UV Technologies as Alternative to Heat Pasteurization of Foods and Beverages: *Is This a Reality?*

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Outline

• Introduction into “Pasteurization” concept

• Legal status of UV for foods and beverages

• UV as Alternative to Pasteurization
  – Juices

• UV as Adjunct to Pasteurization
  – Milk

• Conclusions
FOOD PRESERVATION

INHIBITION
- CHEMICAL: pH, water content and water activity, preservatives
- PHYSICAL: Refrigeration, freezing, drying

INACTIVATION
- STERILIZATION: Heat, Irradiation, Pressure and Heat
- PASTEURIZATION: Milder heat, irradiation, non-thermal physical methods

REMOVAL
- Nano-filtration, Separation, Centrifugation, Cleaning
Foods Categories

Shelf-stable
- pH > 4.6
  - Sterilization
  - Ambient Storage (LAF)
  - Pasteurization
  - Refrigerated Storage + Growth inhibition barriers
    - LAPF, ESL

Acid & Acidified
- 3.5 < pH < 4.6
  - Pasteurization, Ambient Storage + Growth barriers,
    Refrigerated Foods (ESL)

High Acid
- pH < 3.5
  - Pasteurization
  - Ambient Storage
Pasteurization Concept

- Applied for liquid foods
- Milk, beer, juices
- Eliminate the risk of most pathogenic bacteria
- Requires refrigerated storage
- Solids foods can be pasteurized in consumer packages to eliminate post-processing contaminants
Pasteurization

• 1862 - the first pasteurization test was completed by Louis Pasteur and Claude Bernard

• Term “pasteurization” was defined as a process of mild heat treatment to reduce significantly or kill the number of pathogenic and spoilage microorganisms

- Milk (PMO)
  • 63° C for not less than 30 min, LTLT
  • 72° C for not less than 16 s, HTST
  • or equivalent destruction of pathogens and enzyme phosphatase

• Beer
Pasteurization after 2004

- Prior to 2002 FDA considered pasteurization as a thermal treatment
  - FDA would not allow a nonthermal processing technology to promote its treatment as a “pasteurization” process

- September 2004, the USDA National Advisory Committee on Microbiological Criteria for Foods (NACMCF) redefined the term pasteurization

Any process, treatment, or combination thereof, that is applied to food to reduce the most microorganism(s) of public health significance to a level that is not likely to present a public health risk under normal conditions of distribution and storage

*Food Chemical News, 2004*
2004 NACMCF: Alternative Pasteurization Technologies

- Cooking, steam and hot water treatments
- Microwave processing (MW)
- Ohmic/inductive heating
- High pressure processing (HPP)
- UV radiation, irradiation, light
- Pulsed electric fields, pulsed light
- Infrared processing
- Non-thermal plasma
- Oscillating magnetic fields
- Ultrasound and filtration
Establishment of Preservation Process

1. Identification of the organism of concern for food category

2. Identification and selection of the appropriate target end point or specific log reduction (SLR)

3. Identification of critical factors

4. Development of a conservative estimation of the ability of the process to consistently deliver the target end point

5. Validation (microbiological or mathematically) of the lethal treatment delivered

6. Identification of procedures used to control the delivery of the required process.
### Examples of SLR for foods at different pH

