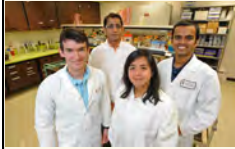



## Challenges in controlling *Salmonella* in poultry and poultry products

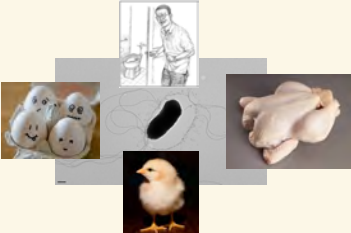




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## Why is *Salmonella* so important?

- Number **ONE** cause of food-borne illness (diarrhea)
- Live poultry is the **reservoir host** of *Salmonella*
- Poultry and poultry products (eggs and meat) are **PRIMARY** sources of human infection



## What is *Salmonella*?


- **Biology of *Salmonella* is complex**
- **Many serotypes (>2500)**
  - At least 10% of these are found in poultry
  - Few are MOST common in the US poultry
  - What *Salmonella* serotypes are most common problems for US poultry meat producers?

**S. Enteritidis**

S. Kentucky

S. Infantis

**S. Typhimurium**



S. Seftenberg

**S. Heidelberg**

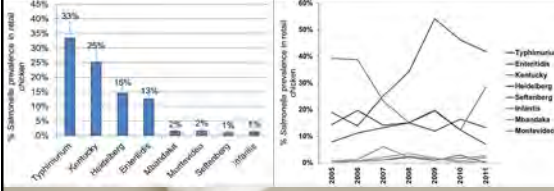
S. Mbandaka

S. Montevideo

## Incidence of *Salmonella* serotypes in the retail chicken in the US

**Most Prevalent Poultry-associated *Salmonella* seroTypes (MPPSTs)**

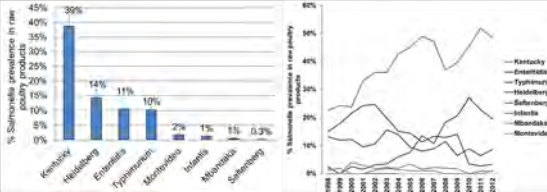
US-FDA-NARMS (2005-2011)



Serotype	% Prevalence
Typhimurium	33%
Kentucky	25%
Heidelberg	16%
Enteritidis	13%
Mbandaka	2%
Montevideo	2%
Infantis	1%
Seftenberg	1%
Illinois	1%

## Incidence of *Salmonella* serotypes in the raw poultry products in the US

USDA-FSIS (1996-2012)



Serotype	% Prevalence
Kentucky	39%
Heidelberg	14%
Enteritidis	11%
Typhimurium	10%
Montevideo	2%
Illinois	1%
Mbandaka	1%
Seftenberg	0.3%

## Population dynamics of *Salmonella* is a challenge & a significant concern

- **MPPSTs**
  - S. Enteritidis
  - S. Typhimurium
  - **S. Heidelberg**
  - S. Infantis
  - S. Mbandaka
  - S. Montevideo
  - S. Kentucky
  - S. Seftenberg

**March 1, 2013 to July 11, 2014:** Foster Farms recalled >47,000 lb of potentially contaminated chicken products (634 sick people)

**January 10, 2014:** Tyson Foods, Inc. recalled ~33,840 lb of potentially contaminated chicken products (9 sick people)

**2013-2014** (mail-order hatchery related outbreaks)

- Mt. Healthy Hatchery (Ohio) - 521 sick people
- Estes Hatchery (Missouri) - 96 sick people
- *Salmonella* in backyard poultry

- 62 cases/year (1996-2004), 123 cases (2006)
- **2014:** Ciprofloxacin resistant **sequence type 198** has emerged in the US and Canada (**African origin?**)
- **WSU (2012):** Two strains isolated from CA broiler samples (resistant to 3<sup>rd</sup> generation cephalosporin)

### Why is *Salmonella* control so challenging?

- Each serotype is unique in its own way
  - Resistance to antimicrobials
  - Infectivity in chickens (eg., high invasive vs low invasive)
  - Biofilm production
- There are phenotypic differences **within** each serotype
  - Not all *S. Enteritidis* strains contaminate eggs equally well
  - Not all *S. Heidelberg* strains are resistant to antimicrobials
- Current food-safety protocols are primarily based on the big TWO
  - S. Typhimurium*
  - S. Enteritidis*

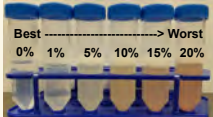
### Why is *Salmonella* control so challenging?

