AN OVERVIEW ON PHYTOSTEROLS

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Abstract : Phytosterols are cholesterol-like molecules found in all plant foods, with the highest concentrations occurring in vegetable oils. They are absorbed only in trace amounts but inhibit the absorption of intestinal cholesterol including recirculating endogenous biliary cholesterol, a key step in cholesterol elimination. Natural dietary intake varies from about 167-437 mg/day. Attempts to measure biological effects in feeding studies have been impeded by limited solubility in both water and fat. Esterification of phytosterols with long-chain fatty acids increases fat solubility by 10-fold and allows delivery of several grams daily in fatty foods such as margarine. A dose of 2 g/day as the ester reduces low density lipoprotein cholesterol by 10%, and little difference is observed between Delta(5)-sterols and 5alpha-reduced sterols (stanols). Phytosterols can also be dispersed in water after emulsification with lecithin and reduce cholesterol absorption when added to nonfat foods. In contrast to these supplementation studies, much less is known about the effect of low phytosterol levels in the natural diet. However, reduction of cholesterol absorption can be measured at a dose of only 150 mg during otherwise sterol-free test meals, suggesting that natural food phytosterols may be clinically important. Current literature suggests that phytosterols are safe when added to the diet, and measured absorption and plasma levels are very small. Increasing the aggregate amount of phytosterols consumed in a variety of foods may be an important way of reducing population cholesterol levels and preventing coronary heart disease.

Index Terms - Endogenous biliary cholesterol , esterification of phytosterols.

PHYTOSTEROLS

INTRODUCTION

The term phytosterols refer to plant “sterols” and “stanols”. Sterols are essentially lipid-like complex unsaturated alcohols without which most living things could not survive as they form the foundation for steroids, which are precursors for vitamin D and certain hormones such as testosterone and progesterone. The most ambiguous of sterols is cholesterol which we have all heard of, as something that clogs up our arteries creating havoc. However, its important role in maintaining cell membrane structure is less appreciated.

Phytosterols (including plant sterols and stanols) cannot be synthesized by humans and all the plant sterols and stanols in the human body therefore originate from the diet . They are known to have several bioactive qualities which possible implications for human health. Their properties for reducing blood cholesterol levels, as well as their other beneficial health effects have been known for many years. It was recognized in the 1950’s that plant sterols lower serum concentration of cholesterols. Plant sterols might also protect against certain types of cancer such as colon, breast and prostrate. The safety of plant sterols, plant stanols and their esters has been affirmed by government agencies such as the US Food and Drug Administration and the European Union Scientific Committee. In addition, these plant fractions have been sanctioned for use in food.

People with high blood cholesterol levels are typically advised by health prossionals to exercise and consume a diet high in fiber and low in the in saturated fats and cholesterol . Although these measures can reduce blood cholesterol , sometimes they do not go far enough . Other cholesterol lowering medicines or adding phytosterols esters to the diet . The enrichment of foods such as margarines wiyh phytosterols is one of the recent developments in the functional foods to enhance the cholesterol-lowering ability of traditional food products. The objective of this article is to present briefly describes of the phytosterols dietary sources and intake, the enrichment of food products with phytosterols legislation and labeling .

1. CHEMICAL STRUCTURE OF PHYTOSTEROLS

Sterols are ubiquitous in eukaryotic cells but absent from prokaryotic . Sterols are anessential component of cell membranes, both animals and plants produce them . They play a key role in cell membrane function . The sterol ring is common to all sterols; the difference are in the side chain . Plant sterols include a wide variety of molecules that are structurally similar to cholesterol ; the principal examples are 4-desmethyl sterols. Plant sterols are C-28 or C-29 sterols, differing from cholesterol (C-27) by the presence of an extra methyl (campesterol) or ethyl (sitosterol) group on the cholesterol side chain. While over 40 plant sterols from seven different plant classes have been identified campesterol (C-28) , stigmasterol (C-29) and especially β- sitosterol (C-29) are the most abundant.

The term plant sterol amd phytosterol are sometimes used as generic terms to include both unsaturated sterols and saturated stanols , but they are used here to refer specifically to the unsaturated compounds . Saturated plant sterols reffered to as plant stanols have no double bond in the ring structure . Plant stanols are produced by the hydrogenation of sterols and are not abuundant in nature . Sitostanol and campesterol are saturated plant sterols , which are found in nature in much smaller amount than plant sterols . The structure of sitosterol,sitostanol, campesterol and campestanol are shown in figure. In food , cholesterol occurs either as the free alcohic sterol or as cholesteryl esters , where as plant sterols occur as free plant sterols , esterified plant sterols, plant steryl glycosides and acylated plant steryl glycosides . It is obvious that chemical , physical and nutritional properties of these phytosterol classes may be very different . The different fractions are assumed to exist in different parts of the cell wall with a structural property . Plant steryl esters are generally believed to be storage products . They can be found in the cytosol of plant cells in droplets or vesicles . The largest amount of plant steryl glycosides fraction of the plant cell and acylated steryl glycosides are believed to exist in mitochondria .

These plant lipid-like components are chemically similar to the dietary and endogenously secreted cholesterol and exist in all foods of plant origin, as monomer, glycosides, esters . They differ from cholesterol only in the identity of one side chain or the presence of the extra double bond . The different chemical forms of phytosterols exist in different compartments of the plant cell . For example:- free phytosterols are mainly found in the plant membrane wall to give structure properties while phytosterol glycosides and esters mainly an found in the cytosol and endoplasmic reticulum .

Vegetable oils are the major source of free phytosterols. Most crude vegetable oil contain 1-5 g/kg of total phytosterols. The major phytosterol components of some of the commonly consumed vegetable oils (crude and refined).

Sitosterol is the major sterol in vegetable oil especially in refined/ crude rapeseed oil while sitostenol occurs at negligible levels in plant lipids . Refining of oils lowers the phytosterols levels. They may also react by atmosphere oxygen and undergo isomerization and other intermolecular transformation reactions. Campesterol and stigmasterol are more labile than sitosterol. Commercially , phytosterols are isolated from vegetable oils , such as soybean oil, rapeseed (canola) oil, sunflower oil or corn oil or from so-called "tail oil", a byproduct of the manufacture of wood pulp. Phytosterols can be hydrogenated to obtain esters are chemically stable material , having comparable chemical and physical properties to edible fats and oils . The substances are insoluble in water, but soluble in non-polar solvents, such as hexane, iso-octane and 2-propanal. The esters are also soluble in vegetable fats and oils.

