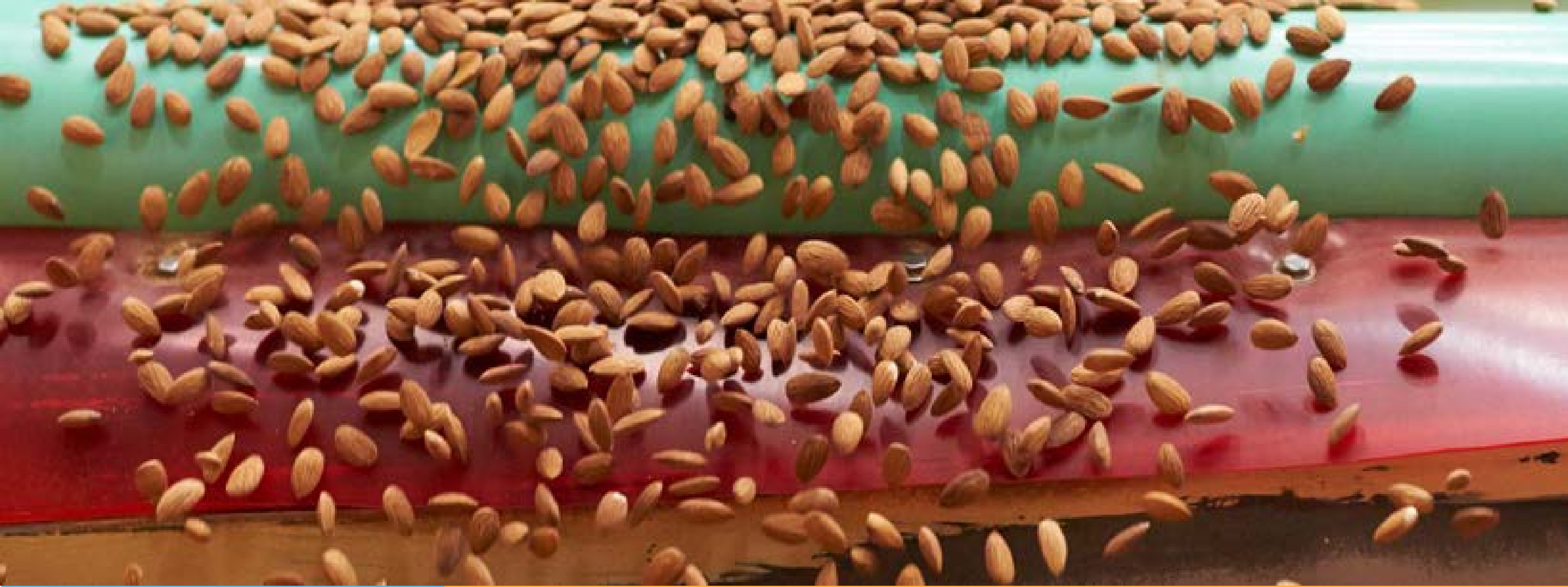

2017 THE ALMOND CONFERENCE

ALMOND CHARACTERISTICS AND TECHNOLOGY CONSIDERATIONS FOR CONTINUOUS INACTIVATION DURING DRY ROASTING

Room 314 | December 5 2017

california almonds® Almond Board of California

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- <u>Sign in and out of each session you attend.</u>
- Pickup verification sheet at conclusion of each session.
- *Repeat this process for each session, and each day you wish to receive credits.*

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Sign in sheets and verification sheets are located at the back of each session room.

AGENDA

- **Tim Birmingham**, Almond Board of California, moderator
- **Doug Beloskur**, BUHLER Group
- **Kaitlyn Casulli**, BUHLER Group

Almond characteristics and technology considerations for continuous inactivation during dry roasting.

Douglas Beloskur
Bühler Aeroglide
Cary, NC

Kaitlyn Casulli
Red Wolf Consulting
East Lansing, MI

Innovations for a **better world**.

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Presenter introduction.

Kaitlyn Casulli is the founder and food safety engineering consultant for Red Wolf Consulting and PhD student at Michigan State University. She holds a Bachelor of Science in Food Science from North Carolina State University and a Master of Science in Biosystems Engineering from Michigan State University. Her academic and consulting work focuses on addressing modeling challenges related validation of pathogen-reduction processes, with a specific focus on low-moisture foods (e.g., developing a model for *Salmonella* inactivation in pistachios, quantitative microbial risk assessment for *Salmonella* in peanuts).

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Phone +1 252 365 0794

Douglas Beloskur is Product Manager, Automation for Buhler Aeroglide. He holds a Bachelor of Science in Mechanical Engineering and a Master of Science in Engineering, from Kettering University in Flint, Michigan, USA. Since joining Buhler Aeroglide in 2007, he has evaluated and commissioned various types of convection drying equipment and conducted drying theory courses all over the world. He has spent nearly three years working in Bühler's head offices in Uzwil, Switzerland as Process Engineering Manager. Doug has also been published in various trade magazines on the topic of industrial automation and thermal processing.

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Phone +1 919 851 2000

Agenda.

1	Presenter Introductions	2 min
2	Dry Roasting Inactivation Background	8 min
3	Impact of Layer Depth on *E. faecium* Inactivation in Almonds	25 min
4	Inactivation Technology Considerations – Continuous Dry Roasting	15 min
5	Q&A	10 min
6	References / Terminology	

Take-away objectives.

- Layer depth did not exhibit influence on inactivation of *E. faecium* surrogate for almonds under typical dry roast conditions.

  Can capacity of your dry roaster be increased?

- Sensor and data collection technology continues to become more robust and less costly, implementation of new technology can improve food safety.

  Can additional sensors and process data improve food safety and reduce operational costs for your dry roasting process?

Dry roasting inactivation background.

