The Dairy Matrix and Health Benefits

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Dairy technology Centre: Health benefits of milk-derived compounds

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Healthy Ageing & Performance Nutrition

Metabolic Health

Healthy Cheeses

Infant Nutrition

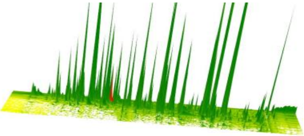
Technology WP: Intelligent Milk Mining
Pipeline of compounds

Process for ‘mining’ milk bioactives

WPC80
NaCaS

Hydrolysis

(Ranges of conditions (pH, time, temperature, enzymes)



Bioactivity Screening

- Glycaemic function
- Inflammation
- Allergy/ immunity
- Muscle synthesis
- Endurance / glycogen resynthesis
- Appetite / Satiety
- **TASTE!**

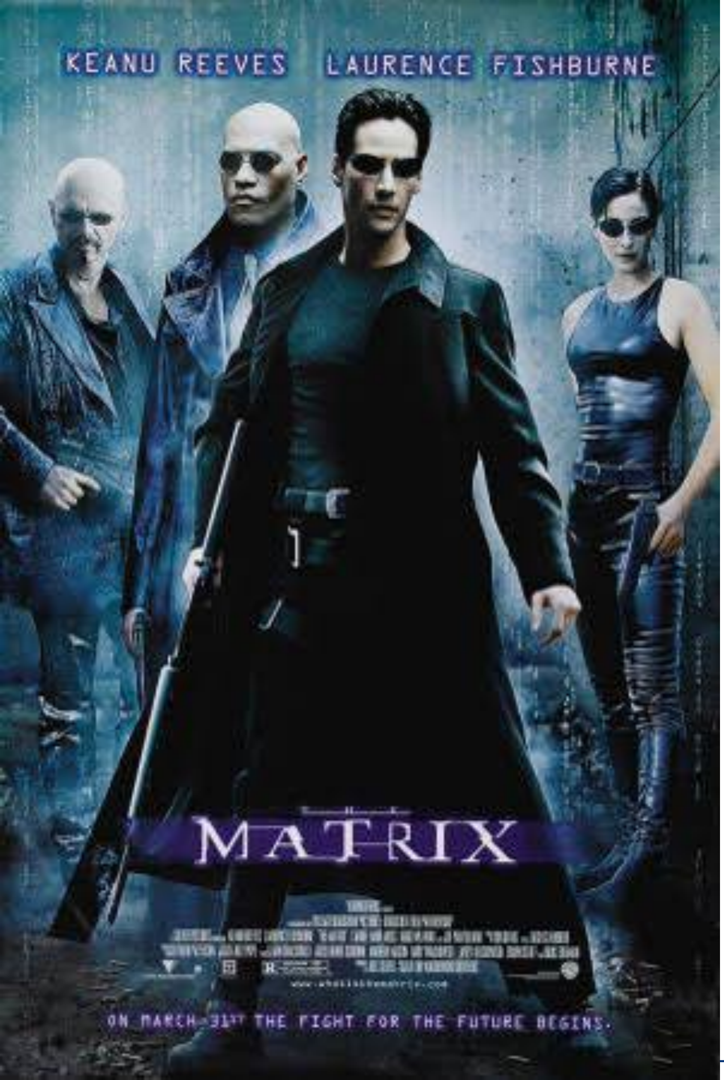
Lead Functional Compounds **(LFCs)**

Tested In :

- Cell models
- Animal Models
- Human Models

Sensory Evaluation

New Functional Food Ingredients



What is the 'Dairy Matrix' ?

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What is the 'Dairy Matrix' ?

The nutrients in dairy work as **a team** – www.ndc.ie

'The constituents of milk or other dairy **foods do not work in isolation**, but rather interact with each other. This is the concept of the 'dairy matrix'; the premise being that the **health effects of the individual nutrients may be greater when they are combined together**'

UCD DUBLIN

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What is the 'Dairy Matrix' ?

'Foods consist of a large number of different nutrients that are contained in a complex structure. The nature of the **food structure and the nutrients therein** (i.e., the food matrix) will determine the nutrient **digestion and absorption**, thereby altering the **overall nutritional properties** of the food'

Thorning *et al, (*2017) AJCN

Moving beyond single nutrients:

- Traditionally, study of nutrients and health - a ‘reductionist’ approach

- Doesn’t allow for the study of a **‘food matrix’ effect**

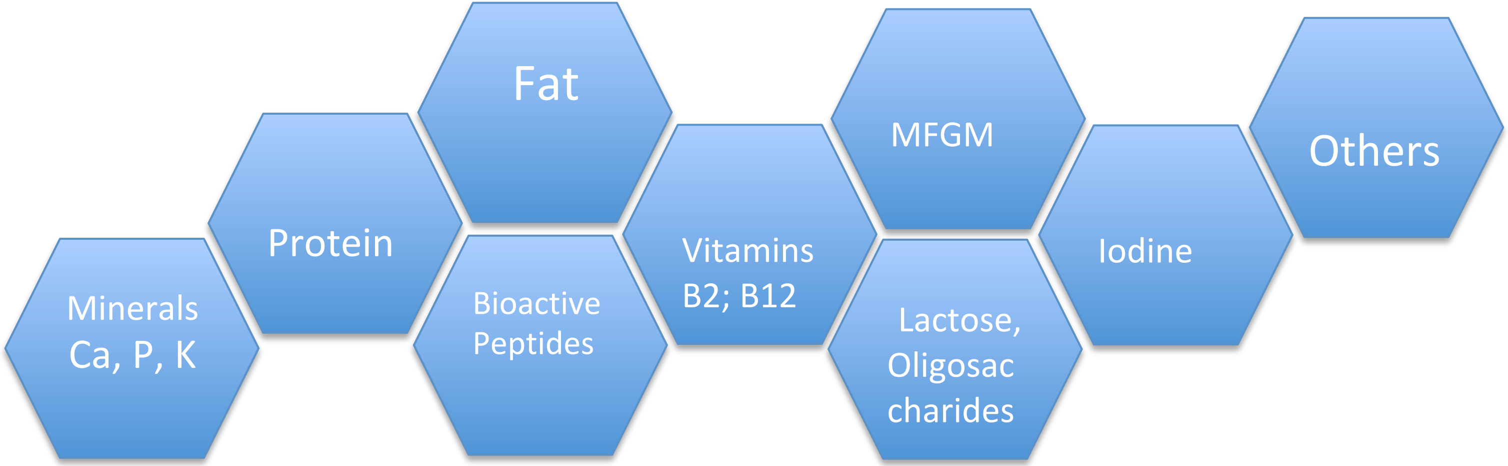
- Examples from almonds demonstrate that the degree of chewing affects the energy extracted
- Also affects protein digestion – can impact allergenicity

- Carotenoids in carrots – raw pieces vs homogenised– show large differences in the bioavailability **(3%, vs 21%)** [(1)]
- Further enhanced **to 39%**, when cooked with oil

1. Hedren et al, (2002) Eur J Clin Nutr,

‘Dairy’ foods are not all the same:

- The ‘Dairy’ shelf : ‘ **Milk, cheese, and yoghurt’**
- **Even this is overly simplistic - ** different types of milk, cheeses and yoghurt
- The matrices within these are varied; protein, peptides, fat content, sugars

