Abstract

Dietary recommendations acknowledge the dairy contribution to a healthy diet but often stress to use the low(er) fat or skimmed versions. The main reason for this message to consumers is the relatively high amount of saturated fatty acids contained in the dairy fats and their (assumed) impact on the risk for developing cardiovascular disease. The primary goal of this paper was to review to what extent current dietary recommendations on intake of preferably low-fat or even skimmed dairy alternatives are justified. It is concluded that different types of dairy products have different effects on risk markers of cardiovascular disease. The message that all saturated fatty acids in all dairy products are bad is an oversimplification lacking appropriate scientific evidence. Further research into the significance of the antihypertensive effect of milk, calcium and dairy proteins seems warranted.

1. Introduction

Traditionally, cows' milk has been considered as a basic food in many diets. Milk is considered as a healthful beverage and consumption of dairy products is associated with overall diet quality. Milk provides an easily accessible matrix, rich in a large variety of essential nutrients like minerals, vitamins and easy digestible proteins with balanced amino acid profiles, and is therefore important to support overall body function. Together with grains, meats, vegetables and fruits, dairy products are considered as nutrient-dense foods, i.e.,

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delivering many nutrients with relatively low energy content, and relevant to health throughout the life cycle (Drewnowski, 2005; Miller, Jarvis, & McBean, 2007). Consumption of dairy products is also associated with beneficial health effects beyond pure nutritional value.

Due to this healthy perception, dairy products have also served as vehicles for functional food ingredients over the last 10 years, such as phytosterols, fish fatty acids and various kinds of probiotic bacteria. Furthermore, dairy has been a rich source for the development of a large variety of health promoting innovative ingredients that found their way to the markets for functional foods and dietary supplements (Michaelidou & Steijns, 2006; Schaafsma & Steijns, 2000; Steijns, 2001a, 2003; Steijns & van Hooydonk, 2000). Finally, the dairy proteins are the preferred choice in special nutrition formulas for (re)building tissues and muscle mass in infants, hospitalized individuals, performance athletes, dieters and the elderly (Steijns, 2001b). Today, dietary recommendations acknowledge the dairy contribution to a healthy diet, yet it is often stressed to preferentially use the low(er) fat or skimmed versions. The main reason for this consumer message is the relatively high amount of saturated fatty acids contained in the dairy fats and their (assumed) impact on the risk for developing chronic diseases (Joint FAO/WHO Expert Consultation, 2003).

This paper will review to what extent this is justified in view of recommended and actual intakes of dairy products and whether the matrix in which the saturated fats are contained may influence health outcomes. A similar review will be given for the ruminant trans fatty acids, which are heavily debated in relation to the reported detrimental health effects of trans fatty acids originating from partially hydrogenated vegetable oils. Finally, the impact of the saturated fatty acids/trans fatty acids in dairy products on disease risk will be viewed in the perspective of total dietary intake.

2. Nutrient density of dairy products

The growing concerns on unhealthy eating patterns in relation to increasing rates of overweight/obesity has led to a variety of approaches to characterize the more healthy and nutritious foods. The terms energy-dense and nutrient-poor are commonly used in this respect. Drewnowski (2005) has reviewed a number of these approaches and discussed their relative merits. The ratio of the nutrient composition of a food to the nutrient requirement in humans is called nutrient density. Calories are considered as the most appropriate denominator to compare the nutritional values of various foods, rather than e.g., portion sizes or servings. Drewnowski (2005) has introduced the concept of a naturally nutrient rich score (NNR) based on averaging the percentage contribution of 14 or 16 selected nutrients to the recommended daily values for 2000 kcal of food. The concept allows comparison of NNR scores within and between food categories and provides a tool to address the concerns of increased intakes of low-cost energy-dense foods in the perspective of the global rise of the incidence of overweight/obesity and the associated risk for development of chronic diseases. Table 1 shows the NNR values for a number of common dairy products using the 14 selected key nutrients listed by Drewnowski (2005): protein, the vitamins A, D, E, C, B1, B2, B11 and B12, the minerals calcium, zinc, iron and potassium, and mono-unsaturated fatty acids (in a more recent version of the NNR score two extra nutrients have been added, vitamin B5 or pantothenic acid, and fibre). It is evident that calcium, protein and the vitamins B2 and B12 contribute significantly to the NNR score of milk, cheese and yoghurt, whereas butter mainly contributes via retinol equivalents and mono-unsaturated fats. The relative contributions to the NNR score of minerals like zinc and potassium or vitamins like B2 and B12 depend on either their fat solubility, their binding to the proteins and/or the energy content of the final product.

The Dutch Food Consumption Survey of 1997/1998 showed that calcium intake in the Dutch population relies for about 70% on dairy intake, whereas the dairy-bound protein, vitamin B2 and vitamin B12 provided 26%, 49% and 39%, respectively, of the intake (Dutch Nutrition Center, 1998).

