Milk Fat – global production, nutrition and research perspectives

Dr. Maneesha S. Mohan
Formerly Teagasc Food Research Moorepark

Dr. Phil Kelly
IDF – Science Programme Coordination Committee
Outline

1. Consumption trend – Nutritional aspects
2. Butter production and trade
3. Recent research on milk fat value addition
Outline

How it all started???

- Consumption trend – Nutritional aspects
- Butter production and trade
- Recent research on milk fat value addition
Consumption trends for milk and fat

Ancel Keys on the cover of Time Magazine in 1961. He claimed that saturated fats in the diet clogged arteries and caused heart disease.
Dietary Fat and Its Relation to Heart Attacks and Strokes

Report by the Central Committee for Medical and Community Program of the American Heart Association

Ad Hoc Committee on Dietary Fat and Atherosclerosis:
Irvine H. Page, M.D., Chairman,
Cleveland, Ohio
Edgar V. Allen, M.D.,
Rochester, Minnesota

Francis L. Chamberlain, M.D.,
San Francisco, California
Ancel Keys, Ph.D.,
Minneapolis, Minnesota
Jeremiah Stamler, M.D.,
Chicago, Illinois
Fredrick J. Stare, M.D.,
Boston, Massachusetts

THE LANCET
Volume 267, Issue 6922, 28 April 1956, Pages 521-527
Originally published as Volume 1, Issue 6922

ORIGINAL ARTICLES
EFFECTS OF FEEDING DIFFERENT FOODS ON SERUM-CHOLESTEROL LEVELS
B. Bronte-Stewart (Physician) M.D., Cape Town, M.R.C.P. (Research Biochemist)
Ph.D., Cape Town, A.R.C., E. Eales (Physician) M.D., D.M., F.R.C.P., J.F. Brock (Professor of Medicine in the University of Cape Town) D.M., F.R.C.P.

Page et al., 1961
Keys et al., 1965
Kannel et al., 1964
Cornfield, 1962
Bronte-Stewart et al., 1956
1. Increase carbohydrate consumption to account for 55 to 60 percent of the energy (caloric) intake.
2. Reduce overall fat consumption from approximately 40 to 30 percent energy intake.
3. Reduce saturated fat consumption to account for about 10 percent of total energy intake; and balance that with poly-unsaturated and mono-unsaturated fats, which should account for about 10 percent of energy intake each.
4. Reduce cholesterol consumption to about 300 mg a day.
5. Reduce sugar consumption by about 40 percent to account for about 15 percent of total energy intake.
6. Reduce salt consumption by about 50 to 85 percent to approximately 3 grams a day.

The Goals Suggest the Following Changes in Food Selection and Preparation

1. Increase consumption of fruits and vegetables and whole grains.
2. Decrease consumption of meat and increase consumption of poultry and fish.
3. Decrease consumption of foods high in fat and partially substitute poly-unsaturated fat for saturated fat.
4. Substitute non-fat milk for whole milk.
5. Decrease consumption of butterfat, eggs and other high cholesterol sources.
6. Decrease consumption of sugar and foods high in sugar content.
7. Decrease consumption of salt and foods high in salt content.
‘Snowball effect’

Regardless of these dietary adjustments..

FAOSTAT, 2016
Bentley and Ash, 2016
Actual health concerns

The 10 leading causes of death in the world 2012

- Ischaemic heart disease: 7.4 million
- Stroke: 6.7 million
- COPD: 3.1 million
- Lower respiratory infections: 3.1 million
- Trachea bronchus, lung: 1.6 million
- HIV/AIDS: 1.5 million
- Diarrhoeal diseases: 1.5 million
- Diabetes mellitus: 1.5 million
- Road injury: 1.3 million
- Hypertension: 1.1 million

Mozaffarin et al., 2016
WHO, 2012
Recent studies about SFA

Blood lipid levels for consumption of saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA) or trans fatty acids (TFA) as an isocaloric replacement for carbohydrates (CHO) as a reference, based on two meta analyses

Micha and Mozaffarian, 2010

Effect of different fat groups on health need to be further studied for different foods and diets
## Health benefits of dairy fats

