Six Years of Food Virology Research: The NoroCORE Project

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Scientific Director, USDA NIFA Food Virology Collaborative
Presentation to FDA Southeast Regional Meeting
October 17, 2017

NoroCORE Food Virology
Collaborative for Outreach, Research & Education

USDA
United States Department of Agriculture
National Institute of Food and Agriculture

NC STATE UNIVERSITY

The USDA-NIFA Food Virology Collaborative

- **Long Term Goal:** To reduce the burden of foodborne disease associated with viruses, particularly noroviruses
- **Approach:** Multi-disciplinary team working in an integrated manner to develop improved tools, skills, and capacity to understand and control foodborne virus risks
- **Objectives (Cores):**

  Molecular virology

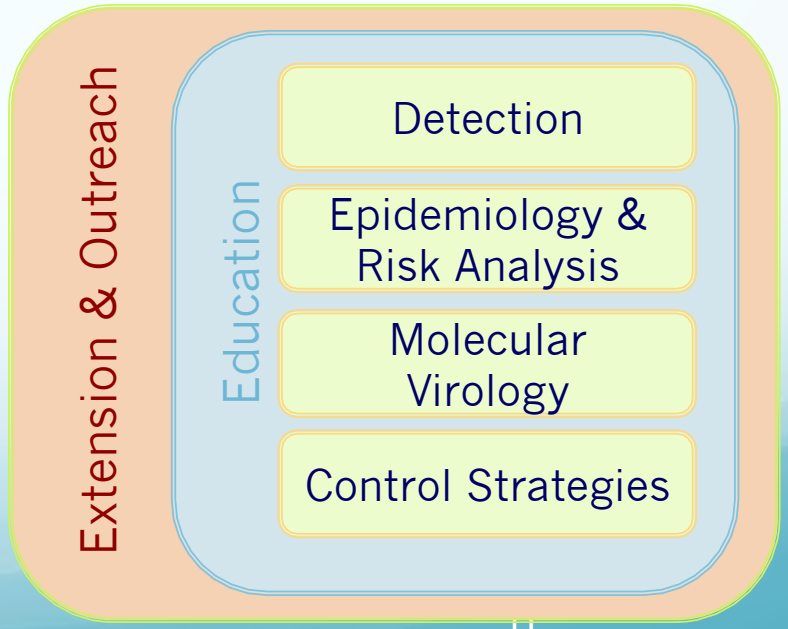
  Detection

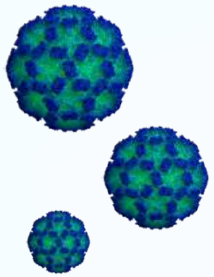
  Epidemiology and Risk Analysis

  Prevention and Control

  Extension and Outreach

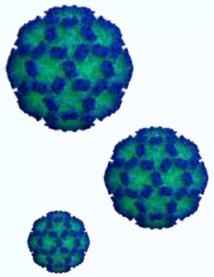
  Education and Capacity Building





Research Activities

- **Molecular Virology:** *Develop improved methods to facilitate the study of foodborne viruses and to further elucidate the significance of viral foodborne disease*
- **Detection:** Develop and validate sensitive, rapid, and practical methods to detect and genotype human norovirus in relevant sample matrices
- **Epidemiology and Risk Analysis:** *Collect and analyze population data on the burden of virus-associated disease, including epidemiological attribution and characterization of risk and costs*
- **Prevention and Control:** *Improve understanding the occurrence and behavior of human norovirus in the food safety continuum so as to inform development of scientifically justifiable control measures*

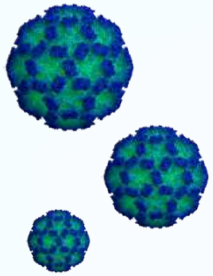


Extension, Outreach, & Education Activities

- **Extension and Outreach:** *Translate and disseminate new knowledge about foodborne viruses into practices that reach target audiences in relevant work environments and across a wide array of stakeholder groups*

- **Capacity Building:** *Build scientific and human capacity to support increased and sustained efforts in food virology by fostering information and exchange, expanding professional capacity through formal student education and training initiatives*

Partners (Collaborators)



Stakeholders

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THE VOICE OF FOOD RETAIL
Feeding Families Enriching Lives

Yum!

Core 1: Molecular Virology

SCIENCE

INFECTIOUS DISEASE

Replication of human noroviruses in stem cell–derived human enteroids

Khalil Ettayebi,[1*] Sue E. Crawford,[1*] Kosuke Murakami,[1*] James R. Broughman,[1] Umesh Karandikar,[1] Victoria R. Tenge,[1] Frederick H. Neill,[1] Sarah E. Blutt,[1] Xi-Lei Zeng,[1] Lin Qu,[1] Baijun Kou,[1] Antone R. Opekun,[2,3,4] Douglas Burrin,[3,4] David Y. Graham,[1,2,5] Sasirekha Ramani,[1] Robert L. Atmar,[1,2] Mary K. Estes[1,2]†

The major barrier to research and development of effective interventions for human noroviruses (HuNoVs) has been the lack of a robust and reproducible in vitro cultivation system. HuNoVs are the leading cause of gastroenteritis worldwide. We report the successful cultivation of multiple HuNoV strains in enterocytes in stem cell–derived, nontransformed human intestinal enteroid monolayer cultures. Bile, a critical factor of the intestinal milieu, is required for strain-dependent HuNoV replication. Lack of appropriate histoblood group antigen expression in intestinal cells restricts virus replication, and infectivity is abrogated by inactivation (e.g., irradiation, heating) and serum neutralization. This culture system recapitulates the human intestinal epithelium, permits human host-pathogen studies of previously noncultivatable pathogens, and allows the assessment of methods to prevent and treat HuNoV infections.

Disease Burden

Food-Related Illness and Death in the United States

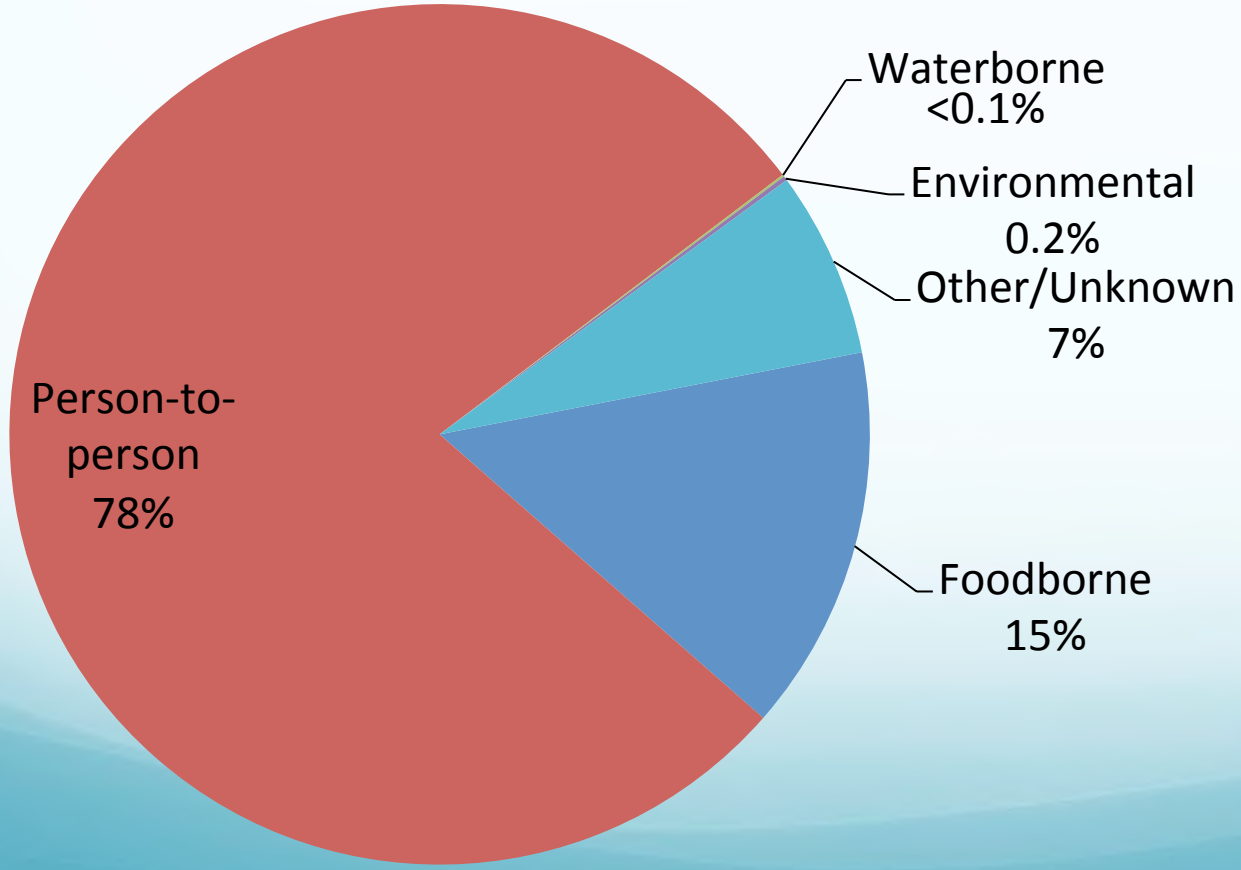
Paul S. Mead, Laurence Slutsker, Vance Dietz, Linda F. McCaig, Joseph S. Bresee, Craig Shapiro, Patricia M. Griffin, and Robert V. Tauxe
Centers for Disease Control and Prevention, Atlanta, Georgia, USA

