Investigating the Safety of Traditionally Processed Dry & Semi-dry Sausages

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An Ancient Tradition

- 6,000 - 8,000 B.C. – evidence of agricultural societies and domestication of livestock
- 2,000 B.C. – written record of pork slaughter, consumption and preservation
  - Preservation by sea salts (impurities) and drying
- Fermented meat products traced to China around 500 B.C.
Modern dry sausages developed in early 18th Century in Southern Europe

- French Revolution
- Napoleonic Wars

Quick, tasty & very SAFE food source

High in protein
- Very physical and active lifestyle
Dry Cured Vs. Wet Cured

Curing

Dry-cured meat products:
- Entire pieces
  - Salting by dry cure or soaking
  - Drying optionally smoking
  - Dry cured hams
  - Dry cured shoulders
  - Dry cured loins

Minced
- Salting by mixing
- Drying optionally smoking
- Dry-fermented sausages

Wet-cured meat products:
- Entire pieces
  - Salting by pickle injection or soaking
  - Cooking optionally smoking
  - Cooked hams
  - Cooked shoulders
  - Cooked loins
  - Cooked tongues
  - Bacon

Minced
- Salting by mixing
- Cooking optionally smoking
- Cooked sausages

FIG. 1.1. DIAGRAM SHOWING THE CLASSIFICATION OF THE MOST-IMPORTANT CURED MEATS AND THE MAIN DIFFERENCES BETWEEN DRY AND WET CURING
(Adapted from Flores and Toldrá 1993)
Classifications of Dry Cured Sausages

- No true Worldwide definition
  - Classified by region (Genoa, Parma or Toscana)
  - Fermented (acid) vs. Non (Dry Salami vs. Coppa)
  - By degree of dryness or texture (semi- vs. dry sausage)
  - By chemical analyses (moisture/protein..pepperoni)
  - By shape (Pancetta, Landjäger, Lovecky), casing, type of casing
  - By surface mold growth (Italian Salame)
Classifications of Dry Cured Sausages

- Traditional

- International by Country – “Signature” Sausage

- United States
  - USDA Labeling Restrictions
  - Good Manufacturing Practices/HACCP
  - USDA Directives
Traditional Classifications

- Italian type – Southern European, or Mediterranean
- Germanic type – Northern European
Italian Types

- Italian salame
- Genoa salami
- Coppa
- Soppresate
- Toscana
- Pancetta
- Prosciutti
- Pepperoni
- Bresaola
Italian Types

- Pork or pork/beef
- Mostly dry types
- Mold covering or white casings
- Not generally smoked
- Fine to coarse cut
- Small to larger casings
- Mild tang, higher pH
- In US,
  - Fermented 70-110 F (American Genoa)
  - Not heated or partially heated (110-125 F)
Southern European or Mediterranean

- Saucisson – France
- Fuet – Spain
- Chorizo – Spain, Portugal
- Salame – Italy
Southern European or Mediterranean

- France
  - Rosette
  - Ring Salami
Southern European or Mediterranean

- Spain - Chorizo

- Turkey – Soujouk sudžuk
Germanic Types

- Summer Sausage
- Thuringer
- Hard Salami
- Cervelat
- Landjäger
- Lebanon Bologna
Germanic Types

- Beef or beef/pork
- more semi-dry types
- smoked
- relatively fine cut......
- “tangy”/higher acid/lower pH
- in US,
  - fermented 90-115 F to pH < 5
  - cooked (160 F) or partially cooked (128 F-140 F)
Germany

- Cured, raw sausage
  - dry fermented, estimated 360 types
- Stored without chilling (>50 F)
- Usually eaten raw
- Sliced or easy to spread
- Safe (fermentation lowers pH, salt/drying lower water activity)
- Technology types:
  - Traditional 65-75 F, >40 hr, >5.0, $a_w<0.99,>3$ wk
  - Fast 72-79 F, <30 hr, 4.5-4.9, $a_w>0.90, 2-3$ wk
  - Very Fast 90-110 F, <15 hr, <4.8, $a_w>0.90, 1-2$ wk

(Schwing & Neidhardt, 2007 in Handbook of Fermented Meat & Poultry Pp. 349--358)
Northern Europe

• Netherlands
  – Boerenmetworst
  – Salami
  – Cervelat

• Belgium/Luxemburg
  – Baquette Salami

• Germany
  – Westphalian Salami
  – Cervelat
  – Teewurst
  – Schlackwurst
  – Landjäger
Canada

- More European types – German & Italian
- “Fermented Smoked Sausage”
  - Shelf-stable
  - $a_w$ 0.85 or less in finished product
  - pH 5.3 or less after fermentation
  - Nitrite = min 100 to 200 ppm input
  - [Salt] = 2.8%

- Specific meat starter culture approval process*
  - Chapter 4 – Annex G “List of Accepted Starter Cultures”
  - Listed By trade name & mfr.

