# Citrus Products and Their Use against Bacteria: Potential Health and Cost Benefits

Todd R. Callaway

Agricultural Research Service/USDA

Food and Feed Safety Research Unit

College Station, TX

# Public perception


# Reality

- Both the EU and U.S. have a VERY safe food supply, but it is still a focus of concern
  - Committed to smart, science-based regulations in future to improve food safety
- In spite of this commitment, too many food borne illnesses still occur
  - Many linked to meat consumption, produce contaminated by animals (or feces) or direct/indirect animal contact

# There is still much to do

- 27% of U.S. population gets foodborne illness each year
- Primary FBP bacteria of economic importance in US direct/indirect (cases) {US$ cost in billions}
  - *Campylobacter* (2.1 million) {18.8}
  - *Salmonella* (1.6 million) {14.6}
  - *Escherichia coli* O157:H7 (67,000) {1}
  - *E. coli* (EHEC) (5,000) {0.07}
  - *Listeria monocytogenes* (5,200) {8.8}
  - Total for top 5 bacteria 3.8 million **$43.3 Bln**
- Total estimated cost (direct and indirect) of food borne illness in the US exceeds $150 billion per year (Scharff, 2010)

# Pathogens in the food supply

- Many foodborne pathogenic bacteria can live in food animals, without causing illnesses
  - *Campylobacter* — Cattle, swine and poultry
  - *Salmonella* — Cattle, swine and poultry
  - EHEC (including O157:H7) — Cattle and some swine
  - *Listeria monocytogenes* — Cattle, swine and poultry
- Depending on season as many as 0-40% of cattle may be positive for EHEC
- 20% of commercial swine may carry *Salmonella*
  - Many predominant serotypes afflicting humans in poultry and swine
- 80-100% of broilers may carry *Campylobacter*

# Why worry about pathogens before harvest?

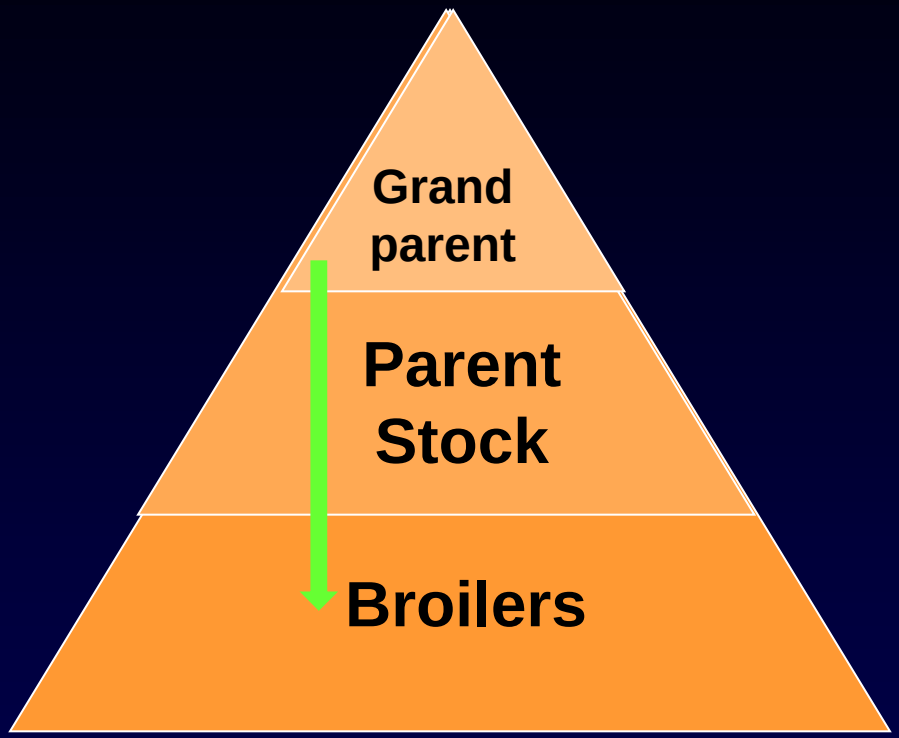
- What benefits are there?
  - Food Safety (Reduced pathogen burden)
    - Cross contamination of carcasses and foods
    - Increased in-plant effectiveness
  - Water Issues
    - Horizontal spread via irrigation and run-off
      - Spinach outbreak, 2006
      - Environmental contamination
  - Agricultural Fair/Open Farms (Petting zoo)/Farm worker safety (Keen et al., 2003)
    - Dust from cattle and O157:H7 outbreak