Foodborne Illness Acquired in the United States—Major Pathogens

Elaine Scallan,[1] Robert M. Hoekstra, Frederick J. Angulo, Robert V. Tauxe, Marc-Alain Widdowson, Sharon L. Roy, Jeffery L. Jones, and Patricia M. Griffin

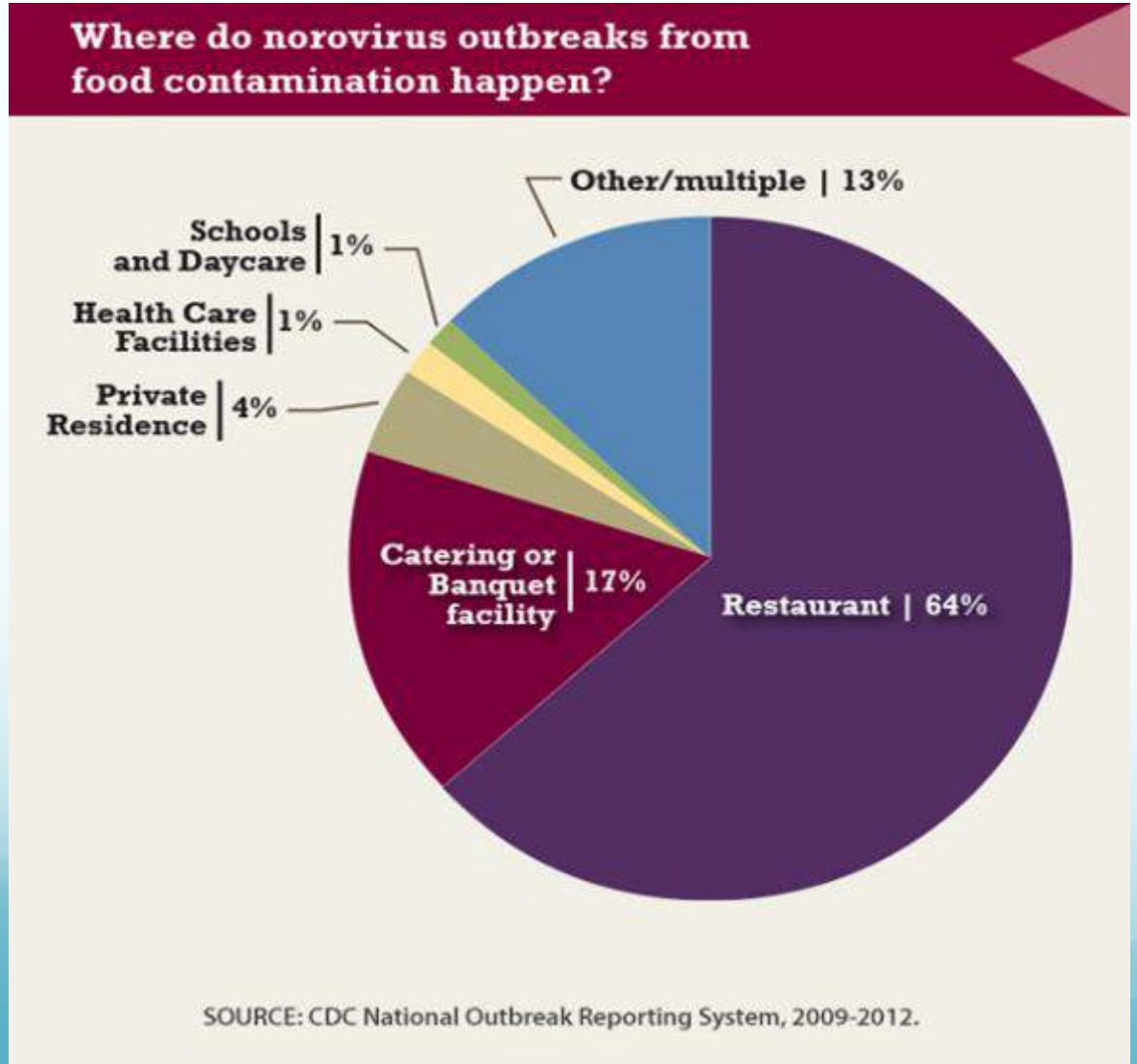
- Human noroviruses are the leading cause of acute gastroenteritis in U.S., probably worldwide
- Responsible for 21 million cases; 70,000 hospitalizations; and 800 deaths annually (CDC estimates)
- $2 billion annually in healthcare and lost productivity costs
- Responsible for >5 million cases of foodborne disease annually
  - Around food-related 15,000 hospitalizations annually [26%, 2nd in rank]
  - Around 150 food-related deaths annually [11%, 4th in rank]
- Cause of food borne disease of unknown etiology?

Core #3: Epidemiology and Risk Analysis



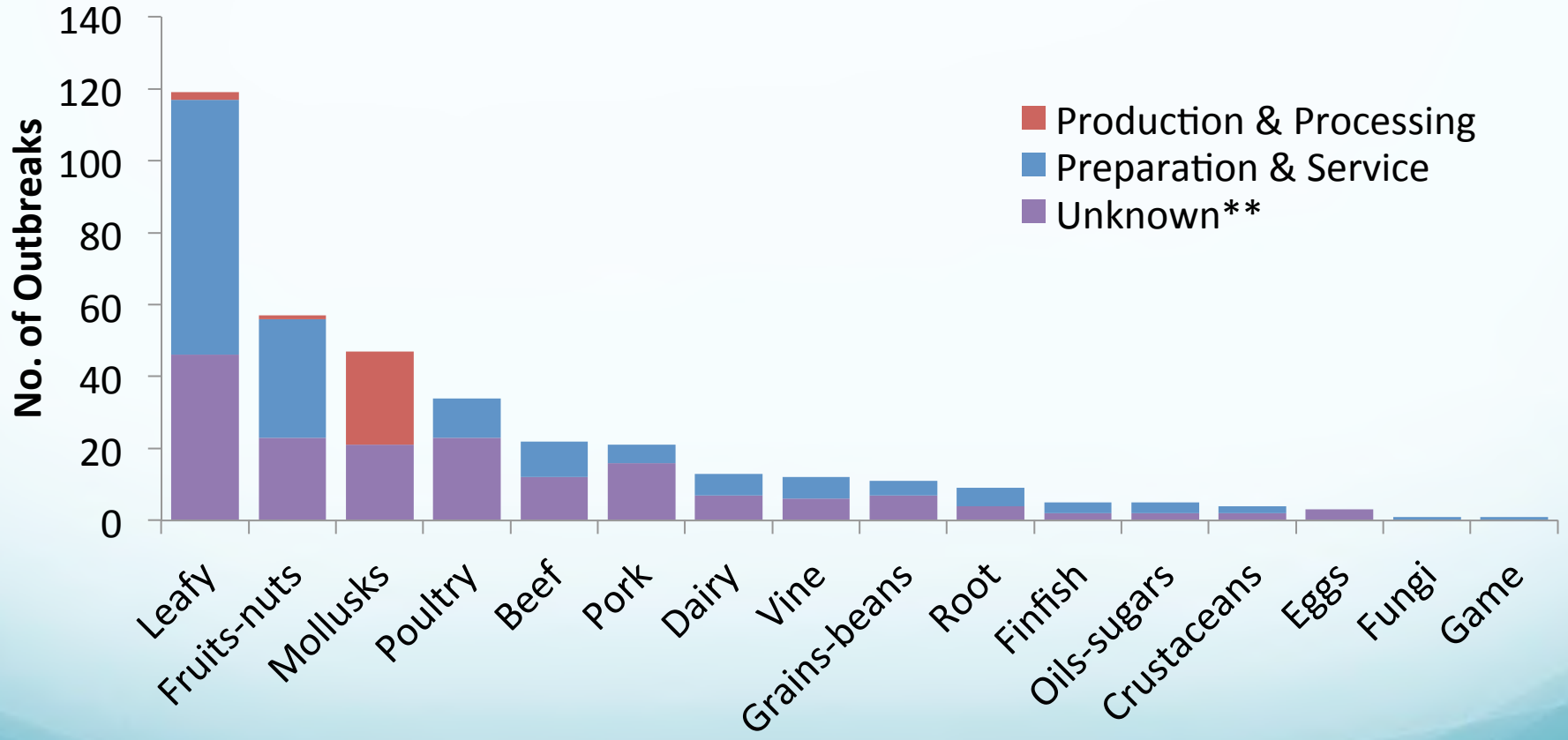
--Fecal matter vs. vomitus
--Low infectious dose
--High degree of shedding
--Virus persistence and resistance
--Important venues

Foodborne Transmission



Infected food workers cause about 70% of reported norovirus outbreaks from contaminated food.

Foods Implicated* in Norovirus Outbreaks Reported to CDC by Commodity and Point of Contamination (2001-2008)



*Limited to outbreaks with a simple food (consisting of a single commodity) implicated
**Insufficient or conflicting information provided in outbreak report

Hall et al. 2012. *Emerg. Infect. Dis.* 18(10):1566-1573.

