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What are the health effects of fat?

Summary In order to answer the question which health benefits are to be expected from dietary fat, we have to differentiate between different kinds of fat with varying fatty acid composition. Saturated fatty acids are commonly judged to have a negative health impact as they lead to increased serum cholesterol levels and a higher risk of coronary heart disease. Therefore, all recommendations stress the importance to limit the intake of saturated fatty acids. Monounsaturated fatty acids, on the other hand, have a positive impact on the serum lipid profile, lead to decreased LDL-oxidation and favorably influence the metabolism of diabetics. However, it is essential that monounsaturated fatty acids be mainly supplied by plant oils like rape seed or olive oil and not by foods that are simultaneously rich in saturated fatty acids. Concerning polyunsaturated fatty acids, it is important to increase the supply of n-3 fatty acids (ratio of n-6:n-3: about 5:1) as there is substantial evidence for their protective effects. If the fatty acid composition of the diet is optimized, even a total dietary fat content of 35 % of total energy intake can be adequate as long as there is enough physical activity and the diet is rich in plant-derived foods like vegetables, fruits, cereals, potatoes, beans and legumes.

Key words CHD – MUFA – PUFA – fatty acids – diabetes

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Introduction

The focus of present scientific discussion is still the question how to optimize the dietary fat intake in order to achieve maximum health benefits, i. e. what the optimum amount and composition of dietary fat is. Over the last few years, there have been plenty of new findings concerning the various effects and modes of action of different fatty acids giving details on their specific role in the organism. Fatty acids are now known to not only play a role in the prevention of cardiovascular diseases via their effect on serum lipids but as well because they directly influence a number of other risk factors in various ways and have direct effect on atherogenesis. Therefore, the health effects of dietary fat have to be judged according to its respective fatty acid composition.

There is scientific consensus that presently, total fat consumption is too high – in particular, because the contribution of saturated fatty acids is too high – and that we have to reduce the consumption of saturated fatty acids. However, there is a controversial discussion whether it can generally be further recommended to reduce fat consumption to 30 % of total daily energy intake. This article summarizes present knowledge concerning the effects of various fatty acids with a focus on their role in CHD and its risk factors. Present recommendations for the dietary intake of fat and various fatty acids will be discussed.

Saturated fatty acids and trans fatty acids

The marked serum cholesterol-increasing effect of saturated fatty acids has been known for a long time [1, 2]. Recent investigations have, however, shown, that only three long-chain fatty acids, namely lauric acid (12:0), myristic acid (14:0) and palmitic acid (16:0), significantly influence total and LDL-cholesterol [3, 4]. These fatty acids reduce the activity of the LDL receptors and

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thereby decrease the cellular LDL uptake [5, 6]. The short and medium-chain fatty acids (4:0–10:0) as well as stearic acid (18:0) do not cause a significant increase of cholesterol levels [3, 7]. For stearic acid, a HDL cholesterol level lowering effect has been described [8].

The finding that some of the saturated fatty acids are neutral with regard to cholesterol levels or CHD is barely relevant for practical dietary recommendations. First of all, those fatty acids that increase cholesterol levels contribute the major portion to our total saturated fatty acid intake. Furthermore, all foods contain a mixture of saturated fatty acids with different chain length. It is therefore impossible to give differentiated recommendations. In addition, we have epidemiological evidence supporting the assumption that there is a positive correlation between saturated fatty acid consumption and the incidence of coronary heart disease [9, 10]. Moreover, there are findings that saturated fatty acids might negatively influence the development of certain types of cancer [11]. Overall, these findings justify a generalized recommendation to limit the consumption of saturated fatty acids.

There is an international consensus to reduce the uptake of saturated fatty acids to less than 10 % of total daily energy supply [12–15].

Unsaturated fatty acids with trans-configuration (trans fatty acids) show the same positive correlation with CHD risk as saturated fatty acids [16, 17]. Various mechanisms contribute to increasing the CHD risk with increasing trans fatty acid intake: first of all, trans fatty acids increase LDL cholesterol and at the same time lower HDL cholesterol [18, 19]. Furthermore, they cause an increase of Lp(a) levels [20] as well as of serum triglyceride levels [21]. In addition, they inhibit enzymes of the eicosanoid metabolism. The latter may result in disturbed prostaglandin balance and increased thrombogenesis [22].

Nowadays, margarine is no longer a major source of trans fatty acids, because the manufacturing processes have been modified. Instead, the major contribution of trans-fatty acids in our diet comes from products containing hardened fats, i. e. pastries, chips as well as fried and convenience foods.

