

What could we do that we are not doing yet regarding predictive microbiology and QMRA approaches to food safety?

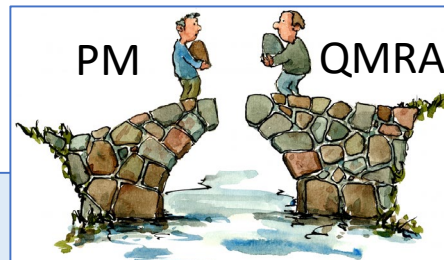
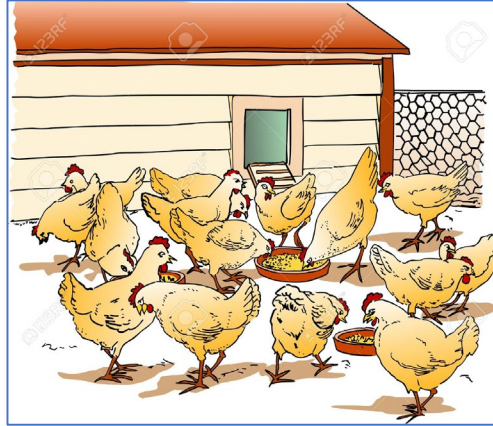
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USDA, ARS, Princess Anne, MD



Current Approach to Food Safety

Pathogen Reduction/HACCP

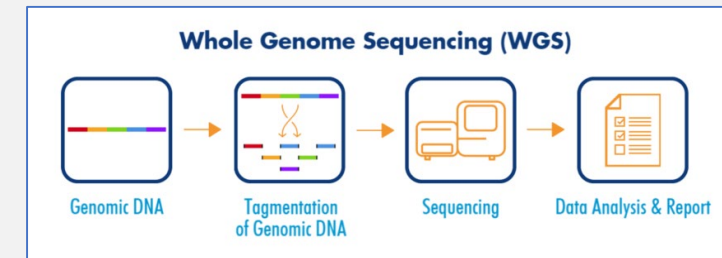
- *Salmonella* Performance Standard
 - Ground turkey
 - 7 positives per 52 samples (325 g) = 13.5%
 - Ground chicken
 - 13 positive per 52 samples (325 g) = 25.0%



Food Safety (↓ dose)

Surveillance/Recalls

- Whole Genome Sequencing
 - Outbreak
 - Attribution



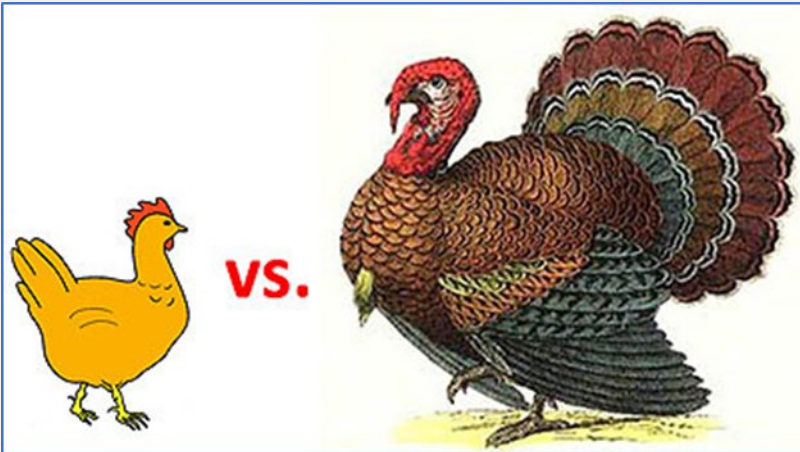
Public Health (↓ response)

Risk Pathway for Individual Lots of Food

Unit Operation (Pathogen Event)



- Type of Poultry Meat
 - Ground chicken
 - Ground turkey



Meal Preparation
(Contamination)

Cooking
(Death)

Consumption
(Dose-Response)

- Model Variables/Risk Factors
 - Serving size
 - Incidence of Undercooking
 - Food consumption behavior
 - Host resistance

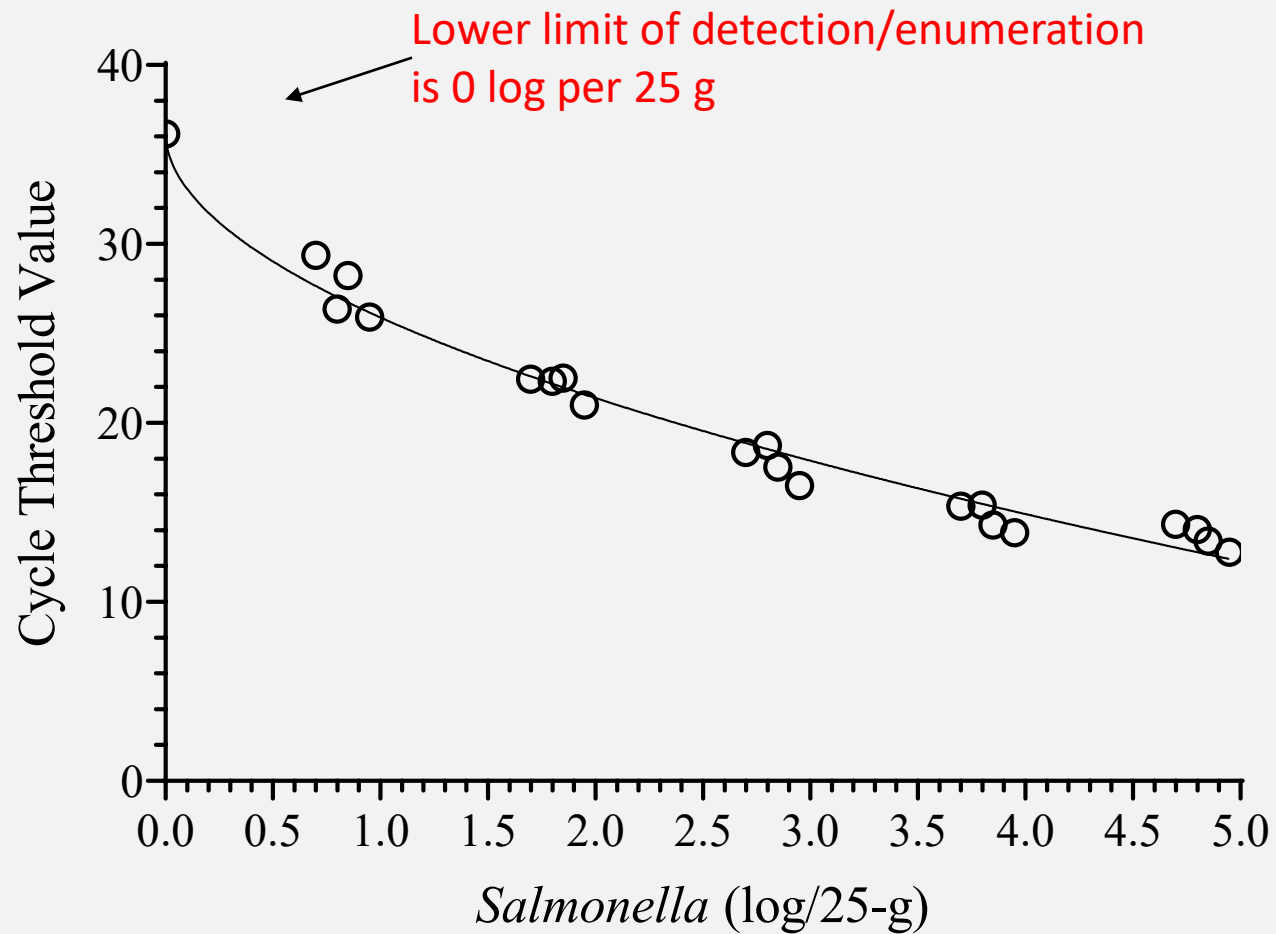
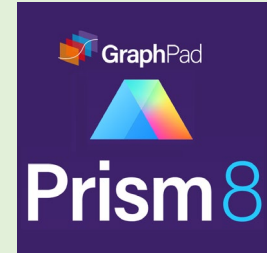