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Evaluation of a Surface Sampling Method for Recovery of Human Noroviruses Prior to Detection Using Reverse Transcription Quantitative PCR

GRACE TUNG-THOMPSON,[1] BLANCA I. ESCUDERO-ABARCA,[1*] JANIE OUTLAW,[1] ARNAUD GANEE,[2] SYLVANIE CASSARD,[2] CLAUDE MABILAT,[2] AND LEE-ANN JAYKUS[1]

Location	Sampling Location					Number Samples Presumptively Positive/ Total Sample Number by Location (%)
	Baby Changing Station (n=4)	Door Handle (n=58)	Flush Handle (n=38)	Sink (n=34)	Toilet Seat (n=66)	
Public Locations	--	3	2	1	--	6/53 (11.1%)
Service Stations	--	--	2	--	1	3/39 (7.7%)
Food Service	1	6	3	1	4	15/108 (13.8%)
Grand Total	1	9	7	2	5	24/200 (11.9%)
Number Samples Presumptively Positive/ Total Sample Number by Sample Type (%)	1/4 (25%)	9/58 (15.5%)	7/38 (18.4%)	2/34 (5.9%)	5/66 (7.6%)	

Location	Surface	Virus Identity
Shopping center	Door handle	Norovirus GII.Pe_GII.4/Sydney2012
Shopping center	Flush handle	Norovirus GII.Pe_GII.4/San Sebastian
Grocery store	Door handle	Norovirus GII.Pe_GII.4/Sydney2012
Gas station	Flush handle	Norovirus Hu/GII-4/New Taipei
Movie theater	Door handle	Norovirus GII.Pe_GII.4/Sydney2012
Bank	Sink	Norovirus Hu/GII-4/New Taipei

Laboratory Evidence of Norwalk Virus Contamination on the Hands of Infected Individuals

Pengbo Liu,[a] Blanca Escudero,[b] Lee-Ann Jaykus,[b] Julia Montes,[a] Rebecca M. Goulter,[b] Meredith Lichtenstein,[a] Marina Fernandez,[a] Joong-Chul Lee,[a] Elizabeth De Nardo,[c] Amy Kirby,[a] James W. Arbogast,[c] Christine L. Moe[a]

Center for Global Safe Water, Hubert Department of Global Health, Emory University, Atlanta, Georgia, USA[a]; Food Bioprocessing and Nutrition Sciences, North Carolina State University, Raleigh, North Carolina, USA[b]; Gojo Industries Inc., Akron, Ohio, USA[c]

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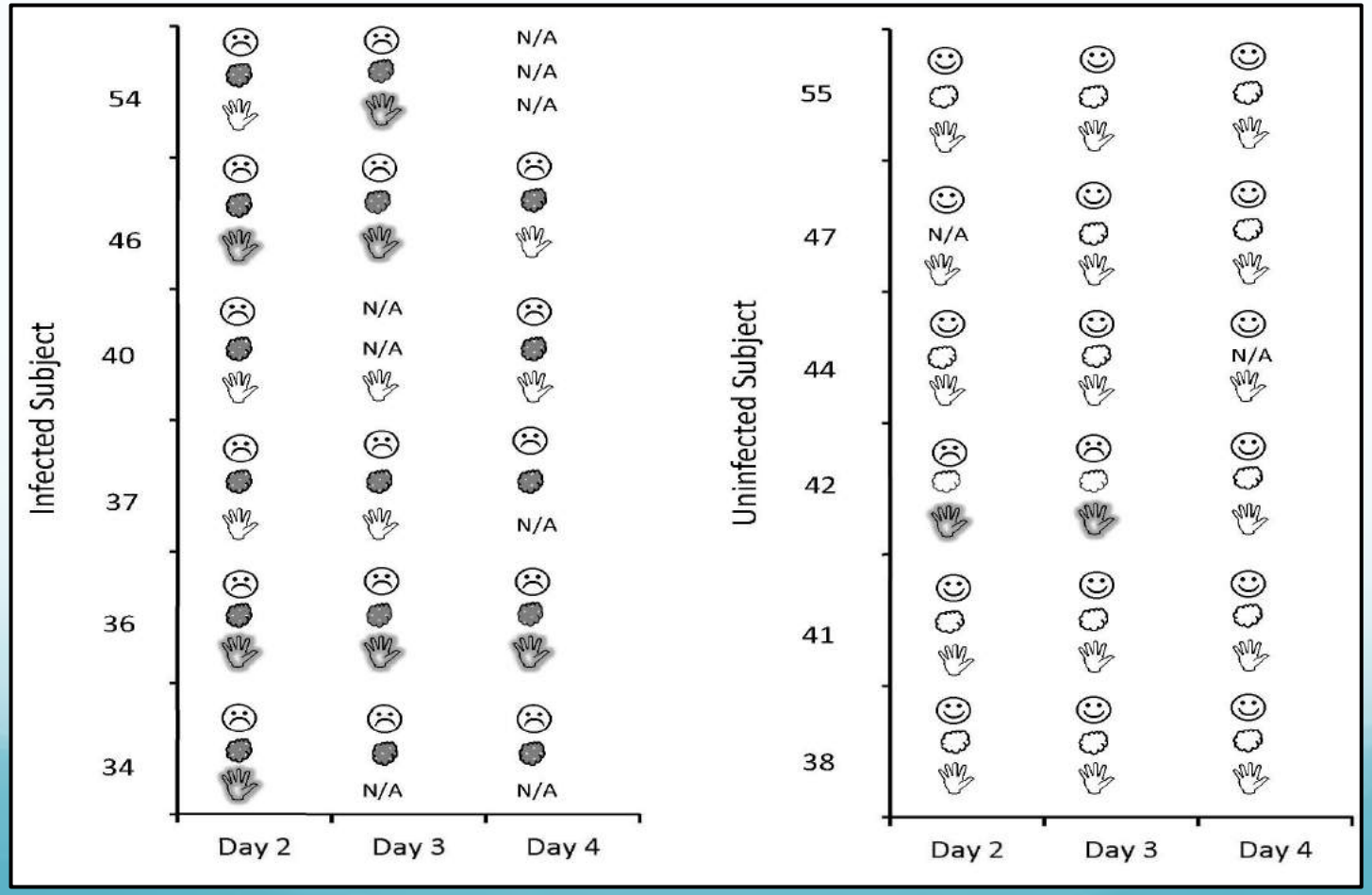
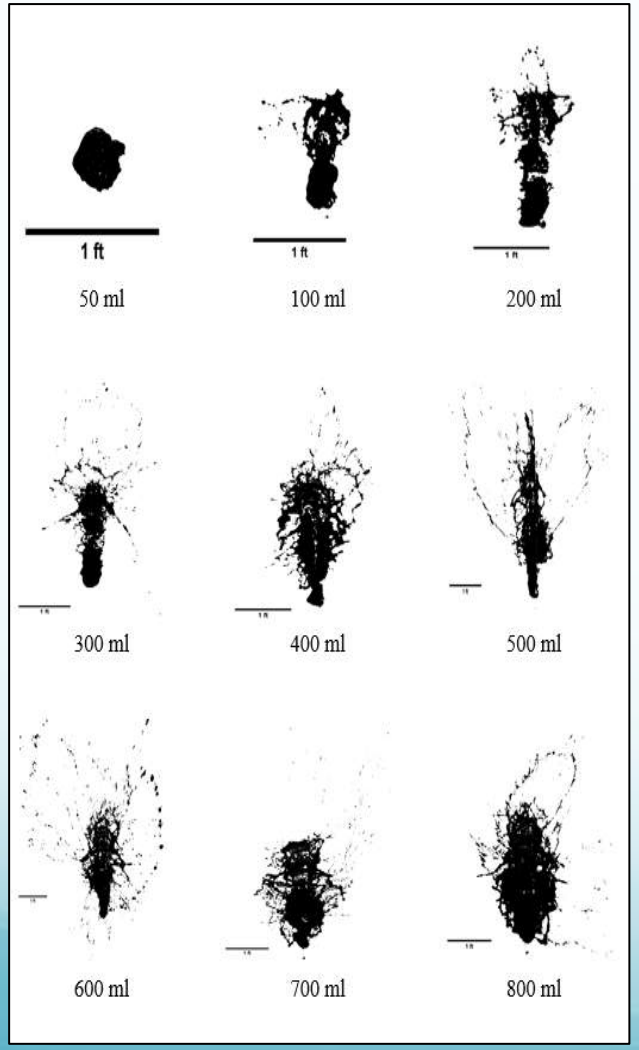
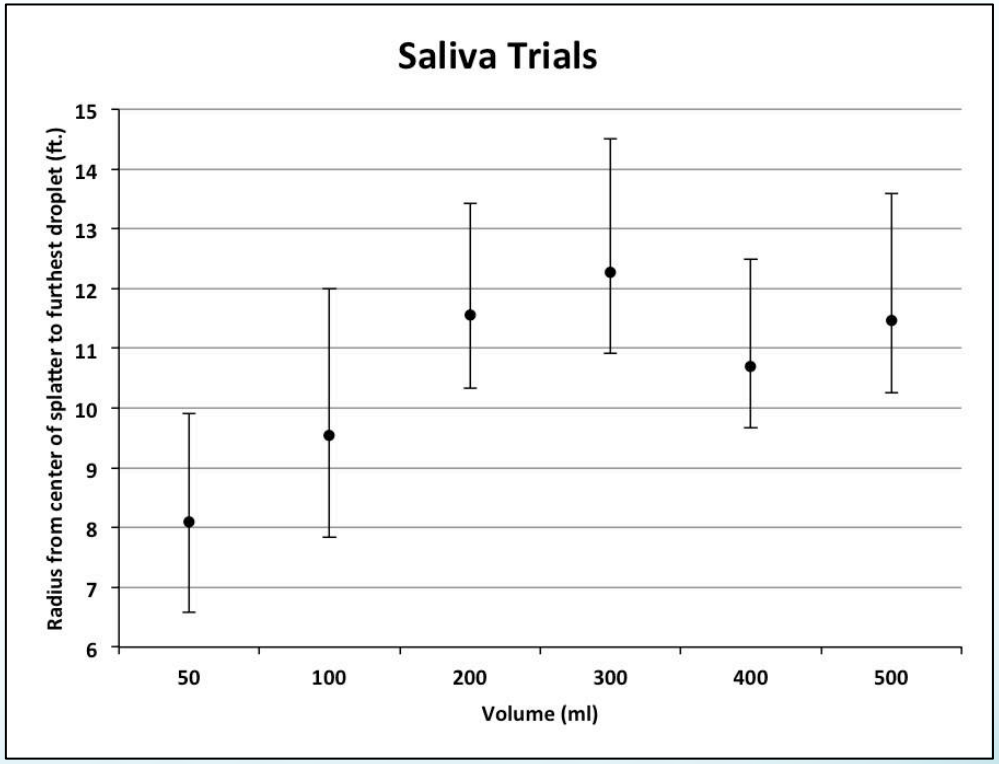