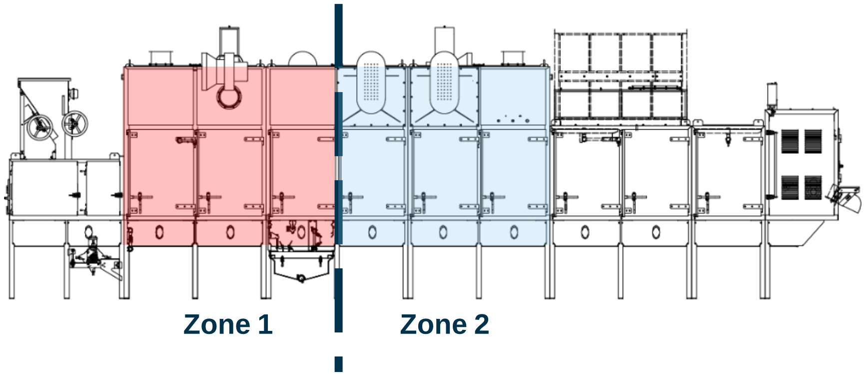
Background.
Dry roasting inactivation

- Uses convective heat transfer as a preservation technology that reduces the probability of spoilage and pathogenic growth

- Brings about positive chemical and physical changes
  - Develops final color and flavor profile synchronously with pathogen reduction
  - Dewaters product for increased shelf stability

- Reduces number of processing steps

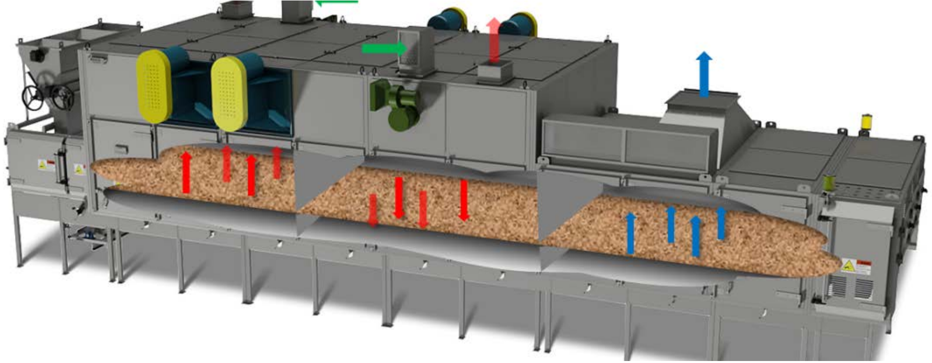
- Reduces cost of finished product

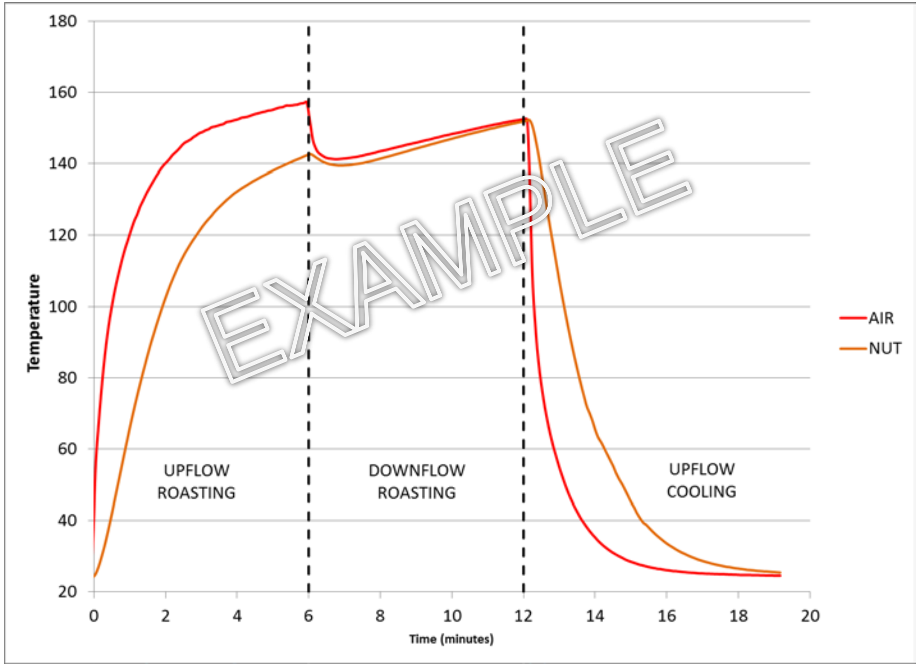


Zone – Referencing a specific dryer area with individually controlled airflow, volume, temperature, exhaust volume, and humidity

Background.
Why validate a dry roasting process for pathogen reduction?

- Dry foods were previously considered low risk because they do not support pathogenic growth
- Pathogenic contamination in dry foods is now broadly recognized (Beuchat et al., 2014)
- Pathogens like *Salmonella* have the ability to survive for long periods of time (>1 year) in dry environments
  - *Salmonella* can cause illness with as few as 1 cell
  - *Salmonella* is often recognized as the target pathogen for validations
- Validation of dry roasting operation reduces a need for further processing
  - No need for PPO or other methods





Background.
Market drivers for new validation services

Shared
- Impact to brand due to market recall.

Producers
- Validation process is expensive and time consuming.
- Validation “minimums” can limit ability to develop desirable product characteristics.
- Wasted product is added cost.
- Re-processing adds cost.
- Industry benchmark of paper records are costly to manage.
- Limiting human interaction with food production.

Machinery OEMs
- Paper recording equipment expensive to supply, difficult to service.
- Instrumentation and automation solutions becoming more effective and lower cost.
- Validation services and products are an added revenue stream.

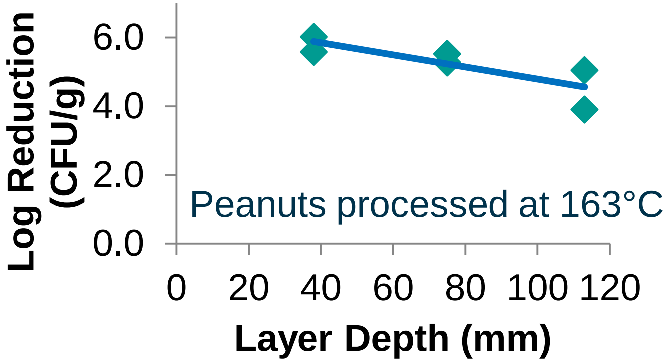
Regulatory / Associations
- FSMA mandates preventive controls for hazards in foods
- Risk management decisions can be made with greater confidence
- Regulatory groups (e.g., GMA) have developed guidelines for low moisture foods with limited published data

Shared
- Impact to people, sickness prevention.
- Future impact to people, lack of food / nutrition availability.

Impact of layer depth on *E. faecium* inactivation on almonds.

Background and justification.