Consumer awareness of dairy products being good sources of calcium for healthy and strong bones and teeth is high. The scientific substantiation for this claim shows moreover that the specific combination of calcium, phosphorous and protein, along with good availability of vitamin D, makes the dairy matrix an almost indispensable part of the diet to build and maintain strong bones (Bonjour, 2005). However, dietary calcium may be associated with other areas of health benefits than bones, such as hypertension, cancer and weight control/body composition (Huth, DiRienzo, & Miller, 2006). These aspects of calcium intake are, however, hardly known to consumers. Similarly, there is rather limited knowledge with consumers on the biological functions of proteins. Results of recent research on the (potential) role of (dairy) protein with respect to prevention of overweight and vitality when growing old may capture their interest in due time. Protein appears to fulfill an important role in mechanisms of satiety and increased thermogenesis related to weight control (Westerterp-Plantenga et al., 2006). It is still premature to conclude that different proteins may have different effects in this respect. During restricted caloric intake, diets with reduced carbohydrates and increased levels of high-quality protein, especially proteins with high leucine content, typical for milk proteins, are effective for weight loss with an apparent metabolic advantage of increased loss of body fat while reducing loss of lean tissue and stabilizing blood glucose (Layman, 2004; Schaafsma, 2006a). Whey proteins have also been implicated for improving conditions of muscle weight loss, such as sarcopenia in the elderly (Schaafsma, 2006b).
3. Saturated fats in dairy products—their impact on cardiovascular disease risk

3.1. Effects on blood lipids as surrogate marker of cardiovascular disease risk

The nutritional image of milk fat has suffered over the last 40 years from its content of saturated fatty acids increasing serum cholesterol, which is considered as a risk factor for coronary heart disease (CHD), mainly due to the pathological process of atherosclerosis in the coronary arteries. This is the basis for recommendations to decrease the intake of saturated fats. The decision to focus on the role of saturated fat in the diet and on blood lipid changes seems reasonable given the cost of cholesterol-related diseases in the population. A wealth of data is available on the topic, including animal, ecological, cross-sectional, prospective cohort and human intervention studies (Parodi, 2004; Sacks & Katan, 2002). Yet, German and Dillard (2004) have debated that the gradual but continuous efforts of the agricultural industry and food companies to further lower saturated fat should wait for clear(er) evidence to indicate which amounts and which types of fatty acids are optimal, not only from a public health perspective but also taking into account more individualized dietary recommendations. An extensive meta-analysis of dietary interventions to study the effect of fatty acids and carbohydrates on blood serum lipid changes was conducted by Mensink, Zock, Kester, and Katan (2003). This analysis comprised 60 eligible studies in the period between 1970 and 1999, whereby dietary cholesterol intake was (kept) constant, only adults were included and feeding periods were at least 14 days to allow for steady-state achievements of measured parameters. Trials with very-long-chain (omega-3) polyunsaturated and medium chain length fatty acids were not included. In total, 1672 participants from 11 countries, 70% being males, were fed test diets up to 91 days. In all trials, fatty acids were exchanged for either other fatty acids or carbohydrates; possible effects of protein and alcohol could not be estimated. For the statistical analysis, each data point consisted of the fatty acid composition of a particular diet (the independent variable) and the mean ratio of serum total to HDL cholesterol or the mean serum lipid or apolipoprotein concentration (the dependent variable) of a group of subjects, as obtained at the end of a dietary period; a total of 159 diet data points could be included. In order to reflect the beneficial effects of HDL-cholesterol, the authors consider the ratio of total to HDL-cholesterol as a better overall marker for assessing the risk of CHD than the total or lipoprotein cholesterol concentrations. In fact, their calculations show that replacing saturated fatty acids and trans fatty acids from industrial origin by cis-unsaturated fatty acids reduces risk most effectively. The meta-analysis furthermore provides evidence that isoenergetic replacement of saturated fatty acids with carbohydrates does not improve the total:HDL-cholesterol ratio, despite nutritional

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### Table 1

Naturally nutrient rich score\(^a\) according to Drewnowski (2005)

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Milk (3.5% fat)</th>
<th>Yoghurt (3.5% fat)</th>
<th>Cheese(^b)</th>
<th>Butter (82% fat)</th>
</tr>
</thead>
<tbody>
<tr>
<td>protein</td>
<td>1.66</td>
<td>2.15</td>
<td>1.96</td>
<td>1.96</td>
</tr>
<tr>
<td>vitamin a</td>
<td>0.62</td>
<td>0.40</td>
<td>0.73</td>
<td>0.60</td>
</tr>
<tr>
<td>vitamin c</td>
<td>0.82</td>
<td>1.07</td>
<td>0.97</td>
<td>0.07</td>
</tr>
<tr>
<td>calcium</td>
<td>2.84</td>
<td>3.69</td>
<td>3.36</td>
<td>3.20</td>
</tr>
<tr>
<td>iron</td>
<td>0.00</td>
<td>0.00</td>
<td>0.20</td>
<td>0.03</td>
</tr>
<tr>
<td>zinc</td>
<td>1.06</td>
<td>1.42</td>
<td>1.42</td>
<td>1.74</td>
</tr>
<tr>
<td>vitamin b1</td>
<td>0.38</td>
<td>0.50</td>
<td>0.86</td>
<td>0.13</td>
</tr>
<tr>
<td>vitamin b1</td>
<td>1.03</td>
<td>1.33</td>
<td>0.91</td>
<td>0.13</td>
</tr>
<tr>
<td>vitamin b2</td>
<td>4.02</td>
<td>5.54</td>
<td>5.03</td>
<td>0.73</td>
</tr>
<tr>
<td>vitamin b12</td>
<td>5.00</td>
<td>6.67</td>
<td>5.15</td>
<td>0.82</td>
</tr>
<tr>
<td>vitamin d</td>
<td>0.28</td>
<td>0.16</td>
<td>0.25</td>
<td>0.32</td>
</tr>
<tr>
<td>vitamin e</td>
<td>0.21</td>
<td>0.00</td>
<td>0.00</td>
<td>0.28</td>
</tr>
<tr>
<td>MUFA(^c)</td>
<td>1.38</td>
<td>0.80</td>
<td>1.09</td>
<td>1.91</td>
</tr>
<tr>
<td>K</td>
<td>1.29</td>
<td>1.71</td>
<td>1.49</td>
<td>0.12</td>
</tr>
<tr>
<td>average</td>
<td>1.47</td>
<td>1.82</td>
<td>1.67</td>
<td>0.86</td>
</tr>
</tbody>
</table>

