

MiniReview

Reducing blood cholesterol by a healthy diet

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Abstract: The number of hypercholesterolemic people is increasing rapidly in the world. Diet and nutrition are important factors in the promotion and maintenance of health throughout life. According to the World Health Organization (WHO) and the Food and Agricultural Organization (FAO), several dietary patterns, along with lifestyle habits (exercise, smoking, and alcohol consumption), constitute major modifiable risk factors in relation to the development of non communicable diseases: cardiovascular diseases (CVD), cancer, type 2 diabetes, obesity, osteoporosis and dental diseases. Improving diet and lifestyle is a critical component of the American Heart Association's (AHA) strategy for cardiovascular disease risk reduction in the general population. Hypercholesterolemia is one of the major risk factors for heart disease. In this review, cholesterol reducing effects of different categories of food are presented. Also technical aspects of adding these functional components to foods are discussed.

Keywords: Cholesterol, functional food, cardiovascular disease, diet

Introduction

Cholesterol is a waxy, fat like substance made in the liver and found only in animal products. It is synthesized in many tissues from acetyl-CoA (Botham *et al.*, 2009). Cholesterol is required to build and maintain cell membranes. It also aids in bile production (which helps digest fats), and is also important for the metabolism of fat soluble vitamins. It is the major precursor for the synthesis of vitamin D and the various steroid hormones which include cortisol and aldosterone in the adrenal glands, and the sex hormones progesterone, the various estrogens, testosterone, and derivatives (Smith, 1991).

There are various types of cholesterol, including low density lipoprotein (LDL) which is a bad form of cholesterol, high density lipoprotein (HDL) which is considered as a good form of cholesterol and triglycerides, a form of fat carried through the bloodstream (James *et al.*, 1998). The main function of LDL is to transport cholesterol from the liver to tissues that incorporate it into cell membranes. HDL carries "old" cholesterol that has been discarded by cells back to the liver for recycling or excretion (Colpo, 2005).

The objective of this paper is an overview of making a few changes in diet. This can reduce cholesterol specially LDL and improves heart

health and decrease the other problems caused by high level cholesterol. We present recent researches carried out on natural foods that help reducing or limiting cholesterol level of body. Finally, we will discuss about technical aspects of enrichment of food products with cholesterol reducing ingredients.

Cholesterol reducing foods

Phytosterols (plant sterols)

Plant sterols are naturally occurring components of plants, especially seeds and oils. Common plant sterols include the unsaturated sterols β -sitosterol, campesterol and stigmasterol and their saturated counterparts sitostanol and campestanol. Although phytosterols and cholesterol have similar chemical structures (vary in side chain), they differ markedly in their synthesis, intestinal absorption and metabolic fate (Moghadasian *et al.*, 1999).

As a food ingredient or additive, phytosterols have been shown to reduce total cholesterol and LDL-cholesterol in normocholesterolemic and hyperlipidemic populations (Micallef *et al.*, 2008). The phytosterols are thought to displace cholesterol from bile acid micelles and/or co-precipitate cholesterol in the intestinal lumen, thereby limiting its uptake (Yokoyama, 2004). Intake of phytosterols and/or phytostanols at the level of 1.5-3.0 g/day has

been documented to reduce blood LDL-cholesterol by 10% (Katan *et al.*, 2003; Demonty *et al.*, 2009).

Technical Aspects

Enriched products with this functional ingredient are recently presented on the markets. Major problems related to enrichment of products with plant sterols are high melting temperature, chalky taste and low solubility in water phase. Administering crystalline phytosterols, however, did not promote a significant decrease in serum cholesterol when compared to phytosterols dissolved in edible fat products (Normén *et al.*, 2003). Esterification of the plant sterols and stanols with long chain fatty acids increases their lipid solubility and facilitates their incorporation into foods (Noakes *et al.*, 2005) to levels as high as 10-20% (Ostlund, 2002).

