

Polyunsaturated fatty acids in the food chain in Europe^{1,2}

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ABSTRACT Intakes of partially hydrogenated fish oil and animal fats have declined and those of palm, soybean, sunflower, and rapeseed oils have increased in northern Europe in the past 30 y. Soybean and rapeseed oils are currently the most plentiful liquid vegetable oils and both have desirable ratios of n-6 to n-3 fatty acids. However, soybean and rapeseed oils are commonly partially hydrogenated for use in commercial frying to decrease susceptibility to oxidative degradation. This process leads to selective losses of α -linolenic acid (18:3n-3). Intake of linoleic acid (18:2n-6) has risen in many northern European countries. In the United Kingdom, intakes have increased from ≈ 10 g/d in the late 1970s to ≈ 15 g/d in the 1990s. The intake of α -linolenic acid is estimated to be ≈ 1 –2 g/d but varies with the type of culinary oil used. There are few reliable estimates of the intake of long-chain n-3 fatty acids, but those are generally ≈ 0.1 –0.5 g/d. The increased use of intensive, cereal-based livestock production systems has resulted in a lower proportion of n-3 fatty acids in meat compared with traditional extensive production systems. Overall, there has been a shift in the balance between n-6 and n-3 fatty acids over the past 30 y. This shift is reflected in the declining concentrations of docosahexaenoic acid and rising concentrations of linoleic acid in breast milk. *Am J Clin Nutr* 2000;71(suppl):176S–8S.

KEY WORDS Essential fatty acids, linoleic acid, α -linolenic acid, docosahexaenoic acid, Europe, food chain, breast milk

INTRODUCTION

The supply of dietary fats in Europe is more diverse than that in North America. Over the past 50 y, this supply has changed quite remarkably. Partially hydrogenated fish oils (PHFOs) were formerly widely consumed in several northern European countries, most notably Norway, the Netherlands, Germany, and the United Kingdom. In the mid-1970s, these fats accounted for $\approx 40\%$ of the oils moving into consumption (1). Although fish oil is a rich source of long-chain n-3 fatty acids, PHFO contains negligible amounts of n-3 fatty acids. Nowadays, fats of vegetable origin have now largely replaced PHFOs. In the 1950s, groundnut oil and olive oil were the major oils available for culinary use in Europe. Yet over the past 2 decades there has been an expansion of the production of low-erucic-acid rapeseed (canola) and sunflower seed oils in Europe (2). In Spain and Portugal, the production of sunflower seed oil now exceeds that of olive oil. Palm-oil use has also increased because of its low cost and functional characteristics that are favored by the food industry. Palm-

oil production in Malaysia and Indonesia has increased to such an extent that it accounts for about one-third of the world's fat production. Soybean and maize oils are also available in Europe, although these tend to be imported from the United States.

Consumption of butterfat, lard, and tallow has also declined (2–5). Selective breeding and butchering techniques have also reduced the fat content of meat sold for home consumption. Despite the large increase in the use of skim and semiskim milk and the reduction in butter consumption in favor of margarine, the decline in butterfat intake is not marked because butter is being used in prepared foods marketed by the food industry (4). The net effect of these changes has been a decrease in the use of animal fats and an increase in the use of vegetable fats relatively high in linoleic acid. The consumption of fish—in particular oily fish, which is a major source of long-chain n-3 fatty acids—has declined markedly this century (5). However, the popularity of oily fish has increased slightly in recent years. Thus, the ratio of n-6 to n-3 fatty acids in the food supply has increased over the past 50 y.

Evidence from food-consumption data

Several problems are encountered when attempting to estimate the intake of polyunsaturated fatty acids from standard food-composition tables because the data are unreliable. Many food tables only give data for total fatty acids and not the individual polyunsaturated fatty acids (PUFAs). It is also difficult to estimate intakes of long-chain PUFAs because food tables only report values to the nearest 0.1 g/100 g food. Meats such as beef, lamb, and poultry make small but significant contributions to the intake of long-chain polyunsaturated fatty acids. The other major problem is the lack of reliable food survey data in many European countries. Whereas the United Kingdom, the Netherlands, and the Nordic countries have reasonably good dietary survey information, data from other countries, particularly those in southern and eastern Europe, are far more limited. Even in the United Kingdom, which conducts an annual survey of household food consumption and expenditure (5), the data require careful interpretation. For example, the composition of milk, meat, and processed foods (eg, margarine) has changed. Furthermore, the

