Webinar

Foodborne Viruses: Detection, Risk Assessment and Control Options in Food Processing

Organised by the Microbiological Food Safety Task Force

12 November 2019
16.00-17.00 CET, 9.00-10.00 EST
Webinar Housekeeping

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• Questions should be submitted to the presenters during the presentation via the Questions section at the right of the screen.
Webinar Housekeeping

- It is important to note that all opinions and statements are those of the individual making the presentation and not necessarily the opinion or view of IAFP.

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- **> 430** Publications
- **25,820** citations on YouTube
- **52** Industry companies
- **> 1000** Voluntary scientists

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ILSI EU Expert Working Group

• Organized by ILSI EU – first meeting 25 June 2015, Brussels
• Consisted of researchers (7) and food industry (7)
• Activities funded by the Microbiological Food Safety Task Force and Emerging Microbiological Issues Task Force

Prof. Albert Bosch – University of Barcelona (Spain)
Dr. Elissavet Gkogka – Arla Foods (Denmark)
Dr. Fabienne Hamon – bioMérieux Industry (France)
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Dr. Soizick Le Guyader – IFREMER (France)
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Dr. Alejandro Amezquita - Unilever (UK)
Prof. Marcel Zwietering – Wageningen University (Netherlands)

Dr. Mette Myrmel – Norwegian School of Veterinary Science (Norway)
Dr. Trevor Phister – PepsiCo Europe (UK)
Dr. Anna Charlotte Schultz – Technical University of Denmark (Denmark)
Dr. Anett Winkler – Cargill (Germany)
Dr. Sophie Zuber - Nestlé (Switzerland)
Dr. Annette Sansom – Campden BRI (UK)
Ms. Lilou van Lieshout – ILSI Europe (Brussels)
Review

Foodborne viruses: Detection, risk assessment, and control options in food processing

Albert Bosch\textsuperscript{a}, Elissavet Gkogka\textsuperscript{b}, Françoise S. Le Guyader\textsuperscript{c}, Fabienne Loisy-Hamon\textsuperscript{d}, Alvin Lee\textsuperscript{e}, Lilou van Lieshout\textsuperscript{a,\textsuperscript{f}}, Balkumar Marth\textsuperscript{g,\textsuperscript{h}}, Mette Myrme\textsuperscript{i}, Annette Sansom\textsuperscript{j}, Anna Charlotte Schultz\textsuperscript{h}, Anett Winkler\textsuperscript{i}, Sophie Zuber\textsuperscript{m}, Trevor Phister\textsuperscript{h}

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\textsuperscript{m} Nestlé Research Centre, Institute of Food Safety and Analytical Science, Vers-chez-les-Blancs, Box 44, 1000 Lausanne, Switzerland
\textsuperscript{n} PepsiCo Europe, Beaumont Park 4, Leycroft Road, LE4 1ET Leicester, United Kingdom
Why Viruses

- Frequent and under-recognized cause
- Ingredients and finished products are affected
- Global trade that impact multiple countries
  - HAV frozen berries from Canada, Serbia and Poland with cases in Italy
  - NoV in frozen strawberries from China affecting 12,000 in Germany
  - 2018 Winter Olympics

- Interpretation of positive detection
- Effective controls measures throughout food chain
Agenda

Housekeeping and Introduction
Tamara Ford, IAFP; Dr. Angeliki Stavropoulou, ILSI Europe and IIT-IFSH, Alvin Lee

Pros and Cons of Available Methods for Foodborne Virus Detection
Dr. Fabienne Hamon, bioMérieux, France

Translating Risk Assessment of Viruses into Practice
Dr. Elissavet Gkogka, Arla Foods, Denmark

Effect of Processing Technologies to Control Viruses in Foods
Dr. Sophie Zuber, Nestlé Research Center, Switzerland

Future Challenges and Gaps
Dr. Alvin Lee, Institute for Food Safety and Health, USA

Q&A after all speakers and please submit questions using the chat box
Pros and Cons of Available Methods for Foodborne Virus Detection

Fabienne HAMON, PhD.
RD molecular biology manager

IAFP/ILSI webinar, November 12th, 2019
THE IDEAL METHOD FOR FOODBORNE VIRUSES DETECTION