Meal Preparation

Contamination

Whole Sample Enrichment, qPCR, Cultural Isolation, Serotyping

Prevalence, number, and serotype data



Whole Sample Enrichment

400 ml BPW + 25 g + 6 h + 40°C + 80 rpm
(e.g. chicken parts)

Contamination Data for Ground Turkey

Date	C _T	Isolate	Log number	Serotype	Rank	Virulence
1/22/2018	29.08	562	0.492	Infantis	6	4.5
1/29/2018	32.71	563	0.125	Typhimurium	3	4.8
1/29/2018	32.18	564	0.164	Typhimurium	3	4.8
1/29/2018	30.59	565	0.312	Typhimurium	3	4.8
1/29/2018	34.84	566	0.020	Typhimurium	3	4.8
1/29/2018	32.36	567	0.150	Typhimurium	3	4.8
1/29/2018	31.67	568	0.206	Reading	> 20	2.7
1/29/2018	30.20	569	0.355	Typhimurium	3	4.8
1/29/2018	30.81	570	0.289	Typhimurium	3	4.8
1/29/2018	33.12	571	0.098	Typhimurium	3	4.8
2/12/2018	33.36	572	0.084	Hadar	> 20	2.5
2/20/2018	32.50	573	0.140	Typhimurium	3	4.8
2/20/2018	33.57	574	0.072	Typhimurium	3	4.8
2/20/2018	35.60	575	0.004	Typhimurium	3	4.8
2/20/2018	29.64	576	0.421	Typhimurium	3	4.8
2/26/2018	34.05	577	0.049	Typhimurium	3	4.8
3/26/2018	30.57	588	0.890	Hadar	> 20	2.5
3/19/2018	26.50	578	1.603	Infantis	6	4.5
3/19/2018	23.01	580	1.147	Kentucky	> 20	0.8
3/19/2018	25.13	582	0.982	Kentucky	> 20	0.8
3/19/2018	25.99	584	0.825	Infantis	6	4.5
3/19/2018	26.88	586	0.314	Infantis	6	4.5
4/9/2018	35.79	589	0.002	Rough_O:eh:-	> 20	2.7
4/16/2018	26.96	590	0.811	4, [5], 12:i:-	5	4.6
4/23/2018	36.15	591	0.000	Reading	> 20	2.7
4/23/2018	32.48	592	0.141	Reading	> 20	2.7



$$\text{Rank} = 1 \text{ to } 20 = 5.1 - 0.1(r_i)$$

Typhimurium (no. 3)

$$v = 5.1 - (0.1 * 3) = 4.8$$

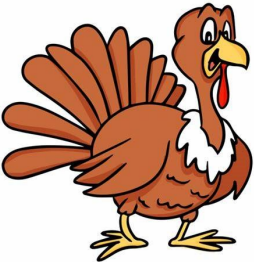
$$\text{Virulence } (v) = 3.9 \text{ (0.8 to 4.8)}$$

$$\text{Rank} > 20 = 3.1 * (c_i / c_{20})$$

Anatum (no. 20) = 257 cases

Kentucky = 63 cases

$$v = 3.1 * (63 / 257) = 0.8$$



Contamination Data Summary

Ground Chicken versus Ground Turkey



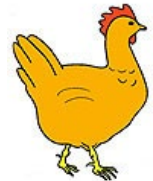
Prevalence = 19%/25 g ($n = 100$)

Number = 0.93 (0 to 2.56) log/25 g



Virulence = 4.6 (4.5 to 4.8)

Raw Ground Chicken			
	<i>s</i>	<i>f</i>	<i>v_I</i>
1	Infantis	13	4.5
2	Enteritidis	5	5.0
3	Typhimurium	1	4.8



vs.



