



Are Trees Getting Fat Too?

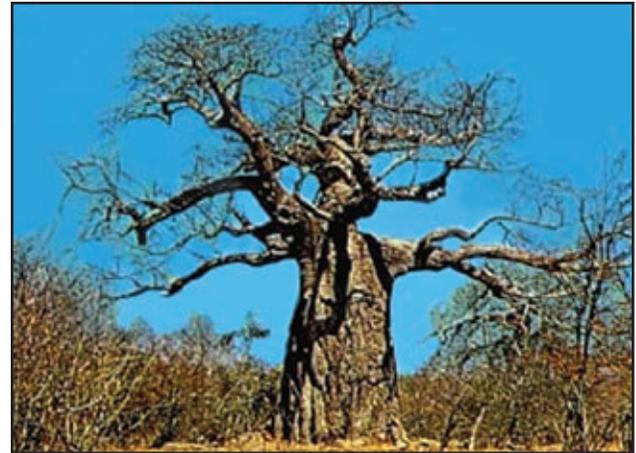
William R. Chaney, Department of Forestry and Natural Resources, Purdue University

The overweight condition of the U.S. citizenry, and even their pets, is all too evident and becoming a national crisis. Is the over indulgence and inactivity responsible for the obese state of humans and their animal friends being imposed on landscape plants as well, resulting in fat trees and shrubs? Thankfully not.

In spite of the fact that pampering with proper care and management are better than ever before, woody plants are accumulating no more fat today than they did centuries ago. If anything, the rise in the number of certified arborists, master gardeners, and professional landscape managers applying their skills along with enforcement of clean air standards have resulted in healthier plants in our urban environments. Nevertheless, the credit for keeping the “weight off” of trees and shrubs is not due to better care by trained professionals and plant health experts, but instead is inherent in important differences between plants and animals. Fats do occur in woody plants and some parts of their anatomical structures even accumulate fat at high concentrations. Still no woody plants are considered overweight and unfit.

What is fat?

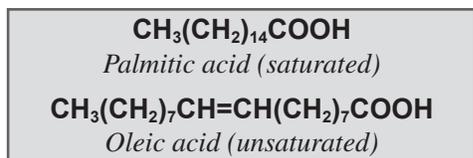
Everyone is acquainted with the white to yellowish greasy substance that forms the fatty tissue of animals. It is recognized as marbling in meat and the edges of a steak. Composed of carbon, hydrogen, and oxygen, this material also can be found in plants. Actually, lipid is the catch-all term that includes fats and oils, phospholipids, glycolipids, waxes, and even terpenes and steroids. All of these substances can be extracted from plant and animal tissues with nonpolar organic solvents (e.g. ether or chloroform). For this discussion, lipids will be defined on the basis of chemical structure rather than merely the physical property of solubility in nonpolar organic solvents. Hence, lipids will be defined as those substances that on heating with sodium or potassium hydroxide form water-soluble soaps. This procedure, known as



Normal growth form of a healthy baobab tree. Enlarged trunk is used to store water for the dry season, not fat.

saponification, results in salts of long-chain fatty acids and is the means by which soap has been made since ancient times. Based on this chemical classification, the different kinds of lipids to be discussed are variations of the combination of alcohols and fatty acids, called esters, with additional chemical groups attached to some of them. Lipids constitute, with proteins and carbohydrates, the chief structural components of all living cells.

Fatty acids usually have a straight-chain structure with an even number of carbon atoms ranging from 8 to 36, because they are synthesized by combining molecules of a two carbon compound, acetyl CoA. They are rarely found free in cells, but rather are bound to other compounds, most frequently forming some kind of lipid. Fatty acids with no double bonds between the carbon atoms contain more hydrogen atoms and are called saturated. Unsaturated fatty acids have structures similar to those of saturated ones, but contain at least one or more double bonds and, consequently, fewer hydrogen atoms. Oleic acid is the most widely distributed and most abundant fatty acid in nature.



