Post Harvest Technology of Horticulture Crops

MFT-2001

Characteristics of Durable and Perishable Crops

Durables	Perishables
Low moisture content, usually 10–15% or less;	High moisture content, typically 50–90%;
Small unit size, typically less than 1 g;	Large unit size, typically 5 g–5 kg, occasionally even larger;
Low-respiration rate, with very small rate of heat generation;	High to very high respiration rate, and rate of heat production;
Hard texture, not easily damaged;	Soft texture, easily damaged, highly perishable
Stable with natural shelf-life of several years.	Natural shelf-life of a few days to at best few months; and
Losses mostly caused by external agents, e.g. agents such as molds, insects and rodents.	Losses mainly caused by external rotting by bacteria and fungi and partly by endogenous factors, respiration, senescence and sprouting.

Causes of postharvest food losses
primary and secondary (Bourne, 1977; Salunke and Desai, 1984):

Primary Causes

1. **Biological and microbiological**: Consumption or damage by insects, pests, animals and microorganisms (fungi and bacteria).
2. **Chemical and biochemical**: Undesirable reactions between chemical compounds present in the food such as browning, rancidity, enzymatic changes, etc.
3. **Mechanical**: Spillages, damages caused by abrasion, bruising, crushing, puncturing, etc.
4. **Physical**: Improper environmental and storage conditions (temperature, relative humidity, air speed, etc.)
5. **Physiological**: Sprouting, senescence, other respiratory and transpiratory changes.
6. **Psychological**: Human aversion or refusal due to personal or religious reasons.

Secondary causes usually are the result of inadequate or nonexistent input and may lead to conditions favorable for primary causes. This can include: improper harvesting and handling; inadequate storage facilities, inadequate transportation, inadequate refrigeration and/or inadequate marketing system.

Causes of postharvest food losses
biological and environmental factors (Kader, 1985)

Biological

- Respiration:
- Ethylene production
- Compositional changes
- Growth and development
- Transpiration
- Physiological breakdown
- Other factors

Environmental

- Light
- Relative Humidity
- Temperature
- other factors (fungicides, growth regulators, etc)

Fruits and Vegetables have living cells!

- **Consume**
  - O_2
  - Substrates
- **Evolve**
  - CO_2
  - Heat
  - Ethylene
  - Lose H_2O through epidermis
- **Metabolically active**
  - Tissue softening
  - Starch to sugars
  - Sorbitol to fructose
  - Organic acids decreasing
  - Flavor volatiles increasing
  - Color changes

Vegetables and Fruits

- Fruits and vegetables are cultivated and processed similarly.
- Many vegetables are fruits by the truest botanical definition.
- Fruits are defined as “those portions of a plant which houses the seeds”- Therefore tomatoes, cucumbers, peppers, okra, sweet corn etc are considered fruits.

What is a fruit?

From a botanical viewpoint, a fruit is the developed ovary of a flower; in other words, it is the product of determinate growth from an angiospermous flower or inflorescence.

From a consumer point of view fruits are "plant products with aromatic flavors, which are either naturally sweet or normally sweetened before eating" (Wills et al., 1989). They are essentially dessert type foods

What is a vegetable?

based on the plant organ used, they can be much more easily grouped into several categories such as seeds, pods, bulbs, roots, flowers, buds, stems, leaves, etc.

From a consumer's point of view "vegetables are soft edible plant products that are commonly salted, or at least not sweetened, cooked and often eaten with meat or fish dishes" (Wills et al., 1989).

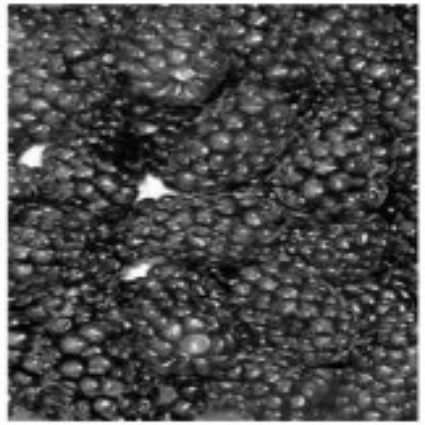
Classification of fruits

- **DRUPE: Stone Fruit - single seeded stone fruit demonstrating a simple morphological evolution**
  - **Developed from a single carpel or from syncarpous gynoecium of a single flower**
  - **Pericarp has a thin outer skin (epicarp)**
  - **Fleshy middle layer (mesocarp)**
  - **Thick hard shell (endocarp) surrounding a single seed**
  - **Examples are cherry, peach, apricot, plum**

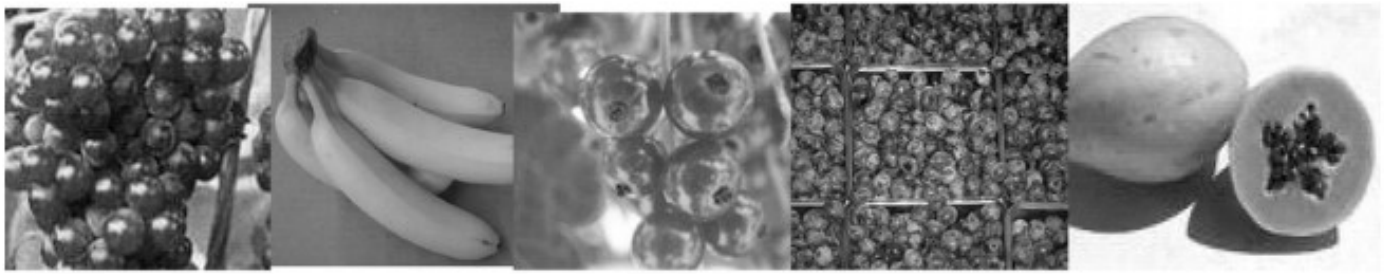



DRUPE - aggregate

- Can have also AGGREGATES of several druplets (developed from a single apocarpous flower with several individual carpels).
- Examples are raspberries and blackberries

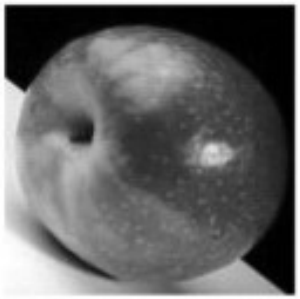


- **BERRY - consists of a simple morphological structure with a thin skin enclosing a juicy flesh containing many seeds**
  - **Examples are grapes, bananas, currants, blueberries, papayas etc.**



Peel structure is markedly different for each kind

- **POME**
  - **Characterized by a flesh developed from the fleshy receptacle which surrounds a harder core containing seeds as in apples and pears**



  - **Aggregated Pome: Strawberries represent an aggregate of single seeded fruits like drupes on a fleshy receptable**

