Risk Assessments for
Salmonella Enteritidis in Shell Eggs and
Salmonella spp. in Liquid Egg Products
October 22, 2004

Outline

- Risk Assessment of *Salmonella* Enteritidis in Shell Eggs
  - Review risk management questions
  - Brief description of model
  - Results
- Risk Assessment of *Salmonella* spp. in Liquid Egg Products
  - Review risk management questions
  - Brief description of model
  - Results

Risk Assessment of *Salmonella* Enteritidis in Shell Eggs
Risk Management Questions *Salmonella* Enteritidis in Shell Eggs

Risk Management Question 1
- What is the number of illnesses per serving and annual number of illnesses from *Salmonella* Enteritidis in pasteurized and non-pasteurized shell eggs?

Risk Management Question 2
- What is the effect of the temperature and length of time (in days) before eggs are collected after they are laid by the hen and then refrigerated and further processed on the estimated risk of illness?

Risk Management Question 3
- What is the number of *Salmonella* Enteritidis in shell eggs before and after a specified pasteurization scenario?

Model Description
Salmonella Enteritidis in Shell Eggs

Inputs by Model Stage (Eggs)
Farm – SE in egg at lay
Storage 1 – growth in egg prior to processing
Pasteurization – pasteurization factor
Storage2 – growth in egg after pasteurization
Preparation – servings per contaminated egg
Cooking – cooking effect
Health Effect – dose response function

Modeling Illnesses – Determine:
- If egg is contaminated with SE
- How much SE is in egg

- Growth due to storage
- Decline due to cooking
- Consumption by one or more persons
- Whether dose causes illness

Modeling Illnesses – Determine:
If egg is contaminated with SE

Factors
- Infected flock
- Infected chicken
- Infection passed to egg

Data Sources
- FSIS surveys
  - SE Pilot Project
- ARS studies
- Published literature

Modeling Illnesses – Determine:
How much SE is in egg

Factors
- Location
  - Shell membrane
  - Albumen
  - Vitelline membrane
  - Yolk
- Egg to egg variability

Data Sources
- Published literature
- Analysis of study data

Modeling Illnesses – Determine:
Growth of SE due to storage

Factors
- SE growth dynamics
- Time
- Temperature
- Location of egg
  - Carton
  - Case
  - Pallet

Data Sources
- National Animal Health Monitoring System survey

- Audits International surveys
- Published literature

Modeling Illnesses – Determine:
Decline of SE due to cooking

Factors
- Type of serving
  - Egg
  - Mixture
  - Beverage
- Type of cooking
- Hard boiled, soft boiled
- Scrambled, fried, omelet
- Raw

Data Sources
- Published literature
- Continuing Survey of Food Intake by Individuals

Modeling Illnesses – Determine:
Consumption by one or more persons

Factors
- One egg may serve more than one person
  - Pooling
  - Multiple eggs in recipe
- More servings per egg = more exposures to fewer SE

Data Sources
- Continuing Survey of Food Intake by Individuals

Modeling Illnesses – Determine:
Whether dose causes illness
- Dose response model developed by Joint Expert Meetings on Microbiological Risk Assessment
- Joint FAO/WHO response to Codex request

Results
Salmonella Enteritidis in Shell Eggs

Baseline Model
- Best estimates
  - Values
  - Distributions
- Designed to model current practices

- What is the number of illnesses per serving and annual number of illnesses from *Salmonella* Enteritidis in pasteurized and non-pasteurized shell eggs?

Risk Management Question 1

- What is the number of illnesses per serving and annual number of illnesses from *Salmonella* Enteritidis in pasteurized and non-pasteurized shell eggs?

  The estimated illnesses per non-pasteurized shell egg is about 7 per million

Risk Management Question 1

- What is the number of illnesses per serving and annual number of illnesses from *Salmonella* Enteritidis in pasteurized and non-pasteurized shell eggs?

  There are about 50 billion shell eggs consumed as table eggs annually in the United States. A table egg is one that is available to cook as an egg or to be incorporated as an ingredient in a recipe. So given 50 billion table eggs and 7 illnesses per million, we would expect to have about 350,000 illnesses.