Typical chemical structure of fatty acids

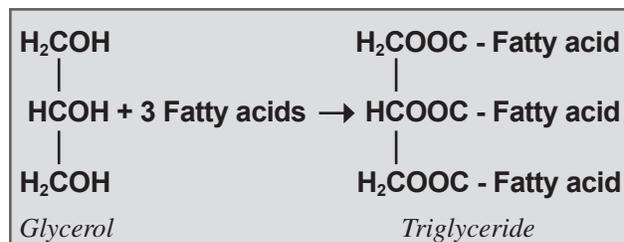
Examples of fatty acids showing the number of carbon (C) and hydrogen (H) atoms they contain.

Saturated acid		
Lauric	C12	H24
Myristic	C14	H28
Palmitic	C16	H32
Stearic	C18	H36
Lignoceric	C24	H48
Montanic	C28	H52
Lacceroic	C32	H48
n-tetratriacontanoic	C34	H68
Unsaturated		
Palmitoleic	C16	H30
Oleic	C18	H34
Linoleic	C18	H32
Linolenic	C18	H30
Arachidonic	C20	H32
Docosahexenoic	C22	H32
Nervonic	C24	H46

There Are Four Different Kinds of Lipids in Trees

Triglycerides

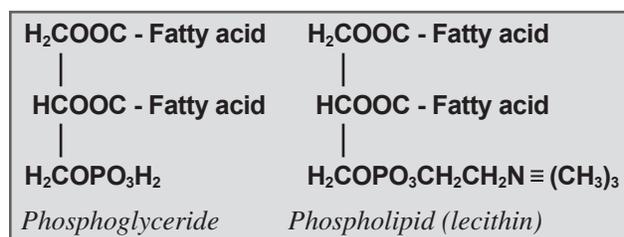
The simplest and most common lipids are the triglycerides. They are esters of the three-carbon alcohol, glycerol, and various fatty acids attached at the -OH groups at all three positions of the glycerol molecule, forming common oils and fats. The major fatty acids found in liquid triglycerides (oils) are unsaturated, such as oleic, linoleic, and linolenic, whereas the major fatty acids in solid triglycerides (fats) are saturated, such as palmitic and stearic acids. Triglycerides are sometimes called nature's storehouse of energy because, on a weight basis, they contain more than twice as much energy as carbohydrates and proteins. For a heart healthy diet in animals, triglycerides containing unsaturated fatty acids (oils) are recommended.



Reaction equation for formation of triglycerides

Phosphoglycerides and Phospholipids

When glycerol combines with a molecule of phosphoric acid at one of its ends and also combines with two fatty acids at the remaining two -OH sites, the compound is called a phosphoglyceride. The phosphoric acid may be further bound in an ester linkage to a nitrogen containing compound such as choline, serine, or ethanolamine or a non-nitrogenous compound such as inositol, or another glycerol or phosphoglyceride to form a phospholipid. Phospholipids are common lipids in membranes including the plasmalemma, endoplasmic reticulum, tonoplast, and those surrounding cell organelles such as mitochondria and chloroplasts. They contain both a hydrophobic, water-insoluble portion (fatty acids) and a hydrophilic water-soluble portion (inositol, choline, ethanolamine, serine) making them ideal for this function.

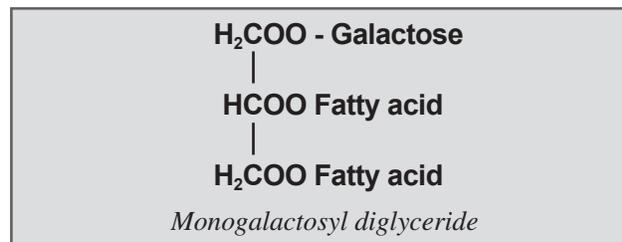


General structure of phosphoglyceride and phospholipid

Glycolipid

When one of the terminal -OH groups of glycerol is attached to one or more sugar molecules and the other two positions are occupied by fatty acids, usually linolenic or linoleic, a glycolipid is formed. This general structure is a diglyceride much like phospholipids except that a sugar is substituted instead of phosphoric acid. The sugar may be galactose or glucose. Frequently two galactose molecules are linked together to form digalactosyl diglyceride and up to five of these sugars are known to be linked together in some glycolipids. When glucose contains a sulfur atom attached to it creating the sugar quinovose, the glycolipid is called a sulfolipid. Palmitic and stearic

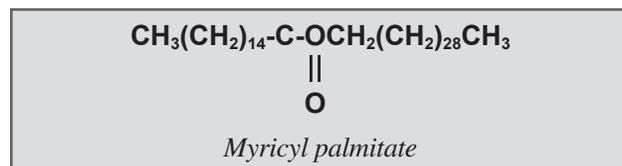
are the predominate fatty acids in sulfolipids. Glycolipids containing alcohols other than glycerol are rare and generally account for less than 1 percent of the lipids in plants.