<table>
<thead>
<tr>
<th>Examples of Products</th>
<th>pH</th>
<th>Pathogen of Concern</th>
<th>Microbial Reduction (Logs)</th>
<th>Enzymes Destruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple cider</td>
<td>&lt;3.5</td>
<td><em>E. coli</em> O157:H7</td>
<td>5-log&lt;sub&gt;10&lt;/sub&gt;</td>
<td>PPO</td>
</tr>
<tr>
<td>Orange juice</td>
<td>&lt;3.5</td>
<td><em>Salmonella</em>, <em>E. coli</em> O157:H7</td>
<td>5-log&lt;sub&gt;10&lt;/sub&gt;</td>
<td>Pectin methylesterase (PME)</td>
</tr>
<tr>
<td>Carrot juice</td>
<td>&gt;4.6</td>
<td>non-proteolytic <em>C. botulinum</em></td>
<td>5-log&lt;sub&gt;10&lt;/sub&gt;</td>
<td></td>
</tr>
<tr>
<td>Milk and milk products</td>
<td>~6.5 - 7</td>
<td><em>Mycobacterium tuberculosis</em>, <em>Coxiella burnetii</em></td>
<td>5-log&lt;sub&gt;10&lt;/sub&gt;</td>
<td>Negative for alkaline phosphatase</td>
</tr>
<tr>
<td>Eggs products</td>
<td>&gt;7</td>
<td><em>Salmonella enteritidis</em>, <em>Salmonella typhimurium</em></td>
<td>7-log&lt;sub&gt;10&lt;/sub&gt;</td>
<td></td>
</tr>
<tr>
<td>In-shell eggs</td>
<td>&gt;7</td>
<td><em>Salmonella</em></td>
<td>5-log&lt;sub&gt;10&lt;/sub&gt;</td>
<td></td>
</tr>
<tr>
<td>RTE meals</td>
<td>&gt;4.6</td>
<td><em>Listeria</em></td>
<td>5-7 log&lt;sub&gt;10&lt;/sub&gt;</td>
<td></td>
</tr>
<tr>
<td>Almonds</td>
<td>&gt;4.6</td>
<td><em>Salmonella</em></td>
<td>5-log&lt;sub&gt;10&lt;/sub&gt;</td>
<td></td>
</tr>
<tr>
<td>Fish and sea products</td>
<td>&gt;4.6</td>
<td>non-proteolytic <em>C. botulinum</em></td>
<td>6-log&lt;sub&gt;10&lt;/sub&gt;</td>
<td></td>
</tr>
<tr>
<td>Crab meat</td>
<td>&gt;4.6</td>
<td>Type E non-proteolytic <em>C. botulinum</em></td>
<td>12-log&lt;sub&gt;10&lt;/sub&gt;</td>
<td></td>
</tr>
</tbody>
</table>
Legislative Status of UV

• **USA – UV irradiation is a food additive**
  
  **FDA**: CFR 21 179.39 UV radiation for the processing and treatment of food
  
  – Surface of food and food products
  – Potable water
  – Juice products
    
    • Reduction of human pathogens and other microorganisms
    • Turbulent flow at Re >2000
  – Baking yeasts
  – Mushrooms
  – Milk

  The acceptance of UV as a food additive for dairy applications 21 CFR 179.39 PMO submission

• **Canada – UV light is a novel technology**
  
  **HC**: Approval by Novel Foods Regulations
  
  – Apple Cider, shelf-life extension

• **EU**
  
  **EFSA**: Approval by Novel Foods Regulations
  
  – Milk after pasteurization for shelf-life extension

• **NZ and Australia**
  
  **FSANZ**: Demonstrate equivalence to thermal treatment
UV Preservation Processes For Fluids

• Shelf-life extension of raw products
  • Milk
  • Juice products
  • Liquid eggs

• Alternative to Heat Pasteurization
  • Fruit and vegetable Juices (high acid or acid)
  • Milk
  • Coconut water, coconut juice (low acid)

• Adjunct to Heat Pasteurization
  • Milk
  • Liquid Eggs
  • LA drinks (coffee)
UV as **Alternative** to Pasteurization

- **Juices**
  - high acid and acid pH < 4.5
    - Apple, orange, apple cider
    - Pathogenic *E. coli, Listeria monocytogenes, Salmonella, Cryptosporidium parvum*

- **Ingredients**
  - Water in dairy processing
  - Liquid sweeteners

- **Beer**
UV Pasteurization of Juices

Validate for pertinent organisms
pH > 4.6 – low acid category
   Clostridium botulinum
pH < 3.5 – high acid category, pH<4.6 acidic
   Pathogenic E.coli, Listeria monocytogenes, Salmonella, Cryptosporidium parvum