- Sensitive and specific
- Broadly reactive, detects all human genotypes
- Can be used for detection and genotyping
- Rapid or, better, real-time results
- Low detection limit
- Easy to use, portable and without requiring specialized equipment
- Works on a variety of sample types (food or environmental) and with adapted sampling protocols
- Able to distinguish between infectious and non-infectious virus
THE REFERENCE METHODS: ISO15216-1 AND ISO15216-2

Target viruses: Norovirus, Hepatitis A virus

Sample extraction

- Hard surfaces: Swabbing
- Salads: Rinsing (glycine)
- Soft fruit: Homogenisation (glycine)
- Bottled water
- Bivalve shellfish: Digestive gland extraction/treatment

Nucleic acid extraction

Volume ~ 100µl

Boom et al., 1990

Amplification

Volume ~ 2 µl

Reverse transcription

Result interpretation

- Conventional PCR
- Hybridisation / sequencing

Confirmation

Real-time PCR (NV and HAV)

Acceptance criteria

Process control (calicivirus? phage?) and real-time

Amplification control (real-time)
# THE REFERENCE METHODS: ISO 15216-1 & 2

## Mandatory quality controls ISO 15216

<table>
<thead>
<tr>
<th>CONTROLS</th>
<th>ISO 15216-1 &amp; 2</th>
</tr>
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<tbody>
<tr>
<td>ANALYSES</td>
<td>REPRODUCTIBLE &amp; REPEATABLE</td>
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<tr>
<td>COMPLEX METHOD</td>
<td>Several controls for each steps</td>
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<tr>
<td>EXTRACTION EFFICACY</td>
<td>VIRUS PROCESS CONTROL [MENGOVIRUS Vmc0]</td>
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<tr>
<td>RT-PCR EFFICIENCY</td>
<td>Internal positive control (RNA molecules)</td>
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<tr>
<td>QUANTIFICATION</td>
<td>PLASMIDS, dsDNA molecules</td>
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<tr>
<td>RT-PCR</td>
<td>CONTROLS [ARN VIRAL OU PLASMIDES]</td>
</tr>
<tr>
<td>NEGATIVE CONTROLS</td>
<td>PRETREATMENT &amp; RT-PCR</td>
</tr>
</tbody>
</table>
The Reference Methods: ISO15216-1 and ISO15216-2

Pros

- Major viruses and food matrices included
- Simple set-up with detailed protocols on reagent and equipment
- Increases confidence on the results due to use of controls and details on how to interpret results
- International recognition of ISO method leading to increased implementation
- Enables the formulation of guidelines
- Possibility to compare and evaluate results from different labs (proficiency testing available)
- Facilities accreditation of laboratories for virus testing
- Some commercial solution based on these ISO are available
Cons

- Improvements of method may be slowed or halted
- Does not include methods for processed food matrices
- High number of controls increases costs
- Cannot distinguish between infectious and non-infectious particles
- Method complexity

Note: BAM method based on ultracentrifugation available for HAV in limited food matrices
Pros

- Uses in outbreak investigations and provide data for risk assessments
- Routine quantification provides data on baseline levels of viruses in food and will inform implementation of acceptable levels
- Systematic confirmation of RT-qPCR results by sequencing provides information on virus strain epidemiology
Cons

- Confirmation of RT-qPCR positive results by sequencing is difficult due to low sensitivity
-Viruses in foods are not evenly distributed
- Low levels of viruses can lead to variation of up to 1 log
- Short amplicons may not be suitable for typing
- Quantification and confirmation increase cost
- Time consuming
DETECTION FROM INTACT VIRUS CAPSIDS

- Use of RNase treatments
- Intercalating Dyes: Propidium or Ethidium Monoazide (PMA or EMA)
- Histo-blood group antigen (HGBA) glycans
- Monoclonal and polyclonal antibodies
- Nucleic acid aptamers and phage display
- Detection of oxidative damages on capsid proteins
DETECTION FROM INTACT VIRUS CAPSIDS

Pros
- Reduces overestimation of the number of infective virus particles

Cons
- A broad range of reagents need to be developed
- Needs careful evaluation of protocols according to type of matrices and different viruses and genotypes
- Infective and non infective controls must be included, no standardization
- Increased costs compared to standard ISO method
DETECTION OF INFECTED VIRUSES

Cell culture

- Available only for some strains of HAV, not easy to apply for routine detection in food samples

- Real breakthrough for NoV:
  - Replication of human norovirus in cell stem-derived human enteroids (Ettayabi et al., 2016). Complex method that need to be optimized
  - Replication of norovirus in zebrafish larvae (Van Dycke et al., 2019), seems to be a simple replication method

