Dietary approaches for management of cardio-vascular health- a review

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Revised: 4 February 2012 / Accepted: 10 February 2012 / Published online: 2 March 2012
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Abstract Dietary patterns of consumers have changed and the importance of diet as a therapeutic adjunct in the form of nutraceuticals has become the trend of the millennium. Major contributory factor behind this trend is the idea of improving health by modifying the diet that is more attractive to the health conscious consumer as compared to drugs. According to a recent report of WHO, prevalence of cardio vascular disease has increased progressively in the past few years. It has been estimated that one-fifth of deaths in India are due to coronary heart disease that is inflicting at a much younger age in Indians than in the West. Such an insight suggests that cardiac health needs protection. Food products containing functional ingredients that are useful in controlling various different diseases are expected to provide health benefits. Recent research indicates that foods rich in omega-3 fatty acids, antioxidant vitamins and fibres may be beneficial for cardio-vascular health.

Keywords Nutraceuticals · Cardio vascular health · Omega-3 fatty acids · Whey proteins · Soy protein · Fibres · Hypocholesterolemic etc.

Introduction

With the evolution of novel technologies and scientific developments in the recent past, area of health foods has taken a new dimension. Also, people throughout the world are becoming increasingly convinced that the foods they consume can not only modulate performance but also influence their risk of acquiring a variety of diseases (Wrick 1995). According to

WHO estimates, 16.7 million people around the globe die of cardiovascular diseases each year (WHO 2003) and nearly 25 million deaths are estimated worldwide by the year 2020. Cardiovascular disease is more numerous in India and China than in all economically developed countries in the world added together. Many lines of evidence suggest that adverse dietary habits are a contributory factor for individuals with moderately raised cholesterol and/or triglycerides (TG) levels is to modify their diet. Drugs that are widely used to lower blood cholesterol are although effective in reducing blood cholesterol levels but are often associated with unpleasant side effects. On the other hand, dietary patterns if modified, especially in the type of fat consumed can have a beneficial impact on disease incidence (Table 1). In recent years, an increasing number of these potential nutritional products with medical and health benefits have gained an important place in the world market (Table 2). The food industry is constantly trying to provide products that are rich in fibre, low in cholesterol, fat and sodium, without compromising on the quality. The world market for functional foods has grown by about 60% over the period 1995–2000 (Varshney 2000).

The outlook for the future for health based foods are bright (Table 3). An overall growth rate of 10% per annum for the next 5 years is possible, significantly outperforming the overall foods and beverage market's growth of about 2% per annum (Weststrate et al. 2002). The following text reviews various dietary functional ingredients beneficial for management of cardiovascular health.

Possible dietary approaches towards reducing cardiovascular disease

A higher intake of total and saturated fat is widely believed to contribute to the development of Coronary Heart Disease (CHD). Current recommendations to decrease the risk of

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Table 1 Type of dietary fat – effect on plasma lipid

Dietary fat	Source	Plasma lipids		
		TAG	HDL-C	LDL-C
Saturated fats (SFA)	Palm oil coconut oil	Appreciably increase	Increase	Increase
Mono-unsaturated fats (MUFA)	Peanut oil Olive oil Avacados	Reduce	Neutral	Reduce
Polyunsaturated fats (PUFA)	Safflower oil Sunflower oil	Appreciably reduce	Reduce	Reduce

TAG triacylglycerol, HDL-C high density cholesterol, LDL-C low density cholesterol

developing atherosclerosis are to limit the fat intake to 25–30% of energy, saturated fat to less than 7% of energy and cholesterol to less than 200 mg/day. There is probably no quick fix for people seeking a simple nutritional approach to cardio protection. However, two groups of nutrients consumed as supplements may be a useful adjunct to cardio protective dietary pattern. A greater benefit might be expected from multifactorial dietary intervention than from changing a single nutrient (Mann 2002). In the primary and secondary prevention context, a dietary pattern that incorporates food and nutrients shown to be associated with reduced risks of CHD can produce, within a few years, risk reductions of the same size as those typically associated with Statin drug therapy.

Type of fat

Several ecological studies have been carried out relating dietary intake of saturated fats and rate of CHD. It is suggested that changes in the diet, especially in the type of fat consumed may be beneficial. In an analysis of Seven Countries Study,

Kroumhout et al. (1985) found a strong positive correlation of 25-year death rates from CHD with intakes of four major long-chain saturated fatty acids and trans fatty acids. A significant positive association between saturated fat intake and CHD risk was found by McGee et al. (1984) and Kushi et al. (1985). While in a study by Shekelle et al. (1981) a significant inverse association between polyunsaturated fat intake and CHD was found. Kris-Etherton and Yu (1997) on the effects of individual fatty acids on plasma lipids and lipoproteins maintained that, in general, saturated fatty acids are hypercholesterolemic while unsaturated fatty acids elicit a hypocholesterolemic effect. However, they emphasized that myristic acid is the most potent saturated fatty acid while stearic acid appears to be neutral. Monounsaturated fatty acids exert a neutral or mildly hypercholesterolemic effect, while trans fatty acids produce effect intermediate to those of the hypercholesterolemic saturated fatty acids, and the cis, mono- and polyunsaturated fatty acids and polyunsaturated fatty acids elicit the most potent hypocholesterolemic effect. Hu et al. (1997) found a weak positive association with intake of trans fatty acids and estimated that replacement of 5% of energy from

