Sous-vide food safety

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How to compare the safety of foods cooked at temperature less than \(~60^\circ\text{C}\) with traditional products?
Discuss general issues arising from during the project?

- Introduction of sous-vide systems
- Time/temperatures used in sous-vide food production
- Data on thermal death of pathogens below 60°C
- Problems with assessing bacterial behaviour at time/temperatures used for sous-vide (or why scientists can’t give straight answers)
Sous-vide: food is vacuum packed in plastic pouches and cooked by emersion in water or in a steam oven

**Proposed advantages:**
- Cooking at required temperature avoids overcooking
- Even cooking throughout product
- Enhanced flavour
- Timing not as critical
- Enhanced nutritional qualities
- Tighter portion control
- Minimise cooking losses
- Separates chef time from service times
- Food preparation time spread over longer period
- Less equipment required for same preparation of meals
- Food reheated as required to reduce wastage
- Food preparation and cooking can be centralised

Restaurants focused on precision cookery
Problem is assessing low temperature cooking methods
“Sous vide cooking is the single greatest advancement in cooking technology in decades.”

Heston Blumenthal, Three-Michelin Star Chef
Cooking temperature depends on type of food

- Primal cuts of meat: Rare~50°C, Med rare~55°C, Med~60°C, WD~70°C
- Secondary cuts of meat: 55-80°C usually for extended times (up to 72h)
- Poultry: 55-80°C, chicken breast 57-66°C
- Vegetables: 80-95°C
- Dairy: 30-85°C
- Eggs: 50-70°C
- Seafood: 42-60°C
Sous-vide service systems

- Interrupted catering system
- Cook to order
- Predictive cooking
- Cook - chill – regenerate
- Cook - chill – predictive regenerate
- Cook use as component in composite food

Regeneration usually 50-55°C
Sous-vide cooking often combined with other techniques

• Brown before cooking e.g. Chicken crown

• Browned after cooking e.g. Steak is seared

• Braised

• Marinate in bag

• Confit
How do you assess safety?

If in doubt stick to safe harbours!
Safety of sous-vide foods usually relies on a mild heat treatment combined with refrigerated storage.
Heat resistance is usually expressed as a D-value which is the time required to inactivate 90% of the population (i.e. reduce to a tenth)
Z-value is the change in temperature necessary to bring about a 10-fold change in the D value.

For thermal processing a value of 10°C has been adopted as standard.

Non-proteolytic *C. botulinum* $z = 9^\circ$C

*L. Monocytogenes* $z = 7.5^\circ$C

*E. coli* O157:H7 in meat $z = 5.4^\circ$C
## Typical heat resistance of organisms

<table>
<thead>
<tr>
<th>Organism</th>
<th>Temperature for 1 log decrease min⁻¹ (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacillus – psychotropic (spores)</td>
<td>100</td>
</tr>
<tr>
<td>Bacillus – mesophillic (spores)</td>
<td>110</td>
</tr>
<tr>
<td>C. botulinum – proteolytic (spores)</td>
<td>115</td>
</tr>
<tr>
<td>C. botulinum – non proteolytic (spores)</td>
<td>80</td>
</tr>
<tr>
<td>Listeria monocytogenes</td>
<td>65</td>
</tr>
<tr>
<td>Escherichia coli</td>
<td>62</td>
</tr>
<tr>
<td>Salmonella</td>
<td>60</td>
</tr>
<tr>
<td>Staphylococcus aureus</td>
<td>60</td>
</tr>
<tr>
<td>Yersinia</td>
<td>58</td>
</tr>
<tr>
<td>Campylobacter</td>
<td>52</td>
</tr>
<tr>
<td>Aeromonas</td>
<td>50</td>
</tr>
</tbody>
</table>
Advisory heat treatments for chilled foods

• Shelf life 10 days max: equivalent to 70°C/2 mins or other measures demonstrably controlling L. monocytogenes

• Shelf life >10 days: equivalent to 90°C/10 mins or other measures demonstrably controlling Group II C. botulinum

Note: food may served directly after cooking

E. Coli
ACMSF 2007 Report on the Safe Cooking of Burgers concluded “advice for cooking of burgers should remain at 70°C for 2 minutes as it presents a high level of confidence of delivering a widely accepted inactivation standard (6-log), and ensures a wide safety margin in the face of considerable real-world variation
Equivalent lethalities

- **ACMSF 1992**
  - Group II C. botulinum: z-value of 9°C, reference temperature 80°C, equivalent lethalities given for 70-90°C

- **ECFF**
  - Listeria: z-value of 7.5°C, reference temperature 70°C, equivalent lethalities given for 60-85°C
  - Group II C. botulinum: z-value of 7°C below 90°C and 10°C above 90°C, reference temperature 90°C, equivalent lethalities given for 80-100°C
• Use equivalent lethalities to divide food into rare or cooked
Sous-vide recipes and equipment are widely available for food service and domestic use.