Prevalence = 26%/25 g ($n = 100$)

Number = 0.185 (0 to 1.6) log/25 g

Virulence = 3.9 (0.8 to 4.8)

Raw Ground Turkey			
	<i>s</i>	<i>f</i>	<i>v_I</i>
1	Infantis	4	4.5
2	Typhimurium	13	4.8
3	Reading	3	2.7
4	Hadar	2	2.5
5	Kentucky	2	0.8
6	4,5,12:i:-	1	4.6
7	Rough_O:eh:-	1	2.7

Contamination Model

Contaminated and Non-contaminated Servings



Rare Event Modeling = Discrete + Pert

Salmonella Contamination Model for Ground Turkey

Prevalence	Log Number	Frequency	Serving	Portion	Cumulative	Serotype	Virulence	Outputs	Settings
0	0.258	0	25	0	0			Serving, g	Mean serving, g
5	0.497	0	50	3	3	Kentucky	0.343	300	300.0
0	0.184	0	75	0	3			Number	Lot size, kg
0	0.953	0	100	0	3			7	907
0	0.113	0	125	0	3			Virulence	Servings
2	0.540	0	150	3	6	Typhimurium	2.057	3.0	3,023
0	0.462	0	175	0	6			Prevalence	
0	0.554	0	200	0	6			1	
1	0.038	0	225	1	7	Infantis	0.643		
0	0.297	0	250	0	7				
0	0.536	0	275	0	7				
0	0.281	1	300	0	7				
0	0.148	0	325						

Pert(0,0.185,1.603)

Discrete({0,1,2,3,4,5,6,7},{74,4,13,3,2,2,1,1})



Cooking

Death

Cooking Model

Location in Food Matrix



Rare Event Modeling = Discrete + Pert

Salmonella Cooking Model for Ground Turkey

Undercooking (0=no,1=yes)	Log reduction	Total bacteria	Survivors	<i>Salmonella</i>	Serotype	Serving	Portion	Cumulative	Serotype	Virulence	Outputs
0	-7.06	4,144,844	0	3	Reading	25	0	0			Serving, g
1	-8.35	4,144,844	0	0		50	0	0			325
0	-8.18	4,144,844	0	0		75	0	0			Number
1	-6.74	4,144,844	0	0		100	0	0			3
0	-7.26	4,144,844	0	0		125	0	0			Virulence
0	-7.37	4,144,844	0	2	Infantis	150	0	0			2.7
0	-6.64	4,144,844	0	1	Infantis	175	0	0			Prevalence
0	-6.64	4,144,844	0	0		200	0	0			1
0	-6.69	4,144,844	0	0		225	0	0			
0	-5.92	4,144,844	0	0		250	0	0			
0	-5.42	4,144,844	0	0		275	0	0			
1	-6.12	4,144,844	3	0		300	0	0			
1	-5.32	4,144,844	19	3	Reading	325	3	3	Reading	2.700	

Discrete({0,1},{85,15})

Pert(-8.4,-7.4,-4.4)

Pert(4.4,6.4,8.4)



Consumption

Dose-Response

Disease Triangle, Dose-Response Model

Food (F) + Host (H) + Pathogen (P) = Disease Triangle Score (DTS) → Illness Dose (ID)

Severity of Response (SR) from <i>Salmonella</i>					
F	H	P	DTS	ID	SR
2.5	4.4	4.7	11.6	1.44	0.402301177
1.0	2.0			0.72	← minimum
1.8	3.5			1.72	← median
2.5	5.0			2.72	← maximum

$$= 0 + (12.5 - \text{DTS}) * 0.8$$

$$= 1 + (12.5 - \text{DTS}) * 0.8$$

$$= 2 + (12.5 - \text{DTS}) * 0.8$$

SR = 0 if dose = 0
SR = dose/ 10^{ID} if dose > 0

Total severity of response per lot = Σ SR

Infection

Illness

0

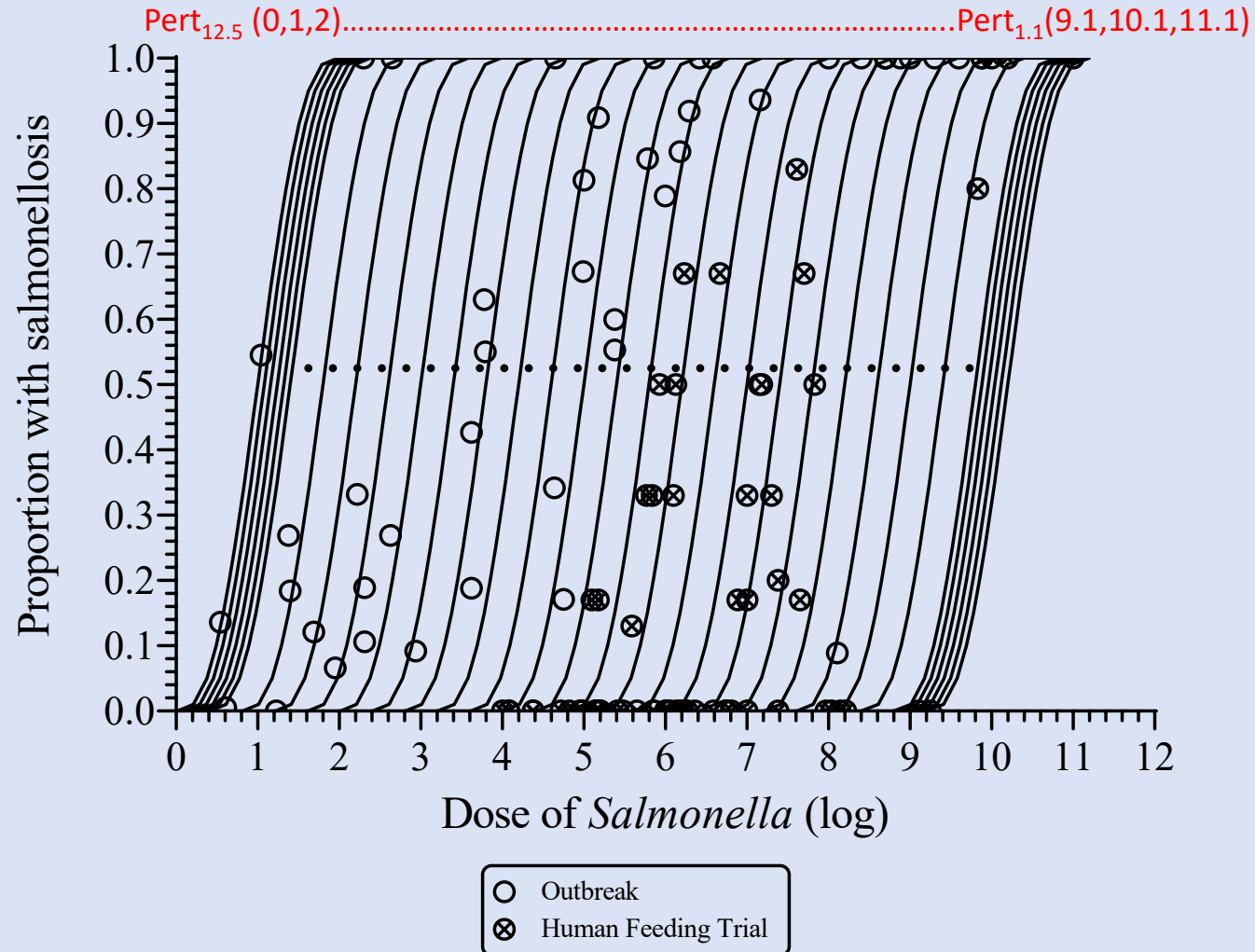
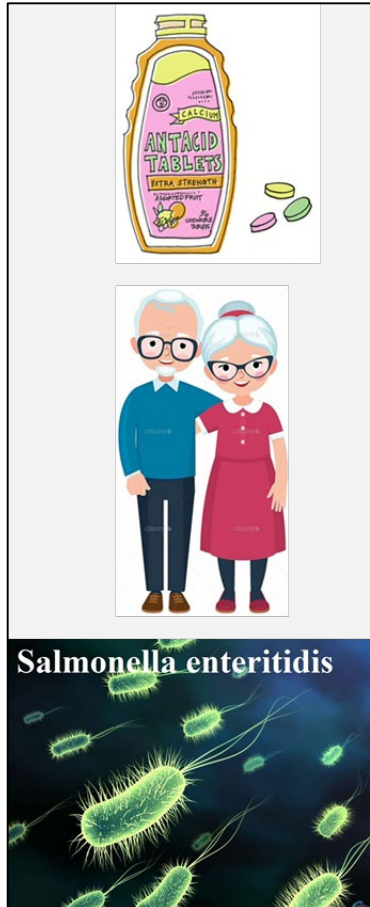
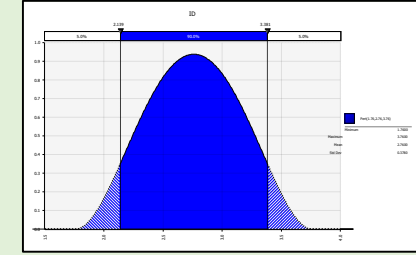
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Increasing severity of response