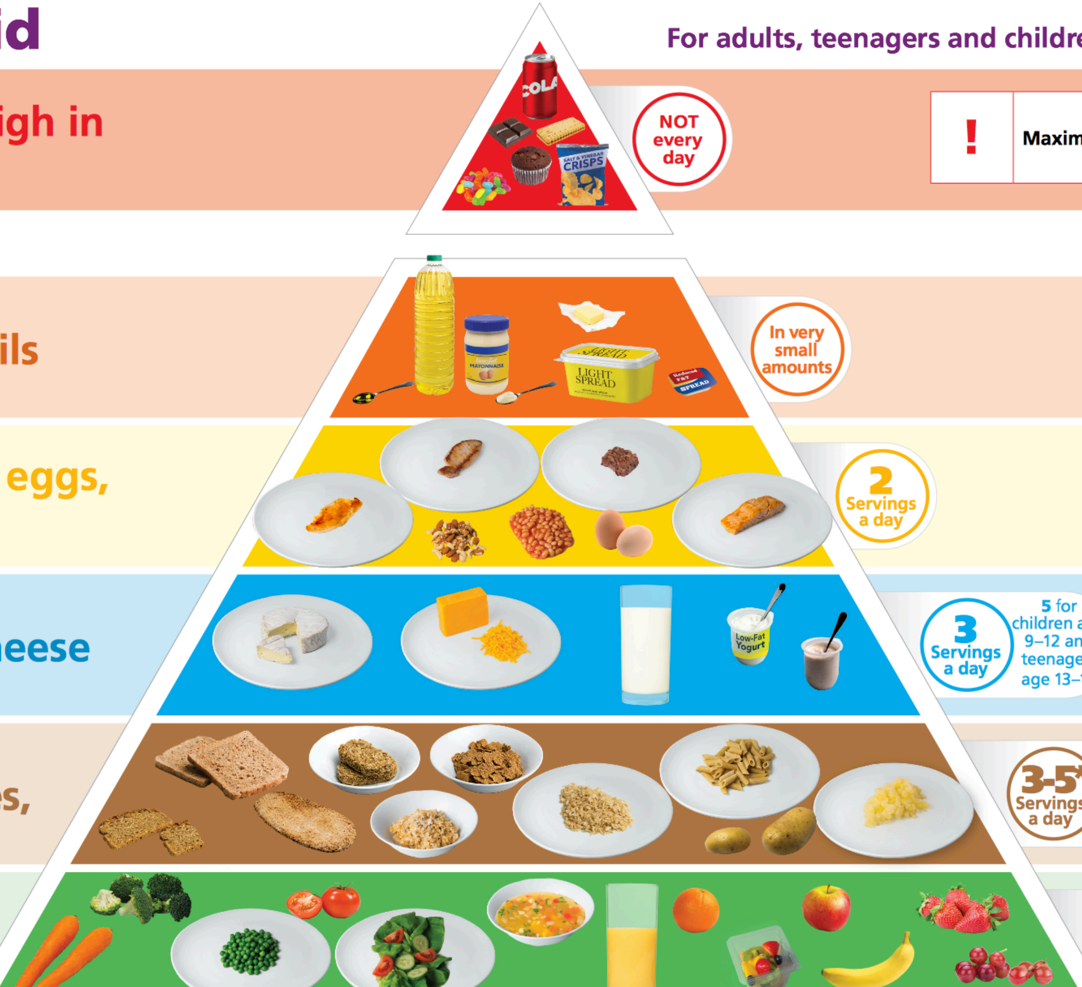


Healthy Food for Life

www.healthyireland.ie

The **Food Pyramid**

For adults, teenagers and children aged five and over



Not needed for good health.

Foods and drinks high in fat, sugar and salt

NOT every day

! Maximum once or twice a week

Needed for good health. Enjoy a variety every day.

Fats, spreads and oils

In very small amounts

Meat, poultry, fish, eggs, beans and nuts

2 Servings a day

Milk, yogurt and cheese

3 Servings a day

5 for children age 9–12 and teenagers age 13–18

Wholemeal cereals and breads, potatoes, pasta and rice

3-5* Servings a day

Up to 7* for teenage boys and men age 19–50

Vegetables, salad and fruit

5-7 Servings a day

'Dairy' foods are not all the same:

(2) Adapted from Thorning *et al, (*2017) AJCN

TABLE 2

Bioactive components and supramolecular structures in different dairy products[1]

	Calcium, mg/100 g	Phosphorus, mg/100 g	MFGM,[2] mg/100 g	Protein,[3] g/100 g, type	Fermented	Fat structure[4]	Protein network
Cheese[5] (25% fat)	659	510	150	23.2, Casein	Yes	MFG/aggregates/free fat	Solid/viscoelastic
Milk (skimmed, 0.5% fat)	124	97	15	3.5, Whey/casein	No	Tiny native MFG/potential MFGM fragments	Liquid
Milk (whole, 3.5% fat)	116	93	35	3.4, Whey/casein	No	Native MFG or homogenized milk fat droplets/potential MFGM fragments	Liquid
Yogurt (1.5% fat)	136	99	15	4.1, Whey/casein	Yes	Native MFG or homogenized milk fat droplets/potential MFGM fragments	Gel/viscoelastic
Cream (38% fat)	67	57	200	2, —	No	Native MFG or homogenized milk fat droplets/potential MFGM fragments	Liquid
Butter	15	24	—	<1, —	No/yes[6]	Continuous fat phase (water-in-oil emulsion)/MFGM-residue traces	—

[1] All values are approximate amounts. MFG, milk-fat globule; MFGM, milk-fat globule membrane.
[2] General estimation on the basis of Dewettinck et al. (11) and Conway et al. (12).
[3] According to food-composition tables from The Technical University of Denmark (13).
[4] General estimation on the basis of Michalski (14) and Michalski et al. (15) and references therein.
[5] Semihard Danbo type, as a point example among many different cheese types.
[6] Depends on the production method used. With indirect biological acidification, starter culture is added to the butter after churning.

Body Fat: Evidence for Matrix Effects

- Dairy foods – contain a variety of fat and protein levels:
- A range of observational studies suggest a role in weight
- control [3]:

	Low (n 499)		Medium (n 500)		High (n 500)		
	Mean	SD	Mean	SD	Mean	SD	P
(A) Calculated as g/d total dairy products†							
Nutrient information							
MD dairy products (g)	107·9[a]	47·9	249·3[b]	41·6	515·7[c]	180·7	<0·01
Demographic information							
Age (years)	43·3	16·9	45·1	17·1	45·1	17·1	0·12
BMI (kg/m²)‡	27·8[a]	5·5	26·9[b]	4·7	26·6[b]	5·0	0·01
M:F ratio§	41:59		49:51		48:42		<0·01
SES (1:2:3:4)‖¶	43:19:16:22		48:19:15:18		49:18:13:19‖		0·44

(3) Feeney *et al* (2016) BJN

(Milk, cheese, yoghurt, cream, butter)

Body Fat: Evidence for Matrix Effects

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Table 1. Metabolic markers of health across tertiles of total dairy consumption