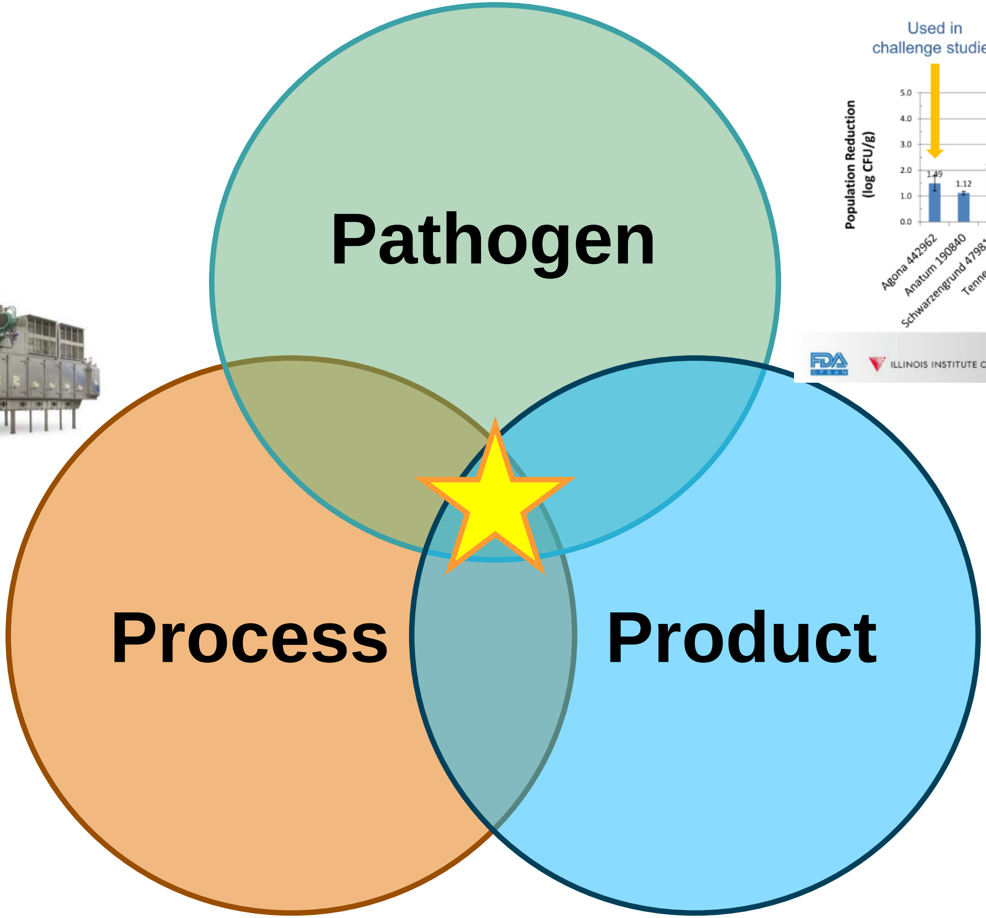
- Previously published study indicated that layer depth had **no statistical effect on inactivation in peanuts** (Poirier et al. 2014).
- Regulatory guidelines indicate that layer depth affects inactivation in almonds (ABC, 2014), but there is **no published study** to confirm this.
- Temperature distributions within a layer ("slab") are driven by its **thickness** (i.e., thinner layers heat up faster than thicker layers).



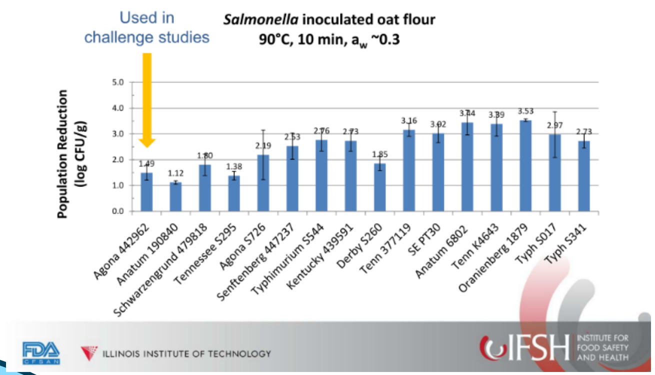
Why did industry fund a study?

- Peanuts are not almonds, results for peanut studies cannot be assumed for almonds.
- To provide guidance on effects of bed depth on almonds.
- Layer thickness has direct correlation to capacity of conveyor-based dry roasters.
- To provide contribution to support industry in producing safer foods.
- To expand knowledge of machinery OEM into microbiology and effects of thermal processing on pathogen reductions.

Factors affecting validation science.



Heat Tolerance Data



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Objective of this study.

The objective of this study is to quantify impact of **layer depth** on *E. faecium* inactivation on almonds for different **retention times** and **process temperatures**

Experimental / data analysis methods.

- Inoculated nonpareil almonds (extra no. 1, 23/25) with *Eneterococcus faecium* NRRL-B 5324 according to Almond Board of California (ABC) protocols (ABC, 2014)

- Treated triplicate inoculated samples in 3x3 matrix using commercially relevant conditions with 3 retention times
  - Times of 0 (untreated control), 12, 24, and 36 min.
  - Process temperatures of 275, 300, and 325°F (135, 149, and 163°C)
  - Layer depths of 2, 4, and 6 in. (5.1, 10.2, and 15.2 cm)
  - Through air velocity 250 fpm (1.3 m/s)
  - Samples placed at midplane of layer depth

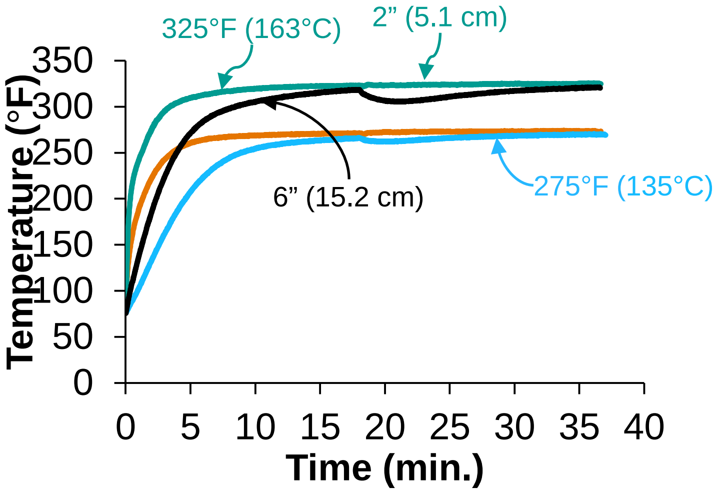
- Product temperature, moisture and a_w were measured and recorded

