Hot water treatment (HWT) of fresh produce to prolong shelf life and reduce losses and waste

Merete Edelenbos and Hinrich Holthusen
Department of Food Science
Aarhus University, Denmark
Merete.Edelenbos@food.au.dk

At harvest
During storage/shelf life

Gloeosporium rot (Neofabraea spp.)

FRUTIC 2018
Optimizing Water Use in the Supply Chain of Fresh Produce
Why is there a growing interest for HWT?

- HWT can reduce food losses and waste
- HWT is an eco-friendly and safe alternative to synthetic fungicides
- A good alternative for organic products
- No residues on the treated product
- There is no human health risks with HWT
- Accepted by consumers
Agenda

- The history of hot water treatment (HWT)
- HWT of fresh produce for disease control
- The mechanisms behind HWT
- Examples with HWT of apples and pears
- The future for HWT
The history of hot water treatment (HWT)

There are basically two treatment strategies:

- Immersion / dipping between 43 and 53 °C for several minutes up to 2 h
- Showering / rinsing between 48 and 63 °C for 10 – 30 s

During treatment:

- Heat is efficiently transferred from the water to the produce
- Operation times are short
- Water ( > 50 °C) can be recycled / reused
The history of hot water treatment (HWT)

Hot water treatment has been used for:

- Postharvest disease control
- Insect disinfection
- Inhibit ripening, sprouting, geotropic curvature
- Induce resistance to chilling injury

Examples of disease control:

- Brown rot in citrus fruits (Fawcett, 1922)
- Gloeosporium / Bull’s eye rot (*Neofabraea* spp.) in apples (Burchill, 1964)
- Grey mold in kiwifruit (Cheah et al., 1992)
- Green and blue mold in oranges (Strano et al., 2014)
Examples of treated horticultural crops

- Apples, pears, peach, nectarine, plum
- Banana, mango, papaya, litchi, kiwifruit
- Clementine, grapefruit, lemon, mandarin, orange, tangerine
- Melon, muskmelon, strawberry
- Avocado, potato, tomato, pepper
The mechanisms behind hot water treatment

Disease incidence rel. to control [%]

Increasing heat-shock induction

Optimal temp.

Heat damage on fruits

Lethal effect on inoculum

Penicillium expansum

Neonectria galligena

Neofabraea spp.

3-min. HWT temperature [°C]

Maxim et al. 2014
Effect on the pathogens

- Lethal or sub-lethal effect on spore germination / mycelial growth
- 3 - 4 log reduction in CFU – and thus a ‘cleaner’ product

Pathogens isolated from infected kiwifruit

Chen et al. 2015
A more ‘clean’ fruit with brushing and HWT

Scanning electron microscopy of the calyx after 2 weeks at 7 °C

A: Brushed
B: Brushed & hot water rinsed (55 °C for 12 s)

S: stomata; C: conidiophore/conidium; h: hyphae

Fallik et al. 1999
Effect on the fresh produce

- Melting of the epicuticular wax
- Occlusion of entry points for wound pathogens
- Physiological changes that induce resistance
- HWT is a balance between mild stress and wounding
Melting and occlusion of entry points in pepper fruits

Scanning electron microscopy of skin after 2 weeks at 7 °C

Fallik et al. 1999
Physiological changes that induce resistance

**Inducing treatments**
- Ozone
- GRAS
- Oligandrin
- HWT
- SA
- Hypobaric
- BFO
- Hyperbaric
- Chitosan
- NO
- MVOCs
- EtOH
- PVOCs

**Physiological changes in host tissues**
- Priming
- PPO
- LOX
- CAT
- PAL
- hsp
- ABA
- SAR
- SA
- MeJA
- INA
- BTH
- EOW
- UV-C
- Si
- NPR1
- ISR
- JA
- BABA-IR
- MAMP
- ROS
- PAMP
- Ethylene

Romanazzi et al. 2016
HWT is a balance between mild stress and wounding

Volatile metabolism Poor flavor & taste

PAL: phenylalanine ammonia-lyase  PPO: Polyphenol oxidase  Partly from Saltveit 2003
HWT of apples

