Innovative uses of milk in human nutrition and health

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Presentation highlights
- Milk - the Mother Nature’s perfect food
- Physiological functionality
- Innovative processing of milk
- The “big three” of functional dairy foods
- New technologies to produce modern functional dairy foods and nutraceuticals
- Innovative approaches to milk production

What is milk.....
- Mother nature’s most perfect food
- Only material “destined” to be used as food......
- ....thus a perfect nutraceutical product
- Solution, emulsion, colloidal suspension
- Contains caseins, whey proteins, lactose, fats, minerals (importantly Ca an P)
- Also contains about 10 000 other compounds

What milk can do... topics of some recent research papers....
- Dietary protein of animal origin is an essential nutrient for bone health (Bonjour, Switzerland)
- Dairy foods appear to play a pivotal role in weight loss management (Zemel, USA)
- Increased intake of dairy products was related to lower periodontis (Al-Zahrani, Saudi Arabia)

Catalysts of developments in dairy technology
- Food safety
- Food quality
- Physiological functionality
- Economic advantages
- Interactions between consumers and technology

Physiologically functional foods and nutraceuticals
- Functional foods: consumed as part of a usual diet, providing benefits beyond basic nutritional functions
- Nutraceuticals: products isolated/purified from foods, provide physiological benefit or disease protection
Nutraceuticals market - 71 billion US $ worldwide - annual growth 14%

Two sides of the dairy industry

The traditional dairy industry ..... 
- Pasteurization, other heat treatments
- Control of fat and protein content
- Membrane processes - "cold-separation"
- Concentration and drying >>>> heat energy
- Fermented dairy products >>>> lactose
- Cheese making >>>> casein + fat + whey
- Ice cream >>> freezing, frozen storage

The modern dairy industry ..... 
- Processing for maximum health benefits
- Extraction of valuable milk components
- Modification of milk and milk components
- Enrichment of milk with healthful components
- Production of nutraceuticals from milk
- Fermentation to convert milk components
- Milk as carrier of healthful bacteria

Physiologically functional dairy products

Three aspects of physiologically functional dairy foods:
1. Probiotic bacteria (+ prebiotics = symbiotics)
2. Bioactive milk components (lactose, whey proteins, minerals (calcium))
3. Bioactive peptides (produced from milk proteins by fermentation or technology)
(4 - also lactose-modified products??)

Probiotics, prebiotics, symbiotics

- Healthful bacteria (acidophilus, bifidobacteria, new strains) - from the time of Metchnikoff
- To maximize probiotic effectiveness - growth promoters (prebiotics - oligosaccharides)
- New fermented dairy products (bioactive yogurts, Evolus, Gaio)
Production and/or extraction of valuable milk components

- Whey proteins
- Lactoferrin
- Lactoperoxidase
- Bioactive peptides
- Emulsifiers from fat globule membrane
- Conjugated linoleic acid (CLA)
- Oligosaccharides

Milk proteins as nutrients and functional components

**Advantages**
- Nutritional value (composition, digestibility)
- Solubility/functional properties (gel, foam, emulsion)
- Bland flavor
- Biological activities

**Limitations**
- Allergenicity
- High cost (low concentrations)
- Bland flavor
- Heat sensitivity (re - biological activity)

Bioactive milk (whey) proteins

- Whey proteins have various biological functions important for the newborn:
  - immunoglobulins
  - lactoferrin
  - lactoperoxidase
- or for milk production:
  - α-lactalbumin

Nutraceutical properties of intact milk proteins

- Carriers of vitamins, minerals and fatty acids
- Anti-cancer properties (lactoferrin? WPI)
- Immunomodulatory properties
- Hypotensive properties (ACE inhibition)
- Stimulation of intracellular glutathione
- Antibacterial properties (lactoferrin, lactoperoxidase)
- Health improvement in HIV-infected patients