General structure of glycolipid

Waxes Including Cutin and Suberin

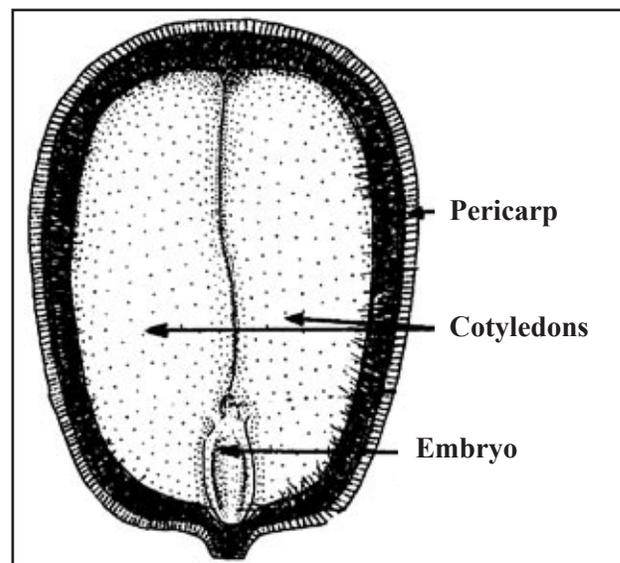
The generic name wax is given to a naturally occurring fatty ester of any alcohol other than glycerol. Most plant waxes contain long-chain alcohols combined with the fatty acids. The fatty acids found in such waxes are generally longer chain compounds than the fatty acids of triglycerides. The C24-C36 fatty acids are most common. The alcohols have the same range of carbon chain lengths. Small amounts of unesterified fatty acids and alcohols may also be found in plant waxes. Although the exact chemical nature of cutin and suberin remains unclear, what evidence there is indicates that they are complex molecules, frequently with more than one ester linkage with fatty acids or other constituents such as lignin, cellulose, tannins, or phenolic acids. Their structure can be entirely linear, but ring structures also occur. The complexity of these compounds is emphasized by the finding of 41 different component fragments in cutin extracted from a plant.



General structure of a simple wax

Occurrence of Lipids in Woody Plants

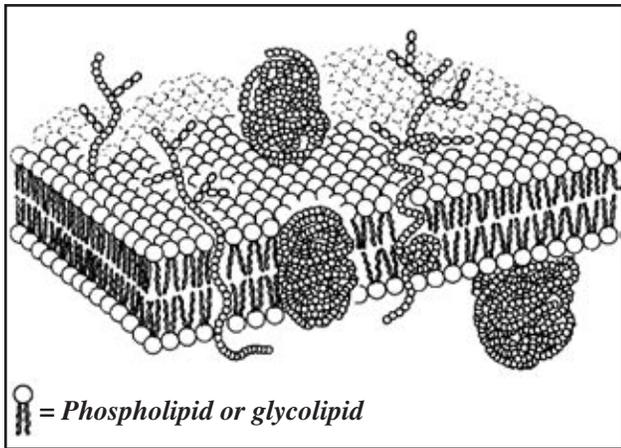
Lipids are important constituents of all living cells in woody plants, but the distribution of the different kinds of lipids varies among organs and location within cells. Whereas the triglycerides usually function as food storage components, phospholipids and glycolipids account for over 50 percent of the membrane structures, and the waxes function as protective coatings on leaves, fruits, and stems. Lipid



Longitudinal section of red oak acorn with cotyledons where 20-30 percent of stored food is triglycerides

concentration in vegetative parts of woody plants is quite low, usually less than 4 percent of the total dry weight. Lipid content of wood also is low, rarely exceeding 2 or 3 percent even though parenchyma cells of the sapwood are important sites for storage of food reserves. The concentration in bark is frequently higher than that of wood, presumably because of the suberin that it contains. As early as 1891, Fisher and other investigators, attempted to classify trees as fat or nonfat (starch) trees on the basis of the predominate type of reserve food in their wood during the winter. Conifers and basswood were classified as high in lipids, and consequently called fat trees, whereas ash, oak, elm, and maple were examples of nonfat trees.