Variable	*Low (1.25–180.6 g)*		*Medium (181.3–323.2 g)*		*High (324.2–1630.0 g)*		*P-value*
	n	*Mean ± s.e.*	n	*Mean ± s.e.*	n	*Mean ± s.e.*	
BMI (kg m^{-2})	465	$27.8^{c} \pm 4.6$	476	$26.8^{c,d} \pm 5.4$	470	$26.7^{d} \pm 4.9$	< **0.001**
Body fat (%)	439	$31.1^{c} \pm 0.7$	442	$27.6^{d} \pm 0.7$	437	$26.8^{d} \pm 0.5$	< **0.001**
Muscle mass (kg)	435	51.6 ± 0.6	440	51.4 ± 0.6	435	50.4 ± 0.4	0.195
Waist circumference (cm)	406	$93.7^{c} \pm 11.0$	428	$91.0^{d} \pm 1.0$	429	$87.8^{e} \pm 13.4$	< **0.001**
Waist-to-hip ratio	408	$0.89^{c} \pm 0.01$	427	$0.88^{d} \pm 0.01$	429	$0.86^{e} \pm 0.1$	< **0.001**

(*figures adjusted for gender, age and energy intakes)

(All dairy, from all foods and recipes)

- (4) Feeney *et al* (2017) Nutr & Diabetes

Body Fat: Evidence for Matrix Effects

- Dairy foods – source of casein (slow) and whey (fast) proteins
- EAAs and Leucine (whey)

- Evidence suggests that dairy protein can help to maintain skeletal muscle mass during energy restriction [5]

- Evidence is mixed regarding whether casein or whey is more beneficial, either for weight loss or body composition [6,7]

- [5] Fresdedt *et al* (2008) *Nutr Metab (5): 1-8*
- [6] Lacroix *et al* (2006) Am J Clin Nutr. 84 (5): 1070-1079
- [7] Dangin *et al* (2001) Am J Physiol Endocrinol Metab 280 (2): E340-E348

RESEARCH ARTICLE

Effects of Dairy Products Consumption on Body Weight and Body Composition Among Adults: An Updated Meta-Analysis of 37 Randomized Control Trials

Tingting Geng, Lu Qi, Tao Huang

Accepted manuscript online: 23 October 2017 Full publication history

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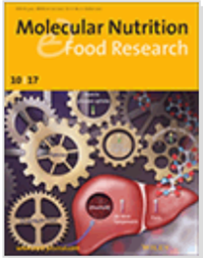

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Methods and results

: We conducted a comprehensive search of the Cochrane Library, PubMed and Embase databases of the relevant studies from 1966 to Mar 2017 regarding dairy consumption on body weight and body composition including of body fat, lean mass and waist circumference (WC). The summary results were pooled by using a random-effects meta-analysis. 37 RCTs with 184,802 participants were included in this meta-analysis. High dairy intervention increased body weight (0.01, 95% CI: -0.25, 0.26, I^2 = 78.3%) and lean mass (0.37, 95% CI: 0.11, 0.62, I^2 = 83.4%); decreased body fat (-0.23, 95% CI: -0.48, 0.02, I^2 = 78.2%) and WC (-1.37, 95% CI: -2.28, -0.46, I^2 = 98.9%) overall. In the subgroup analysis, consumption of dairy products increased body weight (0.36, 95% CI: 0.01, 0.70, I^2 = 83.1%) among participants without energy restriction. Dairy consumption decreased body weight (-0.64, 95% CI: -1.05, -0.24, I^2 = 60.2%), body fat (-0.56, 95%CI: -0.95, -0.17, I^2 = 66.6%) and waist circumference (-2.18, 95%CI: -4.30, -0.06, I^2 = 99.0%) among the adults with energy restriction.

Conclusions

: This meta-analysis suggests a beneficial effect of energy-restricted dairy consumption on body weight and body composition. However, high dairy consumption in the absence of caloric restriction may increase body weight.

Saturated fat and CHD risk – debate

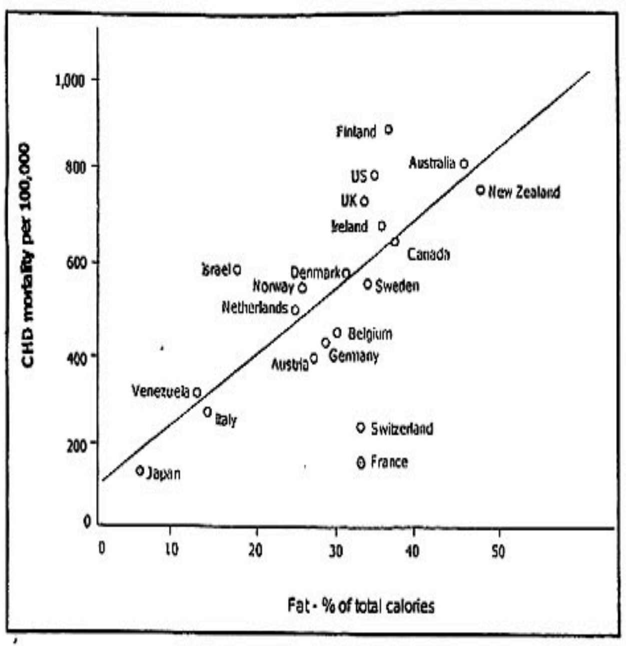


Figure 1. Dietary consumption of fat and Coronary Heart Disease Mortality in Various Countries.