Vomit Splatter





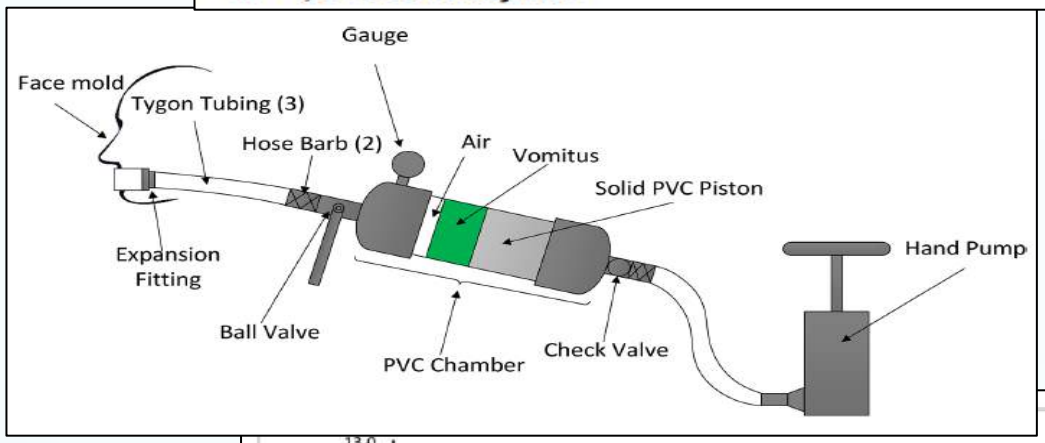
Tung et al., in preparation

RESEARCH ARTICLE

Aerosolization of a Human Norovirus Surrogate, Bacteriophage MS2, during Simulated Vomiting

Grace Tung-Thompson[1¶], Dominic A. Libera[2¶], Kenneth L. Koch[3], Francis L. de los Reyes, III[2‡*], Lee-Ann Jaykus[1‡]

PLOS ONE



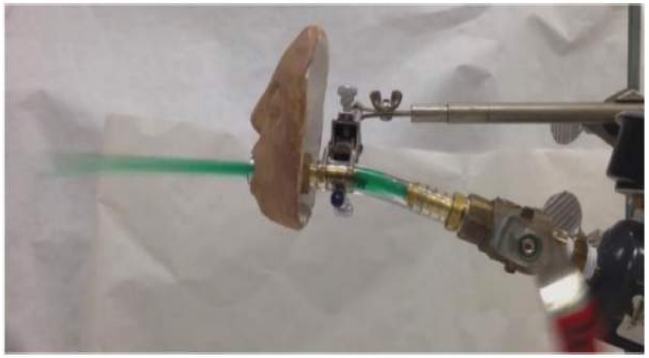
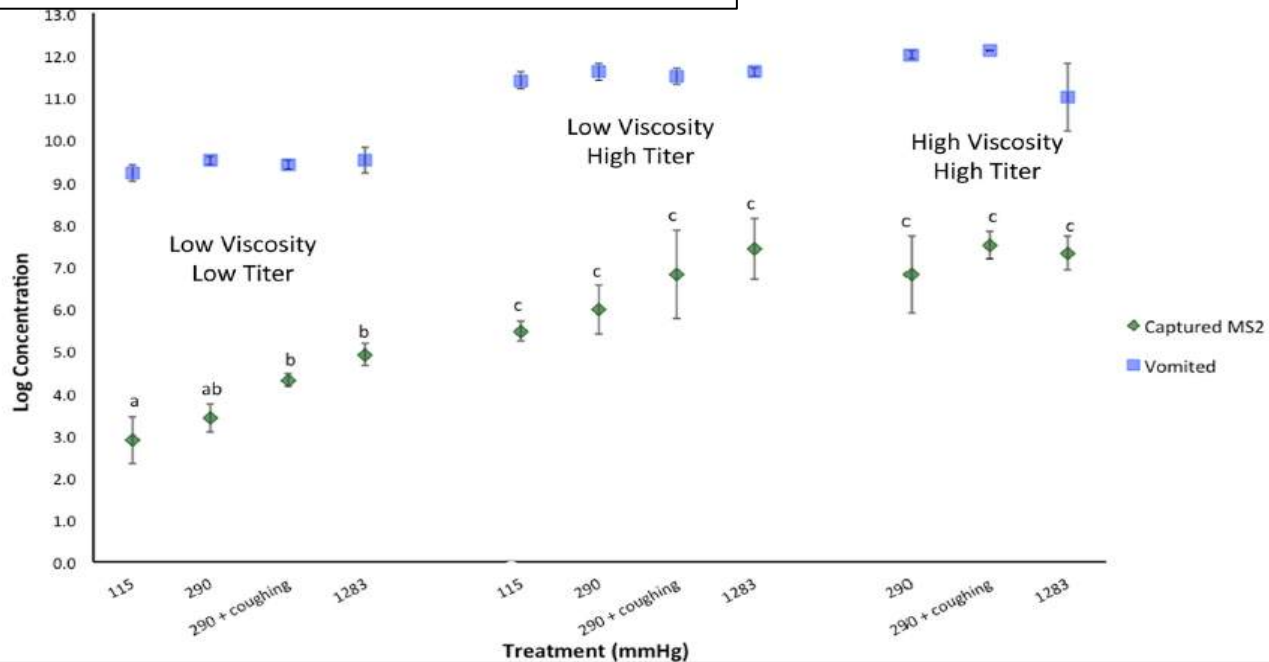


Fig 2. Photo of a Simulated Vomiting Episode. Projectile vomiting of colored simulated vomitus matrix.



RESEARCH ARTICLE

Vomiting as a Symptom and Transmission Risk in Norovirus Illness: Evidence from Human Challenge Studies

Amy E. Kirby*, Ashleigh Streby, Christine L. Moe

Hubert Department of Global Health, Rollins School of Public Health, Emory University, Atlanta, GA, United States of America

PLOS | ONE

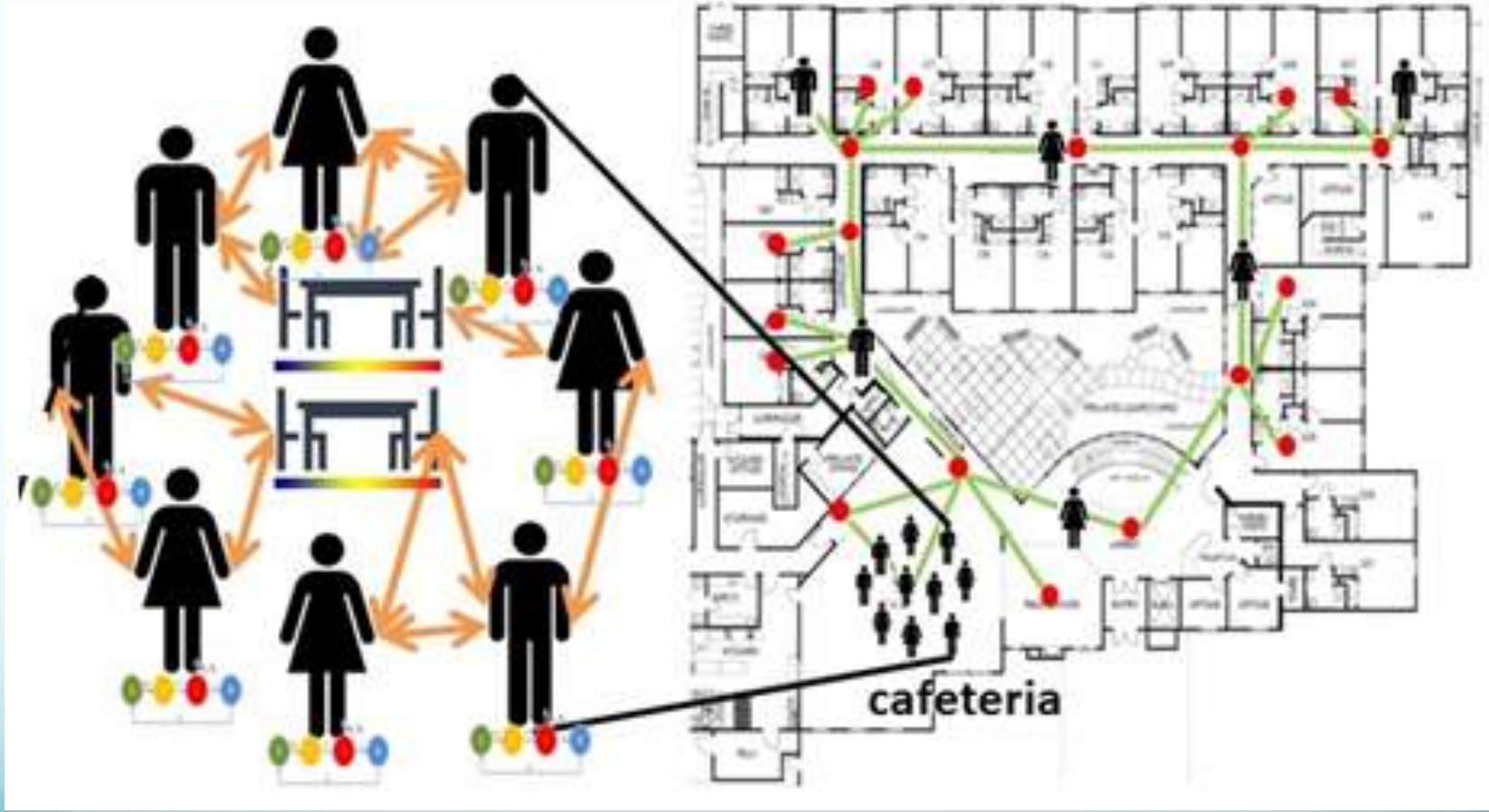
Table 3. Norovirus Titers in Emesis.