115 Pert Distributions for Illness Dose

Disease Triangle Score = 12.5 to 1.1 in 0.1 increments

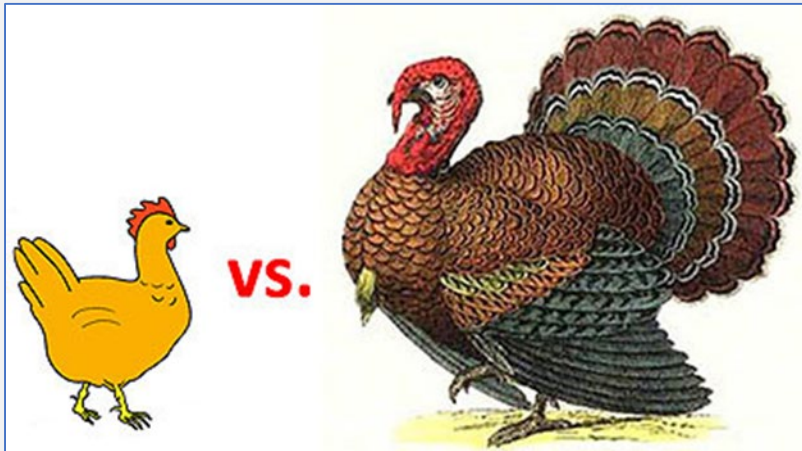


Scenario Analysis

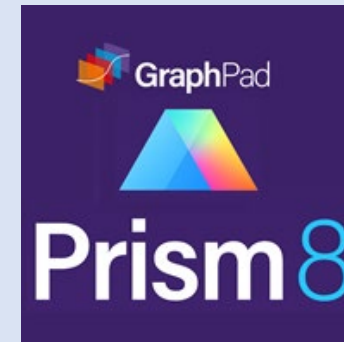
Ground Chicken vs Ground Turkey



- Design (4 x 2 full factorial)
 - Serving size
 - 25, 125, 225, or 325 g
 - Type of ground poultry meat
 - turkey or chicken



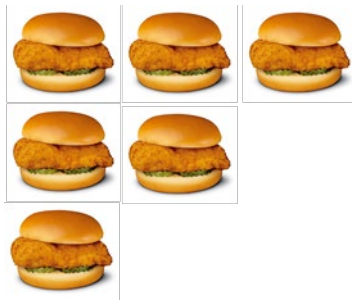
- Statistical Analysis
 - Two-way ANOVA ($P < 0.05$)
 - Tukey's multiple comparison test ($P < 0.05$)