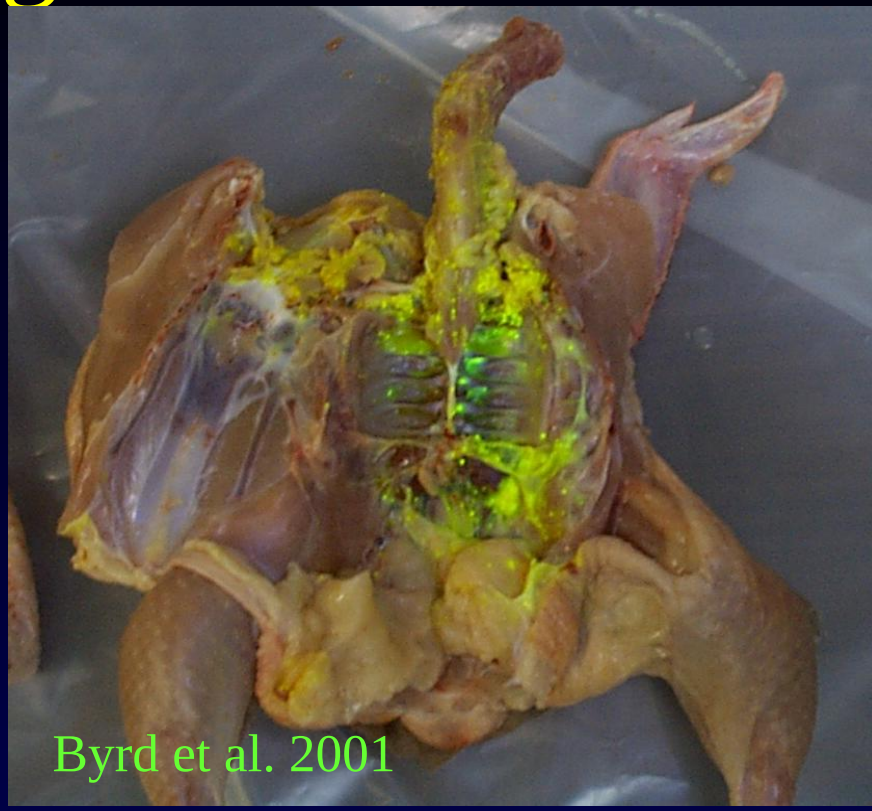

MIKE LUCKOVICH
ATLANTA JOURNAL-CONSTITUTION
AJC. Com 6-12-03
HE LOVES THE PETTING ZOO....
NEWS
ANIMAL TO HUMAN DISEASE

# Improving food safety and animal health

- Improving animal health and productivity has always been focused on the farm
- Focus on food safety "From Farm to Fork"
  - Can improve animal health through reduction in pathogens, or stimulation of immune system
  - Treatments must be feasible and applicable across large numbers of animals to reduce morbidity and mortality and need for Ab
  - Pre-harvest interventions (economic feasibility)

# Challenges




- Vertical spread between generations
- Horizontal Spread
  - 5% positive at hatch can be 95% positive within 3 weeks
  - Sometimes burst in processing, spread to subsequent carcasses

# Challenges to animal industry

- Growth performance is inefficient
  - Especially in ruminants
- Pathogenic bacteria can affect animal health and production efficiency
  - *E. coli* of some form causes disease in all food animals
- Foodborne pathogens can live undetected in all food animal species
  - Cattle, swine, poultry
  - *Campylobacter*, *Salmonella*, EHEC, *Listeria*

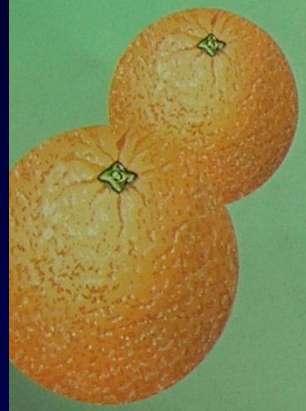
# Pre-harvest Intervention strategies

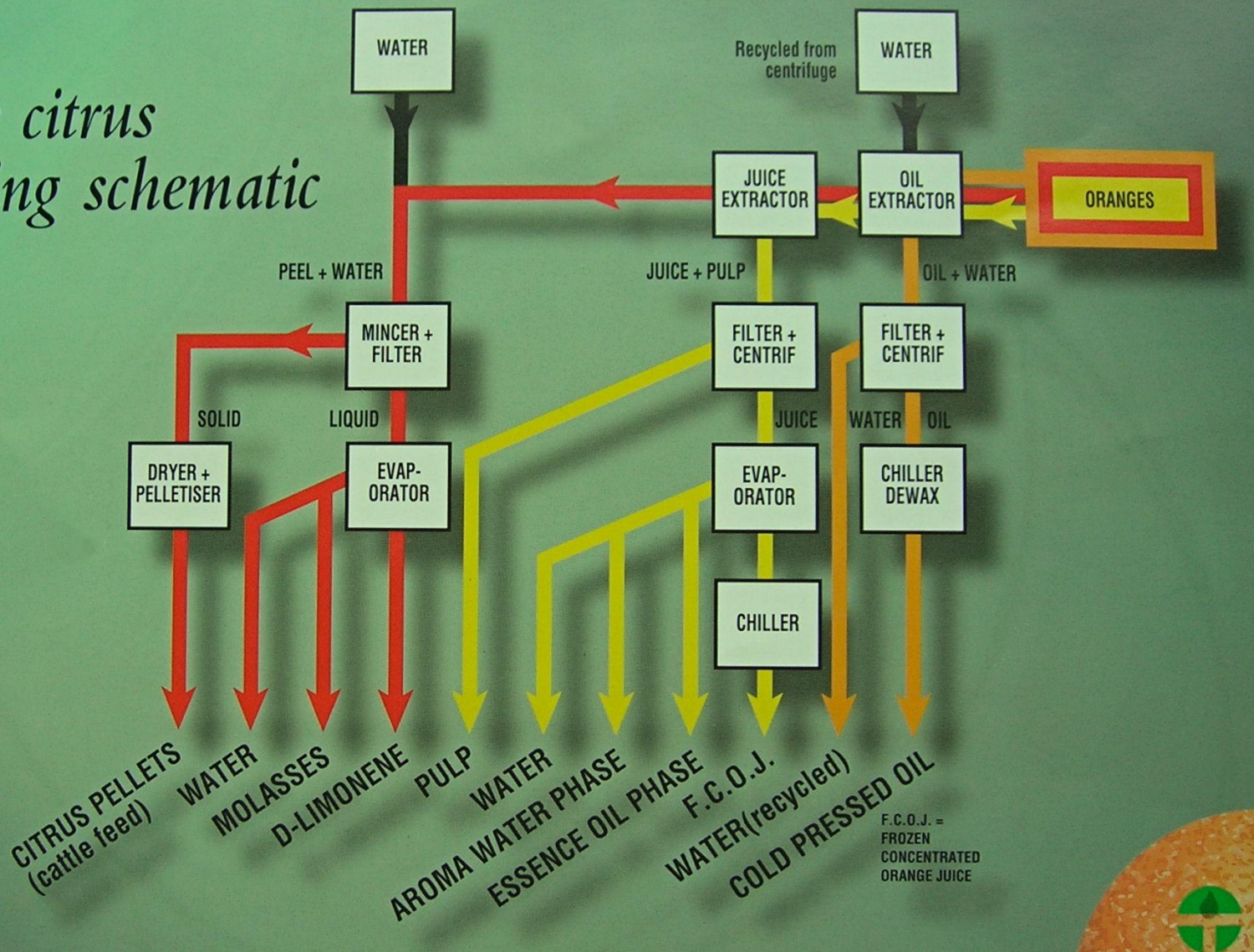
- Anti-Pathogen Strategies
  - *Antibiotics*
  - *Bacteriophage*
  - *Specific inhibition of metabolic pathways*
  - Immunization
- Competitive Advantage Strategies
  - *Competitive exclusion*
  - *Probiotics (Direct-fed microbials)*
  - *Prebiotics*
- Management factors
  - ***Diet (including phytochemicals and organic acids)***
  - Water troughs
  - *Other management factors*

