
# Muscle, Bones and Body Fat:

## The Dairy Matrix and Body Composition

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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

# Overview

- What is the 'Dairy Matrix'?
- Human nutrition -  Moving beyond single nutrients
- Effects of dairy matrices on human health
    - **Muscle**
    - **Bones**
    - **Body fat**
- Cheese – a 'matrix' example


# 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**'

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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



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# Moving beyond single nutrients:

- Traditionally, study of nutrients and health - a 'reductionist' approach

- Doesn't allow for the study of a 'food matrix' effect

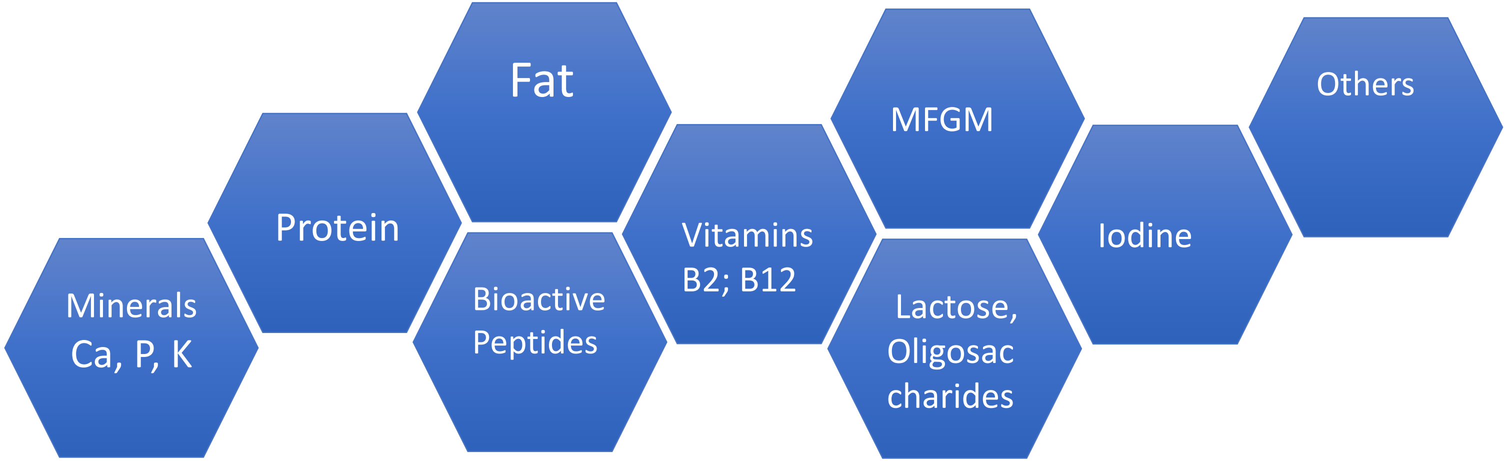
- Examples from almonds demonstrate that the degree of chewing affects the energy extracted
- Also affects protein digestion – can impact allergenicity

- 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




The dairy matrix: a new approach to understanding the health effects of food – November 2017

