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CORRELATION BETWEEN FAT AND CHOLESTEROL CONTENTS OF COMMERCIALLY AVAILABLE DAIRY PRODUCTS

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Abstract

Thirty-three varieties of Hungarian commercial dairy foods were analyzed for fat and cholesterol levels, and a high correlation (r = 0.983) was found between these two compositional attributes. Cholesterol concentration was independent of processing factors such as heat-treatment of the raw material, use of starter culture, type of the starter organisms employed, and whipping or flavoring of the product. The non-fat varieties of fluid, fermented, and dried milks showed significantly increased ratios of cholesterol to fat compared with the other products tested because they contained considerable amounts of small fat globules and, therefore, had a large surface area with cholesterol bound to the fat globule membranes. In conclusion, the cholesterol-to-fat ratios obtained for the individual products or product groups enable the calculation of cholesterol concentrations based on fat contents that can be determined using simple methods.

Introduction

Being one of the essential constituents of cellular membranes and a critical precursor molecule for the synthesis of steroid hormones, cholesterol is undoubtedly important to good health at a certain concentration. It is partly produced in the human body, i.e., synthesized in the liver, and partly comes from consumption of foods of animal origin such as meat, eggs, milk, and the products made from them (*12*). For many years, diets rich in saturated fatty acids and cholesterol and poor in polyunsaturated fatty acids have been considered to lead to a high cholesterol level in the blood, thus resulting in atheroma growth and coronary heart disease in humans (*8*). It is for this reason that bovine milk and dairy products have received adverse publicity. As a result, many people have reduced their consumption of whole milk, butter, and other dairy products. However, the relationship between diet and blood cholesterol content is by no means clear and there are conflicting and contradictory reports in the literature. In addition, there are environmental factors of much greater importance than the cholesterol concentration of the blood (*9*). The current situation emphasizes the importance of cholesterol determination in foods of animal origin because the role of dietary cholesterol in human health and disease has not been clarified as yet (*4*).

The objectives of this study were to determine the cholesterol content of dairy foods commercialized in Hungary, including several special Hungarian products, because rather limited information is available in this field, and to find a relationship between fat and cholesterol values in each product category tested.

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Materials and methods

Thirty-three varieties of commercial dairy products were purchased from food stores located in the western part of Hungary. Three replicates of each variety were obtained from the refrigerated shelves of retail outlets. Upon collection, all products were taken to the analytical laboratory and stored at 4°C until chemical analysis. The entire experimental program was repeated twice.

The fat and cholesterol concentrations of fluid milks, condensed and dried milks, fermented milks, cream products, butters and buttercreams, and hard and semi-hard cheeses were determined according to the standard methods of the Association of Official Analytical Chemists using the Roese-Gottlieb method and the direct saponification-gas chromatographic method, respectively (*1*).

Within each product category tested, the cholesterol-to-fat ratios obtained were subjected to analysis of variance using the general linear model procedure of STATISTICA data analysis software system (*10*). Significant differences among the means were determined by using Duncan's multiple range test at $P < 0.05$ (*10*).

Results and discussion

The fat and cholesterol contents, and cholesterol-to-fat ratios of the fluid milks tested are shown in **Table 1**. The mean fat and cholesterol levels ranged from 0.15% and 1.45 mg 100 g^{-1} in skim milk to 3.61% and 13.84 mg 100 g^{-1} in whole milk, respectively. As a general rule, the higher the fat content, the higher was the cholesterol concentration. However, skim milks were not found to contain proportionally lower levels of cholesterol than low-fat, light, reduced fat, regular-grade, or whole milks. That is, the fat-free products revealed significantly higher ($P < 0.05$) cholesterol-to-fat ratios than the other varieties in this group did. The milks with at least 0.5% fat constituted a uniform group in this respect because an increase of 1% in fat content resulted in an increase of approximately 3.75 mg 100 g^{-1} in cholesterol on average. These results are consistent with the findings of Fletouris et al. (*4*) and Xu et al. (*12*) who found that whole bovine milk had cholesterol concentrations ranging from 12.20 to 13.55 mg 100 g^{-1}.