The daily intake of trans fatty acids should be as low as possible. The American Heart Association recommends an intake of no more than 10 % of total daily energy as cholesterol-increasing fatty acids, i. e. saturated plus trans fatty acids [13].

Monounsaturated fatty acids

The Seven Countries Study yielded the first convincing epidemiologic evidence for a negative correlation between the dietary intake of monounsaturated fatty acids and overall mortality as well as mortality from CHD [23]. Mortality form CHD was particularly low in Mediterranean countries, where olive oil, which is rich in monounsaturated acids, is the main dietary source of fat [23]. However, there are other prospective studies showing an increased CHD risk with increasing intake of monounsaturated fatty acids [24, 25]. However, it has to be considered that the latter studies did not adjust their results for important confounders, e. g. the intake of other types of fatty acids. In the United States, the supply of monounsaturated acids and saturated as well as trans fatty acids is closely related, making the intake of monounsaturated fatty acids a marker for a simultaneously high intake of saturated and trans fatty acids [10]. Regression analysis of data of the Nurses Health study confirmed a protective effect of monounsaturated fatty acids with regard to CHD risk [26].

When monounsaturated fatty acids (most important: oleic acid, 18:1, n-9) are supplied instead of saturated fatty acids in metabolic studies, they lower total and LDL cholesterol significantly and to the same extent as n-6 polyunsaturated fatty acids do [27]. Supposedly, there is a passive mechanism of action: when saturated fatty acids are decreased and unsaturated fatty acids simultaneously increased, the suppression of LDL-receptor activity is neutralized and cellular LDL uptake is improved [5, 6]. The monounsaturated fatty acids are said to have the advantage of not appreciably affecting the protective HDL cholesterol which is lowered under a diet rich in polyunsaturated fatty acids [28, 29]. This effect could, however, not be confirmed in an extensive meta-analysis [27]: both types of fatty acids seem to have HDL-lowering effects. However, the simultaneous decrease of LDL cholesterol is more pronounced, resulting in a decreased LDL/HDL quotient. The authors conclude that monounsaturated and n-6 polyunsaturated acids are equivalent with regard to their quantitative effects on total, LDL and HDL cholesterol.

In healthy subjects, serum triglycerides are not affected by monounsaturated fatty acids [3]. However, in persons with hypertriglyceridemia, a diet high in monounsaturated fatty acids may – in contrast to a diet rich in carbohydrates – even lower triglyceride levels [30, 31].

In patients with type 2 diabetes, a diet rich in monounsaturated fatty acids might positively influence serum lipid and glucose profiles. When comparing the effects of a diet rich in carbohydrates with a diet rich in monounsaturated fatty acids in a meta-analysis, the latter lowered serum triglycerides, slightly increased HDL cholesterol and had no effect on LDL cholesterol [32]. The 24-hour-profile of blood glucose and insulin concentrations showed significantly lower values under a diet rich in monounsaturated fatty acids. Therefore, the American Diabetes Association now recommends variable portions of carbohydrates and monounsaturated fatty acids in the diabetic diet. On condition that the intake of saturated fatty acids is lower than 10 % of total

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energy, the contribution of monounsaturated fatty acids plus carbohydrates should amount to 60–70 % of total daily energy. The optimum ratio of these two nutrients has to be determined individually, depending on the respective lipid status and the individual therapeutic targets for glucose, lipids and body weight [33].

Another advantageous property of monounsaturated fatty acids that has just recently been shown is their protective effect against LDL oxidation. LDL oxidation is probably one important etiologic factor in atherogenesis, as oxidatively modified LDL particles can no longer be taken up by the LDL receptor. Instead, they are taken up by the so-called scavenger receptors of macrophages. Macrophages then accumulate cholesterol, leading to the development of foam cells and so-called fatty streaks. These processes promote the development of atherosclerosis [34–36]. Monounsaturated fatty acids, due to their chemical structure, are much more stable and less prone to lipid peroxidation than the more unstable polyunsaturated fatty acids. A high intake of monounsaturated fatty acid results in an increased monounsaturated fatty acid concentration in LDL particles. This leads to a markedly lower susceptibility of LDL particles to oxidative modifications in vitro when compared to LDL particles containing higher concentrations of polyunsaturated fatty acids due to a diet rich in polyunsaturated fatty acids [37–40].

Based on the numerous favorable effects there is a consensus on the following recommendation: up to 15 % of total daily energy should be supplied in the form of monounsaturated fatty acids, preferably in the form of plant-oils like rape-seed and olive oil [12–14]. According to the United States National Cholesterol Education Program of the year 2001 [15], the upper limit for the intake of monounsaturated fatty acids in a lipid-lowering diet is even 20 % of total energy.