# Dried orange peel/pulp

- Common by-product of orange juice production (disposal is at times problematic)
- Competitively prices into least-cost ration formulation
- Used widely in dairy and feedlot rations in Florida and Southern California
  - Raw orange peel
  - Citrus pulp
  - Citrus pellets (Dried orange peel and pulp)

# *Orange citrus processing schematic*






TREATT PLC

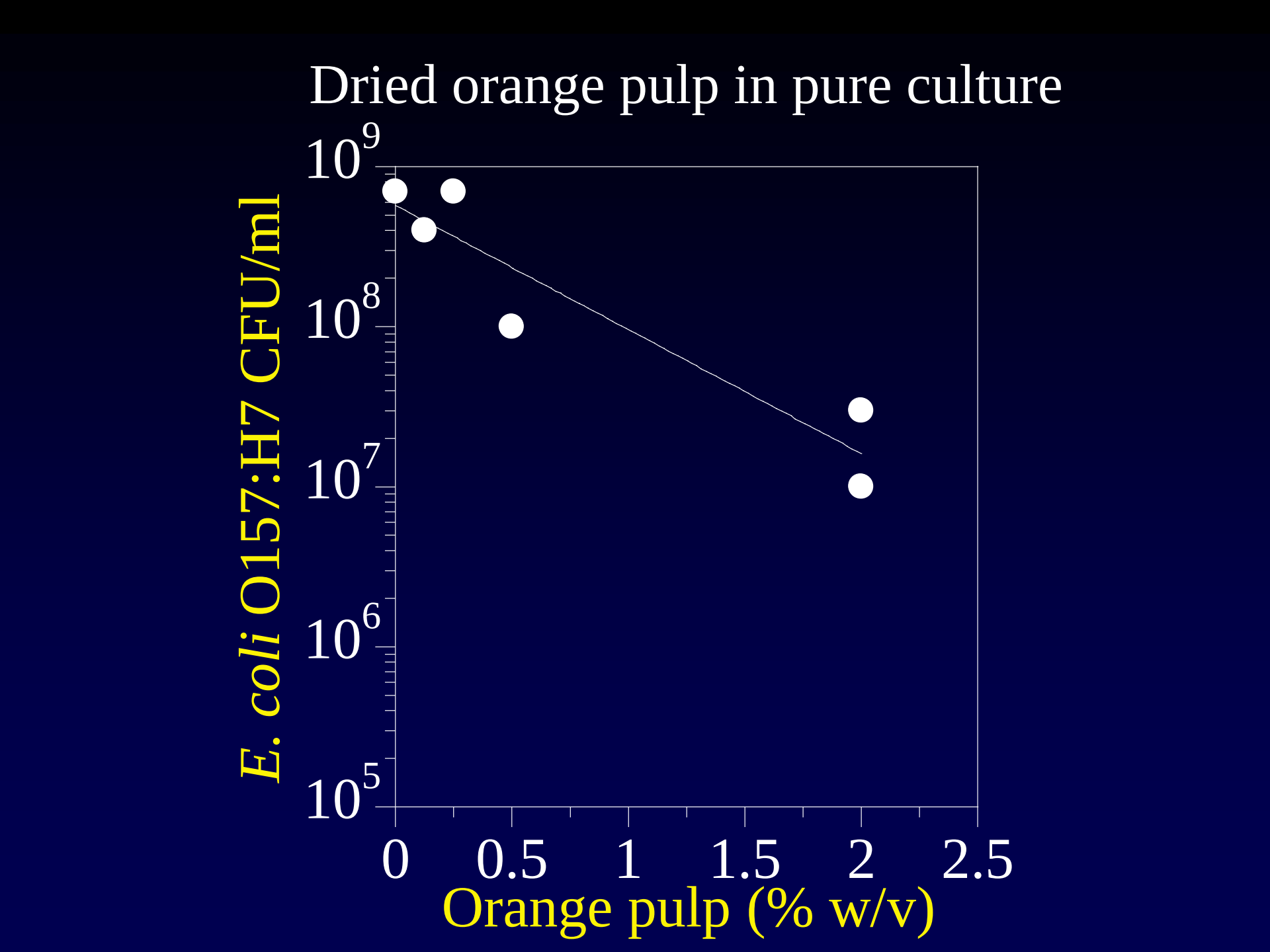
# Dried orange peel/pulp

- Orange oils (e.g., limonene) improve animal health and productivity (esp. in swine)
  - Orange-oil containing products have antibacterial activity against *E. coli* and *Salmonella* spp. (Nannapaneni et al., 2008)
  - Terpeneless fraction contains most activity (Nannapaneni et al., 2008)
- Source of pectin and fermentable fiber to ruminal microbial population
  - 9% CP, TDN 82%, DE 1.64, $NE_m$ 0.88, and $NE_g$ 0.59 Mcal/lb (CSU)

