Risk assessment for *Listeria monocytogenes* in hot-smoked fish in informal markets in Madina, Accra

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BACKGROUND
• *Listeria monocytogenes* is a non-spore forming pathogenic bacterium that causes a highly fatal disease called *listeriosis*

• *L. monocytogenes* is considered the **leading cause of death** among food-borne bacterial pathogens, with a fatality rate of **20-30%**, and up to **75%** in highly immunocompromised individuals

Table 1: Fatality of *L. monocytogenes* infection (CDC, 2000)

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Illnesses</th>
<th>Deaths</th>
<th>% Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Campylobacter</em> spp.</td>
<td>10,539</td>
<td>99</td>
<td>0.95</td>
</tr>
<tr>
<td><em>Salmonella</em> non-typhoidal</td>
<td>15,608</td>
<td>553</td>
<td>3.54</td>
</tr>
<tr>
<td><em>L. monocytogenes</em></td>
<td>2,298</td>
<td>499</td>
<td>21.71</td>
</tr>
</tbody>
</table>

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Foods frequently contaminated

- Milk and milk products
- Soft cheese
- Processed meats, red meat
- Vacuum packaged beef and poultry products
- Lettuce
- Coleslaw
- Fried rice
- Smoked fish
- Salted fish
• Human listeriosis is not documented in Ghana. However, the occurrence of the illness among herds of sheep has been documented.

• The pathogen has been isolated from fresh milk from informal markets, and from coleslaw from restaurants in some parts of Accra (Appiah, 2010; Dogbe 2010 both unpublished).

• Fish has been implicated in listeriosis outbreaks elsewhere (Buchanan et al., 1994; Lindqvist and Westoo, 2000; FAO, 2000).
• Ghana records high rates of fish consumption
  – Per capita fish consumption of 20-25kg, about twice the world average of 13kg
  – Fish purchases account for 22.4% of household food expenditures
  – Fish contributes 60% of total animal protein consumed in Ghana
    (BoG, 2008; Adu-Gyamfi, 2006; Oppey, 2003; Nketsia-Tabiri and Sefa-Dedeh, 2000; Steiner-Asiedu, 1991; Plahar et al., 1991)
• Over 80% of fish landings are processed traditionally
OBJECTIVES

Main: Risk assessment of listeriosis associated with the consumption of traditionally processed fish in Ghana

Specific:
1. To determine the presence and concentration of *Listeria monocytogenes* in traditionally hot-smoked fish
   - Mackerel: *Scomber japonicus*
   - Tuna: *Katsuwonus pelamis*
   - Herrings: *Sardinella eba*
OBJECTIVES

Specific:

2. To determine the exposure of consumers to the pathogen through consumption of the products

3. To determine the risk of illness following ingestion of the pathogen through consumption of traditionally processed fish
METHODS
GENERAL STUDY DESIGN

- **Hazard Identification**: Determination of the ability of an organism to cause harm.
- **Exposure Assessment**: Probability of ingesting hazard, and the likely quantities thereof.
- **Hazard Characterization**: Description of the (severity of the) effect of the hazard following consumption.
- **Dose-response Assessment**: Final quantitative or qualitative description of the nature of the risk.

**Fig. 1: Codex Alimentarius Commission framework for risk assessment, 2003**
HAZARD IDENTIFICATION

- Literature review for information on
  - Nature of organism
  - Occurrence and transmission
  - Pathogenicity
  - Outbreaks
  - Risk assessments
EXPOSURE ASSESSMENT

- Involved consumer survey and laboratory analysis of field samples

Consumer Survey

- Fish consumption patterns
  - Frequency of consumption
  - Quantities often consumed at an instance
  - Form in which consumed

Laboratory analyses

- Prevalence of *Listeria monocytogenes* (presence/absence)
- Concentration of the pathogen (CFU/g)
Consumer surveys

• 150 consumers were interviewed with semi-structured questionnaires on
  – frequency of consumption of the products
  – quantities often consumed at an instance
  – form in which products are often consumed
  – proxy estimation of the consumption pattern among the elderly, children, and pregnant women.
  
• Total respondents: 600
EXPOSURE ASSESSMENT

Laboratory analysis

Primary Enrichment
LEB, 37°C, 24h

Secondary Enrichment
Fraser, 37°C, 24-48h

Plating on Oxford or Chromagar, 37°C, 24-28h
• The **likely number** of *L. monocytogenes* ingested was calculated as

\[
N = C \times Q \quad [1]
\]

N = likely number of *L. monocytogenes* cells ingested  
C = CFU/g of *L. monocytogenes* in the fish product  
Q = serving size of fish product frequently consumed  
(Lindqvist and Westoo, 2000)
The Weibull-Gama model was used to determine the probability of illness (Lindqvist and Westoo, 2000; Bemrah et al., 1998; Farber et al., 1997).

Weibull-Gama dose-response model

\[
P = 1 - \left[ 1 + \left( \frac{N^b}{\beta} \right) \right]^{-\alpha}
\]

\(P = \) probability of infection
\(N = \) dose of \(L.\ monocytogenes\)
\(\alpha, \beta, b = \) model parameters
\(\alpha=0.25, b=2.14\)
\(\beta=10^{10.98} \) for high-risk population
\(\beta=10^{15.26} \) for low-risk population

\(N = C \times Q\)
RISK CHARACTERIZATION

• Quantitative estimate of the risk of illness following consumption of contaminated fish

ASSUMPTIONS

• Fish were consumed as purchased OR were not heat-treated to an extent that guaranteed elimination of *L. monocytogenes*

• All strains of *L. monocytogenes* in the fish products were virulent
RESULTS & DISCUSSION
Key Findings

1. Sanitary conditions of fish processing and handling were unsatisfactory

2. *L. monocytogenes* was detected in at least one sample of each product on informal markets

