The Role of Fats

- Fat provides flavour and texture to foods.

- Fat contributes to making us feel satiated because
  - Fats are more energy dense than carbohydrates or protein
  - Fats take longer to digest
Emulsion-type Products processing

Raw material

Analysis/formulation

Grinding

Chopping/emulsification

Forming

Thermal processing
Schematic Drawing of an Oil-in-Water Emulsion

Lipid Droplets are dispersed in Water (continuous phase)
Figure 7.7  (A) The emulsifying agent is located at the interface between the lipid and water phases. These molecules are oriented so that their hydrophilic portions are in contact with the water phase while their hydrophobic portions are in contact with the lipid phase. (B) One molecule of emulsifying agent.

Hydrophilic portion  Hydrophobic portion
Scanning Electron Microscope Photographs Showing Oil Globules Preferentially Bound by Solubilized Protein Network
Processing defects – Sausages products

- Fat cap and jelly pockets
  - Unstable emulsion
  - Air incorporation during comminution or stuffing
  - Too much collagen protein and insufficient salt soluble myosin protein
  - High fat, high collagen ratio
  - Too fast heating and too excessive final product temperature
- Fat rendering and fat pockets, greasing out
  - Emulsion breakdown
  - Too much collagen protein
  - Too much frozen meat
  - Too long chopping time, high temperature
  - Too fine fat droplets
**Fat melting points and chopping temperature of meat**

<table>
<thead>
<tr>
<th>Fat source</th>
<th>Melting point</th>
<th>Final chopping temp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poultry/abdominal fat</td>
<td>80-110 F</td>
<td>52-55 F</td>
</tr>
<tr>
<td>Pork/back fat</td>
<td>86-104 F</td>
<td>58-62 F</td>
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<tr>
<td>Leaf fat</td>
<td>110-118 F</td>
<td></td>
</tr>
<tr>
<td>Beef/subcutaneous fat</td>
<td>89-110 F</td>
<td>68-73 F</td>
</tr>
<tr>
<td>Kidney fat</td>
<td>104-122 F</td>
<td></td>
</tr>
<tr>
<td>Lamb/subcutaneous fat</td>
<td>90-115 F</td>
<td>68-73 F</td>
</tr>
<tr>
<td>Kidney fat</td>
<td>110-124 F</td>
<td></td>
</tr>
</tbody>
</table>
Fatty Acid Composition of Different Meat Species

- Poultry meats contain relatively higher amount of unsaturated fatty acids than red meats.
- Beef and mutton contain high ratio of saturated fatty acids, especially short chain fatty acids.
- Fish meat contains very high amount of polyunsaturated fatty acids.
- Pork contains high amount of palmitic, oleic and stearic acids. It is in the middle of ruminant meats and poultry meats.
- However, ruminant meats contain CLA (conjugated linoleic acids).
Properties of fats and oils

- Fats are solids or semi solids
- Oils are liquids
- Melting points and boiling points are not usually sharp (most fats/oils are mixtures)
- When shaken with water, oils tend to emulsify
- Pure fats and oils are colorless and odorless (color and odor is always a result of contaminants) – i.e. butter (bacteria give flavor, carotene gives color)
Hydrogenated fats

- Hydrogenation leads to either saturated fats and or trans fatty acids
- The purpose of hydrogenation is to make the oil/fat more stable to oxygen and temperature variation (increase shelf life)
- Example of hydrogenated fats: Crisco, margarine
Trans Fatty Acids

• In 1995 trans fatty acids make up an estimated 4-12% of the average American’s dietary fat intake (Roach et al 2004).
• That’s 2-4% of total energy input, or as much as 13.3 g of trans fatty acid/day!
Trans Fatty Acids

• Hydrogenation- a process to transform saturated fatty acids in the form of oils to a more viscous unsaturated form. (e.g., Vegetable oil → margarine).

• This process results in a combination of cis and trans unsaturated fatty acids.

• Trans fatty acids do occur in nature (Jirovitz et al), but in extremely small amounts. Thanks to the process of hydrogenation, a little bit has turned into a lot.
How do they contribute to heart disease?

• Activity of 12-P LOX is suppressed by all trans fatty acids used
• Cyclooxygenase/thromboxane synthase activity is significantly inhibited by polyunsaturated fatty acids.
• Trans fatty acids may modify the activity of receptors and other membrane proteins.
Cardiovascular Diseases

- Risk factors for cardiovascular disease include:
  - Being overweight
  - Physical inactivity
  - Smoking
  - High blood pressure
  - Diabetes
Dietary Enrichment of CLA

• Ruminants: Milk, Meat

• Non-ruminants: Pork, Broiler, Turkey

• Laying hen: Egg (and meat)
Physiological Effect

- Dietary CLA increased plasma triglycerides and cholesterol content
- Dietary CLA increased liver weight
- Dietary CLA increased fatty acid synthase activity of broiler liver
- The utilization of CLA as an energy source after the first round of \( \beta \)-oxidation may be less favorable than that of linoleic acid
Meat Quality