- **HESPERIDIUM covers the citrus fruits that are a modified form of berries with a well developed peelable endocarp**

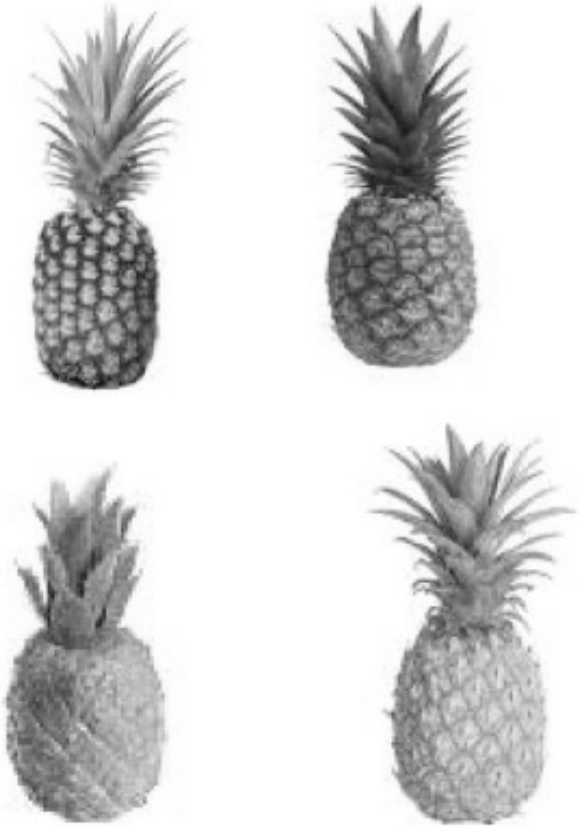
- **PEPO includes fruits belonging to the cucumber family with a berry like characteristic but with a hard outer layer developed from the receptacle.**
- **Examples are melons, cantaloupe, cucumber, etc.**

- **SYNCONIUM represents a multiple morphological behavior. It represents a class of fruits with a hollow fleshy receptacle containing fruits derived from several individual flowers.**

- **A classical example is the fig.**

- **SOROSIS refers to the group of fruits with fleshy floral bracts and receptacle with a terminal leafy shoot.**

- **Pineapple is an example.**



Classification of Vegetables

Kader (1985) classified different vegetables into

(1)bulky vegetative organs mostly comprising of roots, tubers and bulbs,

(2)leafy succulent tissues and

(3)fruit vegetables as follows:

Bulky Vegetative Organs

- Roots:Beet, cassava, carrot, horseradish, radish, parsnip, sweet potato

- Tubers: Potato, yam

- Bulbs: Onion, garlic

Leafy Succulent Tissues

- Leafy: Brussels sprouts, cabbage, celery, lettuce, parsley, spinach

- Floral: Artichokes, broccoli, cauliflower

- Stem: Asparagus, fennel

Fruit Vegetables

- Immature fruit: Bean, cucumber, eggplant, okra, pea, pepper, squash, sweet corn

- Mature fruit: Melons, pumpkin, tomato

Other Classification Methods

- respiration rates (very important)
- respiratory behavior,
- ethylene production rate,
- chilling sensitivity

Based on the respiration rate at 5°C, Kader (1985) grouped the fruits and vegetables into the following categories:

- Respiration rate, < 10 mg CO_2 /(kg.h): Nuts, dates, dried fruits and vegetables; apple, citrus, grape, kiwifruit, garlic, onion, potato, sweet potato

- Respiration rate, 10–40 mg CO_2 /(kg.h): Apricot, avocado, banana, blackberry, cherry, fig, peach, nectarine, pear, plum, raspberry, strawberry, cabbage, cauliflower, carrot, lettuce, lima bean, pepper, tomato

- Respiration rate, > 40–60 mg CO_2/(kg.h): Artichoke, asparagus, snap bean, broccoli, mushroom, green onion, pea, spinach, sweet corn, Brussels sprouts