Comparing Model Estimates to Epidemiologic Estimates

- Surveillance data from year 2000 implied 174,356 human illnesses
- Based on multiplying reported cases by 37
- Uncertainty within multiplier
  - Visit doctor
  - Culture taken
  - Sent to lab
  - Isolate organism
  - Report by lab

Comparing Model Estimates to Uncertainty Based on CDC Estimates

So we looked to see how close our estimate of 350,000 illnesses was compared with epidemiologic estimates when we considered this uncertainty. We used FoodNet data for *Salmonella* and SE to develop a distribution to describe the uncertainty associated with the estimate of SE cases due to shell eggs. The baseline model result fell within the uncertainty associated with the epidemiologic estimate. Recently, we have worked with colleagues to narrow the uncertainty. This yellow line represents our most recent distribution. The new range of uncertainty is much more narrow and the baseline model estimate now appears near the upper end of the distribution. It is still, however, within the bounds of uncertainty and thus, should be a useful model of the farm to table continuum.

Risk Management Question 1

- What is the number of illnesses per serving and annual number of illnesses from *Salmonella* Enteritidis in pasteurized and non-pasteurized shell eggs?

  There are about 125 billion servings of table eggs annually. Thus, there are about 2.8 illnesses per million servings of table eggs.

- What is the number of illnesses per serving and annual number of illnesses from

Salmonella Enteritidis in pasteurized and non-pasteurized shell eggs?

We modeled two pasteurization scenarios. In one, we modeled a 3 log pasteurization. This is equivalent to multiplying the number of bacteria in an egg by 0.001 or reducing the number by 99.9%. This reduction in bacteria due to pasteurization results in an estimate of illnesses per egg of about 2 per million. If we model a 5 log pasteurization we get a reduction to about 1 illness per million eggs.

- What is the number of illnesses per serving and annual number of illnesses from *Salmonella* Enteritidis in pasteurized and non-pasteurized shell eggs?

  The corresponding annual number of illnesses with these pasteurization scenarios is 110,000 for the three log pasteurization and 52,000 for the 5 log pasteurization.

- What is the number of illnesses per serving and annual number of illnesses from *Salmonella* Enteritidis in pasteurized and non-pasteurized shell eggs?

  And these annual number of illnesses correspond with about 9 illnesses per 10 million servings for the three log pasteurization scenario and about 4 illnesses per 10 million servings for the five log pasteurization scenario.

- What is the number of illnesses per serving and annual number of illnesses from *Salmonella* Enteritidis in pasteurized and non-pasteurized shell eggs?

	Non-pasteurized	**Pasteurized**	
		3 logs	**5 logs**
Illnesses/egg	0.000007	0.000002	0.000001
Annual illnesses	350,000	110,000	52,000
Illnesses/serving	0.0000028	0.0000009	0.0000004

- What is the effect of the temperature and length of time (in days) before eggs are collected after they are laid by the hen and then refrigerated and further processed on the estimated risk of illness?

Scenarios Evaluated

- Refrigeration 45 53 60 °F
- Time until refrigeration 0.5 1.0 1.5 days
- Pasteurization 0 3 5 logs

3 X 3 X 3 = 27 scenarios

Results for Storage at 53 F and 60 F

- As many or more illnesses as baseline

Storage at 45 F
Within 0.5, 1, or 1.5 Days of Lay

- What is the effect of the temperature and length of time (in days) before eggs are collected after they are laid by the hen and then refrigerated and further processed on the estimated risk of illness?

  This chart shows the annual number of illnesses for different pasteurization scenarios for eggs stored at 45 degrees within 12, 24, or 36 hours of lay. The orange bars represent the baseline scenarios that we examined earlier. The turquoise bars represent the result of storing eggs at 45 degrees within 36 hours of lay. The red bars show the effect of refrigerating eggs within 24 hours of lay. And the light yellow bars show the effect of refrigerating eggs within 12 hours of lay. Because most producers collect eggs twice a day, refrigerating eggs within 12 hours of lay is essentially the same as refrigerating them as soon as they are collected.

Storage at 45 F
Within 0.5, 1, or 1.5 Days of Lay

- What is the effect of the temperature and length of time (in days) before eggs are collected after they are laid by the hen and then refrigerated and further processed on the estimated risk of illness?

