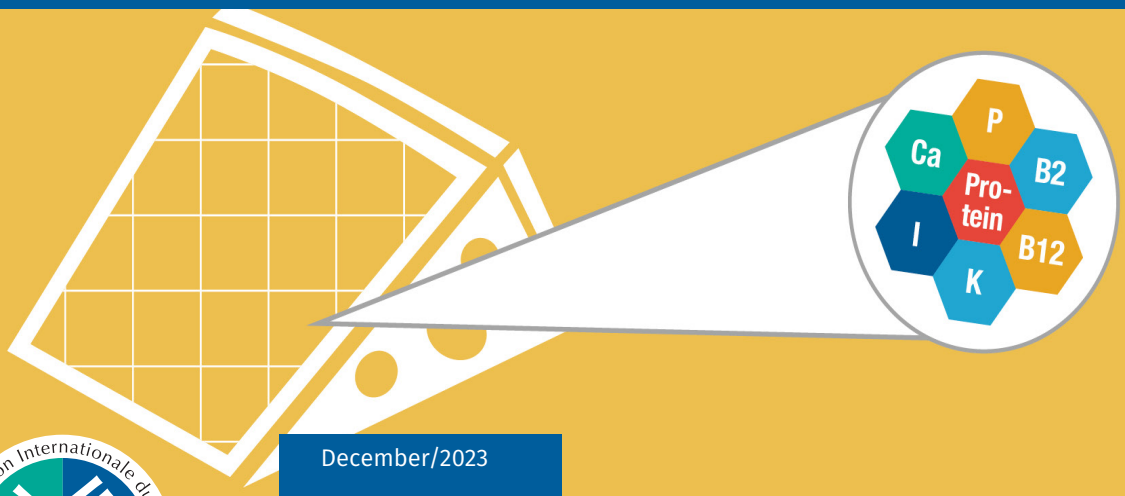

December/2023

Dairy matrix: The case of cheese

Scientific excellence
Industry applicability
Strategic networking
Global influence

Highlights

- The cheese matrix describes the unique structure of cheese, its components, and how they interact, and how this impacts potential health effects upon consumption.
- Despite its saturated fat and sodium content, cheese has unexpectedly shown neutral to beneficial effects on cardiometabolic health outcomes.
- Cheese, despite its sodium content, has been shown to protect blood vessel functioning and has been associated with positive benefits on blood pressure.
- As national dietary guidelines evolve, the focus shifts from recommending food intake solely based on the predicted effects of isolated nutrients to a more holistic approach.

Factsheet series summary

Nowadays, nutrition research focuses on the holistic impact of whole foods on health. This entails the recognition that a food's impact is shaped by the interaction of its components and structure, going beyond the sum of its individual nutrients (i.e., food matrix effect). This factsheet series delves into the emerging body of research on the dairy matrix, reshaping current nutritional and health perspectives. Dairy foods have different matrices that result in distinct matrix effects.

What is the cheese matrix?

The cheese matrix describes the unique structure of cheese, its nutrient and non-nutrient components, and how they interact (Feeney et al., 2021; International Dairy Federation, 2023). The high-quality proteins in cheese form solid networks, while fats, minerals (e.g., calcium, phosphorous, magnesium), vitamins, bacteria and peptides are interspersed. The milk lipids are part of the milk fat globules that are surrounded by a trilayer structure, i.e., the milk fat globule membrane (MFGM), which contains many bioactive components (Lopez et al., 2015). How these elements interact shapes cheese's structure, influenced by factors like the cheese-making process (Fox et al., 1996). Therefore, different cheeses have distinct structural organizations and textures.

During cheese-making, most of the lactose from milk is converted into lactic acid by lactic acid bacteria, which makes ripened cheeses low or free of lactose (Gille et al. 2018). In addition, the content of other nutrients such as calcium depends on the milk coagulation process during cheese-making (Lucey & Fox, 1993).