### Irish milk fat composition

<table>
<thead>
<tr>
<th>Milk products</th>
<th>Product consumption</th>
<th>Fat consumption</th>
<th>Calculated CLA consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g/day/person</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cheese</td>
<td>19</td>
<td>6.3</td>
<td>0.16&lt;sup&gt;1,5&lt;/sup&gt;</td>
</tr>
<tr>
<td>Butter&lt;sup&gt;6&lt;/sup&gt;</td>
<td>8</td>
<td>6.4</td>
<td>0.11</td>
</tr>
<tr>
<td>PUFAs</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>ω-3</td>
<td>0.05</td>
<td>0.08</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CLA</th>
<th>g/day/person</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.7</td>
<td>1.3</td>
<td>1.4</td>
</tr>
</tbody>
</table>

~0.3 g/day/person

- Anticarcinogenic (0.14 – 0.42 g/day effective dosage)<sup>3</sup>
- Anti-atherogenic
- Immune modulating
- Anti-obesity
- Anti-diabetic

---

<sup>1</sup>O’Callaghan, 2016  
<sup>2</sup>Mohan, 2011  
<sup>3</sup>Huth et al., 2006  
<sup>4</sup>CSO, 2011  
<sup>5</sup>Mohan et al., 2013  
<sup>6</sup>O’Callaghan, 2016
Consumption trends for milk and fat

Ancel Keys on the cover of Time Magazine in 1961. He claimed that saturated fats in the diet clogged arteries and caused heart disease.

"3-A-Day. Burn More Fat, Lose Weight."

Page et al., 1961
Keys et al., 1965
USGPO, 1940
Present day - Milk and Butter consumption

Per Capita Consumption of Fat

(USDA, 2016)
Consumption trends and outlook about nutritional aspects of milk fat has changed considerably over the years.

Necessity to evaluate the present status of milk fat production and consumption.

DAIRY ‘MATRIX’ EFFECT – Nutritionally positive!
Milk- and cheese-based diets vs. control diets with attenuated SFA content
• Lower total and LDL cholesterol
• Increased fecal fat excretion
-> “explained by their calcium contents” (Soerensen et al., 2014)
Outline

Consumption trend – Nutritional aspects

Where do we stand now???

Butter production and trade

Recent research on milk fat value addition
Milk and Butter production

**World milk production**
- 1000 mln tonnes in 2025
- Milk fat - 35 mln tonnes (based on 3.5% fat content)

**Irish milk production**
- 7.5 mln tonnes in 2020
- Milk fat – 0.3 mln tonnes (based on 3.5% fat content)

Important to understand the markets for milk fat

IDF, 2015
FDII, 2016
Approximately 61% of Australian exports are to Asian countries (Singapore, Malaysia, Thailand, South Korea, China, Taiwan).

Major players in the butter trade in 2015:

- Russia (96kT)
- China (71kT)
- Saudi Arabia
- Egypt
- Mexico
- USA (41kT)
- UAE
- EU (24kT)

Belarus (88kT) and New Zealand (500kT) are significant exporters, while Belarus (98%), Russia (96kT), and New Zealand (500kT) are major importers.

20% of US exports to Canada include Saudi Arabia, Egypt, Turkey, Lebanon, and UAE.

98% of Russian imports are from South American countries.

29% of EU exports are to the Middle East (Saudi Arabia, Egypt, Turkey, Lebanon, UAE).

20% of US exports to Canada include Saudi Arabia, Egypt, Turkey, Lebanon, and UAE.

CLAL, 2017
IDF, 2016
Butter trade possibilities for Ireland

- Middle East
- South East Asia
- Australia
- Mexico
- China
- New Zealand
- USA

30% of Irish butter exports (200kT) -> UK

BREXIT - Worst Case scenario: Loss of Butter and Cheese markets
- High import tariffs
Summary

- Increase in production of milk fat
- Trade possibilities
- Need to explore new options
Outline

Consumption trend – Nutritional aspects

Butter production and trade

What is the future???