- Carcass chilling:** Important step in reducing *Salmonella*
  - 45-60 min
  - pH ( $\leq 6.5$ )
  - Max. 50 PPM Free Chlorine
  - Temp -  $-4^{\circ}\text{C}$
- High amounts of organic matter (fat, blood and protein) can get accumulated in chiller tank and can reduce available chlorine
- Several contaminating serotypes
- Do different serotypes differ in their susceptibility to chlorine in chiller tanks?**

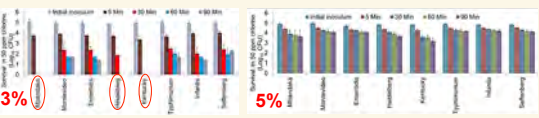



### Why is *Salmonella* control so challenging?

- $> 100,000$  *Salmonella*
- $> 5, 30, 60, 90$  min




- (0%) = All serotypes die within 5 min
- (1% - 2%) = All serotypes die by 30 to 60 min



- MPPSTs differ in their resistance to chlorine
- Are there within serotype differences in resistance? – work is ongoing
- What about other sanitizers (eg., paracetic acid)? – work is ongoing

### Why is *Salmonella* control so challenging?

- Another challenge is EXTERNAL vs. INTERNAL contamination of carcasses




Conventional paradigm is that ALL contamination occurs at EXTERNAL surface of carcasses during processing

- What we KNOW about *Salmonella*?**
  - Salmonella* CAN get inside the internal organs of chickens (liver, spleen, muscle, bone marrow etc)

### Different strains of *S. Enteritidis* differ in their internalization in liver and spleen of chickens

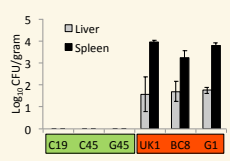
$10^8$  CFU

72h (3 days) old chickens



Sacrifice at 7 days (4 days post-infection)

Determine CFU in Liver and Spleen



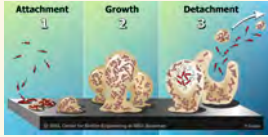
Strain	Liver (Log <sub>10</sub> CFU/gram)	Spleen (Log <sub>10</sub> CFU/gram)
C19	~0.5	~0.5
C45	~0.5	~0.5
G45	~0.5	~0.5
UK1	~1.5	~3.5
BC8	~1.5	~3.0
G1	~1.5	~3.5

### Why is *Salmonella* control so challenging?

- What we DO NOT know**
  - Are all MPPSTs equally efficient in their ability to internalize in organs including bone marrow?
  - Are there within serotype differences for other MPPSTs?
  - Which MPPSTs persist in internal organs until the age of slaughter?
  - If *Salmonella* is HIDDEN in organs, how effective surface decontamination will be?

### Why is *Salmonella* control so challenging?

- Another challenge is **BIOFILM** production by *Salmonella*



- **Biofilms protect *Salmonella***
  - ✓ can carry **billions** of *Salmonella*
  - ✓ can provide **physical barrier** to antimicrobials such as chlorine or other disinfectants
  - ✓ can be **1000 times** more resistant to antibiotics
  - ✓ Provides means to persist in the environment

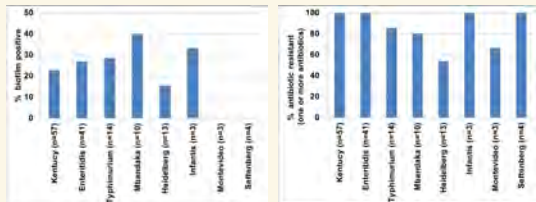
### Why is *Salmonella* control so challenging?

- **Biofilms can be formed on almost ANY surface**



### MPPSTs differ in their ability to form biofilm & resistance to antibiotics

- 145 MPPSTs tested so far
- Most isolates were obtained here at AHFSL, Puyallup
- Biofilm production is common among most MPPSTs
- Antibiotic resistance is common among MPPSTs



### Take home message

- All MPPSTs are potential pathogens
- Current food-safety protocols may not work effectively against all serotypes/strains of *salmonella*
- Need to develop of **serotype-independent strategies** to control *Salmonella* for both on-farm and in-plant control of *Salmonella*
  - Better understanding of the differences in the biology of MPPSTs
  - Infectivity of MPPSTs in chickens (internal vs. external contamination)
  - Biofilm and its role in resistance to carcass decontaminants and persistence in the poultry environment

Questions?