\(^a\)The naturally nutrient rich score (NNR) was calculated for the listed foods using the daily values as presented by Drewnowski (2005). For each nutrient, the amount per 2000 kcal of food is calculated and then expressed as ratio of the recommended daily value, which is based on the dietary reference intakes. The 14 scores are then averaged and after multiplication with 100% the NNR score is obtained, e.g., for full-fat milk (3.5% fat), the NNR score will be 147. Percentages of fat are on a w/w basis.

\(^b\)Gouda type cheese.

\(^c\)MUFA: mono-unsaturated fatty acids.
recommendations in the past to do so. In fact, when predicted changes in the ratio total:HDL-cholesterol were calculated for replacement of 10 energy% in the “average US diet” with various isoenergetic fat mixtures or carbohydrates, the latter yielded the largest increase of all tested combinations.

With regard to individual saturated fatty acids contained in dairy fat, the analysis showed the following. When isoenergetically replacing 1 energy% of carbohydrates, the predicted changes in the ratio total:HDL-cholesterol or in LDL-cholesterol or in HDL-cholesterol concentrations were different when calculated for lauric acid (C12:0), myristic acid (C14:0), palmitic acid (C16:0) and stearic acid (C18:0). The C12:0, C14:0 and C16:0 fatty acids elevated LDL-cholesterol significantly, whereby the shorter chain lengths had more prominent effects. On the other hand, these fatty acids also increased HDL-cholesterol levels significantly, with C12:0 giving higher changes than C14:0 and C14:0 more than C16:0. The effect of C18:0 on both markers was neutral. When calculating the total:HDL-cholesterol, C12:0 revealed a significant lowering, C14:0 and C18:0 showed a tendency to lower the ratio and C16:0 gave an increase. Mensink (2005) has concluded that the effects of stearic acid (C18:0) on LDL-cholesterol are more comparable with the cis-monounsaturated oleic acid (C18:1). He also stated that the formulas used to calculate predicted changes are not conclusive, but should be used as a valuable indication of effects to be expected. A similar conclusion can be drawn from a dietary human intervention study where 7 energy% was provided by either stearic acid (C18:0), oleic acid (C18:1) or linoleic acid (C18:2) (Thijssen & Mensink, 2005). A possible explanation for the discrepancies found versus predictions from formulas may be the use of synthetic fats, whereby, due to interesterification, a substantial part of the fatty acids will also be bound at the sn-2 position of the glycerol backbone, in contrast to natural dairy fat where most of the C18:0 fatty acids are bound to the sn-1 and sn-3 positions (Jensen, 2002). Lingual, gastric and pancreatic lipases predominantly yield free fatty acids from the sn-1 and sn-3 positions, whereas the sn-2 fatty acid is absorbed in the 2-monoglyceride form. Free fatty acids in the intestinal lumen may, e.g., complex with dietary calcium and form soaps that disappear as faecal fat. Absorbed free fatty acids will be reassembled together with the sn-2 glycerol bound fatty acids into chylomicrons. Thus, plasma lipid profiles may be affected by triacylglyceride structure, as shown, e.g., for palmitic acid (Mensink, 2005).

