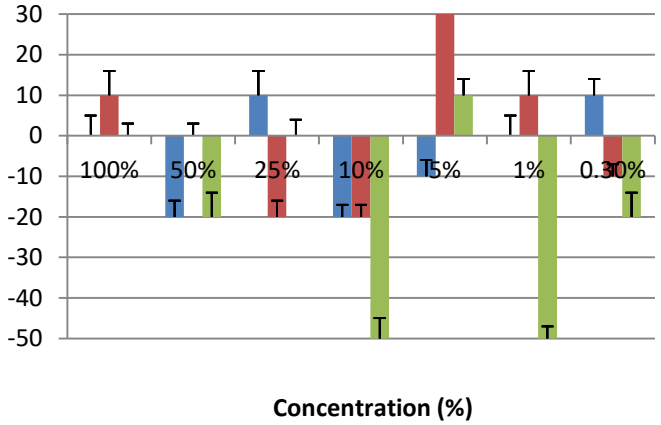




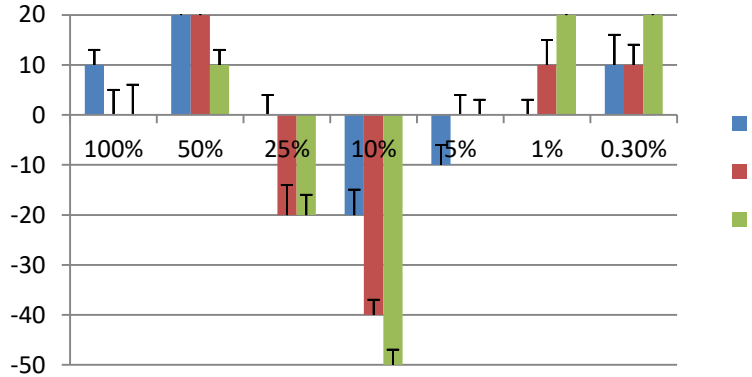
Cloud S-5



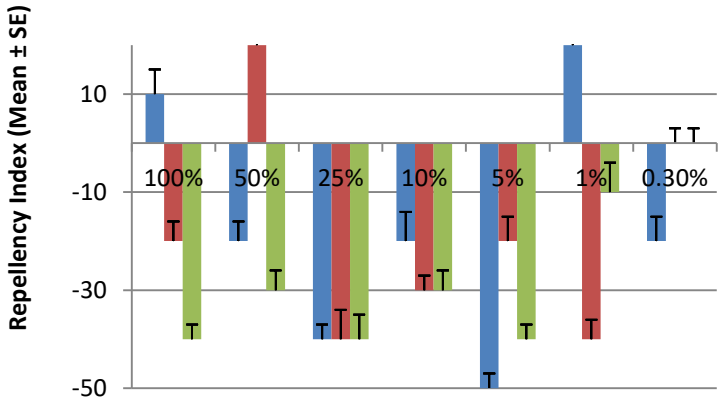
Black deli



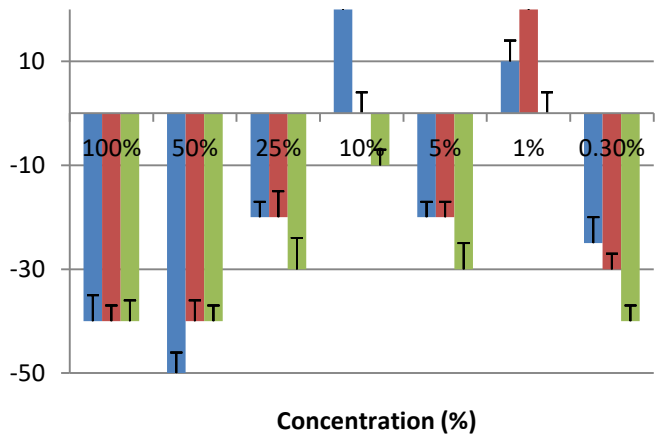
Code V



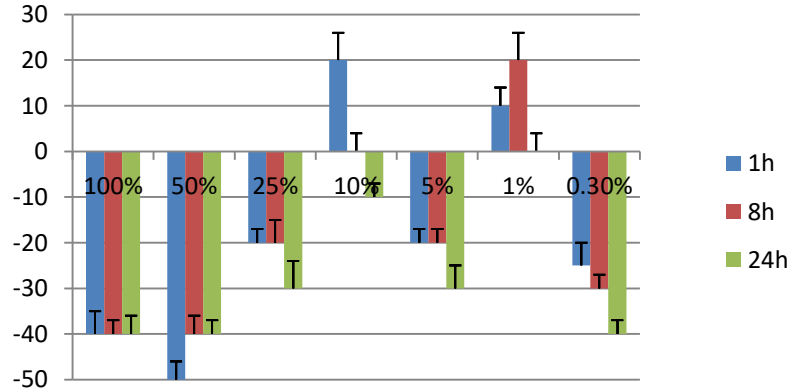
Hickory OS-1473



Code 10



P-1720



Conclusions

- On average, at 24 h, P-1720 attracted mites the most (+20 to -50% RI), while Cloud SC-100 repelled them the most (-10 to +60% RI)

- **Cloud SC-100**, **Code-10** and **Cloud S-AC15** which contained **high to medium carbonyl** concentration may provide some repellency to retard mite infestation in stored semi-moist pet food

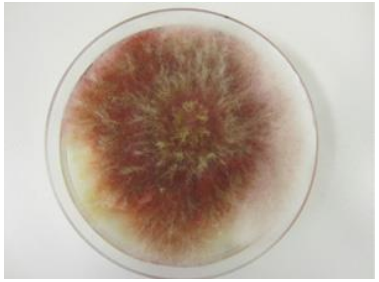
Case Study 2:

Liquid smoke as an antimycotic in semi-moist pet food

Background

- ***Aspergillus flavus* & *Fusarium graminearum***
  - Predominant genera isolated from commercial pet foods[7]
  - Mold spores from environment contaminate packaged foods opened by the consumer and amplify during storage
  - Produce mycotoxins (aflatoxin, DON & zearalenone) toxic to humans & pets
  - Cooking does not reduce mycotoxin content
  - Pet fatalities & dog food recalls due to aflatoxin – Sportmix™ & Sunshine Mills, 2020
- **Wild-type mold**
  - Environmental/mixed mold
  - Relevance to the consumer; aesthetic quality
- <u>Liquid smoke can be a natural intervention to mitigate mold growth in semi-moist pet food</u>

Aspergillus flavus



Fusarium graminearum

Wild-type spoilage mold on pet food

References: 7. Beuno et al., 2000

Experiment 1: Mold challenge study with *Aspergillus flavus*

Procedure:

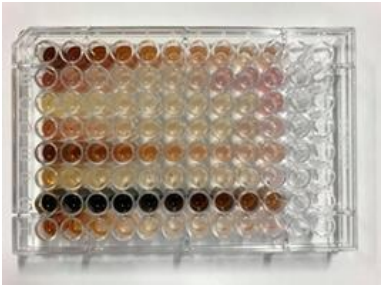
Step 1: Initial screening of smoke concentrations in nutrient broth assays (MIC & MFC)

Step 2: Evaluating in semi-moist pet food

1 mL of fungal inoculum (*A. flavus* ~4 log CFU/mL) inoculated on to 25 g of semi-moist pet food