Establish
Specific Log Reduction
Design Reduction
Equivalent Dose (RED)
Critical process and product parameters

Validate against
Natural micro-flora, Enzymes
Shelf-life studies

Quality effects
Nutritional effects
   vitamins, polyphenols, anti-oxidants
Sensory studies
# Issues to Address for Pasteurization

## Microbiological
- Most UV resistant pathogen organism
  - in milk: 18 pathogens
    - *Mycobacterium tuberculosis*
- UV dose to achieve SLR reduction of pathogens
- Surrogate organisms
- Validation
- Verification tests
- Photo-reactivation

## Chemical
- Effect on composition
- Cholesterol
- Fatty acids photo-oxidation
- Protein oxidation
- Furans
- Effects on Nutrients (Vitamins)
- Volatile compounds
- Off-flavors
- Toxicological concerns
- Allergens
## Commercial UV systems

### Principle

- **Thin film**
- **Dean Vortex flow**
- **Static mixers**
- **Turbulent flow**

### Example

- **CiderCire**, NY USA
- **Salcor Module**, CA, USA
- **Uvivatec**, Germany
- **AseptoRay**, Israel
- **SurePure**, SA
- **MikroTec**, UK
- **Aquafine/Trojan**, Canada
- **Atlantium**, Israel
- **Aquionics**, USA
- **American UV**
- **Ultradynamics**, USA
Examples of UV systems

Mikrotec, UK

Innovative breaking through technology, enabling UV disinfection of turbid liquid.

Surepure Inc, SA

AseptoRay, Israel

CiderSure USA
UV as **Adjunct** to Pasteurization of LA Juices

- **Carrot juice**
  - absorption coefficient at 254 nm [cm⁻¹] 95,8 ± 0,3
  - turbidity [NTU] > 11.000
  - viscosity [mPas] 1,44 ± 0,19; density [g cm⁻³] 1,037 ± 0,001
  - pH 6,44 ± 0,01

- Max Rubner-Institut (Germany); Department of Food Technology and Bioprocess Engineering: *Heat + UV light*

- Heat treatment (65 °C, 5 min) resulted in a 1-2 log reduction of total aerobic microbial count
- Additional 3 log reduction by applying UV-C (4.3 kJ L⁻¹)
- Shelf life of was enhanced to 12 days
- Minimal heat treatment resulted in a reduction of carotenoids
- No carotenoid reduction was observed when UV-C (4.3 kJ L⁻¹) was applied
Why *Adjunct*?

- UV light is not effective against spores as a single alternative treatment

- Difficulty with regulatory submissions
  - Data collection
    - BSL-2 or BSL-3 facility
  - Differences in regulations
    - North America, EU, NZ and Australia, Japan
  - New indicators have to be developed
    - Phosphatase test
UV as Adjunct to Pasteurization

• Spores are organism of concern
  • Low Acid juices and beverages
    – Carrot juice, coconut water, iced coffee
    – *C. botulinum*
    – Combination with mild heat can be required

• Extended shelf-life products
  • Raw milk or juices
  • Acid juices
    – Alicyclobacillus can survive pasteurization
    – juices, iced teas
  • ESL milk
    – Heat resistant spoilage spores
    – UV is used as a post pasteurization treatment
UV Treatment of Milk

• Pre-pasteurization treatment
  – To extend shelf-life of raw milk by controlling high loads of spoilage and pathogenic organisms
  – Non-thermal thermisation process

• Enhance safety and shelf-life of cheese milk
  – Listeria monocytogenes is a concern

• Post-pasteurization treatment
  – To extend shelf-life of pasteurized milk by controlling heat resistant spores

• Treatments of calf milk

• Treatment of human donor milk

Challenge:
optimizing UV dose to achieve microbial reduction and prevent photo-oxidation of lipids and formation of undesired chemical compounds
UV Resistance of Milk Pathogens

- Non-linear character of microbial inactivation
- *Listeria monocytogenes* was the most UV resistant among 8 milk pathogens
- UV dose to achieve 5-log inactivation of *Listeria* was evaluated as **1936 J/l**
# UV Inactivation of Spores in Whole UHT Milk

