CEUs – New Process

Certified Crop Advisor (CCA)
• Sign in and out of each session you attend.
• Pickup verification sheet at conclusion of each session.
• Repeat this process for each session, and each day you wish to receive credits.

Pest Control Advisor (PCA), Qualified Applicator (QA), Private Applicator (PA)
• Pickup scantron at the start of the day at first session you attend; complete form.
• Sign in and out of each session you attend.
• Pickup verification sheet at conclusion of each session.
• Turn in your scantron at the end of the day at the last session you attend.

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
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).

Email  kaitlyn.casulli@redwolfconsulting-llc.com
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.

Email  douglas.beloskur@buhlergroup.com
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

**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 brand due to market recall.
- Impact to people, sickness prevention.
- Future impact to people, lack of food / nutrition availability.

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Bühler Aeroglide | the Almond Conference 2017 | 05 December 2017
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.
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 *Enterococcus 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

#### Table

<table>
<thead>
<tr>
<th></th>
<th>NCSU</th>
<th>UNC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2015</strong></td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td><strong>2016</strong></td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td><strong>Avg.</strong></td>
<td>7 (±0)</td>
<td>9.5 (±1.5)</td>
</tr>
<tr>
<td><strong>Avg.</strong></td>
<td>7 (±0)</td>
<td>9.5 (±1.5)</td>
</tr>
</tbody>
</table>

- **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.

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

*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 almonds

Steam / Blanching
Convective

**Method** - Conductive heat transfer, pressure and time exposure 
**Pros** - Can produce raw almonds 
**Cons** - Added step if roasting required

Fumigation
Chemical

**Method** - PPO gas exposure for time duration  
**Pros** - Can produce raw almonds, reliability  
**Cons** - Consumer concerns with PPO gas

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

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

<table>
<thead>
<tr>
<th>Minimum Temperature</th>
<th>Minimum Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>280°F (138°C)</td>
<td>23 minutes</td>
</tr>
</tbody>
</table>

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

After, truncated

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

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

Where:
- \(D_{\text{ref}}\) 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.
- \(T_{\text{ref}}\) 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.

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 in Microsoft Azure cloud SQL database. Uncontrolled copies can be printed via web-based interface.
## Sensor technology.

### Temperature

<table>
<thead>
<tr>
<th>Measurement Method</th>
<th>RTD or Thermocouple</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pros</strong></td>
<td>Durability against heated environment</td>
</tr>
<tr>
<td><strong>Cons</strong></td>
<td>Thermocouple – wiring type / extension leads</td>
</tr>
<tr>
<td><strong>Where</strong></td>
<td>In convective airstream and in product layer</td>
</tr>
<tr>
<td><strong>Why</strong></td>
<td>To measure heat availability in airstream – air measurements, or to measure heat transfer to product – product surface measurements</td>
</tr>
</tbody>
</table>

### Time

<table>
<thead>
<tr>
<th>Measurement Method</th>
<th>Magnetic proximity sensing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pros</strong></td>
<td>Simple setup</td>
</tr>
<tr>
<td><strong>Cons</strong></td>
<td>Heat limitations</td>
</tr>
<tr>
<td><strong>Where</strong></td>
<td>Using mechanical relationships and variable frequency drive – or – at rotational shaft</td>
</tr>
<tr>
<td><strong>Why</strong></td>
<td>To measure time in heating / cooling sections</td>
</tr>
</tbody>
</table>

### Depth / Distance

<table>
<thead>
<tr>
<th>Measurement Method</th>
<th>Laser, time of flight</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pros</strong></td>
<td>Simple setup</td>
</tr>
<tr>
<td><strong>Cons</strong></td>
<td>Heat limitations, accuracy on varied mediums and distance from target</td>
</tr>
<tr>
<td><strong>Where</strong></td>
<td>Near inlet of roaster</td>
</tr>
<tr>
<td><strong>Why</strong></td>
<td>To maximize capacity, monitor depth per existing HARPC</td>
</tr>
</tbody>
</table>
Process measurements.
Sensor placement

Air temperature measurements

Depth, Time and In-product temperature measurements
Continuous inactivation technology.

Cumulative Inactivation

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

Where:
- \( D_{\text{ref}} \) 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.
- \( T_{\text{ref}} \) 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.
### Terminology

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>OEMs</td>
<td>Original Equipment Manufacturers</td>
</tr>
<tr>
<td>PPO gas</td>
<td>Polypropylene oxide gas</td>
</tr>
<tr>
<td>FSMA</td>
<td>Food Safety Modernization Act</td>
</tr>
<tr>
<td>slab</td>
<td>Synonym of layer</td>
</tr>
<tr>
<td>ABC</td>
<td>Almond Board of California</td>
</tr>
<tr>
<td>ANOVA</td>
<td>Analysis of Variance</td>
</tr>
<tr>
<td>CFU/g</td>
<td>Colony Forming Unit / Gram</td>
</tr>
<tr>
<td>(A_w)</td>
<td>Water activity</td>
</tr>
<tr>
<td>log (logarithm)</td>
<td>A quantity representing the power to which a fixed number (the base) must be raised to produce a given number</td>
</tr>
<tr>
<td>HACCP</td>
<td>Hazard Analysis and Critical Control Points</td>
</tr>
<tr>
<td>CFR</td>
<td>Code of Federal Regulations</td>
</tr>
<tr>
<td>D value</td>
<td>Time required at a given temperature for the reduction of number of viable cells/endospores of a specific organism by 90%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>z value</td>
<td>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.</td>
</tr>
<tr>
<td>TDT</td>
<td>Thermal Death Time</td>
</tr>
<tr>
<td>sample sock</td>
<td>Place where inoculated samples are contained during a inactivation trial.</td>
</tr>
<tr>
<td>HARPC</td>
<td>Hazard Analysis Risk-based Preventative Control</td>
</tr>
</tbody>
</table>
References.

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


Slide 10: Background and Justification.


Slide 11: Factors affecting validation science.


Slide 13: Experimental / Data analysis methods.


Slide 22: Types of pathogen inactivation technology.

- http://ucanr.edu/datastoreFiles/234-2453.pdf (reference only)


Slide 24: HARPC changes applied


Slide 25: Sensor Technology

- https://www.amazon.com/IFM-Efector-O1D100-Photoelectric-Consumption/dp/B00MIVNWAO

Slide 27: Continuous Inactivation Technology

- http://www.almonds.com/sites/default/files/content/attachments/process_validation.pdf

Slide 30: Critiques and Recommendations – Inactivation technology considerations


Slide 34: Terminology

Innovations for a better world.
Thank you!
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
Use #AlmondConf to be part of the conversation on Facebook and Twitter.