Inoculated samples stored in Whirl-Pak bags at 28 °C

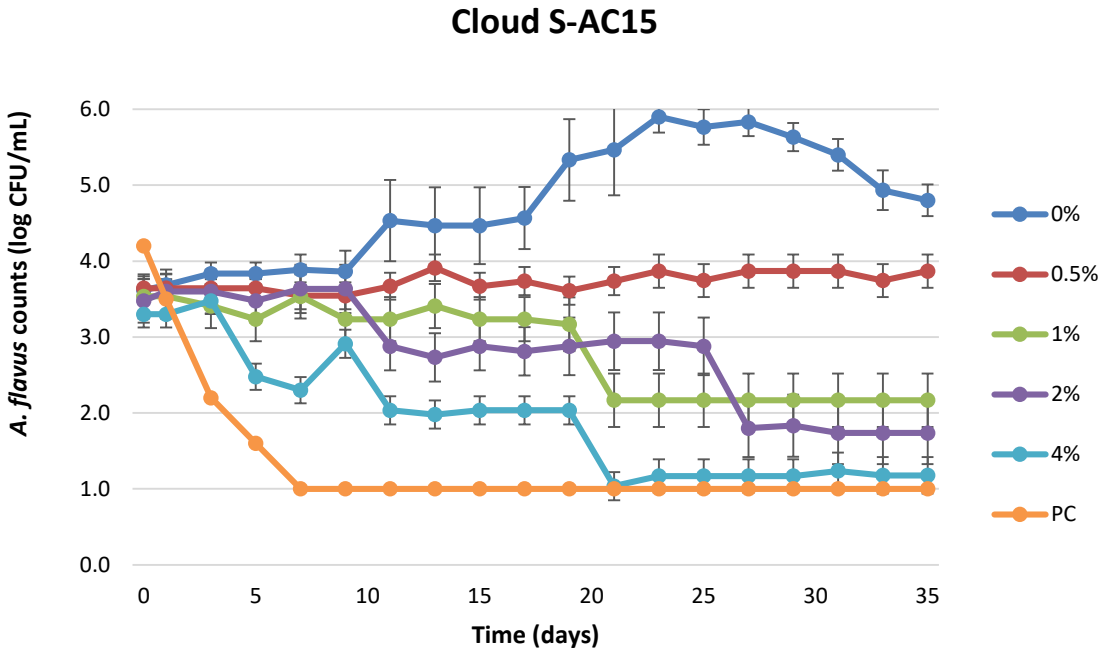
Fungal growth analysis on day 0, 1, 3, 5,…., day 35

