Health Effects of Foodborne Engineered Nanoparticles: Case Studies of Nanoemulsions and Titanium Dioxide Nanoparticles

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Organic Nanoparticles in Foods: Origins & Applications

Lipids
- **Examples:** Surfactant Micelles & Lipid Droplets
- **Function:** Flavor, Texture, Appearance, Nutrition, Delivery

• **Proteins**
  - **Examples:** Casein Micelles & Protein Particles
  - **Function:** Nutrition, Appearance, Delivery

• **Carbohydrates**
  - **Examples:** Nano-starch, Nano-cellulose, Nanogels
  - **Function:** Texture, Appearance, Delivery
Inorganic Nanoparticles in Foods: Origins & Applications

Silver (Ag)
- **Products:** Containers, Packaging
- **Function:** Antimicrobial

Iron Oxide (Fe$_2$O$_3$)
- **Products:** Fortified Foods & Supplements
- **Function:** Nutrition

Titanium Dioxide (TiO$_2$)
- **Products:** Gums, Candies, Bakery Goods
- **Function:** Whitening

Silicon Dioxide (SiO$_2$)
- **Products:** Salt, Sugar, Dried Milk, Dried Ingredients
- **Function:** Anticaking & Flow

Zinc Oxide (ZnO)
- **Products:** Fortified Foods & Supplements
- **Function:** Nutrition
Food Nanoparticles:

- **Titanium Dioxide**
  - *Origin*: Chemical processing of titanium-rich ores
  - *Function*: Lightening agents

- **Nanoemulsions**
  - *Origin*: Microfluidization
  - *Function*: Appearance, Texture, Flavor, Delivery

Intentional versus Non-intentional
Food Nanoparticles: Characteristics

Dimensions

Morphology

Nanoparticle

Core Composition

Surface Composition

Aggregation State

Electrical Charge

Hypothesis:
Nanoparticle properties effect bio-interactions
Food Nanoparticles:
Gastrointestinal Tract Fate

**Mouth**
- pH 5-7
- Enzymes
- Salts
- Biopolymers
- 5 – 60 s

**Stomach**
- pH 1-3
- Enzymes
- Salts
- Biopolymers
- Agitation
- 30 min – 4 hours

**Small Intestine**
- pH 6-7.5
- Enzymes
- Salts, Bile
- Biopolymers
- Agitation
- 1 – 2 hours

**Colon**
- pH 5-7
- Enzymes
- Bacteria
- Agitation
- 12-24 hours

**Food Matrix Disruption**

**Mixing**

**Competitive Adsorption**

**Binding Interactions**

**Absorption**
Absorption of lipophilic food components (LC) encapsulated in nanoemulsions
Formation of mixed micelles (Cryo-TEM)

Oleic Acid ($C_{18:1}$)

Linoleic Acid ($C_{18:2}$)

Lenolenic Acid ($C_{18:3}$)
Department of Food Science
Nanoemulsions Enhanced Bioavailability of Pterostilbene in Mice

Pterostilbene

Olive oil-nanoemulsion

Flaxseed oil-nanoemulsion

Phosphate buffered saline (PBS)

Oral administration

1h 2h 4h 12h

Oral administration
Human Feeding Study

Arm 1

Arm 2

Nanoemulsion

5 Day Washout

1 Day Test

2 Day Controlled Diet

Test Meal

A low-fat lunch

A low-fat Dinner

Baseline Blood Sample
Carotenoids

Lutein

α-carotene

β-carotene

Lycopene
Directed Assembly of **Lipid Nanoparticles** in Gastrointestinal Tract to Enhance Health Benefits of Lipophilic Food Components

- **Bioactive Food Components**
  - **Nanoemulsion Droplets** Formed outside body
  - **Mixed Micelles** Formed in small intestine lumen
  - **Chylomicrons** Formed in enterocytes

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Food Design: Excipient Foods

- Cooking Sauce (Cooked Vegetables)
- Coatings (Raw Nuts)
- Cream or Yogurt (Raw Fruit)
- Salad Dressing (Raw Vegetables)

From: The hierarchical structure and mechanics of plant materials
Lorna J. Gibson, Interface 12 (104), 2012
TiO$_2$ Nanoparticles are found in many foods

Whitening agents
TiO$_2$ Nanoparticles: Change in Particle Corona

Initial

Bare Particle (pH 7)

Mucin-Protein Coated-Particle (pH 7)

Mucin-Protein Coated-Particle (pH 3)

Bile Salt-Protein Coated-Particle (pH 7)
Gut Microbiota → TiO$_2$ NPs → Organ functions
Colonic Inflammation → Metabolism
TiO$_2$ NPs: life-long exposure