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This review explains the concept of a food matrix in context of dairy and summarises current evidence investigating the association between different dairy products and health endpoints.

A publication for health professionals

Dairy
The matrix matters

The dairy matrix – the sum of the nutrients and other components within the physico-chemical structure of a dairy product – is important for health and nutrition.

The critical role of the nutrients in dairy is undisputed. In low- and middle-income countries, such as South Africa, dairy can furthermore provide the gap nutrients known to be deficient or marginal in the diets of the majority of citizens. In the context of non-communicable, chronic diseases, which now affect industrialised societies and emerging economies alike, the dairy components of primary interest are fat, protein (whey and casein), minerals (calcium, magnesium and phosphate), sodium, and parts of the milk fat globule membrane (MFGM).[1]

Diets, however, do not consist of nutrients and food components in isolation: people consume whole foods. Consequently, many countries have adopted food-based dietary guidelines, such as the the dairy-related guideline for South Africa: 'Have milk, *maas* or yoghurt every day'.[2]

It is often assumed that the various dairy products in this food group have comparable compositions, but Table 1 shows that there are major differences between products. As the compositions and structures of different dairy products differ, these products may have different effects on health. The aim of this review is to explain the concept of the food matrix in context of dairy and to summarise current evidence investigating the association between different dairy products and health endpoints.

The food matrix of dairy explained

Foods contain nutrients and other components in a complex structure. The combination of these constituent elements and the physico-chemical nature of the food structure is called the food matrix.[1,3,4] The food matrix is not a static property, and processing can significantly alter it. In the case of dairy products, processes such as fractionation, crystallisation, concentration, separation, heating and dehydration can lead to different product structures (e.g. emulsions, gels, foams, suspensions, heterodisperse systems). This may be achieved through various techniques, including thermal processing, ultra-high pressure, enzyme or membrane technologies, all of which could affect the functional properties of the product, including the relation with health and nutrition.[4]

Digestibility

The matrix of a food affects its digestibility. The macro-nutrients (i.e. fats, carbohydrates and proteins) in food have to be hydrolysed before they can be absorbed. According to Capuano et al.,[3] three specific factors regulate the digestion of macronutrients, namely:

- structural barriers to the action of digestive enzymes; these barriers can either be present naturally or occur as a result of processing
- the structural organisation of macronutrients in a food (i.e. the size and shape of food globules and the physical form of the food)
- dietary components that are present in the gastrointestinal tract.

The food matrix is of prime importance in the digestion of plant foods. The role of cell walls in plant foods – loosely termed dietary fibre – in delaying the digestion of foods is well documented. In this regard, investigations may focus on specific foods, such as nuts or seeds (e.g. almonds), cereals (e.g. oats), legumes or tubers.[3,5] Alternatively, the emphasis may be on the digestion of a particular macronutrient, such as fats[5] or starch.[6]

The link between the food matrix and digestion of animal-derived foods is not as well studied (and probably of lesser importance), but it is an emerging field of investigation. The importance of the MFGM has been highlighted in this regard.[1] In respect of dairy products and lipid digestion, research has shown that in cheese, caseins form a coagulum that encapsulates fat globules, thereby affecting fat digestibility. Further research suggested that the fat in cheese was less accessible to lipase than that in butter, based on the higher faecal fat content found after digestion.[3] However, increased fat excretion may also be related to the presence of calcium in the gut, which could precipitate free fatty acids as insoluble, indigestible calcium soaps.[3] In contrast, milk homogenisation may improve lipid digestibility by reducing the size of lipid globules and so increasing the total surface area available for pancreatic lipase action.[3]

Lamothe et al.[7] compared the digestion kinetics of milks, yoghurts and cheeses in a simulated gastrointestinal environment. Results showed that technological processes had differential effects on the products' matrices, which, in turn, influenced nutrient release.

Other physiological effects

Dairy products may affect health also through their biologically active components, including immunoglobulins, whey proteins and peptides, polar lipids and lactic acid bacteria. The physico-chemical structure of a dairy product affects optimal delivery of these components. In this respect, the interactions between lactic acid bacteria and dairy molecules have been highlighted.[8] Another consideration refers to the influence of prebiotic substrates used in the production of fermented dairy beverages on the viability of the probiotics *Lactobacillus acidophilus* and *Bifidobacterium lactis* in these drinks.[9] The possibility that the food matrix is related to allergenicity has also been raised.[10]

Dairy products and disease risk

In real life, the health effects of dairy products are of interest to health professionals and the consumer.

Table 2 summarises findings regarding the role of dairy products in the development of disease. Current observational evidence (as integrated by meta-analyses) does not support a positive association between the intake of dairy products and cardiovascular risk and type 2 diabetes; in fact, fermented dairy products tend to point to an inverse relationship. Metabolic effects of whole dairy (with reference to body weight, cardiometabolic disease and bone health) are different from those attributed to single nutrients. Different dairy products are distinctly linked to health effects, and this may be associated with different processing methods.