Collect time/temperature processes used in food service and domestic sous-vide cookery. Data was collected from:

- Popular sous-vide cookery books
- Recipes from Chefs and observed by EHOs.
- Bing search “sous-vide recipes” claimed 7,920,000 results. Examine 200 recipes.
Cooking time/temperatures from sous-vide recipes found on internet

Minimum heating time (min) vs. Waterbath temperature (°C)

- Dairy
- Egg
- Fruit & veg
- Offal, sausage etc
- Poultry and small game
- Red meat
- Seafood

Waterbath temperature (°C)

- 70°C/2min equivalent
- 90°C/10min equivalent
Cooking time/temperatures from sous-vide recipes found on internet

Waterbath temperature (°C)

Minimum heating time (min)

- Dairy
- Egg
- Fruit & veg
- Offal, sausage etc
- Poultry and small game
- Red meat
- Seafood

- 70°C/2min equivalent
- 90°C/10min equivalent
Recipes with heat treatment of less than 70°C for 2 min

<table>
<thead>
<tr>
<th>Food</th>
<th>Time (min)</th>
<th>Temp</th>
</tr>
</thead>
<tbody>
<tr>
<td>crème fraiche</td>
<td>480</td>
<td>35</td>
</tr>
<tr>
<td>Poached egg</td>
<td>15</td>
<td>60</td>
</tr>
<tr>
<td>Pork chop</td>
<td>60</td>
<td>55</td>
</tr>
<tr>
<td>pork chops</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>Pigeon</td>
<td>20</td>
<td>59.5</td>
</tr>
<tr>
<td>lobster</td>
<td>25</td>
<td>60</td>
</tr>
<tr>
<td>Shrimp</td>
<td>40</td>
<td>49</td>
</tr>
<tr>
<td>lobster tail</td>
<td>15</td>
<td>58.5</td>
</tr>
<tr>
<td>scallops</td>
<td>35</td>
<td>50.5</td>
</tr>
<tr>
<td>scallops</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>veal medallions</td>
<td>9</td>
<td>58</td>
</tr>
</tbody>
</table>

Also:
- Beef steak
- Fish filet, salmon and trout
- Lamb chops and rack
- Duck breast

Sous-vide crème fraiche:
place whipping cream & butter milk in sealed mason jar and heat at 35°C for 8-12h. Store sealed for up to 3 weeks
Cooking time/temperatures from sous-vide cooking guides, recipe books and observed practices

Minimum heating time (min)

Waterbath temperature (°C)

Dairy
Egg
Fruit & veg
Offal, sausage etc
Poultry and small game
Red meat
Seafood

70°C/2min equivalent
90°C/10min equivalent
Recipes with heat treatment of less than 70°C for 2 min

<table>
<thead>
<tr>
<th>Red meat</th>
<th>Poultry and game</th>
<th>Seafood</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef steak</td>
<td>Duck breast</td>
<td>Salmon</td>
<td>Foie gras</td>
</tr>
<tr>
<td>Lamb chops</td>
<td>Pigeon breast</td>
<td>Trout</td>
<td>Veal sweetbreads</td>
</tr>
<tr>
<td>Pork chops</td>
<td>Rabbit loin</td>
<td>Fish fillets</td>
<td>Calves liver</td>
</tr>
<tr>
<td>Gammon steak</td>
<td>Partridge</td>
<td>Eel</td>
<td>Egg</td>
</tr>
<tr>
<td>Veal</td>
<td>Chicken breast</td>
<td>Scallop</td>
<td></td>
</tr>
<tr>
<td>Venison</td>
<td></td>
<td>Shellfish</td>
<td></td>
</tr>
</tbody>
</table>

Are these products any less safe than equivalent products prepared by traditional methods?
Note. For this rough assessment it was assumed that published lethal rates for *Listeria* and *C. botulinum* can be extended to lower cooking temperatures.

How long can beef ribs cooked for 72h at 60°C be safely kept refrigerated? Or veal roulade cooked for 30h at 70°C?
Problems with calculating equivalent processes

- Are available D-values suitable for extended low temperature inactivation
- How far can you extend the z-value
- What z-value should be used? Should it be product specific?
- What heat is actually applied
- What organism should safety be based on
Effect of measurement time on calculated D-values

Heat treatment of Salmonella at 62.5°C in culture medium, pH 7 with 60% glucose

D-values should not be extrapolated but measured over a 6 log reduction or over a prolonged period to verify shape of inactivation curve.
Observation times

- There is a discrepancy between the times used in sous-vide cooking, which can be up to 72h, and the observation times used by scientists conducting thermal death experiments.