- Dietary CLA improved the oxidative stability of poultry meat
- Dietary CLA decreases the production of hexanal and other aldehydes
- Dietary CLA produced darker color in chicken breast meat
Two main CLA isomers suggested to have beneficial biological effects, which are $trans$-10, $cis$-12 CLA isomer and $cis$-9, $trans$-11 CLA isomer.
Egg Quality

• Dietary CLA accelerated the changes of pH, lipid and water content in egg yolk

• The color of CLA-enriched egg yolk was darker than control eggs

• Dietary CLA and storage of CLA-enriched eggs increased the firmness of hard-boiled egg yolk
How Cholesterol is Used in the Animal Body
Cholesterol and CHD: Theories

- Plasma lipid theory
- Response-to-Injury hypothesis: Lipid and cholesterol oxidation products cause injury
- Combined “Lipid” and “Injury” Hypothesis
Plasma lipid theory (Infiltration theory)

- The infiltration of LDL cholesterol into the wall of an artery is the major factor in the infiltration and progression of atherosclerotic plaques.

- Cholesterol plays a pivotal role.
Plasma lipid theory (Infiltration theory)

- Anitschew (1913): High frequency atherosclerosis in rabbits when fed cholesterol
- Feeding 2% cholesterol diet increased serum cholesterol level by 90 folds and increased atherosclerotic lesion (Langner and Bement, 1985).
- Epidemiological Studies: High serum Cholesterol is related to atherosclerosis
- Intervention reduced atherosclerosis: Cholestyramine (increase the rate of bile excretion)
- High cholesterol induced atherosclerosis but the response varied among rabbits (Duff et al., 1957)
- LDL receptor theory of Goldstein and Brown (1976): familial hypercholesterolemia
Does dietary cholesterol raise serum cholesterol?

- At very high level of intake (> 1000 mg per day): yes. Because physiological compensation mechanisms (decreased synthesis and absorption of C, increased excretion via bile salts) are not good enough to maintain SC level
- At 500 - 800 mg level: 70% can maintain homeostasis by the compensation mechanisms. Approximately 30% increased SC level temporarily and went back to normal.
- Only U.S. has dietary cholesterol level in a dietary guideline
Response-to-Injury Hypothesis

- An injury to the endothelium is the initiating event in atherogenesis
- Reinterpretation of cholesterol study
  Questions on the purity of cholesterol (Taylor et al., 1979)
- USP grade cholesterol was contaminated with COPS
- Epidemiological study: Indian immigrants to London
Endothelial cell injury: Mechanically and chemically

- Hypertension
- Plasma LDL: familial and diet related
- Toxins: COPS, virus, and drugs
- Pure cholesterol was not atherogenic or angiotoxic in spite of being able to induce hypercholesterolemia
- Each COPS were angiotoxic and atherogenic: Cholestan triol, 25-hydroxycholesterol are the most potent atherogenic agents
Combined “Lipid” and “Injury” Hypothesis

- Endothelial injury by Lipid Oxidation Products and then plaque accumulation by LDL, cholesterol

- COPS are initiators of atherosclerosis

- Cholesterol is involved in plaque deposition

- Cholesterol deposition is merely a secondary process preceded by a complex series of pathological changes involving the interplay of endothelial cells, macrophages, platelets, growth factors, chematactic factors, lipoproteins, and foam cells.
Biological effects of cholesterol oxides

- Atherogenicity
- Angiotoxicity
- Cytotoxicity
- Mutagenecity
- Inhibition of enzyme activities: HMGCoAR
Atherosclerotic cascade

- Wound by toxin or hypertension (right brachiocephalic artery is more susceptible)
- Release of chemokines, accumulation of platelets for healing
- Monocytes cross the endothelial cell layer and scavenge oxidized LDL
- Foam cell formation and then fatty streak
- Foam cells secrete chemokines, and platelets and foam cells secrete growth factors
Atherosclerotic cascade

- More monocytes/macrophages and T-lymphocytes accumulate
- Swelling and damage of endothelial cells by the free radicals and smooth cell growth
- Cell rupture and platelets aggregation as a process of wound healing
- LDL, cholesterol esters, lipid, collagen, Calcium deposition
- Plaque formation
- Obstruct arteries and thrombosis
Cardiovascular Disease

Cross-section of (a) a normal artery and (b) a partially blocked artery.
Cholesterol Oxidation

- In solid phase (crystalline cholesterol): side chain oxidation
- In aqueous solution: autoxidation similar to that of other lipids
- Exposure to air, heat, light and radiation accelerate cholesterol oxidation
- Variety of COPS are found in foods: milk products, egg products, fish products
- COPS are absorbed in intestine and transferred by LDL and VLDL
Efforts to solve cholesterol problems

- Use of drug: bile salt sequestrants (Cholestyramine), Nicotinic acid (decrease VLDL production), HMGCoAR inhibitor

- Diet: increase n3 fatty acids and decrease saturated fat consumption

- Removal of cholesterol foods by physical and chemical methods.
Atherosclerotic lesions in aorta of rabbits fed with different levels of dietary cholesterol