Study	# Subjects with Emesis Specimens	# Emesis Specimens	% Subjects with ≥ 1 Positive Emesis	% Positive Samples	Sample Mean Titer[c] (GEC[d]/ml)(SEM[e])	Subject Mean Cumulative Shed (GEC[d])(SEM[e])
1	6	16	50%	63%	5.8×10^5 (2.6×10^5)	1.3×10^8 (9.1×10^7)
2	8	20	75%	90%	9.2×10^5 (3.1×10^5)	3.1×10^8 (1.7×10^8)
All GI	14	36	64%	78%	8.0×10^5 (2.2×10^5)	2.3×10^8 (1.0×10^8)
3	4[a]	8	25%	38%	1.6×10^5 (4.5×10^4)	1.8×10^7 (1.8×10^7)
4	2	13	100%	92%	5.0×10^3 (2.7×10^3)	2.3×10^5 (ND)[b]

Risk Modeling

- NorOPTIMAL (**Nor**ovirus **O**n-line **P**redictive **T**ool to **I**nvestigate **M**itigation **AL**ternatives) is a simulation model designed to compare efficacy of different intervention strategies in microenvironments based on health risk and cost
- Key features of NorOPTIMAL
  - "Agent" based model
  - Probabilistic simulation
  - Inputs informed by research from the collaborative (e.g., transfer rates) and published literature
  - Produces risk metrics include infection probability, disease progression, and outbreak size

Agents interact according to spatial layout and schedule of activities



Core # 4: Prevention & Control

- **Purpose:** Improve understanding the occurrence and behavior of human norovirus in the food safety continuum so as to inform development of scientifically justifiable control measures.
  - Activity 4.1: Evaluate and monitor virus occurrence pre- and post-harvest, including alternative microbiological indicators
  - Activity 4.2: Develop/evaluate novel antiviral agents for hand and surface disinfection in collaboration with industrial partners
  - Activity 4.3: Test efficacy of candidate technologies to remove and/or inactivate viruses and their surrogates in foods (pilot scale)
  - Activity 4.4: Move promising processing technologies toward commercialization using stage-gate approach

Virus Persistence

- Surfaces
  - Room temperature: Days/ weeks
- Foods and water
  - Refrigeration: Weeks/months/ years
  - Freezing: Months/ years
- Also depends on surface/food and virus, RH
- Transferability
  - Variable (0.1%->90%)
  - Depends on moisture, surfaces, pressure, virus
  - Sequential (10X)
- Environmental contamination
  - *Outbreaks*
  - *Endemic*
  - *Virus concentrations*
- *Persistence and concentration on hands*
- *Airborne?*
- *Relative importance (attribution)*

Inactivation: 'Traditional' Methods in Food Processing

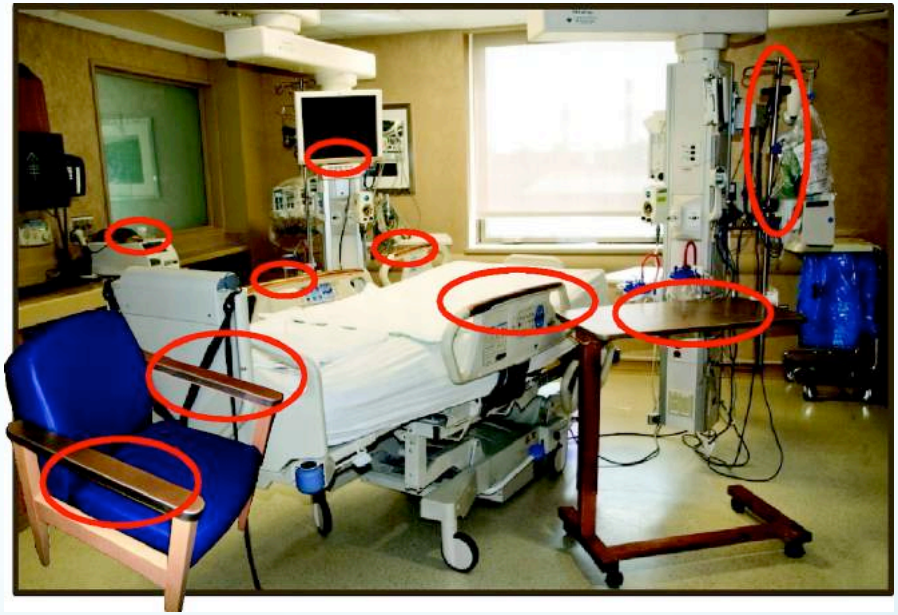
- Product relevance?
- Methods
  - Refrigeration and freezing
  - Drying and a_w
  - Conventional preservatives
- What about heat?
  - Surrogates differ in heat resistance
  - Norovirus and hepatitis A generally more resistant

Prevention: Surface Disinfection, Direct Contact

- Formulation matters
- Efficacy impacted by concentration and contact time
- Active compounds (ingredients)
  - Chlorine, 1,000-5,000 ppm (+)
  - Benzalkonium chloride chloride (-)
  - Phenols
  - *Hypochorous acid, up to 250 ppm*
  - *Silver dihydrogen citrate*
  - *Activated hydrogen peroxide*
  - *Emerging technologies*
    - *Surface coatings (e.g., light activated fluorinated TiO_2)*
    - *Copper ($\geq$70%)*
    - *Nanoparticle technology*
- *Soft surfaces?*
- Potential drawbacks

Copper as a Self Sanitizing Surface

- Used as antimicrobial since ~2500 BC
- Copper touch surfaces reduce hospital acquired infection rates
- Broadly antimicrobial
  - Efficacy against variety of viruses and bacteria
  - Data lacking for human noroivirus



Hypothesis: Copper surfaces may be useful to reduce environmentally mediated human norovirus transmission

Salgado et al., 2013

Destruction of the Capsid and Genome of GII.4 Human Norovirus Occurs during Exposure to Metal Alloys Containing Copper

C. S. Manuel, M. D. Moore, L. A. Jaykus

Department of Food, Bioprocessing, and Nutrition Sciences, North Carolina State University, Raleigh, North Carolina, USA