Table 1 Fat content, cholesterol concentration, and cholesterol-to-fat ratio of Hungarian commercial fluid milks

Type of product	Fat (%)	Cholesterol (mg 100 g^{-1})	Ratio of cholesterol (mg 100 g^{-1}) to fat (%)
Recombined skim milk	0.17±0.01	2.01±0.12	11.82[a]
Skim milk	0.15±0.02	1.45±0.24	9.67[b]
0.5% low-fat milk	0.51±0.03	1.86±0.13	3.65[c]
1.0% low-fat milk	1.05±0.08	3.79±0.10	3.61[c]
Light milk	1.64±0.10	6.30±0.23	3.84[c]
Reduced fat milk	2.01±0.04	7.49±0.13	3.73[c]
Regular-grade milk	2.81±0.03	10.85±0.07	3.86[c]
Whole milk	3.61±0.03	13.84±0.16	3.83[c]

Fat and cholesterol values are means±SD based on 6 observations (3 samples, 2 replicates)
Cholesterol-to-fat ratios followed by the same superscript letter are not significantly different (P>0.05) according to Duncan's multiple range test; values have been calculated from fat and cholesterol means based on 6 observations (3 samples, 2 replicates)

As shown in **Table 2**, the mean fat contents of commercial sweetened condensed milk, powdered skim milk, and powdered whole milk were found to be 8.52, 0.78, and 26.53%, respectively, fulfilling the compositional requirements of Hungarian food regulations (*2*). The

respective cholesterol concentrations for the corresponding products were 35.03, 19.36, and 102.52 mg 100 g^{-1}, indicating that there was a positive relationship between the fat and cholesterol levels of the condensed and dried milks tested. Similarly to what was experienced with fluid milks, the non-fat variety of dried milk had a significantly higher ($P < 0.05$) ratio of cholesterol to fat (24.82) than the fat-rich variety did (3.86). These findings are in agreement with those of Park (*7*), who reported that evaporated and powdered caprine milks had cholesterol-to-fat ratios of 3.69 and 4.28, respectively.

Table 2 Fat content, cholesterol concentration, and cholesterol-to-fat ratio of Hungarian commercial condensed and dried milks

Type of product	Fat (%)	Cholesterol (mg 100 g^{-1})	Ratio of cholesterol (mg 100 g^{-1}) to fat (%)
Skim milk powder	0.78±0.06	19.36±1.52	24.82[a]
Sweetened condensed milk	8.52±0.11	35.03±0.43	4.11[b]
Whole milk powder	26.53±0.57	102.52±1.79	3.86[c]

Fat and cholesterol values are means±SD based on 6 observations (3 samples, 2 replicates)
Cholesterol-to-fat ratios without a common superscript letter differ significantly (P<0.05) according to Duncan's multiple range test; values have been calculated from fat and cholesterol means based on 6 observations (3 samples, 2 replicates)

Seven varieties of commercial non-fat, low-fat, light, reduced fat, and whole fermented milks were analyzed for fat and cholesterol (**Table 3**). The yogurts tested included only traditional varieties fermented with *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus* starter bacteria. Not surprisingly, non-fat yogurt contained the lowest amount of fat and had the highest cholesterol-to-fat ratio. It is worth pointing out that there was no difference in cholesterol-to-fat ratio between the plain and fruit flavored products. It should also be noted that, unlike probiotic bacteria such as *Lactobacillus acidophilus* or *Bifidobacterium* spp. which are capable of reducing the cholesterol levels of milk by incorporating cholesterol into their cellular membranes (*3*, *6*), neither the mesophilic (i.e., kefir) nor the thermophilic (i.e., yogurt) starter organisms were observed to have any cholesterol-lowering effect on milk in this study. Cholesterol concentrations ranged from 13.79 to 14.15 mg 100 g^{-1} in the fermented whole milks. These results are comparable to some previous reports, where the levels of cholesterol in cow milk yogurts and probiotic fermented milks were found to be between 10.3 to 12.7 mg 100 g^{-1} (*4*, *5*).