Polyunsaturated fatty acids

N-6 (omega-6) polyunsaturated fatty acids

N-6 polyunsaturated fatty acids (most important: linoleic acid, 18:2, n-6) lower total and LDL cholesterol concentrations significantly, when they are supplied instead of saturated fatty acids [3, 27]. In addition to the passive mechanism that has already been described for monounsaturated fatty acids, there seems to be an active increase of receptor-dependent LDL uptake, independent of saturated fatty acids. This effect is, however, very small [5, 6]. The HDL cholesterol-lowering effect of polyunsaturated fatty acids and its significance has already been described in the previous section. The influence of n-6 polyunsaturated fatty acids on serum triglycerides has not been completely clarified, but is assumed to be negligible [3].

High intake of polyunsaturated fatty acids leads to an increased susceptibility to lipid peroxidation, as previously explained. This effect is especially negative with regard to LDL oxidation and might play a role in oxidative processes in the cell membrane. It might also even play a role in tumorigenesis.

Actual recommendations for the intake of polyunsaturated fatty acids are mainly based on two aspects: first, the susceptibility of polyunsaturated fatty acids to oxidation; second, the fact that there is no population with a chronically high (above 10 % of total daily energy) polyunsaturated fatty acid intake that gives us any epidemiologic proof for the safety of a high daily intake in this range. Therefore, it is recommended to limit the daily polyunsaturated fatty acid supply to a maximum of 10 % of total daily energy [13–15]. Some institutions even recommend a maximum of only 7–8 % [12, 41].

N-3 (omega-3) polyunsaturated fatty acids

The importance of n-3 polyunsaturated fatty acids has increased over the last few years as there were more and more findings related to their potential health benefits (Table 1). However, it remains unclear whether the specific effects relate to all n-3 fatty acids, i. e. α-linolenic acid (18:3, n-3; ALA), eicosapentaenoic acid (20:5, n-3; EPA) and docosahexaenoic acid (22:6, n-3; DHA) or only to EPA and/or DHA [42].

For CHD prevention, various effects have been described (Table 2). The distinct serum triglyceride-lowering effect of n-3 fatty acids has been known for a long time; it exists, however, only for EPA and DHA, not for ALA [43]. The latter has the same effect on serum lipids as have the n-6 polyunsaturated fatty acids [43]. EPA and DHA inhibit hepatic VLDL-triglyceride synthesis. They mainly reduce the triglyceride content of VLDL particles while the number of particles remains fairly constant [43]. Enriching the diet with n-3 fatty acids can therefore considerably lower serum triglycerides in hyperlipemic patients. A total of 1.5 to 3 g per day is required to achieve a significant effect. Reductions of the triglyceride levels of 25–40 % can then be seen [31].

In normolipemic persons, LDL and HDL cholesterol

Table 1 Diseases that might be prevented or favorably influenced by n-3 fatty acids [42]

1. Coronary heart disease and stroke
2. Essential fatty acid deficiency in infancy (retina and brain development)
3. Auto immune diseases (e. g. lupus, nephropathy)
4. Crohn's disease
5. Breast, colon, and prostate cancer
6. High blood pressure
7. Rheumatoid diseases

Table 2 Effects of n-3 fatty acids in cardiovascular diseases [42]

1. Prevention of arrhythmias
2. Anti-inflammatory and antithrombotic effects
3. Reduced synthesis of cytokines and mitogens
4. Stimulation of endothelial-derived nitric oxide (NO)
5. Decrease of serum triglycerides
6. Reduction of postprandial lipidemia

are little affected by n-3 fatty acids, while in hyperlipemic patients different effects can be seen – depending on the etiology of the hyperlipidemia and on the amount of n-3 fatty acids supplied. For example, an increase in LDL cholesterol might occur in isolated hypertriglyceridemia when more than 10 g of n-3 fatty acids is supplied per day. These effects can so far not be explained [43, 44].

N-3 fatty acids inhibit inflammatory processes by influencing the eicosanoid metabolism. Furthermore, they influence blood coagulation by reducing platelet adhesion and aggregation [42, 45]. This effect can be explained as follows: n-3 fatty acids reduce the transformation of linoleic acid to arachidonic acid and compete with arachidonic acid for the enzymes that are required for eicosanoid synthesis (Fig. 1). The formation of thromboxane A_2, which promotes aggregation and vasoconstriction, is thereby decreased in favor of thromboxane A_3 which has a much weaker effect on aggregation and vasoconstriction. This leads to a decreased risk of thrombosis and increased bleeding time [44, 45]. Decreased leukotriene B_4-formation and a simultaneously increased leukotriene B_5-formation causes a decrease of inflammatory processes [44].