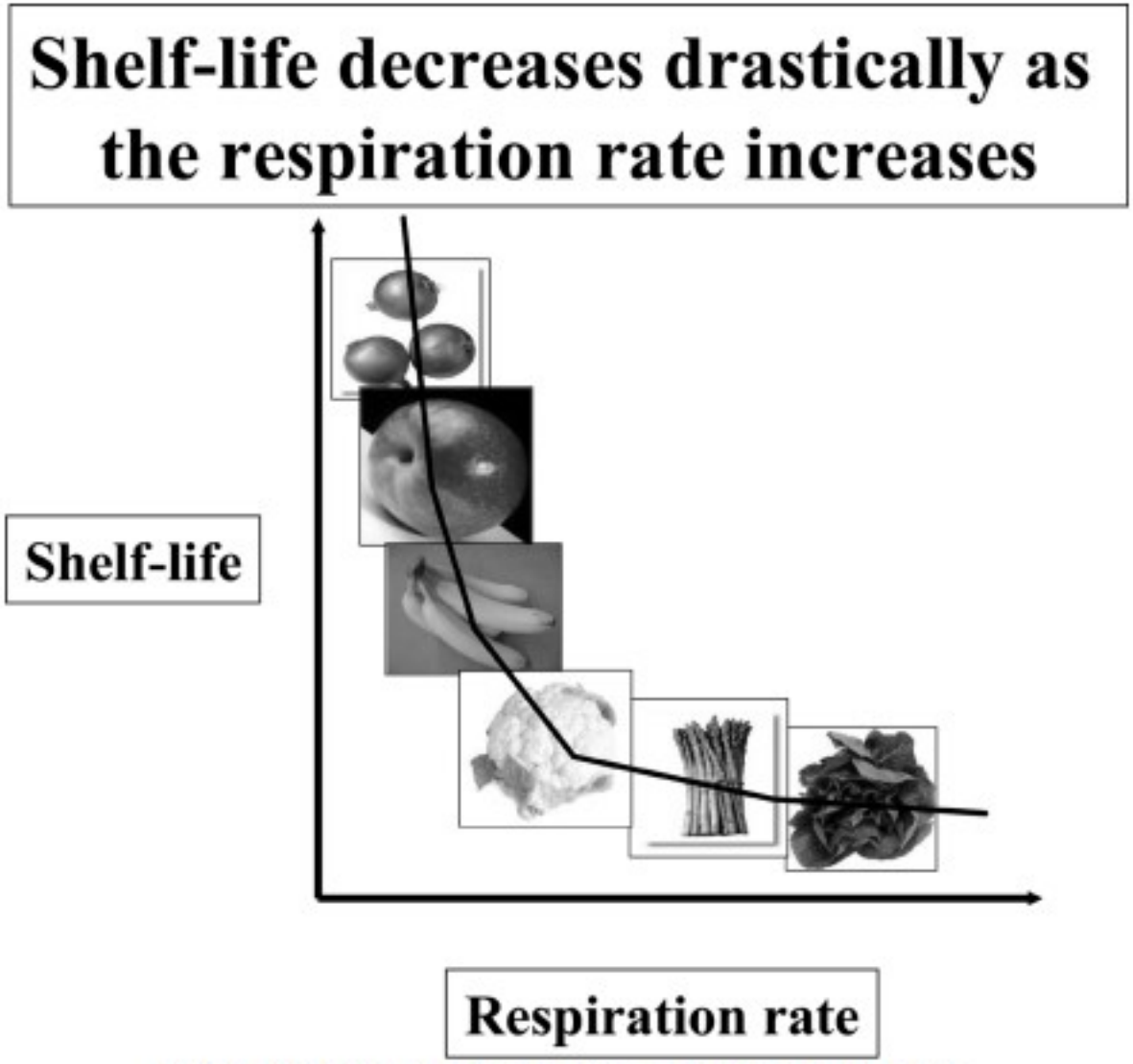


FIGURE 2.3. Storage life of produce vs their respiration rate.

Climacteric fruits	Non Climacteric fruits
a large increase in the respiration and ethylene production rates almost coincident with their ripening	a somewhat uniform rate throughout
Apple, apricot, avocado, banana, biriba, blueberry, breadfruit, fig,guava,jackfruit, kiwifruit, mango, muskmelon, nectarine, papaya, passion fruit, peach, pear, persimmon, plantain, plum, sapote, tomato, watermelon.	Blackberry, cacao, cashew apple, cherry, cucumber, eggplant, grape, grapefruit, jujube, lemon, lime, loquat, lychee, olive, orange, pepper, pineapple, pomegranate, raspberry, satsuma mandarin, strawberry, summer squash, tangerine.

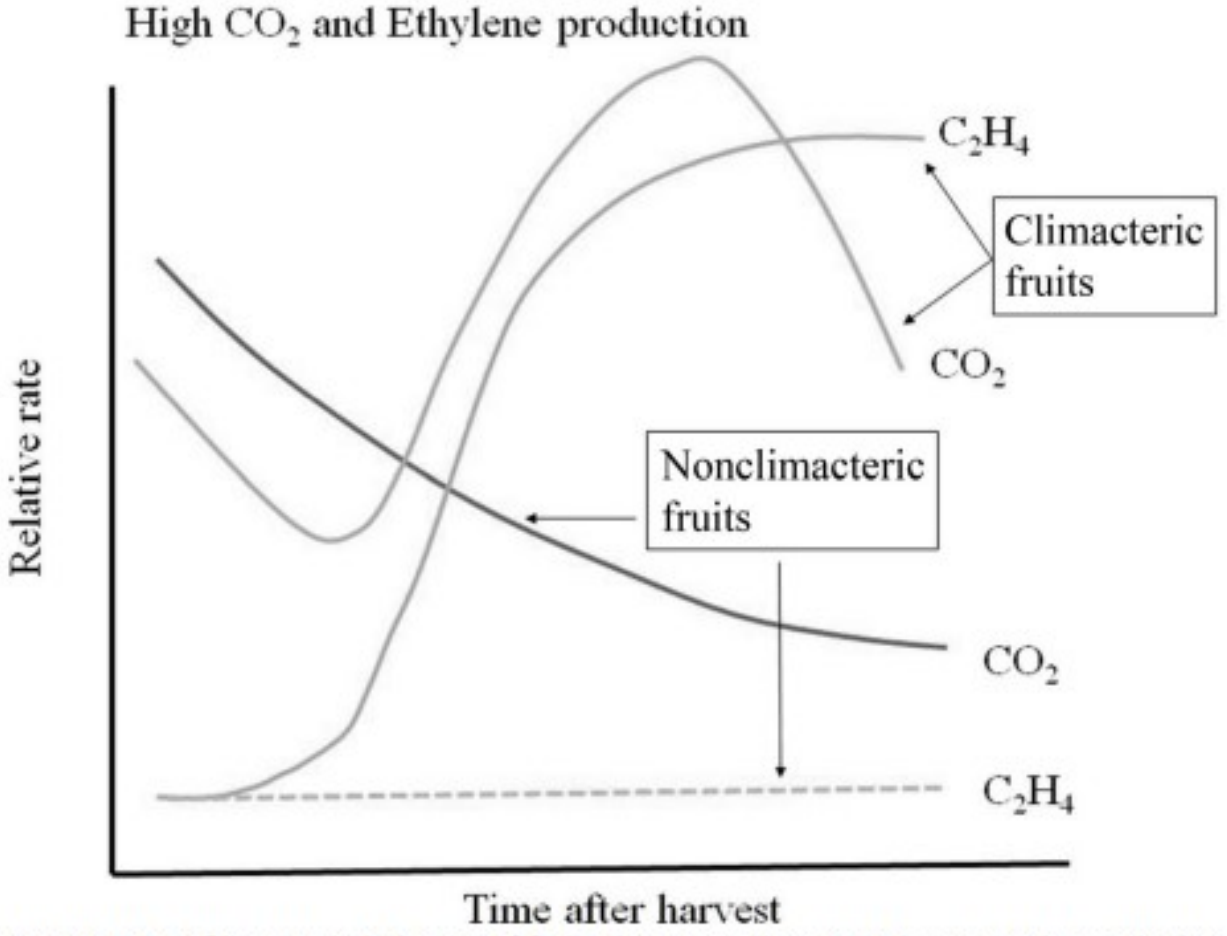


FIGURE 2.4. *Climacteric behavior of fruits demonstrating steep increases in respiration and ethylene production rates at the onset of senescence.*

classification based on relative ethylene production rates

•Ethylene production rate at 20°C below 10 µl C_2H_4 /kg.h:
Banana, blueberry, cauliflower, cherry, citrus, cranberry, fig, guava, mango, honeydew melon

•Ethylene production rate at 20°C between 1–10 µl C_2H_4 /kg.h :
Apple, apricot, avocado, cantaloupe, kiwifruit (ripe) nectarine, papaya, peach, pear, plum.

• Ethylene production rate at 20°C above 100 µl C_2H_4 /kg.h :
Cherimoya, mammee apple, passion fruit, sapote.

classification based on relative chilling sensitivity

Chilling injury is a common physiological disorder in tropical and subtropical commodities which are held at temperatures in the range 0 to 10°C.

- **Group I: Non chilling sensitive commodities**: Apple, apricot, bushberry, cherry, fig, grape, kiwi, nectarine, peach, pear, persimmon, plum, prune, strawberry, artichokes, asparagus, lima bean, beet, broccoli, Brussels sprouts, cabbage carrot, cauliflower, celery, sweet corn, garlic, lettuce, onion, pea, radish, spinach, turnip.