2.1 SOURCES OF PHYTOSTEROLS

Phytosterols are compounds naturally found in plants that reduce the amount of cholesterol your body absorbs, according to Oregon State University's Linus Pauling Institute. This can reduce blood cholesterol levels, which can help lower the risk of heart disease. Traditional diets, before the advent of processed foods, provided as much as 1000 mg of physterols per day. Today, someone eating a typical Western diet consumes less than half that amount. All plant foods provide some phytosterols.

Oils

Plant oils are the most highly concentrated source of phytosterols but they should be unrefined in order to preserve these heart-healthy compounds, according to the Linus Pauling Institute. A tbsp. of sesame oil provides 118 mg of phytosterols while the same amount of corn oil provides 102 mg. Other good choices include canola and olive oils. A recent study in the American Journal of Clinical Nutrition found that when phytosterols were removed from commercial corn oil, cholesterol absorption increased 38 percent. The study also found that the phytosterol content of refined oils varies greatly depending on how the product is refined.

Nuts and Seeds

Nuts and seeds are also an excellent source of phystosterols, according to the Linus Pauling Institute. A study by researchers at Virgina Tech recommended that people snack on pistachios and sunflower seeds as they contained the highest amount of phytosterols among common snack foods. The researchers looked at 27 different varieties of nuts and seeds. Sesame seeds and wheat germ actually provided higher concentrations of phytosterols but the researchers felt that most people don't eat those foods in amounts large enough to make a real difference. A ½ cup of wheat germ provides 197 mg of phytosterols. Other good choices include peanuts, almonds and macademia nuts.

Fortified Foods

Phytosterols have been added to a number of foods in recent years and have been shown in clinical trials to help lower cholesterol, according to the Linus Pauling Institute. A tbsp. of phytosterol-enriched margarine can contain 850 to 1650 mg of phytosterols, depending on the brand. Other phytosterol-fortified foods include mayonnaise, yogurt, milk, cheese, chocolate, orange juice, vegetable oils, salad dressings, soymilk and snack bars. Read the nutrition label to find out whether and how many phytosterols a particular product contains.

Other Sources

Some grains contain significant quantities of phytosterols, according to the Linus Pauling Institute. A ½ cup of wheat bran contains 58 mg while two slices of rye bread provide 33 mg. Brussels sprouts are also high in phytosterols, providing 34 mg in a ½ cup serving. Supplements are also available in the form of beta-sitosterol pills or a soft chew. These supplements should be taken with meals that contain fat in order to reduce absorption of cholesterol, according to the Linus Pauling Institute.

2.2 MECHANISM OF ACTION OF PHYTOSTEROLS

The exact mechanism by which phytosterols decrease serum cholesterol levels is not completely understood, but several theories have been proposed. One of them suggests that cholesterol in the intestine, already marginally soluble, is precipitated into a nonabsorbable state in the presence of added phytosterols and stanols. Another theory is based on the fact that cholesterol must enter bile-salt and phospholipid-containing 'mixed micelles' in order to pass through intestinal cells and to be absorbed into the bloodstream. Moreover, phytosterols may modulate the action of key transporters involved in cholesterol absorption . Cholesterol absorption is a very important physiological mechanism that regulates cholesterol metabolism. A recent trial showed that efficacy of phytosterols is not influenced by dietary cholesterol intake in hypercholesterolemic individuals. Both dietary cholesterol (~300 mg/day) and recirculating biliary cholesterol (~1000 mg/day) mix in the intestine and are partially absorbed. Failure to reabsorb intestinal cholesterol is the principal means of cholesterol elimination from the body. Some studies show that phytosterols compete with and displace cholesterol from bile salt/phospholipid micelles, the form from which cholesterol absorption occurs. During one trial, nine adults were fed a meal containing 500 mg of cholesterol and 1 g beta-sitosterol or 2 g beta-sitosteryl oleate. The addition of beta-sitosterol resulted in a 42% decrease in cholesterol absorption, and the beta-sitosteryl oleate caused a 33% reduction compared to the control group, which resulted in a consequent decrease in plasma cholesterol. Sitosterol has increased affinity for biliary micelles compared with cholesterol, so sitosterol uptake by micelles is energetically favored. Further evidence of the importance of micellar solubility is the finding that the absorbability of different sterols is directly related to their equilibrium micellar concentration.Unlike cholesterol, phytosterols, and to a greater extent, phytostanols, are poorly absorbed and the small amount that is absorbed is actively re-excreted in bile. This results in low serum levels of these sterol molecules. The inhibition of cholesterol absorption is thought to produce a state of relative cholesterol deficiency that is followed by upregulation of cholesterol biosynthesis and LDL receptor activity. Although the exact effect on serum lipoprotein levels is not yet known, it is interesting to notice that some of the known effects of vegetable fats on lipid metabolism are compatible with known mechanisms of action for phytosterols. These actions correspond to what is anticipated from the known effect of phytosterols to reduce delivery of dietary and biliary cholesterol to the liver.

2. MANUFACTURING

3.1 PRODUCTION OF STEROLS FROM VEGETABLE OIL DISTILLATES

Edible vegetable oils, extracted from oil-seeds, are typical refined to remove minor oil components like phosphatides, free fatty acids , pigment and odour, with the least possible damage to the least possible damage to the glycerides and with minimal loss of oil . The convential or castic refining procedure comprises degumming, neutralization , bleaching and deodorization . In physical refining the neutralization step is omitted and residual free fatty acids are removed in the final deodorization step.

Deodorization is the last step in the edible oil refining process in which volatiles are removed, that can cause deteriation of the quality during use in products (flavor,odour,colour and taste stability) . This process relies on the large volatility differences between the oil itself (triglycerides) and the volatile compounds to be removed and is carried out under reduced pressure, an elevated temperature in the presence of a stripping gas. The volatiles are recovered in a vapour condenser with caustic refining the yield of volume distillate is approximately 0.3-0.4% on the processed oil volume. This distillate mainly contains free fatty acids but also significant levels of tocopherols (5-15%) and phytosterols (8-20%).

In a transesterification (methanolysis) step, the glycerides are converted into fatty acid methyl esters and gylcerol and the phytosterol-ester into free phytosterols and fatty acid methyl esters . After removal of the methanol/glycerol phase, the methyl esters are removed and the free phytosterols and tocopherols removed by distillation. The phytosterols are separated from the tocopherols by solvent crystallization and filtration using food grade solvent. The phytosterols are further purified by re-crystallization mainly to remove wax-esters.