- More kinetic data will be required in the 42°C to 55°C region if modelling bacterial behaviour is to be improved.
Longest observation time against treatment temperature

L. monocytogenes

Temperature (°C)
Longest observation time (h)

0.5h
3h

Growth
No growth
Death
How far can you extend the z-value?
D-values for salmonella

Meta-analysis of the inactivation of *Salmonellae*

D-values for salmonella

Meta-analysis of the inactivation of *Salmonellae*

D-values for salmonella

Meta-analysis of the inactivation of *Salmonellae*

D-values for salmonella

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D-values for salmonella

Meta-analysis of the inactivation of *Salmonellae*

D-values for salmonella

Meta-analysis of the inactivation of *Salmonellae*
Which organisms are of interest

- Pathogen of concern may vary with food. Should heat treatments for chicken be based on salmonella and campylobacter?

- Consider parasites, viruses and toxins in addition to bacterial pathogens. How well are kinetics of inactivation understood for addition non bacterial hazard?
The effect of vacuum was seldom studied and it may be a significant factor. Previous studies have shown that thermal inactivation appears higher for cells in the presence of oxygen than in low oxidising conditions.
Effect of water activity

Several recipes call for brining of fish or poultry before cooking and confit recipes use fat added to the vacuum bag

Would $a_w$ be a factor significant in these products? (note $a_w$ decreased rate of destruction)
Critical to the pasteurisation process is maintaining a constant cooking temperature (e.g. ±1°C from set point)

- Check waterbath temperature calibration
- Limit volume of food added to waterbath at one time to prevent temperature being reduced
- Keep product under water
- Separate product to allow good water circulation
- Identify pack to ensure all packs receive adequate treatment
- Probe selected products to confirm temperature predictions (use time for internal temp come-up time +10% for cooking time)
Different types of water bath

• Equipment
  ▪ Stirred
  ▪ Non-stirred
  ▪ Industrial vs homemade?
  ▪ Adapted from other uses e.g. rice cookers, slow cookers etc.

Does method of water circulation affect rate at which heat is transferred into foods?
Is there potential for bacterial growth during sous-vide cooking?
Specific growth rate (h⁻¹)

Temperature (°C)

For illustrative purposes – specific growth rates between 40 and 60°C reported in ComBase
Specific growth rate (h\(^{-1}\))

Temperature (°C)

For illustrative purposes – specific growth rates between 40 and 60°C reported in ComBase

Salmonella
Current limits of models in ComBase

- **E. coli**
- **Listeria**
- **Salmonella**
- **C. perfringens**

**Temperature (°C)**

- **Growth model**
- **Data: Growth**
- **Data: Inactivation**
- **Inactivation model**
Potential growth during sous vide cooking

• Some of the temperatures used for sous-vide cooking potentially allow pathogen growth.

• Should there be guidance on maximum cooking or regeneration times?

• Should recommended maximum treatment time be product specific?
Temperature inside foods during sous-vide cooking

The discussion so far has been based on the cooking time and temperature i.e. the time/temperature in the waterbath. The actual temperature in the food must also be considered.
The importance of any difference between the surface and centre temperature depends on the food.

Potential problem foods?

Liver, Pate and offal?
Chicken? (Pink chicken)
Composite and comminuted products
Tenderised meat?
As the surface heat transfer coefficients and thermal diffusivity of water and most foods are known, it is possible to model the temperature inside foods as well as the surface temperature.
Sous-vide apps predicting temperature and bacterial death are already available

Screen dump from sous vide dash
Graph shows surface and core and estimated reduction in *Salmonella*, *Listeria* and *E. coli*.
Summary: Sous-vide safety considerations

- Products are heat-treated, some are pasteurised but not sterile

- Products usually have pH>4.6, aw>0.93 and do not contain preservatives

- Control of chill temperature / limited shelf-life is a major controlling factor in sous-vide foods

- Product is packed under vacuum

- Packaging prevents post process contamination and can reduce cross contamination

- Shelf-lives can be from >2 days to several weeks. Note 10 day rule in UK
Summary - Food processing heat treatments

>121°C for 2.45min
  Commercial sterility. Food pathogens destroyed

>90°C for 10min, <121°C for 2.45min
  Long life chilled products. Psychrotrophiic food pathogens destroyed

>70°C for 2min, <90°C for 10min
  Pasteurisation. Vegetative food pathogens destroyed

>70°C for 2min
  Food pathogens may survive
Sous-vide safety

- First assess time temperature of cooking
  - <70°C/2 min
  - >70°C/2 min, <90°C/10 min
  - <90°C/10 min

- How long is the product stored

- Any other antimicrobial treatment?

- Is there an equivalent traditionally prepared product that is eaten raw or undercooked?

- What hazards are associated with equivalent traditionally prepared product?
Advisory Committee on the Microbiological Safety of Food (ACMSF)

Ad hoc group on raw, rare and low temperature cooked foods