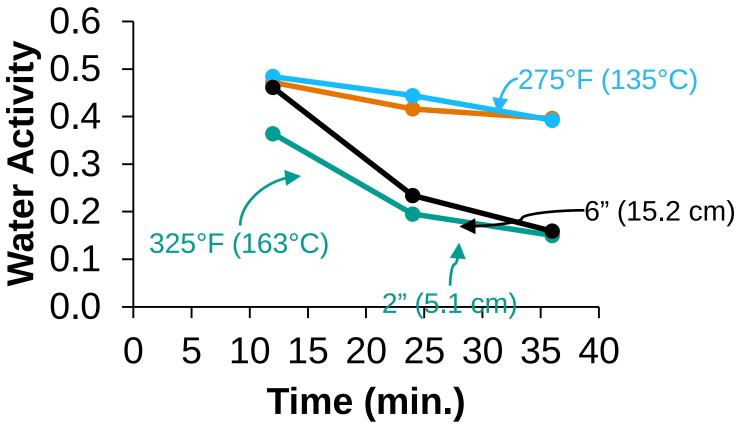
- Cooled treated samples then recovered survivors using ABC protocols (ABC, 2014)

- Ran 3-way ANOVA on log reduction data to determine effects of time, temperature, and layer depth

Physical results.

Example of how layer depth impacts temperature and moisture

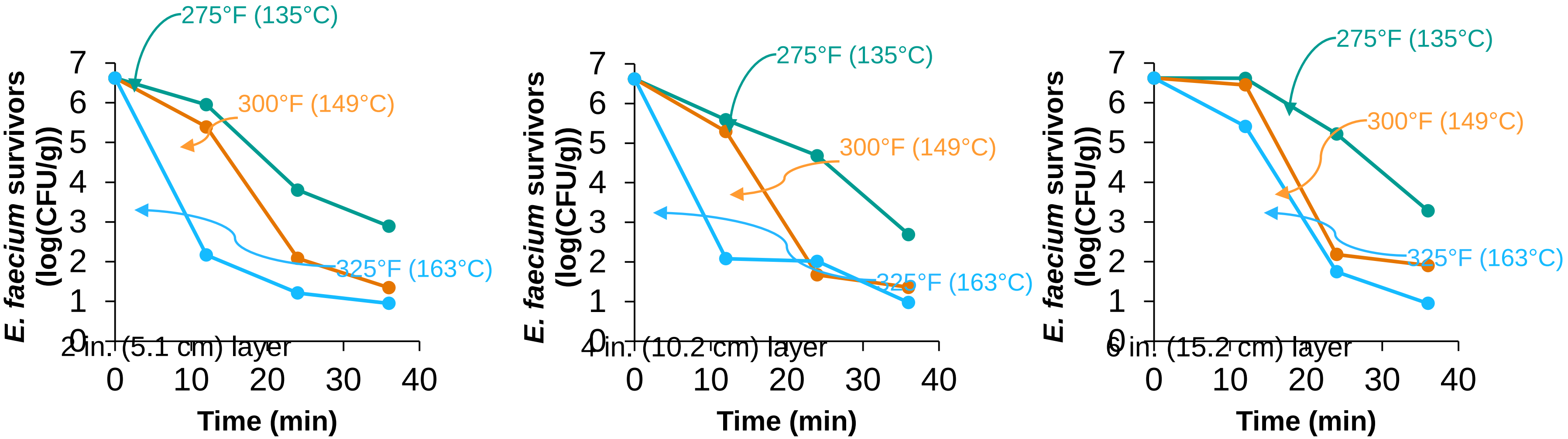




- ➢ Thicker layer depths provided ***increased resistance*** to changes in temperature and moisture

Microbiological results.

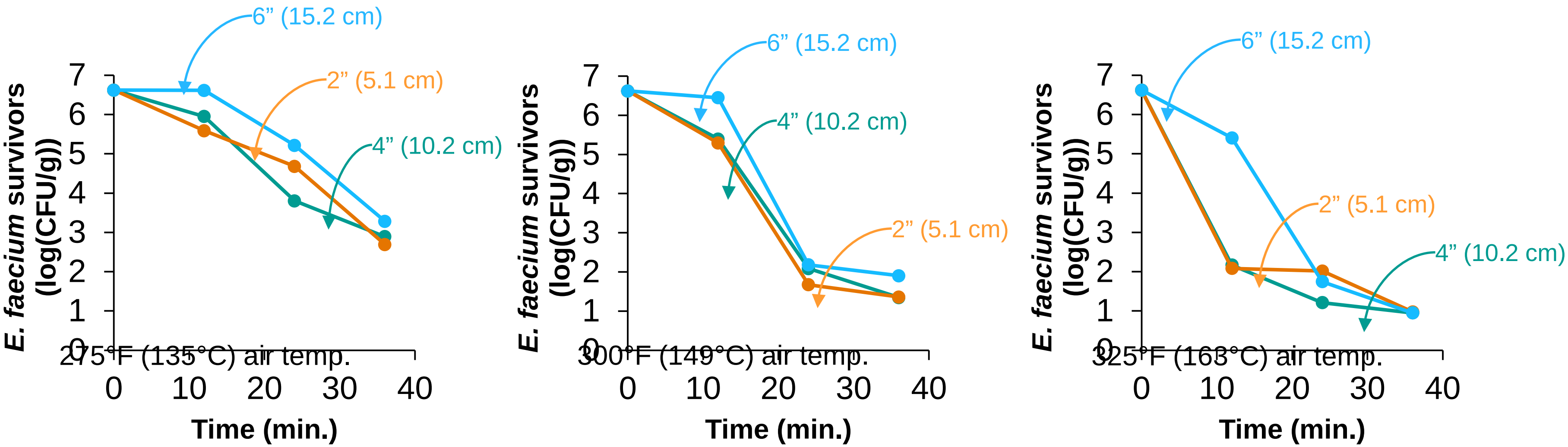
Comparing temperatures at constant layer depths



➢ Higher temperatures corresponded to faster inactivation

Microbiological results.