Numerous mechanisms for the differential effects of dairy products have been proposed, including:

- dairy components (e.g. MFGM) or calcium and phosphate reducing fat digestibility
- MFGM reducing cholesterol absorption
- an association between fat digestibility and blood lipid respons
- reregulation of the blood lipid response by MFGM, milk phospholipids or dairy matrix fermentation.[1]

In addition, the physical structures and textures of the various dairy products mentioned in Table 1 could affect digestion and absorption, appetite sensations and protein metabolism. Examples include the semisolid (gel) vs fluid or solid states, the intermediate metabolites (e.g. bioactive peptides) and different processing methods that affect the micro- and macro- structure of the dairy matrix.

Concluding remarks and future outlook

Despite considerable knowledge gaps in the current understanding of the health effects of the dairy matrix, nutritionists agree that milk, yoghurt, cheese, butter and cream each is unique (in more ways than their fat content) and should be studied accordingly.

The role of dairy in health and nutrition extends beyond its nutrient content. The biofunctionality refers to the sum of nutrients and other components within the particular matrix. This knowledge adds to our current understanding of dairy–disease relationships, explains some contradictory findings in earlier research, and suggests new opportunities of personalised integration of dairy products into the lifestyles of individuals. At the same time, the strong international drive towards dietary patterns attempts to elucidate the link between diet and disease further. Complexity replaces reductionist simplicity: from nutrients to whole foods and their unique matrices to dietary patterns.

Table 1

Comparison of different dairy products (adapted from Kongerslev Thorning et al.[1])

Dairy product	Calcium (mg/100 g)	MFGM (mg/100 g)	Amount of protein (g/100 g); type	Fermented product?	Fat structure	Protein network
Milk, skimmed	124	15	3.5; whey/casein	No	Tiny native MFGs or potential MFGM	Liquid
Milk, (3.5% fat)	116	35	3.4; whey/casein	No	Native MFGs, homogenised milk fat droplets or potential MFGM	Liquid
Yoghurt, (1.5% fat)	136	15	4.1; whey/casein	Yes	MFGs, aggregates or free fat	Gel/ viscoelastic
Cheese (25% fat)	659	150	23.2; casein	Yes	Native MFGs, homogenised milk fat droplets or potential MFGM	Solid/ viscoelastic
Cream (38% fat)	67	200	2; –	No	Native MFGs, homogenised milk fat droplets or potential MFGM	Liquid
Butter	15	–	<1; –	Yes/No	Continuous fat phase (water in oil emulsion) or MFGM traces	–

MFGs = milk fat globule; MFGM = milk fat globule membrane

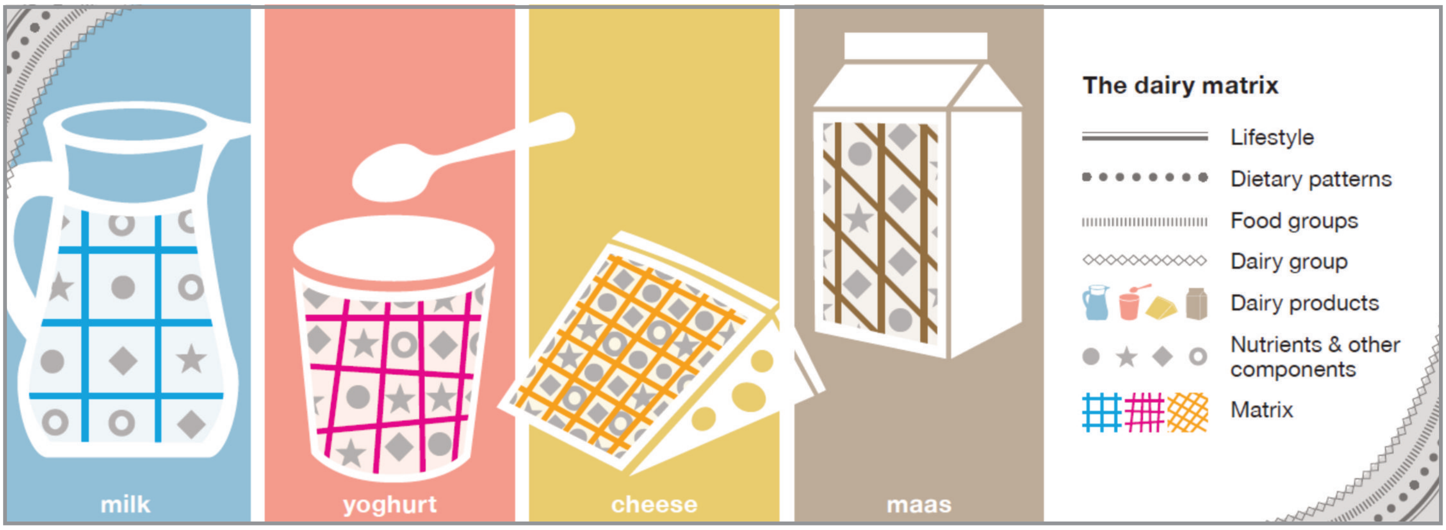
Table 2:
Summary of findings from studies investigating the health effects of dairy products (primarily extracted from Kongerslev Thorning et al.[1])