HWT 3 min
Ingrid Marie and Pinova

20 °C  50 °C  52 °C  54 °C  56 °C

Drying at 24 °C for 25 min

Cold storage at 2 °C for 14 weeks
Effect of HWT on skin temperature

Renata de Paulo Rocha, 2014
Effect of 3 min HWT on fruit temperature

- 20 °C
- 52 °C
- 54 °C
Effect of 3 min HWT on fruit temperature

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Min</th>
<th>Mean</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 °C</td>
<td>18.9</td>
<td>19.6</td>
<td>21.7</td>
</tr>
<tr>
<td>52 °C</td>
<td>19.5</td>
<td>26.3</td>
<td>32.6</td>
</tr>
<tr>
<td>54 °C</td>
<td>19.8</td>
<td>27.2</td>
<td>33.3</td>
</tr>
</tbody>
</table>

Mínimo: 18.9 °C Máximo: 21.7 °C Valor médio: 19.6 °C

Mínimo: 19.5 °C Máximo: 32.6 °C Valor médio: 25.3 °C

Mínimo: 19.8 °C Máximo: 33.3 °C Valor médio: 27.2 °C
Effect of HWT on skin browning in apples

'Pinova' dipped for 3 min at 54 °C

Increased browning

After 7 weeks at 2 °C

Skin browning scale from low to high (0 - 4)
Prediction of skin browning at treatment by volatile analysis

Gas sampling after 2 h at 20 °C

GC-MS analyses

Abundance

Time (min)

20 °C 56 °C

Acetaldehyde

Methanol

Butyl ethanoate

Hexyl ethanoate

Himmeiøe et al. 2016
Prediction of skin browning by volatile analysis

Observed browning after 7 weeks at 2 °C

Predicted browning after 2 h at 20 °C

R² = 0.84

'Ingrid Marie'

'Pinova'

R² = 0.84
Effect of 3 min HWT on apple quality

- Firmness (N)
  - 20 °C
  - 50 °C
  - 52 °C
  - 54 °C
  - 56 °C

- Brix (%)
  - 0
  - 7
  - 14

Storage weeks at 2 °C
Effect of HWT on storage rot in apples

![Graph showing the effect of HWT on storage rot in apples](image)

**Storage rot (%) after 14 weeks at 2 °C**

- HWT for 3 min

**Penicillium expansum**
- Control
- Skin browning

**Physiological disorders**
Equipment for hot water showering

Showering of big boxes with apples

Capacity: 6 – 12 tons / h

Developed by Möstl Anlagenbau, Passail, Austria
Photo: Hanne Lindhard Pedersen. AU, DK.

Showering of single fruits

Capacity: 1.5 tons / h

Developed by Shelah Systems, Kibbutz Alumim, Israel
Modified by ESTEBURG Obstbauzentrum, DE.
Photo: Hinrich Holthusen, ESTEBURG Obstbauzentrum, DE.
Equipment for hot water dipping of single fruits

Developed by Innotheque Aps, Røjle, Denmark.
Photos: Kim Nielsen, AU, DK
Effect of short time HWT on rots in pears

Storage rot (%) after 10 days at 16 °C

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Storage Rot (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 °C</td>
<td>30</td>
</tr>
<tr>
<td>52 °C</td>
<td>20</td>
</tr>
<tr>
<td>54 °C</td>
<td>10</td>
</tr>
<tr>
<td>56 °C</td>
<td>5</td>
</tr>
</tbody>
</table>

HWT for 30 s

Marianne G. Bertelsen, 2015
Effect of short time HWT on skin browning

![Graph showing the effect of HWT on skin browning](image)

- **Safe T at 30 s**: 60°C
- **HWT for 30 s**: Control, 50°C, 52°C, 54°C, 56°C, 58°C, 60°C, 62°C, 64°C

Chlorophyll fluorescence

**FRUTIC 2018**
Optimizing Water Use in the Supply Chain of Fresh Produce
Future for hot water treatment

- Cheap, safe and eco-friendly
- HWT is more suitable for fruit than vegetables
- HWT can be used at harvest and or before packaging
- A strict control of temperature and time is a paramount
- HWT is a balance between mild stress and wounding
- HWT can be used alone or in combination with other techniques
- Improper HWT should be prevented – screening methods before treatment are needed
- A better understanding of the pathogen / tissue response to HWT would help further developments
Acknowledgements

Department of Food Science
Thank you for your attention!