Comparing layer depths at constant temperatures

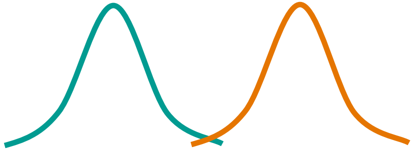


- Layer depth did not show an influence on inactivation

ANOVA 101.
Statistics are important

P-value: Probability that means are the same

Large overlap
Large P-value (P>0.05)
High chance that means are the same



Small overlap
Small P-value (P<0.05)
Low chance that means are the same

	NCSU	UNC	Avg.
2015	7	11	9 (±2)
2016	7	8	7.5 (±0.5)
Avg.	7 (±0)	9.5 (±1.5)	

- Is there a difference in wins by team?
  Yes, **P<0.05**
- Is there a difference in wins by year?
  No, **P>0.05**
- Is there an interaction of team and year?
  NCSU, **-0** from 2015-16
  UNC, **-3** from 2015-16
  Yes, **P<0.05**

ANOVA results.

Factor	Sum Sq.	d.f.	Mean Sq.	F	Prob>F
Layer Depth	0.186	1	0.186	0.280	0.600
Temperature	3.64	1	3.63	5.41	***0.0220**
Time	2.58	1	2.58	3.84	0.0529
Layer Depth × Temperature	0.370	1	0.370	0.550	0.460
Layer Depth × Time	0.0130	1	0.0126	0.0200	0.891
Temperature × Time	8.78	1	8.78	13.1	***0.000500**
Error	67.8	101	0.671		
Total	524	107			

*Significance measured at α=0.05

Within the range of conditions evaluated:

- Temperature had an influence on inactivation ($P<0.05$)
- Layer depth *did not* affect inactivation ($P>0.05$)
- Time was not **statistically significant ($P>0.05$)**, but it was **practically significant** since most treatments achieved >4 log reductions

Summary and conclusions.

- Layer depth influenced **product temperature and moisture**, but **NOT microbial inactivation**.

- Both time and temperature had **practical and/or statistical** implications for microbial inactivation.

Critiques and recommendations.

Impact of layer depth on *E. faecium* inactivation on almonds

- Thermocouple error occurred in some tests, but evaluation of these curves showed no significant difference when compared to curves without thermocouple error.
- Replicates were not conducted individually.
- Independent temperature profiles were not collected for each sample sock.
- Further work will need to be done if other conditions are desired (thicker layer, other temperatures, greater retention time, etc.).
  - These conclusions cannot be extended to conditions outside of those evaluated.
- Inactivation of *E. faecium* may not be dependent on bed depth but other product properties may be (e.g., color consistency).
- Future work on understanding inactivation during dry roasting warm up and cooling could prove beneficial.

Inactivation technology considerations – continuous dry roasting.

Types of pathogen inactivation technology.

Dry Roasting

Convective

Method - Convective heat transfer and time exposure

Pros - Limits processing steps

Cons - Cannot produce raw almond

Fumigation

Chemical

Method - PPO gas exposure for time duration

Pros - Can produce raw almonds, reliability

Cons - Consumer concerns with PPO gas

Steam / Blanching

Conductive

Method - Conductive heat transfer, pressure and time exposure

Pros - Can produce raw almonds

Cons - Added step if roasting required

Hot Oil

Conductive

Method – Conductive heat transfer by hot oil immersion and time

Pros – Reliable kill step and flavor enhancement

Cons – Cannot produce raw almonds and negative health benefits

Simplistic HARPC– Dry Roasting.
Hazard Biological - Salmonella

Type	Critical Limits	Monitors	Corrective Action / Documentation
Typical	Dry roaster air temperature shall not fall below value “X”	Temperature sensor placed in air stream	Product diverted to hold, operator notes on production log, rework
	Dry roaster product temperature shall not fall below value “X”	Temperature sensor placed in product stream	Product diverted to hold, operator notes on production log, rework
	Dry roaster time shall not fall below value “X”	Measurement of time by conveyor speed measurement	Product diverted to hold, operator notes on production log, rework
Conceptual	Product related D and z values are developed and pathogen log reduction is continuously calculated. Log reduction shall not fall below value “X”	Temperature sensor placed in product stream + Measurement of time by conveyor speed measurement	Autonomous actor corrects temperature or time profile, correction data documented managed in CFR Title 21 Part 11 compliant electronic data storage. Daily report generated.

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HARPC changes applied.
Hazard Biological - Salmonella

Before, truncated

Critical Limit

Time/Temperature conditions to achieve at 4-log kill for Salmonella spp. are listed below:

Minimum Temperature	Minimum Time
280°F (138°C)	23 minutes

Monitoring Activity / Frequency / Responsibility

Temperature: Temperature of the product at the coldest spot or demonstration of sufficient time at temperature shall be recorded on a continuous chart recorder.

Time: flow rate shall be recorded continuously or belt speed setting is recorded once per shift and after speed changes by a designated, trained employee.

Corrective Action Activity / Responsibility

…product shall be identified and put on Quarantine Hold by designated trained employee. Notify the designated responsible personnel to determine disposition. Hold/ Release documentation is required.

Records / Location

Temperature Charts, Thermometer Calibration Logs, Residence Time Records, Hold and Release Records, Corrective Action Records, Verification Records - located in Quality Assurance Office.

After, truncated

Critical Limit

Log reduction >4 log. Continuous inactivation of log reduction for Salmonella spp. is described by the following formula:

$$\text{Log reduction} = \sum \left[\left(10^{\frac{T-T_{ref}}{z}} \right) \Delta t \right] / D_{ref}$$

Where:

Dref	is the number of minutes required for a 1-log (90%) reduction of the target organism. Under constant conditions.
t	Is time, in minutes.
T	is the measured temperature in the heat penetration study.
Tref	is the reference temperature of the TDT study.
z	is the number of degrees (°C or °F) of the TDT curve to traverse 1 log cycle.

Monitoring Activity / Frequency / Responsibility

Temperature and roasting time data shall be recorded on <3s interval: Temperature measurements shall be recorded at the coldest lane. All data will be collected within Microsoft Azure cloud SQL database. A local, redundant data buffer of 30 days minimum will exist to mitigate cloud connectivity concerns.

Corrective Action Activity / Responsibility

…product shall be identified and put on Quarantine Hold by pre-defined control limits and automatically diverted to Quarantine Hold location. Notifications are automatically triggered to the pre-designated personnel to determine disposition. All anomalies are logged by event in Microsoft Azure cloud SQL database. Hold/ Release authorization is event logged in Microsoft Azure cloud SQL database by only authorized personnel.