Table 2 Common food ingredients with health attributes

Ingredient	Health claim	Product example
Unsaturated fatty acids	Reduces risk of heart disease	Spreads, cookies
Soluble fibre from whole oats or psyllium husk	Reduces cholesterol and risk of heart disease	Cereals, cookies
Soy protein, soy fibre	Reduces cholesterol and risk of heart disease	Drinks, bars
Folic acid, Vitamin B 6	Decrease homocysteine and risk of cardiovascular disease	Cereals
Probiotic bacteria	Cholesterol reduction, anticarcinogen, antiinfective	Fermented foods
Vitamin E	Protects against cardiovascular disease	Supplements
Vitamin C	Protects against CVD	Drinks, sweets
Low in sodium	Reduces blood pressure	Drinks, soups
Plant stanols and sterols	Lowers cholesterol and risk of coronary heart disease	Margarine, yogurt, cereal bars
Catechins	Reduce cardiovascular risk	Tea
Conjugated linoleic acid	Reduces body weight, protects against cancer	Supplements (small amounts occur naturally in milk, beef and lamb)

CVD cardio-vascular disease

Table 3 Health Foods (Available)

Product name	Ingredients	Brand Name
Shelf-stable milk with added omega-3 s	Omega-3 fatty acids, milk	Nestle and Parmalat
The Heart Bar	L-arginine	Cooke Pharma
NovaDigest	Fructo-oligosaccharides and Fiber	Novartis
NovaCol	Oat-beta-glucan, soy isoflavone, Vit.E and C	Novartis
Goodhabits DHA-enriched Foods (eggs, beef and chicken)	Eggs, beef and chicken with upto 20 times normal level of DHA, 7 times more of Vit.E, 6 times the normal omega-3 content	American Nutraceuticals
Taste of Life Salad dressings	Vit. E enrichment	Kraft foods

DHA docosahexaenoic acid

saturated fats by unsaturated fats would reduce risk by 42% while replacement of 2% of energy from trans fat by unhydrogenated unsaturated fats would reduce risk by 53%. First line of treatment for individuals with moderately raised cholesterol and/or TG is to modify their diet by reducing the percentage of dietary energy derived from fat to approximately 30%, of which not more than 10% of energy should come from saturated fat. Lewis et al. (1981) have reported that dietary studies in the Netherlands involving reductions in fat intake (from 40% energy from fat to 27% energy from fat) resulted in greater than 20% reductions in serum cholesterol and serum triglycerides. Parks et al. (1998) carried out a study to determine whether a program including exercise therapy, stress management and consumption of a diet containing 10% fat could induce regression of cardiovascular disease. Their hypothesis states that LDL particles are altered by oxidation and the altered particles are taken up by the macrophages inside the arterial wall, and that cholesterol-laden macrophages initiate the formation of atherosclerotic plaques. The atherosclerosis-reversal therapy carried out by Zock and Katan 1998 indicate reduced plasma total cholesterol and LDL-C and also reduced LDL oxidation in the patients. The study suggested that a rigorous treatment program, including strict dietary control, might reduce LDL oxidizability, which

could be a factor in promoting cardiovascular health. Table 4 explains effect of dietary fatty acids on blood lipids.

Saturated fatty acids

Different classes of saturated fatty acids have different effects on plasma lipid and lipoprotein levels. Specifically saturated fatty acids with 12–16 carbon atoms tend to increase plasma total and LDL cholesterol levels. Among the cholesterol-elevating saturated fatty acids, myristic acid (14:0) appears to be more potent than lauric acid (12:0) or palmitic acid (16:0) (Kris-Etherton and Yu 1997). In the Oslo study, middle-aged men at high risk of CHD were taken in the experimental group and their intake of saturated fatty acid was replaced as far as possible with whole grain cereals, vegetables, fruits and some unsaturated fatty acids and consumption of oily fish was encouraged. The result was 36% reduction in total deaths and 44% decrease in cardiovascular events associated with a 13% reduction in cholesterol over 6 years when compared with the control group (Hjermann et al. 1981). A review of dietary fatty acids Khosla and Sundram (1996) pointed out that stearic acid (18:0) can not be considered cholesterol elevating and that lauric (12:0) and myristic acids are of concern where diets

Table 4 Effect of fatty acids on plasma lipids

Fatty acid type	Possible effect	Reference
Saturated fatty acids (lauric, Myristic, Palmitic)	Increase plasma total cholesterol & LDL-C	Kris-Etherton and Yu 1997
Saturated fatty acid - stearic	Reduces LDL-C & HDL-C	Aro et al. 1997
Mono-un-saturated fatty acid (Oleic & linoleic)	Partial reduction of HDL-C	Grundy et al. 1986
Omega-6 fatty acids	Reduces total cholesterol	Hu et al. 1999a, b
Omega-3 fatty acids	Reduces tri-glycerides and platelet aggregation	Lovegrove and Jackson 2000
Omega-6 : Omega-3 (ratio)	Lower risk of CHD	Hu et al. 1999a, b
IN GENERAL		
Saturated acids type	Hypercholesterolemic	
Cis, mono & PUFA type	Potential hypocholesterolemic	