- **Group II: Chilling sensitive commodities**: Avocado, banana, citrus, guava, jujube, mango, muskmelon, papaya, passion fruit, pineapple, plantain, tomato, watermelon, snap bean, cucumber, eggplant, okra, olive, pepper, potato, pumpkin, squash, sweet potato.

classification based on the size of fruits and vegetables (Pantastico, 1975).

TABLE 2.1. Sizes of Fruits and Vegetables.

Size Class	Weight Range (g)	Fruits and Vegetables
Very light	< 50	Lanzones, cashew, cherry, tamarind, garlic, strawberry, beans, peas, Brussels sprouts,olives, raspberries, blueberries
Light	50–100	Guava, passion fruit, onion, sweet pepper, tomato
Medium Light	100–250	Apricot, banana, sapote, carambola, radish, carrots, potato, eggplant, sweet potato
Medium	250–500	Mango, plantain, citrus, chayotte, cucumber, lettuce, peach, pear, pomegranate
Medium heavy	500–1,000	Avocado, cabbage, cauliflower
Heavy	1,000–5,000	Papaya, pineapple, soursop, durian, honeydew melon, squash
Very heavy	> 5,000	Jackfruit, watermelon

In summary,

fruits and vegetables are classified based on:

- **botanical,**
- **morphological,**
- **structural and**
- **functional differences** (from postharvest management point of view)

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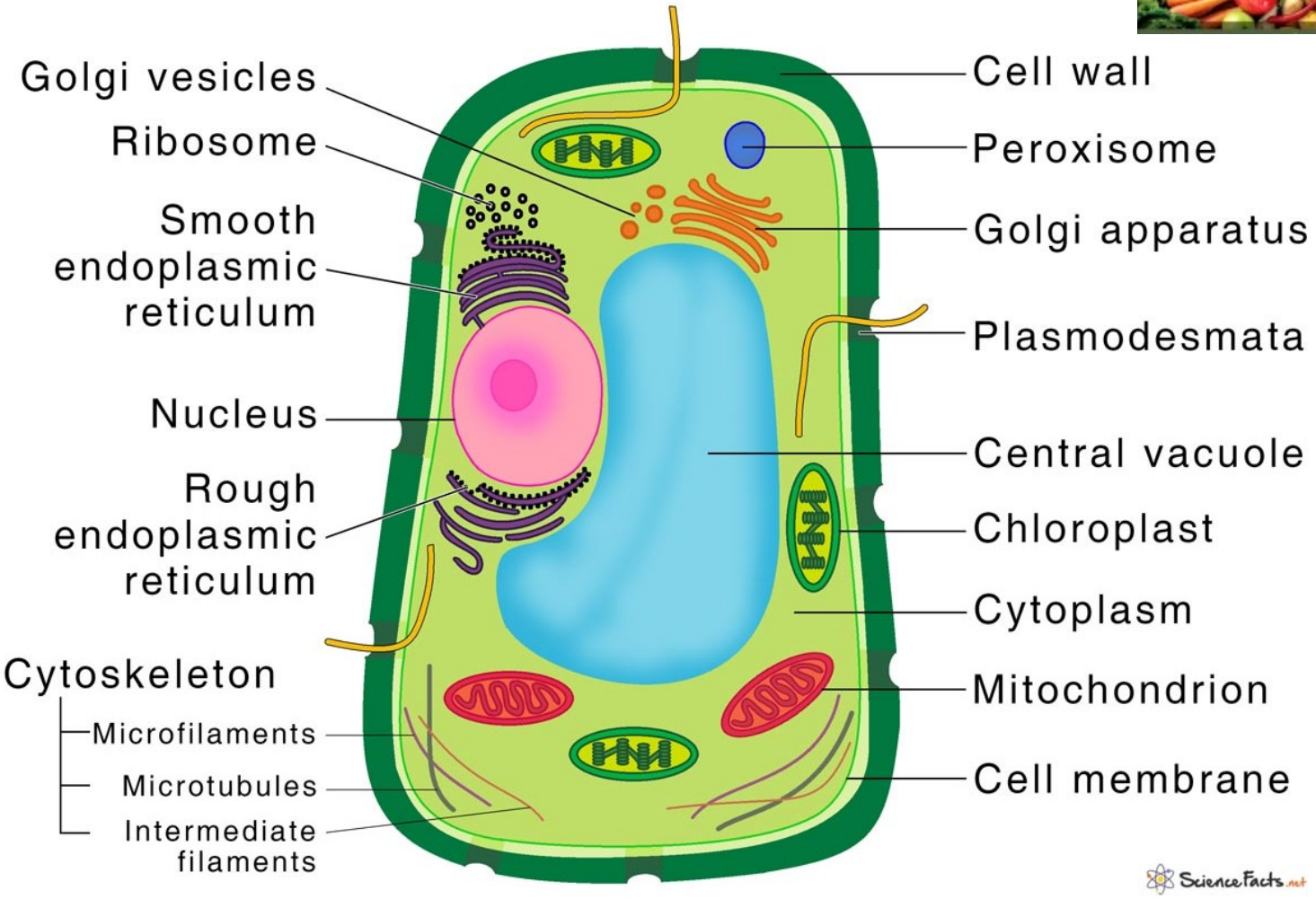
MFT-201

CHEMICAL COMPOSITION

Plant Cell


Golgi vesicles
Ribosome
Smooth endoplasmic reticulum
Nucleus
Rough endoplasmic reticulum
Cytoskeleton
Microfilaments
Microtubules
Intermediate filaments
Cell wall
Peroxisome
Golgi apparatus
Plasmodesmata
Central vacuole
Chloroplast
Cytoplasm
Mitochondrion
Cell membrane
ScienceFacts.net

From a functional point of view, the different tissues in a plant organ can be grouped under three main classes:

- Dermal system (Protective)
- Ground system (Supportive)
- Vascular system (Transportive)

