Functional properties of Dairy Ingredients

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Expected learning outcomes

1. Appreciation of the "value" in value-added dairy ingredients (functional properties, ease of use, etc.)

2. Be more resourceful about utilization of dairy ingredients and be able to link functional properties of dairy ingredients with specific applications/ end use.
1. What do we mean by functional properties?

2. Why functional properties are important?

3. Explain selected functional properties of dairy ingredients with specific examples
   - Solubility
   - Viscosity
   - Water binding, gelling
   - Emulsification
   - Heat Stability
   - Gelation
   - Whipping and foaming

What do we mean by functional properties?

- The functional properties of dairy ingredients may be defined in relation to their performance as ingredients in final product or formulated foods.

- The functional properties of the ingredients are those properties, which provide specific function in the final products. Functional properties determine the overall behavior of ingredients in foods during processing, applications, storage and consumption.

- Functional properties of a particular ingredient determine their end-use in the final product.

- The functional properties of dairy ingredient typically dependent upon:
  - Type and composition of ingredients (e.g. WPC/WPI/IMPC/caseinates)
  - Processing conditions- Primary processing (during ingredient making) and secondary processing (during formulations)
  - Formulations/ Final product (e.g. beverage, soup, sauces, ice cream, bakery)
### Definitions of functional properties

<table>
<thead>
<tr>
<th>Functional properties</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solubility</td>
<td>An ability of ingredient to readily dissolve and remain in solutions under different processing and formulation conditions</td>
</tr>
<tr>
<td>Gelation</td>
<td>Ability of an ingredient to form heat-induced or cold-set gels.</td>
</tr>
<tr>
<td>Emulsification</td>
<td>Emulsification is an ability to keep two immiscible liquid (e.g. water and fat/oil) into stable solution. Milk proteins are excellent clean label emulsifier.</td>
</tr>
<tr>
<td>Heat stability</td>
<td>Heat stability is an ability to withstand severe heat treatments (typically UHT sterilization (140-145°C/ 4-5s) or retort temperatures (120°C/ 20 min)) without coagulation, precipitation or excessive thickening, gelation or viscosity increase. Caseins are very heat stable, but whey proteins are not.</td>
</tr>
<tr>
<td>Whipping/foaming</td>
<td>Ability of an ingredient to make stable foam (e.g. in whipping cream, ice-cream)</td>
</tr>
<tr>
<td>Water binding</td>
<td>Ability of an ingredient to bind water, increase viscosity or thickening effect and retard syneresis</td>
</tr>
<tr>
<td>Flavor and texture</td>
<td>Dairy ingredients provide rich flavor, mouthfeel and desirable texture in many products</td>
</tr>
</tbody>
</table>

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### Consumer is looking for specific attributes (e.g. texture, melt, taste) in the final products
Functional properties determine the specific end use of dairy ingredients

<table>
<thead>
<tr>
<th>Functional Properties</th>
<th>Application /End use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water-binding/thickening</td>
<td>Meat products, bakery products, confectionary, soups and sauces, chocolate, yogurt</td>
</tr>
<tr>
<td>Emulsification</td>
<td>Coffee whiteners, soups, sauces, ice cream, confectionary, meat products</td>
</tr>
<tr>
<td>Foaming whipping</td>
<td>Ice cream, desserts, whipped toppings</td>
</tr>
<tr>
<td>Gelation</td>
<td>Cheese, yoghurt Bakery</td>
</tr>
<tr>
<td>Color/flavor development</td>
<td>Chocolate, confectionary</td>
</tr>
<tr>
<td>Heat stability, nutrition</td>
<td>Recombined milk, infant and clinical, soups, and sauces</td>
</tr>
<tr>
<td>Solubility</td>
<td>Recombined milk, infant and clinical</td>
</tr>
</tbody>
</table>

Huppertz and Patel (2012), Advances in milk protein ingredients. "In Innovations in Healthy and functional foods"; CRC Press publishers

Examples of different functionalities offered by milk components/ingredients

**Whey Proteins**
- Whipping/foaming
- Solubility over wide range of pH (Acidic and neutral pH)
- Heat denaturation
- Gelation

**Caseins**
- Foaming
- Water binding (e.g. sodium caseinates)
- Fat emulsification
- Solubility at neutral pH
- Color/opacity

**Lactose/Permeate**
- Browning/ color development
- Flavor development
- Free flowing agent
- Sodium/salt reduction
- Low sweetening powder

**Milk Fat**
- Unique, rich, pleasant flavor in cooking applications
- Creamy mouthfeel
- Gloss, appearance

Various component of milk can offer different functionality
Depending on application, different dairy ingredients rich in particular milk component can be selected to provide specific functional properties
Final product is a results of three way interactions

Protein concentration, pH, type and amount of added minerals/ionic strength, presence of other components (e.g., sugar, fat)

Severities of heat treatment (UHT/retort), direct/indirect heat treatment, homogenization