A study to compare the effects of phytosterol esters and plant free sterols on beta-carotene and alpha-tocopherol found that phytosterol esters reduced their bioavailability more than did plant free sterols (Richelle *et al.*, 2004).

In the USA, plant sterols, stanols and their esters were given Generally Recognized As Safe (GRAS) status. On the basis of this recognition, the US Food and Drug Administration (FDA) approved fat spreads containing up to 20% of either steryl or stanyl esters (Quilez *et al.*, 2003). EU Commission published Regulation 608/2004/EC concerning the labeling of foods and food ingredients with added phytosterols and/or phytosterol esters, requiring such products to be labeled with additional information including the words "with added plant sterols/plant stanols". In United Kingdom, the food with added phytosterols (labeling) Regulations 2004 were published to provide for the enforcement in England of Regulation 608/2004/EC (Anon., 2004).

Products enriched with phytosterols/stanols are innovative types of functional foods. In the Netherlands, phytostanol enriched margarines (Benecol®) and phytosterol-enriched margarines (Becel pro.activ®) are on the market since 1999 and 2000, respectively. Since 2006 the phytosterol-enriched low-fat margarine, Reducol® has been introduced. Other phytosterol-enriched food products including dairy products have been introduced from 2003 onwards. The brands Becel pro.activ® and Reducol® launched also yoghurt type products, and Becel pro.activ® also includes a milk drink and a yoghurt drink in different flavours. Recently, a phytosterol-enriched cheese (ColActiv®) became available in a number of Dutch supermarkets (De Jong *et al.*, 2008).

Phytosterols have been combined with other

beneficial dietary components including fish and olive oils, psyllium and beta-glucan to enhance their effect on risk factors of CVD (Jones *et al.*, 2009). Table 1 shows reducing effect of plant sterols in yogurt and margarines. Moghadasian and Frohlich (1999) demonstrated that co-administration of plant sterol, soy protein material and isoflavone may synergistically decrease LDL and total cholesterol concentrations in the blood.

Table 1. Reducing effect of plant sterols in yogurt and margarine

Food carrier/ serving size per day	Daily intake	LDL reduction (%)	Reference
Margarine (25 g)	2 g	7.5	(Malcolm, 2000)
Yogurt (3×150 ml)	3 g	13.7	(Mensink <i>et al.</i> , 1992)
Yogurt (2×150 g)	1.8 g (stanols)	6.1	(Clifton <i>et al.</i> , 2004)
Phytosterol- enriched fermented milk	(multiple or single-dose drinkable or spoon yogurt)	10	(Hansel <i>et al.</i> , 2007)

Fibers

Dietary fiber is a collective term for a variety of plant substances that are resistant to digestion by human gastrointestinal enzymes. Dietary fibers classified in 2 major groups depending on their solubility in water, soluble and insoluble fibers. Studies have focused on soluble fibers such as oats, psyllium, pectin and guar gum, and qualitative reviews suggested that these fibers lower total and LDL cholesterol. Water insoluble wheat fiber and cellulose have no effect unless they displace foods supplying saturated fats and cholesterol (Brown *et al.*, 1999). It is thought that soluble fiber lowers blood cholesterol by binding bile acids, which are made from cholesterol to digest dietary fats, and then excreting them (Glore *et al.*, 1994).

β -glucan

β -glucan from barley or yeast has been shown to be hypocholesterolemic. There are several possible mechanisms by which β -glucan is thought to reduce serum cholesterol levels; many are related to the ability of soluble fibres to form viscous gel in the intestinal tract. It has been proposed that β -glucan reduces plasma cholesterol through its ability to bind acids in the gastrointestinal tract. As β -glucan bind bile acid in the intestinal tract, the bile acid level decreases in the body and thus the dietary cholesterol is utilized for the synthesis of bile acid by the liver (Saikia *et al.*, 2011).