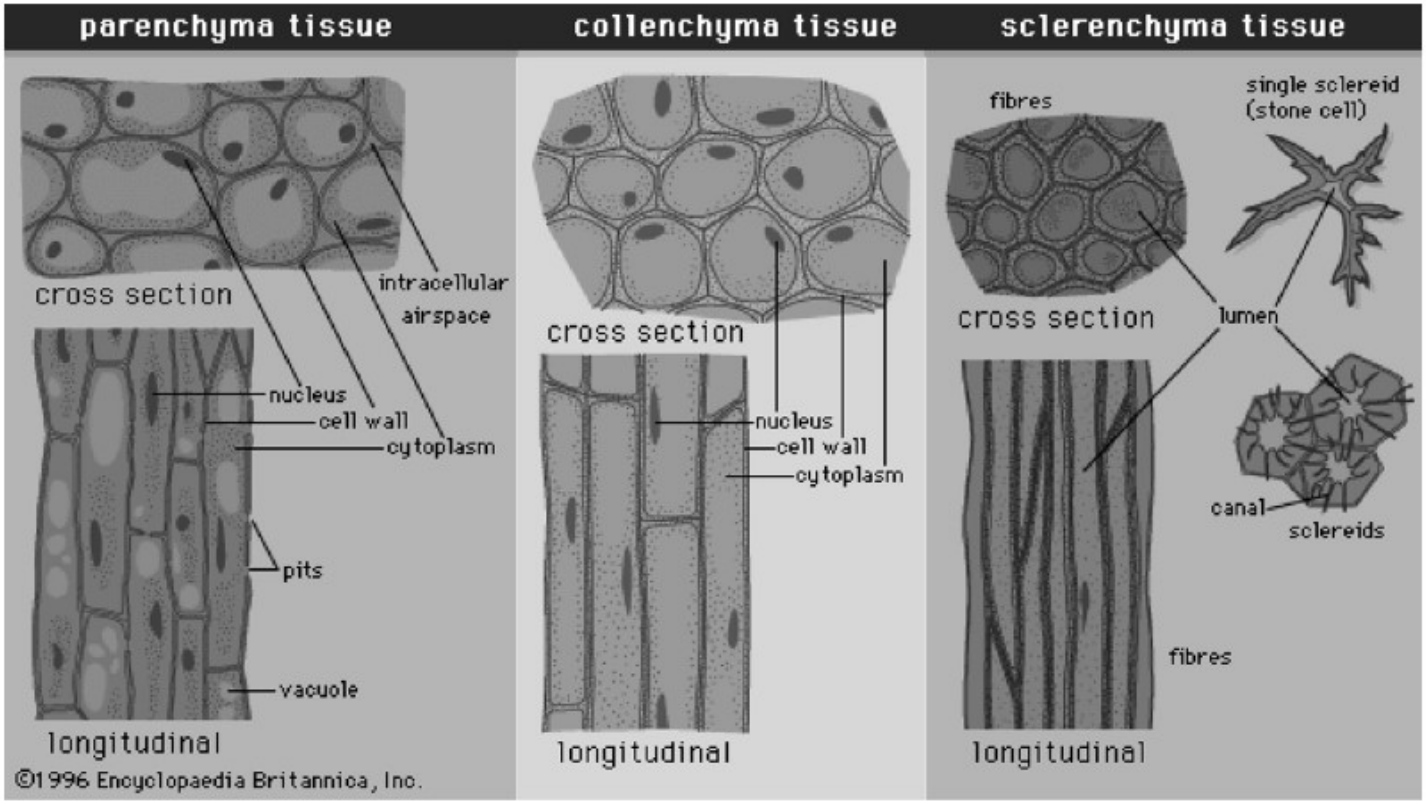


FIGURE 3.2. Structure schematics of a plant cells.

Major components in Fruits and Vegetables

Water

- Carbohydrates
- Proteins
- Fats
- Organic acids
- Vitamins & Minerals
- Pigments
- Flavor constituents

TABLE 4.2. Structural Components of Plant Cells.

Structural Component	Chemical Constituents
Cell wall	
Primary wall	Cellulose, hemi-cellulose, pectic substances, lignin
Plasmalemma	Pectic substances, lipoproteins, phospholipids
Nucleus	Nucleoproteins, nucleic acid, enzymes
Protoplasm	
Vacuole	Inorganic salts, organic acids, oil droplets, sugars, amino acids, vitamins, pigments
Tonoplast	Pectic substances, lipoproteins, phospholipids
Chloroplast	Chlorophyll
Amyloplast	Starch granules, carbohydrates
Chromoplast	Pigments
Oil droplets	Tryglycerides
Mitochondria	Enzymes, co-enzymes, minerals
Ribosome, microsome	Nucleoproteins, nucleic acid, enzymes

TABLE 4.1. Typical Percentage Composition of Edible Portion of Foods of Plant Origin.

Food	Carbohydrate	Protein	Fat	Ash	Water
Cereals	72–79	7–11	1–5	0.7–1.7	12–13
Earth—Vegetables	18–27	1–2%	0.1–0.4	1	70–78
Vegetables	2–17	1–7	0.1–0.4	0.7–1	75–95
Fruits	6–24	0.3–1.3	0.2–0.5	0.3–0.8	73–93

Water

- Most important component as it is life sustaining
- Most of the fruits and vegetables contain 75% water

- 95% water is present in lettuce, cucumber and melons
- 50% water in yam cassava and potato
- 10-15% legumes, cereals

CARBOHYDRATES

- Next most abundant component after water
- 75% solid matter

Carbohydrate content	Commodity
2–20%	vegetables
5–25%	fruits
20–30%	starchy roots and tubers such as potato, cassava and yam
70%	pulses and cereals

TABLE 4.3. Principal Cell Wall Constituents and Their Chemical Nature.

Cellulose	β(1–4) linked glucose; Polymers of up to 12000 glucose units
Hemicellulose	β(1–4) linked xylose; Polymers of 150–200 units of xylose with uronic acid
Pectic Substances	α(1–4) linked galacturonic acid
Lignin	Insoluble, high molecular weight polymers of coumaryl, coniferyl and sinapyl alcohols
Glucomannans	β(1–4) randomly linked glucose and mannose
Arabinogalactans	β(1–3) linked galactose

Dietary Fiber

Composed of cellulose
Hemicellulose
Lignins
Pectins

} Cell wall components

Human system lacks enzyme system to digest it

Absorbs large amount of water and constitute non digestible bulk of the diet

Water soluble : Pectins and gums
Insoluble: cellulose, hemicellulose, lignin

Pre-biotics and probiotics

Prebiotics are defined as "nondigestible food ingredients that beneficially affect the host by selectively stimulating the growth of one or a limited number of bacterial species in the colon, such as *Bifidobacteria and Lactobacilli, which have the potential* to improvethe host's health."

Some examples of prebiotics are
- inulin,
- fructo-oligosaccharides (FOS),
- polydextrose,
- arabinogalactan,
- polyols—lactulose, lactitol.

Important sources of prebiotics are:
Whole grains, onions, bananas, garlic, honey, leeks and artichokes

Probiotic

A probiotic has been defined as "a live microbial food ingredient that, when ingested in sufficient quantities, exerts health benefits" or "live microorganisms which, when administered in adequate amounts, confer a health benefit on the host."