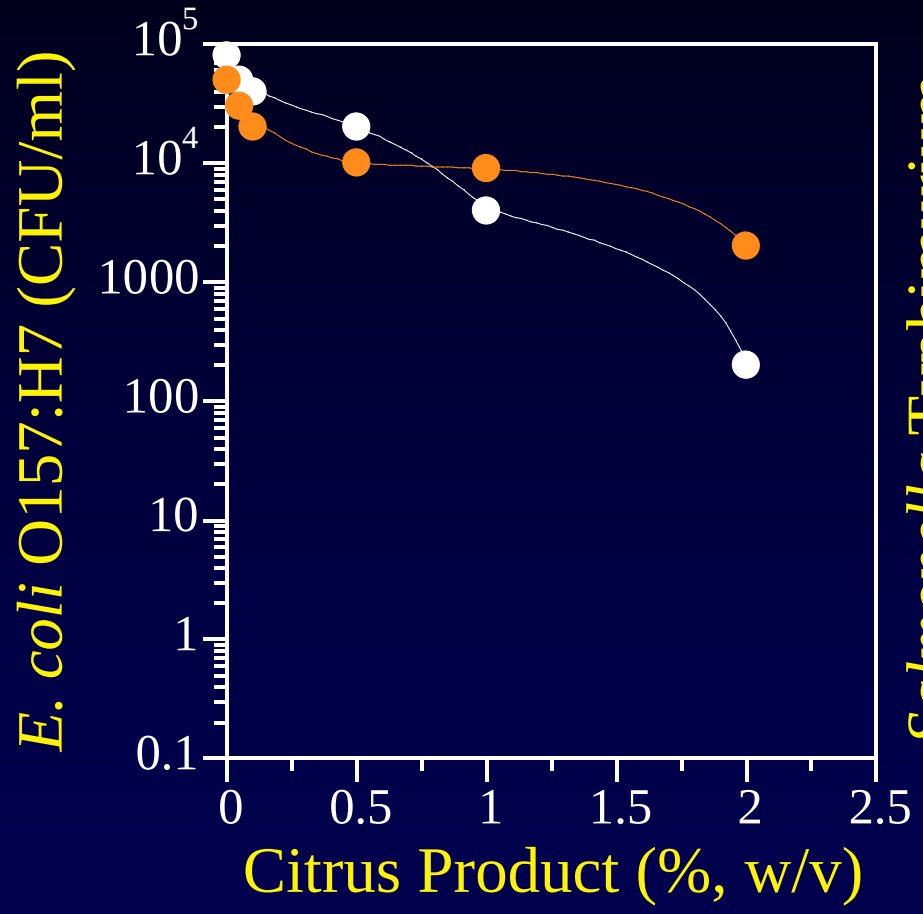
# Objectives

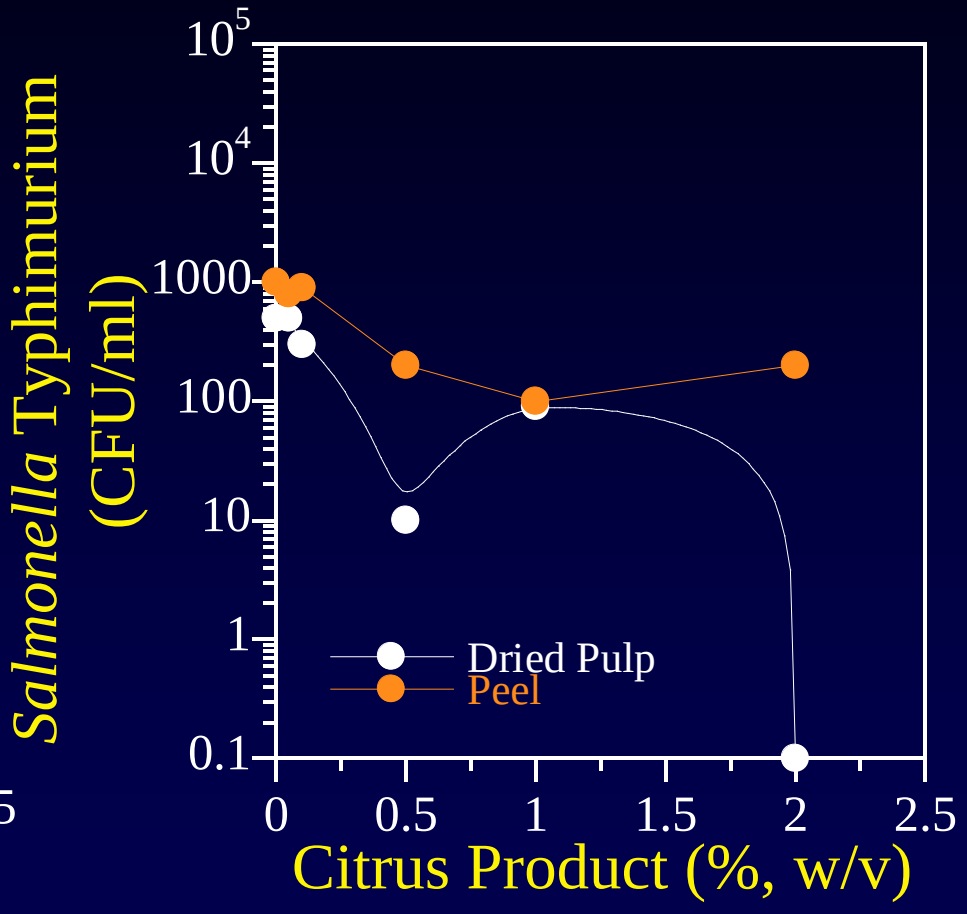
- Diet has an effect on intestinal microbial populations, including EHEC O157:H7
  - Direct and indirect effects, forage ratios
- Orange peel and dried orange pulp are fed to cattle
- Determine the effectiveness as feedstuffs of orange peel and pulp that are by-product from orange juice extractions on:
  - FBP in vitro
  - gastrointestinal populations of *Salmonella* and *E. coli* O157:H7, using sheep as a model for the gut of cattle
  - Gastrointestinal populations of diarrheagenic *E. coli* in swine

# *In vitro* studies


Dried orange pulp in pure culture
$10^9$
$10^8$
$10^7$
$10^6$
$10^5$
*E. coli* O157:H7 CFU/ml
0
0.5
1
1.5
2
2.5
Orange pulp (% w/v)

