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

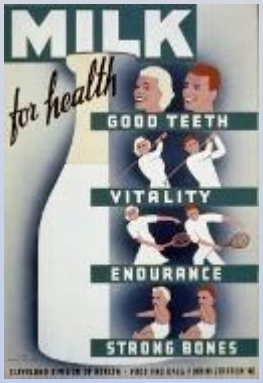
- Consumption trend – Nutritional aspects
- Butter production and trade
- Recent research on milk fat value addition

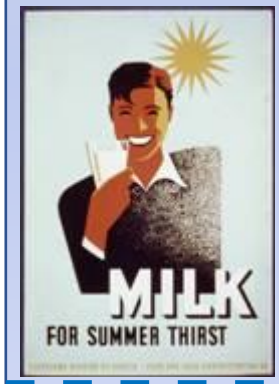
Outline

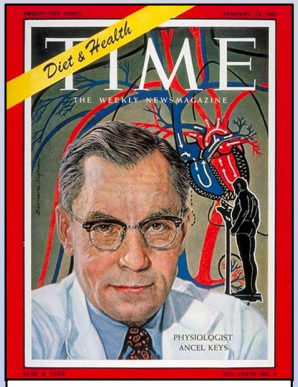
How it all started???

- 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.

1940s

1960s

1980s

2000s

2010s

Page et al., 1961
Keys et al., 1965

USGPO, 1940

Vol. 175, No. 5 *Circulation, Volume XXIII, January 1961*

Special Communication

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 FA… ON SERUM-CHOLESTEROL LEV…

B Bronte-Stewart (PHYSICIAN) M.D. Cape Town, M.R.C… …SEARCH BIOCHEMIST) Ph.D. Cape Town, A.R.I.C, L Eales (PHYSICIAN) M.D. …M, M.R.C.P, J.F Brock (PROFESSOR OF MEDICINE IN THE UNIVERSITY OF CAPE TOWN) D.M. Oxf, F.R.C.P

…actors in Coronary Heart Disease

…luation of Se…al Serum Lip…as Predictors of Co…ary Heart Disease

…he Framingham Study

…NNEL, M.D. …S R. DAWBE…, F.A.C.P., GARY D. M.D., W… …M E. GLENNON, …CIA M. MCNAMARA

Framingham, Massa…setts

Dietary fat

Cholesterol levels

Page et al., 1961
Keys et al., 1965
Kannel et al., 1964
Cornfield, 1962
Bronte-Stewart et al., 1956

Consumption trends - Health concerns

DIETARY GOALS FOR THE UNITED STATES

PREPARED BY THE STAFF OF THE
SELECT COMMITTEE ON NUTRITION
AND HUMAN NEEDS
UNITED STATES SENATE

FEBRUARY 1977

Printed for the use of the Select Committee on Nutrition and Human Needs

U.S. GOVERNMENT PRINTING OFFICE
WASHINGTON, D.C.: 1977

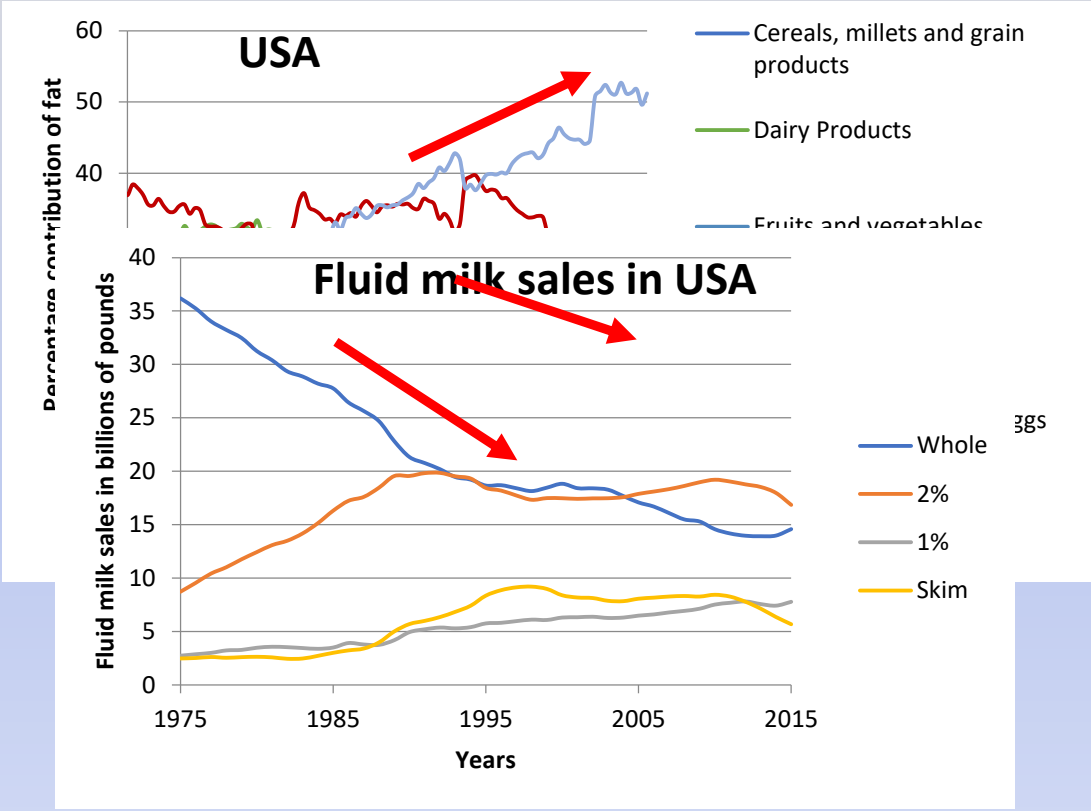
1. Increase carbohydrate consumption to account for 55 to 60 percent of the energy (caloric) intake.
2. Reduce overall fat consumption from approximately 40 to 30 percent energy intake.
3. Reduce saturated fat consumption to account for about 10 percent of total energy intake; and balance that with poly-unsaturated 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.

USGPO, 1977

‘Snowball effect’

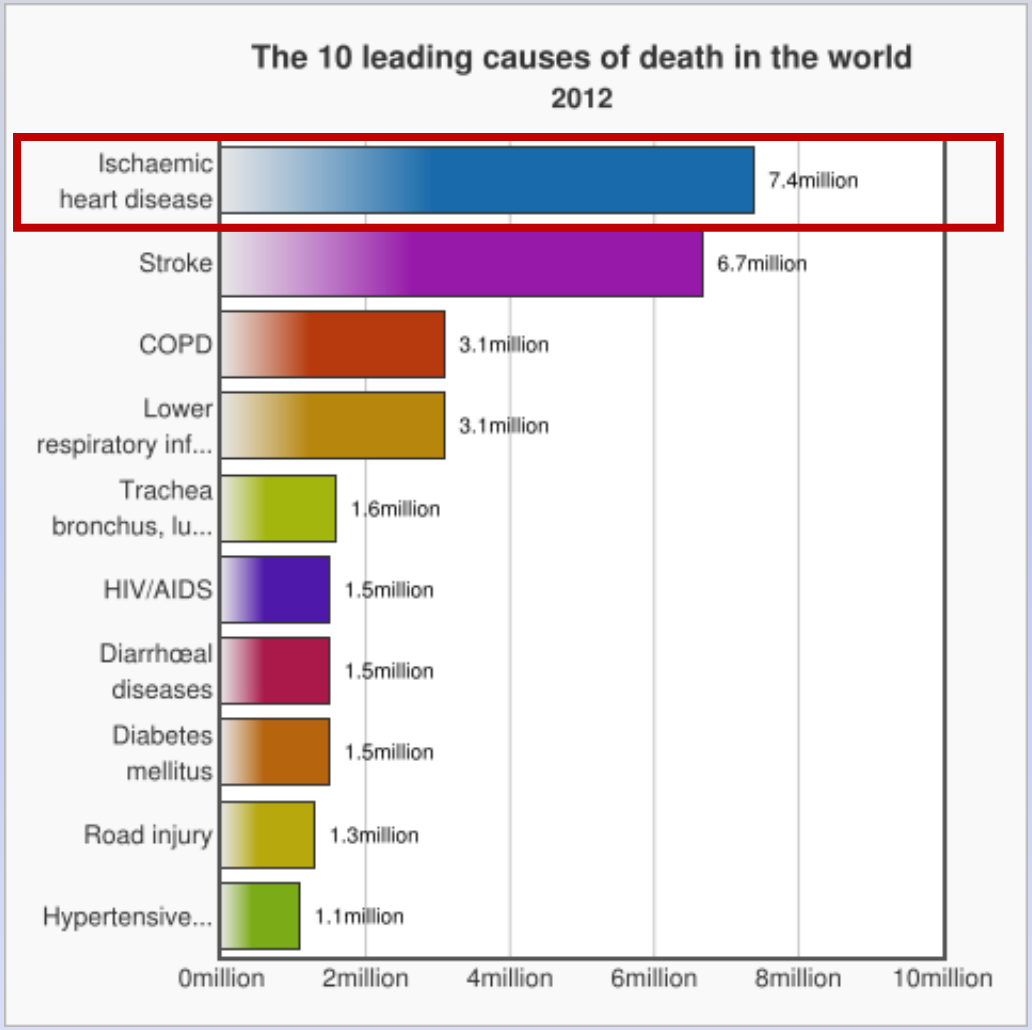


Regardless of these dietary adjustments..