Ex:

Lactobacillus

Bifidobacterium

Food Sources:

Prebiotics

- Asparagus
- Artichokes
- Bananas
- Garlic
- Onions
- Soybeans
- Whole wheat foods

Probiotics

- Aged cheese
- Kefir
- Kimchi
- Miso
- Sauerfraut
- Soy beverages
- Tempeh
- Yogurt

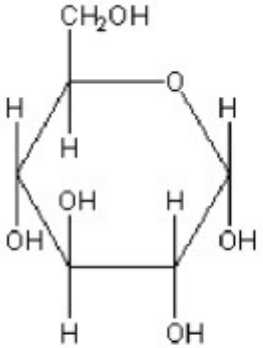
Sugars and Starch

Sugars : ripe fruits and tender vegetables

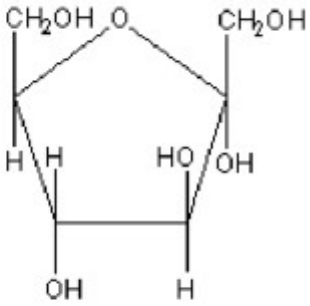
Starch: vegetables and unripe fruits

Common sugars are

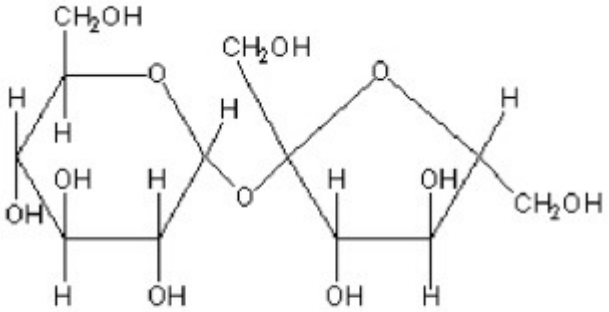
- Fructose,
- Glucose
- Sucrose



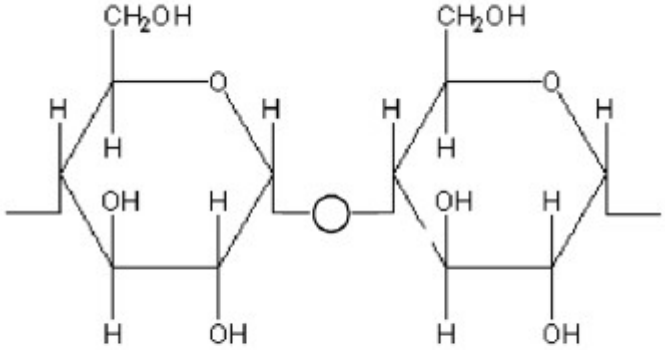
glucose



fructose

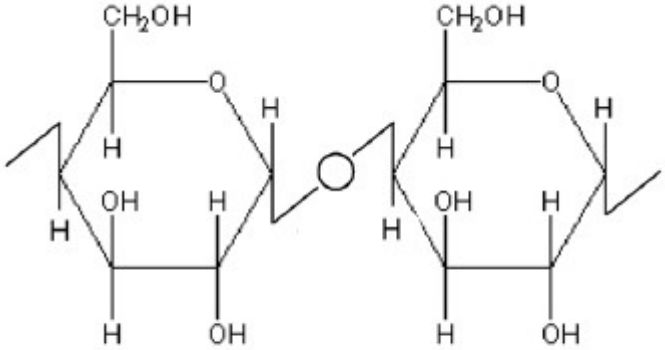


sucrose



starch (α-1,4)

amylase



cellulose (β-1,4)

cellulase

Pectic substances

Important component of cell wall
Non digestbale: water soluble

long-chain polymerized methyl esters of polygalacturonic acid

Upon mild hydrolysis, these yield water soluble pectin which can form gels or viscous colloidal suspensions with sugar and acid.

Useful in fruit industry to make jams and jellies

Fruits and vegetables also contain a natural enzyme that can further hydrolyze pectin
pectin methyl esterase (PME)

Several fruits, for example
tomatoes, oranges, and apples, contain both pectin and the enzyme.

PROTEINS

Fruits: <1%
Vegetables: 2% (with the exception of peas which have 7% protein
Cereals and pulses contain 7–12% protein

Most proteins present in fruits and vegetables are "**storage proteins**"

Common plant proteins are albumins, globulins, gliadins and glutenins

Gluten is a complex formed from gliadins and glutenins following hydration and mixing, and is responsible for the rubbery texture of wheat dough.

FATS AND OILS

content is generally less than 2% (dry weight basis)
Some exceptions

- Palm kernel (70–80% oil),
- avocado (35–70% oil),
- Olive (20–40% oil),
- and laurel (25–55% oil).

Other oil-bearing plant crops,
generally with more than 50% oil on a dry weight basis,
oil seeds like

- soybean,
- sunflower and
- sesame seeds, and several
- nuts (coconut, peanut, and almond)

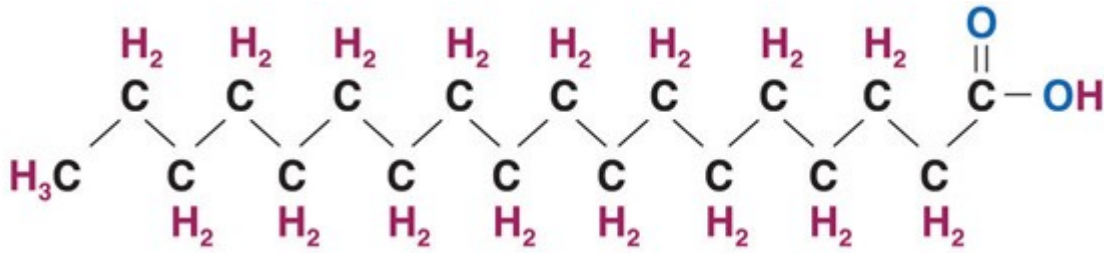
Lipid materials are especially prominent in the protective tissues at

- **cuticle,**
- **epidermis and**
- **Corky tissue**

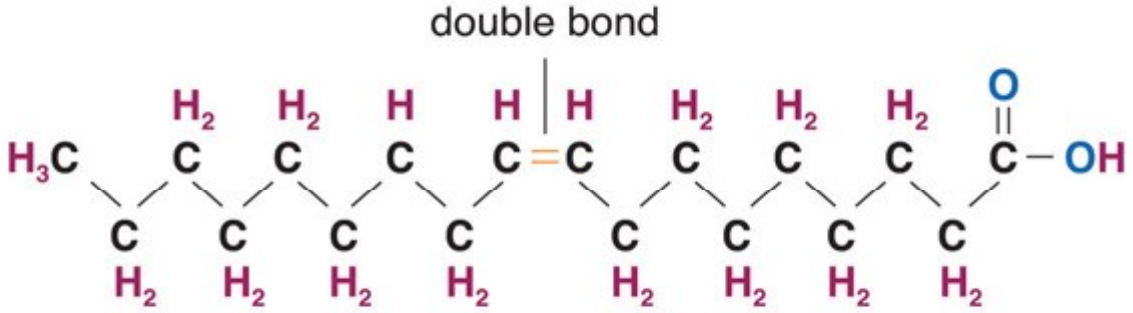
Fats: triglycerides, i.e., fatty acid esters of glycerol.