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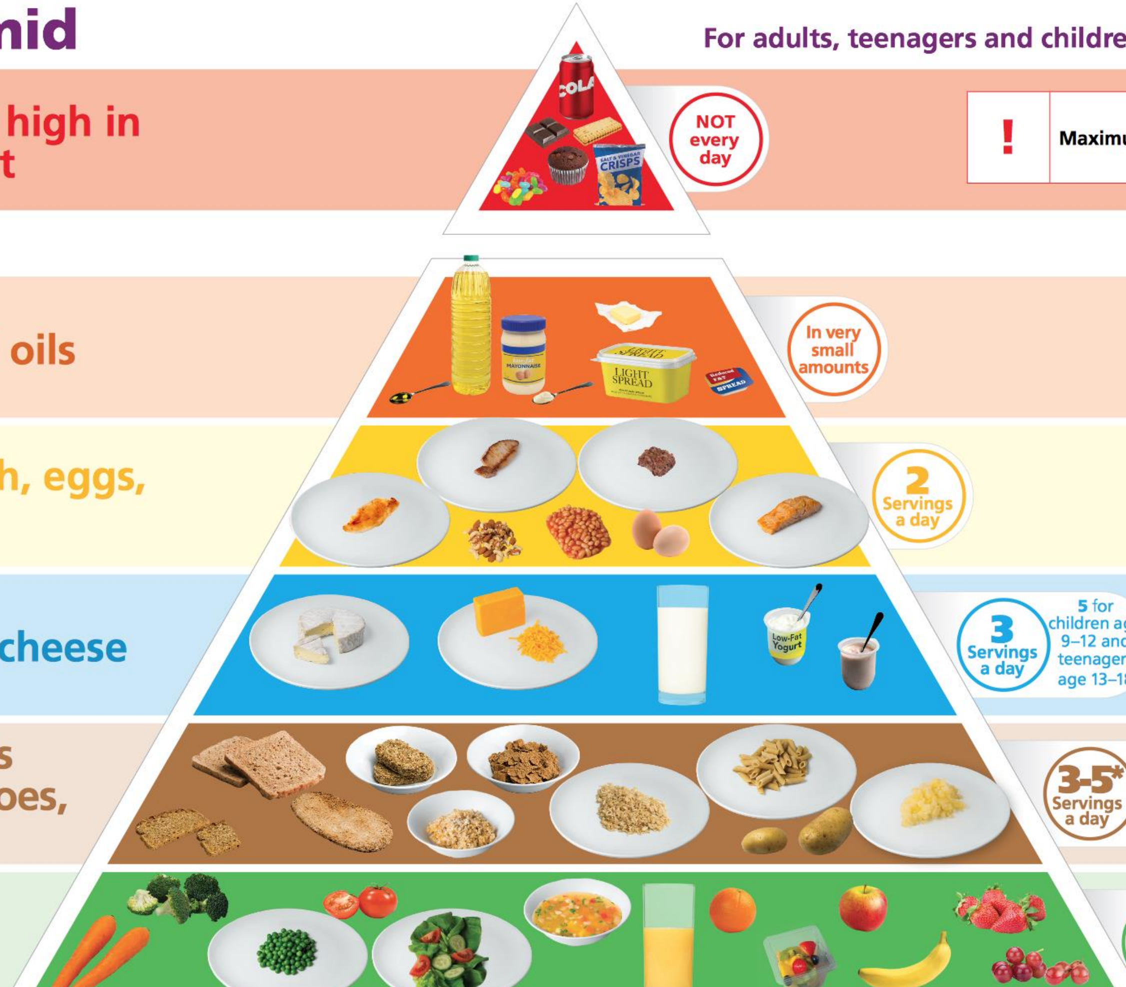
# The **Food Pyramid**

**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

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

# 'Dairy' foods are not all the same:

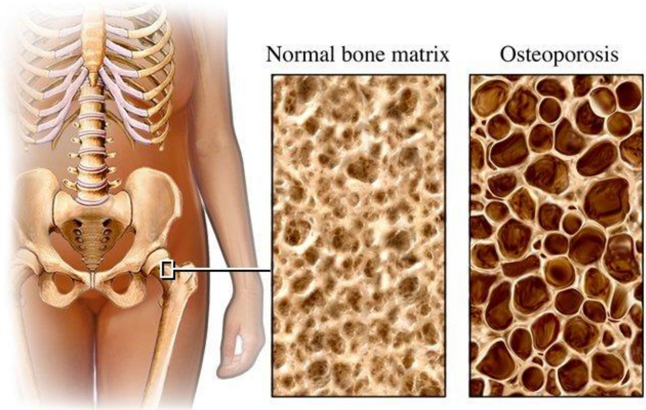
**TABLE 2**

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.

# Bone health: Evidence for Matrix Effects




Bone strength: Quality, structure, Mass and Turnover [1]

- 80-90% of BM content = Ca and P [2]
- Also requires: Protein, Vitamins A, C , D and K , Mg, Zn, Cu, Fe and Fluoride

Dairy: Contain a favourable P:Ca ratio (0.8:1) & range interacting of nutrients [3]

Dairy calcium appears more beneficial than other forms – stimulates renal resorption, meaning a longer-lasting effect

2. Ilch & Kirstetter (2000) Nutrition and Bone Health, J Am Coll Nutr
3. Bonjour et al (2011) J Am Coll Nutr 30:438S-448S