Therefore, several factors affect the cheese matrix of different cheese varieties which in turn significantly impacts nutrient digestion, absorption, and potential health effects of consuming cheese.

Cheese matrix health effects

Cheese has historically had a negative reputation due to its high content of fat, - especially saturated fat - and sodium. Thus, cheese consumption has been negatively portrayed in terms of cardiometabolic risk. However, consistent research, involving extensive large-scale prospective/observational studies and comprehensive meta-analyses, is questioning the conventional belief that full-fat dairy products, including cheese, have negative health implications. Contrary to expectations, evidence suggests that cheese has either neutral or may even safeguard against cardiometabolic health and related risk factors.

Cardiometabolic health

The latest scientific evidence based on systematic reviews and meta-analyses of prospective cohort studies shows neutral or beneficial associations between cheese and cardiovascular (CV) and metabolic health outcomes (see Table 1) (Chen et al., 2021; Feng et al., 2022; Jakobsen et al., 2021; Soedamah-Muthu & De Goede, 2018). These findings were confirmed by a recent umbrella review and updated meta-analysis of prospective studies (Zhang et al., 2023). The authors found that cheese consumption was inversely associated with all-cause mortality, CV mortality, incident CV disease, coronary heart disease (CHD) and stroke with moderate quality of evidence.

Randomised controlled trials consistently show that consuming the same levels of saturated fat in the form of cheese, compared to butter, has positive effects on blood lipids, and generally reduces low-density lipoprotein (LDL) cholesterol (de Goede et al., 2015; Hjerpsted et al., 2011; Tholstrup et al., 2004). This effect was determined to be caused more likely by the cheese matrix rather than individual nutrients (calcium, casein proteins) in a randomized controlled study conducted over a span of 6 weeks with a group of overweight men and women (Feeney et al., 2018). The dairy fat was consumed in three different formats: (1) as full-fat cheddar cheese, (2) as a combination of reduced-fat cheddar cheese and butter, and (3) as a mixture of calcium caseinate powder, butter, and a calcium supplement. After the intervention, a stepwise reduction in total cholesterol and LDL cholesterol was observed in a matrix-dependent fashion, with the highest reduction observed when participants consumed full-fat cheddar cheese.

Cheese consumption may also be associated with a lower risk of prediabetes (Slurink et al., 2023) and protection against type 2 diabetes (T2D) (Mozaffarian, 2019). A large meta-analysis that pooled the findings from 16 prospective cohort studies on adults found that higher levels of dairy fatty acids biomarkers (15:0, 17:0, and t16:1n-7), which are a proxy for consumption of dairy fat, were associated with a lower risk of T2D (Imamura et al., 2018).

In general, a high sodium intake is associated with impairments in vascular function, including endothelial-dependent dilation (EDD). Nevertheless, results from epidemiological studies suggest the benefits of cheese consumption in reducing blood pressure risk (Giosuè et al., 2022). Recently, a randomized clinical trial that tested EDD in the following treatments: 1) low sodium (1500 mg/day) and no dairy; 2) low sodium and high cheese (170 g/day); 3) high sodium (5500 mg/day) and no dairy; or 4) high sodium and high cheese (Alba et al., 2020).

The authors showed that cheese, even in a high sodium diet, helps to preserve EDD by decreasing superoxide radical stress in vessels by providing potentially bioactive components with antioxidant properties. Similarly, another clinical trial found cheese consumption to be protective against sodium-induced impairments in vascular function (Stanhewicz et al., 2016).

There are many possible mechanisms whereby the biological effects of cheese differ from what may be expected based on its saturated fat and sodium content (Torres-Gonzalez & Rice Bradley, 2023). These include reduced fat digestion due to the physical structure of cheese (e.g. hardness, cohesiveness of the cheese that may impact fat digestion); the presence of calcium and fatty acids which form insoluble soaps that enhance fecal fat excretion; polar lipids in the MFGM which may impact postprandial blood lipid levels; and the presence of lactic acid bacteria and other bioactives that may further contribute to the cardiometabolic protective nature of cheese (Timon et al., 2020).