FAOSTAT, 2016

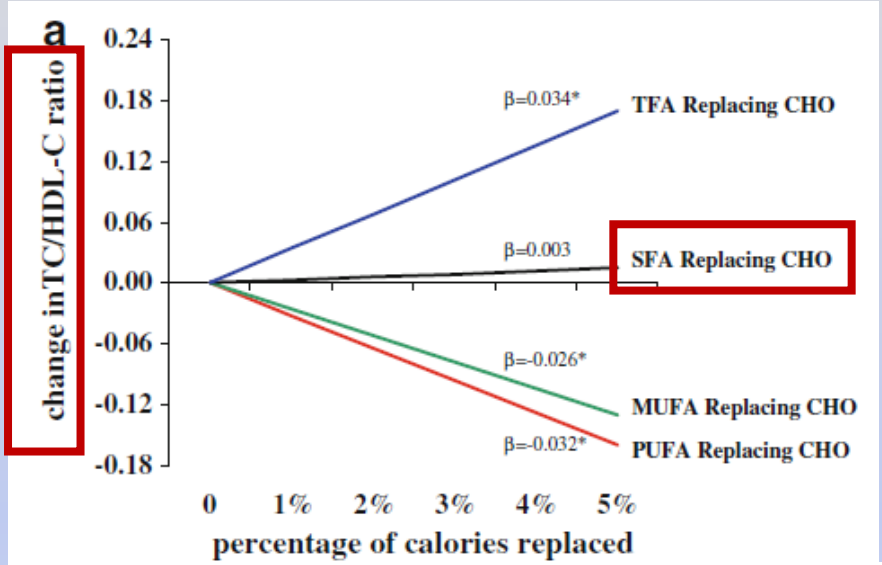
Bentley and Ash, 2016

Actual health concerns



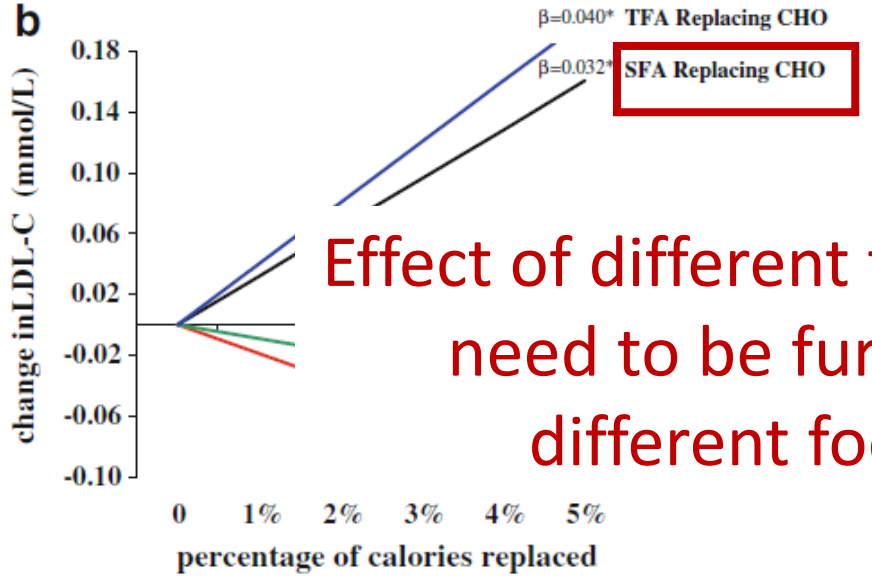
Mozzaffarin et al., 2016
WHO, 2012

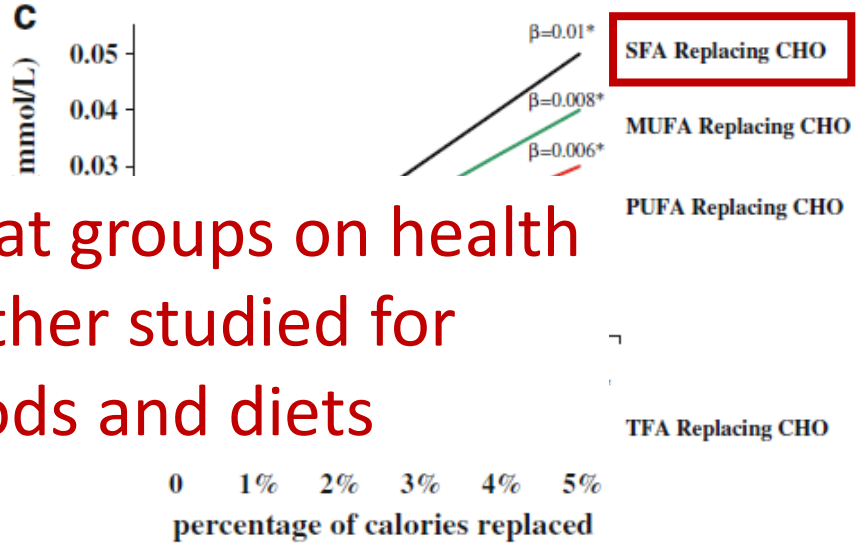
Recent studies about SFA



Blood lipid levels for consumption of saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), poly unsaturated 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 Mozzaffarin , 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

Irish milk fat consumption

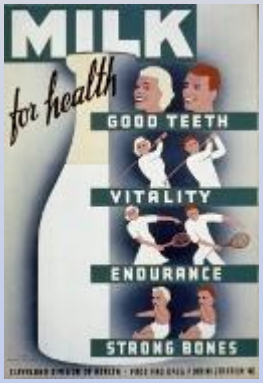
Milk products	Product consumption[4]	Fat consumption	Calculated CLA consumption
	g/day/person		
Cheese	19	6.3	0.16[1,5]
Butter[6]	8	6.4	0.11
PUFA	2	3	3
ω-3	0.05	0.08	
CLA	0.7	1.3	1.4

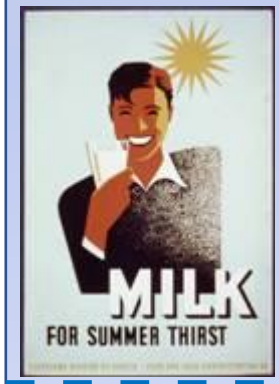
~0.3 g/day/person

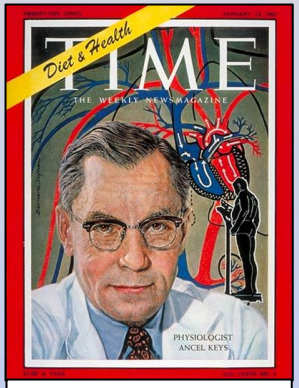
- Anticarcinogenic (0.14 – 0.42 g/day effective dosage)3
- Anti-atherogenic
- Immune modulating
- Anti-obesity
- Anti-diabetic

[1]O'Callaghan, 2016
[2]Mohan, 2011
[3]Huth et al., 2006
[4]CSO, 2011
[5]Mohan et al., 2013
[6]O'Callaghan, 2016

Consumption trends for milk and fat

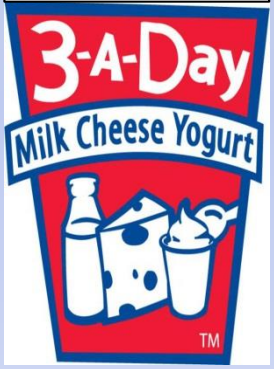






Ancel Keys on the cover of Time Magazine in 1961. He claimed that saturated fats in the diet clogged arteries and caused heart disease.

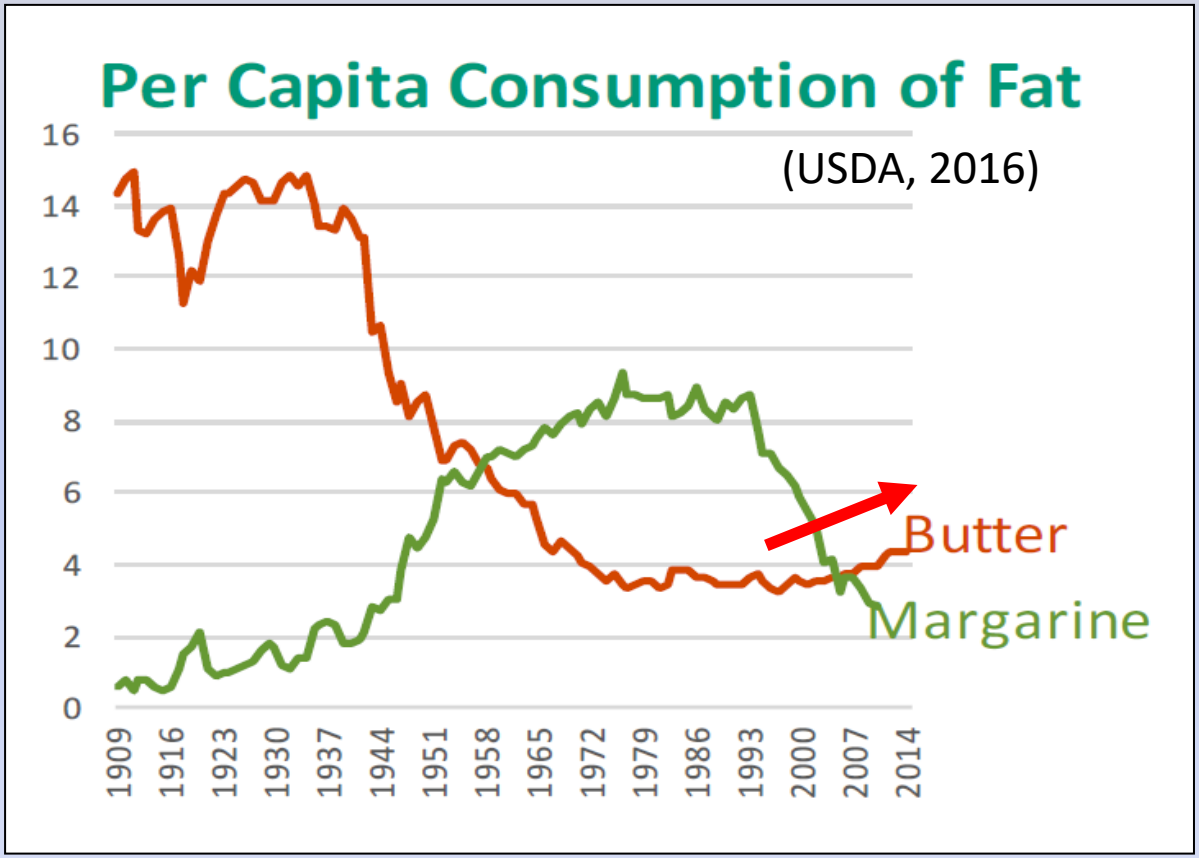
"3-A-Day. Burn More Fat, Lose Weight."