Table 3 Fat content, cholesterol concentration, and cholesterol-to-fat ratio of Hungarian commercial fermented milks

Type of product	Fat (%)	Cholesterol (mg 100 g^{-1})	Ratio of cholesterol (mg 100 g^{-1}) to fat (%)
Non-fat yogurt (flavored)	0.13±0.02	1.46±0.24	11.23[a]
Low-fat yogurt (flavored)	1.05±0.05	4.06±0.24	3.87[b]
Light yogurt (plain)	1.46±0.04	5.80±0.17	3.97[b]
Reduced fat yogurt (flavored)	2.08±0.04	7.99±0.23	3.84[b]
Yogurt (plain)	3.52±0.04	14.15±0.17	4.02[b]
Light kefir	1.45±0.03	5.70±0.15	3.93[b]
Kefir	3.51±0.05	13.79±0.30	3.93[b]

Fat and cholesterol values are means±SD based on 6 observations (3 samples, 2 replicates)
Cholesterol-to-fat ratios followed by the same superscript letter are not significantly different (P>0.05) according to Duncan's multiple range test; values have been calculated from fat and cholesterol means based on 6 observations (3 samples, 2 replicates)

Cultured cream is utilized as an important ingredient in Hungarian cuisine. Therefore, in addition to the commercial sweet cream products, two varieties of cultured creams were also analyzed for fat and cholesterol contents (**Table 4**). The cholesterol level of whipping cream

was higher than that of the other five varieties of cream products tested, which was consistent with the labeled fat concentrations of the cream samples. The results indicated that there was a strong relationship between the fat and cholesterol contents of creams. A 1-% increase in fat resulted in an increase of approximately 3.65 mg 100 g^{-1} in cholesterol on average. Cholesterol concentration was independent of factors such as heat-treatment of the process cream or whipping of the product. It is also noteworthy that neither the 12% nor the 20% cultured cream was different from the sweet varieties in terms of the cholesterol-to-fat ratio, suggesting that the activity of the mesophilic lactic acid bacteria (i.e., *Lactococcus* and *Leuconostoc* species) used as starter organisms did not influence the fat and cholesterol levels of creams. This finding is in accord with our previous observations made on sweet and fermented milks.

Table 4 Fat content, cholesterol concentration, and cholesterol-to-fat ratio of Hungarian commercial cream products

Type of product	Fat (%)	Cholesterol (mg 100 g^{-1})	Ratio of cholesterol (mg 100 g^{-1}) to fat (%)
Coffee cream	10.22±0.23	37.80±1.63	3.70[a]
Cooking cream	20.65±0.40	74.03±1.77	3.58[a]
Whipped cream	21.13±0.35	76.72±2.25	3.63[a]
Whipping cream	30.23±0.58	109.54±1.89	3.62[a]
12% cultured cream	11.95±0.19	44.51±2.48	3.72[a]
20% cultured cream	20.05±0.31	73.66±2.31	3.67[a]

Fat and cholesterol values are means±SD based on 6 observations (3 samples, 2 replicates)
Cholesterol-to-fat ratios followed by the same superscript letter are not significantly different (P>0.05) according to Duncan's multiple range test; values have been calculated from fat and cholesterol means based on 6 observations (3 samples, 2 replicates)

As for the butters and buttercreams, four varieties of these products were tested in this study (**Table 5**). It is well known that butter is required to contain a minimum of 80% milk fat. Sandwich butter is a traditional Hungarian dairy product characterized by 68 to 72% fat content (*2*). Plain buttercream is made from cream with increased solids-non-fat levels using double-stage homogenization, fermentation by lactic acid bacteria, and heat-treatment of the finished product, which, thus, has a fat content of at least 37%, a total solids content of over 45%, and a pH value of 4.0 to 4.6. Unlike butter, buttercream is a product in the form of an oil-in-water type emulsion. As was expected, butters and buttercreams were found to have the highest fat and cholesterol levels of the 33 varieties of dairy products tested. The concentration of cholesterol increased correspondingly with the increased fat contents. The cholesterol-to-fat ratio was approximately 2.80 and 3.10 in butters and buttercreams, respectively, suggesting that buttercream manufacturing procedures might have contributed to the retention of cholesterol. In another trial conducted by Fletouris et al. (*4*), butter also proved to be a rich source of cholesterol, containing this substance at a concentration of 228.1 mg 100 g^{-1}. Despite the high cholesterol level of butter, only 1.5% (7 mg/day) of the total cholesterol intake is provided by this product in Hungary, indicating that butter is not a major contributor of cholesterol to the Hungarian consumer's diet (*11*).

