3rd Food Emulsions Short Course
November 13th & 14th, 2008
University of Massachusetts

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Program Objectives

• Review **Basic Principles** of Emulsion Science & Technology

• Highlight Role of **Functional Ingredients** in Food Emulsions

• Review **Instruments and Methodology** to Prepare and Characterize Food Emulsions

• Highlight Important **New Developments** in Emulsion Science & Technology
Emulsion Science & Technology: Importance to Food Industry

• Development & Improvement of Emulsion-Based Food Products
  – Texture, Appearance, Flavor, Shelf-life
  – Cost, Healthfulness, Label-Friendliness

• Encapsulation, Protection & Delivery of Functional Components
  – Protection of Labile Ingredients
  – Controlled or Triggered Release
Emulsion Science & Technology: Advantages for the Food Industry

- **Problem Solving**: More rapid solution of formulation & processing problems
- **Innovation**: More rapid development of innovative products and processes (Intellectual Property)
- **Efficiency**: More rapid conversion of product concepts into real food products
A diverse group of products with various appearances, textures, stabilities and flavors, but structural similarities.
Emulsions

An emulsion consists of two immiscible liquids (usually oil and water), with one liquid being dispersed as small spherical droplets in the other liquid.

Characteristics:
- Thermodynamically unstable
- Particle Diameter (0.1 to 100 µm)
- Optically Opaque
- Low Surfactant-to-Oil ratio (<1:10)
- High Surface Area (3 m²/g)
Microemulsions

A microemulsion is a mixture of oil, water & surfactant containing colloidal aggregates

Characteristics:
- Thermodynamically stable
- Particle Diameter (5 to 50 nm)
- Optically Transparent
- High Surfactant-to-Oil ratio (> 1:1)
- High Surface Area (300 m²/g)
Nanoemulsions

A nanoemulsion consists of two immiscible liquids (usually oil and water), with one liquid being dispersed as very small spherical droplets in the other liquid.

Characteristics:
- Thermodynamically unstable
- Particle Diameter (10 to 100 nm)
- Optically Transparent
- Intermediate Surfactant-to-Oil ratio (≈ 1:1)
- High Surface Area (30 m²/g)

(Wooster TJ et al, Langmuir 2008)
Emulsion Science & Technology

- **Multidisciplinary Subject**
  - *Traditional*: Colloid & Interface Science, Polymer Science, Physical Chemistry, Analytical Chemistry, Physics, Process Engineering
  - *Foods*: Food Chemistry, Sensory Science, Physiology, Nutrition, Psychology, Social Science
Application of Emulsion Science: Understanding & Controlling Food Properties

Ingredients
- Oil
- Water
- Emulsifiers
- Texture Modifiers
- Solute

Process
- Mix, Homogenize, Heat, Cool, Store, Transport, Prepare

Final Product
- Taste
- Texture
- Appearance
- Shelf Life
- Nutrition

Molecular → Colloidal → Structural → Physicochemical → Sensory & Physiological
Overview of Program

• Day 1: Background & Properties
  – Terminology
  – Droplets: Properties & Characterization
  – Ingredient Functionality
  – Emulsion Formation & Stability
  – 6:00 pm. Reception/Dinner (Room 1009)

• Day 2: Rheology & Novel Delivery Systems
  – Emulsion Appearance, Flavor, Rheology
  – Novel Emulsions & Delivery Systems
D. Julian McClements

Professor, Department of Food Science University of Massachusetts, Amherst, MA, USA

**Expertise:** Food colloids and emulsions; Protein functionality in foods; Fat crystallization; Ultrasonic techniques; Development of nutraceuticals.
Professor, Department of Food Science & Biotechnology, University of Hohenheim, Garbenstr. 25, 70593 Stuttgart, Germany

Expertise: Food biophysics; anti-microbial delivery systems; interfaces in biological systems; nanotechnology; high-intensity ultrasound; ingredient modifications.
Terminology & Definitions

Clarifying Terminology

- Emulsions, Micro-emulsions & Nano-emulsions
- Functional Ingredients
  - Emulsifiers & Surfactants
  - Thickening & Gelling Agents
  - Weighting Agents
- Homogenization
- Emulsion Stability
# Emulsions, Microemulsions and Nanoemulsions

<table>
<thead>
<tr>
<th>Name</th>
<th>Diameter</th>
<th>T/D Stability</th>
<th>Appearance</th>
<th>Surfactant: Oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emulsion</td>
<td>0.1 - 100 µm</td>
<td>No</td>
<td>Opaque</td>
<td>&lt; 1:10</td>
</tr>
<tr>
<td>Nano-emulsion</td>
<td>10 – 100 Nm</td>
<td>No</td>
<td>Clear-Cloudy</td>
<td>≈ 1:1</td>
</tr>
<tr>
<td>Micro-emulsion</td>
<td>5 – 50 nm</td>
<td>Yes</td>
<td>Clear-Cloudy</td>
<td>&gt; 1:1</td>
</tr>
</tbody>
</table>
**Functional Ingredients**

**“Emulsifier”**
- A surface-active molecule that adsorbs to an oil-water interface and forms a protective membrane.

**“Texture Modifier”**
- **Thickening agent**: An ingredient that increases viscosity or forms gels because of its large molecular dimensions.
- **Gelling agent**: An ingredient that increases viscosity or forms gels because of intermolecular cross-links.

**“Weighting Agent”**
- An ingredient that matches the densities of the dispersed and continuous phases.

**“Stabilizer”**
- An ingredient that improves the stability of an emulsion.
Homogenization: The process of converting oil and water phases into an emulsion, or of reducing the size of the droplets in an existing emulsion.
Stability

**Kinetic Stability:** Ability of emulsion to resist changes in its properties during storage or when exposed to specific environmental conditions

Emulsions are Thermodynamically unstable

- **Kinetically Stable**
- **Gravitational Separation (Creaming or Sedimentation)**
- **Flocculation**
- **Coalescence or Ostwald Ripening**
- **Phase Separation**
**Emulsion Type**

**Emulsion Type:** Description of the spatial arrangement of the oil and water phases in an emulsion.

- **Water-in-Oil (W/O)**
- **Oil-in-Water (O/W)**
- **Water-in-Oil-in-Water (W/O/W)**
- **Oil-in-Water-in-Water (O/W/O)**

**Conventional Emulsions**

**Multiple Emulsions**
Structured Emulsions: Emulsion-based Delivery Systems

Nano-emulsions

Lipid Droplets

Filled Lipid Droplets

Multilayer Droplets

Colloidomes

Hydrogel Beads

Filled Hydrogel Beads

Structural Design

Solid Lipid Nanoparticles

Filled Liposomes

Liposomes
Terminology & Definitions

Clarifying Terminology

• Always be sure that you are using or interpreting the terms used to describe emulsions correctly