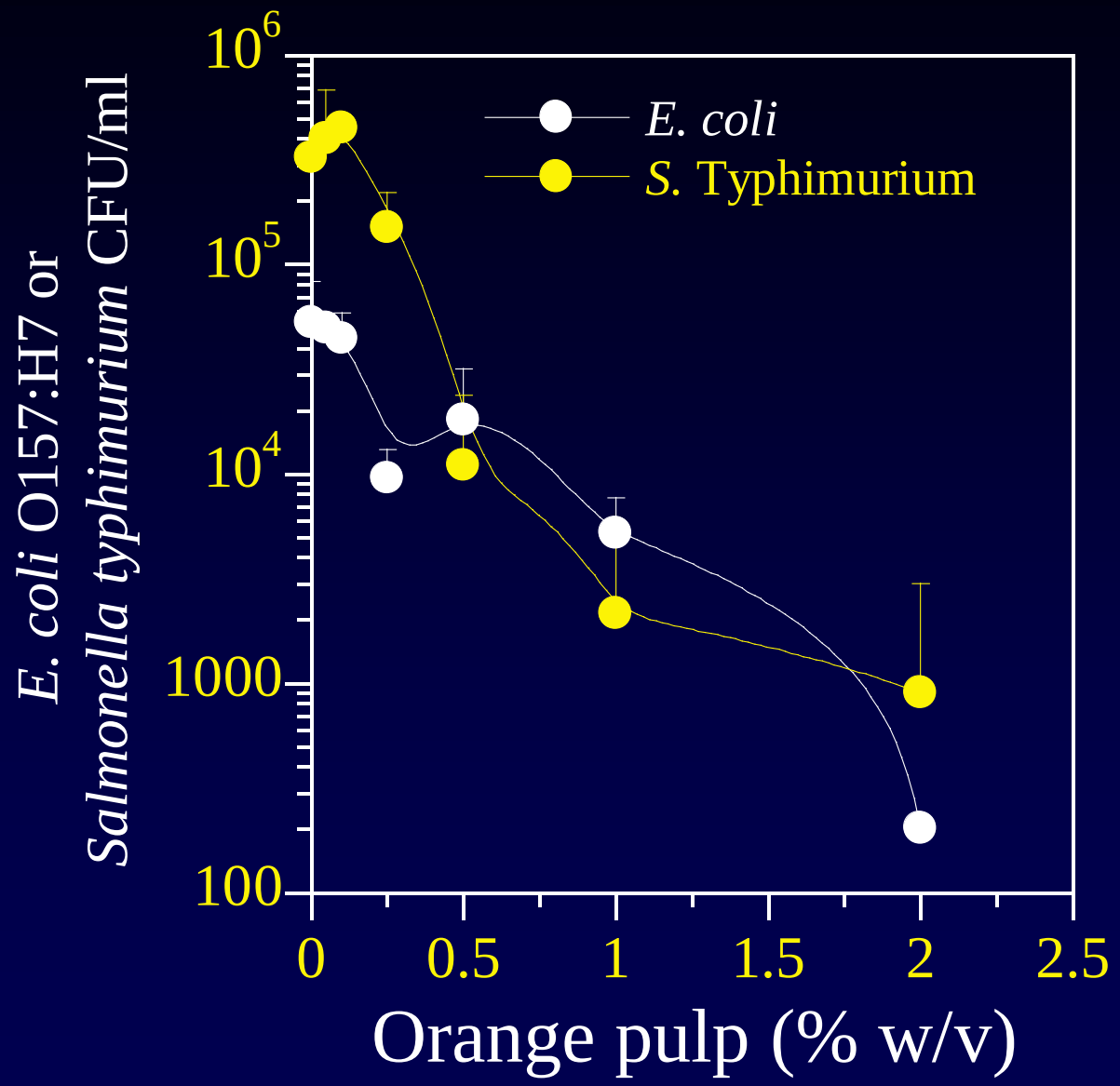
# Orange peel versus dried orange pulp (rumen fluid)



# Results

- In ruminal fluid in vitro fermentations addition of dried orange pulp reduced pathogen populations



# Other Results

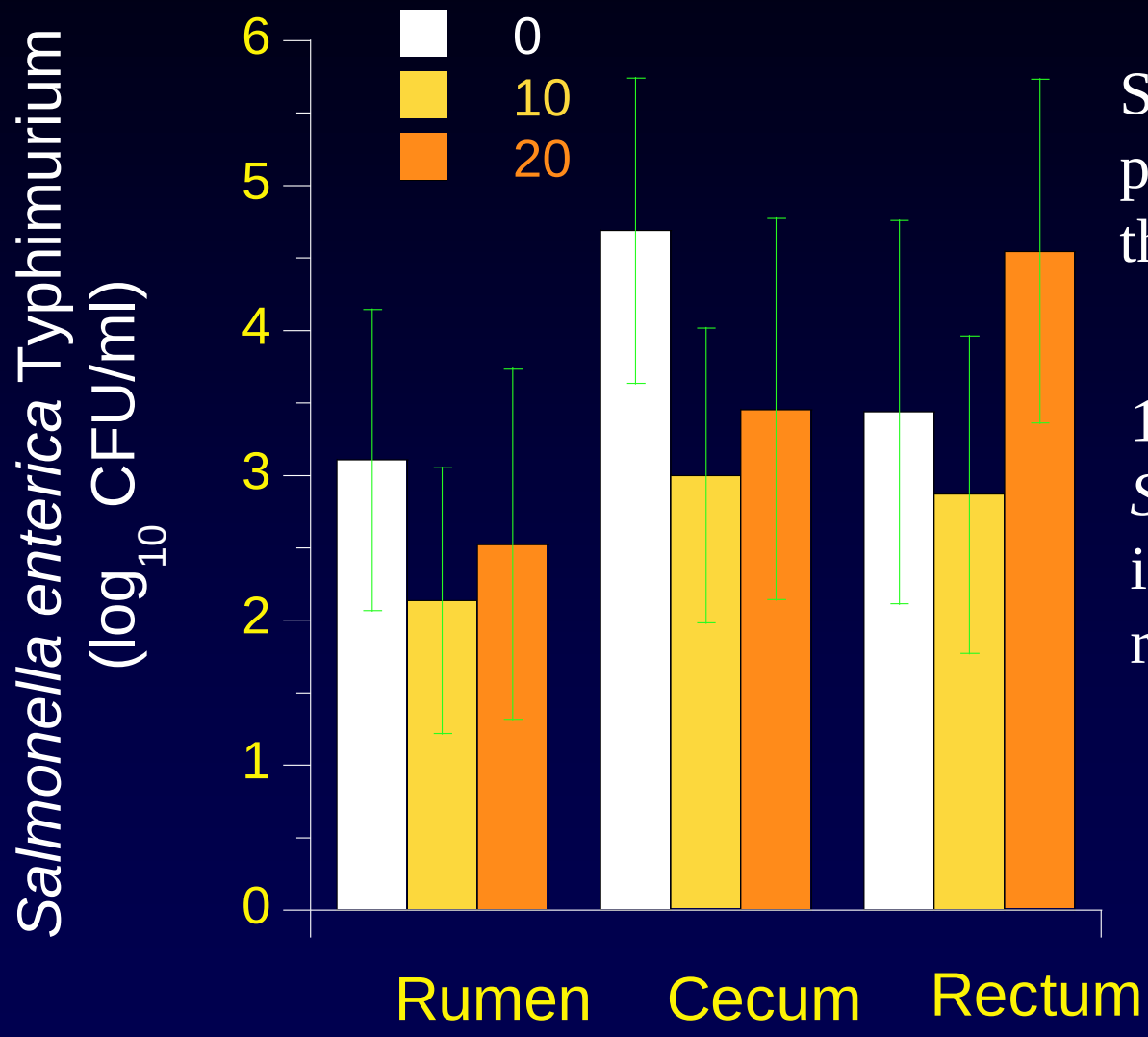
- Final pH was not affected
- TVFA production not affected
- A:P ratio not altered
  - Energetic marker for efficiency of ruminal fermentation efficiency from animal perspective