Technical aspect

Cholesterol lowering effect of β -glucan from oat fiber in slightly hypercholesterolemic subjects may

decrease when β -glucan is incorporated into bread and cookies. β -glucan lowers serum concentrations of total and LDL cholesterol when incorporated into a fruit drink (Naumann *et al.*, 2006). Application of β -glucan prepared from spent brewer's yeast as a fat replacer in mayonnaise was studied, which resulted in the reduced fat (RF) mayonnaises with lower calorie but higher storage stability than their full fat (FF) (100% oil) counterpart. However, the addition of the β -glucan preparation adversely affected mayonnaise appearance and color leading to the significantly lower sensory quality as compared with the FF control sample. Nevertheless, the substitution levels of not more than 50% of oil used were found to be acceptable (Worrasinchai *et al.*, 2006).

Pectin

Pectin is a soluble dietary fiber and has a linear chain of 1-4 linked α -D-galacturonic acid that forms the pectin backbone. In the pharmaceutical industry, it is used to reduce blood cholesterol levels and gastrointestinal disorders (Thakur *et al.*, 1997). The mechanisms appeared to be related to 1) pectin can impair bile acid absorption *in vitro*, 2) certain complex carbohydrates have been shown to bind bile salts. By binding bile salts in the intestine, pectin may interfere with bile acid reabsorption, and thus, increase cholesterol degradation and excretion. Also, by the same mechanism, pectin may interfere with micelle formation which is essential in cholesterol absorption (Kelley *et al.*, 1978).

Technical aspect

In the food industry, pectin is used in jams, jellies, frozen foods, and more recently in low calorie foods as a fat and/or sugar replacer. Pectin can also be used to stabilize acidic protein drinks, such as drinking yogurt. For beverages the chosen pectin type is mixed with other powdered ingredients and then incorporated into the liquid matrix during the manufacturing process.

Guar Gum

Guar gum is a galactomannan, a storage polysaccharide, obtains from the cluster beans (*Cymposis tetragonoloba*). Guar gum, a great source of dietary fiber contains 80-85% total dietary fiber, almost in the soluble form may help to lower blood cholesterol and glucose levels (Pszczola, 2003). The mechanism responsible for the cholesterol lowering effect of dietary fiber like guar is partly related to enhanced excretion of bile acids. LDL cholesterol lowering effect of about 5-10% can be achieved with daily consumption of 8-36 g guar gum (Butt *et al.*,

2007).

Technical aspect

The largest market for guar gum (EU food additive code E412) is in the food industry due to its ability to hydrate without heating, where it is used as a thickener and binder of free water in sauces, salad dressings, ice creams, instant noodles, pet foods, processed meats, bread improvers and beverages.

Psyllium (Plantago ovate)

Psyllium, a water-soluble fiber, has been shown to reduce total cholesterol and LDL cholesterol in humans (Fernandez *et al.*, 1995). Reports of the use of psyllium, largely in hypercholesterolemic men, have suggested that it lowers serum cholesterol as a result of the binding of bile acids in the intestinal lumen and reduces risk of coronary heart disease (Van Rosendaal *et al.*, 2004).

The strong gelling property of psyllium polysaccharides is closely related to its health benefits and applications, such as use as a binding agent in the landscape industry. The origin of this gelling behaviour was due to the fibrillar gel structure of psyllium polysaccharide (Guo *et al.*, 2009).

Technical Aspect

Psyllium offers a potential adjunct to a low-fat diet for the treatment of hypercholesterolemia in the pediatric population because of its ease of incorporation into various foods (Davidson *et al.*, 1996). Psyllium can replace gluten in preparations, products made with modified dough had less fat and fewer calories (Zandonadi *et al.*, 2009).

Vegetables and herbs

The largest amount of published literature exists for guggul, fenugreek, red yeast rice and artichoke, on reductions in total serum cholesterol. Increases in HDL and decreases in LDL levels are seen with guggul (*Commiphora mukul*) and decreases in LDL levels are seen in studies of fenugreek (*Trigonella foenum-graecum*) and artichoke (*Cynara scolymus*), (Thompson Coon *et al.*, 2003).

