Innovative uses of milk in human nutrition and health

University of Alberta

Paul Jelen
Dept. of Agricultural, Food and Nutritional Science
University of Alberta
Edmonton, Alberta, Canada

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 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)

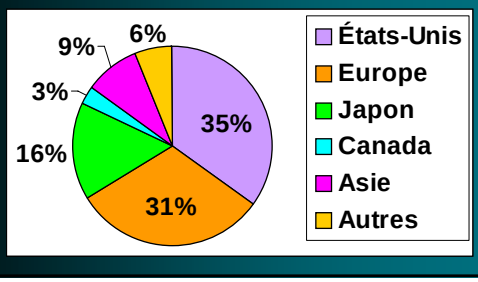
Catalysts of developments in dairy technology

- 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 bill. US $ worldwide - annual growth 14%



Two sides of the dairy industry

Dairy production of milk wordwide - MT

Cow:	500
Buffalo:	75
Goat:	12
Sheep:	10
Other: (camel,yak...)	< 2

World dairy industry annual turnover - M$US

Nestle (CH)	18 000
Dean Foods (USA)	8 600
Dary Farmers (USA)	8 500
Danone (FR)	8 100
Arla (DE/SW)	8 000
Fonterra (NZ)	7 900
Lactalis (FR)	7 100

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:**

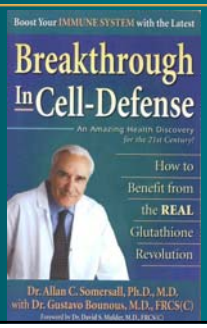
α-lactalbumin

Nutraceutical properties of intact milk proteins

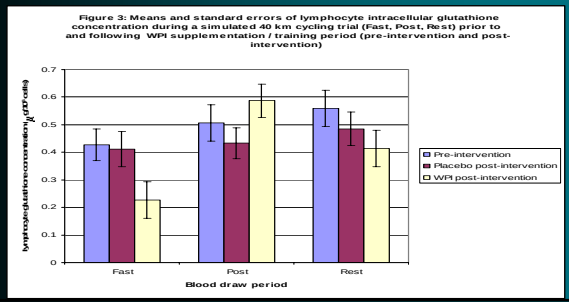
- Carriers of vitamins, minerals and fatty acids
- Anti-cancer properties (lactoferrin? WPI)
- Immunomodulatory properties
- Hypotensive properties (ACE inhibition)
- Stimulation of intracellular glutathione
- Antibacterial properties (lactoferrin, lactoperoxidase)
- Health improvement in HIV-infected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



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 (IC_{50} = 9 µM)**
  - **Ile-Pro-Pro (IC_{50} = 5 µM)**

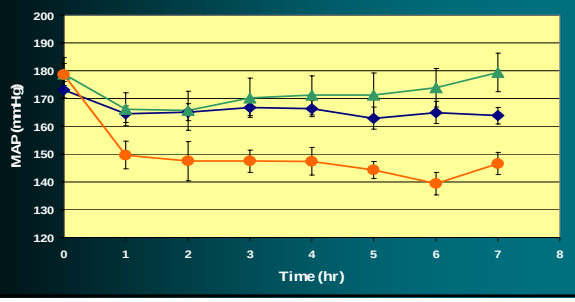
ACE inhibitory peptides produced from casein

- Casokinins
- Clinical data
- Significant pressure reduction with 10 g/day casein hydrolysate
- Dose response
- Example of peptide identified:
  - **α_{s1} 25-27 Val-Ala-Pro (IC_{50} = 2 µM)**

ACE inhibitory peptides produced from whey protein

- BSA
- β-lactoglobulin
- Rat studies
- Dose response
- Example of peptides identified:
  - **β-lg f142-148 (IC_{50} = 43 µM)**
  - **β-lg f102-105 (IC_{50} = 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

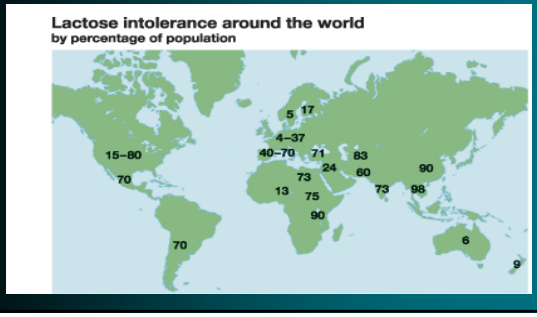
The problem of lactose in milk and dairy products

- lack of the 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

Species	Lactose content (%)	H_2O content (%)
Human	7.1	87.1
Cow	4.6	87.3
Buffalo	4.8	82.8
Goat	4.3	86.7
Sheep	4.8	82.0

How widespread is the lactose intolerance problem ?



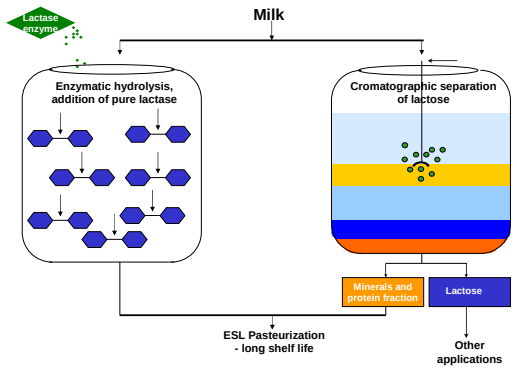
Alleviating lactose intolerance for increased consumption of dairy foods

- 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 free milk



Lactose derivatives: GALACTO - OLIGOSACCHARIDES

Properties	Applications
Di-, tri-, tetra- or higher -saccharides	Probiotic foods
Intermediate sweetness	Nutraceutical (FOSHU) foods (anticarcinogenic)
Highly heat and acid stable	Non-cariogenic foods
Bifidogenic factor	Competing against inulin
Non-digestible	

Innovative approach to a traditional dairy food - cheese

The importance of cheese in world trade

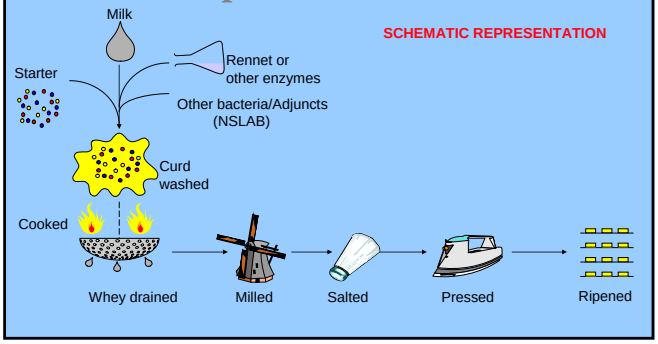
- Total production of cheese in the world: 16 MT
- Total Cheddar production in main countries (kT) :

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)

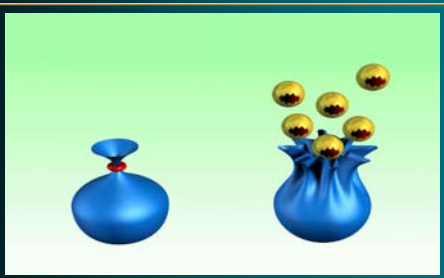
The cheese making process - a complex fermentation



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 of 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)

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….)

BUT…..

- **ARE THE KNOWN OR UNKNOWN COMOPONENTS REALLY EFFECTIVE IN HUMANS???? ….**
- **…and are the concetrations at which they are effective realistic for foods?**

Bioactive cheese made with special care