A Review of Plant Sterols in Spreads and Dairy Foods

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Plant sterols are plant compounds with similar chemical structure and biological functions as cholesterol. Compared with cholesterol, plant sterols contain an extra methyl, ethyl group or double bond in the side chain. The most abundant plant sterols are sitosterol, campesterol and stigmasterol. Due to their structural similarity to cholesterol, plant sterols were first and foremost studied for their cholesterol absorption inhibition properties, and were first described as cholesterol-lowering agents over 50 years ago (1). Absorption efficiency for plant sterols (2-5%) in humans is considerably less than that of cholesterol (60%) except for those with the very rare condition of sitosterolemia (2). Consequently plant sterol levels in plasma are less than one thousandth of the levels in cholesterol (3).

The daily dietary intake of plant sterols is 160-400 mg among different populations. Dietary sources include vegetable oils (especially unrefined oils), nuts, seeds and grains so vegetarians may eat up to 750mg a day, which would provide some degree of cholesterol lowering (4-10).

Plant sterols have only been used in food products since 1995 when a stanol-rich spread (a hydrogenated sterol not available in Australia) was introduced into Finland. Plant sterol-containing spreads were introduced into Australia over 10 years ago. Permission to market plant sterols in low fat milks, low fat yoghurts and breakfast cereals was granted by FSANZ in November 2006 and products in the first category are widely available now. Approval to market phytosterol esters in cheese was granted by FSANZ in February 2010.

Efficacy of plant sterols

Plant sterols have been shown in over 50 publications and subsequent meta analyses to lower LDL cholesterol by about 10% with a maximal effect at a dose of about 2.5-3g/day (11). Tall oil derived plant sterols have been used in studies since 1977 (12) but only a minority of clinical trials have used tall oil sterols. Available literature suggests their efficacy is the same as rapeseed and soybean sterols and stanols (13,14). Two studies have looked at either plant sterols (15) derived from tall oil or stanols (16) in low fat cheese products and these demonstrated LDL cholesterol-lowering of 9.8-10.3%.

Sterols and stanols in spreads

The efficacy of plant sterols (and stanols) in spreads has been widely researched and it has been shown that 2-3g plant sterols a day lower LDL cholesterol on average by 10%. Malcolm Law in 2000 (17) examined 14 trials (4 sterol and 10 stanol) and found that in a qualitative review at doses of 2g per day the average reduction in serum LDL cholesterol was about 9-14%. There was a dose response that was significant with a maximum at about 2g/day. This degree of cholesterol-lowering might reduce the risk of heart disease by a maximum of 25% after 2 years (11). A further qualitative review by Katan in 2003 (18) examined 41 trials and found an average 10% lowering of LDL cholesterol but a formal Cochrane style meta analysis has not been done . Almost all trials have been done in both men and women who were mildly hypercholesterolemic (5-7.5 mmol/L). The same percentage lowering was seen on a normal fat diet and a low fat diet and a significant effect was seen in 3 weeks and persisted for at least 52 weeks with continuing consumption. The volunteers used in these studies would be very similar to the typical patient seen in general practice.

Sterols and stanols in dairy and cereal foods

Fewer studies have demonstrated the efficacy of plant sterols in low fat foods such as bread, cereal, yoghurt and milk, and only 13 studies have been published since 2001. Milk and yoghurt are consumed more commonly than spreads by some population groups and can provide a very useful additional vehicle for delivery of sterols for the treatment of hypercholesterolemia, especially in reduced fat forms of these foods. These studies showed a

6-14% lowering of LDL cholesterol, demonstrating that they are as efficacious in low fat dairy as they are in high fat spreads although yoghurts can be quite variable in their responses The bulk of the trials have used sterols or stanols esterified with a fatty acid to improve lipid solubility.

Sterols and stanols in cheese

Plant sterols and stanols appear to be as effective in some cheese products as in spreads with lowering of LDL cholesterol of about 10% in the small number of studies performed. No significant changes in HDL cholesterol or triglyceride occur with either food carrier. Korpela (16) carried out a parallel, double-blind study in three locations in Finland involving 64 mildly or moderately hypercholesterolaemic subjects who were randomly divided into two groups: a plant sterol group and a control group. The subjects consumed the products for 6 weeks after a 3-week run-in period with a targeted plant sterol intake of 2g/day in the sterol group. Yoghurt, low-fat hard cheese and low-fat fresh cheese enriched with a plant sterol mixture reduced serum LDL cholesterol by average 10.4%. The HDL/LDL cholesterol ratio increased by 16.1% in the sterol group and by 4.3% in the control group (P=0.0001). None of the fat-soluble vitamin levels decreased significantly when changes in serum total cholesterol were taken into account.