Records / Location

Master, controlled copies of Temperature Charts, Thermometer Calibration Logs, Residence Time Records, Hold and Release Records, Corrective Action Records, Verification Records - located Microsoft Azure cloud SQL database. Uncontrolled copies can be printed via web-based interface.

Sensor technology.

Temperature

Measurement Method
RTD or Thermocouple

Pros
Durability against heated environment

Cons
Thermocouple – wiring type / extension leads

Where
In convective airstream and in product layer

Why
To measure heat availability in airstream – air measurements, or to measure heat transfer to product – product surface measurements

Time

Measurement Method
Magnetic proximity sensing

Pros
Simple setup

Cons
Heat limitations

Where
Using mechanical relationships and variable frequency drive –or– at rotational shaft

Why
To measure time in heating / cooling sections

Depth / Distance

Measurement Method
Laser, time of flight

Pros
Simple setup

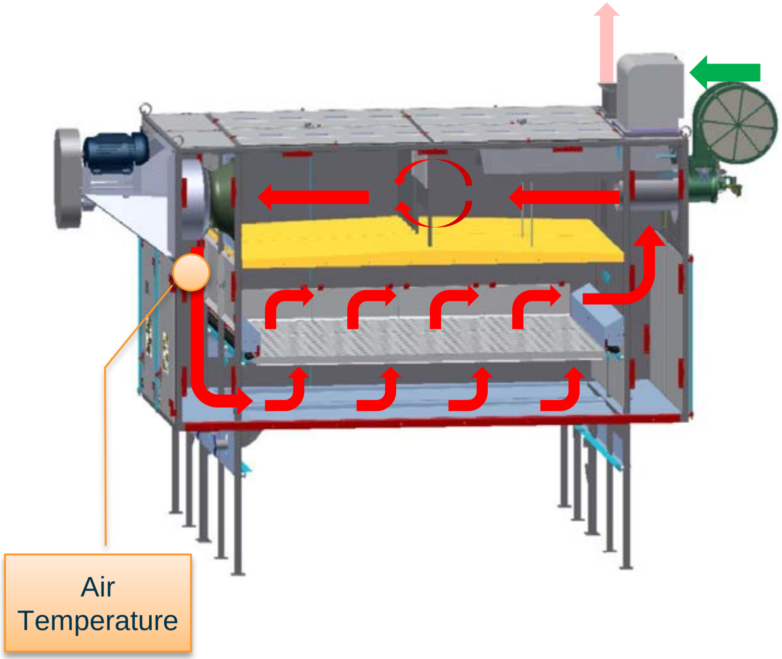
Cons
Heat limitations, accuracy on varied mediums and distance from target

Where
Near inlet of roaster

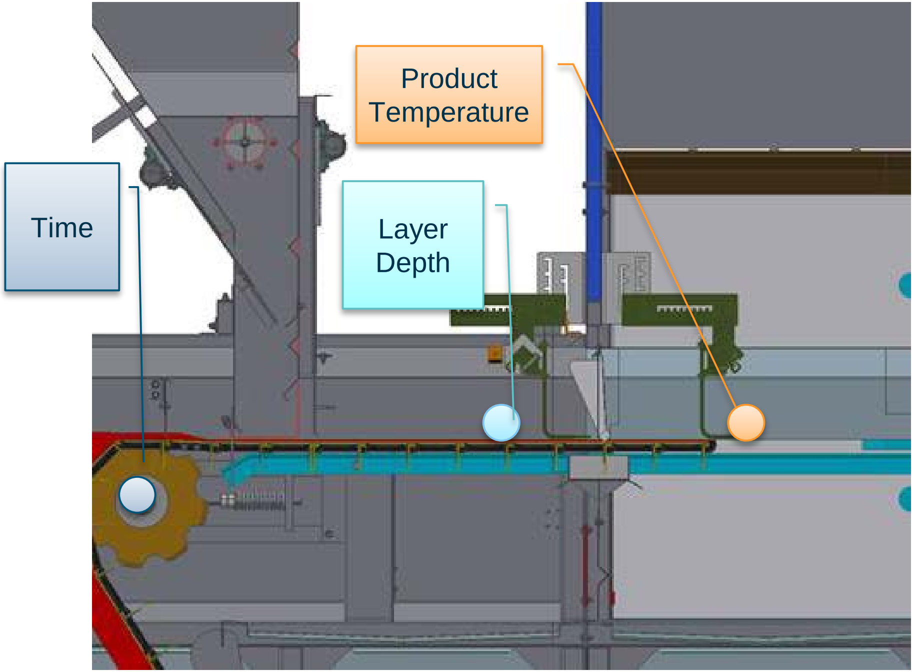
Why
To maximize capacity, monitor depth per existing HARPC

Process measurements.
Sensor placement

Air temperature measurements



Depth, Time and In-product temperature measurements



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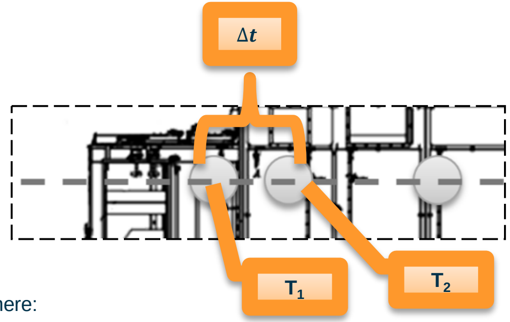
Continuous inactivation technology.