Outcome	No of studies /comparisons	No of events /participants	Relative risk (95% CI)	P	P_{het}	I^2 (%)
All cause mortality	5/7	14 090/99 906	0.99 (0.91 to 1.09)	0.91	0.17	33
CHD mortality	11/15	2970/101 712	1.15 (0.97 to 1.36)	0.10	<0.001	70
CVD mortality	3/5	3792/90 501	0.97 (0.84 to 1.12)	0.69	0.29	19
CHD total	12/17	6383/267 416	1.06 (0.95 to 1.17)	0.29	0.02	47
Ischemic stroke	12/15	6226/339 090	1.02 (0.90 to 1.15)	0.79	0.002	59
Type 2 diabetes	8/8	8739/237 454	0.95 (0.88 to 1.03)	0.20	0.61	0

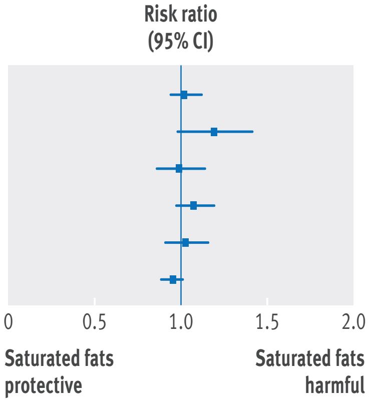
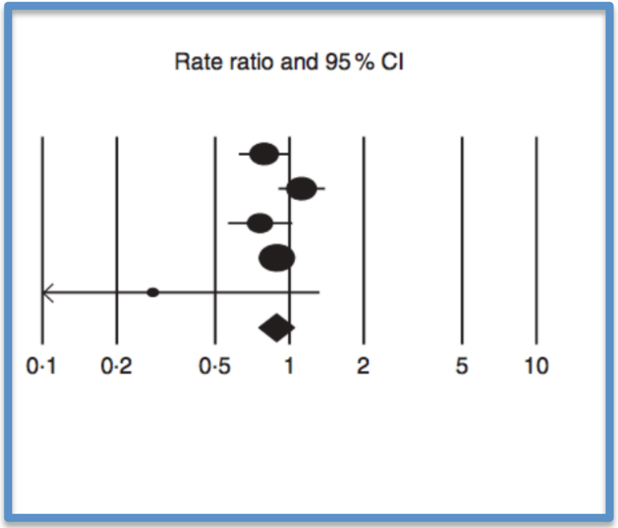


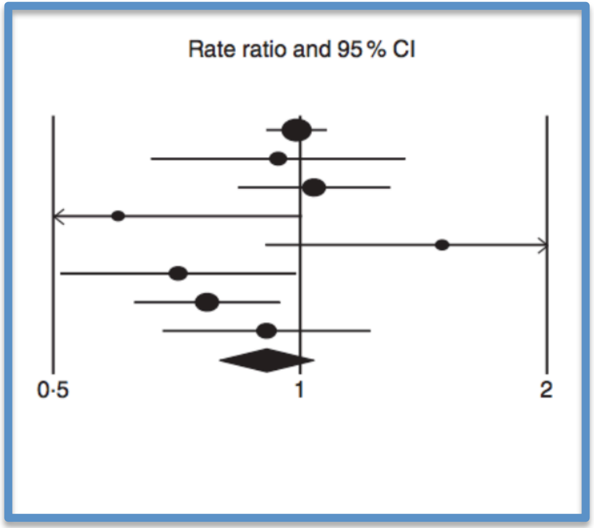
Fig 2 | Summary most adjusted relative risks for saturated fat intake and all cause mortality, CHD mortality, CVD mortality, total CHD, ischemic stroke, and type 2 diabetes. All effect estimates are from random effects analyses. P value is for Z test of no overall association between exposure and outcome; P_{het} is for test of no differences in association measure among studies; I^2 is proportion of total variation in study estimates from heterogeneity rather than sampling error

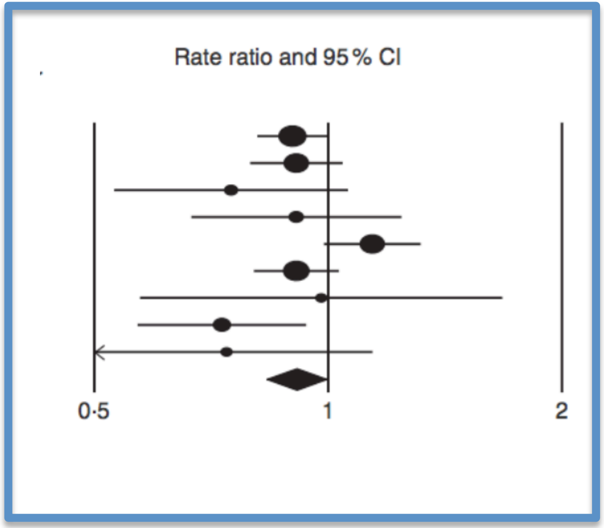
Ancel Keys

De Souza

Alexander (2016, BJN) Meta-analysis of dairy intake and risk of CVD, CHD and Stroke:







31 unique cohort studies – overall, no association (CHD and stroke). Possibly reduced risk for CVD but more detailed data is required on intakes for dose-response analysis

Moving towards Patterns of intake:

Tertiles vs Patterns:

Cluster 1
Full fat Milk

Cluster 2
Low fat milk,
yoghurt

Cluster 3
Butter and
Cream

[8] Feeney *et al* (2017) Nutr & Diabetes

Dietary patterns of dairy:

Table 2. Cluster characteristics—dairy intakes per MJ in the different clusters (n = 1497) and %energy from macronutrients

Variable	*'Whole milk' Cluster* n *675*	*'Reduced fat milks and yogurt' Cluster* n *56z4*	*'Butter and cream' cluster* n *258*	*P-value*
	Mean ± *s.e.*	*Mean* ± *s.e.*	*Mean* ± *s.e.*	
Mean daily saturated fat per g	$32.2^{a} \pm 14.0$	$25.7^{b} \pm 11.\ 0$	$32.2^{a} \pm 11.8$	< **0.001**
Mean daily total fat per g	$80.6^{a} \pm 31.4$	$67.5^{b} \pm 26.0$	$80.7^{a} \pm 26.8$	< **0.001**
% energy MUFA	$12.7^{a} \pm 2.7$	$11.7^{b} \pm 2.7$	$12.6^{a} \pm 2.6$	< **0.001**
% energy PUFA	5.9 ± 2.1	6.1 ± 2.5	5.9 ± 1.8	0.46
% energy SFA	$13.8^{a} \pm 3.5$	$12.2^{b} \pm 3.5$	$14.0^{a} \pm 3.3$	< **0.001**
% Energy fat	$34.7^{a} \pm 6.3$	$32.0^{b} \pm 6.6$	$34.9^{a} \pm 6.2$	< **0.001**
% Energy protein	$16.4^{a} \pm 3.4$	$17.8^{b} \pm 3.7$	$16.5^{a} \pm 3.8$	< **0.001**
Age/years	43.5 ± 17.1	45.7 ± 16.9	44.5 ± 17.2	0.074
Energy/MJ	$8.7^{a} \pm 2.9$	$7.9^{b} \pm 2.6$	$8.8^{a} \pm 2.6$	< **0.001**
Male:female ratio	58:42	41:59	46:54	< **0.001**
Total milk per ml	$26.7^{a} \pm 21.5$	$33.4^{b} \pm 21.8$	$23.9^{a} \pm 16.4$	< **0.001**

- Feeney *et al* (2017) Nutr & Diabetes

Dietary patterns of dairy:

Table 3. Markers of metabolic health across clusters of dairy consumption

Variable	*Cluster 1 'Whole milk'*		*Cluster 2 'Reduced fat milks and yogurt'*		*Cluster 3 'Butter and cream'*		P-value
	n	*Mean ± s.e.*	n	*Mean ± s.e.*	n	*Mean ± s.e.*	
Healthy Eating Index	488	23.3[c] ± 8.5	371	28.0[d] ± 10.0	189	25.0[e] ± 9.4	< **0.001**
BMI (kg m^{-2})	601	26.9 ± 4.6	512	27.3 ± 5.4	239	227.1 ± 4.9	0.474
Body fat (%)	589	29.3 ± 9.1	497	29.1 ± 8.9	231	29.2 ± 8.9	0.593
Muscle mass (kg)	400	50.8 ± 11.0	301	52.3 ± 11.2	161	51.4 ± 11.1	0.205
Waist circumference (cm)	378	89.7 ± 12.3	301	89.2 ± 12.3	166	89.2 ± 14.0	0.443
Waist-to-hip ratio	378	0.87 ± 0.1	301	0.87 ± 0.1	166	0.87 ± 0.1	0.802
BP—systolic (mmHg)	249	123.41 ± 1.0	205	125.42 ± 1.2	164	120.6 ± 1.6	0.053
BP—diastolic (mmHg)	249	78.2 ± 10.7	205	77.7 ± 10.5	105	76.9 ± 10.8	0.338
Serum trigs (mmol l^{-1})	251	1.31[c,d] ± 0.05	212	1.36[c] ± 0.06	106	1.13[d] ± 0.07	**0.028**
Serum total cholesterol (mmol l^{-1})	264	4.94[c] ± 0.07	216	5.16[d] ± 0.06	109	4.8[c] ± 0.1	**0.015**
Serum direct HDL (mmol l^{-1})	262	1.54 ± 0.02	214	1.62 ± 0.03	108	1.57 ± 0.04	0.126
LDL-C (calculated) (mmol l^{-1})	259	2.80 ± 0.06	213	2.91 ± 0.07	108	2.72 ± 0.09	0.217