- Not for routine testing in food

- Cost and time effective

- Mainly use for evaluation of the effectiveness of control strategies, inactivation methods (impact of cleaning process, evaluation of disinfectant, impact of food process...)
DETECTION OF INFECTED VIRUSES

ICC-RTqPCR

- Integrated cell culture - RT-qPCR: cell culture prior molecular detection = increase of sensitivity
- Described for HAV not for NoV
- Detect viruses that do not show cytopathogenic effect
- Shorten time for analysis in comparison to cell culture
- High cost
- No standardization
NEW TECHNOLOGIES: DIGITAL PCR

Pros

- Reduces overestimation of the number of infective particles
- Improves detection sensitivity
- Improves accuracy

Cons

- Broad range of reagents need to be develop
- Needs careful evaluation of protocols according to type of virus and matrices
- Controls for infectious and non-infectious particles
- Increased costs compared to standard PCR method
- One-step format not available for digital PCR
NEW TECHNOLOGIES: NEXT GENERATION SEQUENCING

**Pros**

- Viral/virome identification
- Provide data to improve PCR assays
- Improve knowledge on bacterial/viral contamination (Strubbia et al., 2019, Front Microbiol: NoV diversity in sewage and oysters)
- Could be used for food analysis in the future

**Cons**

- Increase cost and time for sample prep
- No standardized protocols
<table>
<thead>
<tr>
<th>Method</th>
<th>Advantages (pros)</th>
<th>Disadvantages (cons)</th>
</tr>
</thead>
</table>
| ISO/CEN method                 | • Major viruses and food matrices are included  
• Increased confidence in the results due to use of controls and detailed description of how to interpret results;  
• International recognition of an ISO method increases implementation of a harmonized method in laboratories;  
• Introduces the possibility to compare and evaluate results from different laboratories;  
• Facilitates accreditation of laboratories for virus testing.                                                                                       | • Improvements of the methods may be halted  
• Does not include methods for processed food matrices;  
• The high number of controls increases costs;  
• Commercial controls must be available;  
• May lead to non-detection of low levels of virus in some specific matrices;  
• Cannot distinguish between infectious and non-infectious particles;  
• Method complexity.                                                                                                                                       |
| Quantification and confirmation| • Routine quantification provides data on baseline levels of viruses in food production and supply chain environments, making possible a quick (< 24 h) quantification of a high number of samples, which can improve the speed of outbreak investigation and laboratory quality control.  
• Provides quantification of a high number of samples, which can improve the speed of outbreak investigation and laboratory quality control.  
• Provides good correlation between the time from sample collection to onset of symptoms;  
• Provides detailed information on virus strain epidemiology.                                                                                               | • Quantification by RT-qPCR is sensitive to inhibitors and produces unreliable results in the presence of inhibitors;  
• Quantification of fecal samples by RT-qPCR is difficult due to low sensitivity;  
• Quantification and confirmation increase cost;  
• Time consuming.                                                                                                                                             |
| Molecular virus detection       | • Requires detection of the number of infective virus particles, intact virus capsids.                                                                                                                                 | • A broad range of reagents needs to be developed;  
• Needs careful evaluation of protocols according to type of virus and matrices;  
• Infective and non-infective controls must be included;  
• Increases costs compared to standard PCR method.                                                                                                           |
| Detection of infective viruses | • Allows detection of infectious viruses  
• ICC-RT-PCR  
  ○ Is more sensitive than cell culture alone;  
  ○ Detects infectious viruses that do not show cytopathogenic effect;  
  ○ Shortens the time for analysis compared to cell culture alone  
• Pathogen-specific primers drastically increase sensitivity compared to conventional PCR methods;  
• ICC-RT-PCR is not quantitative unless used as a Most Probable Number (MPN) test.  
• Increased costs and sample preparation;  
• Absence of standardized approach for next generation sequencing.                                                                                          |                                                                                                               |
| New technologies                | • Digital PCR  
  ○ Is less sensitive to inhibitors in food matrices;  
  ○ Provides more accurate quantification independent of standard curves;  
  ○ Next generation sequencing can pick up emerging viruses and new virus strains.                                                                       |                                                                                                               |

There is still a lot of work to do for a simple routine method.
Risk Analysis Framework

**Risk assessment:** Assessing the probability and severity of an adverse health effect consequential to a hazard present in food.