Red yeast rice

Red yeast rice, an Asian dietary staple made by fermenting yeast (*Monascus purpureus*) on rice, is rapidly gaining recognition as a cholesterol-lowering agent in United States, Indonesia, Japan, Taiwan, and Philippine people are been used as *Monascus-nata* complex (Sheu *et al.*, 2000). The HMG-CoA reductase activity of red yeast rice comes from a family of naturally occurring substances

called monacolins. Monacolins K, also known as mevinolin or lovastatin, is the ingredient in red yeast rice. However, red yeast rice contains a family of nine different monacolins, all of which have the ability to inhibit HMG-CoA reductase. Other active ingredients in red yeast rice include sterols (beta-sitosterol, campesterol, stigmasterol, sapogenin), isoflavones, and monosaturated fatty acids (Heber *et al.*, 1999). Red yeast rice modestly decreased total and LDL cholesterol, was well-tolerated, and was an acceptable alternative in patients intolerant of other lipid lowering medications (Venero *et al.*, 2010).

Technical aspect

Red yeast rice is used as a flavoring and coloring agent, and to preserve the flavor and color of products such as fish, meat and fruit flavored yogurt, also pigments produced by the mold, *Monascus purpureus*, offer a possible alternative to certified food dyes or natural pigments now used (Erdoğan *et al.*, 2004).

Garlic

The active ingredients of garlic (*Allium sativum*), allicin, and other sulfur compounds may act as HMG-CoA reductase inhibitors reducing the production of cholesterol in the liver (Isaacsohn *et al.*, 1998). Allicin may prevent the retention of LDL cholesterol by the body. Reported mechanisms include reduced hepatic HMG-CoA reductase activity and increased bile acid excretion (Warshafsky *et al.*, 1993). Table 2 summarizes some studies done on cholesterol reducing effect of garlic.

Table 2. Summaries some studies done on cholesterol reducing effect of garlic

Serving	Effect on LDL	Reference
Fresh garlic (1.5-3 g/d) for 2-6 month	lower cholesterol by 9%	(Warshafsky <i>et al.</i> , 1993)
Garlic supplemented diets	inhibit the synthesis of cholesterol in the liver	(Yeh <i>et al.</i> , 2001)
Garlic (600-900 mg/d) for one-to-four month period	lower cholesterol by 9 to 12%	(Silagy <i>et al.</i> , 1994)

Green tea

Green tea is a popular beverage derived from the tea plant (*Camellia sinensis*). Based on the observations, it is likely that green tea or its catechins lower the absorption and tissue accumulation of other lipophilic organic compounds (Koo *et al.*, 2007). In another study, it observed that heat treated catechins high in gallic acid gallate (GCG) and catechin gallate (CG) were more effective in inhibiting cholesterol absorption than a catechin mixture high in epigallocatechin gallate (EGCG) and

epicatechin gallate (ECG), (Ikeda *et al.*, 2003). The tea flavin enriched green tea extract is an effective adjunct to a low saturated fat diet to reduce LDL in hypercholesterolemic adults (Maron *et al.*, 2003).

Technical Aspects

Rong and Zhou (2004) added various types of tea extracts to bread with good success. Table 3 presents cholesterol reducing effect of other herbs.

Table 3. Presents cholesterol reducing effect of some edible herbs

Herb	Effect on LDL reduction	Reference
Artichoke	limits synthesis of cholesterol	(Andrew, 2005)
Wild yam	decreases in LDL, increases in HDL	(Ulbricht <i>et al.</i> , 2003)
Berberine	lower serum cholesterol levels	(Kong <i>et al.</i> , 2004)
Maitake	reduces cholesterol by increasing fat metabolism	(Fukushima <i>et al.</i> , 2001)
Guggul	reduces serum cholesterol	(Urizar <i>et al.</i> , 2003)
Fenugreek	reduces serum total cholesterol, triacylglyceride and LDL-cholesterol	(Moosa <i>et al.</i> , 2006)