Saturated fatty acids with a chain length up to 10 C-atoms are sometimes referred to as medium-chain fatty acids, but C4:0 and C6:0 may also be referred to as short-chain fatty acids. Marten, Pfeuffer, and Schrezenmeir (2006) define medium-chain triacylglycerols (MCT) as mixed triacylglycerols of saturated fatty acids with a chain length of 6–10 carbons, i.e., hexanoic acid (C6:0, common name capronic acid), octanoic acid (C8:0, common name caprylic acid) and decanoic acid (C10:0, common name capric acid). In bovine milk C6:0 to C10:0 may comprise 4–12% of the total fatty acids. More than 90% of C6:0 has been reported to be located at the sn-3 position of the glycerol backbone, whereas most of the C8:0 and C10:0 have been found on either the sn-2 or the sn-3 position (Jensen, 2002). The average intake of C4:0 to C10:0 fatty acids in the Netherlands has been estimated to be about 1.7 g per day from the 1997–1998 Dutch Food Consumption Survey (1998); the 95% percentile value was about 3.6 g. Dairy products account for most of the intake of especially C4:0 and C6:0, whereas the category fats/oils/ sauces also contributes for about 30% to C8:0 intake. Few data are available on the effects of MCT on fasting blood lipid levels using amounts that are reasonable when compared to habitual intakes. Nosaka et al. (2003) tested a margarine with 5 g MCT in a standard diet of 2200 kcal with 28 energy% of fat, and compared blood lipid results versus a diet enriched in mono- and polyunsaturated fatty acids during a 12-week intervention. Cholesterol and triglyceride levels were gradually reduced in both groups, but somewhat more in the MCT group. Thijssen (2006) calculated in her thesis the effects of C8:0 and C10:0 on the change in the ratio total:HDL-cholesterol versus 10 energy% replacement of oleic acid (C18:1), based on her own data and those taken from studies of Temme, Mensink, and Hornstra (1996, 1997). An increase of 0.2 units was found, almost comparable with the calculated effect for C16:0. Yet, dietary intake of C16:0 is 10-fold higher and 10 energy% of the 2 fatty acids will equal to about 25 g of MCT assuming 2200 kcal energy intake per day. More research in humans will be needed to verify the effects of C4:0 to C10:0, but a tentative conclusion would be that saturated fatty acids with a chain length below 10 C-atoms will not significantly contribute to blood lipid levels at actual intakes of dairy products.

3.2. How do saturated fats in dairy products influence the particle size of LDL-cholesterol?

LDL-cholesterol is heterogeneous in nature. LDL subclasses have been defined based on characteristics like buoyant density, size, charge, lipid and apolipoprotein content (Berneis & Krauss, 2002). Four subclasses have been defined, LDL-I to LDL-IV, with LDL-I having the largest particle size and LDL-IV the smallest. LDL subclasses may vary greatly among individuals and the variation is independent of total LDL-cholesterol. The peak LDL particle diameter and density are strongly related to plasma levels of very-low-density lipoprotein (VLDL) and triglycerides. The smaller particles are the more dense particles and contain more of apolipoprotein B, which is considered as a strong, independent predictor of initial and recurrent coronary events (Sacks, 2006). Small-density LDL particles are associated with reduced LDL receptor binding, greater propensity for arterial binding and entry, and faster oxidation. The majority of individuals clusters in a so-called phenotype A with
predominantly large- and medium-sized LDL particles, whereas phenotype B has higher proportions of small-dense LDL particles. There is evidence that phenotype B is influenced by genetic factors, and from short-term feeding studies (3–6 weeks), its prevalence increases when the dietary ratio of carbohydrate to fat increases (Krauss, 2005; Krauss, Blanche, Rawlings, Fernstrom, & Williams, 2006). Whether the diameter and the levels of small-dense LDL-particles predict increased cardiovascular risk is still debated.

Wolk, Vessby, Ljung, and Barrefors (1998) have proposed that average long-term ruminant fat intake can be assessed by measuring the contents of the saturated fatty acids pentadecanoic acid (C15:0) and heptadecanoic acid (C17:0) in adipose tissue. These two fatty acids are synthesized by the bacterial flora in the rumen of ruminants and cannot be synthesized in the human body. Their analysis was based on a mean daily milk fat intake of 20.0 ± 9.1 g and 3.0 ± 1.5 g fat from ruminant meat according to food records, representing 29.2 ± 8.9% and 4.6 ± 2.2% of total fat, respectively. Levels of C15:0 and C17:0 were 1.05% and 0.61% in milk fat and 0.43% and 0.83% in ruminant meat fat, respectively. In a follow-up paper, Wolk, Furuheim, and Vessby (2001) showed that when adipose tissue is available, its myristic acid (C14:0) content can also serve as a reflection of dairy intake, and furthermore that C15:0 levels in serum cholesterol esters or phospholipids may be used. Sjogren et al. (2004) used serum phospholipid analysis of C15:0 and C17:0 to investigate cross-sectionally whether dairy fat intake was associated with the predominance of small-dense LDL-cholesterol particles (subclass LDL-III) in 291 healthy 62–64-year-old men. A graded inverse association was found. Furthermore, it was found that a greater proportion of these milk fat representing fatty acids was associated with larger LDL particles (subclass LDL-II). The individuals of the lowest tertile of the LDL-III class had a 2.5% higher intake of milk fatty acids compared with the highest tertile. This difference corresponded to ~200–400 mL of pure milk (with higher or lower fat content, respectively). The authors concluded that LDL particle size distribution appears to be modified by dietary factors with an apparently beneficial effect of milk products.