**Risk management:** Selecting, implementing and monitoring suitable options to accept, minimize or reduce the assessed risk after carefully evaluating the contents of the risk assessment.

**Risk communication:** Interactive information and opinion exchange between risk assessors, risk managers, consumers, food businesses, academics and other interested parties.

**EFSA**

**Risk assessment**

**Risk communication**

**Risk management**

**European Commission**
Risk Assessment Approaches

**Bottom-up risk assessment**
(food chain-based)

**Top-down risk assessment**
(epidemiology-based, surveillance-based)
Risk Assessment Types

Risk assessment (top-down or bottom up)

- Qualitative
- Semi-quantitative
- Quantitative

- Deterministic
- Stochastic
Bottom-up Risk Assessment

**Hazard identification**
- Which hazards in food have the potential to cause an adverse health effect?
  - Mode of production?
  - Routes of contamination?
  - Product formulation?
  - Product association with specific hazards?

**Exposure assessment**
- What is the intake of the hazard through food and if relevant from other sources?
  - Initial concentration?
  - Prevalence?
  - Hazard increases, decreases, or remains stable?
  - Cross-contamination?

**Hazard characterization**
- What is the response to the hazard for different potential doses through food?
  - Dose response curve (epidemiological data)
  - Healthy vs susceptible population?
  - Portion sizes?

**Risk characterization**
- What is the probability and severity of the effect in relation to this hazard in food?
  - Frequency of consumption?
  - Population immunity?
Top-down Risk Assessment

Reported risk
- What is the reported incidence of illness due to this hazard?

Population risk
- What is the actual incidence of illness in the community?

Foodborne risk
- What is the incidence due to food?

Foodborne hazard
- Priorities in terms of products/product groups for managing the hazard?

National surveillance system:
- Epidemiological data (outbreaks, notification data)

Active surveillance:
- Underreporting rate

Source attribution:
- Food
- Environment
- Travel
- Human
- Animal

Food product or product group source attribution
- Risk ranking
Overview of Bottom-up Risk Assessments

- 23 publications
- 36 product-virus combinations
- 6 viruses, 8 product groups
- 3/23 qualitative, 3/23 deterministic, 17 quantitative

Product groups:
- drinking water
- eggs
- poultry
- forest fruit
- leafy greens
- seafood
- other
- pork

Viruses:
- Norovirus
- Hepatitis A
- Avian influenza
- Ebola
- Hepatitis E
- Rotavirus

Product groups: drinking water, eggs, poultry, forest fruit, leafy greens, seafood, other, pork

Viruses: Norovirus, Hepatitis A, Avian influenza, Ebola, Hepatitis E, Rotavirus
# Top-Down vs Bottom-Up Risk Assessments

<table>
<thead>
<tr>
<th>Bottom-up risk assessments</th>
<th>Top-down risk assessments</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Interventions</td>
<td>• Interventions</td>
</tr>
<tr>
<td>• Risk for standard industry practices</td>
<td>• Risk for incidental contamination events</td>
</tr>
<tr>
<td>• More focus on interventions than on risk</td>
<td>• More focus on risk than on interventions</td>
</tr>
<tr>
<td>• Industry/food chain safety management</td>
<td>• Public health authorities/governmental food safety management</td>
</tr>
</tbody>
</table>
Most Important Interventions for the Control of Viruses

- Setting adequate targets for inactivation
  - e.g. 85-90°C for at least 1.5 min (CAC, 2012)
- Raw material/food production controls
  - GAP, GHP, GMP + validation & verification
- Increased surveillance of high risk food commodities
  - e.g. soft fruits (European Commission, 2012)
- Control spread via food handlers
  - e.g. adequate hand hygiene + suitable period of absence/sickness leave
Effect of Processing Technologies to Control Viruses in Foods

Sophie Zuber, PhD
Nestlé Research, Switzerland

Member of the ILSI Expert Group on Control options for Viruses in Food Processing

Webinar, November 12, 2019
Outline

Set the scene
- Recent virus outbreaks - Critical raw materials - Surveillance data
  - Which matrix-process combinations need validation?