1940s 1960s 1980s 2000s 2010s

Page et al., 1961
Keys et al., 1965
USGPO, 1940

Present day - Milk and Butter consumption



Summary

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

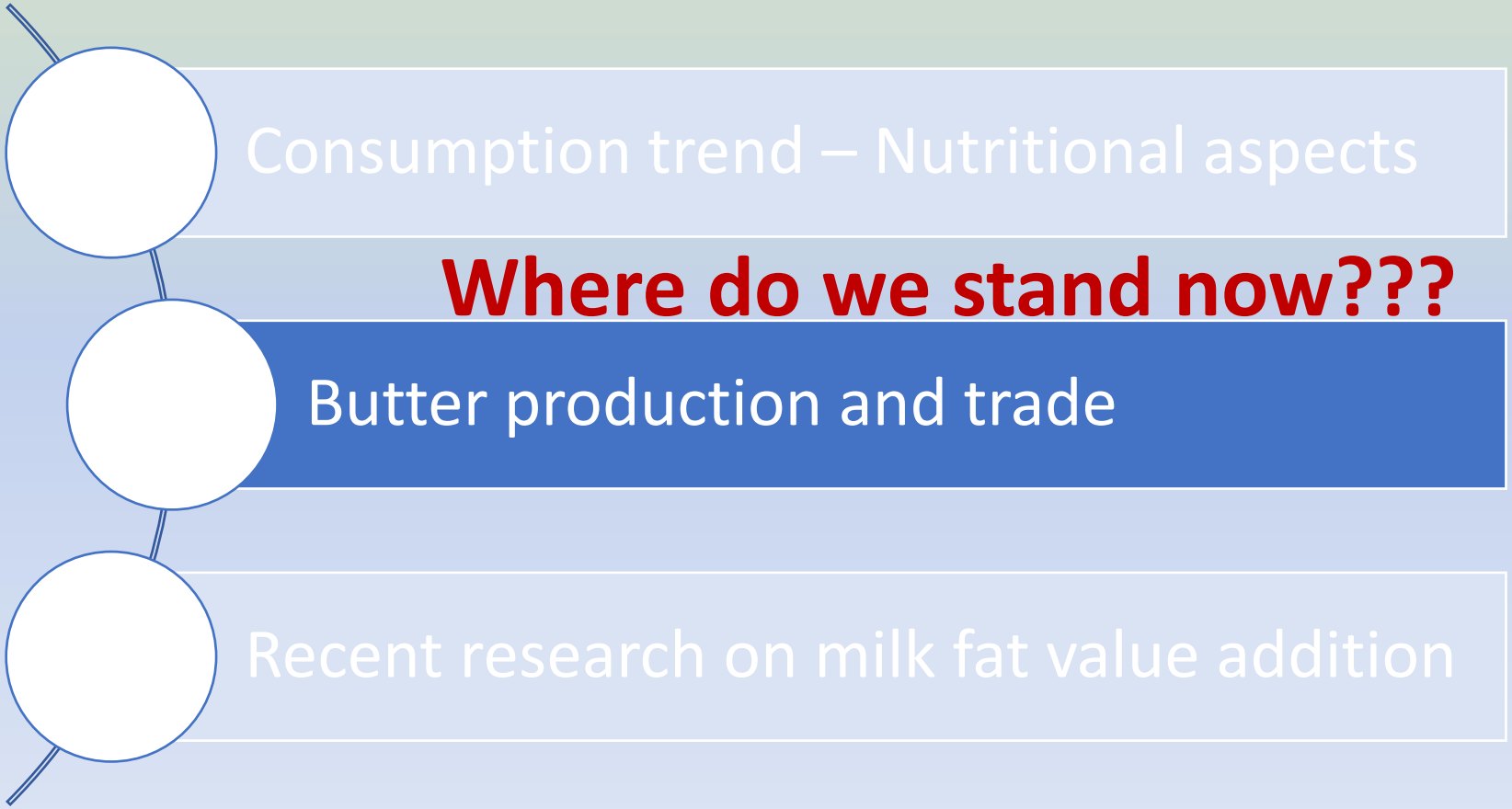
DAIRY 'MATRIX' EFFECT – Nutritionally positive!

Milk- and cheese-based diets vs. control diets with attenuated SFA content

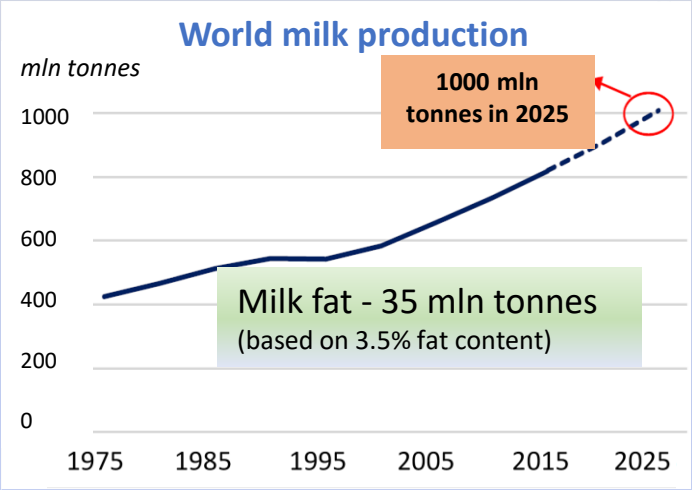
- Lower total and LDL cholesterol
- Increased fecal fat excretion

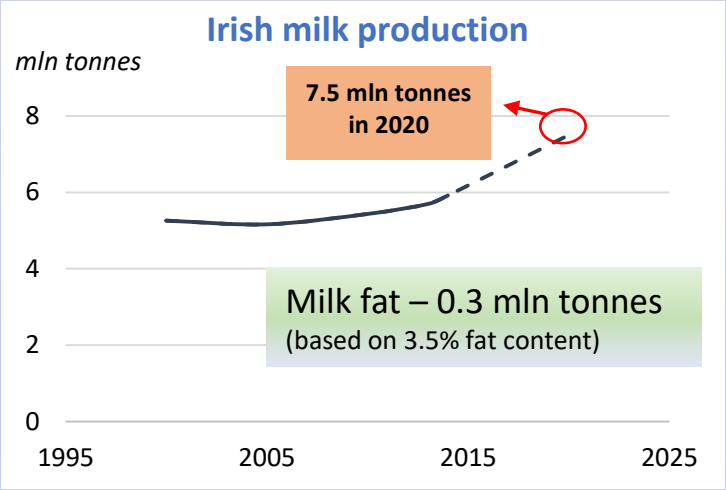
-> "explained by their calcium contents" (Soerensen et al., 2014)

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





Important to understand the markets for milk fat

IDF, 2015
FDII, 2016

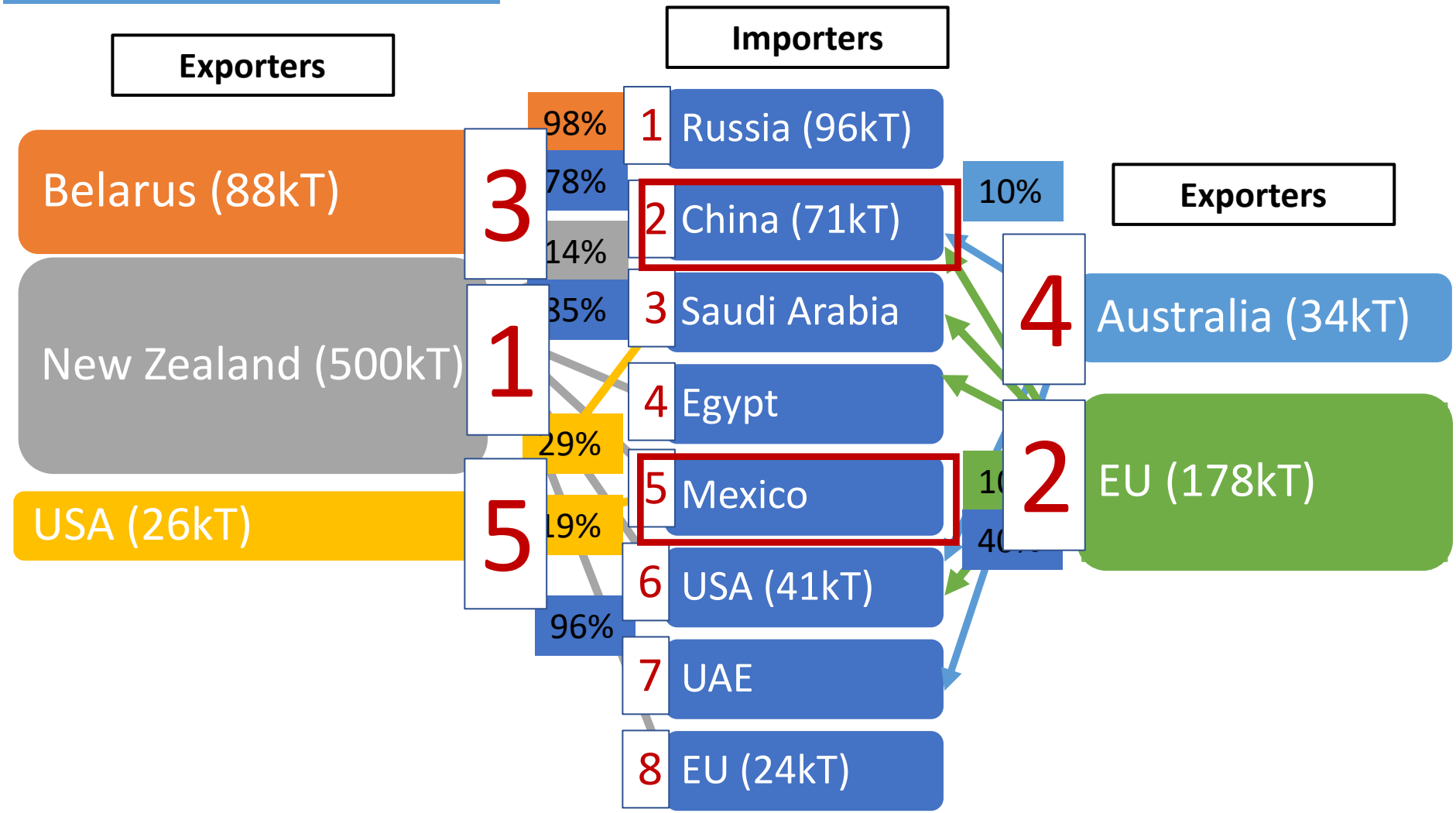
20% of US exports to Canada

(Saudi Arabia, Egypt, Turkey, Lebanon, UAE)