TAG triacylglycerol, HDL-C high density cholesterol, LDL-C low density cholesterol

contain palm kernel oil, coconut oil or dairy products as major dietary constituents. Although stearic acid has little effect on total and LDL-cholesterol concentrations compared to carbohydrate, it may lower HDL-C compared to monounsaturated or polyunsaturated fatty acids, and the HDL-lowering effect of stearic acid was particularly strong among women (Yu et al. 1995). It has been reported by Aro et al. (1997) that compared with myristic and palmitic acids; stearic acid reduced LDL concentration but also reduced HDL level. With regard to palmitic acid (16:0), its response depends upon the metabolic status and age of the subjects under study, while older hypercholesterolemic individuals benefit from decreased consumption of palmitic acid and all saturated fatty acids. The relative levels of dietary cholesterol and linoleic acid have a significant bearing on the cholesterol response of palmitic acid.

Grundey et al. (1986) have suggested that the effect of oleic acid (cis 18:1) and linoleic acid (18:2) on LDL cholesterol are similar, and that the greater effect of linoleic acid on total cholesterol is through reduction of HDL cholesterol. It has been shown by Sardesai (1998) that oleic acid when substituted for saturated fatty acids decreases plasma cholesterol level. Therefore, the present recommendation is to decrease saturated fatty acids and increase the intake of monounsaturated acids. Such a diet has been consumed in the Mediterranean region where the concentration of plasma cholesterol and rates of CHD were found to be low.

Omega-6 polyunsaturated fatty acids

Dietary polyunsaturated fatty acids have been sub classified as n-6 and n-3, indicating the location of the carbon involved in the first double bond from the omega end of the carbon chain. The major n-6 fatty acid in the diet is α -linolenic acid (an essential fatty acid) which serves as the precursor for arachidonic acid (20:4, n-6), and have important biological effects in the body. Linoleic acid clearly has a hypocholesterolemic effect when substituted for dietary saturated fatty acids, reducing both LDL and HDL-C concentrations. However, arachidonic acid has little effect on plasma lipoprotein concentration (Nelson et al. 1997). Numerous metabolic studies have shown strong cholesterol-lowering effects of vegetable oils rich in linoleic acid when substituted for dietary saturated fat (Grundey et al. 1982). Dietary intervention trials using high-polyunsaturated fat diets have been more effective than those using low-fat-high-carbohydrate diets in lowering total serum cholesterol as well as rates of CHD (Sacks 1994). In prospective cohort studies among men, a strong inverse association for polyunsaturated fat was found in Western Electric Study (Shekelle et al. 1981) and borderline inverse associations were found in the Ireland-Boston Heart Study (Kushi et al. 1985) and the usual care group of the Multiple Risk Factor Intervention Trial (MRFIT) (Dolecek 1992). Omega-6 polyunsaturated fat

may have other beneficial effects on cardiovascular disease besides improving lipid profile. In the Nurses' Health Study, a higher intake of n-6 polyunsaturated fat was associated with a significantly lower incidence of type-2 diabetes (Hu et al. 1999a). In addition, animal studies have suggested an anti-arrhythmic effect when sunflower oil (rich in linoleic acid) was fed (Abeywardana et al. 1991). In the Nurses' Health Study (Hu et al. 1999b), the ratio of polyunsaturated fat to long-chain saturated fatty acids (P: S ratio) was strongly associated with a lower risk of CHD. It suggested that replacing long-chain saturated fat with polyunsaturated fat is likely to substantially reduce the risk of CHD. In addition, when intakes of polyunsaturated and trans fats were considered together (Hu et al. 1997), the lowest risk of CHD was observed among those who were in the lowest quintile of trans fat and the highest quintile of polyunsaturated fat. These results indicate a substantial benefit to substituting polyunsaturated fat (such as unhydrogenated soybean or corn oil) for trans fat (such as hard margarine) in the diet or other foods high in trans fatty acids.

Omega-3 fatty acids

These are considered as essential fatty acids. These can be found in fish and certain plant oils. There are three major types of omega-3 fatty acids that are ingested in foods and used by the body: (a) α -linolenic acid (ALA) (b) Eicosapentaenoic acid (EPA) (c) Docosahexaenoic acid (DHA). Once eaten, the body converts ALA to EPA and DHA, which are more readily used by the body. The benefits of the increased intake of n-3 PUFA lie in their ability to reduce thrombosis and decrease plasma TG levels (Lovegrove and Jackson 2000). Most epidemiologic studies and clinical trials using n-3 fatty acids in the form of fish or fish oil have been carried out in patients with coronary heart disease. However, studies have also been carried out on the effects of α -linolenic acid (ALA) in normal subjects and in patients with myocardial infarction (De Lorgeril et al. 1994). The hypolipidaemic effects of n-3 fatty acids are similar to those of n-6 fatty acids, provided that they replace saturated fats in the diet. Omega-3 fatty acids have the added benefit of consistently lowering serum triglyceride (TG) concentration, whereas the n-6 fatty acids do not and may even increase them (Phillipson et al. 1985).