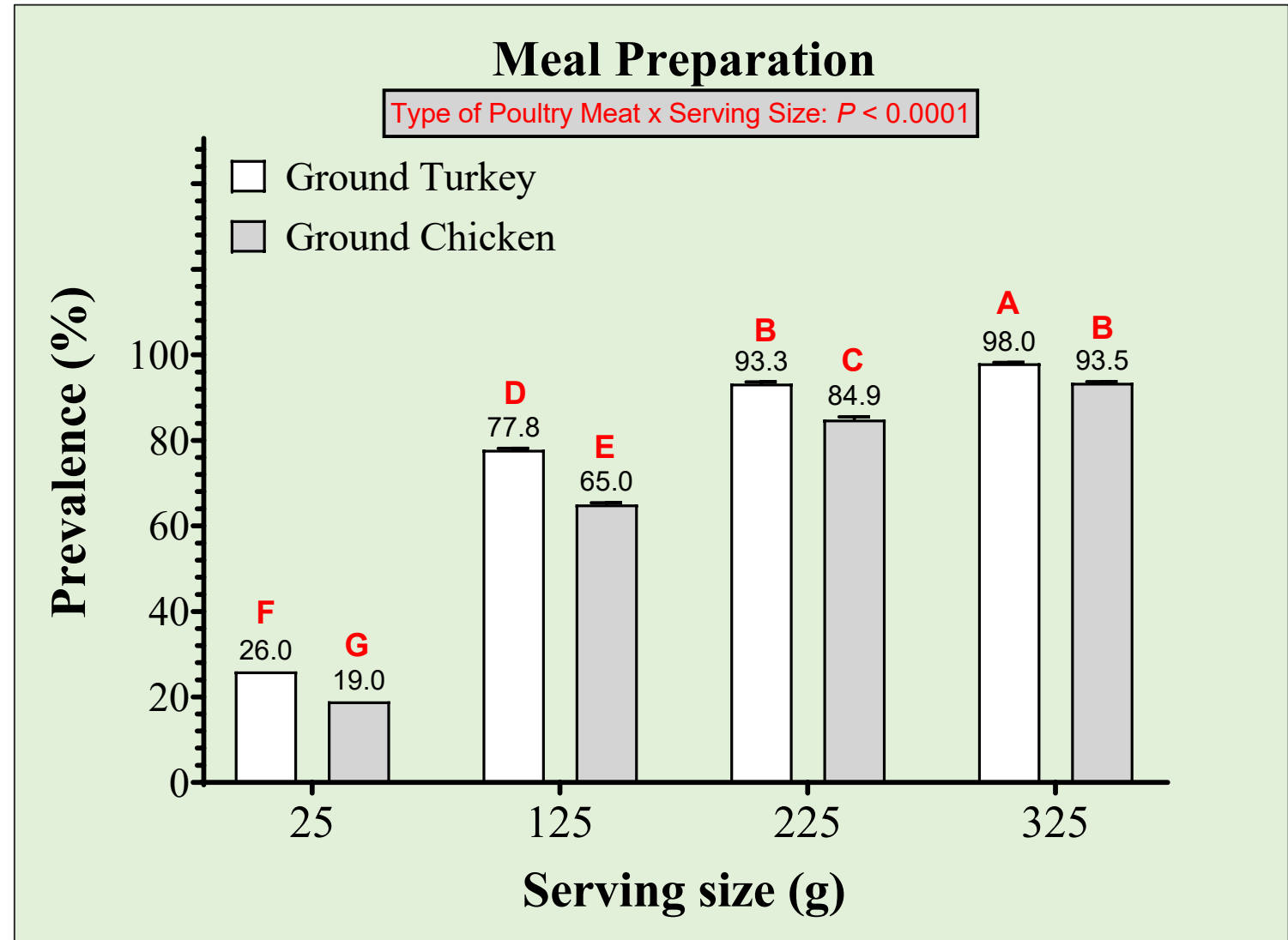


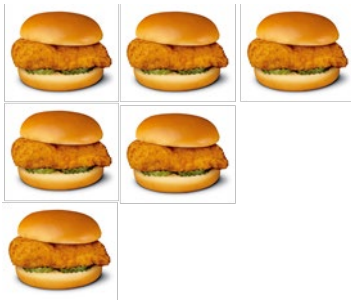
Simulation Settings

- Latin Hypercube sampling
- 10 simulations
- 10 different random number generator seeds
- Lot size = 2,000 lbs or 907 kg
- Iterations
 - 36,280 for 25 g
 - 7,256 for 125 g
 - 4,031 for 225 g
 - 2,791 for 325 g