- Feeney *et al* (2017) Nutr & Diabetes

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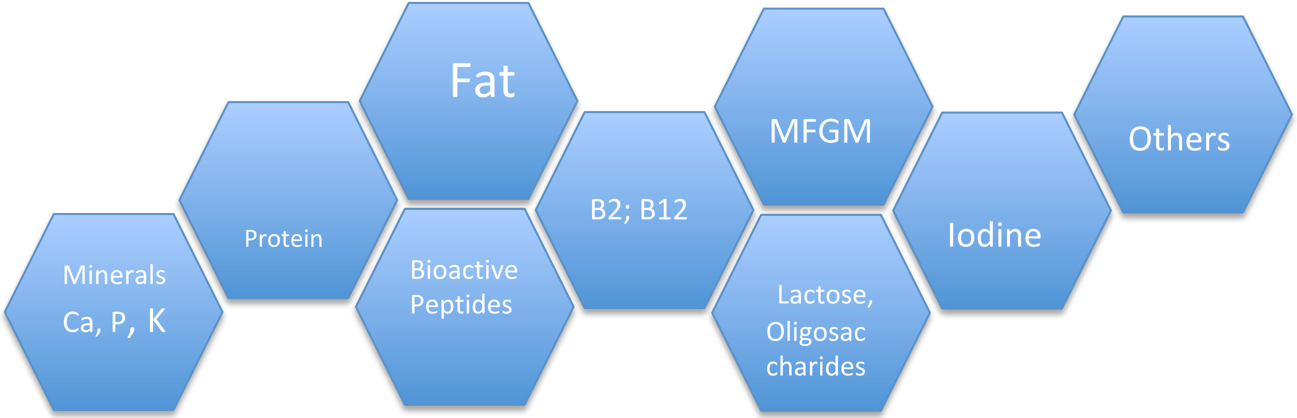
- The matrices within these are varied; protein, peptides, fat content, sugars



Dairy & metabolic health: Intervention studies

Author (year)	Population	Study design and measurements	Key Findings
Tholstrup *et al,* 2004	14 healthy m, aged 20-31	RCT – everyone did all 3 arms - 20% energy from cheese/milk/ daily for 3 wks. Cheese: 205g per 10MJ energy.	Fasting LDL was higher after the butter diet vs the cheese (p=0.037 after 3 weeks) Same trend (0.057) for total cholesterol
Biong, 2004	22 healthy subjects (9 m) aged 23-54	RCT, 3 arms. 1:Jarlsberg cheese, 2:butter+calcium, 3:butter+egg white protein	Total cholesterol sig. lower after CH diet than after BC diet (−0·27 mmol/l; P=0·03),LDL down 0.22,but,p=0.06 (NS)
Sofi *et al*, 2010	10 healthy subjects, 6f. Median age 51.5	200g per week pecorino, naturally enriched in CLA, or control cheese (commercially available)	Significant improvement in markers of heart health.
Hjerpsted et al 2011	49 men and women healthy aged 22-69 (mean age 55.5 yr, mean BMI 25.2	Subjects replaced 13% energy with fat from either cheese or butter, for 6 weeks, following a 14d run in (normal diet).	No diff between LDL and HDL between run-in and cheese diet. Cheese diet resulted in better lipid profile than butter diet
Schlienger et al, 2014	Mildly hypercholesterolemic subjects	Subjects ate 2x daily servings of Camembert cheese (intervention) or 2 x 125g ff yog (control group).	No change in bp. or in plasma lipids following 2 weeks cheese vs 2 weeks yog. consumption
Nilsen et al (2014)	N=186, 56%f, mean age 51y	Gamalost (a Norwegian cheese) consumption, BP	Self reported cheese consumption associated with reduced bp

Dairy & metabolic health: Intervention studies

Author (year)	Population	Study design and measurements	Key Findings
Thorning et al (2015)	14 o/w females, post- menopausal mean age 59, mean BMI 28.8	Subjects completed randomised cross-over trial, consisting of 3 arms 1) high cheese (96–120g) 2) non-dairy, high-meat 3) a non-dairy, low-fat, high-carbo control. Measured impact on lipids &fecal fat excretion	Diets w/ cheese and meat as primary sources of SFAs cause higher HDL –c & apo A1 - & appear less atherogenic than low-fat, high-carbohydrate diet. Cheese diet increases fecal fat excretion.
Nilsen et al (2015)	153 healthy male & female participants	Participants randomized to one of three groups: Gamalost, a low-fat Norwegian cheese (50 g/day), Gouda-type 27% fat (80 g/day) (matched for protein), control group -limited cheese intake.	Cholesterol levels did not increase after high intake of 27% fat Gouda-type cheese over 8 weeks' intervention, and stratified analysis showed that participants with metabolic syndrome had reduced cholesterol by end.
Aune et al (2013)	**Varied;**	**Systematic review, coupled with dose-response meta-analysis on risk of T2D**	**8% lower risk of T2D per 50g cheese consumption High-fat dairy consumption associated with healthier BMI and body composition**