Nutritional value of a fat/oil depends on its unsaturation (presence of one or more double bonds)

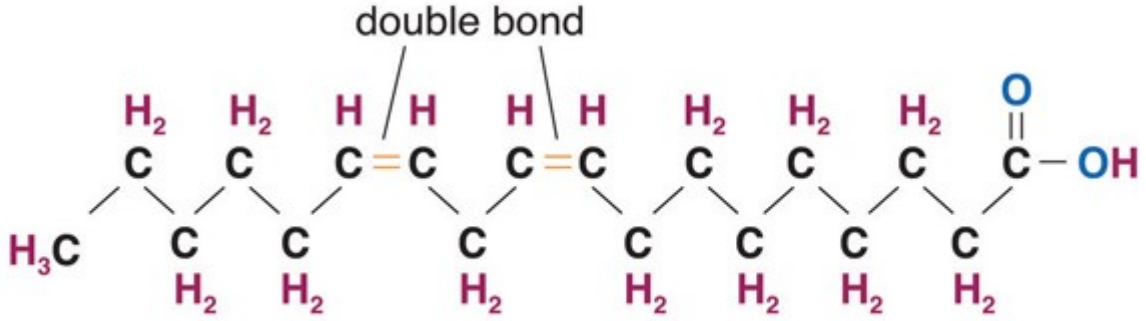
Stearic acid
$C_{18}H_{36}O_2$
A saturated fat



Oleic acid
$C_{18}H_{34}O_2$
A monounsaturated fat

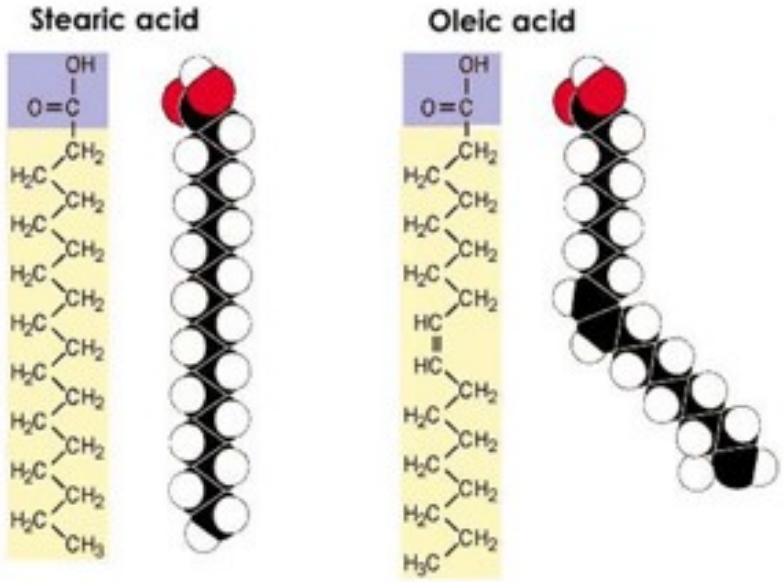


Linoleic acid
$C_{18}H_{32}O_2$
A polyunsaturated fat



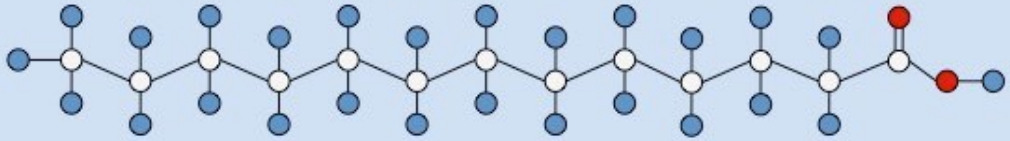
Fats

- Saturated fats
  - Solid at room temperature
  - Fatty acid is saturated
    - No double bonds
- Unsaturated fats
  - Liquid at room temperature
  - Double bonds (1+) in fatty acid

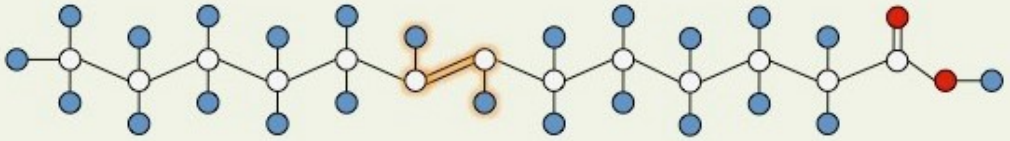


Type of Fatty Acid	Double Bonds	Diagram
Saturated	None	
Monounsaturated	One	
Polyunsaturated	Multiple (>1)	

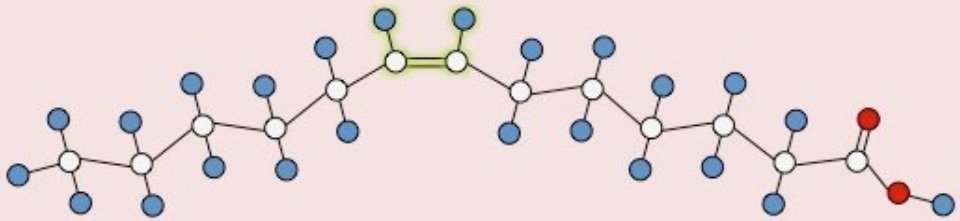
Saturated fatty acid
(***no*** double bonds)



Unsaturated – ***trans***
(H atoms opposite)



Unsaturated – ***cis***
(H atoms same side)
⟹ *bent configuration*



○ = C ● = O ● = H

TABLE 4.4. Lipid Content of Some Foods.