Source of n-3 fatty acids

A low rate of Cardiovascular disease in populations with very high intake of fish, such as Alaskan Native Americans (Middaugh 1990; Newman et al. 1993), Greenland Eskimos (Bang et al. 1976; Kromann and Green 1980) and Japanese living fishing villages (Hirai et al. 1980; Kagawa et al. 1982) suggests that fish oil may be protective against atherosclerosis. Kroumhout et al. (1985) reported that as little as 30 g

of lean fish per day lowered the mortality from coronary heart disease by 50% than men who rarely ate fish. In the Western Electric Study, Daviglus et al. (1997) have found that men who consumed 35 g or more of fish per day had a 4% lower risk of fatal CHD. Two intervention studies, the Diet and Reinfarction Trial (DART) (Burr et al. 1989) and the GISSI Prevenzione Trial (1999) have evaluated whether fish consumption or fish oil supplementation reduces coronary mortality among myocardial infarction (MI) patients. The results of DART reveal that subjects who received fish advice had a significant reduction in total mortality of 29% after 2 years. The more recent GISSI-Prevenzione trial randomly assigned 11,324 MI patients to four different groups: n-3 fatty acids (850–882 mg EPA and DHA (1:2); vitamin E (330 mg α -tocopherol); a combination of n-3 fatty acids and vitamin E and Control group. Daily supplementation with n-3 fatty acids resulted in a 10 to 15% reduction in the main end points (death, non-fatal MI and stroke). Stark et al. (2000) conducted a study on the effects of n-3 fatty acid supplementation, specially fish oil, on postmenopausal women either receiving or not receiving Hormone Replacement Therapy (HRT) and reported that fish oil supplement significantly reduced serum concentrations by an average of 26% in both HRT-status groups without affecting other lipid variables. The effect was estimated to decrease CHD risk by 27% in postmenopausal women.

The protective effects of marine n-3 fatty acids are probably due to multiple mechanisms, including reducing TG levels (Harris 1989), reducing platelet aggregation (Von Shacky 2000) and anti-arrhythmic effects (Kang and Leaf 2000). Fish oil may also improve endothelial dysfunction, an early marker of atherosclerosis (DeCastrina et al. 2000; Goodfellow et al. 2000). Additionally, clinical experimental studies have shown that n-3 fatty acid supplementation improves endothelial-dependent vasomotor function (Goodfellow et al. 2000; Fleischhauer et al. 1993).

Alpha-linolenic acid (ALA)

It is an essential n-3 fatty acid for humans (Neuringer and Connor 1986; Neuringer et al. 1988) adequate intake of ALA and long-chain n-3 fatty acids is especially important for infants, young children (Nelson and Chamberlain 1995) and patients requiring parenteral and enteral nutrition (Holman et al. 1982; Bjerve et al. 1987; Nelson and Chamberlain 1995). In a dietary intervention study of French farmers by Renaud and Nordoy (1983) changed the type of fats by replacing butter with rapeseed oil and margarine rich in ALA. They found that EPA content of plasma lipids and platelet phospholipids increased significantly and platelet aggregation was significantly diminished after 2 years of feeding. In one of the experiments significant reductions in cardiac arrhythmia were observed by Siebert et al. (1993), in animals fed red meat

supplemented with canola oil (8% ALA), when compared to the control group (fed only red meat). Interestingly, mortality was even lower in the canola oil group than in fish oil group (7% vs 10%). Several epidemiological studies have examined the association between ALA intake and risk of CHD. In the usual care group of the Multiple Risk Factor Intervention Trial (Dolecek 1992), men in the highest quintile of ALA intake (expressed as percentage of energy) had a 40% lower CHD mortality compared to men in the lowest quintile. In the Health Professionals Follow-up Study (Ascherio et al. 1996), a 1% increase in linolenic acid intake (expressed as percent of energy) was associated with a 40% lower risk of fatal CHD. In the Finnish Alpha-Tocopherol, Beta Carotene Cancer Prevention Study (Pietinen et al. 1997), men in the highest quintile of energy-adjusted ALA intake had 25% lower CHD mortality. Hu et al. (1999b) found an approximately 50% lower risk of fatal CHD among women who consumed oil and vinegar salad dressing frequently (five to six times or more a week) compared to those who consumed this salad dressing less than once a month, after adjusting for vegetable consumption. Given the strong evidence to support beneficial effects of ALA on cardiovascular disease, flaxseed as well as other important dietary sources of ALA (eg. unhydrogenated canola and soybean oils and walnuts) can be incorporated into a healthy and balanced diet for the prevention of cardiovascular disease (Connor 1999). This is especially important for those choosing not to consume fish.

Type of protein

Scientific evidences reveal (Fosst and Tome 2000) that type of dietary protein may play a positive role in controlling high blood pressures, plasma cholesterol levels, liver cholesterol levels and LDL cholesterol.

Milk proteins Gerdes et al. (2002) suggested that whey containing various bioactive components (peptide fractions from α -lactoalbumin and β - lactoglobulin) that may have positive effect against hypertension and lowering cholesterol levels. Whey peptides formed during digestion process, may show ACE inhibitory activity which in turn control high blood pressure (Nurminen 2000). Opioid peptides having pharmacological similarity to opium, show promise as blood pressure modulator. Pfeuffer and Schrezenmier (2000) studied properties of milk bioactive substances and demonstrated that glycol-macro protein (GMP) derived peptides have antithrombotic activity. Beena and Prasad (1997) fed rats on yoghurt fortified with whey proteins, in the form of condensed and hydrolysed condensed whey, and found that whey proteins have marked effect on lowering of LDL cholesterol. They further found that whey proteins also lower liver cholesterol and significantly reduce plasma cholesterol by 35%.