3.2PRODUCTION OF STEROLS FROM WOOD PULP / TALL OIL

Commerically grown coniferous tree (Pinus sp.) are the usual source of wood that is chemically digested in the so-called Kraft-pulping process. In the alkaline process the wood chips are digested at pH 14 (hence the term "soap") for about 18 hrs at 50˚C to free the wood fibres . The soapy material (black liquor pulping soap) is then separated from the celluose pulp. The soapy liquid phase which is obtained contains more than 2% phytosterols. One way of recovering these sterols is through solvent (methanol) extraction directly from the soap, after which the phytosterols are purified by precipitation from the solvents. More commonly the tall oil soap is acidified to produce an oily phase which is a mixture of free rasin, fatty acids and neutral components , most importantly consisting of strerols, fatty alcohols, squalence waxes and other esters . This mixture is reffered to as crude tall oil.

Crude tall oil is refined into different fractions (example- rosin acids, fatty acids) by distillation, where the phytosterols esters, in the residue. This is known as tall oil pitch and serves as the raw material for the production of tall oil phytosterols. The concentration of phtosterols in tall oil pitch is in the range of 5-15%.

Pure phytosterols are obtained from the tall oil pitch , mainly containing high boiling fatty acids esters , resins acids and the phytosterols. The tall oil pitch is saponified with food grade caustic soda to hydrolyze phytosterol esters and saponify the fatty acids. The mix is then neutralized with a food-grade mineral acid (such as sulphuric acid, hydrocholric acid or phosphoric acid). Thereafter the aqueous phase is removed and any remaining water is removed by flash evaporation . The residual pitch is distilled in a number of steps to recover the phytosterol fraction. This fraction is finally purified through solvent re-crystallization using food grade solvents.

3.3 PRODUCTION OF PHYTOSTANOLS FROM PHYTOSTEROLS

Starting with the unsaturated phytosterols from any of the processes described above pure saturated phytostanols can be obtained by hydrogenation. In this process the double-bond in the sterol molecule is saturated by the addition of hydrogen. This reaction is carried out in a suitable solvents under high hydrogen pressure, generally using a npble-metal based catalyst

Phytostanols thus produced mainly consist of sitostanol and campestanol . Phytostanol produced from tall oil sterols typical contain ~90% sitostanol and ~10% campestanol , where as a blend of stanols obtained from vegetable oils, typically from soyabean oil, contains 68-75% sitostanol and 25-32% campestanol . It should be noted that stanols are also naturally-occuring . Especially in tall oil phytosterols , the level of phytostanols can be as high as 15% .

3.4 PRODUCTION OF PHYTOSTEROL AND PHYTOSTANOL ESTERS

Phytostanol and phytosterol esters are produced through esterfication of plant stanols or sterols with fatty acids from common vegetable oils . Thus, the fatty acids composition of the esters is similar to the parent vegetable oil used as a souce of the fatty acids.

Esterification of phytosterols and phytostanols modifies the phsical properties from high-melting crystalline powders with low oil solubility into liquid or semi-liquid substance that can easily be incorporated into a variety of foods (fat containing). The proportion of the phytosterols backbone is 60% by weight of the ester and that of the fatty acids tail approximately 40% by weight.

The phytosterols and phytostanols can be esterified with fatty acids from vegetable oils by 2 different routes :

- Direct esterification using free fatty acids.
- Trans esterification using fatty acid methylesters.

3. CHEMICAL CHARACTERIZATION

4.1 COMPOSITION AND PROPERTIES:-

The physical characterization are composition of different commercial phytosterols, phytostanol and their esters are summarized in table.

Phytostanol and phytosterol esters are chemically stable , fat- type materials having comparable chemical and physical properties to edible fats and oil . The product is insoluble in water, but soluble in non-polar solvents, such as hexane, iso-octane and 2-propanol. The esters are also soluble in vegetable fats and oil.

Heat stability of the esters is camparable to or even better than that of the parent vegetable oil or oil blend from which the fatty acids were derived . During shelf-life studies (long-term storage) , as pure material or in a product , phytostanol and phytosterol esters produce similar decomposition products to those of adible oils and fats as oxidation of the fatty acid moiety is the major cause of the quality deterioration and formation of off-flavours in oils and fats . The phytosterol and phytostanol moieties are very stable at ambient temperature, at higher temperature some oxidation may occur.

4.2 QUALITY OF PHYTOSTEROLS, PHYTOSTANOLS AND THEIR ESTERS

Phytosterols , phytostanols and their fatty acids esters should not contain contaminant or other impurities in concentration that may prevent or limit their use in food products . Major contaminants to analyze or moniter in the final ingredients are :-

- Heavy metals (Cd,Pb,Hg,As).
- Pesticides.
- Dioxins/ Furans / PCBs.
- Polycyclic aromatic hydrocarbon (PAHs)

Analysis of total phytostanol / phytosterol and ester content is generally measured on both the pure ingredients as well as the final food products . if required the level of free phytosterols and phytostanols can be separately analyzed . The product specification of the esters may set minimum value for esterfication and limit the free stanol/ sterol content .
The conventional fats and oil analyses of water content , free fatty acids and peroxide value are generally performed to ensure good stability of the phytosterols , phytostanols and their esters during storage in pure form as well as in the supplemented foods .

4. ANALYTICAL METHODS

Quantitative determination of phytosterols and phytostanols as their trimethylsilyl derivative in the presence of an internal standard is carried out by capillary gas chromatography (GC) equipped with a flame ionization detector (FID) . In addition to quantitative amounts of stanols/sterols in the sample, the GC analysis provides information also on the distribution of individual sterol components and possiblesterol degradation products. So far, there are no official reference methods developed particularly for the analysis of phytosterols or phytostanols present in sterol-enriched food stuffs or ingrients.

Some international reference methods exist for the analysis of sterols as natural minor food components (sterol content 1% or less), whereas the sterol/stanol concentrations in phytostanol ester ingredients or enriched fuctional food products may be as high as 8%.

A number of methods are available for the analysis of naturally occuring or addad phytosterols/phytostanols in foods. Most methods are based on hot saponification in the presence of an internal standard with KOH in ethanol to break the ester bonds. The unsaponifiable material containing phytosterols/phytostanols is extracted with an organic solvent of nitrogen gas. Sterols/stanols are silylated and analysed by GC-FID. A GC/FID method has been developed and validated for determining sitosterol. Campesterol and stigmasterol is saw palmetto and dietary supplements and it may be suitable for analyzing the main sterols/stanols in different types of food. However, different sample preparation procedures may be required and saponification of the sample ia required if esterified plant sterols are present. Alternatively, a GC/FID method for phytosterols in margarine may be used.