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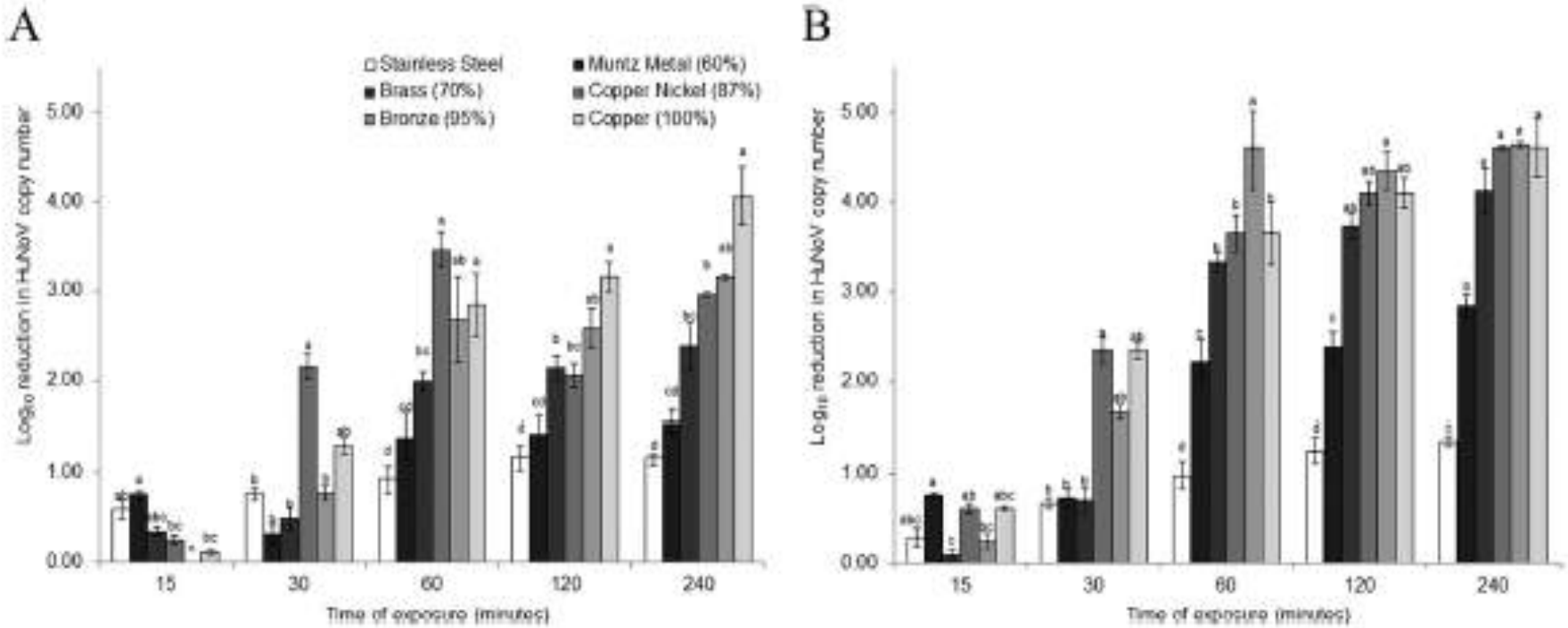

FIG 1 Genome and capsid degradation of GII.4 HuNoV during exposure to copper-containing surfaces. Degradation of the GII.4 HuNoV RNA genome and capsid occurs during exposure to copper-containing surfaces. Twenty-five-microliter aliquots of 20% fecal suspensions positive for GII.4 HuNoV were placed onto various alloys at room temperature and eluted at select time points. Sample eluates were analyzed by RT-qPCR without RNase treatment to determine genome integrity (A) and by RT-qPCR following RNase treatment to determine capsid integrity (B). The values in parentheses after each alloy indicate the percentage of copper in the alloy. The drying time was included in the total exposure time and was ~20 to 30 min. The HuNoV RNA copy number was estimated by comparing C_T values to a standard curve. Letters above the bars indicate statistically significant differences ($P < 0.05$) between alloys for each exposure time. Error bars represent standard errors of the means. All experiments were performed in triplicate.

Electron Microscopy Results

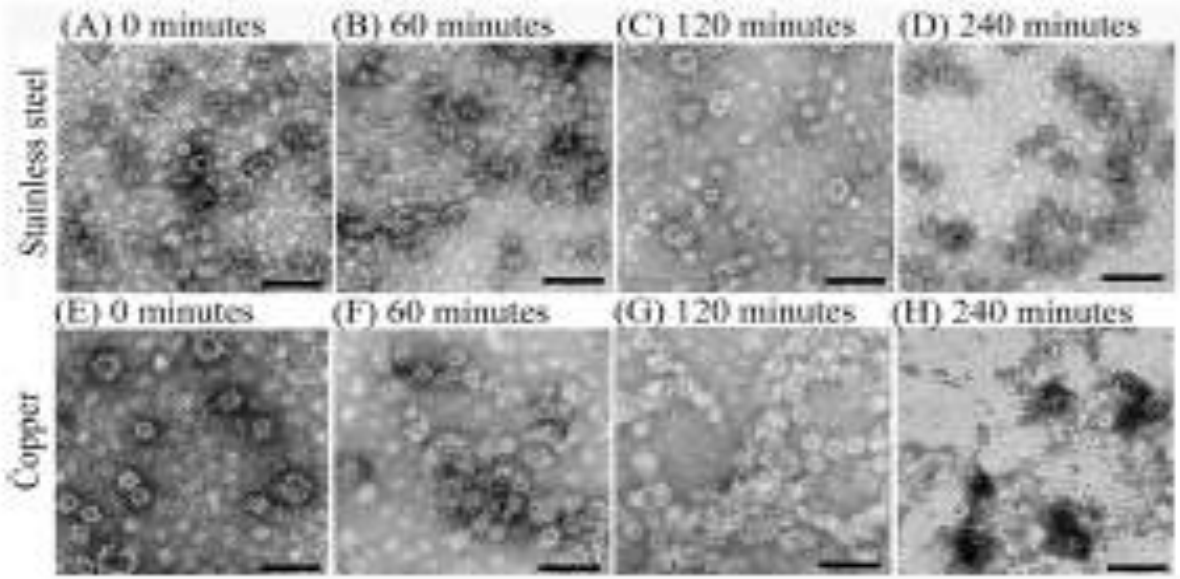

FIG 2 Effect of copper surfaces on the integrity of HuNoV VLPs. One microliter of purified GII.4 Grimsby HuNoV VLPs (concentration of 1,700 ng/μl) was placed onto copper or stainless steel surfaces and eluted at various time points between 0 and 240 min. Eluted samples were negatively stained with 2% uranyl acetate and visualized by transmission electron microscopy. Bar, 0.1 μm.

What Doesn't Work

Contents lists available at ScienceDirect

International Journal of Food Microbiology

journal homepage: www.elsevier.com/locate/ijfoodmicro

Electron beam inactivation of Tulane virus on fresh produce, and mechanism of inactivation of human norovirus surrogates by electron beam irradiation

Ashley Predmore [a,*], Gabriel C. Sanglay [a], Erin DiCaprio [b], Jianrong Li [b], R.M. Uribe [c], Ken Lee [a]

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[b] Department of Veterinary Biosciences, College of Veterinary Medicine, The Ohio State University, Goss Laboratory, 1925 Coffey Road, Columbus, OH 43210-1240, USA

[c] College of Technology, Kent State University, 375 Terrace Drive, Van Deusen Hall, Kent, OH 44242, USA

Effect of Grape Seed Extract on Human Norovirus GII.4 and Murine Norovirus 1 in Viral Suspensions, on Stainless Steel Discs, and in Lettuce Wash Water

Dan Li,[a] Leen Baert,[a] Dongsheng Zhang,[b] Ming Xia,[b] Weiming Zhong,[b] Els Van Coillie,[c] Xi Jiang,[b] and Mieke Uyttendaele[a]

Laboratory of Food Microbiology and Food Preservation, Faculty of Bioscience Engineering, Ghent University, Ghent, Belgium[a]; Cincinnati Children's Hospital Medical Center, University of Cincinnati College of Medicine, Cincinnati, Ohio, USA[b]; and Institute for Agricultural and Fisheries Research, Technology and Food Science Unit, Melle, Belgium[c]

The anti-norovirus (anti-NoV) effect of grape seed extract (GSE) was examined by plaque assay for murine norovirus 1 (MNV-1), cell-binding reverse transcription-PCR for human NoV GII.4, and saliva-binding enzyme-linked immunosorbent assay for human NoV GII.4 P particles, with or without the presence of interfering substances (dried milk and lettuce extract). GSE at 0.2 and 2 mg/ml was shown to reduce the infectivity of MNV-1 (>3-log PFU/ml) and the specific binding ability of NoV GII.4 to Caco-2 cells (>1-log genomic copies/ml), as well as of its P particles to salivary human histo-blood group antigen receptors (optical density at 450 nm of >0.8). These effects were decreased as increasing concentrations of dried milk (0.02 and 0.2%) or lettuce extract were added. Under an electron microscope, human NoV GII.4 virus-like particles showed inflation and deformation after treatment with GSE. Under conditions that simulated applications in the food industry, the anti-NoV effect of GSE using MNV-1 as a target organism was shown to be limited in surface disinfection (<1-log PFU/ml, analyzed in accordance with EN 13697:2001). However, a 1.5- to 2-log PFU/ml reduction in MNV-1 infectivity was noted when 2 mg of GSE/ml was used to sanitize water in the washing bath of fresh-cut lettuce, and this occurred regardless of the chemical oxygen demand (0 to 1,500 mg/ml) of the processing water.