Soy proteins In early 1970s American Heart Association suggested usage of soy proteins as a replacement for animal proteins for better cardio-vascular health. This led into number of researchers studying effect of soy proteins on various aspects of cardio health. Reported that diet rich in soy protein substantially reduce LDL cholesterol in severe hypercholesterolemia. They found textured soy protein (50% soy flour +50% soy protein concentrate) was effective than soy protein isolate containing 90% protein.

Dietary fibre

It is an umbrella term for a heterogeneous mixture of plant food components like edible plant cell, polysaccharides, lignin and associated substances resistant that are to digestion by the alimentary enzymes of humans (Gordon 1999). The heterogeneity of dietary fibre is the primary reason for the diversity of its physiological effects. Dietary fibres may be classified as water-soluble or gel forming viscous fibres and water insoluble fibres. Soluble fibre consists of pectin, gums and mucilages found in fruits, oat, barley, dried beans and legumes. They delays gastric emptying, slows glucose absorption, enhances immune function and lowers cholesterol levels. Whereas insoluble fibres consist of cell wall components and hemicellulose present mainly in most grain products and vegetables. They shortens bowel transit time, increases faecal bulk and renders faeces softer.

Role of dietary fibre in prevention of cardiovascular disease

A strong evidence for links between dietary fibre and atherosclerotic cardiovascular disease have been observed from animal studies (Pilch 1987), epidemiological observations (Rimm et al. 1996) and a limited number of clinical trials (Anderson 1995). Results of various human studies indicate that a variety of different soluble fibres, including guar, psyllium, pectin and oat bran have hypocholesterolemic properties (Stark and Madar 1994). While, insoluble fibres contribute to faecal bulk and transit times and have little or

no effect on cholesterol metabolism (Kritchevsky 1988; Madar and Odes 1990).

It was found by Morris et al. (1977) that those with a high intake of dietary fibre from cereals had a lower rate of CHD subsequently than the rest of the group. Over the past 20 years, numerous studies have examined the association between dietary fibre intake and risk for CHD (Table 5). Liu et al. (1982) conducted a univariate analysis on data for both men and women aged 35–74 year from twenty economically advanced countries. They found that fibre intake, estimated from consumption of vegetables, fruits, grains, legumes, yielded a significant inverse correlation with CHD mortality rates. An investigation by Kroumhout et al. (1985) enlisted the help of 871 middle-aged men in the Netherlands to evaluate risk indicators for CHD. After 10 year of follow-up, it was suggested that a diet of at least 37 g of dietary fibre per day might be protective against chronic diseases such as CHD. Khaw and Barrett-Connor (1987) evaluated the relationship between dietary fibre intake and 12 year mortality rates from ischemic heart disease in a population-based cohort of 859 men and women living in Southern California. They showed that every 6 g increase in daily fibre consumption was associated with a 25% reduction in ischemic heart disease mortality.

Decreasing the LDL cholesterol concentrations is one of the most effective means of decreasing risk for coronary heart disease (Manson et al. 1995). Dietary fibre, especially soluble, viscous fibres effectively decrease serum cholesterol and LDL cholesterol concentrations, which may contribute to their protective role against CHD (Anderson et al. 1990). Most soluble or viscous fibres have hypocholesterolemic effects (Anderson et al. 1990; Glore et al. 1994). In general, these soluble fibres, such as psyllium, oat bran, guar and pectin, decrease serum cholesterol and LDL cholesterol concentrations without affecting serum triglycerides. Often, consumption of these soluble fibres is accompanied by distinct reductions in serum HDL concentrations.

Anderson et al. (1994) and Anderson (1995), studied effect of fibres on serum lipids of rats after 3 week of consuming purified diets on animal models and compared 6–10 fibres in each study. They reported that psyllium had the largest cholesterol-lowering effect by decreasing serum

Table 5 Effect of dietary fiber on plasma lipids

Fiber type	Intake/day	Possible effect	Reference
Inulin	4–6 g	Reduces total cholesterol, tri-glycerol, plasmaVLDL	Fiordaliso et al. 1995 Trautwin et al. 1998 Tomamatsu 1994
Beta-Glucan (Oat fiber)	3–4 g	Reduces plasma cholesterol, Binds bile salts 7 enhance fecal excretion	Whyte et al. 1992 Levrat et al. 1994
Oligosaccharides	6–10 g	Reduces total cholesterol	Tomamatsu 1994

VLDL very low density lipoprotein

cholesterol by 32% and liver cholesterol by 52%. Oat gum and Guar gum were slightly less effective and decreased serum cholesterol by approximately 22%, compared with values for cellulose-fed rats. Pectin has been reported to have a wide range of effects, depending on molecular weight and degree of methoxylation (Ebihara et al. 1979; Judd and Truswell 1982), whereas oat bran and soy fibre produce modest effects (Anderson et al. 1994; Anderson 1995). In humans, psyllium and guar gum are reported to be the most effective cholesterol-lowering soluble fibres (Anderson et al. 1990). The hypocholesterolemic effects of psyllium (Olson et al. 1997), guar gum (Todd et al. 1990) and oat bran (Ripsin et al. 1992) are well documented by meta - analyses.

