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Cholesterol and Plants

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There is a widespread belief among the public and even among chemists that plants do not contain cholesterol. This error is the result (in part) of the fact that plants generally contain only small quantities of cholesterol and that analytical methods for the detection of cholesterol in this range were not well developed until recently *(1)*. Another reason has to do with the legalities of food labeling that allow small quantities of cholesterol in foods to be called zero *(2)*. The fact is that cholesterol is widespread in the plant kingdom although other related sterols, such as β-sitosterol (henceforth referred to as sitosterol), generally occur in larger quantities. No current biochemistry text that we have examined provides an accurate account of cholesterol in plants. Here is a suggested paragraph for the next generation of biochemistry texts:

> More than 250 steroids have been described in plants *(3)*. Of these, perhaps sitosterol, which differs from cholesterol by an ethyl substituent at position 24, is the most common. But plants also contain cholesterol both free and esterified. Cholesterol occurs as a component of plant membranes and as part of the surface lipids of leaves where it is sometimes the major sterol. The quantity of cholesterol is generally small when expressed as percent of total lipid. While cholesterol averages perhaps 50 mg/kg total lipid in plants, it can be as high as 5 g/kg (or more) in animals.

A sample of current biochemistry textbooks shows that the question of cholesterol in plants is, at best, treated in a misleading way.

> "Cholesterol…is only rarely found in plants." *(4)* (False)
>
> "Similar [to cholesterol] sterols are found in other eucaryotes: stigmasterol in plants." *(5)* (True , but misleading)
>
> Plant cell membranes have no cholesterol. *(6)* (False)
>
> Related [to cholesterol] sterols are present in plant membranes. *(7)* (True, but misleading)
>
> Cholesterol is absent from prokaryotes but is found to varying degrees in virtually all animal membranes. *(8)* (True, but why are plants not even mentioned?)
>
> Plants contain little cholesterol. (True) Rather, the most common sterol components of their membranes are stigmasterol and beta-sitosterol. (Not quite right, see Table 1). *(12)*

In addition, only Garrett and Grisham *(13)* discuss the interesting question of the effects of plant steroids on cholesterol levels in humans. Although evidence for these effects has been in the literature for some time, a number of other commonly used textbooks make no mention either of the occurrence of cholesterol in plants nor of the effects of plant sterols on cholesterol metabolism in humans.

Table 1. Subcellular Distribution of Cholesterol in Plants

Source	Free cholesterol (%)[a]	Cholesterol esters (%)	Reference[b]
Green bean leaves			
whole	1	1	*9*
chloroplasts	24	33	
mitochondria	–	–	
microsomes	1	28	
Etiolated bean leaves			
whole	6	23	*9*
chloroplasts	27	26	
mitochondria	–	–	
microsomes	6	34	
Organelles of 21-day maize shoots[c]			
nuclei	22	*76*	*10*
chloroplasts	2	52	
mitochondria	1	32	
microsomes	1	32	

[a]Percent of total sterols.

[b]For more data, see ref *11*.

[c]The 4-demethyl sterols were 72% of the total sterol ester fraction and 5% of the free sterol fraction

Table 2. Cholesterol Content of Some Plant Oils

Source	Cholesterol/ (mg kg^{-1})	Reference
Palm oil	20	*14*
Palm oil	16	*1*
Palm kernel	17	*1*
Coconut oil	14	*1*
Cottonseed oil	45	*1*
Soybean oil	29	*1*
Corn oil	55	*1*
Peanut oil	24	*1*
Sunflower seed oil	14	*1*
Canola oil	53	*1*
Avocado oil	<30	*15*
Olive oil	0.5–2	*16,17*
Sesame oil	ca. 1	*16,17*

NOTE: By contrast, brains, egg yolk, butter, pork, and clams have the following approximate cholesterol content respectively (in g/kg): 20, 15, 2.5, 0.6, and 0.5 *(18)*.

Data and Discussion

Occurrence

The quantity of cholesterol in a number of common vegetable (plant) oils is given in Table 2. According to FDA rules, cholesterol quantities less than 2 mg/serving may be labeled as zero *(19).* The reader should check the label on whatever oil is currently on the shelf. *Caveat emptor.* It is clear that cholesterol and its esters are important constituents of plant membranes and that this has been known for more than thirty years. Table 2 also gives some data on the sterol fraction of some plant organelles.

While cholesterol is usually a minor constituent of the sterol fraction in plants, it is the major constituent of some plant surfaces. The cholesterol and sitosterol makeup of the sterol fraction of various canola surfaces is shown in Table 3. The proportion of cholesterol in the sterol fraction of the genera Liliaceae, Solanaceae, and Scrophulariaceae is especially large (Itoh et al. in refs *3* and *22*)

Cholesterol and Plant Sterols

There is considerable interest in plant sterols owing to their cholesterol-lowering effects. While Garrett and Grisham *(13)* are to be commended for elaborating on this matter in their textbook, their descriptions are incorrect and likely to cause misunderstanding.

> Despite their [plant sterols] structural similarity to cholesterol, minor isomeric differences and/or presence of methyl and ethyl groups in the side chains of these substances result in their poor absorption by intestinal mucosal cells. Interestingly, although plant sterols are not effectively absorbed by the body, they nonetheless are highly effective in blocking the absorption of cholesterol itself by intestinal cells.

This paradox is attributable to inaccuracies in the above statements.

A typical western diet contains 400–600 mg cholesterol and 200–400 mg plant sterols (sitosterol and campesterol) per day. While 40–60% of the cholesterol is absorbed, less than 20% of campesterol and less than 5% of sitosterol are absorbed *(23).* Current models *(24)* propose the initial uptake of cholesterol and plant sterols from the intestine into the enterocyte (intestinal mucosal cell) by a common transporter (called NPC1L1) expressed at the lumenal surface. Subsequently, by mechanisms that are still unknown, sorting of these various sterols takes place inside the enterocyte with the majority of cholesterol being transferred to chylomicrons and most of the plant sterols selectively pumped back into the intestine by two ATP-dependent transporters (called ABCG5 and ABCG8). This means that the discrimination is by a selectivity of egress not ingress. This provides a basis for understanding sitosterolemia, a rare inherited disease in which there is hyper-absorption of plant sterols from the small intestine. Sitosterolemic individuals absorb cholesterol and plant sterols (presumably using NPC1L1) but are unable to re-transport sitosterol into the intestine owing to mutations in ABCG5 or ABCG8 *(24).*

Although plant sterols are not absorbed by the body as effectively as cholesterol, they *are* absorbed *(23).* The cholesterol-lowering effects of plant sterols (and their esters) are due in part to their competition with cholesterol for packaging into mixed micelles that are taken up by NPC1L1.

Table 3. Sterol Content of Rape (Canola)

Source	Cholesterol (%)	Sitosterol (%)
Leaves		
surface	71.5	0.6
intracellular	15	30
Seeds		
surface	7.2	62
intracellular	0.7	67
Seed pods		
surface	35	21

NOTE: Data is given as percent of total sterols. Data on the cholesterol content of the surface lipids of cabbage, leek, radish, spinach, okra, and green pepper also available *(20).* There are also large changes in the cholesterol/sitosterol ratio during plant development (ref *21* and references therein).

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