U.S. Standards of Identity

- Standards of identity for Semi-dry Fermented Sausages
  - Subpart I -- Semi-Dry Fermented Sausage [Reserved]

- Standard of Identity for Dry Fermented Sausages
  - Subpart J — Dry Fermented Sausage [Reserved]

(9 CFR 319 Subparts I & J)
Standards in the U.S. based on ...

- Labeling restrictions include analyses of % moisture ÷ % protein = **M/P Ratio** (historical market basket survey)

- Legal processing requirements & voluntary GMP’s incorporated into HACCP Plan

- Continuing FSIS Directives for food safety (Monitoring and Validations..*E coli 0157:H7, Salmonella, CPS, Listeria*)

- RTE Products/*Listeria* Regulation (October, 2003)
U.S. label restrictions

- Dry Cured – cannot be brine injected
- Dry Salt Cured – can be injected (not immersed)
- Genoa Salami – usually all pork coarse ground, MPR 2.3:1, not smoked
- Hard Salami – smoked dry salami made from beef and pork, MPR 1.9:1
- Italian Salami – white mold traditional covering
- Pepperoni – pork and beef (<55% beef and no edible by-products) MPR 1.6:1
Shelf Stability – U.S. Labeling Restrictions

• Dry Sausage – MPR 1.9:1

• Semi-dry Sausage – 3.1:1 and pH ≤ 5.0
  – OR pH ≤ 4.5 (pH 4.6 and a_w ≤ 0.91) and in an intact form or vacuum sealed if sliced and have brine concentration of ≥ 5% and cured with NO_2 or NO_3 and smoked with wood.
Fermented Sausage Production
Volume Worldwide

• Germany
• US
• Spain
• South America
• Italy
• France
• Belgium
• Denmark, Austria, Switzerland
Dry and Semi-dry Sausages

- Dry Sausage examples (U.S.)
  - Pepperoni
  - Salami – Cotto, Genoa, Hard, Italian

- Semi-dry Sausage examples (U.S.)
  - Summer Sausage
  - Snack sausages (e.g. Slim Jim®)
  - Thuringer Cervelat
  - Lebanon Bologna
  - Landjäger
Good Manufacturing Practices (GMPs)

- Voluntary Industry recommendations (now HACCP)
- For safety (coagulase positive staphylococci)
  - fermentation rate
  - final pH
  - drying times
- Definitions – dry and semi-dry sausages
- Critical control points (CCP’s)
  - pH control
  - time/temperature control
GMPs - Definitions

- **Dry Sausage**
  - bacterial action/acidification
  - pH 5.3 or less
  - prescribed time interval for pH reduction
  - dried, 25-50% moisture removal \( (M/P) \)

- **Semi-Dry Sausage**
  - bacterial action/acidification
  - pH 5.3 or less
  - prescribed time interval for pH reduction
  - dried up to 15% moisture removal \( (M/P) \)
Good Manufacturing Practices – CP’s

- pH control
  - 5.3 or less to control CPS (coagulase positive staph)
  - pH monitoring < 110 F surface
- Fermentation
  - commercial starter culture (usage rate)
- acidulation – USDA approval acids (encapsulated)
Good Manufacturing Practices – CP’s

• Time and Temperature
  
  – specific “degree-hours” for fermentation
  – equals the degrees in excess of 60°F x hours of fermentation
  
  – Less than 90°F, must not exceed 1200 hr max
  – 90°F to 100°F, 1000 hr max
  – Greater than 100°F, 900 hr max
Degree – Hours, examples

- Constant Temperature 80 °F, 55 hr to reach 5.3 pH
  - Degrees: 80 – 60 = 20
  - Hours: 55
  - Degree – hours: 20 x 55 = 1100 (passes test)
    - (1200 degree–hour maximum @ 80 °F)