5. FUNCTIONAL USE

Function in products:- Phytosterols and phytostanols in free or esterified form are added to foods for their properties to reduce absorption of cholesterol in the gut and thereby lower blood cholesterol levels . It is now generally accepted that sterols and stanols have the same cholesterol lowering efficacy. The daily doses, considered optimal for the purpose of lowering blood cholesterol levels are 2-3 g of phytostanols and or phytosterols, which translates to 3.4-5.2 g in esterfied form. This recommeded daily dose is typically divided in 1-3 portion of food providing 1.7-5.2 g ester, with equal 1-3 g phytostanol and or phytosterols equivalents .

In some cases phytosterols and phytostanol esters can be used as a fat replacer because the phytostanol/sterol moiety of the ester molecule does not provide any energy to the body . Moreover, phytostanol esters may be used to modify the fatty acids composition of a fat blend and replace part of the hard fat in margarines and spreads. Furthermore these esters can provide a crispy texture (prevents sogginess) to cereal products by coating the product surface. Both phytosterol and phytostanol esters give an enhanced creamy texture to low fat dairy products (yoghurt/drinking yoghurt). They may also improve the taste of food products by masking bitterness and hence reduce the amount of sugar or other sweetener required to obtain a pleasant taste and mouth feel (example- in soya drinks).

FOOD CATEGORIES AND USE LEVELS: - Phytosterols , phytostanols and their esters are incorporated into a variety of foods and beverage and supplements produced by a growing number of food and beverage manufacturers .

PHYTOSTEROLS (ESTER) PRODUCTS: - The main products formates (phytosterol ester levels are given between brackets) are:-

- Margarines and low fat (3.4g/30g)

- Yoghurts (1.25g/125ml)
- Yoghurts drink (3.4g/100ml)
- Milk (5g/lt).

6. THE ENRICHMENT OF FOOD PRODUCTS WITH PHYTOSTEROLS

The use of foods containing phytosterol is relatively recent development in human nutrition. Phytosterols as functional food ingredients in foods , appear to be a practical and safe option for improving cholesterol levels in the population . These components are incorporated now-a-days into a wide variety of food products. To produce functional foods containing elevated levels of plant sterols and stanols is the aim of many food companies. New techniques have allowed the incorporation of plant sterols and stanols into food forms without affecting the texture and taste. There has been increased interest in these natural compounds after canola oil based margarine, enriched by sitostanol ester, was introduced commercially in Finland in 1995 and in the United States and European countries in 1999.

Margarine containing plant stanol esters is among the first example of a functional food with proven LDL cholesterol-lowering efficiacy. Since fats are necessary to solublize sterols , margarines are an ideal vehicle for them , although cream cheese , salad dressing and yoghurt are also used . Phytosterols can also be incorporated into baked products, fruit juice, ice-cream and other vehicles. Commericially phytosterols are currently contained in bars, vegetable oils, orange-juice, mayonnaises, milk, yoghurt, yoghurt drinks, soy-milk, meat and soups and green teas . One can foresee an endless list of food products into which phytosterols will be incorporated. Phytosterols are also being sold or develop mixed with other functional ingredients such as – fibre,healthy oils,non-absordable diacylglycerol almonds, soy protein and viscous fibres and minerals .

In early studies of the cholesterol lowering efficacy of phytosterols, plant sterols were in the form of a crystalline powder (esterified form) and had to beused in relatively large quantities to achieve significant lowering of cholesterol. Unesterified plant sterols were in the form of a crystalline powder unesterified plant sterols (or free) are not water soluble and their solubility in fat is limited , their use in food applications is restricted . Plant sterol and stanols esters are far more lipid soluble than plant sterols and stanols. The commercial esterification of plant sterols and stanols with fatty acids from vegetable oil has made it possible to produce spreads and other food containing the desired esters.

Plant stanols are prepared from the hydrogenation of naturally occurring, mixed phytosterols that are found in wood and various vegetables oils . Sitostanol and campestanol exist in quantifiable amounts in cereals , fruits and vegetables but generally of less concentration than the unsaturated phytosterols . For use in the commericial product , stanol esters are prepared by interesterification of stanols with the fatty acids of vegetable oil such as canola oil .

Esterification of plant stanols with fatty acids derived from vegetables oils converts them from a crystalline powder with low lipid solubility into fatty substances that can easily be incorporated into a variety of foods. Initially, esterified plant stanols and sterols were commercially used in fat-based foods such as margarines, shortenings and mayonnaise, but recent clinical studies have shown that the cholesterol-lowering efficiacy of esterified plant sterols and stanol is independent of food matrix . The use of a low fat vehicle for delivery of stanol esters was tested by Mensink et al (2002) who randomized healthy individuals consuming stanol ester taken in the form of margarine (80% fat) with added stanol ester (Miettinen et al.,1995; Hallikainen & Unstipa,1999) .

Plant stanol ester contained in low-fat yogurt was effective in reducing cholesterol level in a habitual diet without restriction of fat and cholesterol intake. With esterification of plant stanol, the food vehicle does not have to have a high fat content to be an effective means of delivery of plant stanol products to be labeled with additional information including the words with added plant sterol/plant stanols.

7. DIETARY SOURCES AND INTAKES

Phytosterols can be found at widely varying concentration in the fat-soluble fractions of seeds, root stem, branches, leaves and blossoms. They are constituents of both edible and oranamental plants, including herbs, shrubs and trees. As natural constituents of the human diet, phytosterols are naturally found in all food items of plant origin, principally oils, but also pulses and dried fruits. Their content is highest in edible oils, seeds and nuts . The total contents are very variable and range from nearly 8g/kg in corn oil to 0.5g/kg in palm oil, with intermediate levels being found in commonly used oils. Tall oil contains a higher proportion of plant stanols than do vegetable oils . Phytosterols are of products based on vegetable oils, such as margarines. The refining process cited leads to a significant reduction in phytosterols in vegetable oils and it would therefore be very interesting to develop industrial methods which minimize these losses.