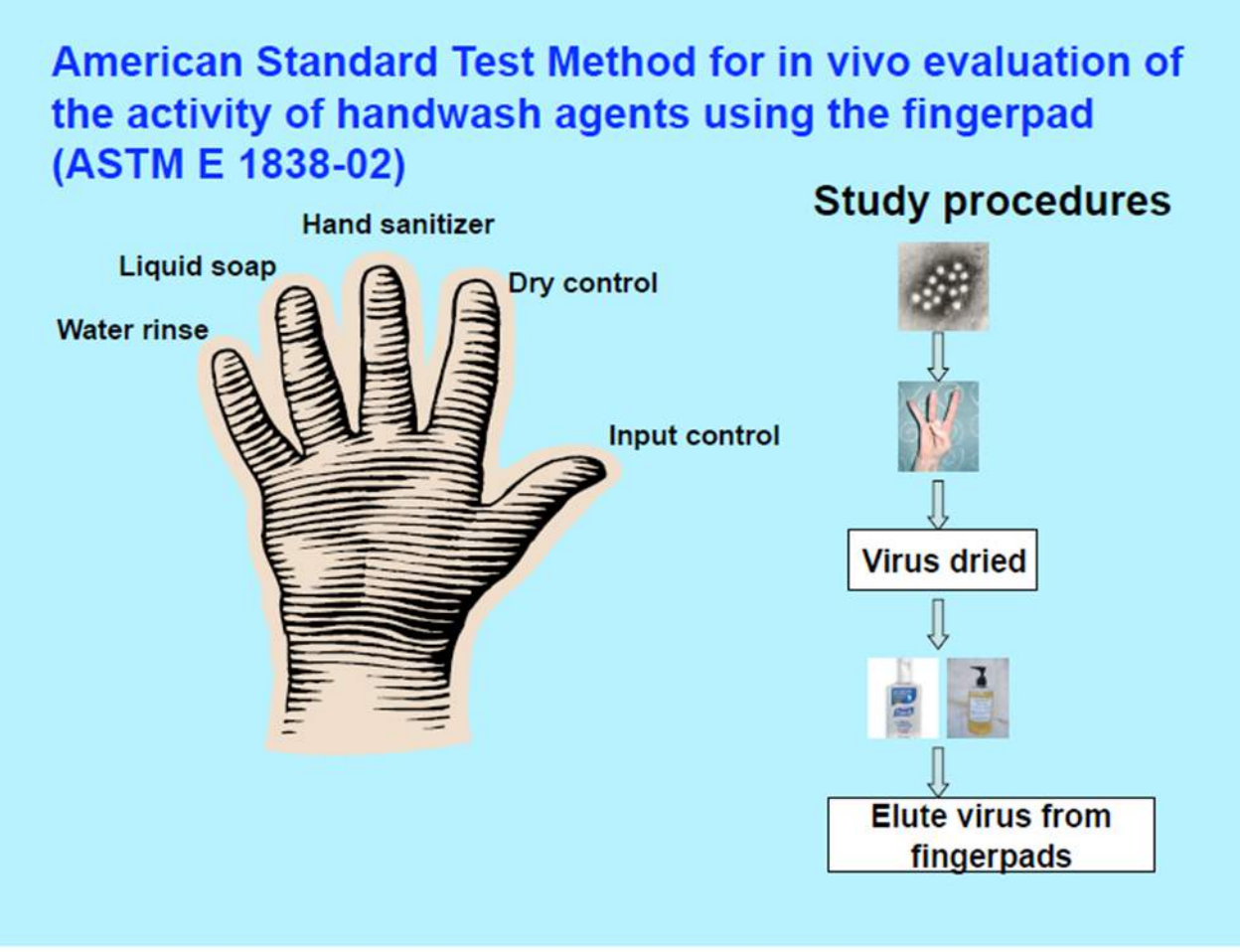
Prevention: Surface Disinfection, Indirect Contact (Fogging)

- Broad spatial coverage
- Potential drawbacks
- *Application approach and concentration matter*
- *Active ingredients*
  - *Hydrogen peroxide*
  - *ClO_2*
  - *Others?*
- *Application to clean-up after vomiting event or reservoir locations like restrooms?*
- *Soft surfaces?*

Hand Sanitizers

- Product type [actives]
  - Alcohol [60-90%, ethanol, isopropanol, n-propanol] (-)
  - *Povidone-iodine (+/-)*
  - Benzalkonium chloride chloride (-)
  - Triclosan (-)
  - Chlorhexidine (-)
  - *"Sanitwice"?*
  - *Emerging actives*
    - *Copper*
    - *Bismuth subsalicylate*
    - *Others?*
- Formulation matters
- Product application (volume and time)
- Validation/methodological issues
- Regulatory/licensing/use issues

ASTM E-1838-02 (Fingerpad Method)



Norovirus Strain-Specific Ethanol Sensitivity

RESEARCH ARTICLE

Strain-Specific Virolysis Patterns of Human Noroviruses in Response to Alcohols

Geun Woo Park[1]*, Nikail Collins[1,2], Leslie Barclay[1], Liya Hu[3], B. V. Venkataram Prasad[3], Benjamin A. Lopman[1], Jan Vinjé[1]

1 Division of Viral Diseases, Centers for Disease Control and Prevention, Atlanta, GA, United States of America, 2 Atlanta Research and Education Foundation (AREF), Atlanta, GA, United States of America, 3 Verna Marrs McLean Department of Biochemistry and Molecular Biology, Baylor College of Medicine, Houston, TX, United States of America

PLOS ONE | DOI:10.1371/journal.pone.0157787 June 23, 2016

Table 2. Virolysis patterns of GII norovirus strains after exposure to ethanol and isopropanol.

-			Reduction in RNA titer (log_{10} RNA copies/ml)[1]					
Genogroup	Strain ID	Genotype	50% Ethanol	70% Ethanol	90% Ethanol	50% Isopropanol	70% Isopropanol	90% Isopropanol
GII	2010746610	GII.1	0.2 ± 0.1	0.3 ± 0.2	0.7 ± 0.3	0.1 ± 0.1	0.1 ± 0.1	0.4 ± 0.1
	2010746618	GII.2	0.4 ± 0.2	0.4 ± 0.2	0.7 ± 0.1	0.2 ± 0.1	0.2 ± 0.2	0.3 ± 0.2
	2013775428	GII.4[3]	2.3 ± 0.2	2.3 ± 0.3	2.4 ± 0.1	2.0 ± 0.5	0.9 ± 0.3	2.4 ± 0.1
	2013775418	GII.4[3]	1.2 ± 0.5	2.5 ± 0.5	2.7 ± 0.4	1.4 ± 0.3	0.9 ± 0.2	1.5 ± 0.4
	2010746350	GII.4[4]	0.4 ± 0.1	0.5 ± 0.2	1.4 ± 0.3	0.4 ± 0.1	1.0 ± 0.5	2.4 ± 0.4
	2010746173	GII.4[4]	0.2 ± 0.1	0.5 ± 0.4	0.9 ± 0.1	0.0 ± 0.2	0.0 ± 0.0	1.0 ± 0.3
	2010746526[2]	GII.4[4]	0.4 ± 0.2	0.4 ± 0.2	1.6 ± 0.3	0.5 ± 0.2	0.5 ± 0.1	1.5 ± 0.1
	2013775232	GII.4[5]	2.0 ± 0.3	2.1 ± 0.1	2.2 ± 0.1	0.2 ± 0.1	0.1 ± 0.2	2.1 ± 0.6
	2013751795	GII.4[5]	1.1 ± 0.2	2.2 ± 0.5	1.6 ± 0.2	1.0 ± 0.2	0.5 ± 0.3	0.9 ± 0.3
	2013843445	GII.4[5]	1.8 ± 0.8	1.9 ± 0.7	2.4 ± 0.2	1.1 ± 0.3	0.4 ± 0.3	1.8 ± 0.2
	2013843449	GII.4[5]	2.5 ± 0.4	3.0 ± 0.2	3.1 ± 0.3	1.8 ± 0.3	0.7 ± 0.1	1.7 ± 0.2
	2010746514	GII.7	0.1 ± 0.0	0.4 ± 0.1	0.7 ± 0.1	0.1 ± 0.1	0.1 ± 0.1	0.8 ± 0.8
	2012706250	GII.12	0.0 ± 0.1	0.1 ± 0.1	0.7 ± 0.1	0.0 ± 0.2	0.0 ± 0.1	0.0 ± 0.2
	2010746037	GII.12	0.0 ± 0.2	0.0 ± 0.1	0.2 ± 0.2	0.0 ± 0.2	0.0 ± 0.1	0.0 ± 0.1
	2010746401	GII.12	0.3 ± 0.3	1.4 ± 0.1	1.6 ± 0.1	0.2 ± 0.1	0.0 ± 0.2	0.4 ± 0.1
	2010746174	GII.13	0.3 ± 0.1	0.4 ± 0.1	0.2 ± 0.2	0.5 ± 0.2	0.5 ± 0.1	0.0 ± 0.2
	Average reduction		0.9 ± 0.5	1.2 ± 1.1	1.4 ± 0.9	0.6 ± 0.7	0.3 ± 0.4	1.0 ± 0.8

Core #5: Extension and Outreach

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Gaps in Food Safety Professionals' Knowledge about Noroviruses

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Consumer Education Needed on Norovirus Prevention and Control: Findings from a Nationally Representative Survey of U.S. Adults

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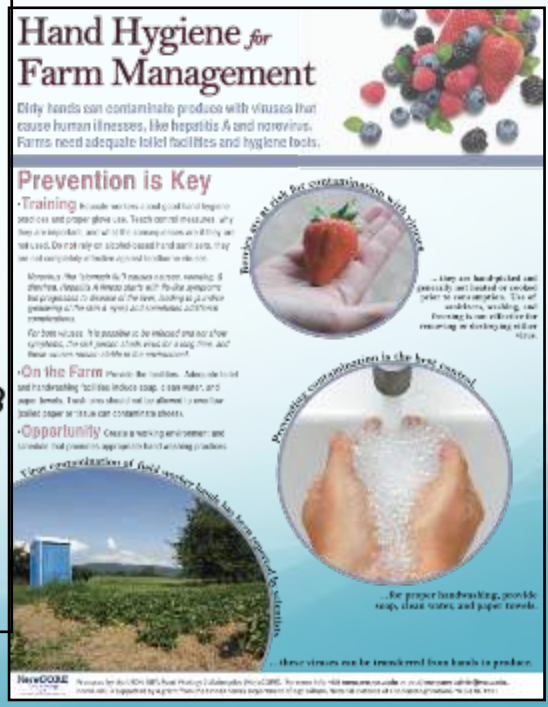
Prevention: Extension and Outreach