Nuts

Nuts include dietary fiber, plant sterols and phytochemicals. Nuts are high in fat, mainly monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs). The benefit of nuts has been attributed to their high level of PUFAs, a high polyunsaturated/saturated (P/S) ratio, and their high MUFA content (Mattson *et al.*, 1985). Over the past several decades evidence has accumulated suggesting that dietary intake of saturated fatty acids (SFA) and trans fats increase cardiovascular risk, but MUFA and PUFA intake decrease risk. The changes in dietary fat intake that have been occurring since the 1970s have been a reduction in SFA and replacement of SFA with PUFA. The apparent protective effect of increasing the PUFA/SFA ratio supports these dietary changes in the prevention of CVD (Erkkilä *et al.*, 2008).

Walnuts

Walnuts display a high fat content (62-68%), being rich in MUFA and PUFA (Tapsell *et al.*, 2009), fiber (5-10%), phytosterols, vitamins, niacin, antioxidants and other micronutrients (Olmedilla-Alonso *et al.*, 2006). Research shows that adding walnuts to diet decreases LDL levels comparing to diets without the supplement (Tapsell *et al.*, 2004).

Macadamia

Macadamia nuts contain substantial levels of plant sterols (1.28 mg/g lipid), which are shown to inhibit cholesterol absorption. Macadamia nuts as part of a healthy diet favorably altered the plasma lipid profile, despite an increase in the dietary fat content (Garg *et al.*, 2003).

Pistachio

Pistachio nuts significantly decrease in total cholesterol levels and total cholesterol/HDL and LDL/HDL ratios, and an increase in HDL levels (Kocyigit *et al.*, 2006). The substitution of pistachio nuts for other fat calories in the form of snacks for a consecutive three-weeks period can significantly improve the lipid profile in patients with moderate hypercholesterolemia. It seems that it was due to a change in MUFA content of the pistachio diet (Edwards *et al.*, 1999).

Almonds

Almonds can help lower cholesterol. The almonds fiber content is a dietary factor known to reduce cholesterol and its plant sterols, which may help to limit cholesterol absorption. The fatty acid composition is also a main factor that lowers LDL cholesterol and preserves HDL cholesterol (Agunbiade *et al.*, 2006).

Technical Aspects

Nuts are generally high in vitamin E and fiber, characteristics which would make them healthier alternatives to snack foods such as microwave popcorn, buttered popcorn, most candy bars, potato chips, etc.

Milk and dairy products

Dairy products are including fermented and non-fermented. Studies strongly suggest that fermented milk (FM) have an important cholesterol lowering potential (Anderson *et al.*, 1999). Fermented milk has been shown to cause an increase in human gut bacterial content. These bacteria, once resident in the large intestine, are believed to ferment food derived indigestible carbohydrates. Such fermentation causes increased production of short chain fatty acids, which decreases circulatory cholesterol concentrations either by inhibiting hepatic cholesterol synthesis or by redistributing cholesterol from plasma to the liver. Furthermore, increased bacterial activity in the large intestine results in enhanced bile acid deconjugation (St-Onge *et al.*, 2000). The mechanism of action is probably that the bacteria deconjugate bile acids which, when deconjugated, coprecipitate with cholesterol at a pH <5.5. The liver will compensate for the loss of bile acids by converting cholesterol into new bile acids. This conversion might lower serum cholesterol levels (De Roos *et al.*, 1999). Consumption of milk products containing *Lactobacillus acidophilus* has the potential for reasons of preventing or controlling intestinal infections, improving lactose digestion in persons classified as lactose maldigestors, helping

control serum cholesterol levels and exerting anticarcinogenic activity (Lye *et al.*, 2009). Results showed that lactobacilli were able to reduce cholesterol via conversion of cholesterol to coprostanol, aided by the ability of strains to produce cholesterol reductase. The strains studied may be potential health adjunct cultures in fermented dairy products with possible in vivo hypocholesterolemic effects (Lye *et al.*, 2010). Based on newer knowledge of "*L. acidophilus*", a single strain of the organism probably will not produce all these benefits at optimal levels. Careful selection of specific strains of "*L. acidophilus*" combined with proper production and handling procedures is necessary to ensure that desired benefits are provided to consumers (Gilliland, 1989).