Table 1. Cheese consumption and cardiometabolic health outcomes in dose-response meta-analysis of cohort studies.

Study	Stroke	Type 2 Diabetes	Coronary heart disease	Hypertension	Overweight or obesity
(Zhang et al., 2023)	Beneficial	Neutral	Beneficial	Neutral	
Feng et al. (2022)		Neutral		Neutral	Neutral
Chen et al. (2021)	Neutral		Neutral	Neutral	
Jakobsen et al. (2021)	Neutral		Beneficial		
Soedamah-Muthu and De Goede (2018)	Neutral	Neutral	Neutral		

Beneficial refers to a statistically significant reduced risk. Neutral refers to no statistically significant effect – neither beneficial nor harmful. Grey cells indicate the parameter was not assessed.

Bone and musculoskeletal health

Several studies have shown that cheese consumption is important for bone health (Geiker et al., 2020) but also prevention of osteoarthritis (Denissen et al., 2019), and hip strength (reduced fracture risk) (Feskanich et al., 2018). Bian et al. (2018) showed that consumption of fermented products, including cheese, but not total dairy and cream, is associated with lower risk of hip fracture in cohort studies. Fermented dairy products are often reported to enhance absorption of nutrients with demonstrated bone health benefits (Biver et al., 2018). This might be due to the bacterial content of some cheese and their beneficial effect on the gut microbiome and intestinal inflammation, which results in inhibition of bone resorption and stimulation of bone formation (Geiker et al., 2020). Also, vitamin K_2, present in some cheese varieties, has been associated with health benefits (Lundberg et al., 2022). However, Hidayat et al. (2020) showed a lower risk of hip fracture with higher consumption of yoghurt but not with cheese. The authors suggested that the bone health effects may differ according to the type of cheese. Indeed, fresh cheese, "petit-suisse" cheese and quark showed better efficacy in reducing the risk of bone loss compared to ripened cheese (Biver et al., 2018).

A recent study showed that consumption of cheddar cheese leads to a slower but more sustained appearance of branched-chain amino acids in circulation over the postprandial period, peaking at ~120 min, yet with a lower glycemic profile, compared to an isonitrogenous amount of milk. Both milk and cheese stimulated a muscle anabolic program associated with mTORC1 signalling that was

more evident with milk, but more persistent with cheese (de Hart et al., 2021).

Other health effects

Cheese consumption has not been associated with an increased risk for colorectal cancer development (Alegria-Lertxundi et al., 2022; Barrubés et al., 2018; Jin et al., 2020).

Furthermore, cheese consumption has been associated with beneficial dental health (Shkembi & Huppertz, 2023). Stimulation of salivary flow, and the subsequent buffering effect of salivary compounds thereby neutralizing plaque acids, is one of the proposed mechanisms. The inhibition of plaque bacteria reducing bacterial load and thereby reducing acid production is another. Finally, cheese releases high amounts of calcium and inorganic phosphate into dental plaque, which reduces demineralisation and stimulates remineralization. All these mechanisms may contribute to dental health and are an illustration of the versatility of the cheese matrix.

Conclusions

Cheese is the best case proving that health effects go beyond nutrients. Its consumption, despite of the saturated fat and sodium content, is not associated with the common belief that it negatively impacts human health. The growing body of scientific evidence on the neutral or beneficial effects of cheese and the potential role of its complex matrix supports the inclusion of cheese as a relevant nutrient-provider in healthy dietary patterns. This is particularly significant as national dietary guidelines shift from recommending food intake solely based on the predicted effects of isolated nutrients, whether beneficial (e.g., calcium, protein) or potentially harmful (e.g., saturated fats, sodium).

Acknowledgments

This factsheet was prepared under the leadership of members of the IDF Standing Committee on Nutrition and Health.

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