The dietary intake of phytosterols among and within different human population varies greatly depending in the type and amount of plant foods eaten. Although cooking oils, margarine and peanut butter are the main sources of phytosterols in the diet, phytosterols are also consumed in seeds, nuts, cereals and legumes. The consumption of phytosterols can range between 170mg/day in population eating western diets and 360mg/day in diets rich in vegetable products . The dietary intake of plant stanols is usually only about 50mg/day unless the diet is supplement with tall oil , which is derived from conifers and is rich in sitostanol . The normal dietary intake of plant stanols is much less than that of plant sterols. Consequently, the normal dietary intake of palnt stanols is negligible . In order to achieve a cholesterol lowering benefit approximately 1g/day of plant sterols or plant stanols need to consume. At the same time recent studies of plant stanol and stanol esters in humans have shown, however, that maximum cholesterol-lowering benefit is achieved at doses of 2-3g/day. Although people consume phytosterol everyday in food, the amounts are often not great enough to have significant cholesterol lowering effect.

Phytosterols can be incorporated into traditional food products. Also, finding and cultivating varieties with higher phytosterols contents will increase consumption in the population. Genetic modification becomes a powerful tool for related purposes.

Table 1. **Total phytosterol contents of selected food**

Food	Serving	Total Phytosterols
Wheat germ	½ cup (57g)	197
Corn oil	1 tablespoon (14g)	102
Canola oil	1 tablespoon (14g)	91
Peanuts	1 ounce (28g)	62
Wheat bran	½ cup (29g)	58
Animals	1 ounce (28g)	34
Brussels sprouts	½ cup (78g)	34
Rye bread	2 slices (64g)	33
Macadamia nuts	1 ounce (28g)	33
Olive oil	1 tablespoon (14g)	22

8. List of Food (with high phytosterols) That Help Lower Serum Cholesterol

Plant sterols, phytosterols, are cholesterol-like compounds that are found mostly in vegetable oils, nuts and legumes. There are about 44 sterols known to exist in plants. The most abundant phytosterols are, however, beta-sitosterol, campesterol, and stigmasterol. Phytosterols are not produced in the body. Thus, their sole source is diet.

Phytosterols have the same function as cholesterol in the body. Cholesterol is necessary component of cell membrane and required for the synthesis of sex hormones and bile acids. However, when cholesterol is high in the blood (serum) it is associated with heart disease. Plant-based diet rich in phytosterols is known to reduce serum total cholesterol and low density lipoprotein (LDL) cholesterol. On the other hand, diet based on animal food (meat, egg etc.) contributes to elevated serum cholesterol level.

For example, in one study it was found that subjects fed with wheat germ containing high phytosterol had

42% lower cholesterol in their blood as compared to those who were fed phytosterol-free wheat germ.

The mechanisms suggested on how phytosterols help reduce serum cholesterol include enhancing excretion of cholesterol, interfering with cholesterol synthesis, and competing for cholesterol acceptor sites in the intestinal walls.

Some animal studies have also shown that phytosterols inhibit or slow down tumor development.

On average, a conventional Western diet provides 250 mg/day of phytosterol. Whereas a vegetarian diet provides 2 times of that.

In the following table is a list of foods high/low in phytosterols. Generally, oils have high phytosterol content where as vegetables and fruits have lower content. The phytosterol content presented below is the sum of beta sitosterol, campesterol, and stigmasterol.

Table 2. Total phytosterols content in phytosterol food sources

Phytosterol food sources	Total phytosterol content (mg/100g)
Oils	
Rice bran	1055
Corn	952
Wheat germ	553
Flax seed	338
Cottonseed	327
Soybean	221
Peanut	206
Olive	176
Coconut	91
Palm	49
Vegetables	
Beet root	25
Brussels sprout	24
Cauliflower	18
Onion	15
Carrot	12
Cabbage	11
Yam	10
Fruits	
Orange	24
Banana	16
Apple	12
Cherry	12
Peach	10
Pear	8

Dietary phytosterols appear to play an important role in the regulation of serum cholesterol and appear to provocatively exhibit anticancer properties. These data provide a strong rationale for their use in functional foods.

9. LEGISLATION AND LABELLING :-

In the USA, plant sterol,stanols and their esters were given Generally Recognised as Safe (GRAS) status. On the basis of this recognition , the US Food and Drug Administration (FDA) approved fat spreads containing upto 20% of either steryl or stanyl esters

10. PHYTOSTEROLS FORTIFICATION

Lipophilic Microconstituents of Milk :-

Milk has long been recognized as a source of macro- and micronutrients, immunological components, and biologically active substances, which not only allow growth but also promote health in mammalian newborns. Many milk lipids, lipid-soluble substances, and their digested products are bioactive, including vitamins and vitamin-like substances. Vitamins A, E, D, and K and carotenoids are known as highly lipophilic food microconstituents (HLFMs), and all occur in milk. HLFMs also include phytosterols, which, although they are not vitamins, are nevertheless biologically active and present in milk. Fat-soluble micronutrients, including fat-soluble vitamins, are embedded in the milk fat fraction, and this has important implications for their bioaccessibility and bioavailability from milk. In fact, the fat component of milk is an effective delivery system for highly lipophilic microconstituents. The vitamin content of animal products can be enhanced by increasing the feed content of synthetic or natural vitamins or precursors. An advantage of augmenting milk microconstituents by animal nutrition rather than milk fortification is that it helps safeguard animal health, which is a primary factor in determining the quality, safety, and whole-someness of animal-origin foods for human consumption. The milk fat delivery system offers numerous possibilities for exploitation by nutritionists. For example, the payload could consist of enhanced levels of several micronutrients, opening possibilities for synergic effects that are as yet incompletely understood .

11. Dietary Effects of Structured Lipids and Phytosteryl Esters on Cardiovascular Function in Spontaneously Hypertensive Rats.

This study examined the dietary effects of sesame oil (SO)-based structured lipids (SL) and phytosteryl esters (PE) on cardiovascular function in conscious spontaneously hypertensive rats (SHR) fed high-fat (HF) diets (20% w/w fat). The dietary groups were as follows: normal diet (4.5% w/w fat), SO, SO fortified with PE (SOP), SL, and SL fortified with PE (SLP).

Mean arterial blood pressures were similar in all groups, whereas resting heart rates (HR) were higher in all HF-fed groups.

