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Review

Water-soluble dietary fibers and cardiovascular disease

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Abstract

One well-established way to reduce the risk of developing cardiovascular disease (CVD) is to lower serum LDL cholesterol levels by reducing saturated fat intake. However, the importance of other dietary approaches, such as increasing the intake of water-soluble dietary fibers is increasingly recognized. Well-controlled intervention studies have now shown that four major water-soluble fiber types—β-glucan, psyllium, pectin and guar gum—effectively lower serum LDL cholesterol concentrations, without affecting HDL cholesterol or triacylglycerol concentrations. It is estimated that for each additional gram of water-soluble fiber in the diet serum total and LDL cholesterol concentrations decrease by −0.028 mmol/L and −0.029 mmol/L, respectively. Despite large differences in molecular structure, no major differences existed between the different types of water-soluble fiber, suggesting a common underlying mechanism. In this respect, it is most likely that water-soluble fibers lower the (re)absorption of in particular bile acids. As a result hepatic conversion of cholesterol into bile acids increases, which will ultimately lead to increased LDL uptake by the liver. Additionally, epidemiological studies suggest that a diet high in water-soluble fiber is inversely associated with the risk of CVD. These findings underlie current dietary recommendations to increase water-soluble fiber intake.

Keywords: β-glucan; Psyllium; Pectin; Guar gum; Cholesterol-lowering mechanism; Cardiovascular disease

Contents

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1. Introduction

Despite remarkable improvements in its prevention, diagnosis and therapy, cardiovascular disease (CVD) remains the leading cause of morbidity and mortality in the United States and most Western countries [1]. One well-established way to reduce the risk of developing CVD is to lower serum LDL cholesterol levels by making dietary changes. In addition to reducing saturated fat and cholesterol intake, and increasing *cis*-unsaturated fat intake, the importance of other dietary approaches, such as increasing the intake of water-soluble dietary fibers has become increasingly recognized.

Dietary fiber is a collective term for a variety of plant substances that are resistant to digestion by human gastrointestinal enzymes. Dietary fiber can be classified as either water-soluble or water-insoluble. The structural or nonviscous fibers (lignins, cellulose, and some hemicelluloses) are water-insoluble. Vegetables and cereal grains are especially rich in water-insoluble fiber, with the highest amounts in wheat and corn. Water-insoluble fiber is responsible for increased stool bulk and help to regulate bowel movements. The natural gel-forming or viscous fibers (pectins, gums, mucilages, algal polysaccharides, some storage polysaccharides, and some hemicelluloses) are water-soluble. Foods rich in water-soluble fiber are dried beans, oats, barley, and some fruits and vegetables [1]. The mean total daily fiber intake amongst adults in most industrialized countries is well below 25 g, the minimal amount recommended by various health organizations. Of total dietary fiber intake, approximately 20% is water-soluble and 80% is water-insoluble [2].

The main purpose of this review is to discuss the effects of different water-soluble dietary fiber types—β-glucan, psyllium, pectin, and guar gum—on cholesterol metabolism and cardiovascular risk. We limited the review to those water-soluble fibers for which more than five intervention studies were published. First, we focused on the hypocholesterolemic effects of these four major water-soluble fiber types. Next, possible mechanisms underlying the cholesterol-lowering effects were described. Finally, we summarized the epidemiological studies that contrasted the intake of total dietary fiber with that of cereal fiber, an excellent source of water-soluble fiber.

2. Hypocholesterolemic effect of water-soluble fibers

2.1. β-glucan

β-glucan is a water-soluble fiber found in cereals, in particular oats and barley, as well as in yeast, bacteria, algae, and mushrooms. In fact, one of the richest sources of β-glucan is the cell wall of baker's yeast *Saccharomyces cerevisae*. Regardless of its source, β-glucan is a polysaccharide composed of glucose molecules. In bacteria and algae, however, the glucose molecules are joined by β-(1→3)-glycosidic bonds forming a linear chain, while in yeast and mushrooms the glucose molecules are joined by β-(1→3)- and β-(1→6)-glycosidic bonds, and in oats and barley by β-(1→4)- and β-(1→3)-glycosidic bonds. Thus, β-glucan from these latter sources is composed of branched chains. Functional foods enriched with β-glucan from mainly oats are widely available on the market to decrease serum LDL cholesterol.

De Groot et al. were the first to report that in healthy men 3-week consumption of 300 g of bread, containing 140 g of rolled oats, decreased serum total cholesterol concentrations by 11% [3]. Since that time, many studies have been carried out on the cholesterol-lowering effects of oats, which were later found to be due to their β-glucan contents [4]. Results of several uncontrolled metabolic ward trials have been summarized by Anderson et al. and reductions in serum total cholesterol from 13% to 26% were reported [5]. These reductions were mainly found in the LDL cholesterol fraction. Although many of these metabolic ward studies showed impressive lipid reductions [6–8], trials with free-living subjects reported considerably more variability in lipid responses. Some studies found reductions greater than 10% [9–11], but a few studies demonstrated virtually no benefit [12–14]. Inconsistencies in the reported effects of oat products may be due to several factors, such as mode of administration, or differences in solubility or molecular weight. Kerckhoffs et al., for example, investigated the effects of β-glucan in bread and cookies (study 1) and in orange juice (study 2). In study 1, forty-eight mildly hypercholesterolemic subjects received bread and cookies rich in wheat fiber or bread and cookies rich in β-glucan (5.9 g per day) for 3 weeks. Serum LDL cholesterol concentrations decreased slightly by 3% after β-glucan consumption. This change however did not reach statistical significance. In study 2, the same sources and daily amounts of control fiber and β-glucan as in study 1 were provided. Twenty-five subjects now consumed orange juice containing either wheat fiber or β-glucan for 2 weeks. It was found that serum LDL cholesterol concentrations decreased significantly by 6.7% [15]. Thus, this study suggest that the food matrix and/or the food processing affects the hypocholesterolemic properties of β-glucan.

Water-solubility and molecular weight of β-glucan may also influence its hypocholesterolemic effect. Indeed, it has been postulated that the viscosity of β-glucan in the intestinal tract, which is positively related to its solubility in water and molecular weight, is an important determinant of its LDL cholesterol-lowering effects. Highly water-soluble β-glucan, with moderate to high molecular weight, may reduce serum LDL cholesterol levels better than β-glucan with a low water-solubility and low molecular weight. This difference in effect is explained by the assumption that a higher intestinal viscosity lowers the reabsorption of bile acids, leading to an increased excretion of bile acids. Increased bile acid excretion promotes bile acid synthesis from cholesterol, which will increase LDL cholesterol uptake in the liver.

Although a few individual studies showed virtually no effects, several meta-analyses concluded that water-soluble fiber from oat products effectively lowered serum total and LDL cholesterol concentrations [16–18]. In the most recent meta-analysis, Brown et al. estimated that 1 g of water-soluble fiber from oats lowered total and LDL cholesterol concentrations with −0.037 mmol/L and −0.032 mmol/L, respectively [18] (Fig. 1). Studies were