<table>
<thead>
<tr>
<th>Spore</th>
<th>5-log Reduction (J/L)</th>
<th>5-log Reduction (J/cm²)</th>
<th>$R^2$</th>
<th>RMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Paenibacillus lautus</em></td>
<td>&gt;8800</td>
<td>&gt;11.950</td>
<td>0.9952</td>
<td>0.0994</td>
</tr>
<tr>
<td><em>Bacillus cereus</em></td>
<td>7480</td>
<td>10.158</td>
<td>0.9960</td>
<td>0.1276</td>
</tr>
<tr>
<td><em>Paenibacillus amylolyticus</em></td>
<td>5896</td>
<td>8.007</td>
<td>0.9928</td>
<td>0.2100</td>
</tr>
<tr>
<td><em>Bacillus pumilus</em></td>
<td>4752</td>
<td>6.453</td>
<td>0.9964</td>
<td>0.1717</td>
</tr>
<tr>
<td><em>Bacillus licheniformis</em></td>
<td>4048</td>
<td>5.497</td>
<td>0.9909</td>
<td>0.2426</td>
</tr>
</tbody>
</table>
UV as Adjunct to Refrigeration and Pasteurization of Milk

**Environmental factors**

- **Operational factors**

  - **Raw Milk**
    - Pasteurization
    - Ultra-pasteurization
    - UV + Pasteurization Post-Treatment

  - **Processing**
    - Pasteurization
    - Recontamination

  - **Packaging**
    - ESL = 60-90+ days if filled & packaged with ESL filler & distributed at 4°C

  - **Refrigerated Storage & Distribution**

**Key Points**

- *Past.* = 18-21 days if distributed & stored at 4°C
- ESL = 60-90+ days if filled & packaged with ESL filler & distributed at 4°C
UV for Shelf-Life Extension of Raw Milk

• SurePure SP40 UV unit

• UV doses up to 2.0 kJ/l were effective to reduce total viable counts, psychrophiles and coliforms up to 2, 3 and 4-log reductions

• E.coli O157:H7, Salmonella, Yersinia, Staphylococcus, Listeria monocytogenes and Campylobacter jejuni – 5-log reduction at 2 kJ/l

• Raw milk - up 14 day extension of shelf-life

• Microbiological efficacy is achieved without any discernable denaturing of the product`s consistency, color, flavor or aroma
UV for Pasteurised Milk

EFSA scientific opinion: January 2016

• The novel food is cow’s milk (whole, semi-skimmed or skimmed) to which a treatment with ultraviolet (UV) radiation is applied after pasteurisation in order to extend the shelf life of the milk. This treatment results in an increase in the vitamin D3 concentrations.

• The Panel considers that the provided compositional data, the specifications and the data from batch testing do not give rise to safety concerns.

• The data provided on the production process are sufficient and do not give rise to safety concerns.
Efficacy of UV Light for Milk

• UV treatment of raw milk can achieve a 3 to 4 log$_{10}$ reduction of initial microbial load measured as standard plate, psychrotrophic, coliform and thermoduric counts
  – Extend shelf life of raw milk up to 14 days

• UV was found effective against pathogenic bacteria found in milk. A reduction in *Escherichia coli O157:H7, Listeria monocytogenes, Salmonella senftenberg, Yersinia enterocolitica and Staphylococcus aureus* can be achieved
  – Ensure the safety of milk

• UV light can destroy spoilage spore formers in milk
  – Extend shelf of pasteurized milk (ESL)
Conclusions

- Alternative non-thermal technologies including UV light are available as adjuncts to pasteurization and ESL processes
  - Can offer energy savings, better quality, longer shelf life during transportation

- As a non-thermal and non-chemical preservation UV light can be used for milk and juice products as
  - adjunct to refrigeration
  - pasteurization
  - ESL method

- Regulatory approval is a hurdle for commercialization
Dr. Tatiana Koutchma

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Questions?