Jauhiainen (15) conducted a randomized double-blind parallel-group study in sixty-seven mildly hypercholesterolaemic volunteers (24 men, 43 women). During the 5-week intervention, the subjects in the stanol group consumed a hard cheese enriched with 2g of plant stanols per day, and the subjects in the control group, a control cheese with no plant stanols. In the stanol ester group, as compared to the control group, LDL cholesterol decreased by 10.3% (P‹0.001). The change in LDL cholesterol was 0.36 (95% CI =-0.53 to -0.18).There were no significant changes in high-density lipoprotein cholesterol (HDL), triglycerides or apolipoprotein B concentrations between the groups. The lack of change in the latter suggests LDL particles are have got smaller and contain less cholesterol but have not been reduced in number. Apo B has not often been measured in plant sterol and stanol interventions.

Clifton (unpublished) assessed the effect of 2g/day of tall oil sterol in cheese slices and cream cheese. Forty-eight subjects completed the study. They had an average BMI of 28 (range 19-39.2), age 58 years (range 38-71 years), an average total cholesterol of 5.7 (range 4.1-7.6 mmol/L) and LDL cholesterol of 3.7 (range 2.6-5.8 mmol/l). LDL cholesterol decreased by 4 and 4.8% respectively (both p‹0.01). If only participants with a baseline total cholesterol of 5.5 mmol/L or above are considered then the change in LDL cholesterol is 0.23 mmol/L (or 6%) and 0.29 mmol/L (or 8%) for cheese slice and cream cheese respectively.

The relative effectiveness of plant sterols in different foods

As noted above, sterol-enriched dairy products, whether high or low in fat, are as effective as non-dairy spreads in lowering LDL cholesterol but there have been few head-to-head comparisons in the same individuals except the study by Noakes (19). In the Noakes' study plant sterol-enriched milk lowered LDL cholesterol by 6-8% and the sterol-enriched spread lowered it by 8-10% and there was no statistical difference between them. There was no additive effect from consuming both milk and spread containing plant sterols (total 4g/day). The only head-to-head comparison of the relative effectiveness of different food forms as sterol carriers was performed by Clifton et al (20). 58 people consumed 1.6g/day of esterified sterols in either milk, yoghurt, bread or breakfast cereal for 3 weeks each. Serum total and LDL cholesterol levels were significantly lowered by consumption of phytosterol-enriched foods: milk (8.7 and 15.9%) and yoghurt (5.6 and 8.6%). Serum LDL cholesterol levels fell by 6.5% with bread and 5.4% with cereal – they were both significantly less efficacious than sterol-enriched milk (P‹0.001). Plasma sitosterol increased by 17-23% and campesterol by

48-52% with phytosterol-enriched milk and bread. Lipid-adjusted beta-carotene was lowered by 5-10% by sterols in bread and milk respectively. Thus although bread did not lower LDL cholesterol to the same degree as milk the plant sterols appeared to be available for absorption and to interfere with beta carotene absorption. Whether cholesterol absorption was inhibited equally is not known.

Richelle et al (21) compared the effects of free and esterified sterols in low fat milk on cholesterol absorption. Inhibition of cholesterol absorption was equal (about 60%) but the esterified sterol interfered with beta carotene (50% inhibition) and tocopherol absorption (20% inhibition) significantly more than free sterol suggesting a free sterol formulation (which is not available on the market yet in Australia) might have less potential adverse effects.

However, a recent paper by Jones et al (22) showed no efficacy of free sterol in lowering TC and LDL-C when consuming a sterol-enriched low-fat beverage. Moreau et al (23) have suggested that, at least with free sterols and stanols, the efficacy in lowering LDL-C is dependent on the formulation and delivery in a 'bioavailable' physical state. This implies that efficacy may need to be assessed for each phytosterol formulation in the context of the form of delivery. This may also be the case with esterified phytosterols delivered by low fat foods, as the number of studies which have examined efficacy is relatively small. A recent paper also showed that consuming up to 9g/d of esterified plant stanols lowers LDL by 17.4% compared with 7.4% with 3g/day suggesting there may be some benefit from higher doses of stanols. No adverse effects on carotenoid levels were shown (24).

Conclusion

In conclusion current literature today supports that plant sterol-enriched spreads, full fat milks and yoghurts and a wide variety of cheese forms are efficacious in cholesterol lowering.

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