The pressor responses to the alpha1-adrenoceptor agonist, phenylephrine (5 microg/kg), were similar in all groups. However, the pressor responses to phenylephrine (10 microg/kg) were diminished in SO- or SL-fed SHR, whereas they were not diminished in SOP- or SLP-fed SHR. The depressor responses elicited by the nitric oxide (NO) donor, sodium nitroprusside (5 and 10 microg/kg), were not diminished in HF-fed rats. Baroreflex-mediated changes in HR were variously decreased in the HF-fed groups, and this decrease tended to be greater in SOP and SLP than in SO and SL groups. The depressor and tachycardic responses elicited by the beta-adrenoceptor agonist, isoproterenol, were equivalent in all groups. The depressor responses elicited by the endothelium-dependent agonist, acetylcholine (0.1 microg/kg), and the hypertension elicited by the NO synthesis inhibitor, NG-nitro-L-arginine methylester (25 micromol/kg), were similar in all groups. These findings demonstrate that (1) HF diets increase resting HR and impair baroreflex function in SHR, whereas they do not obviously affect endothelium-dependent vasodilation, and (2) fortification with PE may be deleterious to cardiovascular function (eg, baroreflex activity) in SHR.

PINE PHYTOSTEROLS FOR AUTOIMMUNE DISEASES

Phytosterols are essentially sterols that are derived from plants. These are compounds that are extremely effective in modulating the immune system. Phytosterols have been known to be able to treat the symptoms caused by many different autoimmune diseases. The phytosterols enhance the activity of some specific cells in the body and also help inhibit the activity of specific cells in the immune system, thereby treating autoimmune diseases without compromising the overall immunity of the body.

PINE PHYTOSTEROLS FOR ULCERATIVE COLITIS

- While there have not been any significant studies linking the action of sterols and sterolins with ulcerative colitis, lab tests have suggested that these chemicals can help control the damage done to the mucosal surface by the immune system. Phytosterols tend to decrease the pace of inflammation by decreasing release of inflammatory factors. They can also regulate the useful T cells to increase the balance of immune response in the body. Further, the phytosterols can help kick in recovery mechanisms too.

PINE PHYTOSTEROLS FOR HYPERTHROIDISM

- When the immune system begins to attack the thyroid gland, there can be many serious effects on the growth of the body. Pine phytosterols tend to decrease the specific immune factor, also known as interleukin 6, which is primarily responsible for the triggering off of the autoimmune reaction. Thyroid function is allowed to resume to the normal when the autoimmune responses are triggered off.

PINE PHYTOSTEROLS FOR LUPUS

- Lupus is a condition that stems from the over-production of auto antibodies. These auto antibodies, when released into the body, cause significant damage to the body by destroying healthy organs. Pine phytosterols specifically target the T cells that tend to inhibit the formation of antibodies. The fat of the plant also balances the synthesis of the body's immune factor so that the virus, which is triggering release of auto antibodies, can be destroyed and removed from the body.

PINE PHYTOSTEROLS FOR CELIAC DISEASE

Celiac disease is an autoimmune disorder that damages the small intestines, causing malabsorption of nutrients. Phytosterols have the ability to inhibit production of specific immune cells while allowing other immune cells to continue their normal functioning. In this way, the auto antibodies, which attack the intestinal walls and cause the damage and the inflammation to the organ, can be controlled. Meanwhile, the body remains immune to further attacks from bacteria and viruses, because phytosterols allow immune factor to continue functioning.

CONSIDERATION

There are many plants and fruits from which phytosterols can be extracted, but pine trees have more amounts of fats and phytosterols than most other plants from which these chemicals are extracted. However, the extraction processes need to be optimum for the phytosterols to be effective against autoimmune disorders. If manufactured and administered correctly, phytosterols can also help in repairing any damage that has been caused due to the autoimmune disorder.

WHAT ARE THE SIDE EFFECTS OF PHYTOSTEROLS

Phytosterols are very safe alternatives to many of the prescription drugs on the market for reducing high cholesterol levels in human beings. As a plant derivative, it provides an all-natural alternative to chemical options.

Features

Phytosterols are a natural compound found in plants. They serve as a natural alternative to many of the drugs prescribed for lowering high cholesterol. While the human body requires certain levels of cholesterol for metabolic function, too much of a good thing causes serious health issues, including heart attack, strokes and/or death. Phytosterols inhibit the synthesis of cholesterol. They help reduce the production and absorption of bad cholesterol, but they are not completely without side effects.

Functions

Phytosterols essentially create an internal environment in the human body that while still processing cholesterol, effectively eliminates most or all of the excess through natural means. It helps the body do what it was intended to do.

Types

The most common forms of phytosterols are sitosterol, stigmasterol, campesterol and brassicasterol. These forms are created from plant sterols and plant stenols. Stenols are simply hydrogenated forms of sterols.

Minor Side Effects

There are no minor common side effects that have been determined from using phytosterols. The packagers of phytosterols have to list major side effects, but unlike their chemical counterparts in the pharmaceutical world, there are no minor ones.

Major Side Effects

While there are major side effects listed on phytosterols that are purchased in health stores, they are extremely rare. These side effects include severe allergic reactions, i.e. rash, hives, itching, difficulty breathing, tightness in the chest, and swelling of mouth, face, lips or tongue. In addition, other listed side effects include body swelling and numbness or tingling of skin.

Prevention/Solution

Almost all of the side effects listed as "major" are relieved simply by taking an over-the-counter medication like Benadryl. However, it is recommended by health practitioners that medical attention is sought immediately when experiencing any of these symptoms.

BENEFITS OF PHYTOSTEROLS

Phytosterols are plant-based compounds similar in structure to cholesterol. Many Americans do not get enough phytosterols because a typical Western diet is deficient in plant-based foods. Because of the many benefits of phytosterols, some doctors and nutritionists advise that consumers increase their intake of phytosterol-containing foods and consider the use of phytosterol supplements. Ongoing research supports the theory that phytosterols are an important and critical part of a healthy diet.

CHOLESTEROLS

Phytosterols act directly within the digestive system, blocking the absorption of cholesterol by as much as 40 percent. This makes phytosterol a very important part of a diet or treatment program for people with a history of elevated LDL cholesterol levels. The effect of phytosterols on cholesterol absorption may explain the reduced cholesterol rates in people who consume a predominantly plant-based diet. The phytosterol supplements contained in both food and supplements can decrease total cholesterol levels, which will in turn help to reduce risk of cardiovascular disease. Experts widely recommend phytosterol-enhanced foods--including oils, breakfast cereals and butter subsitutes--for patients with high cholesterol.