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TABLE 1

Average daily intake of n-6 and n-3 fatty acids calculated from food tables in The Dietary and Nutritional Survey of British Adults¹

Fatty acids	Men (n = 1087)	Women (n = 1110)
n-6		
(g/d)	14.2 (5.3, 29.4)	9.9 (3.4, 21.3)
(% of energy)	5.2 (2.8, 9.4)	5.2 (2.6, 9.5)
n-3		
(g/d)	2.00 (0.73, 3.71)	1.41 (0.51, 2.99)
(% of energy)	0.74 (0.36, 1.33)	0.75 (0.40, 1.45)

¹ \bar{x} (2.5th and 97.5th percentile). From reference 6.

proportion of meals consumed outside the home has risen. However, these data clearly show how the consumption of butterfat and milk fat has declined and that of vegetable oils and margarine has increased. Current estimates of dietary intake (6) from a large dietary survey in the United Kingdom are shown in **Table 1**. Unfortunately, these estimates do not distinguish between the different n-3 fatty acids. Similar estimates of PUFA intake have been made in the Netherlands where, eg, α -linolenic acid was estimated to provide $\approx 0.5\%$ of energy intake (1.2 g/d) (7). It is difficult to make reliable estimates of the intake of long-chain PUFAs from dietary intake surveys.

Estimates from chemical analyses of diets

One of the earliest reliable estimates of PUFA intake was made in the Seven Countries Study (8), in which intakes were estimated by chemical analyses of composite diets. This study suggested that in the 1960s, linoleic acid accounted for $\approx 3\text{--}4\%$ of energy intake. Recent dietary surveys suggest that intake of linoleic acid has increased by $\approx 50\%$ over the past 2 decades (3, 9). This increase occurred in Sweden and The Netherlands before it occurred in the United Kingdom. To illustrate this point, we compared the results of chemical analyses of 3-d duplicate diets typical of the average British diet collected in 1980 and 1992 (**Table 2**) by using the same analytic method in our laboratory. The results of these analyses showed that estimates of total n-3 fatty acid intake are lower than estimates from food tables; this may be because food tables do not allow for losses of α -linolenic acid during hydrogenation of vegetable oils. There is clearly a need to validate accurately estimates calculated from food-table data with those obtained by chemical analyses.

Estimates of intake from blood and adipose tissue lipids

Measurements of linoleic and α -linolenic acids in adipose tissue can also be used to estimate dietary intakes. Wood et al (12) first showed that Scottish men had lower proportions of linoleic acid in adipose tissue than did Swedish men. The same group (13) more recently measured the proportions of linoleic and α -linolenic acid in adipose tissue of men from several European countries. In this study, the mean proportions of linoleic and α -linolenic acids in adipose tissue were 12.9% and 0.8% of the total fatty acids, respectively. These data suggest that the ratio of linoleic to α -linolenic acid is somewhat higher than that estimated from calculation of dietary intakes, but is similar to the estimates from chemical analyses of diets. During consumption of high-fat diets, little biosynthesis of fat occurs (14). Thus, it

can be argued that the proportion of linoleic and α -linolenic acids in adipose tissue should be the same as that in the dietary fat (15). For a diet supplying 40% of energy from fat, the adipose tissue data suggests that average intakes of linoleic and α -linolenic acids were $\approx 5\%$ and $\approx 0.3\%$ of energy from fat, respectively, giving a ratio of $\approx 16:1$.

Further evidence of an increased intake of linoleic acid in the diet comes from the analyses of breast milk, a good indicator of the composition of maternal dietary PUFA intake (16). In the United Kingdom there is evidence that the proportion of linoleic acid in breast-milk lipids has increased from 7–10% to $\approx 14\%$ (17). The proportion of α -linolenic acid in breast-milk lipids has also increased in the United Kingdom, probably as a result of the increased use of low-erucic-acid rapeseed oil. However, there is some evidence to suggest that the proportion of docosahexaenoic acid (22:6n-3) in breast milk has declined slightly. This could be a consequence of high intakes of linoleic acid, which inhibits the synthesis of docosahexaenoic acid from α -linolenic acid. The fatty acid composition of breast milk is now similar in most European countries (18).