Recent research on milk fat value addition
Milk fat modifications

- Composition
- Fractionation/Enrichment
- Functional properties
Milk fat modifications

Composition
- Grass feeding/Dietary manipulation
- Enzyme modifications

Fractionation/Enrichment

Functional properties
Modification in milk fat composition

Grass feeding

• Higher unsaturated fatty acids (UFA), ω-3, conjugated linoleic acid (CLA) and vitamin E

<table>
<thead>
<tr>
<th>Fatty acid components</th>
<th>Control milk</th>
<th>Grass fed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saturated (SFA)</td>
<td>53</td>
<td>49</td>
</tr>
<tr>
<td>Unsaturated (UFA)</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>ω-3</td>
<td>0.05</td>
<td>0.08</td>
</tr>
<tr>
<td>CLA</td>
<td>0.7</td>
<td>1.5</td>
</tr>
</tbody>
</table>

• Changes crystallization and textural properties

O’Callaghan et al., 2016
Modification in milk fat composition

Grass feeding

Application:
Kerrygold spreadable butter, Ornua

Solid Fat content (SFC) % at 4 C from DSC

Couvreur et al., 2006
Modification in milk fat composition

Dietary manipulation in cattle

- Oilseeds, marine algae, rumen protected lipids, fish meals and fish oil
- Goal: Enhance the polyunsaturated fatty acids (PUFA)

<table>
<thead>
<tr>
<th>Fatty acid components</th>
<th>Control milk</th>
<th>Fish oil fed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>--------------</td>
<td>--------------</td>
</tr>
<tr>
<td>SFA</td>
<td>65</td>
<td>62</td>
</tr>
<tr>
<td>UFA</td>
<td>34</td>
<td>37</td>
</tr>
<tr>
<td>ω-3</td>
<td>1.2</td>
<td>1.7</td>
</tr>
<tr>
<td>CLA</td>
<td>0.6</td>
<td>1.6</td>
</tr>
</tbody>
</table>

- Changes crystallization and textural properties

Mohan et al., 2013
Modification in milk fat composition

Dietary manipulation in cattle

Application:
Dromona butter, Northern Ireland
- Whole rapeseed in the dairy concentrate for grazing dairy cows

![Graph showing solid fat content in milk fat on dietary inclusion of whole rapeseeds.](image)

SFC in milk fat on dietary inclusion of whole rapeseeds

Solid fat content at 5 ºC vs. Level of oil inclusion (g oil/day per cow)

Fearon et al., 2004
Modification in milk fat composition

Enzymatic modification

• Lipases catalyze reactions
  • Hydrolysis
  • Interesterification
    • Acidolysis, alcoholysis, ester-ester exchange

• Applications
  • Modification of milk FA profile to suit the profile of human milk, with more palmitic acid in the sn-2 position of TG
  • Improves spreadability of butter spreads
  • Enhance milk fat nutritional properties
  • Flavour enhancement – accelerated ripening

Kontkanen et al., 2011
Milk fat modifications

Fractionation/Enrichment
- Dry melt crystallization
- Super fluid extraction
- Enrichment of phospholipids and diacylglycerols

Functional properties

Composition
Fractionation/Enrichment of milk fat components

Dry melt fractionation

- Controlled cooling of melted fat to crystallize portion of the milk fat

Melted milk fat
- Cooling & Crystallization
- Filtration/centrifugation

Solid fraction (Stearin-29)
- Cooling & Crystallization
- Filtration/centrifugation
  - Stearin-19
  - Olein-19
- Process continues.....

Liquid fraction (Olein-29)
- Cooling & Crystallization
- Filtration/centrifugation

Use of dry melt fractions in products:
- Low melting – confectionary products
- Medium melting – biscuits, cakes, pastries
- High melting – chocolate and ice cream

Amer et al., 1985
Fractionation/Enrichment of milk fat components

Supercritical Fluid Extraction (SFE)

- Unique solvent properties of gases above its critical pressure and temperature

Approaches:
- Extraction of short, medium or long chain fatty acids based on the activity of specific lipases\(^1\)
- Prepare controlled mixtures of acylglycerols with specific concentrations of MAGs, DAGs and TAGs\(^2\)
- Fractions with different melting points\(^3\)

\(^1\)Mesiano et al., 1999
\(^2\)Lubary et al., 2010
\(^3\)Büyükbeşe et al., 2014
Fractionation/Enrichment of milk fat components

Phospholipid enrichment

Phospholipids have health benefits, antioxidant and emulsifying properties

Methods

• Cream washing and microfiltration\(^1\)
• Salt precipitation and microfiltration\(^2\)
• Microfiltration and supercritical fluid extraction\(^3\)
• Enzyme hydrolysis and filtration\(^4\)