Source	Lipid Content (% dry weight basis)	Source	Lipid Content (% dry weight basis)
Oil-palm	70–80	Snap beans	1.1
Avocado	35–70	Corn	2.6
Olive	30–70	Almonds	58
Laurel	25–55	Cashew	46
Grape	0.2	Coconut	65
Banana	0.1	Peanut	49
Apple	0.06	Sesame	50
Artichoke	1.3	Sunflower	50
Potato	0.1	Side salad	0.1
Potato chips	14	Side salad with dressing	1.2
Onion	0.1	Eggplant	0.2
Fried onion	3.5	Fried eggplant	7.4

FATS

Trans Fats

- Hydrogenated vegetable oils
- Fast foods
- Cakes/pastries
- Chocolate
- Deep Fried Food

Saturated Fats

Vegetable Fats

- Coconut
- Palm oil
- 3-in-1 & 2-in-1 beverages, creamer, condensed milk

Animal Fats

- Poultry skin
- Fatty meat
- Butter
- Ghee
- Tallow / lard
- Full cream dairy products

Unsaturated Fats

Polyunsaturated

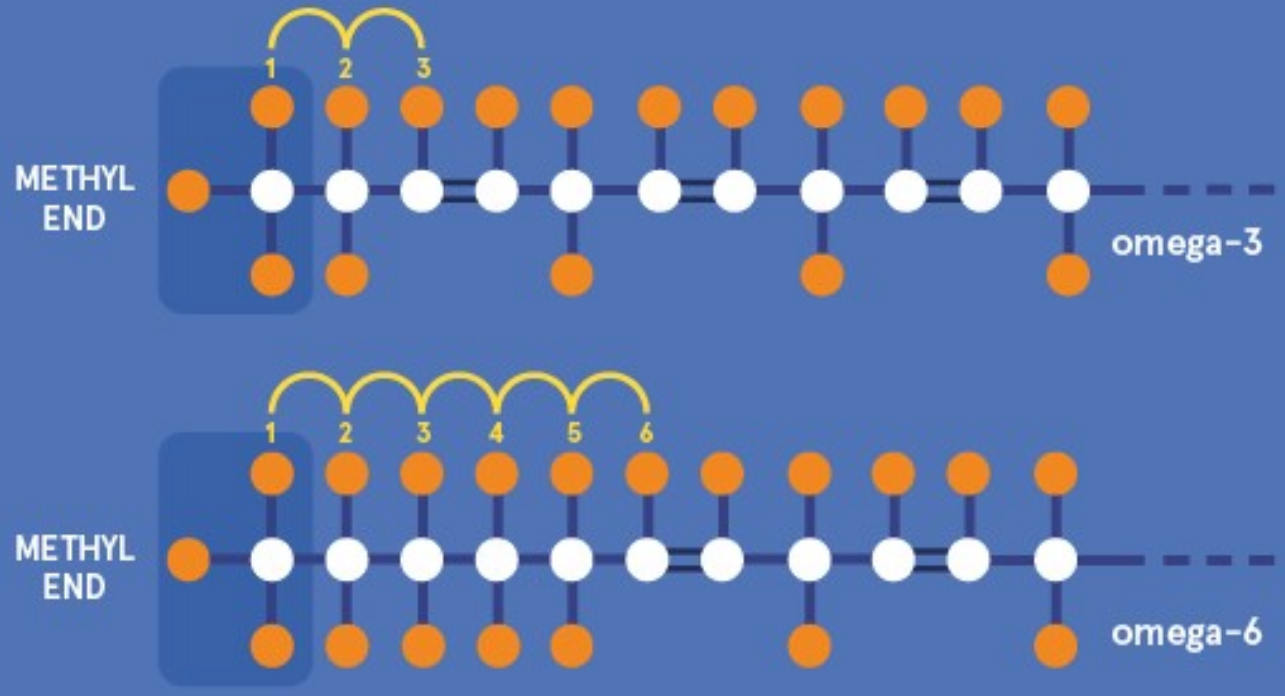
- Corn oil
- Soybean oil
- Sunflower oil
- Seeds
- Cold-water fish

Monounsaturated

- Olive oil
- Canola oil
- Peanut oil
- Sesame oil
- Avocado
- Most nuts

WHAT ARE OMEGA-3 & OMEGA-6 FATS?

omega-n refers to the number (n) of the carbon atom with the first double bond from the methyl end



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THE OMEGA FATTY ACIDS

Fatty Acid Family	Name	Structure	Food Source
Omega-3	Alpha-linolenic acid (ALA)	18:3 (n-3)	Walnuts, flaxseed oil, soybeans, canola oil
	Eicosapentaenoic acid (EPA)	20:5 (n-3)	Fatty fish and fish oils
	Docosahexaenoic acid (DHA)	22:6 (n-3)	Fatty fish, fish oils. algal oils
Omega-6	Linolenic acid (LA)	18:2 (n-6)	Corn, safflower, soybean, cottonseed and sunflower oils
	Gamma-linolenic acid (GLA)	18:3 (n-6)	Evening primrose oil, borage oil, black current seed oil
	Arachidonic acid (ARA)	20:4 (n-6)	Meat, poultry, eggs
Omega-9	Oleic acid (OA)	18:1 (n-9)	Olive oil, grapeseed oil

ORGANIC ACIDS

acetic, citric, malic, oxalic, etc.

Other acids dormant in some commodities are

- Tartaric acid in grapes and avocado,
- oxalic acid in spinach and
- isocitric acid in blackberry
- Malic acid in apples, apricots, cherries etc.

VITAMINS AND MINERALS

Fruits and vegetables: Richest source of Vit C
Important source of Vit A and folic acid

Mineral rich vegetables are:
Spinach (Calcium, 3–300 mg/100 g),
Sweet corn (Magnesium, 2–90 mg/100 g),
Seeds and sprouts (Phosphorous, 7–230 mg/100 g),
Celery (Sodium, 0–124mg/100g;
Chloride, 1–180 mg/100 g),
Parsley, green foods (Iron, 0.1–4 mg/100 g) and
High protein tissues (Sulphur, 2–170 mg/100 g).

PIGMENTS

The natural coloring in fruits and vegetables depens on a large number of individual chemical compounds, which fall naturally into three main groups:

- chlorophylls
- carotenoids
- flavonoids (anthocyanins)

Anti- nutritional elements

Lathyrus sativus: β-*n*-methylaminoalanine

Cycus circinalis: β-nalylaminoalanine

Certain mushrooms: acromelic acid

TABLE 4.7. Toxic Constituents of Plant Foodstuffs.

Name of the Toxin	Occurrence in Food
Protease (Enzyne) Inhibitors	Beans (soy, mung, kidney, lima, navy), chickpeas, peas, potato cereals
Hemaglutinins	Beans (soy, kidney, black, yellow), peas, lentils
Saponins	Soybean, peanuts, sugar beets, peanuts, spinach, asparagus
Glucosinolates (goitrogenic)	Cabbage, turnip, rutabaga, radish, rapeseed, mustard
Cynides and cynogens	Peas, lima beans, pulses, flax, cassava, tapioca, almonds
Gossypol	Cottonseed
Allergens	Practically all foods
Phytoalexins	Sweet potato, celery, parsnip, broad beans
Alkaloids	Mushrooms, herbal tea
Solanin	Sprouting potatoes
Aflatoxin	Peanuts
Furocumarin	Parsnip
Oxalic acid	Rhubarb, spinach