Summary: Cheese consumption: overall 'healthier' blood lipid profiles (higher HDL, lower LDL and lower trigs).
Some questions remain:

- **How important is the matrix?**
- **Is the effect seen for all populations?**

Cheese Matrix Studies - UCD

- Tests the hypothesis that fat needs to be **within the cheese matrix** to see effects

Inclusion Criteria: Over 50's population, with BMI of 25 or over

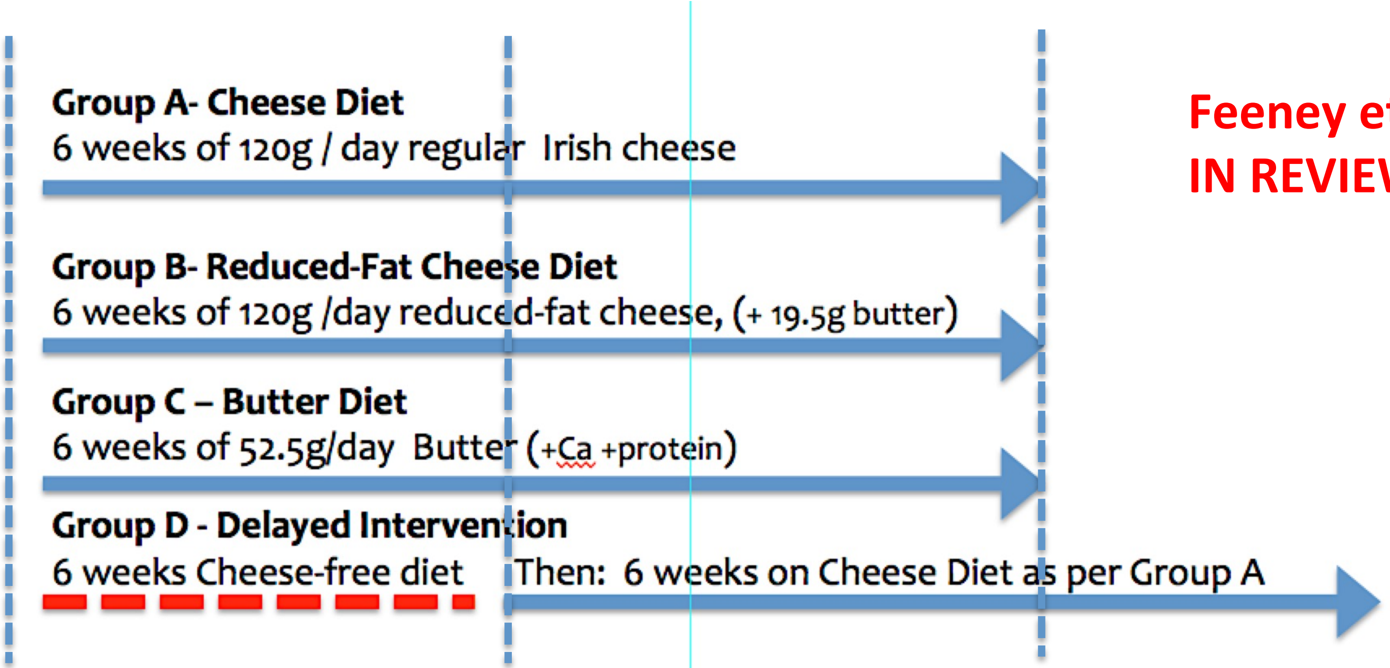
Intervention: 42g fat in 3 matrices (cheese, butter or reduced fat cheese) for 6w

Outcomes: Markers of heart health (LDL-C, HDL-C, key inflammatory cytokines

***Group A* – 120g full-fat Irish Cheddar**
***Group B* – 120g reduced fat Irish Cheddar, + butter**
Group C* – Butter, Calcium Caseinate powder, Calcium Tablet (500mg*)
***Group D* – Delayed – As per A but 6 weeks no cheese first**

Cheese Matrix Studies – UCD

Feeney et al
IN REVIEW



Baseline: Bloods BMI, BF, dietary records

Midway: dietary records

End: Bloods, BMI, BF%, dietary records

Dairy Matrix Studies - UCD

Mechanistic follow up-studies:

Cheese Calcium Study
- Adjusting Ca levels with natural cheese
- Faecal Fat excretion

Post Prandial Study
- Crossover trial
- Different dairy matrices
- Post prandial lipids

Simulated Digestion Studies
- Casein-based food structures, different fat contents
- Simulated digestion

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Summary

- **The Dairy Matrix** – the sum of the nutrients and food structure
- Link between SFA and health appears ***food-source dependent***
- Strong suggestion of a matrix effect in cheese for fat & cholesterol metabolism
- Nutrition research future: ***foods, & patterns of foods***
- Food Science research - opportunity to engineer ***healthier food structures***