Acidophilus milk

Factors influencing the efficacy of acidophilus milk to lower serum cholesterol are type of milk employed for product manufacture, age, sex, food habits and initial concentration of cholesterol of test subjects. Consumption of acidophilus milk as a dietary adjunct can be recommended (Sarkar, 2003). It was hypothesized that the higher level of immunoglobulin G (IgG) was responsible for the decline in cholesterol concentrations (St-Onge *et al.*, 2000). "*L. acidophilus*", being the natural inhabitant of intestine and possessing bile salt hydrolase activity, can be exploited during the manufacture of acidophilus milk and its application as a means for reducing cholesterol level is recommended (Sarkar, 2003).

Kefir

Kefir is another fermented dairy product that may decrease LDL content of blood. Results indicate that Kefir grains contains cholesterol degrading enzyme (Farnworth, 2005).

Sea products (Omega-3 fatty acids)

Omega-3 fatty acids (n-3 fatty acids or ω -3 fatty acids) are a family of unsaturated fatty acids. Omega-3 PUFA concentrates provide a useful alternative for the intake of required amount of fatty acids (Kapoor *et al.*, 2011). Because these essential fatty acids (EFAs) cannot be synthesized in the human body, they must be derived from dietary sources. Flaxseed, hemp, canola, and walnuts are generally rich sources of the omega-3 PUFA Alpha-Linolenic Acid (ALA). Fish provide varying amounts of omega-3 fatty acids in the form of docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) (Logan, 2003).

Omega-3 fatty acids lower plasma triglyceride levels, particularly in persons with

hypertriglyceridemia, by inhibiting the synthesis of very-low-density lipoprotein (VLDL) cholesterol and triglycerides in the liver (Kapoor *et al.*, 2011). Omega-3 fatty acids has demonstrated an efficacy and safety in adult patients with high and very high triglycerides adjunct to diet, and the reduction in serum triglyceride levels was dependent on the baseline triglyceride levels (McKenney *et al.*, 2007). The FDA has concluded that dietary dosages of up to 3 g per day of omega-3 fatty acids from marine sources are GRAS. For persons who are vegetarians or non-fish eaters, a total daily intake of 1.5 to 3 g per day of ALA seems to be beneficial (Kris-Etherton *et al.*, 2002).

Technical Aspects

Due to high oxidization susceptibility and undesirable aroma of these fatty acids, enrichment of foods with those sources, has a negative effect on sensory properties of enriched foods. It has been shown that microencapsulation protects PUFAs against oxidation (Barrow *et al.*, 2009). This is a technology that involves coating or entrapping of material within a secondary material or system (Madene *et al.*, 2006). The pioneer in launching an omega-3-enriched milk was the Italian dairy company Parmalat. Its 'Plus Omega 3' milk was launched in 1998 and is a semiskimmed milk enriched with 80 mg omega-3. It is recommended for use by all health-conscious consumers in a dose of half a litre per day (Mellentin *et al.*, 1999).

Conclusion

Cholesterol is a blood fat needed by the body in moderate amounts. High level of cholesterol can lead to several diseases like as coronary artery disease, atherosclerosis and heart attack. There are several foods that have been shown to reduce cholesterol level. Most studied lowering cholesterol foods are, foods containing plant sterols, stanols, soluble fibers and omega-3 fatty acids. During the past decade, enrichment of food products with functional ingredients is a major objective of food product developers. The market of this category of products has a big increasing rate. For example, the market of functional dairy products had a value of about 50 billion dollar in 2005 and has 8% increasing rate until 2010 (Market research 2008). Cholesterol lowering foods in combination with a healthy lifestyle are the most effective ways of lowering cholesterol level naturally.

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