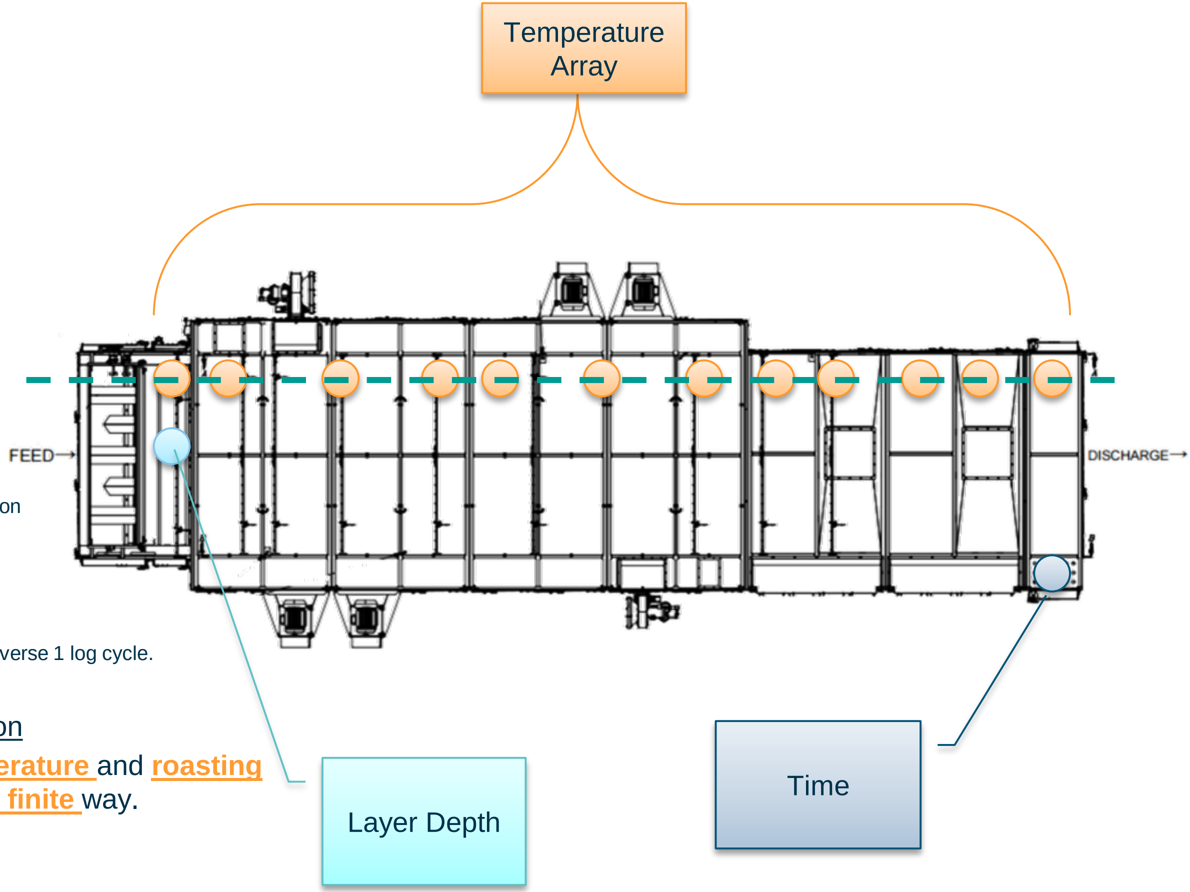
Cumulative Inactivation

Formula: Log reduction = $\sum\left[\left(10^{\frac{T-T_{ref}}{z}}\right)\Delta t\right]/D_{ref}$



Where:

D_{ref}	is the number of minutes required for a 1-log (90%) reduction of the target organism. Under constant conditions.
t	Is time, in minutes.
T	is the measured temperature in the heat penetration study.
T_{ref}	is the reference temperature of the TDT study.
z	is the number of degrees (°C or °F) of the TDT curve to traverse 1 log cycle.



Traceability Improvements with Cumulative Inactivation

Ability to monitor product layer depth, surface temperature and roasting time from start to finish of roasting process in a more finite way.

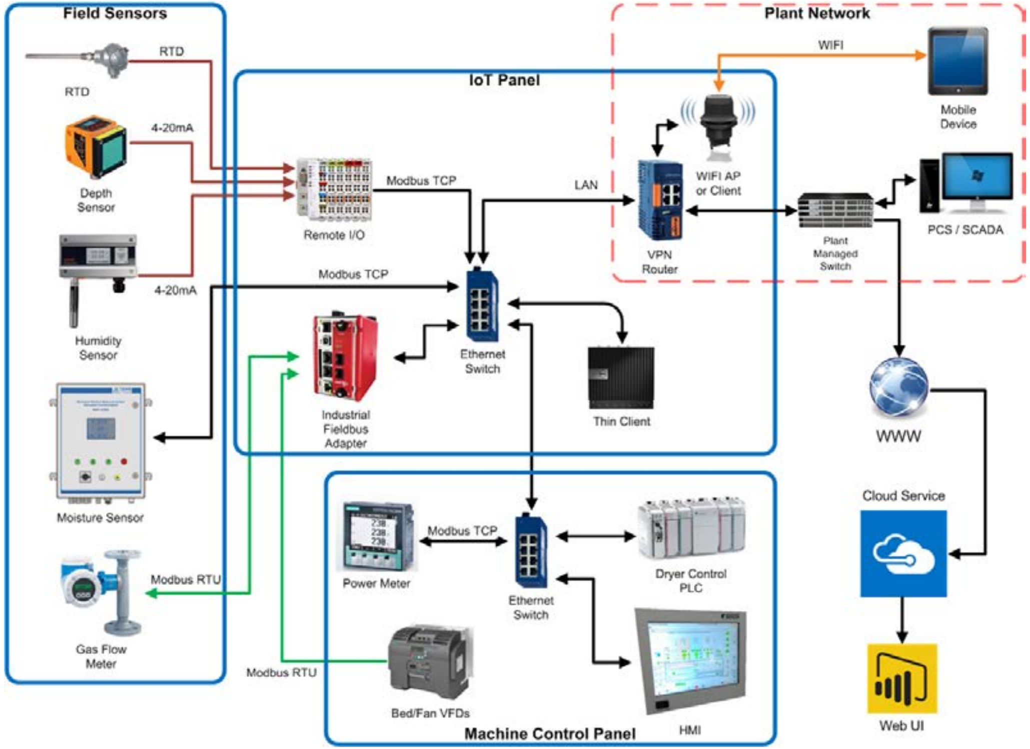
Data collection and records management methods.
Concept

Field Sensors Layer
Place where sensors are located and connected into machinery “neural” network. These connections are analog or digital direct wire, or communicated over industrial protocol to the IoT panel layer.

IoT Panel Layer
Place where sensor data is aggregated and formatted for transmission to cloud based storage. Affords opportunity for local processing for “near-real-time” events.

Machine Layer
Place where machine critical operations are done (e.g. safety management). This also includes sensing equipment which can be transmitted over industrial protocol to the IoT panel layer.

Cloud and Web Visualization Layer
Offsite, non-self hosted infrastructure, low costs for single machine related volumes. Receives all data from IoT panel layer and is final storage location for information. Affords location for event management, data visualization and big data analytics. Also allows aggregation with other databases which may enrich the quality of machinery related data.