Thailand, S. Korea, China, Taiwan)

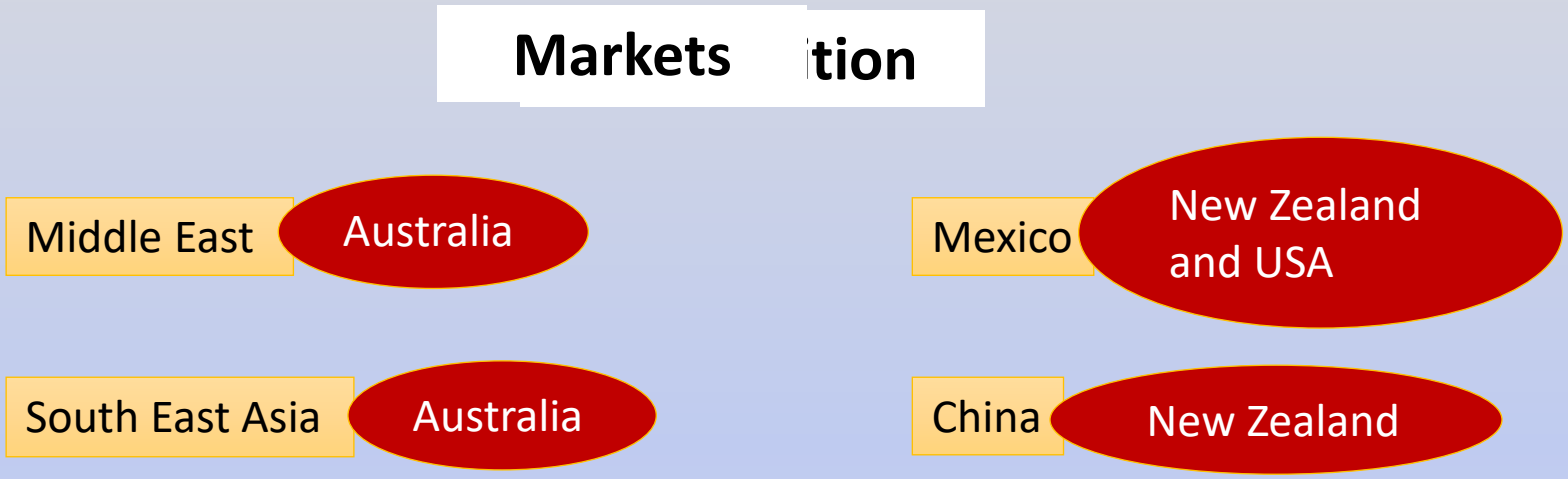
CLAL, 2017

IDF, 2016



Major players in butter trade -2015

Butter trade possibilities for Ireland



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

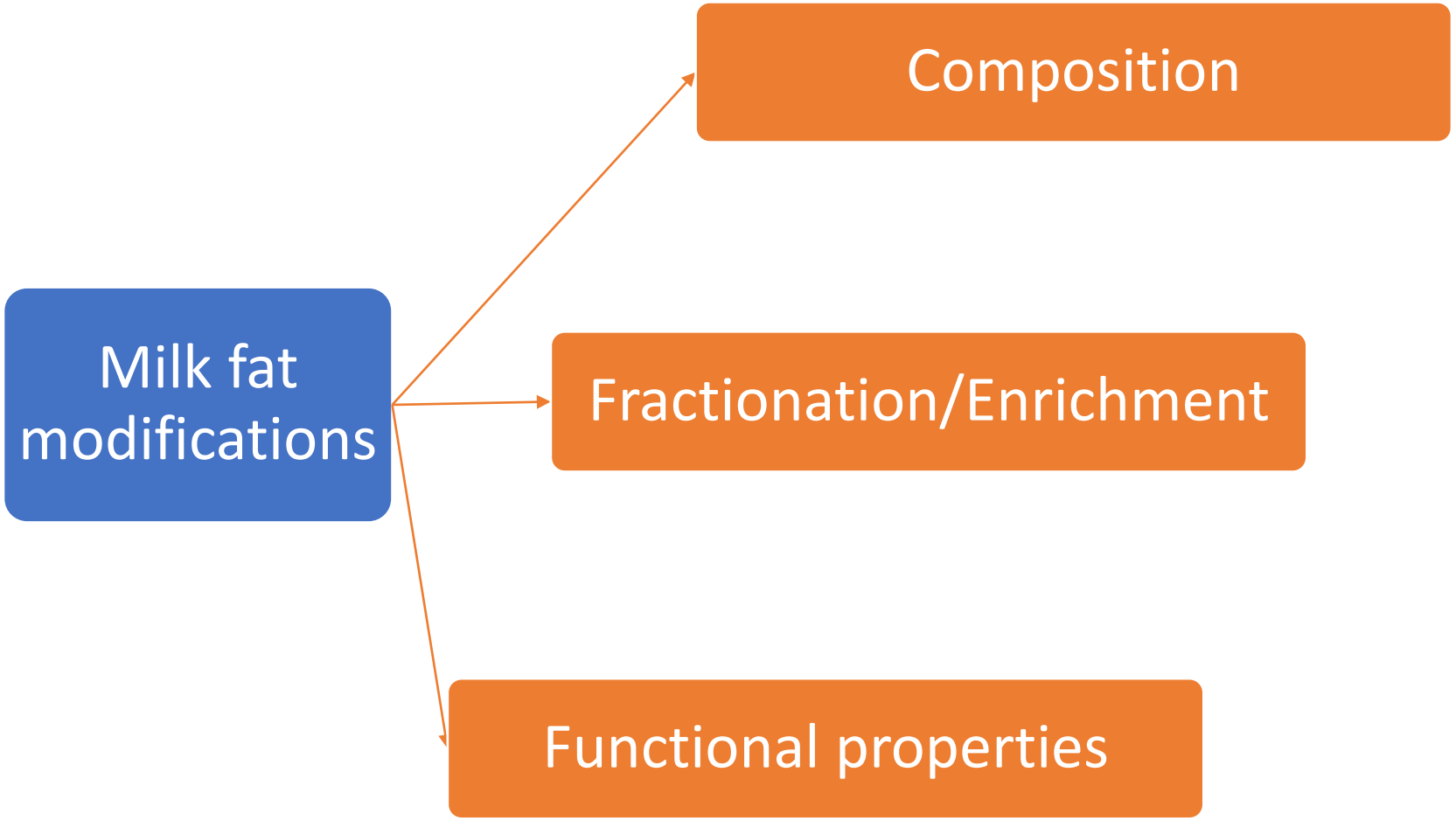
Need to explore new options

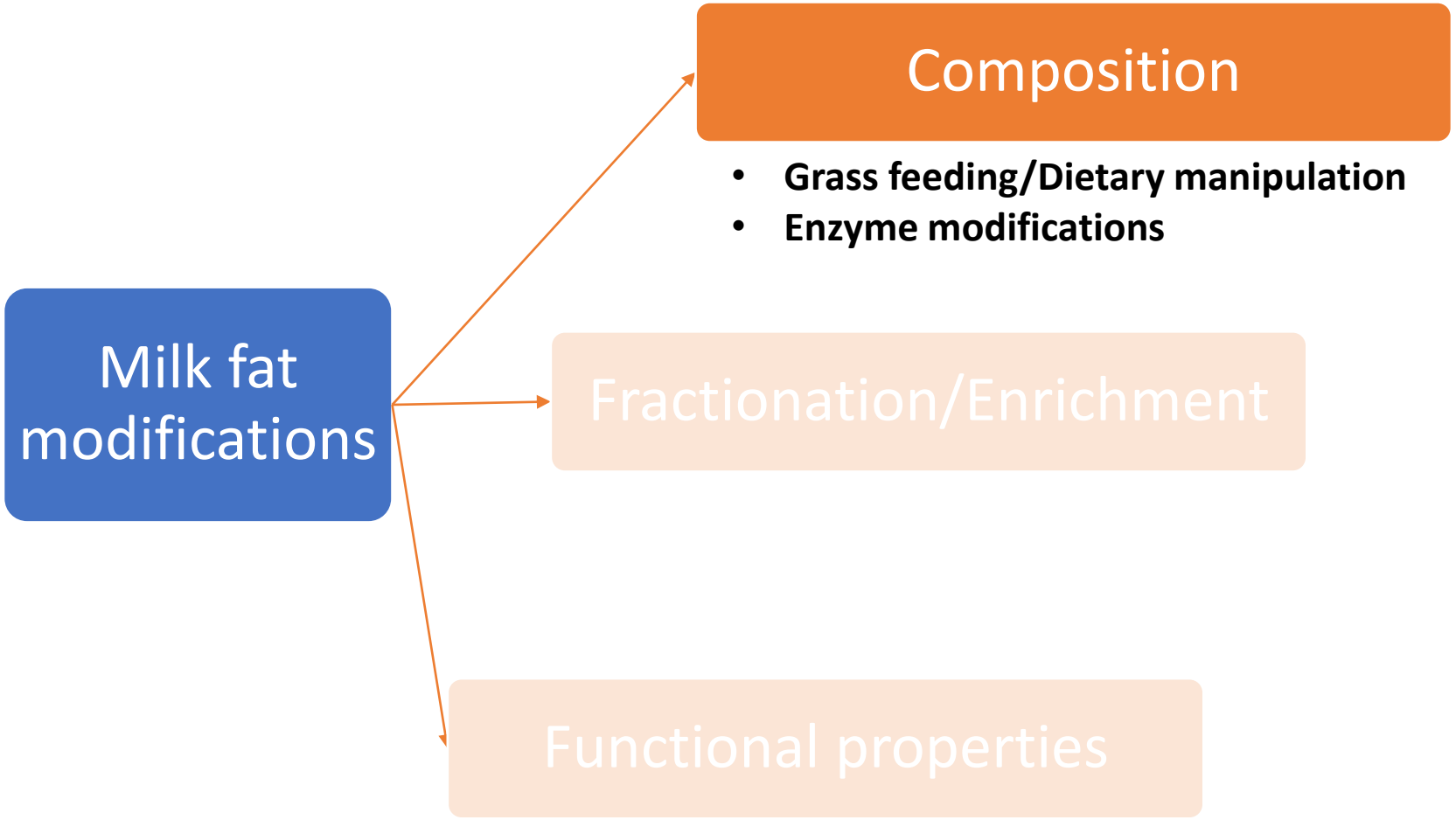
Outline

- 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

Fatty acid components	Control milk	Grass fed
	----------fatty acids g/100g----------	
Saturated (SFA) ↓	53	49
Unsaturated (UFA)	19	19
ω-3	0.05	0.08
CLA ↑	0.7	1.5