Recent findings show that n-3 fatty acids have cardioprotective properties in addition to their antithrombotic and anti-inflammatory effects, as they play a role in maintaining endothelial function. Dysfunctions of vascular endothelia are a major etiologic factor in atherogenesis. Endothelial dysfunction develops when the endothelium is increasingly and permanently activated. Under these conditions, the expression of adhesion molecules is increased, leukocyte and platelet adhesion changes and the production of vasodilative nitric oxide (NO) is decreased [46]. It could be demonstrated that n-3 fatty acids decrease the expression of adhesion molecules, reduce leukocyte-endothelium interaction and increase NO production [47].

Epidemiologic findings of a negative correlation between the intake of n-3 fatty acids and mortality from CHD provide further evidence for the protective effects of n-3 polyunsaturated fatty acids [48–50].

At present, it is impossible to exactly define the desirable daily intake of n-3 fatty acids. Presently, the ratio of n-6 to n-3 fatty acids in the average German diet is about 10:1. There is a consensus that this ratio should be decreased to 5:1, i. e. the proportion of n-3 fatty acids should be increased [14, 51]. This goal can be achieved when fish (rich in n-3 fatty acids: mackerel, herring, salmon, tuna) and oils rich in ALA, e. g. rapeseed oil, are consumed regularly.

Conclusions

The beneficial or detrimental effects of dietary fats on our health and well-being largely depend on their fatty acid composition. It is therefore important to develop more specific recommendations concerning the dietary intake of different fatty acid groups instead of postulating a general decrease in overall fat consumption. It is still mostly recommended not to exceed a total daily fat intake of 30 % of total energy [12–14]. However, even diets with a slightly higher fat content do not necessarily have a negative health impact. They can be even equivalent under the condition that 1) total fat content does not

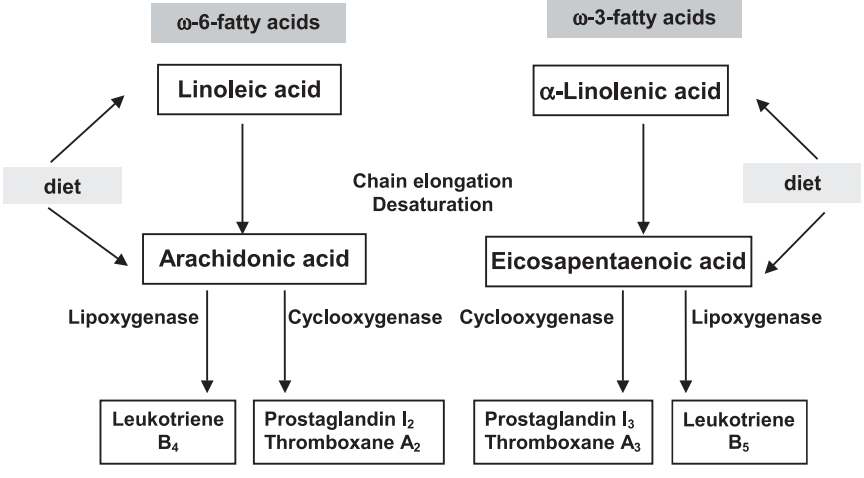

Fig. 1 Formation of eicosanoids from n-3 and n-6 fatty acids. Eicosanoids are synthesised from either arachidonic or eicosapentaenoic acid. These fatty acids are either directly supplied via the diet or are derived from dietary linoleic and a-linolenic acid by elongation and desaturation. Arachidonic and eicosapentaenoic acid can either be used to synthesise leukotrienes (lipoxygenase pathway) or prostaglandins and thromboxanes (cyclooxygenase pathway)

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exceed 35 % of total daily energy intake, 2) the content of saturated fatty acids does not exceed 10 %, 3) monounsaturated fatty acids from plant oils like rapeseed or olive oil supply the major portion of dietary fat, 4) the ratio of n-3 to n-6 is increased in favor of n-3 fatty acids and 5) the diet is rich in plant-derived foods such as whole meal cereal products, fruits, vegetables, legumes and potatoes [15, 41]. This type of diet with a higher focus on fat is especially suitable for persons with regular physical activity. It corresponds to the characteristics of the traditional Mediterranean diet, which is typically not necessarily low in fat. The major source of dietary fat is olive oil, rich in monounsaturated fatty acids, while the consumption of products with saturated fatty acids is low. Simultaneously, plant-derived foods are the main component of the daily diet. The health benefits of the traditional Mediterranean diet are indisputable. It can be adapted to country specific preferences by integrating country specific foods and will then convince by its health benefits as well as its excellent taste.

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