Future thoughts.

Impact to validation of finished products:

- Can autonomous actors validate continuous high volume production faster, at less cost and more reliably than humans?

- How do autonomous actors augment the validation capabilities of your current staff? (e.g. less paperwork, less clipboard time)

Value drivers:

- If continuous inactivation technology can be completed by autonomous actors what would it mean for?
    - Consumer protections
    - Product recalls
    - Waste from field to fork
    - Abilities of current employees
    - Clarity of validation work

Critiques and recommendations.
Inactivation technology considerations

Critiques of presented technology:

- Added cost for instrumentation calibration requirements
- Clean ability of added sensing equipment
- Additional wiring / installation for added sensing equipment
- log reduction preventative control, corrective action steps are theoretical
- D, z values as presented by ABC are related to aluminum almond core temperature, thus further modelling is required to relate mixed stream flow to aluminum almond core temperatures

Critiques of presentation materials:

- Not all types of inactivation technology listed, a more comprehensive list has been compiled by UC Davis – see references slide.
- Not all inactivation technology explored in relationship to improved inactivation technology.

Wrap-up

Take-away objectives.

Can capacity of your dry roaster be increased?

Our study finds layer depth did not influence *E. faecium* inactivation for almonds. Each % increase in layer depth will result in % increase in production rate.

Can additional sensors and process data improve food safety and reduce operational costs?

We assert that the addition of sensor and control technology available today processors can monitor in real time calculated pathogens kill which allows for faster corrective actions if deviations occur . This improves a producer's ability to make safe food, reduces product waste and machinery downtime.

Q&A

Terminology.

OEMs -	Original Equipment Manufacturers
PPO gas -	Polypropylene oxide gas
FSMA -	Food Safety Modernization Act
slab -	Synonym of layer
ABC -	Almond Board of California
ANOVA -	Analysis of Variance
CFU/g -	Colony Forming Unit / Gram
A_w -	Water activity
log (logarithm) -	A quantity representing the power to which a fixed number (the base) must be raised to produce a given number
HACCP -	Hazard Analysis and Critical Control Points
CFR -	Code of Federal Regulations
D value -	Time required at a given temperature for the reduction of number of viable cells/endospores of a specific organism by 90%.
z value -	The number of degrees Fahrenheit or Centigrade required for a thermal death time curve to traverse 1 log cycle. The z-value gives an indication of the relative impact of different temperatures on a microorganism, with smaller values indicating greater sensitivity to increasing heat.
TDT -	Thermal Death Time
sample sock -	Place where inoculated samples are contained during a inactivation trial.
HARPC -	Hazard Analysis Risk-based Preventative Control

References.

Slide 7: Why validate a dry roasting process for pathogen reduction?

- Beuchat LR, Komitopoulou E, Beckers H, Betts RP, Bourdichon F, Fanning S, Joosten HM, Ter Kuile BH. 2013. Low-Water Activity Foods: Increased Concern as Vehicles of Foodborne Pathogens. Journal of Food Protection, 76(1), 150-172.

Slide 10: Background and Justification.

- Poirier D, Sanders TH, and Davis JP. 2014. *Salmonella* surrogate reduction using industrial peanut dry roasting parameters. Peanut Science, 41:72-84.
- Almond Board of California (ABC). 2014. Guidelines for Using *Enterococcus faecium* NRRL B-2354 as a Surrogate Microorganism in Almond Process Validation. California Almonds.

Slide 11: Factors affecting validation science.

- Grasso E and Anderson N. 2014. Validation of Extrusion Temperature as a CCP in Low-Moisture Foods. Food Safety Seminar Focused on Pet Food Processing. Kansas City, KS.

Slide 13: Experimental / Data analysis methods.

- Almond Board of California (ABC). 2014. Guidelines for Using *Enterococcus faecium* NRRL B-2354 as a Surrogate Microorganism in Almond Process Validation. California Almonds.

Slide 22: Types of pathogen inactivation technology.

- http://www.fumigationservice.com/phosphine.htm
- http://ucanr.edu/datastoreFiles/234-2453.pdf (reference only)
- http://naturalsociety.com/discovered-dirty-little-secret-almonds/

Slide 23: Simplistic HARPC– Dry Roasting.

- https://www.foodonline.com/doc/the-abc-s-of-building-a-food-safety-plan-from-haccp-to-harpc-0001

Slide 24: HARPC changes applied

- Industry Handbook For Safe Processing of Nuts, 2010 Feb 22. (add link)

Slide 25: Sensor Technology

- https://www.grainger.com/product/TEMPCO-RTD-Probe-5FYH9
- https://www.amazon.com/IFM-Efector-O1D100-Photoelectric-Consumption/dp/B00MIVNWAO
- http://www.directindustry.com/prod/electro-sensors/product-12082-42219.html

Slide 27: Continuous Inactivation Technology

- http://www.almonds.com/sites/default/files/content/attachments/process_validation.pdf
- Anderson, D. G. and L. A. Lucore. 2012. Validating the Reduction of Salmonella and Other Pathogens in Heat Processed Low-Moisture Foods. Alliance for Innovation & Operational Excellence, Alexandria, VA. Published online at http://community.pmmi.org/Alliance/Home/ Accessed [23 October 2017].

Slide 30: Critiques and Recommendations – Inactivation technology considerations

- Harris, L. J., S. Yada, L. R. Beuchat, and M. D. Danyluk. 2017. Inactivation of microorganisms in nuts and nut pastes – published treatments [Tables and references]. Available at: http://ucfoodsafety.ucdavis.edu/Nuts_and_Nut_Pastes.

Slide 34: Terminology

Anderson, D. G. and L. A. Lucore. 2012. Validating the Reduction of Salmonella and Other Pathogens in Heat Processed Low-Moisture Foods. Alliance for Innovation & Operational Excellence, Alexandria, VA. Published online at http://community.pmmi.org/Alliance/Home/ . Accessed [23 October 2017].

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Thank you!

Almond Board of California

The Almond Conference

What’s Next

Tuesday, December 5 at 12:00 p.m.

- The Almond Food Safety Plan: Teaching Example for FSMA Preventive Controls – Room 314
- Investing Across the Globe – Room 306-307
- What You Should Consider Before You Grow – Room 308-309
- The Update from Our Friends Down Under: What’s Truly Applicable to California – Room 312-313

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