3. *L. monocytogenes* was detected in at least one sample from each step in processing except
   - Fresh, frozen mackerel and herrings
   - Hot-smoked tuna, mackerel and herrings sampled immediately after processing

4. Counts were low ($10^2$-$10^3$ CFU/g)

5. Low risk of ingestion and infection
PROCESSING AND HANDLING
Table 1: Average prevalence of *Listeria monocytogenes* in traditionally processed fish purchased from informal market

<table>
<thead>
<tr>
<th>Product</th>
<th>Number of samples purchased</th>
<th>Number of samples positive for <em>L. monocytogenes</em></th>
<th>Prevalence of <em>L. monocytogenes</em> (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoked tuna</td>
<td>15</td>
<td>12</td>
<td>80</td>
</tr>
<tr>
<td>Smoked mackerel</td>
<td>15</td>
<td>14</td>
<td>93</td>
</tr>
<tr>
<td>Smoked herrings</td>
<td>15</td>
<td>10</td>
<td>67</td>
</tr>
</tbody>
</table>
Fig. 1: Average counts of *L. monocytogenes* in fish samples

- **KA**: kako (salted)
- **KO**: koobi (salted)
- **MO**: momoni (salted)
- **TU**: tuna
- **MA**: Mackerel
- **HR**: herrings
- **DR**: dried fish
Fig. 2: Event tree for risk of ingestion of *Listeria monocytogenes* through consumption of traditionally smoked fish purchased from informal markets.
Table 1: Likely numbers of *L. monocytogenes* ingested through consumption of contaminated TPF fish on informal markets in Ghana

<table>
<thead>
<tr>
<th>Product</th>
<th>C (CFU/g)</th>
<th>Q (g)</th>
<th>N=CxQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuna</td>
<td>1.40x10³</td>
<td>&gt;200</td>
<td>≥3.20x10⁵</td>
</tr>
<tr>
<td>Mackerel</td>
<td>1.60x10³</td>
<td>&gt;200</td>
<td>≥2.80x10⁵</td>
</tr>
<tr>
<td>Herrings</td>
<td>4.00x10²</td>
<td>151</td>
<td>6.04x10⁴</td>
</tr>
</tbody>
</table>

C: average counts across five markets  
Q: Most frequently consumed quantities  
N=likely number of *L. monocytogenes* ingested

\[
P = 1 - \left[ 1 + \frac{(N^b)/\beta}{\alpha} \right]^{-\alpha}
\]
RISK ESTIMATION FOR LOW-SUSCEPTIBILITY CONSUMER

• Dose required for illness = ≥ 10^9 cells
  (Buchanan et al., 1997; Schlech, 1999)

• Mean Lm CFU
  – Herrings = 8.33x10^2 CFU/g
  – Mackerel = 2.90x10^3 CFU/g
  – Tuna = 2.10x10^3 CFU/g
Probability of illness among 18-49yrs from consuming smoked mackerel contaminated with *L. monocytogenes*
Probability of illness among 18-49yrs from consumption of traditionally smoked herrings contaminated with *L. monocytogenes*
Risk of illness among 18-49yr tuna consumers
Comparison of probability of illness from consumption of tuna, mackerel and herrings

Confidence

Probability of illness

Values in Millionths

Mean = 0.000132

Mean = 0.000248

95% = 0.000170

95% = 0.000318

Mean = 8.012E-006

0.2

0.4

0.6

0.8

1.0

0

298.185

397.58

99.2

169.9

5.0%

100.0%

0.0%

90.0%

0.0%

5.0%
RISK ESTIMATION FOR HIGH-SUSCEPTIBILITY CONSUMER

• Dose required for illness = ≥ 10^4 cells
  (Buchanan et al., 1997; Schlech, 1999)

• Average Lm CFU
  – Herrings = 8.33x10^2 CFU/g
  – Mackerel = 2.90x10^3 CFU/g
  – Tuna = 2.10x10^3 CFU/g
Comparison of probability of illness

- Tuna / Average
- Herring / Average
- Mackerel / Average

Confidence

Probability of illness

Mean = 0.2478
Mean = 0.2478
Mean = 0.3250

0.0285
0.0285
0.3250
HIGH-RISK vs. LOW-RISK GROUPS
Comparison of risk of illness from herrings: Low risk vs. High Risk

Confidence vs. Probability of illness Values in Thousands

Mean = 8.012E-006

Mean = 0.0285

5.0% 90.0% 5.0%
0.0% 0.0% 100.0%
EFFECT OF MITIGATION
<table>
<thead>
<tr>
<th>Mode of consumption</th>
<th>AHI ADULT</th>
<th>ELDERLY</th>
</tr>
</thead>
<tbody>
<tr>
<td>As is</td>
<td>1.00E-04</td>
<td>2.07E-01</td>
</tr>
<tr>
<td>Mitigation</td>
<td>6.90E-06</td>
<td>1.93E-02</td>
</tr>
</tbody>
</table>
Effect of mitigation on risk reduction among 18-49yrs, tuna
Exposure Assessment

• Traditionally smoked tuna, mackerel and herrings on informal markets are potential vehicles for the transmission of *L. monocytogenes*

• Depending on the kind of product and quantity consumed at an instance, consumers are exposed to ingesting $10^2$ to $10^5$ cells of *L. monocytogenes*
Hazard Characterization and Dose-Response

- Depending on dose ingested and susceptibility to infection, consumers have a 1 in 10 to 1 in 100,000,000 risk of illness.

Risk Characterization

- Risk of ingestion and infection are generally low. However, individuals who either consume TPF from informal markets as is or do not heat-treat the products sufficiently increase their risks of ingestion and infection, and vice versa.
THANK YOU