Table 5 Fat content, cholesterol concentration, and cholesterol-to-fat ratio of Hungarian commercial butters and buttercreams

Type of product	Fat (%)	Cholesterol (mg 100 g^{-1})	Ratio of cholesterol (mg 100 g^{-1}) to fat (%)
Buttercream (plain)	40.55±1.11	126.65±4.65	3.12[a]
Buttercream (flavored)	36.94±0.56	114.38±2.70	3.10[a]
Sandwich butter	69.73±0.86	196.33±4.66	2.82[b]
Butter	80.88±0.85	225.42±12.18	2.79[b]

Fat and cholesterol values are means±SD based on 6 observations (3 samples, 2 replicates)
Cholesterol-to-fat ratios followed by the same superscript letter are not significantly different (P>0.05) according to Duncan's multiple range test; values have been calculated from fat and cholesterol means based on 6 observations (3 samples, 2 replicates)

Table 6 illustrates the fat and cholesterol levels, and cholesterol-to-fat ratios of commercial semi-hard (Trappist, Hajdú, Óvári, and Edam) and hard (Pannónia) cheeses. Although Pannónia, an Emmental-type Hungarian hard cheese, was found to have the highest fat content, its cholesterol concentration (91.11 mg 100 g^{-1}) was hardly any higher than that of Edam (89.15 mg 100 g^{-1}), a semi-hard cheese containing the lowest amount of cholesterol among the cheeses tested in this study. Similar figures were obtained by Fletouris et al. (*4*) in a previous work, where Emmental and Edam cheeses were reported to contain cholesterol at concentrations of 85.7 and 82.9 mg 100 g^{-1}, respectively. As a result, Pannónia had a significantly lower ($P < 0.05$) cholesterol-to-fat ratio than the semi-hard cheeses did. The cholesterol concentrations of Trappist, Hajdú, Óvári, and Edam cheeses were proportional to the fat contents of the products. Thus, the cholesterol-to-fat ratio of semi-hard cheeses was in the range of 4.09 to 4.17. The results of this research suggest that the specific manufacturing procedures of hard and semi-hard cheeses did influence the cholesterol concentration of the finished product.

Table 6 Fat content, cholesterol concentration, and cholesterol-to-fat ratio of semi-hard and hard cheeses commercialized in Hungary

Type of product	Fat (%)	Cholesterol (mg 100 g^{-1})	Ratio of cholesterol (mg 100 g^{-1}) to fat (%)
Trappist cheese	25.64±0.41	106.99±1.88	4.17[a]
Hajdú cheese	24.95±0.69	103.37±2.74	4.14[a]
Óvári cheese	25.34±0.47	104.06±1.90	4.11[a]
Edam cheese	21.78±0.28	89.15±1.53	4.09[a]
Pannónia cheese	26.73±0.46	91.11±1.83	3.41[b]

Fat and cholesterol values are means±SD based on 6 observations (3 samples, 2 replicates)
Cholesterol-to-fat ratios followed by the same superscript letter are not significantly different (P>0.05) according to Duncan's multiple range test; values have been calculated from fat and cholesterol means based on 6 observations (3 samples, 2 replicates)

Conclusions

Cholesterol concentration was independent of processing factors such as heat-treatment of the raw material, use of starter culture, type of the starter organisms employed, and whipping or flavoring of the product. A high correlation (r = 0.983) was found between cholesterol and fat values. However, skim milks and the products made from them, which were found to have decreased, albeit not proportionally decreased, levels of cholesterol, showed extremely high cholesterol-to-fat ratios compared to their non-skim counterparts. The most plausible explanation of this observation is that non-fat milk products contain significant quantities of small size fat globules and, consequently, have a large surface area. Because cholesterol is associated with the fat globule membrane, an increased ratio of cholesterol to fat is obtained for these products. The results of this study can be used for various purposes

such as food labeling, consumer information, quality control of milk products, and development of new dairy foods. In addition, they may also be needed when establishing dietary guidelines for the general public according to health concerns, when formulating diets for population groups with special requirements, or when assessing fat and cholesterol intakes in epidemiological studies aimed at investigating the relationship between diet and health. It is worth noting, however, that although dietary cholesterol does raise plasma cholesterol levels in most people, the chief culprit is saturated fat. The most effective way to control blood cholesterol is to reduce foods high in saturated fat.

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