HEART HEALTH

Phytosterols not only decrease cholesterol levels, but they also have other mechanisms of action that appear to be protective against cardiovascular disease. The Food and Drug administration approves the statement that a healthy diet containing .8 g per day of phytosterols can reduce the risk of heart disease. It's unlikely that phytosterol supplements alone will help to combat cardiovascular disease, but the natural phytosterols found in plant-based foods can play a critical role in supporting the health of the heart. Many doctors advise patients with heart disease to eat a diet rich in phytosterols or take appropriate supplements

CANCER

- Priliminary evidence indicates that phytosterols may provide some protection against three common forms of cancer: breast, prostate and colon. This may partially explain why people who eat a macrobiotic diet are less likely to develop these common, but deadly, diseases. Additionally, even after cancer has developed, phytosterols show some promise in helping to shrink or slow the growth of tumors. This is especially true when large doses of phytosterols are consumed as supplements. Although early evidence is very promising, patients with cancer should take phytosterols only under the guidance of a physician.

ANTI-INFLAMMATORY EFFECT

Some studies have shown that phytosterols can help to decrease production of inflammatory cells, including neutrophils. This may make them a healthy alternative to conventional anti-inflammatory medications, such as steroids and NSAIDs like aspirin and ibuprofen. Unfortunately, evidence for this nutraceutical method is still very limited. However, they are a low-risk alternative to conventional NSAIDs and may help to alleviate fever, pain and other symptoms of inflammation, both on a chronic and short-term basis.

Benefits vs Risks

Phytosterols are, for all their benefits, not without some degree of risk. Since studies of phytosterols have been somewhat limited in scope, it is possible that there are dangers that have not yet been evaluated. Until there is more evidence, the Food and Drug administration advises against the intake of more than 3 g per day of phytosterols.
One of the few known risks associated with phytosterol intake is the decreased absorption of vitamin E. While one study also indicated that it may decrease absorption rates of vitamin D3, other research has contradicted this theory. It may be advisable to take supplements of vitamin D and vitamin E for people who take in large quantities of phytosterols.

The Effect of Phytosterols on Male Testosterone

Phytosterols, also called plant sterols, are plant-based compounds that compete with dietary cholesterol in your intestines. The intake of phytosterols may reduce the amount of cholesterol your intestines and lower blood cholesterol levels. Phytosterols may impact testosterone absorbed from metabolism in males through their interactions with the 5-alpha-reductase enzyme. Although animal models show that a high intake of phytosterols will reduce serum testosterone levels, human trials thus far have failed to demonstrate such effects.

Phytosterols

- Phytosterols are found in certain plants and are similar in structure to the cholesterol molecule. Foods that are particularly rich in phytosterols include natural vegetable oils, unprocessed grains, nuts and legumes. Phytosterols reduce the amount of cholesterol we absorb from food, and therefore lower serum LDL cholesterol (i.e. bad cholesterol). The National Cholesterol Education Program recommends 2 g of plant sterols per day for dietary therapy for elevated LDL cholesterol.

Some studies, such as "Dietary phytosterol inhibits the growth and metastasis of MDA-MB-231 human breast cancer cells grown in SCID mice," which was published in the March-April 2000 edition of the Anticancer Research Journal, have also found high phytosterol diets to lower the incidence of cancer, although the results are not conclusive as of yet.

2. Testosterone

- Testosterone is a hormone that is produced primarily in the male testes and is responsible for many of the male traits, such as facial hair, deep voice and muscle tone. In men as well as women, a limited amount of testosterone is also manufactured in the adrenal gland (which is why females also have testosterone, despite lacking testes).

- Numerous enzymes interact with testosterone, resulting in the manufacture of hormone metabolites, such as estradiol and DHT.

5-**Alpha-Reductase**

The enzyme 5-alpha-reductase is a critical enzyme that converts testosterone to dihydrotestosterone, or DHT. DHT is a more potent metabolite of testosterone and is known to lead to hair loss, as well as other side effects, including the aggravation of some forms of cancer. According to the study titled "Phytosterol feeding induces alteration in testosterone metabolism in rat tissues," published in the Journal of Nutritional Biochemistry in December 1998, phytosterols can inhibit 5-alpha-reductase, and can, in theory, reduce testosterone's effects on the body.

Animal Studies

- In the same study, titled "Phytosterol feeding induces alteration in testosterone metabolism in rat tissues," published in the Journal of Nutritional Biochemistry in December 1998, scientists conclude that dietary phytosterols fed to rats lowered the activities of the enzymes of testosterone metabolism. It must be noted, however, that the animals in the study were given fairly large doses of phytosterols.

Human Studies

- Unlike rat studies, research carried out with human subjects failed to record a significant effect of phytosterols on testosterone metabolism. A study published in the European Journal of Clinical Nutrition in May 2003, titled "Safety of long-term consumption of plant sterol esters-enriched spread," concluded that free and total testosterone levels in men were unaffected.

3. PHYTOSTEROLS STABLE IN FUNCTIONAL FOODS

4. The stability of plant sterols in functional foods for cholesterol reduction is high, says a new study from Spain which adds to the safety data surrounding phytosterols.
5. Tests with eight commercially available plant sterol-containing ingredients showed that, under oxidizing conditions, only a very small quantity of oxidation products were produced, report researchers from the University of Valencia and the Hero Institute for Nutrition.
6. “From the results obtained (low rate of oxidation) in the ingredients tested, we can conclude that the plant sterols remain stable in these ingredients,” wrote the researchers in the Journal of Agricultural and Food Chemistry.
7. **Dosage**
8. Numerous clinical trials in controlled settings have reported that daily consumption of 1.5 to 3 grams of phytosterols/-stanols from foods can reduce total cholesterol levels by eight to 17 per cent, representing a significant reduction in the risk of cardiovascular disease.
9. According to a recent market research conducted by Frost & Sullivan, phytosterols are the most heart health targeted and benefited from approved health claims in many markets (as well as recently approval from the European Food Safety Authority).
10. Despite a wealth of studies supporting the efficacy, the Spanish researchers behind the new study state that, as far as they are concerned, “only one study has been published on the evaluation of the oxidation of phytosterols in different vegetable oils added as microcrystalline phytosterols suspensions prepared from wood-based fractions”.
11. **Stability tests**
12. In order to test the stability towards oxidation, the researchers employed gas chromatographic (GC) technique with mass-spectrometric detection to identify the specific types of plant sterols present in certain sterol-containing ingredients, and then GC with a flame ionization detector (GC-FID) to quantify the phytosterols.
13. Eight commercially available phytosterol-containing ingredients were tested, with the sterols present in esterified or free form, and derived from pine, soybean, rapeseed, soybean, corn, and sunflower oils in one of three physical forms: Powder, oil paste, or liquid emulsion. Sterols were tested in their original state and then after thermo-oxidation.
14. Results showed that the most prevalent sterol was beta-sitosterol, and that under oxidizing conditions this produced a range of so-called plant sterol oxidation products (POPs). However, oxidation of beta-sitosterol was limited to between 10 to 50 micrograms per 100 g of beta-sitosterol.