4. Trans fatty acids in dairy products— their impact on cardiovascular disease risk

The global discussion on definition of trans fatty acids (tFA), needs for labelling and conclusions from scientific research lacks consensus so far on the topic whether natural trans fatty acids derived from animal products such as meats and dairy products, have a similar impact on health as those originating from industrial processing of oils (PHVO; partially hydrogenated vegetable oils) (Hunter, 2006; Huth, 2007; Kühlsten et al., 2005). Two kinds of statements are available based on scientific expert evaluations. The first one is that ruminant derived trans fatty acids should be treated differently from PHVO originated tFA. The second one highlights that there is “missing evidence” on the effect of natural tFA. In other words, there is a lack of data comparing the health effects of tFA derived from various sources under “ceteris paribus” conditions (isoenergetic diets with otherwise identical fatty acid profile). An example of the first type of statement can be found in the 2003 report of the Danish Nutrition Council (Stender & Dyerberg, 2003). The second type of statement is exemplified by the 2004 report of the European Food Safety Authority (EFSA Report, 2004). A recent review by Mozaffarian, Katan, Ascherio, Stampfer, and Willett (2006) concluded that the sum of the current evidence suggests that the public health implications of consuming trans fats from ruminant products are relatively limited, possibly due to lower levels of intake (typically less than 0.5% of total energy intake), different biologic effects (ruminant and industrial trans fats share some, but not all, isomers), or the presence of other factors in dairy and meat products that balance any effects of the small amount of trans fats they contain.

4.1. Compositional differences between tFA from PHVO and ruminants

There is overlap of tFA isomers in fats of ruminant origin (meat, dairy) or PHVO. In ruminant fat vaccenic acid (VA; C18:1, trans11 or C18:1t, n-7) typically accounts for 14–72% (average 43%; 1765 milk fat samples analysed) of all trans-18:1 isomers (Precht & Molkentin, 1995). In dairy fat, the distribution pattern of trans-C18:1 depends significantly on the feeding management, e.g., pasture versus barn feeding. The predominant C18:1,trans isomer in PHVO is elaidic acid (EA; C18:1,t, n-9), amounts of which can vary in the range of 15–46%; the C18:1,t,trans10 isomer ranks second (average 21%), and VA represents on average 13% of total tFA (De Greyt, Radany, Kellens, & Huyghebaert, 1996).

4.2. Physiological differences between VA and EA

There is evidence in cells of various origins that VA and EA are different with respect to fatty acid metabolism (Kühlsen et al., 2005; Lock, Parodi, & Bauman, 2005; Parodi, 2004). Whether this is relevant in vivo is not clear, but all effects of VA as compared to EA are considered favourable or at least neutral. A prominent characteristic of VA is its conversion to conjugated linoleic acid C18:2,cis9,trans11 (CLA; rumenic acid) in the human body, on average about 19% (Lock et al., 2005). Hypolipidaemic effects have been reported for rumenic acid, whereas the C18:2,trans10,cis12 isomer had hyperlipidaemic properties when compared to baseline after 8 weeks daily supplementation with about 2.5 g (Tricon, Burdge, Williams, Calder, & Yaqoob, 2005).
4.3. Human intervention studies

So far, one study has tried to investigate the difference between ruminant VA-enriched and PHVO EA-enriched diets under “ceteris paribus” conditions. The design of this study has been published (Chardigny et al., 2006), but the results have so far been presented only during seminars. In this so-called TRANSFACT study, the primary aim was to assess possible differential effects on plasma HDL-cholesterol concentrations. It appears that with a daily intake of 10–12 g of trans fatty acids (5–5.5 energy%) for 3 weeks HDL-C is lowered by the EA-enriched diet and not by the VA-enriched diet; however, this is seen only in women and not in men. Yet, in women, but not in men, LDL-C decreased in the group using the EA-enriched diet; a possible explanation may be the differences in the oleic acid content of the EA-enriched diet. The final publication needs to be awaited in which these differences are placed in perspective. Thus, it is likely that this study will not resolve the question whether VA and EA have differential effects on blood lipid markers for cardiovascular disease. Moreover, a possible gender issue is raised. This study shows also that it is rather difficult to perform a study under “ceteris paribus” conditions, despite the fact that four- to seven-fold C18:1, “ceteris paribus” conditions, despite the fact that four- to seven-fold C18:1, 

trans fatty acids has also been taken in another intervention study on blood lipid profiles in healthy middle-aged men (Tricon et al., 2006). This UK study investigated in a placebo-controlled cross-over design, which affects UHT milk (470–491 mL per day), butter (~16 g per day) and cheese (33–40 g per day) enriched with CLA and VA had on blood lipid markers for heart disease risk. Habitual intakes of milk, butter and cheese were 212 mL, 14 g and 28 g per day, respectively. CLA and VA intakes per day rose from 168 mg in the control to 1508 mg in the enriched product for CLA and from 312 to 4689 mg for VA. The diets were eaten during 6 weeks in randomized order with a wash-out period of 7 weeks. No significant differences were found between the diets. There were no detrimental effects of the control dairy products on the blood lipid profile, despite the fact that the subjects doubled their consumption of milk and that the milk was full fat. Whereas the total trans-18:1 isomers in the modified dairy products contributed about 2.1% of dietary energy, no significant effect was noted on blood lipid profile markers.