	Pasteurization		
Days	**None**	**3 logs**	**5 logs**
0.5	77,000	14,000	7,200
1.0	130,000	33,000	17,000
1.5	240,000	66,000	32,000
Base	350,000	110,000	52,000

- What is the number of *Salmonella* Enteritidis in shell eggs before and after a specified pasteurization scenario?
  - Pasteurization decreases the number, BUT
  - Regrowth can occur

Potential for Human Illness at
Various Model Stages

The number of bacteria at each model stage is actually a distribution. It may be easier to think of these distributions in terms of their ability to cause human illness. Thus we can think of the potential for human illness at various model stages if humans were to consume raw eggs at those stages. This is, of course, unrealistic, but it does show how

the potential risk of eggs changes in the farm to table continuum. This light blue line shows the number of illnesses expected after each stage without pasteurization. If all eggs were consumed raw in the layer house, there would be about 600,000 illnesses. The potential illnesses increase to about 1.5 million by the time we reach the end of home storage. Finally, cooking reduces the potential illnesses to about 350,000, our baseline value.

If eggs are subjected to 3 logs of pasteurization, the potential for human illness drops substantially. Furthermore, the potential for additional illness does not increase as rapidly. This is because bacteria have now been eliminated from most contaminated eggs. Cooking further reduces the risk. Five logs of pasteurization further reduces the potential for eggs to cause human illness.

Uncertainty and Sensitivity

- Baseline model evaluates effect of variability
  - Iterates through specific values and distributions
- Nominal range sensitivity analysis
  - Series of scenarios
  - Set all inputs except one to the baseline values
  - Set remaining inputs to upper or lower bound

Uncertainty and Sensitivity

- Inputs with greatest effect
  - Storage temperatures
  - Growth parameters
  - Prevalence of contaminated eggs
  - Pasteurization

Summary of Shell Egg Model

- Baseline model estimates about 350,000 illnesses per year
- Quick refrigeration at 45F and pasteurization at 5 logs both effective in reducing illnesses
- Combination of refrigeration and pasteurization more effective than either alone

Risk Assessment of *Salmonella* spp. in Egg Products

Outline

- Review questions
- Brief description of model
- Anchoring of model
- Results

Risk Management Question 1

- What is the number of illnesses per serving and annual number of illnesses from *Salmonella* spp. in pasteurized egg products (e.g., liquid whole eggs, yolks, and egg

whites)?

Risk Management Question 2

- What is the number of *Salmonella* spp. in a liter of egg product (whole, yolk, lbumen) before and after a specified pasteurization scenario?

Differences in
Egg Products Model from
Shell Egg Model

Egg Products Model

- *Salmonella* spp.
- processor to table
- illnesses per serving

Shell Egg Model

- *Salmonella* Enteritidis
- farm to table
- illnesses per egg

Modeling Illnesses – Determine:

- How many *Salmonella* in a serving
- Decline due to pasteurization
- Growth due to storage
- Decline due to cooking
- Whether dose causes illness

Modeling Illnesses – Determine:
How many *Salmonella* in a serving

Factors

- *Salmonella* per gram in liquid egg product
  - White
  - Whole
  - Yolk
- Size of serving

Data Sources

- FSIS raw egg product baseline study

Modeling Illnesses – Determine:
Decline of *Salmonella* due to pasteurization

Factors

- Type of egg product
  - White, whole, yolk
- Additives
  - Salt, sugar
- Temperature
- Time

- Seven combinations – products, additives

Data Sources
- UEP sponsored pasteurization study

Modeling Illnesses – Determine:
Growth of *Salmonella* due to storage

Factors
- Growth dynamics
- Time
- Temperature

Data Sources
- SE growth dynamics
- RTI expert panel

Modeling Illnesses – Determine:
Decline of *Salmonella* due to cooking

Factors
- Type of serving
  - Egg
  - Mixture
  - Beverage
- Type of cooking
  - Thoroughly cooked
  - Undercooked

Data Sources
- Continuing Survey of Food Intake by Individuals
- Cooking of shell eggs

Modeling Illnesses – Determine:
Whether dose causes illness

- Dose response model developed by Joint Expert Meetings on Microbiological Risk Assessment
- Joint FAO/WHO response to Codex request