Animal studies have consistently shown that fibres that reduce plasma cholesterol increase neutral sterol or bile acid excretion (Illman and Topping 1985; Kritchevsky 1988; Arjmandi et al. 1992). Many large epidemiological studies such as Nurses' Health Study and Scottish Heart Health Study have demonstrated a reduced risk for CHD in both men and women who consume higher amounts of dietary fibre (Anderson and Hanna 1999; Todd et al. 1999; Wolk et al. 1999). A recent meta-analysis examining soluble fibre sources from pectin, oat bran, guar gum and psyllium reported a small but significant reduction in serum cholesterol levels (Brown et al. 1999). The studies on effect of fibre on cholesterol levels generally report a decrease in total cholesterol and LDL cholesterol with no changes in HDL or triglycerides. Studies have also been done on using combination foods effective in lowering plasma cholesterol and TG concentrations.

Oat as dietary fibre

Oats contains significant amounts of soluble dietary fibre which comprises mainly of β -glucan. Dietary oats has been shown to confer a number of significant physiological effects in the prevention or alleviation of disease, and thus may be considered as a multifunctional food. The ability of oats to reduce plasma cholesterol, and in particular the low-density lipoprotein (LDL)-cholesterol fraction, has received substantial attention. The soluble fibre β -glucan gum is the major hypocholesterolemic component (Ripsin et al. 1992; Welch 1995). The United States Food and Drug Administration (FDA) has recently recognized a claim which states 'diets low in saturated fat and cholesterol that include soluble fibre from whole oats may reduce the risk of heart disease'. To be eligible for a claim, oat products should provide at least 3 g β -glucan/day, which is equated to 60 g whole oat product (flakes, meal or flour) or 40 g oat bran. Oat products also exhibit prebiotic effects. Topping et al. (1989) suggest that oat bran in combination with long chain n-3 PUFA from fish oil results in lowering of total cholesterol and plasma TG.

Effects of oat fibre

Oat bran has an appreciable level of soluble fibre, which has been shown to reduce plasma cholesterol levels under controlled conditions (Whyte et al. 1992). It has been reported by DeGroot et al. (1963) that rolled oats in the form of bread when given to 21 male volunteers resulted in 11% reduction in serum cholesterol over a period of 3 week. The studies of Anderson et al. during the period of 1984–1993, suggest that oat bran might reduce total serum cholesterol in hypercholesterolemic subjects by as much as 20% with no change in HDL cholesterol. Meta-analysis by Ripsin et al. (1992), tested the hypothesis that oat supplementation would lower serum cholesterol levels. Ten clinical trials were evaluated, and a reduction of 5.9 mg/dl in total cholesterol was noted in subjects consuming an oat supplement. However, the most significant reductions were found in trials that used hypercholesterolemic subjects with initially higher cholesterol levels. In a study by Anderson et al. (1984), it was found that when hypercholesterolemic men were randomly allocated to oat-bran supplemented diets for 21 days, their serum cholesterol concentration was decreased by 19% and calculated low-density lipoprotein cholesterol by 23%. Kirby et al. (1981) reported that oat-bran intake selectively lowers serum low-density lipoprotein cholesterol (LDL-C) concentrations of hypercholesterolemic men. On oat-bran diets, average reductions in serum total cholesterol concentrations were 13%; plasma LDL-C concentrations were 14% lower while HDL-C concentrations were not changed.

Diminishing total plasma cholesterol concentrations with oat bran intake has been reported by Schrijver et al. (1992). They further reported that non-heated and baked oat bran had comparable effects on plasma cholesterol. Processing does not reduce the hypocholesterolemic effect of the fibre supplement and in fact shows a trend towards producing a greater hypocholesterolemic effect than unprocessed fibre (Shinnick et al. 1988). Using strict criteria to select a number of oat bran studies for meta - analysis Ripsin et al. (1992) concluded, *inter alia*, that daily doses of beta - glucan more than 3 g were needed for good effect. Furthermore, it was observed that those subjects who had the most dramatic decrease in cholesterol levels were those who had the highest initial serum cholesterol concentrations to begin with. Shinnick et al. (1988), have also reported that diets containing 4–6% oat fibre resulted in substantially lower liver cholesterol and plasma cholesterol as compared to cellulose diet. Behall et al. (1997) used a 1 and 10% beta glucan level of *Oatrim* and found that the optimal daily intake of beta glucan might be quite modest (ca.6 g); overall, the subjects achieved an average reduction in serum cholesterol of 22% and lost weight.

Inulin as dietary fibre

Inulin is a carbohydrate belonging to a class of compounds known as fructans. It is composed mainly of linear chains of fructose units linked to a terminal sucrose molecule (Gibson et al. 1994). Some 36,000 plants from a wide variety of genera contain inulin as an energy reserve, or as an osmoregulator, and many such plants are being consumed by mankind for centuries. The commonly consumed foods containing inulin include wheat, onions, garlic, bananas, leeks, artichokes and asparagus (Van Loo et al. 1995). Because inulin is resistant to digestion in the upper gastrointestinal tract (Knudsen and Hesso 1995) it reaches the large intestine essentially intact, where it is fermented by indigenous bacteria. Thus, it may be classified as a soluble dietary fibre (Roberfroid 1993).