4.4. Dietary intake of ruminant tFA

A review of estimates of the world-wide consumption of all tFA has recently been published (Craig-Schmidt, 2006). Intake of tFA due to ruminant products, such as meat, milk and butter, is below 2 g per day in 14 European countries studied in the TRANSFAIR study (Hulshof et al., 1999). Based on data from a cross-sectional dietary survey conducted in 1995, a recent analysis from Denmark, a country with a relatively high dairy intake, showed the following results for dairy products derived intake of tFA (CLA included) within various population groups (Jakobsen et al., 2006). The 90 percentile dairy food intake in g per day were, respectively, 813, 964, 946 and 703 for the age groups (in years) 1–6, 7–14, 15–29 and 30–80; a total of 3098 males (49%) and females (51%) were included. The corresponding dairy tFA intake was 1.9, 2.1, 2.5 and 2.7 g per day, respectively. The median intake of ruminant tFA in the Danish population aged 1–80 years was estimated to be 1.7 g per day (0.9–2.7), corresponding to 0.7% of energy intake (0.5–1.0), with dairy products being the main source of ruminant tFA. Based on a whole year average, this Danish analysis calculated the total amount of ruminant tFA as 4.84 g per 100 g milk fat; the CLA content was calculated to be 0.48 g per 100 g fat; thus the ruminant tFA level without CLA was about 4.4% on fat. The above Danish analysis showed that the energy contribution of ruminant tFA (excl. CLA) corresponded to about 0.63 energy%, i.e., below the generally recommended dietary level of 1%. Assuming similar values for tFA and CLA in milk, cheese, yoghurt and butter products, a median daily intake of 1.7 g of dairy tFA corresponds to eating/drinking daily the following dairy servings: 400 mL of 1.5% fat milk, 200 g 3% fat yoghurt, 20 g Gouda cheese (31% fat) and 20 g butter (82% fat).

A meta-analysis of four prospective studies with almost 140,000 individuals calculated a 23% higher risk for incidence of CHD for 2 energy% of dietary tFA (Mozaffarian et al., 2006). On the other hand, when 1 energy% tFA replaces 1 energy% carbohydrate, the ratio total:HDL-cholesterol will increase with 0.025 unit (Mensink et al., 2003); an increase of 0.1 unit is associated with 5.3% higher cardiovascular risk. Assuming linear relationships between tFA intake and cardiovascular risk, one tends to conclude that ruminant tFA intake from actual daily dairy consumption has insignificant nutritional relevance in relation to cardiovascular disease risk. Nevertheless, further studies are needed to confirm this.

5. Do different types of dairy products have different effects on cardiovascular disease risk?

Whereas in the previous sections emphasis was mainly on estimates of cardiovascular disease risk starting from constituents contained in the dairy matrix, and moreover with focus on blood lipid profiles, this section will address possible differences between the variety of dairy products available and review other risk factors for cardiovascular disease, such as blood pressure.

An interesting overview on dairy products and cardiovascular disease, based on an analysis of observational as well as intervention studies, has been presented recently by Tholstrup (2006). According to the formulas developed by Mensink et al. (2003), butter will increase the ratio of
total: HDL-cholesterol when it replaces isoenergetically 10 energy% mixed fat in the “average” US diet. Yet, when butter and cheese are compared in intervention studies with respect to blood lipid changes at comparable saturated fat intakes, it appears that cheese provides more beneficial profiles. It should be mentioned, however, that the dairy fat intakes in these intervention studies are fairly high, e.g., 40 g (17 energy%), e.g., 120 g cheese per day for a number of weeks; Nestel, Chronopulos, & Cehun, 2005) or 20 energy% (93 g of butter; 305 g of hard cheese; Tholstrup, Hoy, Normann Andersen, Christensen, & Sandström, 2004). This raises the question to what extent normal, balanced physiology is compromised or how relative lack of other dietary fats may influence outcomes (Tholstrup et al., 2006). Nevertheless, cheese eating has so far only sparsely been related to cardiovascular disease risk; Tholstrup’s review lists a number of correlation, cross-sectional and case-control studies that are in line with this statement. The fact that cheese has not been established as a dietary risk factor for cardiovascular disease in epidemiological studies, despite its high levels of saturated fat and salt, may also be related to the presence of menaquinone vitamers (vitamin K2) that are present due to fermentation processes. The physiological function of vitamin K is to catalyse the post-translational carboxylation of certain glutamate residues in some proteins. In this process, gamma-carboxyglutamate (Gla) is formed. Hence, vitamin K-dependent proteins are also known as Gla-proteins. These proteins have a diversity of regulatory functions with respect to blood coagulation, bone turnover, vascular repair processes, prevention of vascular calcification, cell cycle regulation, cell-cell adhesion and signal transduction. The side chain, however, determines whether a species arrives in a certain tissue or cell. K2 is preferentially transported and taken up by the arterial cells, whereas K1 has a preference for the liver (Berkner, 2005; Vermeer et al., 2004). Geleijnse et al. (2004) have analysed tertiles of intake of both vitamin K1 (phyloquinone) and K2 (menaquinone) in relation to CHD mortality and aortic calcification in the prospective Rotterdam study, a cohort comprising 7983 men and women aged 55 years and over (78% of the eligible population) who live in a defined district of the city of Rotterdam in the Netherlands. The relative risk (RR) of CHD mortality was reduced in the mid (RR = 0.73) and upper (RR = 0.43) tertiles of dietary menaquinone compared to the lower tertile (RR = 1.0); RR for severe aortic calcification were 0.71 and 0.48, respectively. Phyloquinone intake was not related to any of the outcomes. The energy-adjusted intake of menaquinone for the medium tertile was defined as 21.6–32.7 μg per day, which corresponds, e.g., to 32–48 g of hard cheese (Schurgers & Vermeer, 2000).

