MOLECULAR GASTRONOMY
- a Scientific Look at Cooking

"The proof of the pudding is in the eating"

Medieval English proverb

CENTER FOR CATALYSIS
JONAS UDMARK & SIGNE GRANN HANSEN

GROUP SEMINAR 15 JUNE 2010
OUTLINE

• MOTIVATION

• SCIENTIFIC INVESTIGATIONS:
  - CASE STUDY #1: SOUFFLÈ SWELLING
  - STRUCTURE AND COMPOSITION OF DISHES

• TECHNOLOGICAL APPLICATIONS:
  - CASE STUDY #2: CHOCOLAT CHANTILLY
  - APPLIED LAB TECHNIQUES
MOLECULAR GASTRONOMY

- Gastronomy: “Intelligent knowledge of whatever concerns man’s nourishment”

Discovering and elucidating phenomena and mechanisms related to food, cooking, eating and drinking.

- Why do we cook as we do?
- Doesn’t cooking deserve to be more than just a “routine activity”?
- Why do we eat certain foods and avoid others?
- Can we make a fruitful co-operation between investigation (science) and application (cooking)?
Molecular Gastronomy

- Cooking is traditionally based on empirical traditions and not on rational understanding of the involved phenomena.

- Cookbooks are strange mixtures of remarkably precise observations and dubious, or even false, advice.

  ...old wives’ tales, proverbs...

- But sometimes they do work! And sometimes they don’t.

- Is a more systematic approach needed?

  Maybe, maybe not — but it certainly is very rewarding for the people engaged.
MOLECULAR GASTRONOMY

- Knowledge divides into two categories:

1) **Technology applications**: for restaurants, for homes, for the food industry - “Molecular Cooking”

2) **Scientific/educational application**:

   New insights into culinary chemical/physical processes

   New dishes, new applications of unpopular or odd ingredients/raw materials

   Proof/disproof of “tips & tricks”
FLAVOUR DEVELOPMENT

- Raw food contains flavours

- But the vast majority of food has been cooked or processed in some way
TRANSFORMATIONS BEFORE COOKING

Slicing/chopping

Already this initiates enzymatic reactions

E.g. in onions: sharp, pungent taste caused by sulfur-containing compounds

If to be avoided:

• Never cut the onion (whole-baked onions)
• Or marinate in acid immediately afterwards (e.g. lemon juice)
• Yields much milder taste because of enzyme denaturation
TRANSFORMATIONS DURING COOKING

Ingredients → Transformation = "Cooking" → Dish(es)

Cooking with heating/cooling
- Texture development
- Flavour development
- Or both

Roasting
Frying
Boiling
Freezing
FLAVOUR DEVELOPING TRANSFORMATIONS

Flavour developing reactions/processes include, among others:

• Hydrolysis
• Oxidation (usually bad)
• Caramelisation
• Maillard reactions:
  – Louis Maillard, 1912: amino acids + reducing sugars → brown syrup
  – In food: yields both volatile as well as high MW compounds; furthermore coloured pigments, and also heterogeneous polymers.
  – Quite well-understood, but very hard to predict!
MAILLARD REACTIONS – SCHEMATIC OVERVIEW

For a more detailed review of the Maillard reactions, see:
CASE STUDY #1: SOUFFLÉ SWELLING

Cheese soufflés

General recipe: To a viscous béchamel sauce (made from butter, flour, and milk) is added grated cheese, egg yolks and whisked egg whites

Role of egg whites: To induce swelling of the soufflé

But by which mechanism?

SOUFFLÉ STUDY: PROBLEM FORMULATION

• Common presumption:

  Thermal dilation of air bubbles trapped in whipped egg whites?

• NO

• $T/p$ measurements inside the soufflé and application of the ideal gas law suggests maximum volume increase should be 20%

• But empirical data tells that soufflés can easily double their size during cooking

SOUFFLÈ STUDY: EXPERIMENT

- To investigate the influence of the firmness of egg whites on the swelling of soufflés

1) Whites whisked until first soft peaks observed

2) Whites whisked so hard that one whole egg (62 g) could stand on top of them

- Resulting soufflés:

1 2
SOUFFLÉ STUDY: CONCLUSION

Suggested explanation:

• Ramakin reaches oven temperature (180 °C) at surface
• Water vapour formed in bottom of soufflé is responsible for the swelling
• Firmly whipped egg whites retain the vapour much better than do the softly whipped.

Thus, the second soufflé is forced to inflate.

Implication/utilisation:

Soufflé of 375 g loses app. 10 g water during cooking.

If the soufflé surface was vapour-proof, this would be retained and increase the soufflé size to ca. 10 L

STRUCTURE AND COMPOSITION

How to describe components’ structures and compositions?

CDS/NPOS:

“Complex Dispersion Systems/Non-Periodical Organization of Space”

How is part \( X \) of a dish composed? /

How is the dish/a component overall constructed of parts \( X,Y,Z,... \) ?

Precise and formalised scientific description of states and transformations

Evaluation of well-known dishes can lead to innovation of new analogous dishes
## STRUCTURE AND COMPOSITION

- **CDS: Complex Dispersion Systems**

How is part $X$ of a dish composed?

<table>
<thead>
<tr>
<th>State descriptors</th>
<th>Distribution operators</th>
</tr>
</thead>
<tbody>
<tr>
<td>G: gas</td>
<td>@: inclusion</td>
</tr>
<tr>
<td>O: oil</td>
<td>/: dispersion</td>
</tr>
<tr>
<td>W: water</td>
<td>+: combination of more phases</td>
</tr>
<tr>
<td>S: solid</td>
<td>exp: repetitions</td>
</tr>
</tbody>
</table>

**Examples**

- **O/W**: Emulsion of oil in water — *mayonnaise*
- **(S/W)@$^9$**: Granules dispersed into a plasma, included in like layers nine successive times — *egg yolk*
STRUCTURE AND COMPOSITION

Examples of whole transformations:

• Overall making of mayonnaise: \( O_{95} + W_{5} \xrightarrow{E_{W}} O_{95}/W_{5} \)

• Foaming of an emulsion: \( O/W + G \rightarrow (G + O)/W \)
APPLIED MOLECULAR GASTRONOMY: CHOCOLAT CHANTILLY

- Case study #1: The invention of a new dish

Chocolat chantilly

a kind of “chocolate mousse without eggs”

APPLIED MOLECULAR GAstronomy: Chocolat Chantilly

- Based on a generalization of the “whipped cream-system”

\[
f(O,S)/W + G \rightarrow [G + f(O,S)]/W
\]

What can be changed?

- O: any liquid fat
- W: any aqueous solution
- G: any gas

Melt chocolate in water under heating: O/W emulsion

Then whip it while cooling below 34 °C: “whipped chocolate foam”

Similarly: Chantilly foie gras, Chantilly cheese, Chantilly olive oil

APPLIED LAB TECHNIQUES

• Ultrasonic bath for efficiently creating very finely dispersed emulsions

Sauce hollandaise
APPLIED LAB TECHNIQUES II

- Temperature controlled heating baths employed for cooking perfectly boiled eggs

At 65 °C, the egg yolk does not yet coagulate, whereas the egg white does exactly so.
APPLIED LAB TECHNIQUES III

• Vacuum desiccators employed for removing moisture from potatoes prior to roasting

Old-fashioned way is to dry the potatoes by dapping them with a dish cloth or paper towel.
APPLIED LAB TECHNIQUES IV

- Instant-freeze baths employed for rapid cooling of emulsions to avoid crystal formation

\[ \text{N}_2 (l) \]  

\textbf{De-li-cious ice cream!}