Immunopotentiation by intracellular glutathione

- Whey protein used as a basis for sport nutrition
- ...but also as an immuno-potentiating agent...
- ...based on work of Dr. Gustavo Bounous (McGill University, Montreal)....
- ...promoting intracellular glutathione synthesis

Intracellular glutathione in lymphocytes of cyclists

**Figure 3**: Means and standard errors of lymphocyte intracellular glutathione concentration during a simulated 40 km cycling trial (Fast, Post, Rest) prior to and following WPI supplementation / training period (pre-intervention and post-intervention).
Modification of milk and milk components......
- ...to increase the Ca content (UF)
- ...to avoid allergy problems (β-lactoglobulin)
- ...to improve the survival of probiotic bacteria
- ...for increased immunopotentiation
- ...leading to better utilization of dairy products (protein standardization)
- ... increasing marketability of dairy products

....the case of milk proteins: bioactive peptides

Two ways to generate bioactive peptides:
- Microbial Fermentation
  - in dairy products
  - in a reactor
- In vitro enzymatic hydrolysis

Bioactive peptides to alleviate hypertension......
- 30% of mortality related to hypertension or to it’s renal, cardiac or cerebral complications
- Systolic pressure >140 mm Hg
- Diastolic pressure >90 mm Hg
- Vasoconstriction of blood vessels involves kidney, blood and adrenal glands via renin, angiotensin & aldosterone

ACE inhibitors in fermented milk products
- Calpis (L. helveticus + S. cerevisiae)
  - Clinical data
  - Significant blood pressure reduction
  - Dose response
  - Examples of peptides identified:
    - Val-Pro-Pro (IC50 = 9 µM)
    - Ile-Pro-Pro (IC50 = 5 µM)

ACE inhibitory peptides produced from casein
- Casokinins
  - Clinical data
  - Significant pressure reduction with 10 g/day casein hydrolysate
  - Dose response
  - Example of peptide identified:
    - αs1 25-27 Val-Ala-Pro (IC50 = 2 µM)

ACE inhibitory peptides produced from whey protein
- BSA
  - β-lactoglobulin
  - Rat studies
  - Dose response
  - Example of peptides identified:
    - β-lg f142-148 (IC50 = 43 µM)
    - β-lg f102-105 (IC50 = 172 µM)
Blood pressure reduction in SHR model

Modification of milk and milk components - the case of lactose
- A unique disaccharide (glu-gal) found in milk
- Primary source of energy for the newborn
- Milk of all mammals contains lactose
- Human milk particularly rich in lactose
- Bacteria utilize lactose in fermentations
- Lactose intolerance widespread worldwide

The problem of lactose in milk and dairy products
- Lack of ability to digest the lactose in most adult populations worldwide ……
  - Lactose maldigestion (normal case for adults)
  - Lactose intolerance (real or perceived?)
  - Symptoms: flatulence, borborygmi, diarrhea...
- Low lactose and lactose-free dairy products a major industrial opportunity
- Lack of suitable technology a major hindrance

Concentration of lactose in milk of different mammals

<table>
<thead>
<tr>
<th>Species</th>
<th>Lactose content (%)</th>
<th>H₂O content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human</td>
<td>7.1</td>
<td>87.1</td>
</tr>
<tr>
<td>Cow</td>
<td>4.6</td>
<td>87.3</td>
</tr>
<tr>
<td>Buffalo</td>
<td>4.8</td>
<td>82.8</td>
</tr>
<tr>
<td>Goat</td>
<td>4.3</td>
<td>86.7</td>
</tr>
<tr>
<td>Sheep</td>
<td>4.8</td>
<td>82.0</td>
</tr>
</tbody>
</table>

How widespread is the lactose intolerance problem?