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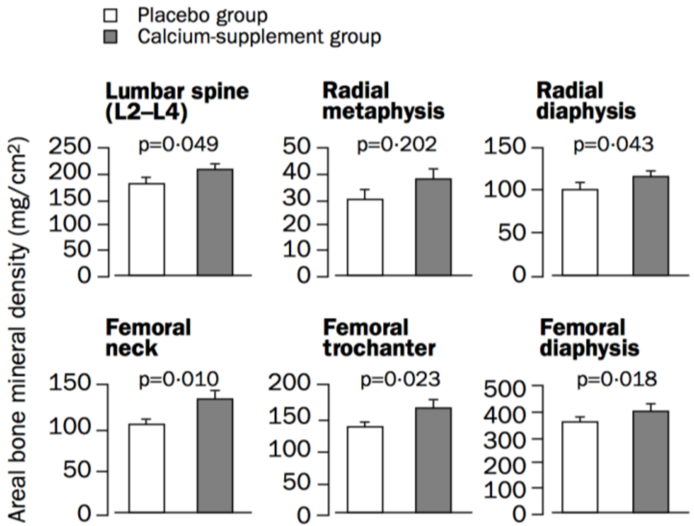
# Bone health: Evidence for Matrix Effects

- Follow up study of bone mineral mass in 8y girls [(4)]
- Supplemented with dairy-derived calcium phosphate, or placebo, for n=48 weeks

| | Placebo group (n=54) | Calcium-supplemented group (n=62) |
|---|---|---|
| Age (years) | 8·0 (0·1) | 7·9 (0·1) |
| Height (cm) | 127·4 (0·7) | 128·1 (0·8) |
| Weight (kg) | 26·6 (0·6) | 26·3 (0·5) |
| Body-mass index (kg/m²) | 16·3 (0·3) | 15·9 (0·2) |
| Bone-mineral density (mg/cm²) | | |
| Radial metaphysis | 301 (4) | 293 (3) |
| Radial diaphysis | 431 (4) | 437 (4) |
| Femoral neck | 622 (10) | 640 (10) |
| Femoral trochanter | 497 (8) | 508 (7) |
| Femoral diaphysis | 1026 (11) | 1028 (11) |
| Lumbar spine | 618 (7) | 619 (9) |

All values are mean (SD).




- Increases in BMM maintained for 3 years post-intervention

[4.] Bonjour *et al* (2001) The Lancet 358, 1208-12

# Bone health: Evidence for Matrix Effects

Dairy foods: greater effects than equivalent Ca supplements:

- An intervention using **cheese** to supplement Ca observed a greater increase in BMD vs Ca alone, or Ca + Vit D (as supplements) [5]

- When supplemented with 700mg Ca via dairy foods, BMD increased by up to 10%, vs 1-5% with 700 mg given as non-dairy supplement [6]

✧**Protein may enhance Ca balance by promoting absorption**
✧**Casein phosphatides and / or lactose may enhance Ca absorption**
✧**Fermented dairy may further enhance Ca absorption**

[5] Kerstetter *et al* (1995) Nutr Res Rev 328-332
[6] Cheng *et al* (2005) AJCN 82:1115-1126

Osteoporos Int. 2017 Oct 27. doi: 10.1007/s00198-017-4285-8. [Epub ahead of print]

# Milk and other dairy foods and risk of hip fracture in men and women.

Feskanich D[1], Meyer HE[2,3], Fung TT[4], Bischoff-Ferrari HA[5], Willett WC[6,7].

Author information

## Abstract

The role of dairy foods for hip fracture prevention remains controversial. In this study, among US men and women, a glass of milk per day was associated with an 8% lower risk of hip fracture. This contrasts with a reported increased risk with higher milk intake in Swedish women.

**INTRODUCTION:** The purpose of this study was to examine whether higher milk and dairy food consumption are associated with risk of hip fracture in older adults following a report of an increased risk for milk in Swedish women.

**METHODS:** In two US cohorts, 80,600 postmenopausal women and 43,306 men over 50 years of age were followed for up to 32 years. Cox proportional hazards models were used to calculate the relative risks (RR) of hip fracture per daily serving of milk (240 mL) and other dairy foods that were assessed every 4 years, controlling for other dietary intakes, BMI, height, smoking, activity, medications, and disease diagnoses.

**RESULTS:** Two thousand one hundred thirty-eight incident hip fractures were identified in women and 694 in men. Each serving of milk per day was associated with a significant 8% lower risk of hip fracture in men and women combined (RR = 0.92, 95% confidence interval (CI) 0.87 to 0.97). A suggestive inverse association was found for cheese in women only (RR = 0.91, CI 0.81 to 1.02). Yogurt consumption was low and not associated with risk. Total dairy food intake, of which milk contributed about half, was associated with a significant 6% lower risk of hip fracture per daily serving in men and women (RR = 0.94, CI 0.90 to 0.98). Calcium, vitamin D, and protein from non-dairy sources did not modify the association between milk and hip fracture, nor was it explained by contributions of these nutrients from milk.

**CONCLUSIONS:** In this group of older US adults, higher milk consumption was associated with a lower risk of hip fracture.