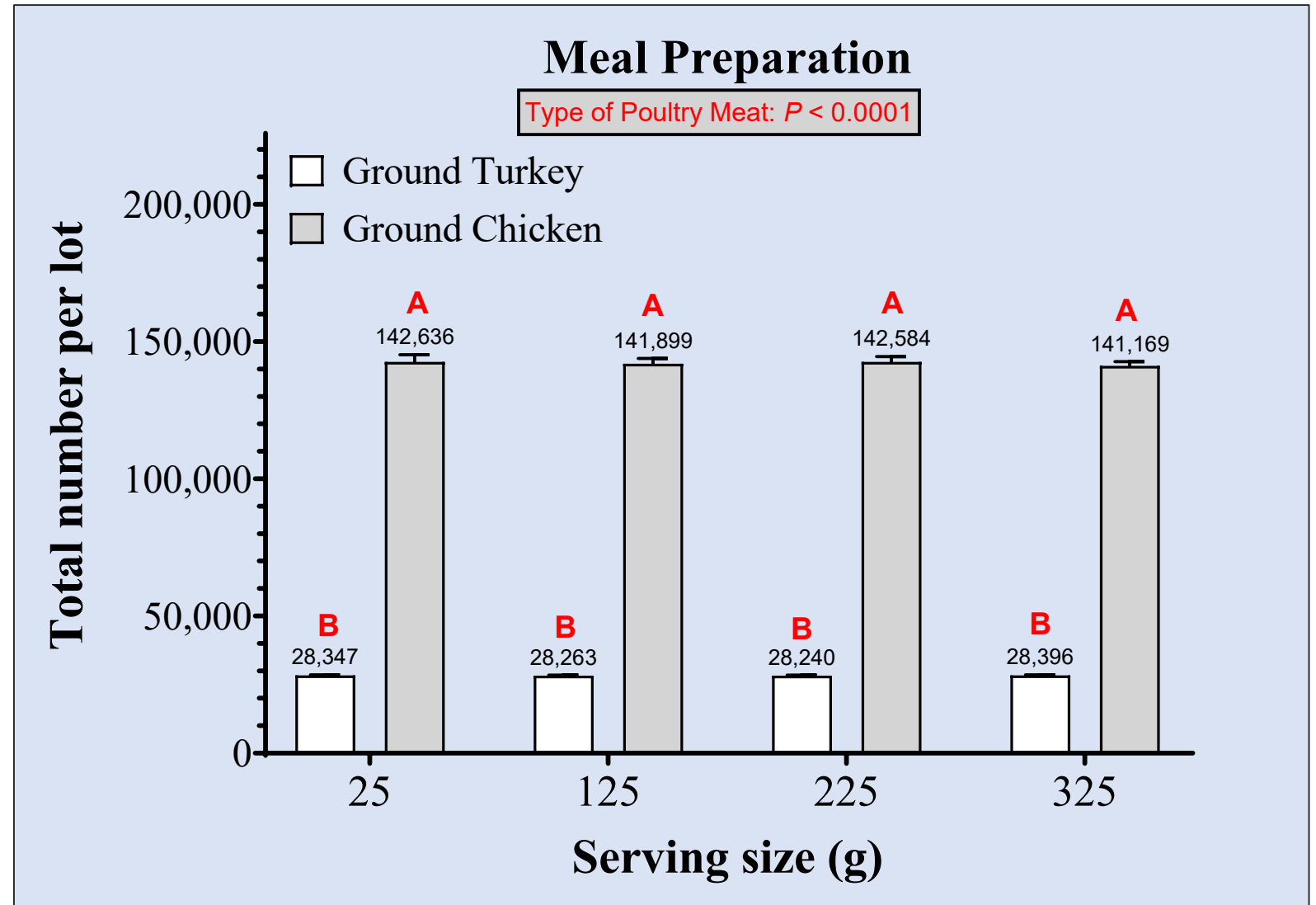


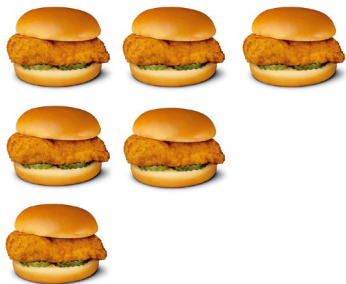
Salmonella
Prevalence per
Lot



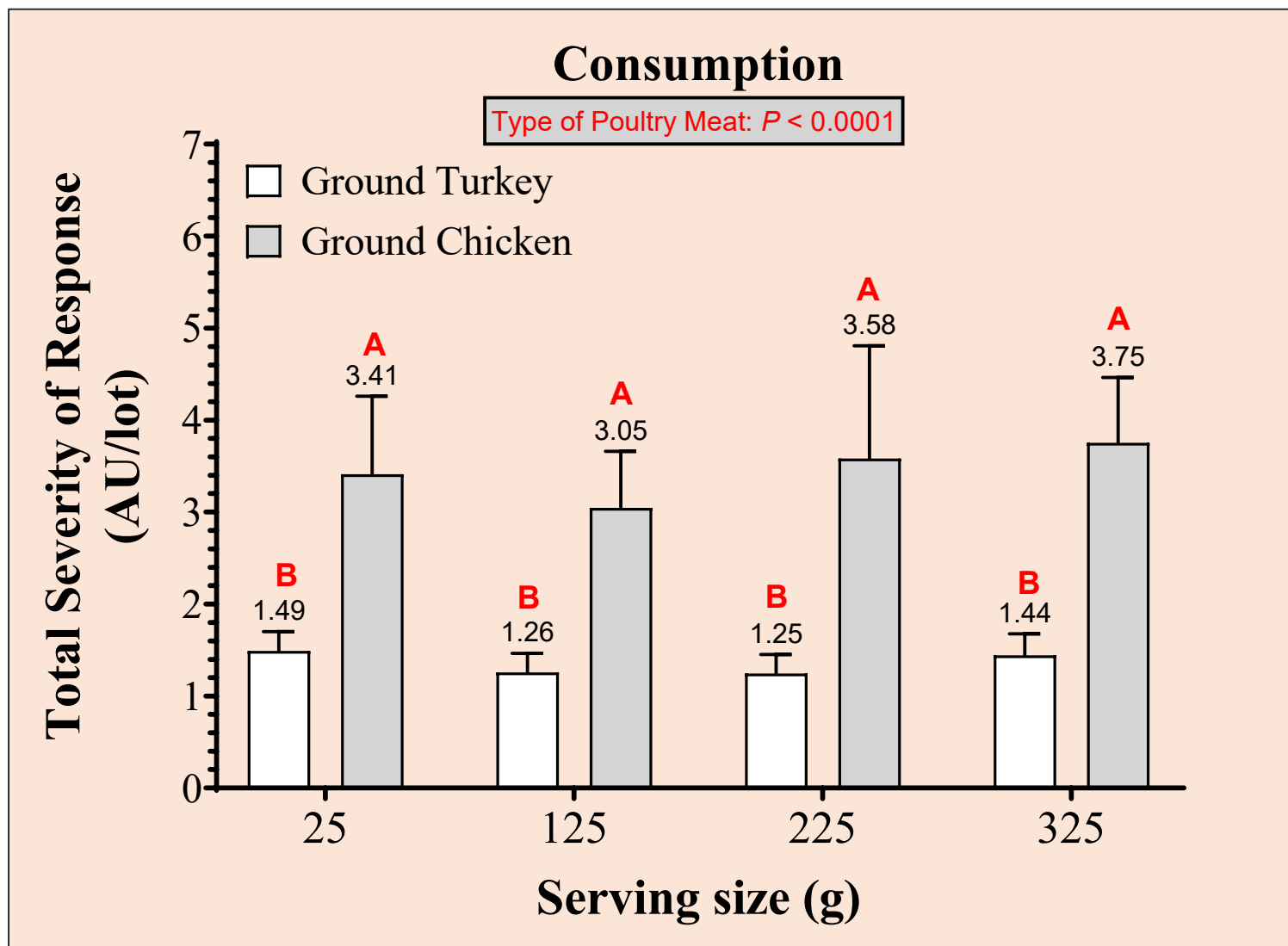


Salmonella
Total Number
per Lot



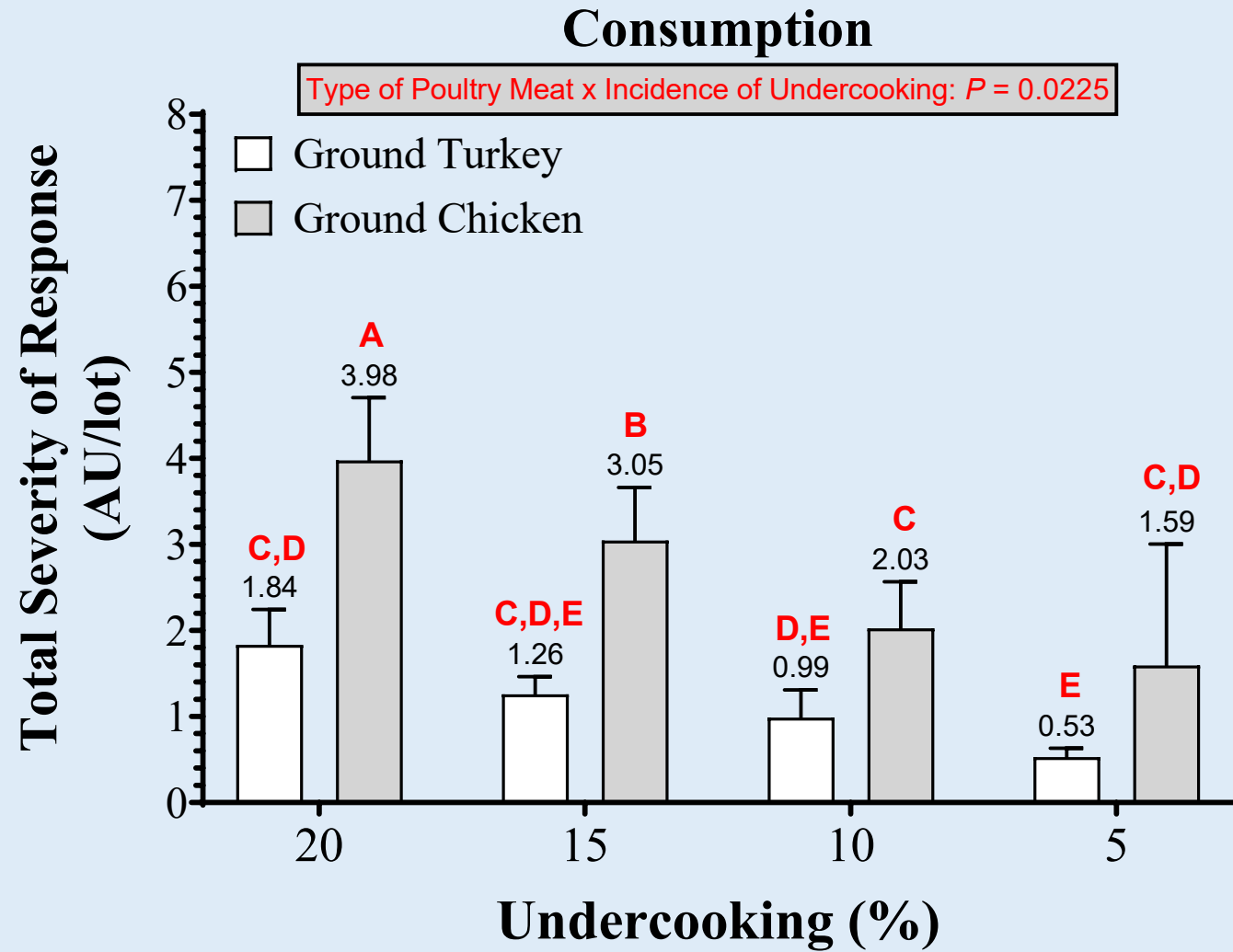


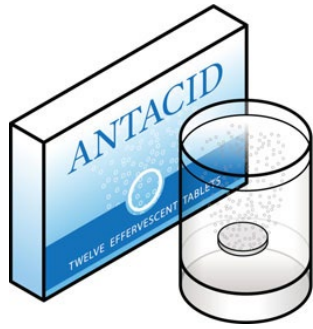
Salmonella
Total Severity
per Lot



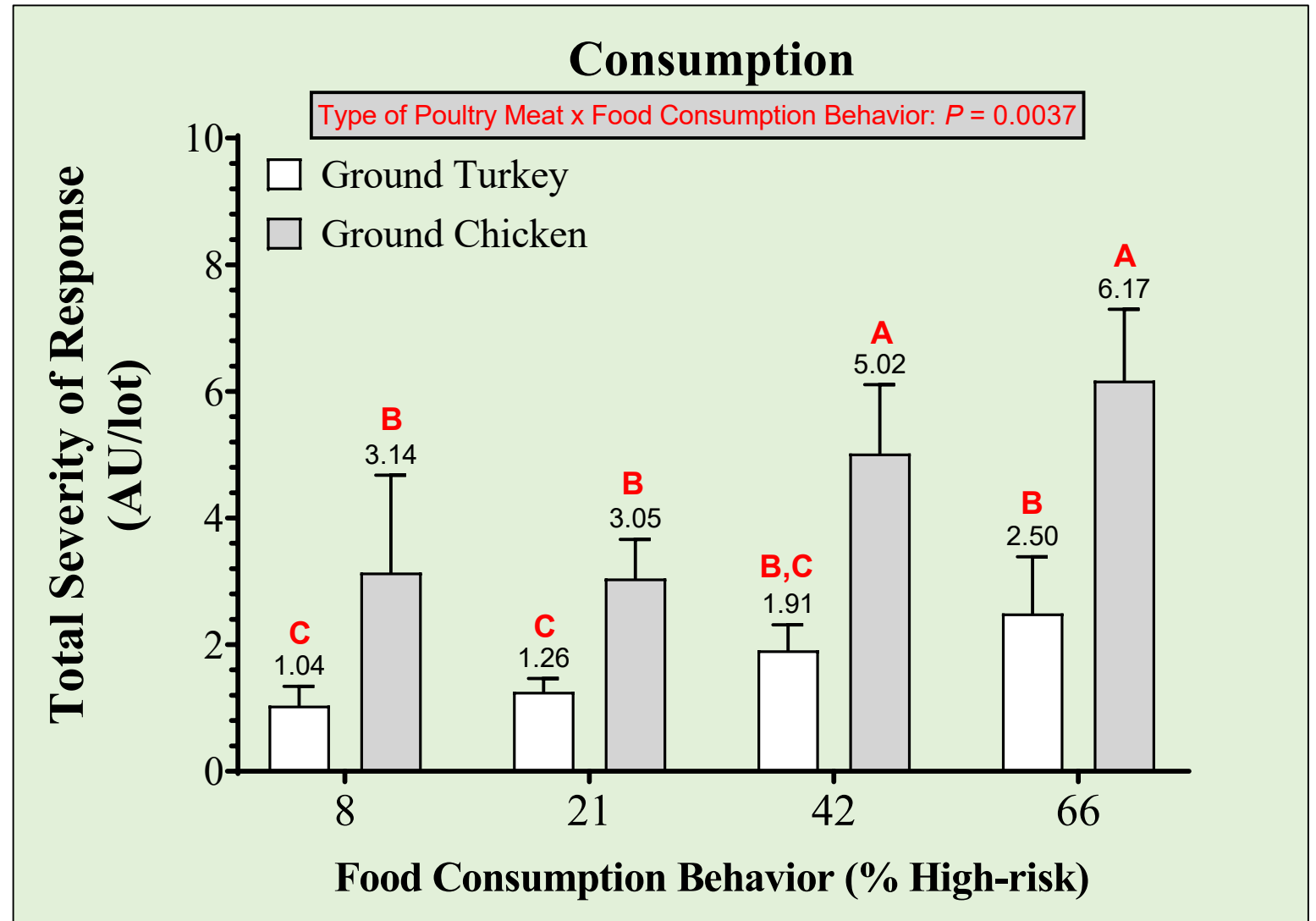