\(^1\) Britten et al., 2008
\(^2\) Corredig et al., 2003
\(^3\) Astaire et al., 2003
\(^4\) Barry et al., 2016
Modification of functional properties

High pressure processing

• Static (up to 1000MPa) or dynamic (up to 400 Mpa) high pressure
• Disrupts milk fat globules

Applications
• Addition of hydrolysed caseins and emulsifying agents produced good body for whipped cream\(^1\)
• Smaller fat globules provides creamier and smoother texture in soft cheeses and dairy gels\(^2\)
• Lipase activity accelerated\(^2\)

\(^1\)Ihara et al., 2015
\(^2\)Chandrapala et al., 2015
Modification of functional properties

Sonocrystallization

Factors affecting crystallization, microstructure and texture of fats

- Composition
- Cooling rate
- Crystallization temperature
- Shear force
- Emulsified fat

- Crystal size
- Solid fat content

- α
- β'
- β

POLYMORPHISM

- Storage

Microstructure

Texture

Source: Buldo, 2012
### Modification of functional properties

**Sonocrystallization**

- Polymorphic forms of milk fat crystals

<table>
<thead>
<tr>
<th>Properties</th>
<th>α-form</th>
<th>β′-form</th>
<th>β-form</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density &amp; Melting point</td>
<td>Least</td>
<td></td>
<td>Highest</td>
</tr>
<tr>
<td>Stability</td>
<td>Least stable</td>
<td>Metastable</td>
<td>Highest stable</td>
</tr>
<tr>
<td>Crystal morphology</td>
<td></td>
<td>Optimal</td>
<td>Large plate-like crystals</td>
</tr>
<tr>
<td>Crystal network</td>
<td></td>
<td>Optimal</td>
<td>Poor and brittle</td>
</tr>
<tr>
<td>Applications</td>
<td></td>
<td>Butter</td>
<td>Confectionary</td>
</tr>
</tbody>
</table>

Buldo, 2012
Modification of functional properties

Sonocrystallization

• High Intensity Ultrasound used 24KHz, energy density 17.5 J/mL at 14°C, 22°C, 26°C, and, 30°C

• Factors affecting crystallization - temperature, frequency and energy density

Frydenberg et al., 2013
Overall Summary

• World consumption and demand for milk fat is increasing with changing outlook towards the health effects of fat consumption, especially in the developed countries

• Consumption might not keep in pace with the projected increase in production of milk and milk fat
  • Volatility in farm gate milk prices -> modulating supply/demand

• NZ’s historical milk expansion:
  • Surplus milk fat disposal via commodity markets e.g. cheese and whole milk powders (new Asian markets)
  • Can this be emulated??
Overall Summary (Contd..)

• Role of New Technologies
  • HIU - Improved control of milk crystallisation
    • Better quality/quality control of milk fat products (butters/spreads)
    • Improved physical properties and better consumer attributes (e.g. spreadability)

• Leveraging milk fat’s positive attributes
  • Phospholipids – health benefits: enhanced recovery opportunities
  • Milk fat formulations -> enhanced PLs and CLAs.
  • Milk fat fractionation: Improving technologies for cleaner mid-range fraction. Potential for interesterification and SFE extraction

Remember: Milk fat is an expensive starting substrate! Adding value essential!!!
Acknowledgement:

Dr. Sean Hogan
Dairy Processing Technology Centre
Dairy Science dept., South Dakota State University
References


References


References

References


References

### CLA content in milk, cheese and butter

<table>
<thead>
<tr>
<th>Product</th>
<th>TMR</th>
<th>Pasture fed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk$^1$</td>
<td>0.67</td>
<td>1.52</td>
</tr>
<tr>
<td>Cheese$^{1,2}$</td>
<td>1.09</td>
<td>2.5*</td>
</tr>
<tr>
<td>Butter$^3$</td>
<td>0.67</td>
<td>1.8</td>
</tr>
</tbody>
</table>

*Calculated by multiplying the ratio of CLA in pasture fed to TMR fed milk$^1$ with the CLA content in cheese from TMR fed cattle$^2$  

$^1$O’Callaghan et al., 2016  
$^2$Mohan et al., 2013  
$^3$O’Callaghan et al., 2016