- Audiences
  - *Fresh produce*
  - *Shellfish*
  - *Retail (food handlers)*
  - *Consumers*
  - Public health officials
- Methods
  - Curricula
  - Training programs
  - Written materials
- Issues
  - Resources
  - Evaluation
  - Compliance
  - Sustained behavior change



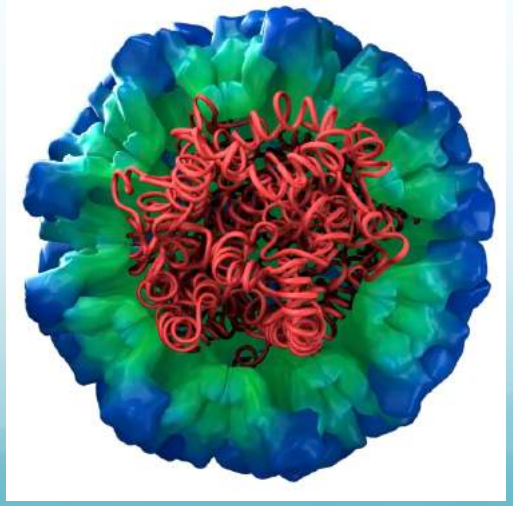
Core 5: Extension and Outreach

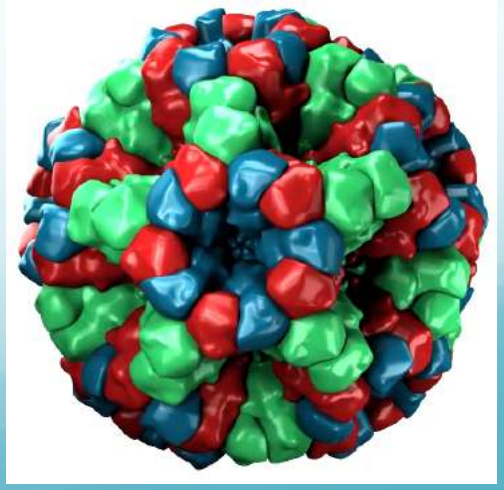
- Fresh Produce Industry
  - Contributions to national GAPs training curriculum
- Molluscan Shellfish Industry (ISSC)
  - Contributions to national harvester/dealer training curriculum
  - Educational video
  - Recreational boaters
- Food Service/Grocery Industries
  - Environmental sampling
  - Vomit/fecal matter clean-up guidelines
- Sanitation and Hygiene Industry (including CLIA)
  - Testing candidate technologies

Core 6: Capacity Building

- Website
- Comprehensive reagent/protocol exchange
  - VLPs, glycans, reverse genetics systems
  - CDC "Platinum Panel"
- Literature database
  - Freely accessible papers to collaborators (n>3,000)
  - Freely accessible abstracts on Web
- Discretionary funding
- Student training
  - Undergrad: 11 (NCSU, Clemson, BCM, Emory, UGA, OSU, IIT)
  - Grad: 12 (BCM, Emory, OSU, Rutgers, Clemson, U-DE, NCCU, GSU, UGA, NCSU)

Educational Visuals





Hand-Washing

Lynette's Norovirus Nightmare

The Norovirus Nightmares keep on coming and this one is a doozie.

Imagine you and 20 of your family members have norovirus…now put yourselves in a snowed-in cabin…with one bathroom!

That's our latest Norovirus Nightmare from Dr. Lynette Johnston of our Admin Team, which she calls "Quality Family Time" and pushed through the emotional scars to share with us here:

The twin of the cabin where things went horribly

Thanks to an upbringing of farming, family vacations were nonexistent. With half of my siblings and I in our post-farming life, we had the ingenious idea of a family trip to the mountains during Christmas 2006 to show our kids the true meaning of *quality* family time. After much planning and anticipation, as well as a very brief mention of a niece feeling better from what seemed to be too much of Grandma's rum cake, twenty-one members of my family headed to the slopes of New Mexico.

Morgan's Norovirus Nightmare

The great stories just keep on coming from our NoroCORE members, and this one goes to show how norovirus can mean fun for the whole family!

Name: Morgan Chao

Institution: Clemson University

Position title: Project Coordinator in Food, Nutrition, and Packaging Sciences

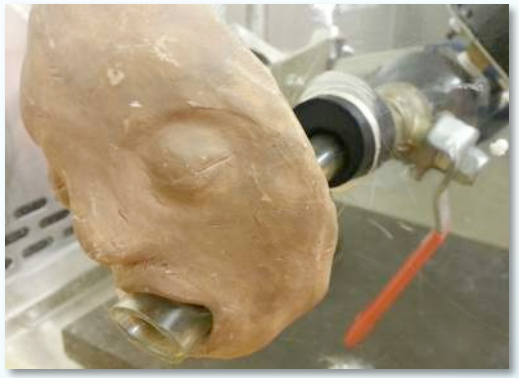
Morgan demonstrating her disease for the human norovirus

Please describe a time you believe you had norovirus:

It was a night… Just like this…

Well, actually, it was a day… early February, 2013. My family had gathered for a lovely weekend on the farm. My cousin, along with her mom, her husband, and their children were stopping through on their way home from Disney World. Our visit was lovely… at first.

On Saturday we were all enjoying our lunch when one of the little ones presented hers again, like, in projectile form. Bless her heart, the poor little thing didn't even know to get up from the kids' table. Her dad, mom, and grammy were the first to spring into action. Her dad quickly grabbed some cleaning solution and towels (paper or cloth, I don't remember) to clean up the mess. The rest of us didn't want to touch the vomit or go near her, to be honest.



The Traveling Microbiologist

Summary of Achievements

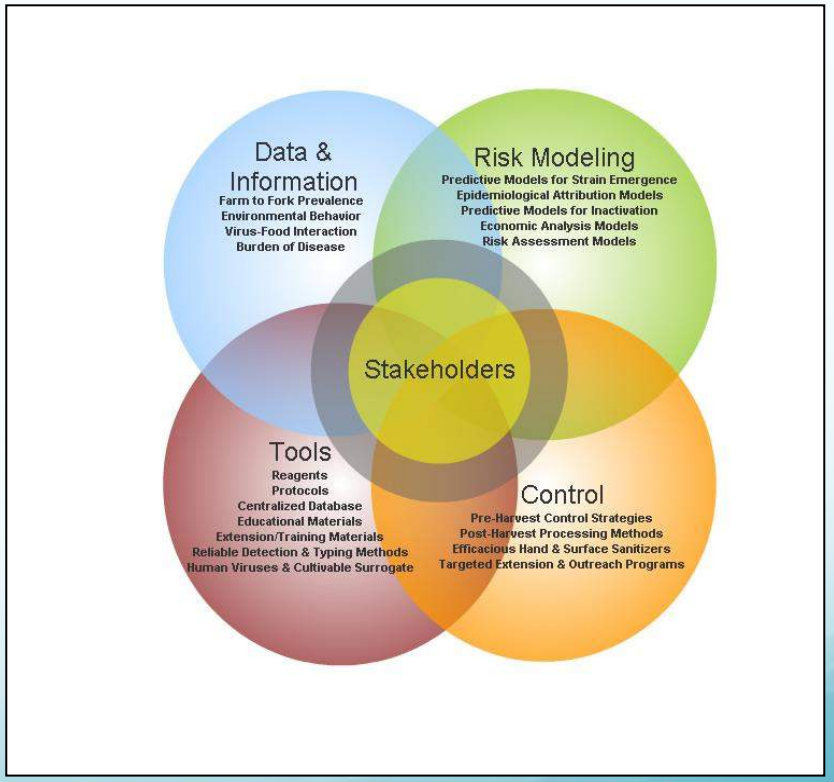
- Cell culture model!
- Comprehensive surrogate comparison, Tulane probably most relevant
- Detection
  - Lots of ligands with broader reactivity
  - Microarrays for genotyping
  - Better understanding of infectivity dilemma
- Key epidemiological findings
  - Improved understanding of disease burden
  - Role of fresh produce and “complex” foods
  - Importance of food handler
  - Children/elderly
- Aerosolization of virus during vomiting
- Prototype risk model

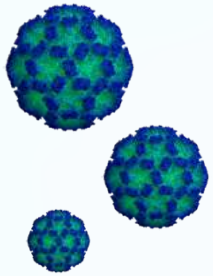
Summary of Achievements

- Food processing
  - Resistance to most commonly used food processes
  - Perhaps more heat resistant than previously thought
  - Novel processes of promise
  - What does not work
  - Hurdle approach?
- Sanitizers and disinfectants
  - None result in complete inactivation at normal use recommendations
  - High concentrations and long contact times necessary, particularly on surfaces
  - Copper may be promising

Lessons Learned

- Cross disciplinary, holistic approach
- Share the wealth
- Team-building is critical
- Time commitment by leadership
- Budget for support staff
- Money makes things happen!
- Inevitable administrative hurdles
- Listen to stakeholders
- Evaluation is a challenge!
- Others…..





Follow our progress…

NoroCORE

Food Virology

Collaborative for Outreach, Research & Education

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NoroCORE Food Virology
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USDA United States Department of Agriculture National Institute of Food and Agriculture

NC STATE UNIVERSITY

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