Inputs by Model Stage
Breaking – *Salmonella* in serving before pasteurization – Baseline data
Pasteurization – pasteurization factor – UEP sponsored study
End Product Sampling
Storage – growth of *Salmonella* in serving after pasteurization
Cooking – Cooking effect
Health Effect – dose response function

Anchoring Model

- Purpose
  - Ensures that results are consistent with reality
- Egg products model
  - Unanchored model gives high estimate of human illnesses compared to epidemiologic estimates

Anchoring Model

Method

- Pasteurization levels adjusted to give results consistent with end product sampling
- Consequence
  - Pasteurization level for egg white adjusted from 3.25 logs to 5.0 logs
  - Other egg products consistent with end product sampling and not adjusted

Results

Salmonella in Egg Products

Policy Question 1

- What is the number of illnesses per serving and annual number of illnesses from *Salmonella* spp. in pasteurized egg products (e.g., liquid whole eggs, yolks, and egg whites)?

Policy Question 1

- What is the number of illnesses per serving and annual number of illnesses from *Salmonella* spp. in pasteurized egg products (e.g., liquid whole eggs, yolks, and egg whites)?

As for shell eggs, we have divided this question into parts. This chart shows the expected illnesses per serving for pasteurization scenarios ranging from 5 to 12 logs of reduction due to pasteurization. At this level of pasteurization the effect is fairly linear. So increasing pasteurization from 6 logs to 7 logs means reducing the illnesses per serving by nearly a factor of 10. This chart assumes that all egg products are pasteurized to the given pasteurization levels.

Policy Question 1

- What is the number of illnesses per serving and annual number of illnesses from *Salmonella* spp. in pasteurized egg products (e.g., liquid whole eggs, yolks, and egg whites)?

We next look at the annual number of illnesses. This chart shows the annual number of illnesses expected for each of the given pasteurization levels. This chart shows the straight line relationship seen in the previous chart. There would be about 240,000 illnesses given a 5 log reduction, about 28,000 given a 6 log reduction, and about 2900 given a 7 log reduction.

The baseline model result is about 37,000 illnesses. This does not mean that all egg products currently undergo what looks like about a five and a half log reduction. Rather, it means that if we aggregate the illnesses for all of seven product types with baseline pasteurization, storage, and cooking assumptions we get about 37,000 illnesses.

Policy Question 1

- What is the number of illnesses per serving and annual number of illnesses from *Salmonella* spp. in pasteurized egg products (e.g., liquid whole eggs, yolks, and egg whites)?

Baseline model result: 37,000 illnesses

LR	Human Illnesses
5	240,000
6	28,000
7	2900
8	280
9	28
10	3
11	0
12	0

Policy Question 2

- What is the number of *Salmonella* spp. in a liter of egg product (whole, yolk, albumen) before and after a specified pasteurization scenario?

Number of *Salmonella* spp. in a Liter Before and After Pasteurization

This chart shows the number of *Salmonella* per liter before and after specified pasteurization scenarios. On the x-axis are levels of *Salmonella* per liter. On the y-axis is the percent of liters of egg product that are at or below the corresponding levels of *Salmonella*. The vertical white line represents one *Salmonella* per liter. The levels of *Salmonella* before pasteurization in whole egg is shown in this line. Because the line intersects the vertical white line at 10%, we would expect that 10% of liters would have less than one *Salmonella* and that 90% would have more than one *Salmonella* per liter. Over 50% would have more than 1000 *Salmonella* per liter. The next line shows the results of a 3 log reduction due to pasteurization. Now, only about half of the liters would be expected to have one or more *Salmonella*. With a 6 log reduction, less than 5 percent would be expected to have more than one *Salmonella* and with a 9 log reduction, it is unlikely to have surviving bacteria.

Policy Question 2

- What is the number of *Salmonella spp.* in a liter of egg product (whole, yolk, albumen) before and after a specified pasteurization scenario?
  - Before pasteurization
    - ~90% > 1 / liter
  - After pasteurization

- 3 logs: ~50% > 1 / liter
- 6 logs: ~5% > 1 / liter
- 9 logs: ~0% > 1 / liter

Model Output Sensitive To:Incoming level of *Salmonella*

- Log reductions due to pasteurization
- Use of end-product
  - Cooking

Summary of Egg Products Model

- Anchored baseline model estimates about 37,000 human illnesses
- Each log increase in pasteurization results in a log decrease in illness