- Changes crystallization and textural properties

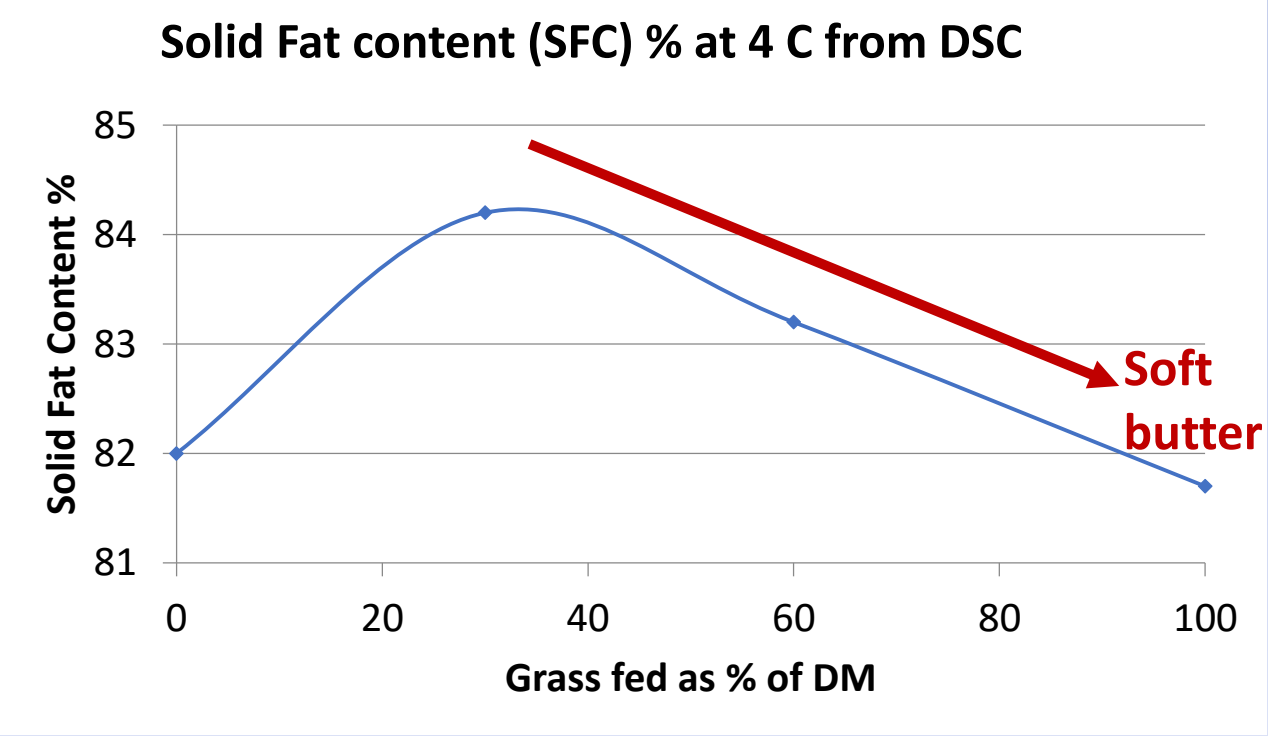
O'Callaghan et al., 2016

Modification in milk fat composition

Grass feeding

Application:

Kerrygold spreadable butter, Ornua



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)

Fatty acid components	Control milk	Fish oil fed
	----------fatty acids g/100g----------	
SFA ↓	65	62
UFA ↑	34	37
ω-3 ↑	1.2	1.7
CLA ↑	0.6	1.6

- Changes crystallization and textural properties

Mohan et al., 2013

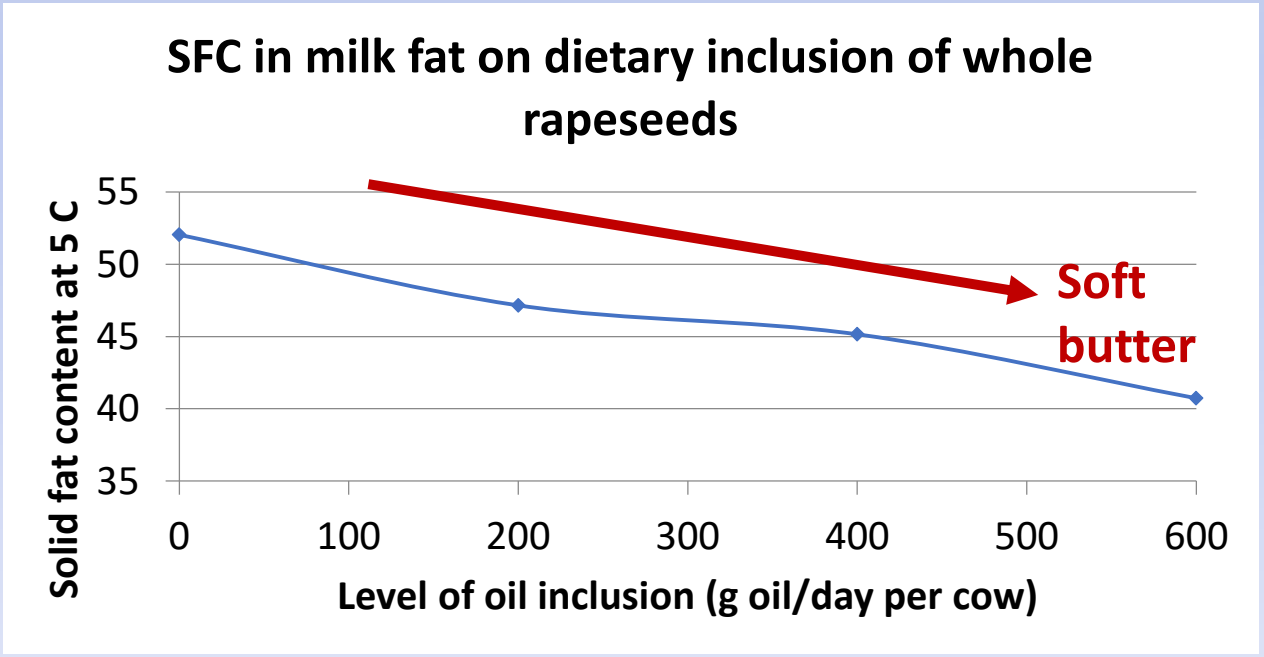
Modification in milk fat composition

Dietary manipulation in cattle

Application:

Dromona butter, Northern Ireland

- Whole rapeseed in the dairy concentrate for grazing dairy cows



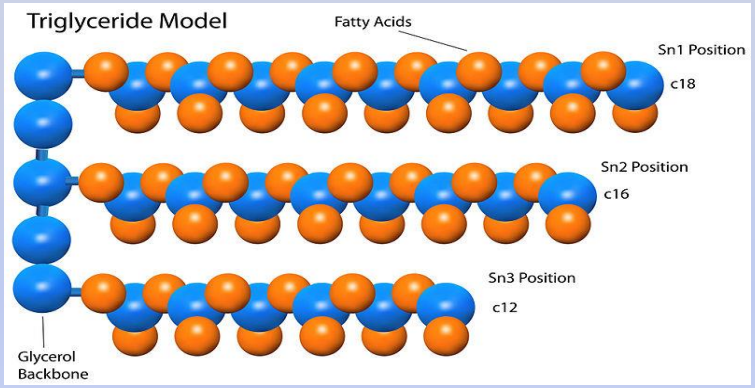
Fearon et al., 2004

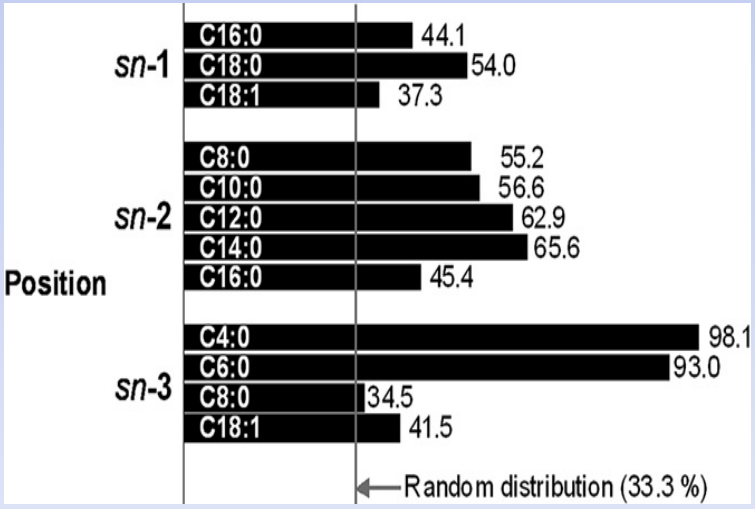
Modification in milk fat composition

Enzymatic modification

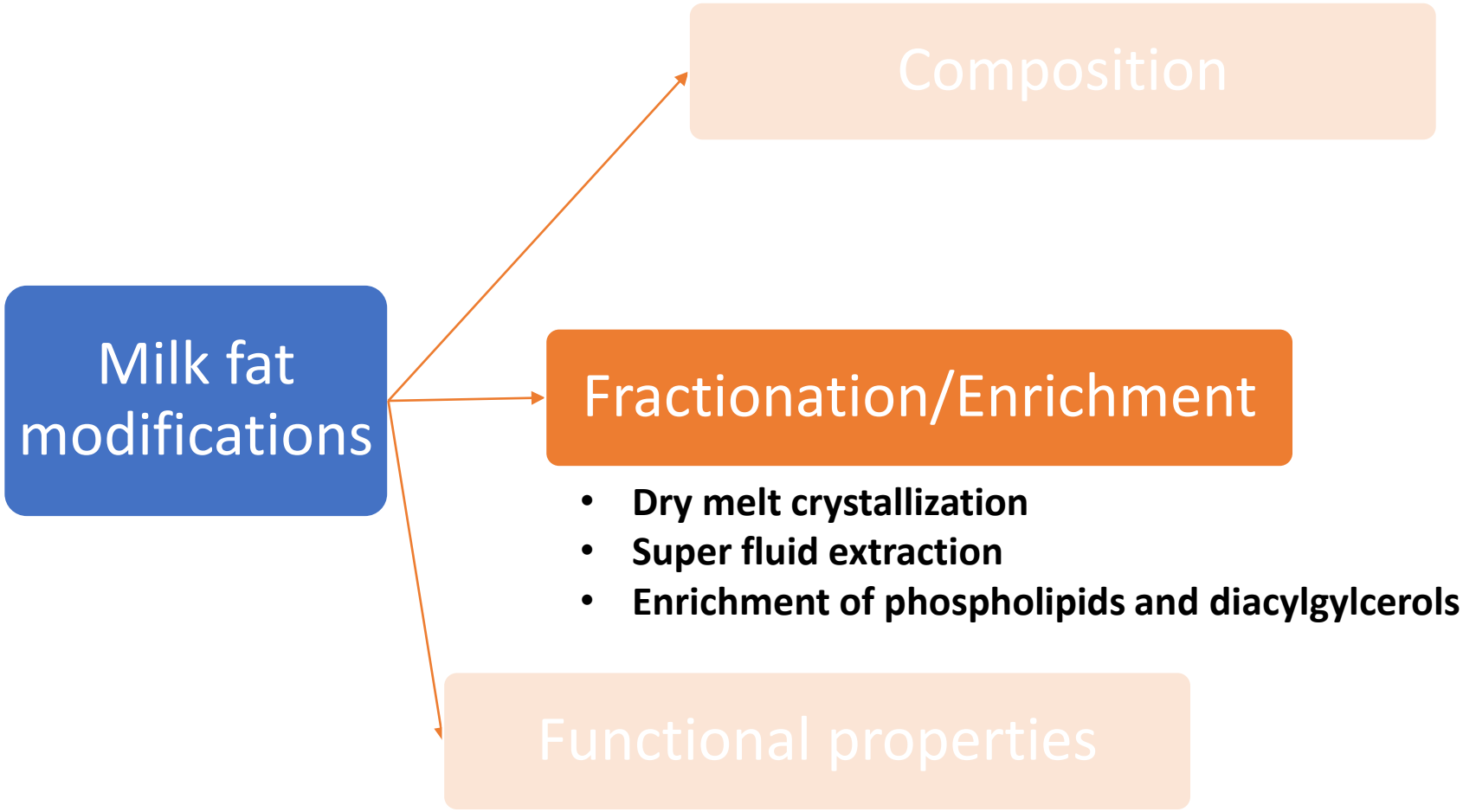
- Lipases catalyze reactions
  - Hydrolysis
  - Interesterification
    - Acidolysis, alcoholysis, ester-ester exchange

- 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

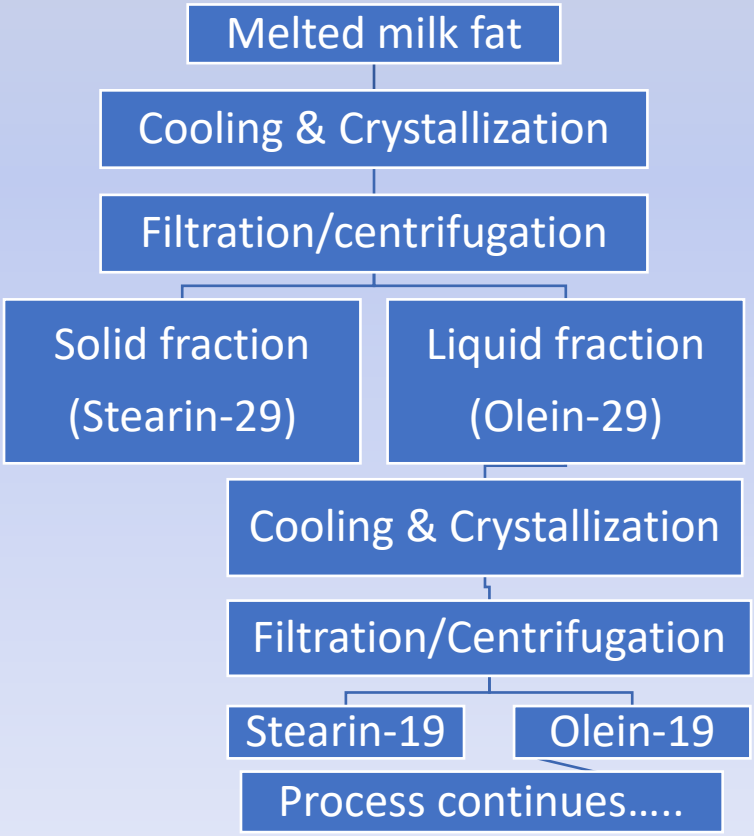


- **Dry melt crystallization**
- **Super fluid extraction**
- **Enrichment of phospholipids and diacylgylcerols**

Fractionation/Enrichment of milk fat components

Dry melt fractionation

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



Use of dry melt fractions in products:

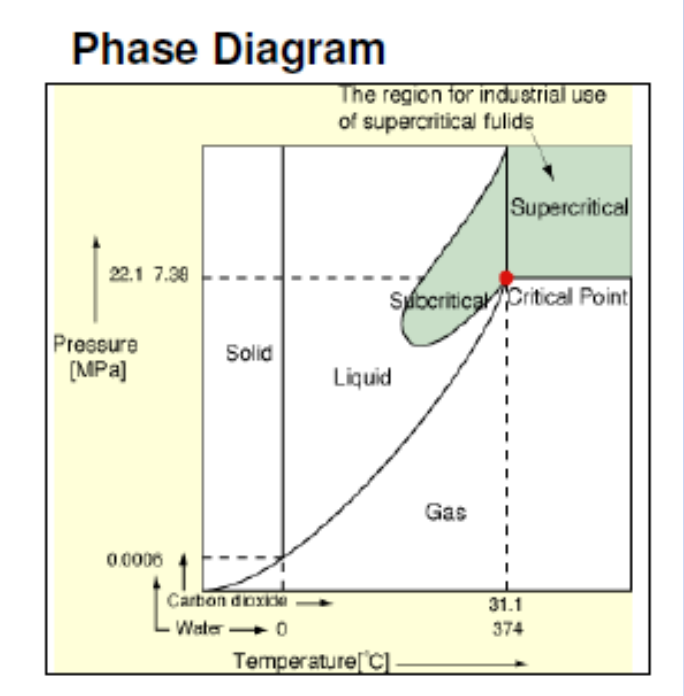
- Low melting – confectionary products
- Medium melting – biscuits, cakes, pastries
- High melting – chocolate and ice cream

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]