Type of study	Disease endpoint	Main findings
Meta-analyses of observational studies	**Stroke risk**	• Total dairy intake: Not associated • Specific products: ◦ Total milk: A 7% lower risk per 200 g increment in daily intake (*RR*: 93; 95% CI: 0.88–0.98; $p = 0.004$) ◦ High-fat (but not low-fat) milk: Direct association ◦ Cheese: Marginally inverse association per 40 g intake per day (*RR*: 0.97; 95% CI: 0.94–1.01). ◦ Yoghurt: No association ◦ Combined intake of $\geqslant 2$ dairy products: A 9% lower risk per 200 g intake per day (*RR*: 91; 95% CI: 0.83–1.01).
	Hypertension	• Total dairy, low-fat dairy and milk: Linear inverse association • Specific products: ◦ Low-fat dairy: A 4% lower risk per 200 g intake per day: (*RR*: 0.96; 95% CI: 0.93–0.99). ◦ High-fat dairy, fermented dairy, yoghurt: No association
	Type 2 diabetes mellitus	• Total dairy intake: Inverse relationship per 200 g increment in daily intake (*RR*: 0.97; 95% CI: 0.95–1.00) • Specific products: ◦ Yoghurt: For 80 g vs 0 g/day: *RR*: 0.86; 95% CI: 0.83–0.90 ◦ Cheese, cream, total milk, low-fat milk, high-fat milk, total high-fat dairy: No association
Intervention studies comparing dairy products with dairy components	**Body weight and body composition**	• Cow's milk vs control vs soy milk fortified with calcium vs calcium carbonate supplement: Weight loss of 5.8%, 4.3%, 3.8% and 4.8%, respectively; result suggests an effect of the dairy matrix due to its calcium and protein components. • Skimmed cow's milk vs casein vs whey protein compared with water: Skimmed milk and milk proteins increased leptin levels and lean muscle and fat mass, suggesting an effect of dairy protein rather than of the matrix.
	Cardiovascular risk	• Calcium from milk and low-fat yoghurt attenuated postprandial lipaemia, in contrast to the effect of a calcium carbonate supplement. • Calcium supplement (500 mg) vs meal with supplement vs dairy product meal vs calcium-fortified juice: Largest delay in serum calcium elevation in dairy product meal. • 30 g Grana Padano cheese per day vs placebo (i.e. flavoured bread mixed with fats and salts of chemically equivalent composition): Cheese resulted in a significant reduction in systolic and diastolic blood pressure.
	Bone health	• Calcium supplement vs calcium plus vitamin D vs cheese: Cheese was associated with a higher percentage change in cortical thickness of the tibia after 2 years in 10–12-year-old girls. • Dairy products vs calcium supplement vs control: After 12 months, dairy consumers had the greatest improvement in pelvis and spine density and total bone mineral density.
Interventions controlling for within-product differences	**Blood lipids**	• Cheese, milk and butter in whole diets, rendered 'equivalent' through the addition of fat, protein (casein and whey) and lactose: No difference between cheese and milk with regard to the effect on blood lipids, yet butter still increased LDL cholesterol. Thus, protein and lactose do not explain the differential effect of cheese and butter on blood lipid levels. • Meals including 45 g sour cream, whipped cream, butter or cheese resulted in different postprandial effects on serum triglycerides, HDL cholesterol and insulin activity in healthy adults.[4]
Interventions with full-diet designs	**Blood lipids**	• Cheese vs butter: Fat delivered in isolation (butter) has a different effect from fat delivered in a cheese matrix. • Cheese vs full-fat yoghurt: No difference • Buttermilk (rich in MFGM) vs skimmed milk with the same amount of fat vs butter: Buttermilk and skimmed milk showed similar effects, but butter increased total cholesterol.

RR = relative risk; CI = confidence interval; LDL = low-density lipoprotein; HDL = high-density lipoprotein; MFGM = milk fat globule membrane

Complexity replaces simplicity:

Exploring the path from nutrient to whole food and from the dairy matrix to dietary patterns in a particular lifestyle



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