- Variable Temperature – each step analyzed for degree – hour contribution: highest temperature segment determines maximum allowable
Prescribed Treatment of Pork...Products...to Destroy Trichinae

Heating – min internal temperature/time

<table>
<thead>
<tr>
<th>Minimum Degrees Fahrenheit</th>
<th>2 hours</th>
<th>1 hour</th>
<th>30 minutes</th>
<th>15 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>120</td>
<td>21 hours.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>122</td>
<td>9.5 hours.</td>
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<td></td>
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<tr>
<td>124</td>
<td>5 hours.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>126</td>
<td>2 hours.</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>128</td>
<td>1 hour.</td>
<td></td>
<td></td>
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<tr>
<td>130</td>
<td>30 minutes.</td>
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<tr>
<td>132</td>
<td>15 minutes.</td>
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<td></td>
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<tr>
<td>134</td>
<td>6 minutes.</td>
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<td></td>
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<tr>
<td>136</td>
<td>3 minutes.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>138</td>
<td>2 minutes.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>140</td>
<td>1 minute.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>142</td>
<td>1 minute</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>144</td>
<td>instant</td>
<td></td>
<td></td>
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</tbody>
</table>

Refrigeration (freezing) – max temp/min time

Curing – Prescribed Methods 1 – 7 composition, piece diameter, casing diameter, times and temperatures

FSIS Compliance Guideline for the Prevention and Control of Trichinella and Other Parasitic Hazards in Pork and Products Containing Pork

March 2016

This guideline is designed to help establishments, particularly small and very small establishments, in understanding the available options that are effective for the prevention and control of *Trichinella spiralis* and other parasitic hazards in ready-to-eat (RTE) and not-ready-to-eat (NRTE) pork products and products containing pork.
USDA RTE **Proposed** Performance Standards

- Federal Register, February 27, 2001 Vol. 66 No. 39 page 12590

- Food safety performance standards for all RTE and partially heat-treated meat and poultry
  - Lethality (ie. Specific reductions **during process**)
  - Stabilization in **final product** during cooling & shelf-life
  - Includes dried and fermented meat and poultry products although Lethalities have not been finalized *
    except for  *E. coli* 0157:H7 in beef containing products
USDA Lethality Performance Standards
(only containing beef)*

- Additional lethality performance standard for *E. coli* O157:H7 for fermented RTE products containing beef
- Probability of remaining numbers of *E. coli* O157:H7 in 100 g of finished product
  - e.g. 2.67% probability of >1 *E. coli* O157:H7

- 5-log reduction of *E. coli* O157:H7

* Avoid by eliminating beef in meat block
Lethality Requirements

(Dried Sausages w/ beef)

Options to ensure 5-log reduction of E. coli 0157:H7

1. Utilize heating step in 9CFR318.17 or 9CFR318.23
2. Apply a validated heat treatment of equal lethality
3. Hold & test finished products using ICMSF lot acceptance criteria
4. Apply a validated min 5-log reduction or process that results in <1 E. coli 0157:H7/100g
5. Sample raw ingredients (mix) to demonstrate there is <1 E. coli 0157:H7/g and apply a 2-log lethality treatment
Landjäger Formulation

• Meat Block
  – Pork Boneless Ham
  – Beef knuckles
  – Pork Backfat

• Nonmeat Ingredients
  – Salt, red wine, spices, sugar, garlic
Traditional Landjäger Processing

1. Grind/Chop
2. Stuff into casings
3. Press
4. Ferment (74°F)
5. Pre-dry / Smoke
6. Dry to water activity
Grinding/Chopping
Grinding/Chopping
Press

Fermentation occurs in press
Pilot Study - Objective 1

1. Determine if the suggested processing protocol:

   a. will result in a $5 \log_{10}$ CFU/g reduction of *E. coli* O157:H7 ATCC 43895

   b. is capable of controlling *L. monocytogenes* Scott A and *Salmonella* Typhimurium ATCC 14028
Pilot Study - Objective 2