Data are available from several European countries on the fatty acid composition of plasma and platelet phospholipids that can be used to indicate the balance between n-6 and n-3 fatty acids (19–21); differences among European countries are few. This ratio is influenced not only by the absolute intake of these fatty acids but also by the relative proportions of n-6 to n-3 fatty acids. However, individuals who consume fish regularly have higher concentrations of docosahexaenoic acid in their plasma phospholipids than do persons who do not consume fish. Increasing the intake of linoleic acid leads to a decrease in the proportion of docosahexaenoic acid in plasma phospholipids. There has been a trend, in particular in the United Kingdom, toward vegetarian diets, which tend to have even higher ratios of linoleic to α -linolenic acids and are often devoid of long-chain n-3 fatty acids; the ratio of n-6 to n-3 fatty acids in plasma, erythrocytes, and platelet phospholipids is highest in this group (10).

Recommended intakes

Estimates of minimum requirements for essential fatty acids are often based on the *Report of the Panel on Dietary Reference Values of the Committee on Medical Aspects of Food Policy* (United Kingdom; 22), in which the suggested minimum requirement for linoleic acid is $\approx 1\%$ of energy intake. The same report suggested that the minimum requirement for α -linolenic

TABLE 2

Estimated dietary intakes of polyunsaturated fatty acids derived from chemical analyses of 3-d duplicate diets in British men¹

Fatty acid	1980 ² (n = 10)	1992 ³ (n = 18)
	g/d	
18:2n-6	10.2 \pm 1.63	15.4 \pm 1.23
18:3n-3	1.0 \pm 0.17	1.9 \pm 0.25
20:5n-3	0.2 \pm 0.15	0.3 \pm 0.10
22:6n-3	0.4 \pm 0.27	0.2 \pm 0.18

¹ $\bar{x} \pm$ SE.


²From reference 10.

³From reference 11.

acid was 0.2%. Other authorities have suggested minimum requirements of $\approx 0.5\%$ of dietary energy (2). The British Nutrition Foundation Task Force on Unsaturated Fatty Acids (3) recommended intake equivalent to 1–2 portions of oily fish per week or a daily intake of 0.5–1.0 g long chain n–3 fatty acids.

Conclusion

It appears that intakes of linoleic acid have increased substantially over the past 2 decades. Vegetable oils, such as sunflower and corn oil, with high ratios of linoleic to α -linolenic acids are now used widely in place of more traditional fats such as olive oil, lard, and butter. Although some oils are naturally rich in α -linolenic acid, the process of partial hydrogenation decreases the amount of α -linolenic acid in the product. Meat from ruminant animals contains n–3 fatty acids (23), but consumption of lamb and beef has fallen over the past 20 y in the United Kingdom (5). Furthermore, the practice of feeding ruminants concentrated, cereal-grain-based feed rather than grass leads to lower amounts of α -linolenic acid in dairy products and meat (22). Consequently, the contribution made by ruminant fats to the dietary intake of n–3 fatty acids has declined.

The increased interest in the potential health benefits associated with the consumption of long-chain n–3 fatty acids has led to the sale of supplements and fortified foods containing these fatty acids. There is a long history of cod-liver oil use in the United Kingdom and in Nordic countries. Fish-body oils are also sold as health food supplements in several European countries. Recently, foods such as bread, pasta, and margarine have been fortified with long-chain n–3 fatty acids. Fish oils, particularly liver oils, can be contaminated with polychlorinated biphenyls and dioxins, but there are also algal sources of long-chain n–3 fatty acids. There are, however, several regulatory concerns surrounding these dietary sources of n–3 fatty acids. Algal oils are regarded as novel foods in the European Union and their use has yet to be accepted. There are also concerns about the oxidative stress that can result from increased intakes of n–3 fatty acids if they are not accompanied by adequate intakes of vitamin E. 

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