Effects of inulin

The effects of chicory fructans on triglyceridaemia have been studied mainly in rats, but preliminary human studies have already been reported. Data concerning the effect of inulin on cholesterolaemia are scarce, but one study performed on slightly hypercholesterolemic volunteers has reported a significant reduction both in total and LDL cholesterol (Davidson et al. 1998). Dramatic reductions in serum triglycerides have been reported in rats consuming relatively high doses of oligofructose, although reductions in cholesterol have been seen only with long-term feeding (Delzenne et al. 1993; Fiordaliso et al. 1995). Recent studies have shown the effects on serum triglycerides to be due to reduced secretion of VLDL particles from the liver and to be associated with reduced activity and gene expression of the key regulatory enzyme, fatty acid synthase (Kok et al. 1996). As per the study by Trautwin et al. (1998), plasma total concentrations in male hamsters were significantly lowered by 18, 15 and 29% in hamsters fed 8, 12 and 16% inulin respectively. Moreover, significant reductions in VLDL concentrations occurred in hamsters fed 16% inulin while plasma TG were significantly reduced by 40 and 63% in hamsters fed 12 and 16% inulin respectively. It is also reported that male Wistar rats when fed a diet supplemented with inulin (10% in diet) significantly lowered serum TG and phospholipid concentrations (Delzenne et al. 1993). The hypotriglyceridemia is mostly due to a decrease in the concentration of plasma VLDL (Fiordaliso et al. 1995). This effect is due to a reduced hepatic de novo fatty acid and TG synthesis (Kok et al. 1996). It has been hypothesized that there is modulation of hepatic cholesterol synthesis by fermentation products, e.g. propionate and the increased faecal excretion of bile acids has a major impact on hypolipidaemic effect (Levrat et al. 1994).

Studies in experimental animals and limited data from human subjects suggest that dietary inulin like other soluble

dietary fibres may modulate the concentration of serum lipids (Tomamatsu 1994; Fiordaliso et al. 1995). Supplemental inulin could prove to be useful adjunct in the dietary management of hypercholesterolaemia by performing the following functions: 1) having a possible direct influence on serum lipids, 2) replacing certain cholesterol-raising fatty acids in some food formulations, and 3) reducing the calorie density of selected foods by substituting inulin for part of the fats or sugars in the foods (the caloric content of inulin is 4.13 kJ/g (or 1 Kcal/g) (Roberfroid et al. 1993). Significantly lower triglyceride and cholesterol concentrations in male volunteers who consumed 9 g inulin (*Raftiline*) added to a rice breakfast cereal for a period of 4 week was observed by Canzi et al. (1995). The study was a randomised sequential design with a placebo period (rice cereal) followed by a test period (rice cereal plus inulin). Total cholesterol and LDL-C levels were reduced by 5 and 7% respectively, with the inulin treatment compared with the placebo. Fasting triglycerides were reduced by 27% during inulin treatment and remained significantly lower 4 week after the end of the inulin phase. More recently, Davidson et al. (1998) in a randomised cross-over trial in subjects with modest hyperlipidemia, showed significantly lower total and LDL concentrations during inulin compared with placebo phases, but there was no effect on HDL-C levels or serum triglyceride concentrations. In a study conducted on 58 middle-aged subjects with moderately raised blood lipid concentrations, subjects consumed 10 g/day of inulin or placebo in a powdered form, which could be added to beverages, soups, cereals etc. During 8 week intervention, the serum triglycerides levels were 19% lower than the control group.

Brighenti et al. (1999) also observed significantly lower triglycerides and cholesterol concentrations in young male volunteers who consumed 9 g inulin added to a rice breakfast cereal for a period of 4 weeks and levels remained significantly lower for 4 weeks after the end of the inulin phase. Causey et al. (2000) also observed a significant reduction in serum triglycerides concentrations in subjects with moderate hyperlipidemia given 18 g/d inulin for 3 weeks.

Antioxidant vitamins

A complex antioxidant system normally protects mammalian cells and cholesterol from the injurious effects of free radicals. Antioxidants are substances that, when present at much lower concentrations than an oxidizable substrate, significantly delay or prevent its oxidation. Certain essential antioxidants are provided by the diet. These include vitamin E, beta-carotene and vitamin C, which protect cells from damage by oxidants (Padh 1991). Esterbauer et al. (1992) showed that the antioxidant content of LDL influences its susceptibility to oxidation in vitro. Increasing the vitamin E content of the LDL by dietary supplementation of volunteers also inhibited oxidation of LDL to the atherogenic

form. Cross-cultural investigations (Gey 1986, 1992) have found that mortality due to cardiovascular disease is inversely related with a cumulative antioxidant index. A study by Riemersma et al. (1989) suggests that low plasma concentrations of vitamin E and C and beta-carotene are associated with high risk of angina in middle-aged Scottish men.