# *In vivo* studies

Effects on foodborne pathogen populations within the gut of ruminants

# Design

- Sheep (n = 24) were fed feedlot rations with 0, 10 or 20% of diet replaced with dried orange pellets for 14 d
- Sheep were orally inoculated with $10^9$ CFU *Salmonella* Typhimurium
- Tissues were collected 96 hr after inoculation and quantified

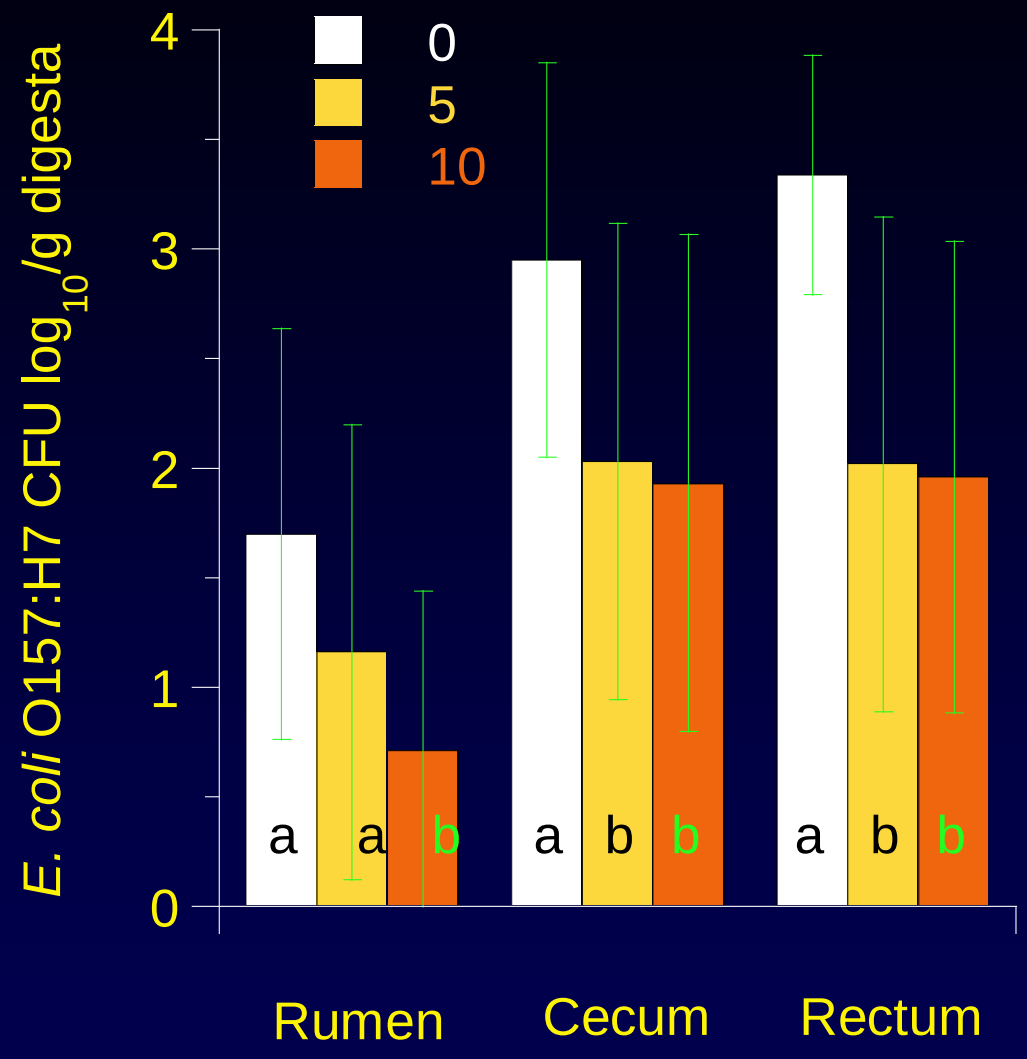



Sheep fed 20% orange peel consumed less peel than did sheep fed 10%

10% OP reduced *Salmonella* populations in rumen, cecum and rectum

# Design

- Sheep (n = 24) were fed feedlot rations with 0, 5 or 10% of diet replaced with dried orange pellets for 14 d
- Sheep were orally inoculated with $10^9$ CFU *Salmonella* Typhimurium
- Tissues were collected 96 hr after inoculation and quantified