Lipid content of fruits and seeds is much higher than that of vegetative structures. Triglycerides are important deposits in reproductive structures such as pollen grains, fruits, and seeds for many species because they serve as concentrated energy reserves for developing embryos and expanding pollen tubes. For example, oil accumulates in the fruit or pericarp of avocado and olive and in the seeds of oil palm, walnut, tung, pecan, and almond. Olive fruits contain 20 to 30 percent oil, seeds of Brazil nut, coconut palm, pinyon pine, and pecan contain 60 to 70 percent triglycerides as oils and fats, and acorns of red and scarlet oak have 20 to 30 percent. There is some seasonal variation in lipid content with a tendency toward accumulation in the winter or spring and a decrease during the summer. For example, the lipid content of walnut cotyledons (kernels) is 3 percent in July and 62 percent when mature in October.

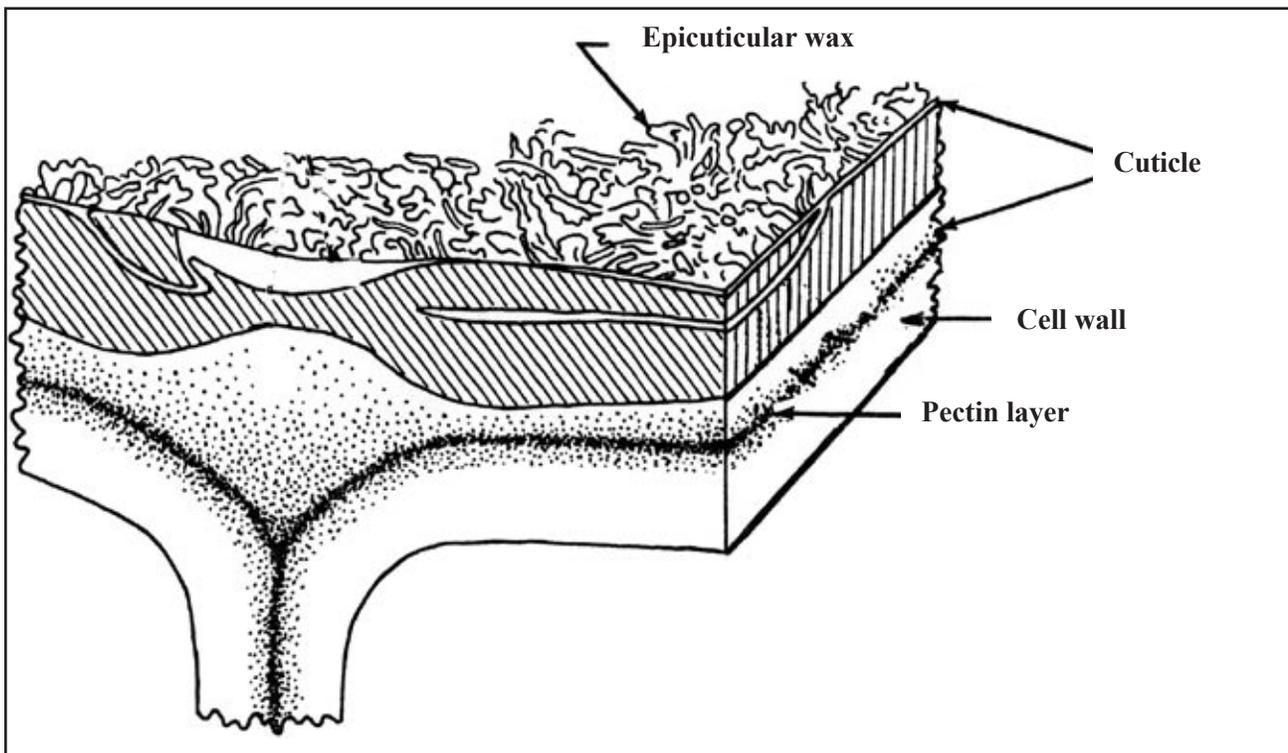


Typical membrane structure with bilayer of phospholipids and glycolipids

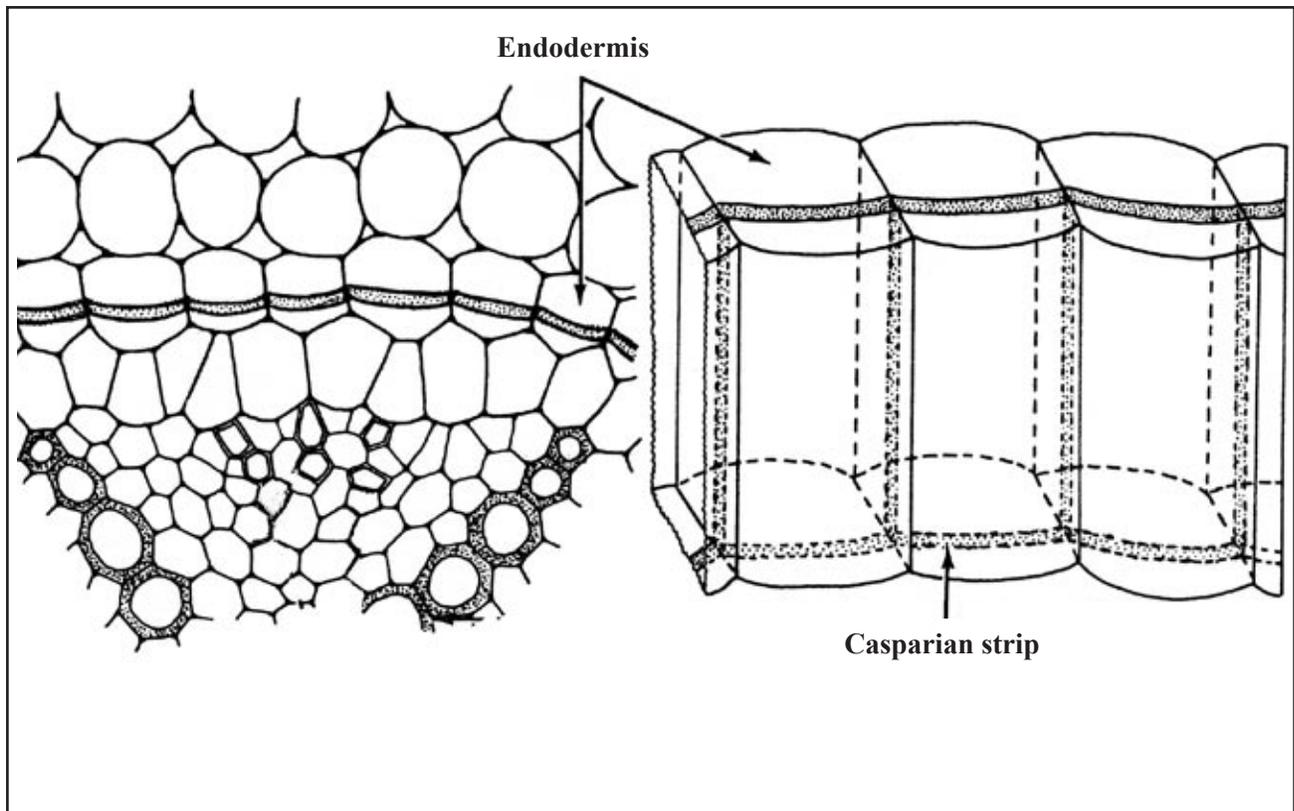
In the plant kingdom as a whole, oleic and palmitic acids are the most abundant fatty acids in lipids. The leaf tissues of most kinds of plants contain lipids with similar fatty acids, chiefly palmitic, linoleic, and linolenic, with considerable linolenic acid in chloroplast lipids. Much more variation occurs among species with respect to the fatty acids found in seeds than in leaves, and those in seeds usually differ from those found in the vegetative structures of the same plant.