Contents lists available at ScienceDirect

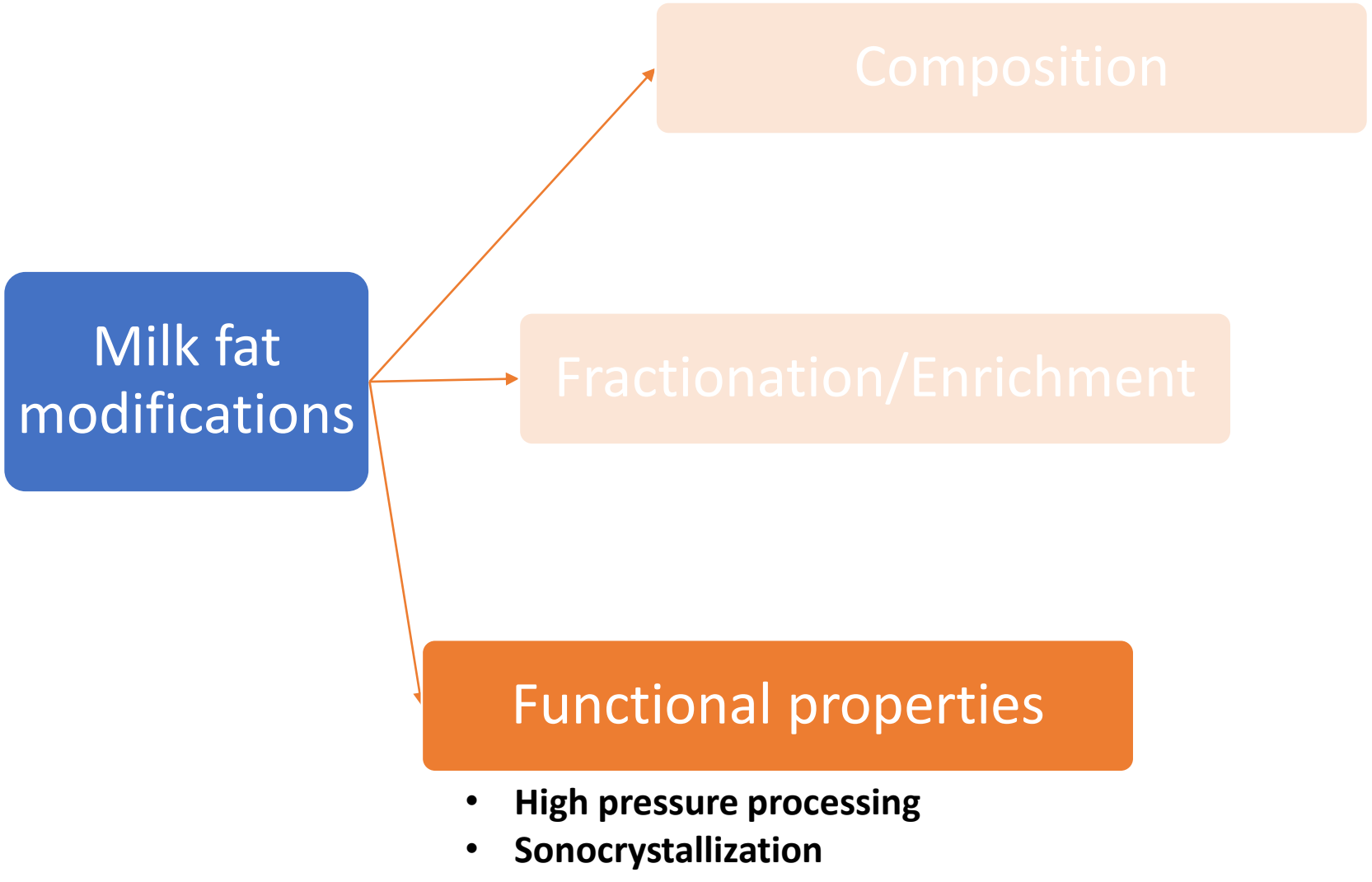
International Dairy Journal

journal homepage: www.elsevier.com/locate/idairyj

Selective enrichment of dairy phospholipids in a buttermilk substrate through investigation of enzymatic hydrolysis of milk proteins in conjunction with ultrafiltration

Kate M. Barry [a, b], Timothy G. Dinan [b], Philip M. Kelly [a, *]

[1]Britten et al., 2008
[2]Corredig et al., 2003
[3]Astaire et al., 2003
[4]Barry et al., 2016


Milk fat modifications
Composition
Fractionation/Enrichment
Functional properties
• High pressure processing
• Sonocrystallization

Modification of functional properties

High pressure processing

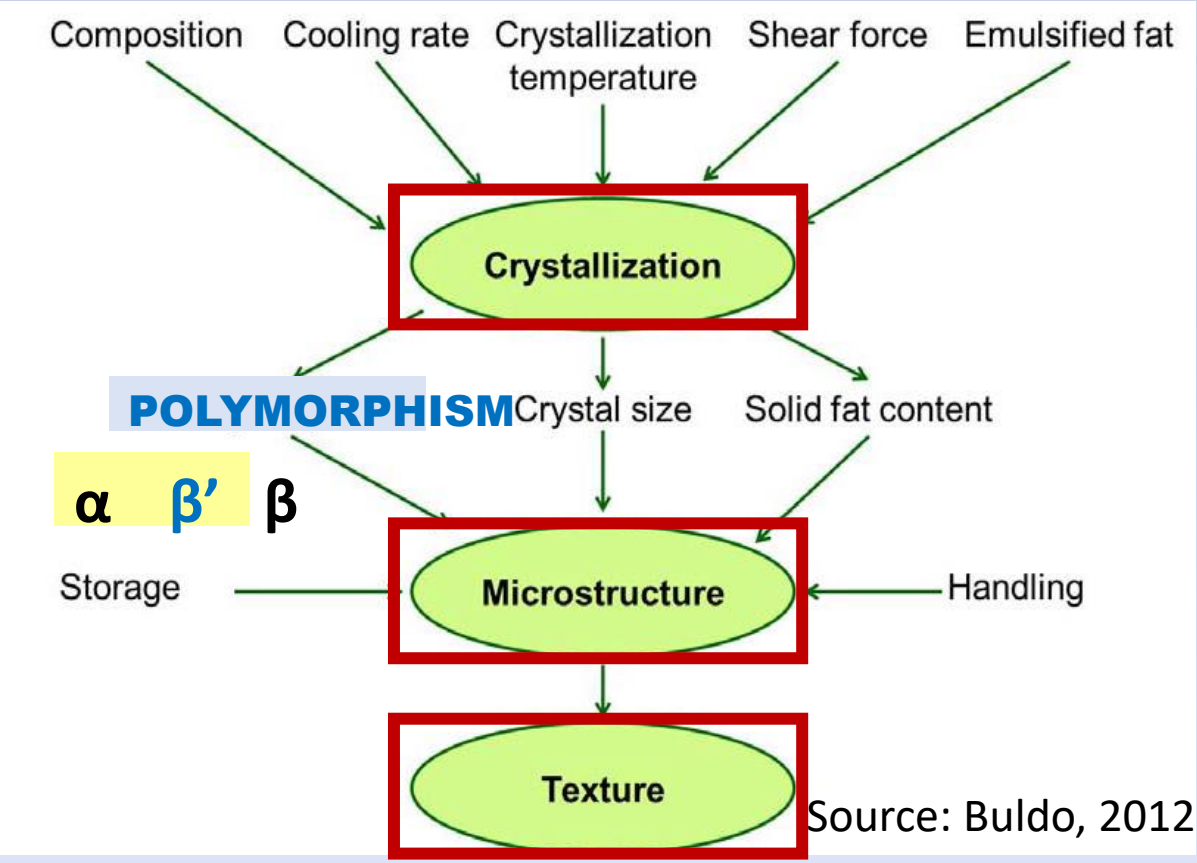
- Static (up to 1000MPa) or dynamic (up to 400 Mpa) high pressure
- Disrupts milk fat globules
- Applications
  - Addition of hydrolysed caseins and emulsifying agents produced good body for whipped cream[1]
  - Smaller fat globules provides creamier and smoother texture in soft cheeses and dairy gels[2]
  - 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

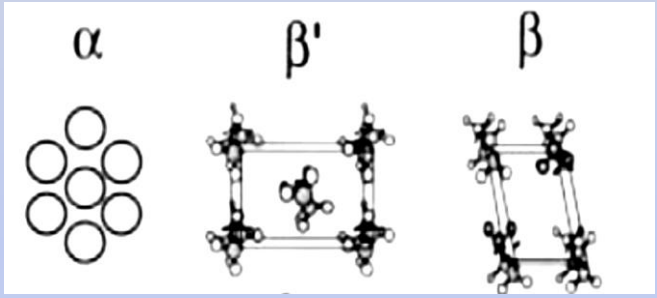


Source: Buldo, 2012

Modification of functional properties

Sonocrystallization

- Polymorphic forms of milk fat crystals



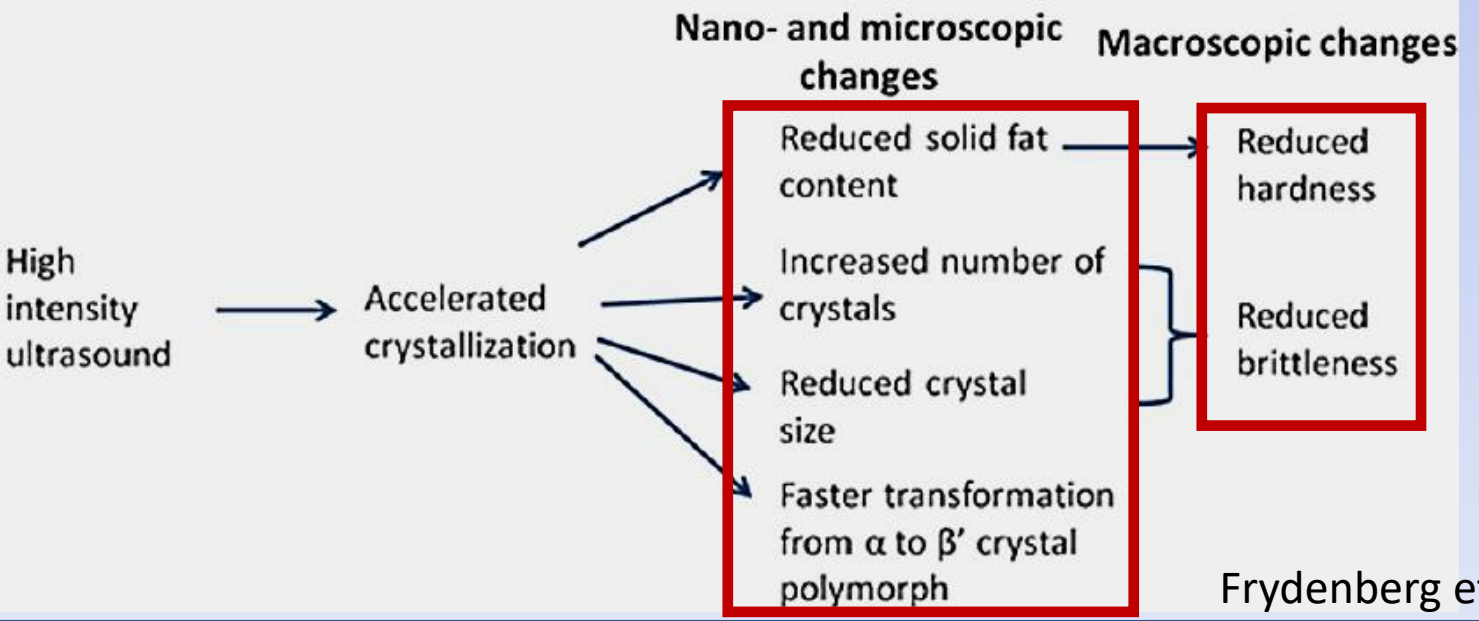
Properties	α-form	β'-form	β-form
Density & Melting point	Least		Highest
Stability	Least stable	Metastable	Highest stable
Crystal morphology		Optimal	Large plate-like crystals
Crystal network		Optimal	Poor and brittle
Applications		Butter	Confectionary