5 and 10% OP reduced *E. coli* O157:H7 populations in rumen, cecum and rectum

P < 0.05 indicated by different letters within each tissue

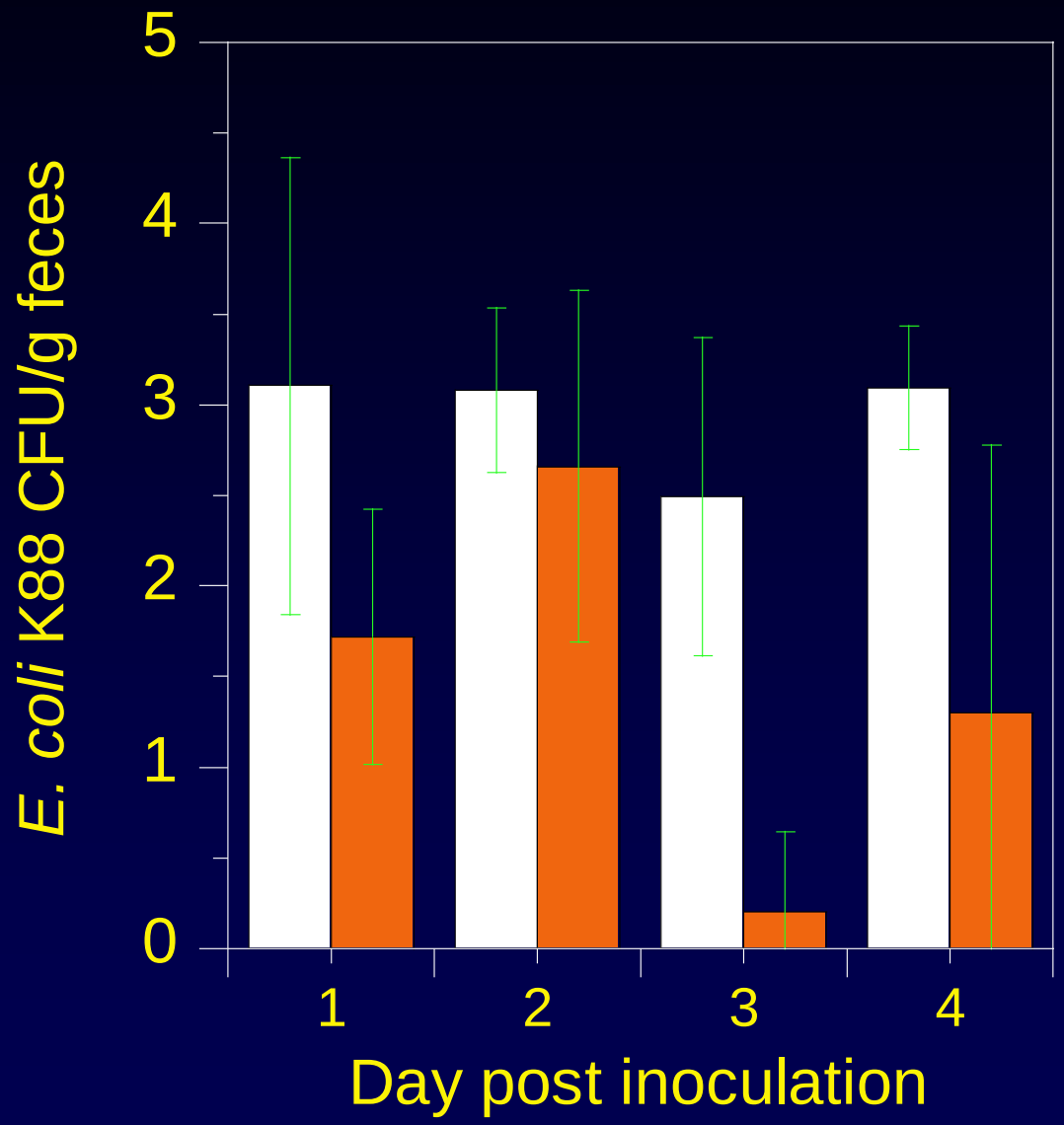
# *In vivo* studies

Effects on diarrheagenic bacterial populations within the gut of swine

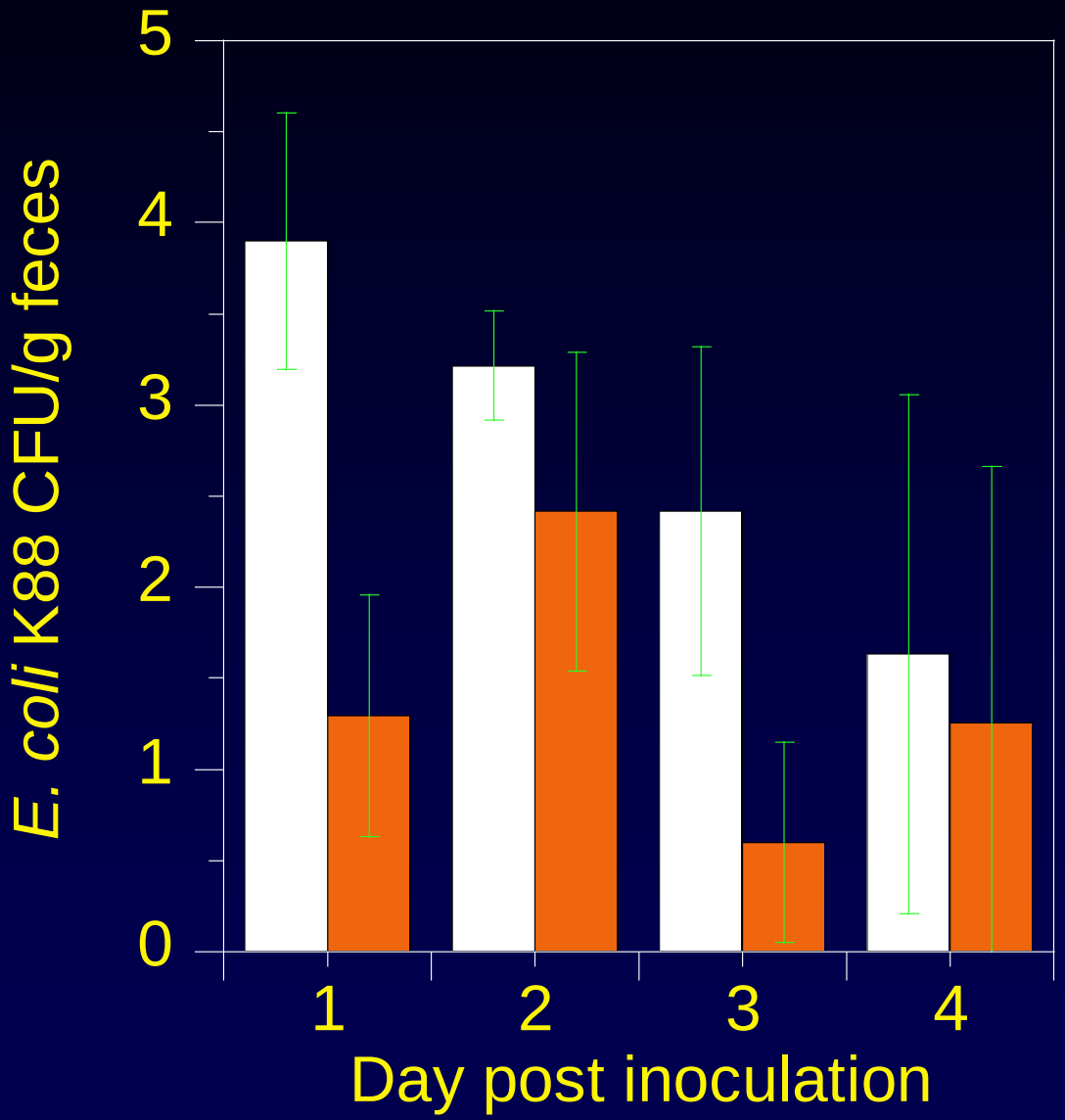
# Design

- Pigs (n = 36; 30 kg) were fed finishing rations with 0 or 10% of diet replaced with dried orange pellets for 28 d
- Swine were orally inoculated with $10^7$ CFU *E. coli* K88 (diarrheagenic)
  - PWECD strain, morbidity and mortality in weaned pigs
- Pigs were sacrificed (n = 5/trt) daily beginning 1 d after inoculation and populations enumerated (n =3/trt on d 4)

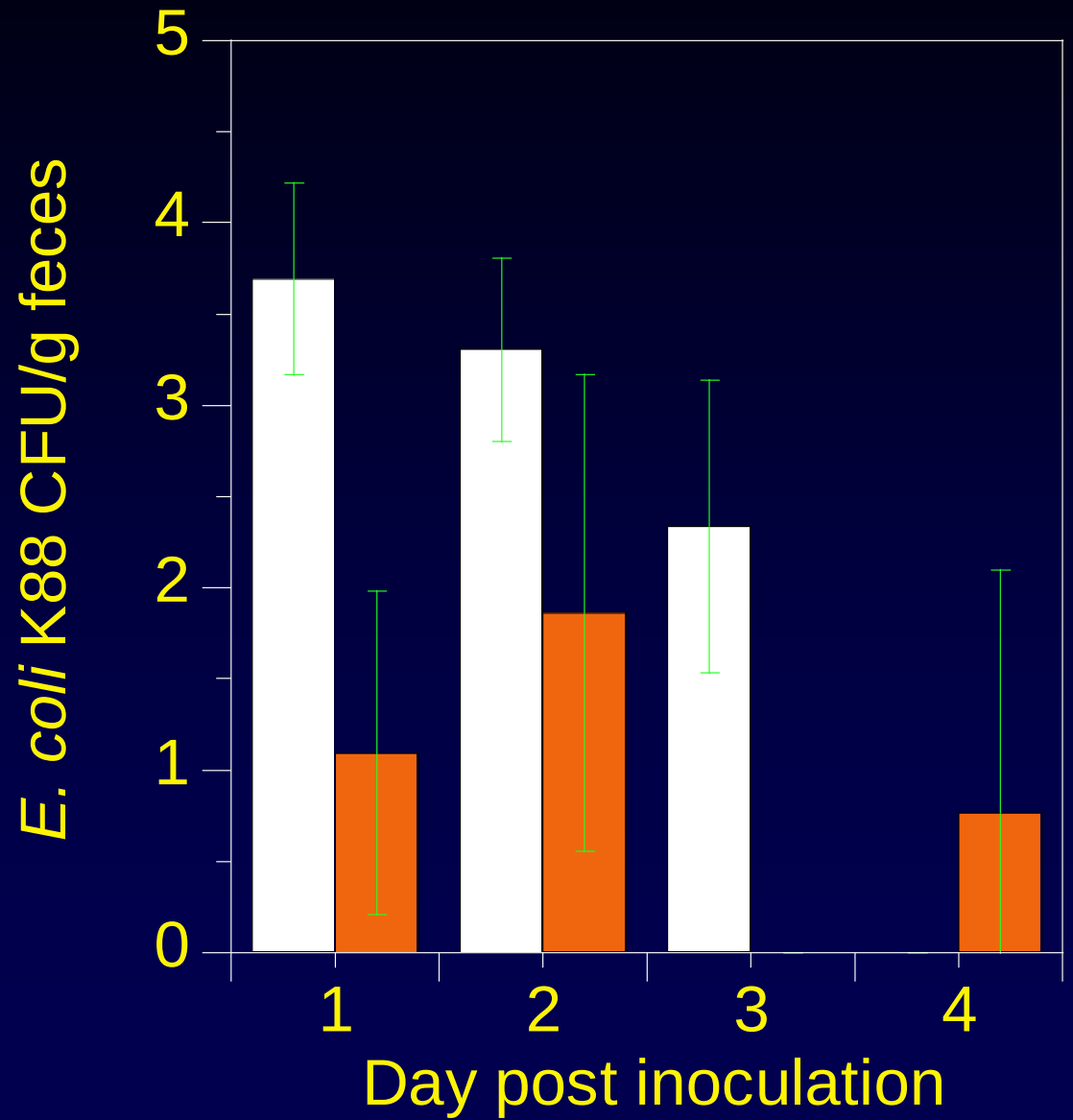
# Cecum



# Spiral Colon



# Rectum



# Application in Industry

- Orange peel and pulp is currently fed to cattle
  - No feeding restrictions, and cheap typically
  - Approximately $0.12/hd/d
  - There are some palatability considerations
- Reduces *Salmonella*, EHEC and *E. coli* in intestinal tract approximately 10-fold
  - Can improve animal productivity (reduce morbidity)
  - Stimulation of immune function

# Application in Industry

- Green, proactive approach that benefits consumers and producers
  - Simple, clear and logical to producers and consumers
  - Not a silver bullet
- Nutritional benefit to animals supplemented with “value added”
- Improves food and environmental safety and can enhance profitability for food animal producers