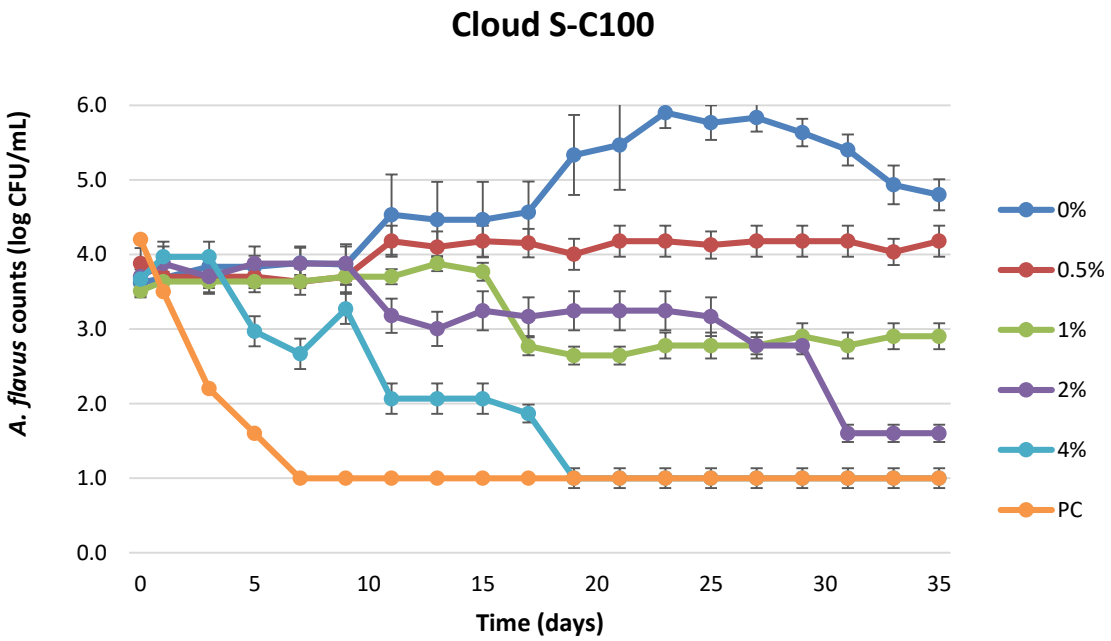


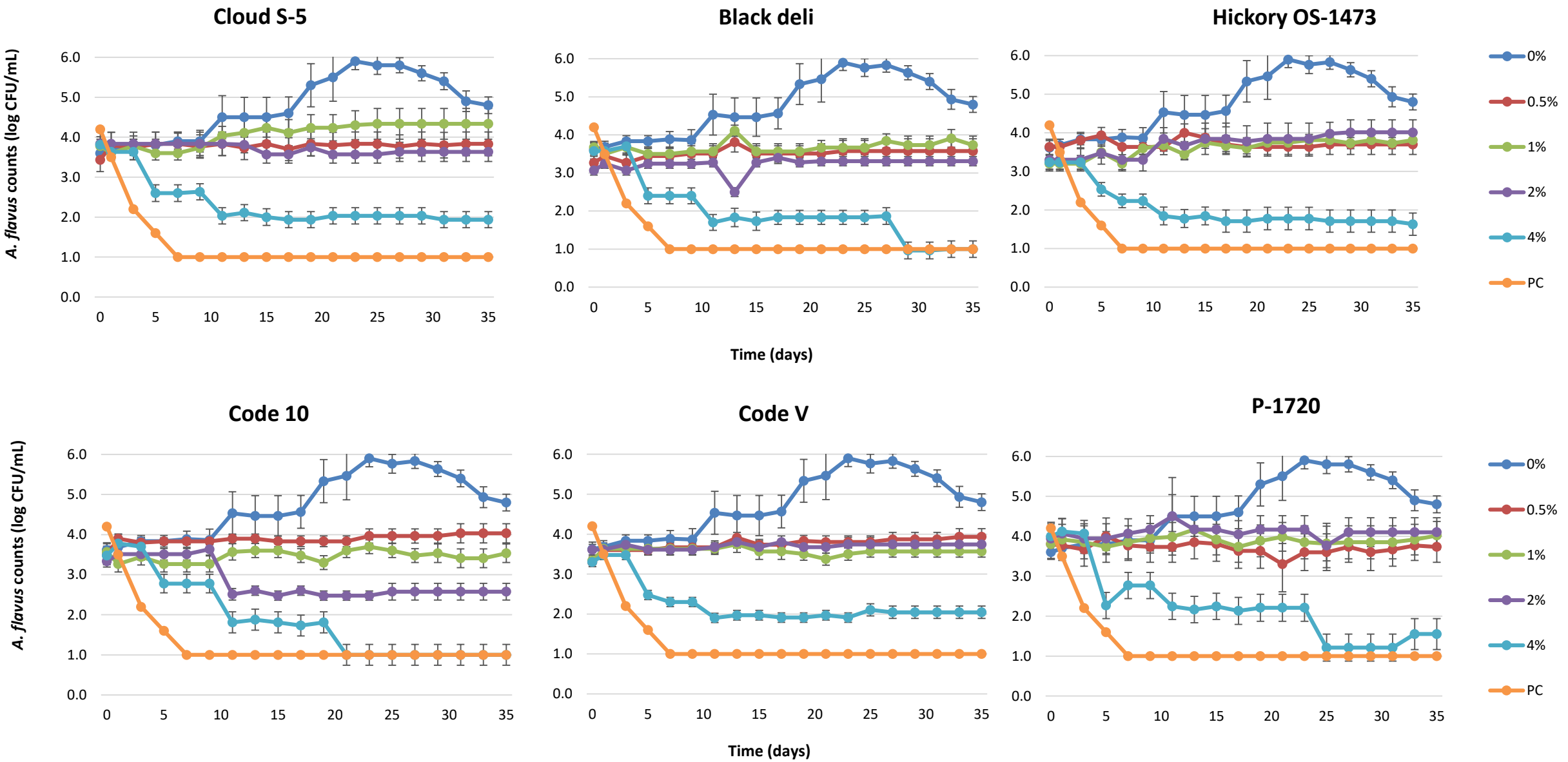
MIC assay

***Aspergillus flavus* colonies**

Mean logarithmic counts (log CFU/mL) of *A. flavus* in semi-moist pet food treatments with inclusion of liquid smokes at 0.5%, 1%, 2% and 4% concentrations in comparison with untreated (0% smoke) and positive control (potassium sorbate treatment). Limit of detection is 1 log CFU/mL for this study. Counts at 0 h indicate initial load of *A. flavus* in inoculum.