Vitamin E

The term ‘Vitamin E’ is often used to denote a mixture of biologically active tocopherols, which are potent inhibitors of lipid peroxidation. Vitamin E functions as a cellular antioxidant, protecting susceptible cellular components such as unsaturated fatty acids by interrupting free radical reactions that otherwise can cause membrane damage. There are at least two plausible mechanisms by which Vitamin E might protect against heart disease. One by protecting blood lipoproteins, that carry cholesterol through the bloodstream, against oxidation (Reaven et al. 1993; Jialal et al. 1995) thereby retarding the development of atherosclerosis. A second mechanism involves the inhibition of blood clotting, a process that is involved in the initiation of a heart attack (Calzada et al. 1997). The major dietary sources of vitamin E are vegetable oils such as olive and rapeseed, which are rich in vitamin E and low in PUFA but high in monounsaturated fatty acids, are functionally more beneficial. The epidemiological and biochemical studies indicate that protection of high-risk groups from cardiovascular disease could require an intake of 36–100 mg/day of vitamin E (Diplock 1992). The Cambridge Heart Antioxidant Study (CHAOS) was designed to test the hypothesis that treatment with a high dose of alpha-tocopherol (400 or 800 IU/d) would reduce the risk of myocardial infarction in patients with evidence of coronary atherosclerosis (Stephens et al. 1996). A cross-cultural study of 16 European population groups showed that the risk of heart disease was higher in populations with low blood levels of Vitamin E (Gey et al. 1991). Two large observational epidemiological studies conducted by researchers from the Harvard School of Public Health showed that middle-aged men and women who took

single-entity vitamin E supplements (100 IU/d or more) had substantially lower risks of heart disease than those with lower vitamin E intakes (Rimm et al. 1993; Stampfer et al. 1993). These investigations suggest that an intake of ≥ 100 IU/d of vitamin E would exert a beneficial effect on reducing the risk of CHD.

Vitamin A

Carotenoids are primarily symmetrical, C-40, polyisoprenoid structures with an extensive conjugated double bond system. Of all the carotenoids, beta-carotene is particularly effective at scavenging peroxy radicals under physiological conditions and is also a potent scavenger of singlet oxygen (Burton 1989). A possible synergistic action of beta-carotene with vitamin E is indicated by the study of Palozza and Krinsky (1992). They reported that beta-carotene and lycopene inhibit the oxidation of LDL to its atherogenic form. It has been reported by Chow et al. (1986) that plasma carotenoid concentrations are lower in smokers, a high-risk cardiovascular disease group than in non-smokers. Diplock (1992) suggests an intake of 15–25 mg/day for high-risk groups. Several epidemiological studies have associated high dietary intakes or blood levels of beta-carotene with reduced risks of heart attack (Gey et al. 1993; Kritchevsky et al. 1993; Manson et al. 1995; Rimm et al. 1993). In a clinical trial conducted by Gaziano et al. (1990) for men with high-risk of cardiovascular disease indicated that there were reduced cardiovascular risks in subjects taking beta-carotene supplementation as compared to those taking placebos.

Vitamin C

Vitamin C is a strong, water-soluble antioxidant and is the first line of defence against oxidative stress in plasma. It serves as an intercellular and extra cellular quencher of free radicals, thereby protecting cells and their components. It efficiently scavenges O_2^- , OH^- , peroxy radicals and singlet oxygen. Vitamin C can thus protect biomembranes and LDL from peroxidative damage. Ascorbate also potentiates the action

Table 6 Ways to modify foods to attain functionality

Food modification by addition of	Examples of possible functionality
Phytochemicals	Antioxidant, lower risk of CHD, lower risk of cancer, lower blood pressure
Bioactive peptides	Enhanced immune function, enhanced bioavailability of minerals, hypotensive
Dietary fiber	Prevention of constipation, lower risk of colon cancer, lowering of blood cholesterol
Omega-3 polyunsaturated fatty acids	Lower risk of heart attack, lower risk of some cancers, enhanced immune system
Probiotics	Improved gastrointestinal function, enhanced immune system, lower risk of colon cancer
Prebiotics	Improved gastrointestinal function, enhanced immune system, lower risk of colon cancer

CHD coronary heart diseases

of Vitamin E by reducing the tocopheroxy radical to tocopherol, thereby preventing its potential pro-oxidant effect in LDL particles. Therefore, supplementation with vitamin E and C might be more effective than supplementation with vitamin E alone (Liu and Meydani 2002). According to a study by Fang et al. (2002), vitamin C and E supplementation retards the early progression of Arteriosclerosis in heart transplant patients. Their action is primarily inhibition of plaque growth. The incidence of cardiovascular disease is inversely related to plasma vitamin C concentrations (Gey et al. 1987). Plasma vitamin C concentrations are 50% of those in non-smokers (Chow et al. 1986; Duthie et al. 1993). An optimum intake of 100–150 mg/day for high-risk groups is suggested by Esterbauer et al. (1992).

Conclusion

Evidences suggest that adverse dietary habits are a contributory factor for individuals with moderately raised cholesterol and triglycerides (TG) levels. Foods consumed can modulate performance and influence the risk of acquiring a variety of diseases. Current recommendations to decrease the risk of developing atherosclerosis are to limit the fat intake to 25–30% of energy, saturated fat to less than 7% of energy and cholesterol to less than 200 mg/day. Dietary intervention trials using high-polyunsaturated fat diets have been more effective than those using low-fat-high-carbohydrate diets in lowering total serum cholesterol as well as rates of CHD occurrence. Foods can be modified using a variety of nutraceutical substances including plant fibres, beta-carotene, phytochemicals, bioactive peptides, omega-3 PUFA, isoflavones, tocotrienols, allyl sulphur compounds, conjugated linoleic acid and probiotics and/or prebiotics to become functional (Table 6). These may be helpful in reducing the blood serum cholesterol and triglyceride content that are major culprits towards CHD.

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