# Muscle : Evidence for Matrix Effects

- Performance nutrition: Recovery after exercise
- Healthy Ageing: Maintenance of Muscle Mass

## Ideal Rehydration Fluid:

- Na
- K
- Slow gastric emptying

## Muscle Recovery & Repair:

- High quality protein
- Essential AA's
- BCAAs
- Skeletal AA uptake

**Glycogen Re-synthesis**

# Muscle : Evidence for Matrix Effects

- Healthy Ageing: Maintenance of Muscle Mass

**Sarcopenia: Age-related loss of muscle mass**

✧ Higher protein intakes to stimulate MPS
✧ Protein quality – Leucine is key – Whey protein a good source
✧ Studies suggest greater effects of dairy (Whey) protein than EAAs alone [7,8]

- Studies also suggest **25-30g protein**, **at each meal,** is optimal for prevention [9]
- Evidence for matrix effects – further research needed on different dairy products

[7]Phillips et al., (2009) Am J Coll Nutr 28:343-354
[8]Katsanos et al (2008) Nutr Res 28: 651-658
[9]Paddon-Jones & Ramussen (2009) Curr Opin Nutr Metab Care, 12: 86-90

# 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 : [10]

| | 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 |
| MD dairy servings | 0·97 | 0·6 | 1·8 | 0·6 | 3·3 | 1·2 | <0·01 |
| Demographic information | | | | | | | |
| Age (years) | 43·3 | 16·9 | 45·1 | 17·1 | 45·1 | 17·1 | 0·12 |
| BMI (kg/m$^2$)‡ | 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 |

[10] Feeney *et al* (2016) BJN

(Milk, cheese, yoghurt, cream, butter)

# Body Fat: Evidence for Matrix Effects

**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 | $51.6 \pm 0.6$ | 440 | $51.4 \pm 0.6$ | 435 | $50.4 \pm 0.4$ | 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** |

(All dairy, from all foods and recipes)

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

- [11] 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 [12]

- Evidence is mixed regarding whether casein or whey is more beneficial, either for weight loss or body composition [13, 14]


- [12] Fresdedt *et al* (2008) *Nutr Metab (5): 1-8*
- [13] Lacroix *et al* (2006) Am J Clin Nutr. 84 (5): 1070-1079
- [14] 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

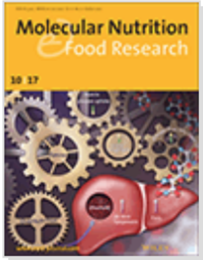
Tingting Geng, Lu Qi, Tao Huang

**Accepted manuscript online:** 23 October 2017 Full publication history

**DOI:** 10.1002/mnfr.201700410 View/save citation







## 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.

# Moving towards Patterns of intake:

## Tertiles vs Patterns:

**Cluster 1**
Full fat Milk


**Cluster 3**
Butter and
Cream

**Cluster 2**
Low fat milk, yoghurt


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

# Dietary patterns of dairy:

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**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] ± 14.0 | 25.7[b] ± 11. 0 | 32.2[a] ± 11.8 | < **0.001** |
| Mean daily total fat per g | 80.6[a] ± 31.4 | 67.5[b] ± 26.0 | 80.7[a] ± 26.8 | < **0.001** |
| % energy MUFA | 12.7[a] ± 2.7 | 11.7[b] ± 2.7 | 12.6[a] ± 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] ± 3.5 | 12.2[b] ± 3.5 | 14.0[a] ± 3.3 | < **0.001** |
| % Energy fat | 34.7[a] ± 6.3 | 32.0[b] ± 6.6 | 34.9[a] ± 6.2 | < **0.001** |
| % Energy protein | 16.4[a] ± 3.4 | 17.8[b] ± 3.7 | 16.5[a] ± 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] ± 2.9 | 7.9[b] ± 2.6 | 8.8[a] ± 2.6 | < **0.001** |
| Male:female ratio | 58:42 | 41:59 | 46:54 | < **0.001** |
| Total milk per mL | 26.7[a] ± 21.5 | 33.4[b] ± 21.8 | 23.9[a] ± 16.4 | < **0.001** |