Alleviating lactose intolerance for increased consumption of dairy foods
- Lactose hydrolysis (milk becomes sweeter):
  * Acid-catalysed hydrolysis
  * Immobilised enzyme technology
  * Membrane-based enzyme reactors
  * Free (soluble) purified enzymes
- OR……
- Lactose-free milk
The lactose free milk

- Chromatography used in sugar industry
- Chromatographic separation of lactose from milk
- Residual fraction contains all proteins and salts
- Residual lactose hydrolyzed to produce the same level of sweetness as in milk
- Final patented process - two streams
- Result: lactose-free milk (<0.01% lactose)

Lactose derivatives: GALACTO - OLIGOSACCHARIDES

<table>
<thead>
<tr>
<th>Properties</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Di-, tri-, tetra- or higher - saccharides</td>
<td>Probiotic foods</td>
</tr>
<tr>
<td>Intermediate sweetness</td>
<td>Nutraceutical foods (FOSHU)</td>
</tr>
<tr>
<td>Highly heat and acid stable</td>
<td>foods (anticarcinogenic)</td>
</tr>
<tr>
<td>Bifidogenic factor</td>
<td>Non-cariogenic foods</td>
</tr>
<tr>
<td>Non-digestible</td>
<td>Competing against inulin</td>
</tr>
</tbody>
</table>

Innovative approach to a traditional dairy food - cheese

The importance of cheese in world trade

- Total production of cheese in the world: 16 MT
- Total Cheddar production in main countries (kT):
  - United states 1 275
  - United Kingdom 240
  - New Zealand 250 (?)
  - Australia 160
  - Canada 130
  - Ireland 74
- Total production of Cheddar: > 2 MT (i.e. ~15% of all cheese made in the world)
  (Emmental ~ 500 kT; Gouda-type 1.4 MT)
**Bioactive cheese - a traditional food with added health benefits**

- **Festivo cheese (MTT, Finland):**
  - low fat milk (high CLA content?)
  - starter culture containing 12 components
  - activity of ACE inhibitory peptides highest after 13 weeks ripening

- **CLA formation in cheese (ALP, CH):**
  - lactic and propionic acid bacteria can form CLA during ripening of Emmentaler, blue and other cheeses

**Bacteria as a source of enzymes in cheese ripening**

**New trends in milk production**

- Modifications of milk composition:
  - manipulation of lactose output (?)
  - milk protein modifications
  - modifications to immunoglobulin content

- Modification of milk fat composition (PLFS)
  - increased CLA production

- Increased productivity of cows
- Automated milking systems

**Conjugated linoleic acid (CLA) as a nutraceutical component**

- CLA found in foods of produced by ruminants
- Product of microbial metabolism
  - in rumen
  - in fermented dairy foods
  - in cheese

- Several isomers, not all have health benefits

**Proposed healthful effects of Conjugated Linoleic Acid**

- inhibits carcinogenesis / tumorigenesis
- reduces body fat content
- increases muscle mass build-up
- decreases atherosclerosis
- mitigates hyperinsulinaemia
- enhances the immune system
- alters favourably the LDL/HDL ratio

**Organic milk production and other milk quality issues**

- Automated milking vs. organic milk production
- Combined effect of feed and breed (e.g. Alps)
- Increased production of colostrum-like milk
- Use of Bovine Growth Hormone
**Dairy Technology developments in a context of time**

“… most of the technologies that will shape the dairy industry 10-20 years from now are already known…”

“…technology will be both an enabler and a follower of trends…”

(Marshall, IDF Congress, 1998)

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**In conclusion…novel uses of milk in nutrition and health**

- Milk based components can be isolated and used in many other foods
- Modification of milk components for increased physiological functionality
- Bacteria “happy” in the milk can be used for improved physiological functionality
- Dairy products are probably full of still unknown, nutraceutically-interesting components (osteopontin, mucines…)

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**BUT…..**

- ARE THE KNOWN OR UNKNOWN COMPONENTS REALLY EFFECTIVE IN HUMANS???? ....

- …and are the concentrations at which they are effective realistic for foods?

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**Bioactive cheese made with special care**