Sous vide cooking and chemistry

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How often do you cook?

(a) Cook almost everyday.
(b) Not daily, but quite a lot.
(c) Only for special occasions.
(d) Almost never.
sous vide /su: ’vi:d/ adjectival & adverbial phr.
L20. [ORIGIN French, from sous under + vide vacuum.]
Of food: (prepared) by cooking in vacuumized pouches at precisely controlled temperatures.
Optimal food temperatures

- **Beef, lamb, and pork**
  - ~50 °C  Rare
  - ~55 °C  Medium-rare
  - ~60 °C  Medium
  - >70 °C  Well done

- **Fish and shellfish**
  - ~49 °C  Medium-rare

- **Baked goods**
  - ~90 °C  Breads, rolls, muffins, etc.
Common kitchen heat sources

\(-70 \, ^\circ C\)  Slow-cooker

100 \, ^\circ C\)  Boiling water

125–200 \, ^\circ C\)  Oven

150–250 \, ^\circ C\)  Skillet

200–350 \, ^\circ C\)  Grill

1500–2000 \, ^\circ C\)  Blowtorch
Sous vide cooking:

- Cook at the food’s optimal temperature.
- If 55 °C is medium-rare,
  then use a 55 °C water-bath
  ⇒ meat can’t exceed 55 °C
  ⇒ nothing overcooked
  ⇒ medium-rare from edge to edge
Vacuum-sealing benefits

► Removing air improves heat transfer
► Increases shelf-life
  • Food can’t be recontaminated
  • Inhibits off-flavors from oxidation
  • Reduces aerobic bacterial growth
► Improves nutrition and flavor
  • Stops flavor volatile evaporation
  • Stops nutrients leaching into water
Outline

- Soft-cooked eggs
  - Protein denaturation
- Beef chuck roast
  - How heating changes meat
  - Extended heating tenderizes
- Chicken breasts
  - Pasteurizing for safety
Protein denaturation
Protein denaturation

- Heat — cooking, baking, ...
- Mechanical agitation — whipping
- pH change — vinegar, lemon juice, ...
- Inorganic salts — curing and brining
- Organic compounds — alcohol marinades
- Detergents — cleanup
Yolk temperatures in 75 °C water

Measured yolk temperatures of 14 chicken eggs.
Reaction rate

- **Temperature**
  - Arrhenius reactions:
    - 10 °C increase roughly doubles rate
  - Yolk denaturation:
    - 1 °C increase roughly doubles rate

- **Catalysts**
  - Enzymes catalyze biochemical reactions

- **Concentration**
When you grill meat or poultry, do you
(a) always use a thermometer to see when it’s done,
(b) sometimes use a thermometer, or
(c) never use a thermometer?
Meat proteins

Meat’s about 75% water, 20% protein, and 5% fat and other substances.

Proteins:

- Muscle fibers
  - mostly myosin & actin
- Soluble proteins
  - mostly enzymes and myoglobin
- Connective tissue
  - mostly collagen, less elastin
Meat protein denaturing

In traditional cooking when heating:

- Muscle fibers shrink starting 35–40 °C up to ~80 °C
- Soluble proteins aggregate and gel starting ~40 °C and finishing ~60 °C
- Connective tissues shrink starting ~60 and more intensely above ~65 °C
Doneness

50 °C  Rare — muscle fibers and soluble proteins start denaturing

55 °C  Medium-rare — more muscle fibers and soluble proteins denature

60 °C  Medium
— most soluble proteins denatured

>70 °C  Well done
— connective tissue start denaturing
— muscle fibers squeeze out water
If you eat beef, do you prefer it

(a) rare,
(b) medium-rare,
(c) medium, or
(d) well done?
If 55 °C is medium-rare, why not cook at 55°C?