Salmonella
Total Severity
per Lot



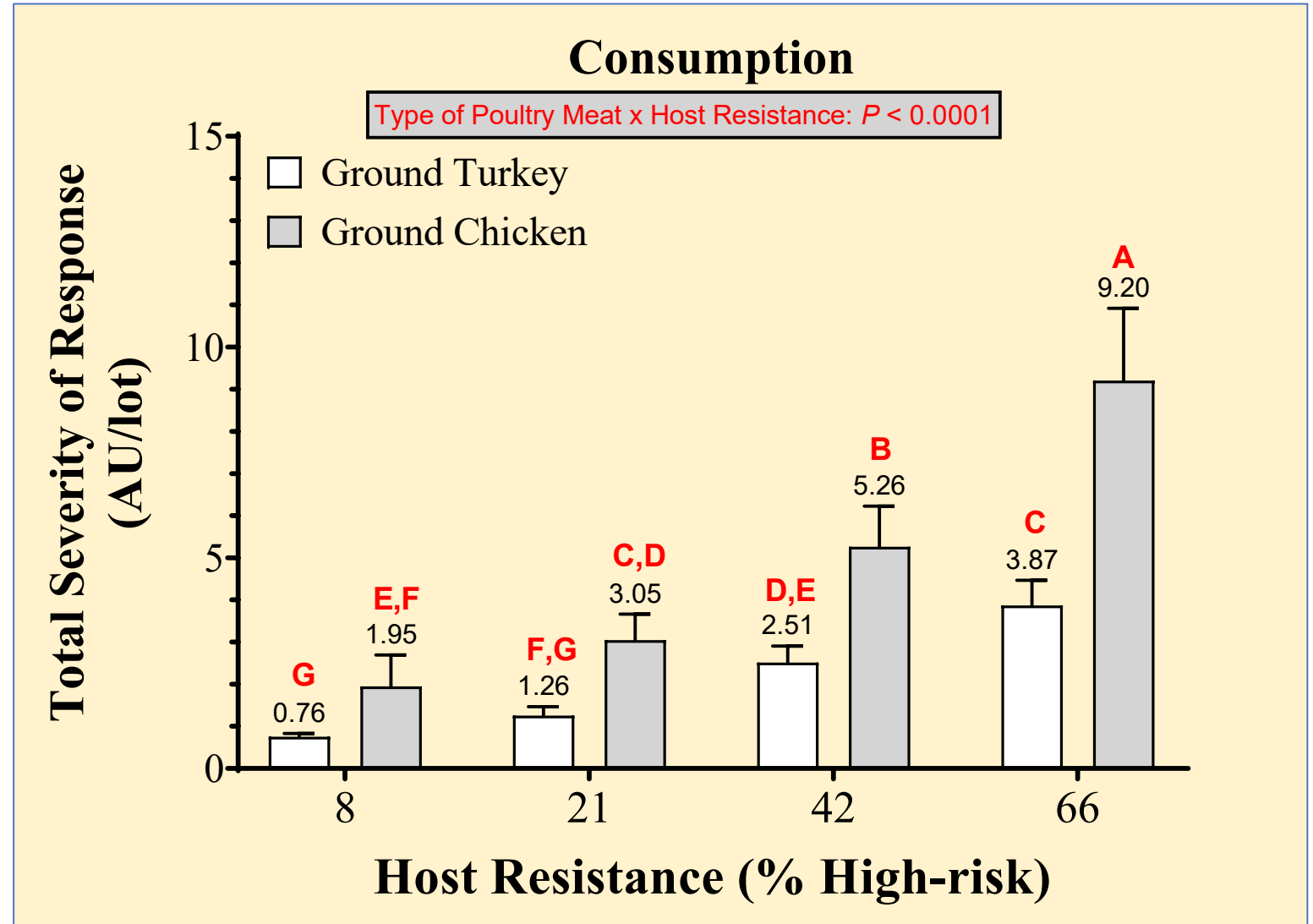


Salmonella
Total Severity
per Lot





Salmonella
Total Severity
per Lot



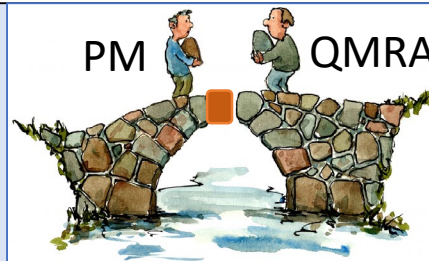
What could we do that we are not doing yet regarding predictive microbiology (PM) and QMRA approaches to food safety?

prevalence
number