Cloud S-5
Black deli
Hickory OS-1473
Code 10
Code V
P-1720
A. flavus counts (log CFU/mL)
Time (days)
0%
0.5%
1%
2%
4%
PC

Conclusions

- At **4%** , **~2.5 log reduction** observed for Cloud S-AC15, P-1720, Cloud SC-100, Code 10 and Black deli. At **2%** and **1%**, Cloud S-AC15 and Cloud SC-100 had the highest reductions of ~**1.7** and **1** log respectively

Fungal growth on <u>untreated</u> sample on day 29

- Averaging across all concentrations, efficacy is:

  Cloud S-AC15 > Cloud S-C100 > Code 10 > Black deli

  Hickory, Code V, Purepal, and Cloud S-5 were the least effective

- **Cloud S-C100 (high carbonyl)** and **Cloud S-AC15 (high acid, medium carbonyl)** have the potential to act as an antimycotic or **fungistatic** at modest levels (**~2%**) in semi-moist pet food

Fungal growth on <u>smoke-treated</u> sample on day 29

Experiment 2: Days to mold (shelf life) study

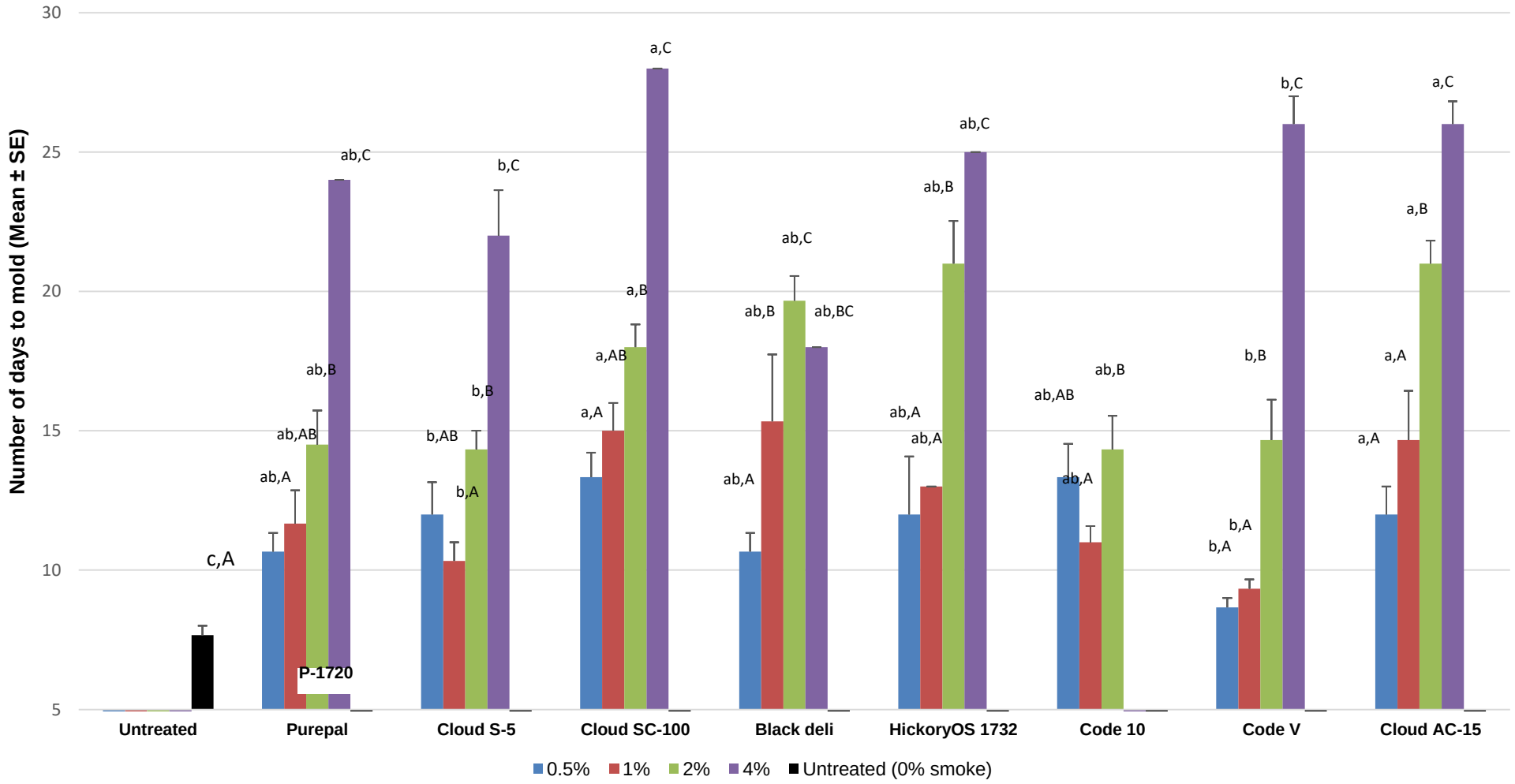
Procedure:

- About 30 g of semi-moist pet food sample placed in Whirl-Pak bags with 4 pin holes
- Stored at 28°C and 65-70% RH in total darkness
- Samples observed every day over 30 days for visible mold growth on the surface
- Number of days taken for the first mold colony to appear on the surface of the sample was recorded

Days-to-mold shelf-life study

Wild-type mold colony visible on pet food

Mean number of days taken to observe mold growth in semi-moist pet food with inclusion of liquid smoke (S1 to S8) at 0.5%, 1%, 2% and 4% in comparison to the untreated (0% smoke). Positive control (potassium sorbate treatment) did not show visible mold growth during the 30-day period (data not shown).



Each mean is based on *n* = 3 replications. Means among **treatments across concentrations** followed by different letters in **lower case** are significantly different ($P<0.05$, Tukey's test). Means among **treatments within each concentration** followed by different letters in **upper case** are significantly different ($P<0.05$, Tukey's test).

Conclusions

- Liquid smoke preparations at 0.5%, 1%, 2% and 4% extended the shelf life of samples by an average of 3.9, 4.8, 9.5 and 16.4 days respectively when compared to the untreated (7.7 days)

- At 4%, smoke treatments extended shelf life of samples by up to 20 days. At 0.5% the shelf life was prolonged by only up to 5 days

- Overall, **Cloud SC-100 (high carbonyl)** and **Code 10** (**medium carbonyl, medium phenol**) seemed to be the most effective in prolonging the number of days to mold by 26-28 days

Publications

- Deliephan, A., Phillips, T. W., Subramanyam, B., Aldrich, C. G., Maille, J., & Manu, N. (2023). Efficacy of liquid smoke to mitigate infestations of the storage mite, *Tyrophagus putrescentiae*, in a model semi-moist pet food. **Animals**, 13(20), 3188.

- Deliephan, A., Dhakal, J., Subramanyam, B., & Aldrich, C. G. (2023). Effects of liquid smoke preparations on shelf life and growth of wild type mold and *Aspergillus flavus* in a model semi moist pet food. **Frontiers in Microbiology**, 14, 1154765.

Thank You!

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