Virus inactivation studies
- Challenges for validation
  - Examples: Thermal processing, HPP, gaseous ozone
  - Outlook
<table>
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<tr>
<th>Date</th>
<th>Code</th>
<th>Country</th>
<th>Description</th>
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<tr>
<td>10/07/2019</td>
<td>2019.2402</td>
<td>Spain</td>
<td>norovirus (GI and GII/2g) in live venus clams (Chamelea gallina) from Italy</td>
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<tr>
<td>05/07/2019</td>
<td>2019.2407</td>
<td>Spain</td>
<td>norovirus (genogroup I) in live oysters from France</td>
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<tr>
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<td>2019.2415</td>
<td>Spain</td>
<td>norovirus (GI/2g) in live oysters (Crassostrea gigas) from France</td>
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<tr>
<td></td>
<td>2019.2374</td>
<td>Spain</td>
<td>norovirus (GI/GII/2g) in live venus clams (Chamelea gallina) from Italy</td>
</tr>
</tbody>
</table>

**Public Health Alert Concerning** Hepatitis A Virus Contamination of Kroger Brand Frozen Blackberries and Costco Kirkland Signature Brand Three Berry Blend

**Dates from Iran linked to Hepatitis A outbreak for second time in 2 years**

By Joe Whitworth on May 1, 2019

**Surveillance Study of Hepatitis A Virus RNA on Fig and Date Samples**

Ingeborg L. A. Boxman, Nathalie A. J. M. te Loeye, Kyara Klunder, Geke Hägele, and Claudia C. C. Jansen


A total of 91 fig and 185 date samples were analyzed by reverse transcription (RT) real-time PCR for the presence of hepatitis A virus (HAV) RNA. Two batches of dates tested positive, and the HAV RNA detected was genotyped as IA. These findings warrant further development of methods applicable to food which is consumed untreated and is exported from countries in which HAV is endemic.
Effectiveness of control measures: Target reduction level for viruses?

\[ H_0 - \sum R_{A,B,C} - \sum I_{A,B,C} \leq POs \]

- Initial load at primary production
- Reduction (Supplier and Factory)
- Performance objective (Increase (Growth, Recontamination))

- Prevalence is based on detection by qPCR
- For NoV only surrogate inactivation data available
- Validation data from lab scale studies only

\(^1\) ICMSF conceptual equation
NOROVIRUS, CULTURED.

A 48 YEAR MYSTERY SOLVED
Dr. Mary Estes and her Lab at Baylor College of Medicine have successfully cultured human norovirus in intestinal cells.
Scientists have been trying to culture the virus since the first norovirus outbreak was described in 1968.
The lack of an in vitro culture system has long been considered the single greatest barrier to norovirus research.

HISTORY OF NOROVIRUS RESEARCH

1929
RUMORED
Dr. John Zahorsky, a pediatrician, gives the name “winter vomiting disease” to a common childhood illness that causes vomiting, diarrhea, and a fever.

1972
VISUALIZED
The Norwalk virus is first seen by Dr. Albert Kaplikan and his team at NIH using immune electron microscopy (IEM).

1992
CREATED
Empty shells of norovirus proteins (capsids) are artificially created by the Estes Lab. These virus-like particles are not infectious and enable studies of the capsid.

READ THE ARTICLE

WHAT IS NOROVIRUS?

- It is a tiny (~27nm), spherical virus belonging to the Caliciviridae family.
- It is the most common cause of diarrhea in the world and the most common cause of foodborne illness in the United States.
- An estimated 1 in 15 Americans experience the virus each year, amounting to around 20 million cases.
Human Norovirus Replication in Human Intestinal Enteroids as Model to Evaluate Virus Inactivation

Veronica Costantini, Esther K. Morantz, Hannah Browne, Khalil Ettayebi, Xi-Lei Zeng, Robert L. Atmar, Mary K. Estes, Jan Vinjé

Emerging Infectious Diseases • www.cdc.gov/eid • Vol. 24, No. 8, August 2018
## Which matrix-process combinations?

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<th>Steaming</th>
<th>HPP</th>
<th>Washing</th>
<th>Blanching</th>
<th>Drying</th>
<th>Freeze-drying</th>
<th>Candying</th>
<th>Pasteurising</th>
<th>Curing</th>
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<tbody>
<tr>
<td><strong>Cooking</strong></td>
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<td><strong>Blanching</strong></td>
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<td><strong>Drying</strong></td>
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<td><strong>Freeze-drying</strong></td>
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<td><strong>Candying</strong></td>
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<td><strong>Pasteurising</strong></td>
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### Process Parameters

- Chilled & frozen storage
- pH, $a_w$
- Antiviral food component & packaging
- Sanitizers
- Thermal processing
- High pressure processing
- Irradiation