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

- Astaire, J.C., R. Ward, J.B. German and Jiménez-Flores, R. 2003. Concentration of Polar MFGM Lipids from Buttermilk by Microfiltration and Supercritical Fluid Extraction. J. of Dairy Sci. 86(7): 2297-2307.
- Barry, K. M., Dinan, T. G., & Kelly, P. M. (2017). Selective enrichment of dairy phospholipids in a buttermilk substrate through investigation of enzymatic hydrolysis of milk proteins in conjunction with ultrafiltration. *International Dairy Journal*, *68*, 80-87.
- Bentley, J., & Ash, M. (2016). Butter and Margarine Availability Over the Last Century. *Amber Waves*, (06). https://www.ers.usda.gov/amber-waves/2016/july/butter-and-margarine-availability-over-the-last-century/
- Britten, M., S. Lamothe and Robitaille, G. 2008. Effect of cream treatment on phospholipids and protein recovery in butter-making process. Int. J. of Food Sci. & Tech., 43: 651–657.
- Bronte-Stewart, B., Antonis, A., Eales, L., & Brock, J. (1956). Effects of feeding different fats on serum-cholesterol level. *The Lancet, 267*(6922), 521-527.
- Buldo, P. (2013). *Crystallization of Fat in and Outside Milk Fat Globules-Effect of Processing and Storage Conditions: PhD Thesis*. Department of Food Science, Aarhus University.
- Büyükbeşe, D., E. E. Emre and A. Kaya. 2014. Supercritical carbon dioxide fractionation of anhydrous milk fat. Journal of the American Oil Chemists' Society. 91(1):169-177.
- Chandrapala, J., L. Ong, B. Zisu, S. L. Gras, M. Ashokkumar, and S. E. Kentish. 2016. The effect of sonication and high pressure homogenisation on the properties of pure cream. Innovative Food Science & Emerging Technologies, 33:298-307.
- CLAL (2017). Production and markets of different countries. http://www.clal.it/en/

References

- Cornfield, J. (1962). *Joint dependence of risk of coronary heart disease on serum cholesterol and systolic blood pressure: a discriminant function analysis.* Paper presented at the Fed Proc.
- Corredig, M., R.R. Roesch and Dalgleish, D.G. . 2003. Production of a Novel Ingredient from Buttermilk. J. of Dairy Sci. 86(9): 2744-2750
- Couvreur, S., C. Hurtaud, C. Lopez, L. Delaby and Peyraud, J.L. 2006. The Linear Relationship Between the Proportion of Fresh Grass in the Cow Diet, Milk Fatty Acid Composition, and Butter Properties, J. of Dairy Sci. 89 (6):1956-1969.
- CSO (2011). Agriculture - Consumption per Person of Dairy Products. http://www.cso.ie/multiquicktables/quickTables.aspx?id=aba02_2
- European Commission (2017). EU Milk Market Observatory. European Commission-Agriculture and rural development. http://ec.europa.eu/agriculture/market-observatory_en http://ec.europa.eu/agriculture/sites/agriculture/files/market-observatory/milk/pdf/trade-main-competitors_en.pdf
- FAOSTAT (2016). http://www.fao.org/faostat/en/#home
- FDII, 2016. http://www.fdii.ie/Sectors/FDII/FDII.nsf/vPages/Dairy~trade-and-economics?OpenDocument
- Fearon, A. M., C. S. Mayne, J. A. M. Beattie and Bruce, D. W. 2004. Effect of level of oil inclusion in the diet of dairy cows at pasture on animal performance and milk composition and properties. J. Sci. Food Agric. 84: 497–504.
- Frydenberg, R. P., Hammershøj, M., Andersen, U., & Wiking, L. (2016). High intensity ultrasound effects on heat-induced whey protein isolate gels depend on α-lactalbumin: β-lactoglobulin ratio. *International Dairy Journal*, *56*, 1-3.

References

- Goudédranche, H., J. Fauquant and J.L. Maubois. 2000. Fractionation of globular milk fat by membrane microfiltration. Le lait, 80(1), pp.93-98.
- Huth, P. J., D. B. DiRienzo, and G. D. Miller. 2006. Major scientific advances with dairy foods in nutrition and health. *Journal of Dairy Science* 89,1207–1221.
- IDF(2015). The world dairy situation 2016. *Bulletin of the International Dairy Federation* 481/2015
- IDF(2016). The world dairy situation 2016. *Bulletin of the International Dairy Federation* 485/2016
- Ihara, K., M. Hirota, T. Akitsu, K. Urakawa, T. Abe, M. Sumi, T. Okawa and T. Fujii. 2015. Effects of emulsifying components in the continuous phase of cream on the stability of fat globules and the physical properties of whipped cream. J. of Dairy Sci. 98(5): 2875-2883.
- Kannel, W.B., Dawber, T.R., Friedman, G.D., Glennon, W.E. and Mcnamara, P.M., 1964. Risk Factors in Coronary Heart DiseaseAn Evaluation of Several Serum Lipids as Predictors of Coronary Heart DiseaseThe Framingham Study. *Annals of Internal Medicine*, *61*(5_Part_1), pp.888-899.
- Keys, A., Anderson, J. T., & Grande, F. (1965). Serum cholesterol response to changes in the diet. *Metabolism, 14*(7), 747-758. doi: http://dx.doi.org/10.1016/0026-0495(65)90001-6
- Keys, A., Grande, F., & Anderson, J. T. (1974). Bias and misrepresentation revisited: Perspective" on saturated fat. *The American Journal of Clinical Nutrition, 27*(2), 188-212.

References

- Kontkanen, H., Rokka, S., Kemppinen, A., Miettinen, H., Hellström, J., Kruus, K., ... & Korhonen, H. (2011). Enzymatic and physical modification of milk fat: A review. *International Dairy Journal*, *21*(1), 3-13. https://www.researchgate.net/profile/Hannu_Korhonen2/publication/224900632_Enzymatic_and_physical_modification_of_milk_fat_A_review/links/542853ed0cf238c6ea7cd448.pdf
- Micha, R., & Mozaffarian, D. (2010). Saturated Fat and Cardiometabolic Risk Factors, Coronary Heart Disease, Stroke, and Diabetes: a Fresh Look at the Evidence. *Lipids, 45*(10), 893-905. doi: 10.1007/s11745-010-3393-4
- Mohan, M. S. (2011). Enhancement of conjugated linoleic acid (CLA) content in cheddar cheese by combining dietary manipulation of cattle and CLA producing starter culture: SOUTH DAKOTA STATE UNIVERSITY http://gradworks.umi.com/15/04/1504595.html.
- Mohan, M. S., Anand, S., Kalscheur, K. F., Hassan, A. N., & Hippen, A. R. (2013). Starter cultures and cattle feed manipulation enhance conjugated linoleic acid concentrations in Cheddar cheese. *Journal of Dairy Science, 96*(4), 2081-2094. doi: http://dx.doi.org/10.3168/jds.2012-6101
- Mozaffarian, D., Benjamin, E. J., Go, A. S., Arnett, D. K., Blaha, M. J., Cushman, M., ... & Howard, V. J. (2016). Heart Disease and Stroke Statistics—2016 Update. *Circulation*, *133*(4), e38-e360
- O'Callaghan, T. F., Faulkner, H., McAuliffe, S., O'Sullivan, M. G., Hennessy, D., Dillon, P., . . . Ross, R. P. (2016). Quality characteristics, chemical composition, and sensory properties of butter from cows on pasture versus indoor feeding systems. *Journal of Dairy Science, 99*(12), 9441-9460. doi: http://dx.doi.org/10.3168/jds.2016-11271
- O'Callaghan, T. F., Hennessy, D., McAuliffe, S., Kilcawley, K. N., O'Donovan, M., Dillon, P., . . . Stanton, C. (2016). Effect of pasture versus indoor feeding systems on raw milk composition and quality over an entire lactation. *Journal of Dairy Science, 99*(12), 9424-9440. doi: http://dx.doi.org/10.3168/jds.2016-10985

References

- OEAD-FAO (2016). Agricultural Outlook 2016-2025. http://stats.oecd.org/index.aspx?queryid=71240
- OEAD-FAO (2008). Agricultural Outlook 2008-2017. http://www.oecd.org/trade/agricultural-trade/40715381.pdf
- Page, I. H., Allen, E. V., Chamberlain, F. L., Keys, A., Stamler, J., & Stare, F. J. (1961). Dietary Fat and Its Relation to Heart Attacks and Strokes. *Circulation, 23*(1), 133-136. doi: 10.1161/01.cir.23.1.133
- Reiser, R. (1978). Oversimplification of diet: coronary heart disease relationships and exaggerated diet recommendations. *The American Journal of Clinical Nutrition, 31*(5), 865-875.
- USDA-FAS (2016). Dairy: world markets and trade USDA. https://www.fas.usda.gov/data/dairy-world-markets-and-trade
- USGPO (1940). Milk - for health, good teeth, vitality, endurance, strong bones. *Posters of the WPA* / Christopher DeNoon. Los Angeles : Wheatly Press, c1987, no. 229 http://www.loc.gov/pictures/item/98518818/
- USGPO (1940). Milk - for summer thirst. *Posters of the WPA* / Christopher DeNoon. Los Angeles : Wheatly Press, c1987, no. 200 http://www.loc.gov/pictures/item/98518818/
- World Health Organization. "The top 10 causes of death: The 10 leading causes of death by country income group (2012)." *WHO*. WHO Media Centre, May. 2014. http://www.who.int/mediacentre/factsheets/fs310/en/index1.html

CLA content in milk, cheese and butter

Product	TMR	Pasture fed
	g/100g FA	
Milk[1]	0.67	1.52
Cheese[1,2]	1.09	2.5*
Butter[3]	0.67	1.8

*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