Ecological studies have found associations between milk consumption and differences in CHD mortality (Artaud-Wild, Connor, Sexton, & Connor, 1993; Moss & Freed, 2003). However, these types of studies are subject to many potentially confounding factors. In the absence of randomized intervention trials, cohort studies yield the best evidence possible. Elwood, Pickering, Hughes, Fehily, and Ness (2004) analysed 10 such studies with almost 400,000 subjects, 8 million man-years of observation and a total of 8500 vascular disease events. Apart from one small study based on selected vegetarians, no study gave evidence of any increase in vascular risk associated with the consumption of milk. Compared with subjects who consumed little or no milk, the RRs in the subjects whose consumption of milk was high were reduced for a stroke (RR = 0.83; 0.77–0.90 for 95% CI), for a heart attack (RR = 0.87; 0.74–1.03) and for any vascular disease event (RR = 0.84; 0.78–0.90). The review lacks good data on the fat contents of the milk consumed and for how long. Yet, it must be assumed that in some of the studies full-fat milk has been consumed for quite some time, merely due to non-availability of reduced fat milk (Elwood, Pickering, Fehily, Hughes, & Ness, 2004).

Fermented milks have been reported to have modest cholesterol lowering properties, although not consistently. The type of bacterial strain(s) appears to be relevant and survival in the gut seems to be a kind of prerequisite. A link to the metabolism of short-chain fatty acids and bile deconjugation appear to be involved mechanistically (Kießling, Schneider, & Jahreis, 2002; St-Onge, Farnworth, & Jones, 2000).

6. Dairy products and blood pressure

Diet and lifestyle have a substantial impact on the prevalence of hypertension in Western societies, with different ranking of risk factors within populations. Overweight, physical inactivity, high salt intake and low potassium intake appear to be the major contributors to hypertension in Western societies (Geleijnse, Grobbee, & Kok, 2005). Apart from sodium and potassium, calcium and magnesium are also important for the physiology of blood pressure regulation (Karppanen, Karppanen, & Mervalla, 2005). Most dairy products provide high levels of bioavailable calcium. Milk and yoghurt provide reasonable amounts of magnesium and potassium, whereas cheese contains relatively high amounts of sodium needed for preservation, taste and/or textural purposes.

Miller, DiRienzo, Reusser, and McCarron (2000) reviewed the biomedical literature on systolic and diastolic blood pressure lowering in function of calcium supplements or dietary calcium and concluded that results with dietary calcium appeared to be more consistent. Furthermore, these authors recommended that three to four servings of dairy products per day, as a combination of milk, yoghurt and cheese, are required for optimal blood pressure control. The Dietary Approach to Stop Hypertension intervention studies have furthermore provided strong evidence that inclusion of (low fat) dairy in a diet rich in fruits and vegetables, and reduced in fats, sweets, meat and sugar-containing beverages, significantly increased the lowering of both systolic and
diastolic blood pressure compared with the control diet (Cradick et al., 2003). Ruidavets et al. (2006) provided evidence that dairy products and dietary calcium are independently associated with helping to maintain normal systolic blood pressures. Less strong associations were found for diastolic blood pressure. Their cross-sectional analysis comprised 912 men, aged 45–64 years, and randomly selected from the MONICA survey on cardiovascular risk factors (1995–1996) in three French towns: Lille, Strasbourg and Toulouse. The relationships were investigated based on food intake assessments of 3 consecutive days and took into account multiple other outcome variables, such as body weight, dyslipidemia, diabetes, smoking, physical activity and hypertension medication. Average consumption of milk, fresh cheese, cheese, butter, whole dairy products and calcium in the population were 105, 65, 44, 15, 229 g and 798 mg per day, respectively. After multivariate adjustments, the difference in systolic blood pressure between the lowest and the highest of the quintiles was 4.1 mm Hg for calcium, 3.8 mm Hg for milk, 4.4 mm Hg for the combination milk and fresh cheese, and 7.0 mm Hg for total dairy intake. In this study, 72% of the calcium intake was provided by dairy products. It is therefore not surprising that the association with blood pressure was stronger when the consumption of both dairy products and dietary calcium is high. The association between dairy products and blood pressure was stronger and more significant in the subsample from which subjects with hypertensive medication were excluded.

The fat contents of the various dairy products were not further specified by Ruidavets et al. (2006). With regard to milk, a Spanish prospective cohort study suggests that low-fat milk is associated with a lower risk of hypertension (Alonso, Beunza, Delgado-Rodriguez, Alfredo Martinez, & Martinez-González, 2005). In this so-called SUN cohort low-fat dairy, but not whole fat dairy consumption, was associated with a lower risk of incident hypertension among 5880 university graduates, average age 37 years and followed for about 2 years (median 27 months). Quintiles of total dairy consumption ranged from about 150 till about 800 g per day; low-fat dairy (92% as skim or partially skimmed milk) ranged from about 50 to 475 g per day.