Protein of type, composition, structure, amount of minerals

Processed parameters

Ingredient functionality

Final Product

Final product is a results of three way interactions

Functional properties of milk powder can be altered depending on the processing conditions (example)

<table>
<thead>
<tr>
<th>Type of milk powder and typical pre-heat treatment</th>
<th>Functionality</th>
<th>Examples of product/applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low heat powders (162°F /15s)/ (72°C /15s)</td>
<td>Solubility, flavor, emulsion stability, rennetability</td>
<td>Recombined Milk Recombined cheese, milk standardization</td>
</tr>
<tr>
<td>Medium heat powder (194-220°F /30s)/ (90-105°C /15s)</td>
<td>Emulsion, foaming, water absorption</td>
<td>Ice cream, chocolate, confectionary</td>
</tr>
<tr>
<td>High heat powder (248°F/1-2min)/ (120°C/1-2 min)</td>
<td>Heat stability, water absorption, viscosity, texture</td>
<td>UHT recombined milk Recombined evaporated milk Confectionary, baked foods</td>
</tr>
</tbody>
</table>

Patel et al. (2007), Lait 87, 251–268
Various formulations and process parameters affects the performance of proteins in the final products

- Storage conditions and storage related changes
- pH of the product
- Processing (UHT, Pasteurization)
- Added minerals/ ionic strength
- Other component present
- Type of proteins (e.g. casein/ whey proteins)
- Concentration of protein
- Amount and type of minerals (e.g. mono vs. divalent)

Solubility
**What is Solubility?**

It is an ability of dairy ingredients to readily go in the solution and remain soluble under different processing conditions such as heat treatments or in different formulations such different pH or mineral levels.

**Why is it important?**

During reconstitution or while making beverages, complete solubalization or rehydration of dairy ingredients is very important:

- To avoid defects (e.g. chalkiness/Gritty texture)
- To avoid settling of floating of particles
- To provide desired nutritional and functional benefits

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**Dissolving Dairy Ingredients: Different scenario**

- **Scenario 1** Completely Soluble (excellent solubility)
- **Scenario 2** Partly soluble (Poor solubility)
What is the impact of ingredients with poor solubility?

- **Poor solubility**
  - Functionality in final products may be affected (e.g. viscosity, Heat stability, emulsification, foaming)
  - May affect nutritional properties and nutritional claims
  - And shelf-life stability
  - Secondary processing considerations (e.g. time to dissolve/hydrate, fouling, product yields and/or losses
  - May affect sensory aspects (e.g. taste, texture) and lead to defects (e.g. Chalky, sedimentation)

Solubility: Various steps involved in reconstitution/rehydration of ingredients

- **Wetting**
  - *Wettability*: Ability of powder particles to absorb solvent (e.g. water) at its surface (“get wet”)
- **Sinkability**
  - *Sinkability*: Ability of powder particles to go below the water surface
- **Dispersibility**
  - *Dispersibility*: Ability of wetted particles to go below the water surface
- **Solubility**
  - *Solubility*: Dissolution of soluble agglomerates into solvent
Several factors can affect reconstitution of dairy ingredients

- Water quality (Hardness, mineral content etc.)
- Reconstitution temperature
- pH of the solvent
- Other component present in the solvent (e.g. sugar, competition with other components, availability and mobility of water)
- Particle chemistry surface composition e.g. fat on surface, surface charge (hydrophilic or Hydrophobic, denaturation and aggregation of proteins)
- Particle morphology—particle size and shape, agglomeration, porosity, surface area, etc.

Example: Hydration profile of MPC 85 in milk/water at different temperature

Source: KJ Burrington, Clean label presentation
What is heat stability?

Heat stability can be defined as an ability of a given sample to withstand UHT sterilization (140-145°C/4-5s) or retort temperatures (120°C/20 min) without coagulation, precipitation or excessive thickening/gelation/viscosity increase.
Why heat stability is important?

Heat stability of dairy ingredients is very important for their applications in high protein beverages.

Native whey proteins

Heat treatment

Unfolding and aggregation

viscosity increase

Stable

Instable

de Kort (2012) and Saglam (2011)

viscosity increase
Further/ gel formation
Applications of dairy ingredients in the beverage applications

- Meal Replacements
- Sports Drinks
  - Recovery Drinks /Isotonic beverages
  - Body Building/Muscle Building
- Energy Drinks
- Juice Drinks
- Protein waters
- Healthy Aging

Performance and storage stability of the protein in beverages is further affected by various factors

- Type protein used
- Too much un-adsorbed proteins (for emulsions)
- Type and amount of minerals
- Other components present in the system
Various factors can affect the heat stability of milk and food systems (formulations)

Factors related to milk composition e.g. TS, protein, salt balance
- Seasonal variations
- Natural variations

Factors affecting heat stability
Related to formulations e.g. Additives, sugar, salts, phosphate, citrate

Related to processing conditions e.g. pre-heating/heating, homogenization
Interactions with carbohydrates, fats, minerals, concentration effects, pH, Ionic strength

Emulsification
Emulsification

In the process of making oil-in-water emulsions, oil/water interfaces are created. These interfaces are protected by adsorption of surfactants and partially lost again by recoalescence of those emulsion droplets that are not protected quickly enough by surfactants.