You can with sous vide cooking.
Holding meat at 55–60 °C for hours to days increases tenderness because
- Enzymes can catalyze connective-tissue protein hydrolysis
- Collagen slowly starts to denature around 51 to 53 °C
Beef chuck roast

55°C/131°F

1½ hr

3 hr

6 hr

12 hr

24 hr

48 hr
Meat flavor

1. Browning or Maillard reaction
   • Roast and savory flavors
   • Starts noticably \(~130\,^\circ\text{C}\)
   • Good browning starts \(~150\,^\circ\text{C}\)

2. Fat makes
   • lamb taste like lamb and
   • beef taste like beef.
Maillard reaction

- Complex reaction between amino acids and reducing sugars
- Produces hundreds of reaction by-products
- Reaction rate increased by
  - Increasing temperature
  - Adding a reducing sugar
  - Increasing the pH
Rapid browning methods

► Beef and lamb
  • Butane blowtorch
  • Very hot grill or broiler

► Chicken and pork
  • Pan with smoking-hot oil
  • Shimmering oil with 4% glucose wash
  • Very hot grill or broiler
Beef chuck roast

1. Preheat water to 55 °C for medium-rare
2. (OPTIONAL) Pre-sear with blowtorch or grill
3. Vacuum-seal roast in a large pouch
4. Put into water bath for 1–2 days
5. Remove from pouch and pat dry
6. Sear each side to a mahogany brown
7. Season and serve immediately
When do you stop cooking a chicken breasts?

(a) When it’s juices run clear.
(b) When it’s white when you cut into it.
(c) When it reaches 75 °C/165 °F.
(d) When it’s dry and stringy.
(e) Some other criteria.
Food microorganisms

- Spoilage
- Beneficial
- Pathogenic
Many ways to reduce pathogens

- Heat — both time and temp important
- Inorganic salts — curing
- pH changes — acidifying
- Herbs and spices — essential oils
- Mechanical agitation — very high pressures
- Alcohol — marinades
- Ionizing radiation — not for home kitchens
“Danger Zone”? 

- Traditional “danger zone” is 5 to 60 °C
- Food pathogens don’t grow below —1.3 °C
- Food pathogens don’t grow above 52.3 °C
- Dangerous growth takes days at 5 °C
- Pasteurization takes 43 min at 60 °C but 3 hr 20 min at 55 °C
Pasteurization reduces risk

- Reduce but can’t eliminate pathogens
- Healthy may need $10^5$ to $10^9$ to get sick
- Immunocompromised 1–10/g to get sick
- 15–20% of US immunocompromised
- $10^6 \rightarrow 1$ reduction usually recommended
Pathogens of interest

- *Salmonella* species
- Pathogenic strains of *Escherichia coli*
- *Listeria monocytogenes* — the toughest
  - $10^6 \rightarrow 1$ after 2 min at 70 °C
  - $10^6 \rightarrow 1$ after 20 min at 62.5 °C
  - $10^6 \rightarrow 1$ after 200 min at 55 °C
- Spore forms, like the *Clostridium* species
Sous vide chicken breasts

1. Preheat water bath to 60 °C.
2. Individually vacuum-seal the breasts.
3. Put sealed pouches in water bath.
4. Cook them for at least 2 hours.
5. Remove from bath and pouches. Pat dry.
6. Sear in a skillet with smoking-hot oil.
7. Serve immediately.
Balance time and temperature

- Doneness
  - Temperature
- Texture
  - Time

Safety
Pork chops

- Medium-rare to medium $\Rightarrow$ 55–60 °C
- Moderately tender
  $\Rightarrow$ short to moderate cooking times
- 60 °C & 20 mm thick
  $\Rightarrow$ 1½ hours to pasteurize
Filet mignon

- Rare to medium-rare $\Rightarrow$ 50–55 °C
- Prized tenderness $\Rightarrow$ short cooking time
- 50–55 °C & short time $\Rightarrow$ can’t pasteurize
  $\Rightarrow$ healthy people only
- 50 °C $\Rightarrow$ pathogen growth
  $\Rightarrow$ minimize time
- 55 °C $\Rightarrow$ short time or mushy texture
Additional Resources

- www.DouglasBaldwin.com
  - Free sous vide cooking guide
  - YouTube video demos
- D.B.’s *Sous Vide for the Home Cook* (2010)
  - Over 200 recipes
  - Less technical than website or review article
- Other food science books:
  - N. Myhrvold et al.’s *Modernist Cuisine* (2011)