The phospholipids are essential because of their role in membrane structure of cells and their organelles, and as bridges or binding agents between polar and nonpolar cell constituents. Because they have both charged, water-attracting (hydrophilic) groups and lipid, water-repelling (hydrophobic) groups, phospholipids are moderately soluble in both water and lipids and serve, therefore, an important role in cells in binding both types of compounds together. Because a wide assortment of fatty acids and nitrogen-containing bases can be assembled in various combinations, an extensive array of phospholipid molecules with differing properties is found in cell membranes. Phospholipids may also play a dynamic role in transport across membranes.

Glycolipids are widely distributed in plants, especially in green leaves. They are concentrated in chloroplasts and may comprise over 50 percent of the membrane lipids. They are much lower or nonexistent in mitochondria. Sulfolipids are most common in chloroplasts, but they occur in nonphotosynthetic tissues too. In leaves, the amount of glycolipids greatly exceeds the amount of phospholipids. As with phospholipids, possible involvement of galactolipids in ion transport across membranes has been suggested.



Outer cell wall of the upper epidermis of a leaf with its protective coating of cuticle and epicuticular wax



Endodermis of young root showing casparian strip made of suberin

The outer surfaces of stems, leaves, fruits, and even flower petals are covered to varying degrees of thickness with a relatively waterproof layer, the cuticle. The cuticle is composed of wax and cutin and is anchored to the epidermal cells by a layer of pectin. The cuticle is physiologically important because it restricts water loss from cells, reduces leaching of nutrients, provides a barrier to air pollutants, and influences entry of agricultural chemicals into leaves, fruits, and stems. Some of the chemicals in cuticle wax even inhibit growth of pathogenic organisms. When present in irregular masses, waxes make leaf surfaces difficult to wet; hence a surfactant or wetting agent is added to spray materials to ensure even coverage and uptake into leaves.

Deposition of waxes on leaves is an important adaptation to drought. Water loss from leaves has been shown to be 300 to 500 times higher following extraction of the cuticular wax, emphasizing the importance of leaf waxes in drought avoidance by plants. Cutin or suberin also may accumulate on cell surfaces exposed to intercellular spaces and increase the resistance to evaporation of water from cells surrounding sub-stomatal chambers. The amount of wax on leaves varies from trace amounts to as much

as 15 percent of the dry weight of the leaf, and it differs with plant species, genotype, leaf age, and environmental conditions. The amount of leaf wax that forms is favored by high light intensity, low relative humidity, and drought.

Waxes are produced largely during early stages of leaf expansion. Fully expanded leaves generally have lost the capacity to produce large amounts of wax. Hence, old leaves with their thin layers of wax often have high transpiration rates, lose large amounts of minerals by leaching, and have low resistance to pathogens.

Suberin is another component of waterproof layers, chiefly in the cork cells of the periderm in bark and the outer layer of seed coats. The suberin deposits surrounding cells of the endodermis in young roots known as casparian strips, force uptake of soil nutrients through living cells, providing a means for plants to regulate what enters the plant. The casparian strip of suberin also protects vascular tissues from microbial attack. Suberization is involved in wound healing of plant tissues, and suberin is an important constituent of the barrier zones formed during compartmentalization. Wounding triggers induction of enzymes involved in synthesis of suberin.

Comparison of the Source and Movement of Lipids in Humans and Plants

In humans a certain amount of body fat is essential. The minimal amount needed according to the American Council on Exercise varies substantially with gender, ranging from 10 to 12 percent for women and only 2 to 4 percent for men, the bulk of which is triglyceride. Lipids are the main form of energy storage in humans as well as most other animals. Subcutaneous accumulations help insulate against cold temperature and cushion and insulate organs and tissues from mechanical trauma. Acceptable levels of body fat in healthy humans range from 25 to 31 percent for women and 18 to 24 percent for men. Percent body fat higher than these levels indicate obesity. This simply means that a reasonably fit man weighing 165 pounds with 20 percent body fat contains 33 pounds of fat with the remainder of his body being bone, organ tissue, blood, and everything else. This lipid is distributed in varying amounts in all organs as well as in certain specialized connective tissue, the adipose tissue, in which a large part of the cytoplasm of cells contains droplets of lipid. The large amount of lipid found in most animal tissues is in contrast to the situation in plants, where lipid is found in abundance only in fruits and seeds.

Since trees don't maintain a constant body temperature or have organs that need protection from impact shock, their essential fat needs are much lower. In addition, the systems for transporting and circulating nutrients, hormones, vitamins, and foods are vastly different between animals and plants.