The proteins in milk (whey protein and caseins) and phospholipids present in the butter milk can successfully act at oil/water interfaces to form and stabilize emulsions.

Milk protein can be an excellent, clean label emulsifier

The unfolding of the dairy protein exposes hydrophobic amino acid that facilitate the ability of the protein to orient at the oil/water interface and stabilize emulsion.
Foamability/ Whip ability

• Foaming/ whipping is defined as the creation and stabilization of gas bubbles in a liquid.
• Milk proteins have surface-active properties. Milk proteins easily adsorb on fat globule interfaces during homogenization and to the air water interface during whipping. It is well known that both caseins and whey proteins have excellent surface active properties
• Dairy ingredient such as WPC, WPI, MPC and skim milk powders are beneficial in the development of foam/ incorporation of air. e.g. during manufacture of Ice cream, frozen desserts, whipped toppings, meringues, mousses and cakes.
Foamability/ Whip ability

The whipping properties of dairy protein ingredients are affected by many factors, such as:
• Concentration and state of the dairy proteins,
• pH
• Ionic environment
• (pre-) heat treatment and
• the presence of lipids

As dairy protein concentration increases, foams become denser with more uniform air bubbles of a finer texture. Generally, overrun increases with protein concentration to a maximum value after which it decreases again.

Viscosity

Dairy ingredients play an important role in controlling the texture/modifying the rheological properties of foods.

Viscosity development is closely related to gelation properties

Dependent upon the state of the protein, dairy proteins can contribute a desired viscosity to a wide range of foods such as:

Soups,
Sauces,
Salad dressings,
Batters and
Yogurts

Source: USDEC milk powder manual
**Water binding**

The amount of water held in a gel under a given set of conditions is referred to as its water-holding or water-binding capacity.

It is possible to achieve desired water binding when dairy ingredients such as MPC, WPC, WPI and milk powders are used in viscous food products such as beverages, soups, sausages and custards.

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**Water binding**

The water binding and associated properties (i.e., swelling, gelation and viscosity) of proteins are the major determinants of texture in a number of processed food products such as cheese, yogurt and reduced-fat dairy foods.

The water enclosed in the gel's three dimensional structure, can reduce the cost of food (as water is inexpensive) and can also improve sensory perception.
Gelation

Dairy proteins, have the ability to form rigid, heat-induced irreversible gels that hold water and fat, and provide structural support.

Gelation is a two-step mechanism that involves an initiation step, the unfolding or dissociation of protein molecules, followed by an aggregation step in which association or aggregation reactions occur, resulting in gel formation.

Browning/ Color development

- Browning is important functional property in many foods.
- Milk powders contribute to browning when the protein and reducing sugar lactose undergo Maillard browning. For example, during baking or cooking, the protein’s amine groups react with lactose and other reducing sugars present in formulations, delivering an appealing color to baked goods and sauces.
- Lactose does not get fermented by baker’s yeast in yeast-leavened bakery products. It remains available for crust color development.
- Milkfat’s pleasant cream color rounds out the color of viscous products such as sauces, soups, salad dressings and beverages. It also contributes to opacity.

Source: USDEC milk powder manual

Flavor/Aroma

Overall, dairy proteins are quite bland, and contribute no foreign or off-flavors to foods when used as an ingredient.

During heat processing, the lactose present in milk powders reacts with dairy proteins leading to the production of different flavors including sour organic acids balanced by sweet and caramel.

The milkfat present in milk powders provides creamy, dairy notes and richness. Milkfat also acts as a flavor carrier for fat-soluble ingredients, spices, herbs and sweet flavors.

Also, milkfat’s low melting point ensures complete flavor release.
### Comparative overview of functionality of dairy ingredients

<table>
<thead>
<tr>
<th>Functionality</th>
<th>WPC</th>
<th>WPI</th>
<th>MPC</th>
<th>MPI</th>
<th>Micellar casein</th>
<th>Sodium caseinates</th>
<th>Calcium caseinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solubility (60°F)</td>
<td>****</td>
<td>****</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>***</td>
<td>*</td>
</tr>
<tr>
<td>Solubility (120-130°F)</td>
<td>****</td>
<td>****</td>
<td>****</td>
<td>***</td>
<td>***</td>
<td></td>
<td>***</td>
</tr>
<tr>
<td>Viscosity (10% protein solutions in water at 60°F)</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>***</td>
<td>**</td>
</tr>
<tr>
<td>Gelling (10% protein solutions, heated 195°F/10 min)</td>
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<td>****</td>
<td>*</td>
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<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Heat stability (5% protein solution, 285°F in oil bath)</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>***</td>
<td>****</td>
<td>****</td>
<td>***</td>
</tr>
</tbody>
</table>

**Keys:**
- * Poor
- **Good
- ***Very Good
- ****Excellent

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Thank you for your attention

We love dairy ingredients