virulence



undercooking
food consumption behavior
host resistance

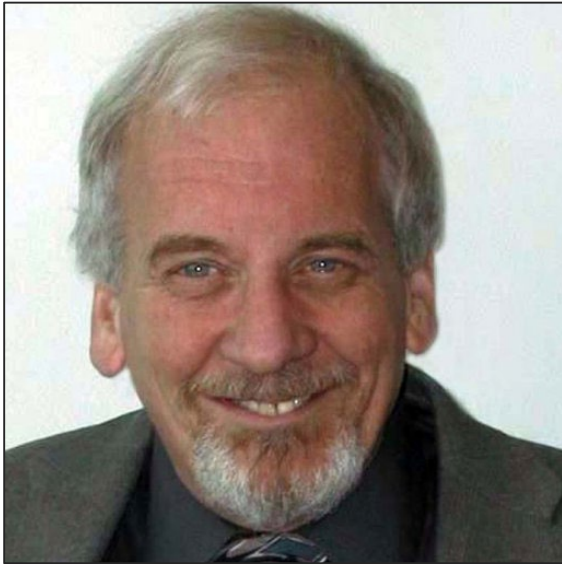
Food Safety (↓ dose)



Public Health (↓ response)

Congratulations Bob on your retirement and for all that you did to establish USDA, ARS as a leader in predictive microbiology and risk assessment!

Best Wishes,
Vijay and Tom



Thank you!