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**Contents list available at** [ScienceDirect](https://www.sciencedirect.com)

**International Journal of Food Microbiology**

**Review**

Foodborne viruses: Detection, risk assessment, and control options in food processing

Albert Bosch, Elisavet Gkogka, Françoise S. Le Guyader, Fabienne Loisy-Hamon, Alvin Lee, Lilou van Lieshout, Balkumar Marthi, Mette Myrmed, Annette Sansom, Anna Charlotte Schulz, Anett Winkler, Sophie Zuber, Trevor Phister
Virus inactivation studies: Challenges

- NoV
  - MNV (Murine Norovirus)
  - FCV (Feline calicivirus)
  - TV (Tulane virus)

- HAV
  - HAV HM-175

- HEV
  - HEV genotype 3 strain 47832c

Pathogen versus surrogate
### NoV and its surrogates: Thermal processing

<table>
<thead>
<tr>
<th>Control measures</th>
<th>Matrix</th>
<th>Virus</th>
<th>Log(_{10}) reduction</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>72°C, 1 min</td>
<td>Water</td>
<td>MNV</td>
<td>&gt;3.5</td>
<td>Hewitt et al., 2009</td>
</tr>
<tr>
<td>80°C, 1 min</td>
<td>Spinach</td>
<td>MNV</td>
<td>≥ 2.4</td>
<td>Baert et al., 2008</td>
</tr>
<tr>
<td>75°C, 0.25 min</td>
<td>Raspberry puree</td>
<td>MNV</td>
<td>2.8</td>
<td>Baert et al., 2008</td>
</tr>
<tr>
<td>95°C, 2.5 min</td>
<td>Basil</td>
<td>FCV</td>
<td>&gt; 4</td>
<td>Butot et al., 2009</td>
</tr>
<tr>
<td>60°C, 15 min</td>
<td>Stool</td>
<td>HuNoV</td>
<td>&gt;5</td>
<td>Ettayebi et al., 2016</td>
</tr>
</tbody>
</table>

How will HuNoV inactivation data compare with the different surrogates?
Application of HPP on fresh and frozen berries to inactivate Murine Norovirus: Matrix effect

- Higher inactivation of MNV on strawberries compared to blueberries
Ozone gas

Inactivation of Foodborne Pathogens and Their Surrogates on Fresh and Frozen Strawberries Using Gaseous Ozone

Zhi Zhou, Sophie Zuber, Frédéric Cantegreil, Imca Sampers, Frank Devleeschouwer, and Mieke Uytendaele

At 6% ozone for 30 min, 3.3 and 1.8 log<sub>10</sub> for MS2 and MNV, respectively

Pilot-scale trials of interest to the industry, but no suitable surrogate identified
## Processing options and their efficacy to reduce the virus risk

<table>
<thead>
<tr>
<th>Processing Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal processing</td>
<td>High inactivation of most surrogates at 75 °C in high water activity foods</td>
</tr>
<tr>
<td>High pressure processing</td>
<td>High inactivation of most surrogates between 400 and 600 MPa, except Poliovirus and Aichi virus</td>
</tr>
<tr>
<td>Frozen and chilled storage</td>
<td>Low reduction of most surrogates</td>
</tr>
<tr>
<td>pH and water activity</td>
<td>Low reduction of most surrogates, except FCV which is pH sensitive</td>
</tr>
<tr>
<td>Antiviral components and essential oils</td>
<td>Viral inactivation is time and concentration dependent</td>
</tr>
<tr>
<td>Sanitizers</td>
<td>Low inactivation of most surrogates on fresh produce</td>
</tr>
<tr>
<td>Light based technologies</td>
<td>High inactivation in clear liquids &amp; on surfaces of most surrogates</td>
</tr>
<tr>
<td>Ionising radiation</td>
<td>Low reduction of most surrogates at FDA approved dosages</td>
</tr>
</tbody>
</table>
It is key to minimize the viral load in the field

... and to continue filling research gaps

- Work on wider application of cultivable HuNoV and HEV
- Develop surrogates for pilot-scale validations
- Fill gaps regarding surrogate choice, inoculum level and inoculation methods
Questions?

Questions should be submitted to the presenters during the presentation via the **Questions section** at the right of the screen.

Slides and a recording of this webinar will be available for access by IAFP members at [www.foodprotection.org](http://www.foodprotection.org) within one week.