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

# Dietary patterns of dairy:

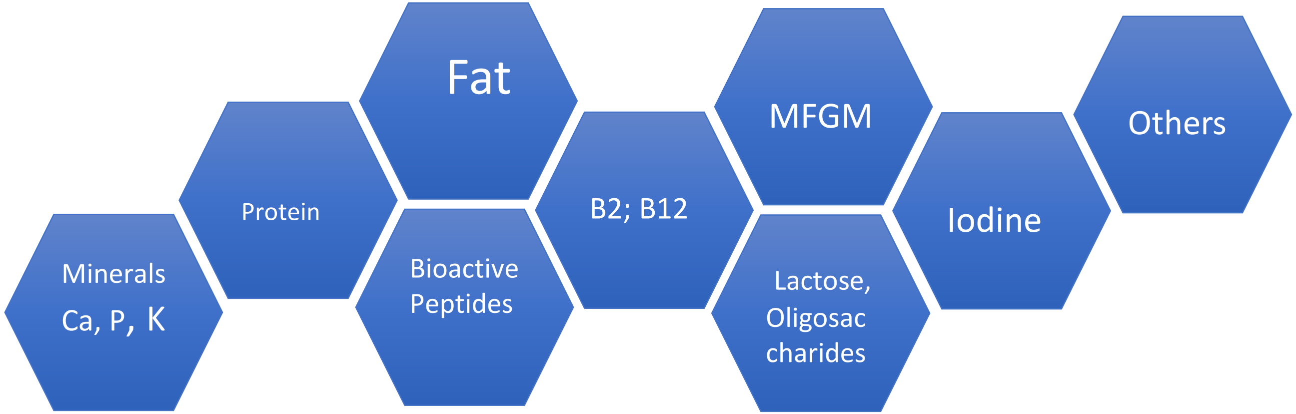
**Table 3.** Markers of metabolic health across clusters of dairy consumption

| *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

# ‘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




The dairy matrix: a new approach to understanding the health effects of food – November 2017

# Overview

- What is the 'Dairy Matrix'?
- Human nutrition - Moving beyond single nutrients
- Effects of dairy matrices on body composition:
  - **Muscle**
  - **Bones**
  - **Body fat**
- Cheese – a 'matrix' example

# Cheese & 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 |

# Cheese & 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. |

**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

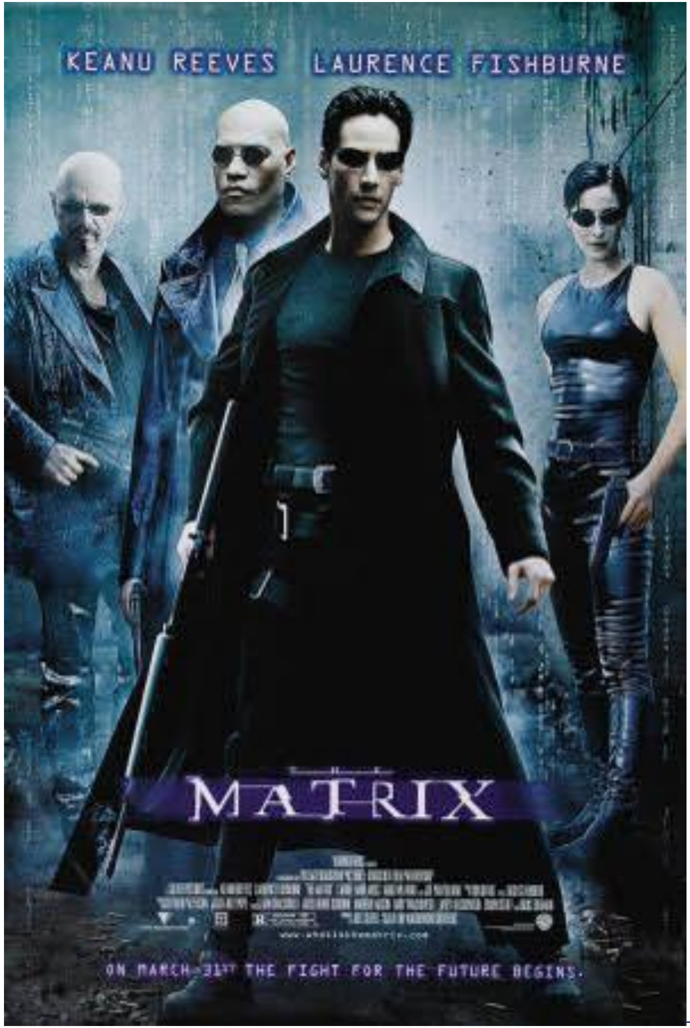
- Tests the hypothesis that fat needs to be **within the cheese matrix** to see effects

**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**




# Summary

**The Dairy Matrix** – the sum of the nutrients and food structure

- Dairy products are not all the same
- Evidence for matrix effects on body composition
- Matrix effect of cheese: fat & cholesterol metabolism

## Future: foods, patterns, and synergies?