For mammals the circulatory system is dependent on the pumping action of the heart and blood, a specialized living tissue consisting of several components, one of which is plasma. About 55 percent of blood is plasma, a straw-colored clear liquid. Dissolved in the plasma, which is 95 percent water, are vitamins, hormones, clotting factors, minerals, antibodies, enzymes and proteins, dissolved oxygen and carbon dioxide, and lipids, principally in the form of triglycerides. Lipids are the only food ingested by mammals that are not completely digested before they are absorbed. Some breakdown of fat and oils to fatty acids and glycerol does occur in the intestine. The free fatty acids act as soaps, surrounding intact fat molecules, making them soluble in water. These droplets are passed through the intestinal wall into the blood and lymph system where they are transported to sites of utilization or storage through an intricate system of arteries and veins. Due to their insolubility

in water, triglycerides are able to move in blood only because they are reconstituted in droplets that have a polar outer surface allowing for solubility in the high water content of blood. Upon arrival at fatty tissue in other regions of the body, the intact fat molecules are released and new fat molecules are made from the free fatty acids. Not all triglycerides occurring in the blood are derived from food that is eaten as small quantities are made in the liver.

The level of triglycerides in blood is ideally 150-200 mg/dL. As everyone is well warned and aware, a sedentary lifestyle and excessive caloric intake of carbohydrates, fats, and alcohol can lead to even higher levels of triglycerides. Humans can consciously influence fat content of blood and body tissues in most cases through diet and exercise, i.e. eat less and move more.

Trees in contrast are well adapted to their sedentary condition. They do not ingest food, but make their own in the photosynthetic process. Even though photosynthetic rate can be influenced by genetic selection for faster growth, planting the right tree in the right place, proper balance of irrigation and fertilization, and control of insects and disease incidence, the end product is still sugars. The distribution of sugars from sites of production to sites of utilization and storage depends on their solubility in water and the creation of pressure gradients in the phloem that constitutes the transport system of trees and other plants. How these sugars are used, and whether they are converted to lipids or starch for storage, are controlled by enzymatic processes coded for in the genes of woody plants. Synthesis of oil and fat occurs in the organs where they are stored since their insolubility in water makes translocation in phloem tissue impossible. There is considerable variation in the quantities of lipids produced in different kinds of trees; lipids being the predominate food reserve in some (e.g., conifers and basswood) and starch in others (e.g., ash, elm, maple, oak).

Commercial Fats and Oil from Trees

Many useful products and a lucrative commercial market are derived from plant fats and oils. The major uses are for cooking and manufacturing of paints, varnishes, lacquers, soaps, detergents, plastics, and as compounds in linoleum and oil-cloths. Most of these fats and oils are extracted from fruits and seeds with coconut, olive, and palm oils among the most important. More than three million tons of copra, dried coconut meat, is used annually for oil extraction.

Nearly two million tons of olive oil and more than a million tons of palm oil enter markets every year. The oils containing large amounts of unsaturated fatty acids combine with oxygen when exposed to the air and form the hard films characteristic of drying oils such as that obtained from seeds of the tung tree.

The protective wax coatings on leaves and stems of plants are less voluminous and are typically a more expensive commodity than the vegetable oils and fats. For example, highly prized and durable carnauba wax is removed from leaves stripped from the slow-growing fan-palm, where it develops as thick secretions in response to the seasonal drought and scorching winds of its native habitat in northeastern Brazil.

Conclusion

Although trees and shrubs do contain fats, the levels of accumulation are well regulated physiologically, negating the need for arborists to worry about adding bariatrics to their professional tool kit. Trees and shrubs are certainly plagued by bacteria, viruses, fungi, and environmental stresses the same as animals including humans, but obesity is one serious malady that does not and will not afflict woody plants.



NEW 7/04

It is the policy of the Purdue University Cooperative Extension Service, David C. Petritz, Director, that all persons shall have equal opportunity and access to the programs and facilities without regard to race, color, sex, religion, national origin, age, marital status, parental status, sexual orientation, or disability. Purdue University is an Affirmative Action institution.

This material may be available in alternative formats.

1-888-EXT-INFO