15. In view of this low rate of oxidation in the ingredients tested, it can be concluded that the plant sterols remain stable in these ingredients.

PHYTOSTEROLS IN FERMENTED MILK HELP LOWER CHOLESTEROL

Phytosterols added to low-fat fermented milk may help lower LDL cholesterol levels, according to a study conducted by French researchers and reported in the American Journal of Clinical Nutrition. Phytosterols are naturally occurring plant chemicals that are structurally related to cholesterol. Prior studies have demonstrated that consuming 1.5 to 3 grams of plant sterols in food daily can lead to cholesterol reductions of anywhere from eight to 17 percent. Most of these studies have added the sterols to high-fat foods, however, which high-cholesterol patients may not want to consume frequently. Researchers studied 194 people with slightly high LDLcholesterols level (between 130 and 190 milligrams per deciliter). Half of the participants were given two servings of low-fat fermented milk daily, while the other half had 0.8 grams of plant sterol ester added to the same type and dose of milk. After three weeks, the group consuming the phytosterol-supplemented milk experienced a 9.5 percent reduction in LDL cholesterol levels relative to the control group; after six weeks, this reduction decreased to 7.8 percent relative to the control group.

In addition, participants drinking the supplemented milk also experienced lowered concentrations of oxidized LDL relative to the control group. There was no significant change, however, to HDL cholesterol or plasma triaglycerol levels.

"Daily consumption of 1.6 g plant sterols in low-fat fermented milk efficiently lowers LDL cholesterol in subjects with moderate hypercholesterolemia without deleterious effects on biomarkers of oxidative stress," the researchers said.

According to a report by Frost and Sullivan, the European market products containing plant sterols or plant stanol esters was €146m ($184.6m) in 2005. The report estimates that this market will increase by 114 percent to €312.5m ($395.2m) by 2012.

High levels of cholesterol, and LDL cholesterol in particular, have been linked to an increased risk of cardiovascular disease . Cardiovascular disease is one of the top killers in the United States, responsible for 30 percent of all deaths.

WHY DO PLANTS PRODUCE PHYTOSTEROLS

Sterols are an important class of organic molecules found in many different organisms. Phytosterols are sterols produced in plants. They play important roles in structuring cell membranes, analogous to the role fulfilled by cholesterol in humans.

Types

- In animals like humans, cholesterol is the major sterol, while ergosterol is the most prominent member of this class of compounds in fungi. Plants, by contrast, possess a more diverse array of different sterol molecules. Stigmasterol and sitosterol are two of the more common phytosterols.

Function

- Sterols are highly hydrophobic, or water-repelling, meaning that like oil molecules, they mix poorly with water. Typically, they constitute part of the cell membrane, where they help to keep the membrane fluid and preserve its temperature stability. Phytosterols also help to organize sections of the plasma membrane called "lipid rafts," which serve as part of many other important biological pathways.

Effects

- Many vital processes in plants involve specialized lipid rafts. The growth of root hairs and pollen tubes are two common examples. Since they help organize these regions of the plasma membrane -- and since they play a crucial role in preserving membrane stability and fluidity -- phytosterols are indispensable for plants.

EFFECTS ON THE ABSORTION OF FAT SOLUBLE VITAMINS AND ANTIOXIDANTS

The most important concern about plant sterols is that they reduce the absorption of some fat-soluble vitamins. A review of some of these randomized trials showed that plant sterols and stanols lower blood concentrations of beta-carotene by about 25%, concentrations of alpha-carotene by 10%, and concentrations of vitamin E by 8%. However, an important point in the interpretation of these results is that a key role for these vitamins may be to protect LDL-C from oxidation. Sterols appear to reduce the amount of LDL-C, and lipophilic carotenoids and tocopherols are known to be associated with LDL particles. Thus, it may be appropriate to adjust, or correct, blood concentrations of these vitamins for the lower LDL-C concentrations. With this adjustment, stanols and sterols did not significantly lower blood concentration of vitamin E, but concentrations of beta-carotene were reduced by 8-19%.

It has been suggested that compensation for this impact on serum carotenoid levels can occur either by increasing the intake of carotenoid-rich foods or by taking supplements containing these carotenoids. This has been attempted in one clinical study, which indicated that an increase in dietary carotenoids when consuming plant sterols or stanols was effective in maintaining plasma carotenoid levels. A recent study showed that consumption of phytosterol-fish oil ester resulted in higher beta-carotene and retinol levels than other phytosterol esters. Finally, it has been noted that administration of free phytosterols and phytostanols may not induce malabsorption of fat-soluble vitamins and antioxidants as much as that caused from consumption of the fatty acid ester forms. If this is verified in more studies, it might bring even more attention to the use of the free phytosterols and phytostanols in functional foods.

CONCLUSION

Over the past decade, the possibility of using phytosterols as ingredients in functional foods has led to numerous research studies in relation to numerous reseach studies in relation to their ability to reduce blood cholesterols. Phytosyerols has also been shown that they can control certain illness if they are ingested in the same quantities required for cholesterol reduction . Initially, phytosterols esters were commericially used in margarines , but recent clinical trials show that phytosterol esters effectively reduce blood cholesterol even used in food vehicle with a low fat content .

The present sources of phytosterols are limited. It is estimated that 2500 tonnes of vegetable oil needs to be refined to produce 1 tonne of phytosterols. Another source of phytosterol is tall oil which is derived from the process of paper production from wood and 2500 tonnes of pine is required to produce 1 tonne of phytosterols. In the longer term, the addition of plant sterols and stanols to foods could be an important public health policy if new technology and economics of scale can lower the cost and enable a greater demand to be met.

Phytosterols are naturally found in all plant origin food products . People consume these components every day . Naturally available phytosterols have effects on cholesterol metabolism . However , cholesterol lowering effect attributed to phytosterols in food products would be of limited significances . Due to their physico-chemical behaviour at air/water interfaces, phytosterols are good raw material for the development of liquid crystals and original biological and pharmaceutical applications.

Until recently, it wasn’t possible to enhance food products other than with minerals and vitamins . Now , food fortification with plant extracts is becoming a growing phenomenon . One plant extract that is having huge impact on human health is phytosterols. Phytosterols are now being incorporated into a growing repertoire of food products that include spreads , dressing, yogurts , snacks and cereals.

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