A modest association between dairy intake and a lower blood pressure was also found in the Hoorn study, using cross-sectional data from 2064 men and women aged 50–75 years (Snijder et al., 2007). The median intake of dairy servings was 4.1 per day. Borderline significant inverse associations were found for dairy desserts, milk and yoghurt, both for systolic and diastolic blood pressure. Moore et al. (2005) observed that diets rich in fruits, vegetables and dairy products had beneficial effects on blood pressure during childhood. Ninety-five children, who enrolled in the study between 3 and 6 years, had smaller yearly gains in blood pressure with two or more servings of dairy products during a 8-year follow-up period. Effects on systolic pressure were stronger than on diastolic pressure.

As milk proteins are the source of a number of bioactive peptides influencing blood pressure (López-Fandino, Otte, & van Camp, 2006; Townsend, McFadden, Ford, & Cadée, 2004), further research into the significance of the antihypertensive effect of dairy proteins seems warranted. At the moment, it is unclear whether dairy protein or fractions thereof and dairy bound calcium have different mechanistic effects on the regulation of blood pressure.

7. Milk and the metabolic syndrome

The metabolic syndrome is a cluster of metabolic disorders such as dyslipidemia, hypertension and reduced insulin sensitivity. Many of these symptoms are related to the development of overweight and obesity. The role of milk products in relation to this complex multifunctional disorder has recently been reviewed and discussed by Pfeuffer and Schrezenmeier (2006) and will therefore not be included in this paper. Their conclusion is that dairy products contain a number of constituents, like minerals, proteins, peptides, medium chain tryglycerides, lactose and organic acids that may, directly or indirectly, beneficially affect insulin sensitivity, weight, blood pressure and lipid levels.

8. Conclusions and outlook

The primary goal of this paper was to review to what extent current dietary recommendations on intake of preferably low-fat or even skimmed dairy alternatives are justified. Whereas it is well established that replacement of butter by unsaturated fats will have beneficial effects on blood lipid profiles as surrogate markers for longer term cardiovascular disease risk, the message that all saturated fatty acids in all dairy products are bad is an oversimplification lacking appropriate scientific evidence. It is also evident that more scientific research is needed before it can be concluded that the naturally present ruminant trans fatty acids have similar health outcomes as the ones produced from industrial hydrogenation of vegetable oils and that the estimated cardiovascular risk from actual or recommended dairy intake would be rather small. Recent research also shows that formulas that have been developed and refined over the years to measure blood lipids provide valuable tools for the design of randomized controlled trials, but that actual study outcomes not always coincide with predicted expectations. Reasons for aberrations in various studies may simply be macronutrient compositions of the intervention diets, e.g., the ratio of protein to carbohydrate, or other ingredients contained in or taken away from the original matrix. The mere presence or absence of calcium, or protein/peptides or specific vitamins may influence longer term health outcomes,
explaining different effects of butter, milk, yoghurt or cheese varieties. Tholstrup (2006) concluded in her review of the recent research since 2000 that “when guiding principles such as balance, variety and moderation are stressed, there is no strong evidence that dairy products increase the risk of CHD in healthy men of all ages as well as in healthy young and middle-aged women”. Further investigations are needed, certainly in view of the increasing epidemic of obesity where prevention has failed so far, and to establish whether dairy products provide opportunities to reverse the unfavourable health disorders. Maybe more focus should be given to the study of food products and their role in health promoting diets. The intrinsic nutrients in most dairy products, delivered at moderate to low caloric intakes, and when taken at adequate levels, may be associated with important health care savings, as pointed out by McCarron and Heaney (2004). These authors calculated that if Americans would increase their intake of dairy foods to the recommended levels of three to four servings per day, the 5 year projected cost savings would be in the order of US$200 billion (108), 35% of which due to reductions in prevalence of mild-to-moderate hypertension.

The Dutch RIVM, the National Institute for Public Health and Environment, develops models to calculate the effects of risk factors for chronic diseases. In the 2006 report “Our food, our health—Healthy diet and safe food in the Netherlands” (van Kreijl, Knaap, & van Raaij, 2006) the overall health loss, measured in DALYs (Disability Adjusted Life Years: a measure which combines death and illness, using a disability weighing factor for the seriousness of the illness), caused by an unhealthy diet is comparable with that caused by smoking. Assuming that behaviour change towards recommended levels of intake of healthy foods/nutrients occurs gradually, “middle scenarios” calculated health effects based on assumptions that consumption of saturated fatty acids was reduced by 2.5 energy% and consumption of trans fatty acids was reduced by 0.5 energy%. Loss in DALY’s for adults aged 20 and above for this “middle scenario” were 10,000 for saturated fats and 22,000 for trans fatty acids. A decrease with 1 BMI unit would save 56,000 DALY, increased fish eating would save 46,000 DALY, and increased fruit and vegetables intake 38,000 and 21,000 DALY, respectively. A recent update of the model, with new input on RR for cardiovascular disease and some cancers versus intake of fruits and vegetables, concluded that the biggest impact on health improvement would arise from increased fruit intakes up to recommended levels of 200 g per day. A further decrease of saturated fatty acids would generate about 10-fold less health gain, whereas the effect of a further decrease of trans fatty acids was considered as minimal due to the fact that projected intakes will be below 1 energy% (Buchner, Hoekstra, van den Berg, Wieleman, & van Rossum, 2007). An analysis of the effects of dairy consumption seems worthwhile to undertake.

References