2. Determine if there is competition between the pathogenic organisms

   a. Cocktail inoculation

   b. Single inoculation
Methodology - Inoculum preparation

**Single**
- L. monocytogenes Scott A
- E. coli O157:H7 ATCC 43895
- S. Typhimurium ATCC 14028

**Cocktail**
- Listeria monocytogenes (ATCC® 7644)
- Salmonella enterica (ATCC® 14028)

Image source: http://www.hardydiagnostics.com/catalog.html
Procedures

1. Receive raw product 4°C
2. Inoculate with pathogens
3. Stuff into casings
4. Press
5. Ferment (23-25°C/74-75°F)
6. Pre-dry / Smoke
7. Dry to water activity
Starter Culture

- *Pediococcus acidilactici*
- *Pediococcus pentosaceus*
- *Lactobacillus sakei*
- *Staphylococcus xylosus*
- *Staphylococcus carnosus*
- *Debaryomyces hansenii*
Procedures

• Ferment to pH ≤ 4.8
  – Specific starter culture

• Smoke (mild heat treatment)
  – Internal temp < 100°F

• Drying to water activity of ≤ 0.88

• Storage (vacuum packaged) 23-25°C
  – 28 days
Results – Survival of Pathogens

Single Inoculation

Cocktail Inoculation
Discussion

• Desired pH was reached by day 3 and rapid pathogen reduction was observed after day 2

• *S. Typhimurium* was $5 \log_{10}$ by day 20 and similarly to *L. monocytogenes*

• Studies have concluded that *E. coli* O157:H7 reductions during manufacturing do not exceed 2-log reductions (Skandamis & Nychas, 2007)

• Porto-Fett et al. (2008)
  – *E. coli* O157:H7 reductions of $3.48 \log_{10} \text{cfu/g}$
Conclusions

• The starter culture present in the meat batter:
  – effectively controlled *L. monocytogenes*.
  – delayed *S. Typhimurium* during processing, drying & storage

• Despite the low pH and $a_w$ not able to achieve 5-$\log_{10}$ CFU/g reduction of *E. coli O157:H7* (4.92 $\log_{10}$ CFU/g)
Next Steps

• Landjäger modified formulation and/or processing
  – Full scale challenge study
  – Only cocktail inoculation
    • No evidence of competitive inhibition
  – Three replicates
Modified Procedures

1. Inoculate trim with pathogens
2. Antimicrobial Treatment
3. Grind & Stuff
4. Press
5. Ferment (74-75°F)
6. Pre-dry / Smoke
7. Dry to water activity
## Results – Survival of Pathogens

Average counts ($\log_{10}$ CFU/g) and log reductions of *E. coli* O157:H7, *L. monocytogenes*, and *Salmonella* spp.

<table>
<thead>
<tr>
<th></th>
<th><em>E. coli O157:H7</em></th>
<th><em>L. monocytogenes</em></th>
<th><em>Salmonella</em> spp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial</td>
<td>7.45 ± 0.52</td>
<td>6.11 ± 0.95</td>
<td>6.69 ± 0.74</td>
</tr>
<tr>
<td>4.5% Lactic Acid Spray</td>
<td>6.92 ± 0.67</td>
<td>5.85 ± 0.95</td>
<td>6.44 ± 0.49</td>
</tr>
<tr>
<td>Fermentation &amp; Drying</td>
<td>3.87 ± 0.38</td>
<td>2.41 ± 0.25</td>
<td>2.02 ± 1.00</td>
</tr>
<tr>
<td>28d Storage</td>
<td>0.82 ± 0.26</td>
<td>1.09 ± 0.32</td>
<td>0.77 ± 0.23</td>
</tr>
<tr>
<td>LR</td>
<td>6.62 ± 0.13&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.02 ± 0.58&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.32 ± 0.67&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Note: ± denotes the standard errors of the mean, LR calculated by subtracting final log counts from initial log counts. LR with different letter superscripts are significantly ($p < 0.05$) different by difference of least square means.
Discussion

• Full challenge study incorporated lactic acid treatment to trim prior to grinding

• $\geq 5$-log reduction for all pathogens achieved
Conclusions

- Traditional processing alone not sufficient to achieve the desired 5-log reduction
- Additional interventions with antimicrobials and bio-protective cultures
- Able to validate process without thermal lethality step
Next Steps

• Validation of other fermented sausage types and whole muscle charcuterie

• Publication of research
Acknowledgements

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  — Josef & Elizabeth Brunner
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