Colorants

Natural Colorants

- Natural
  - Tetrapyrrole - chlorophylls
  - Isoprenoid – carotenoids
  - Benzopyran - anthocyanins, flavonoids
  - Polyphenols - tannins
  - Melanin derivative, carmelization products

Color measuring systems

- Visible spectrum – 400 – 800 nm
  - White –reflect at high level over entire range
  - Grey/black reflect equally
  - Red-reflect higher wavelength, absorb lower
  - Blue – reflect lower wavelength, absorb higher
- Three factors –
  - spectral composition of light source
  - Chemical and physical characteristics of the object
  - Spectral sensitivity of properties of the eye

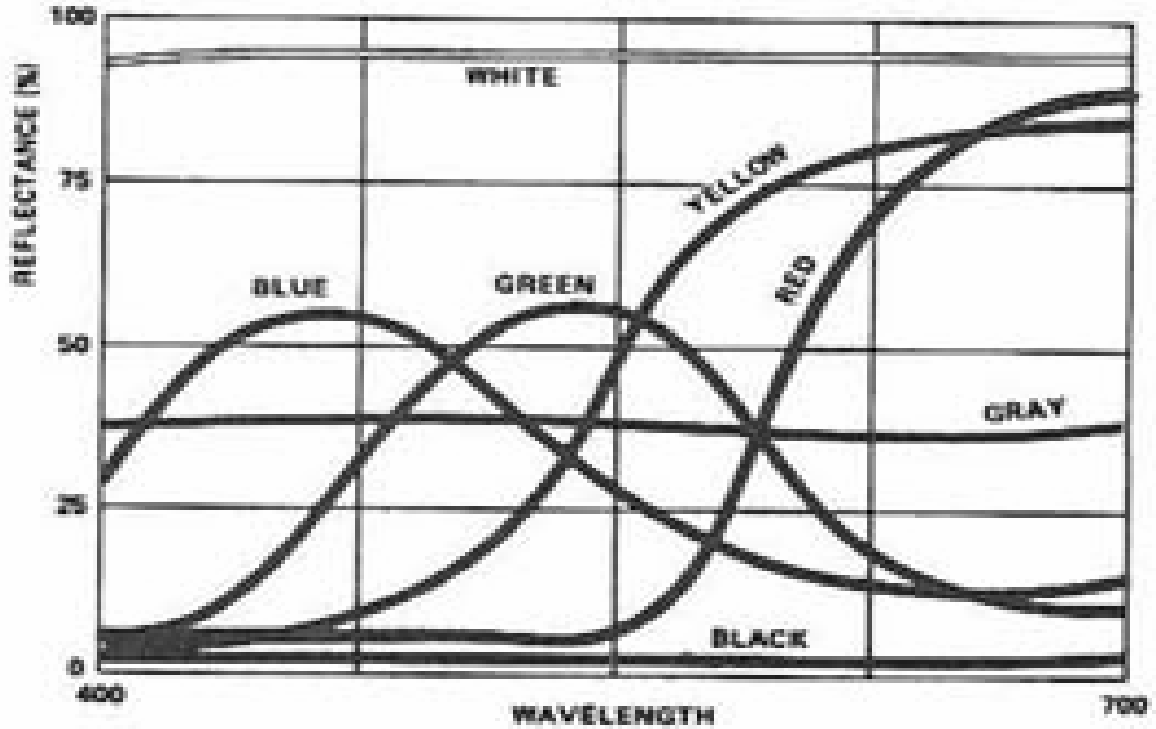


Figure 6–1 Spectrophotometric Curves of Colored Objects. *Source:* From Hunter Associates Lab., Inc.

Table 6–1 Complementary Colors

Wavelength (nm)	*Color*	*Complementary Color*
400	Violet	Yellow
450	Blue	Orange
500	Green	Red
550	Yellow	Violet
600	Orange	Blue
650	Red	Green
700		

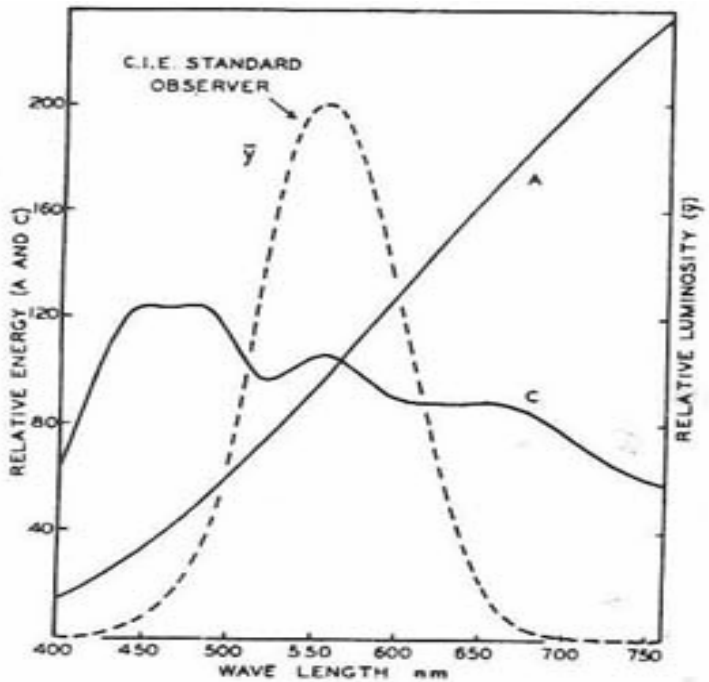


Figure 6–2 Spectral Energy Distribution of Light Sources *A* and *C*, the CIE, and Relative Luminosity Function γ for the CIE Standard Observer

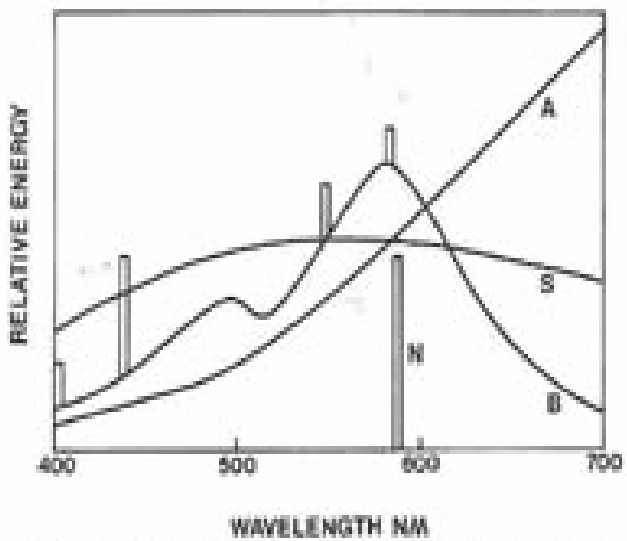
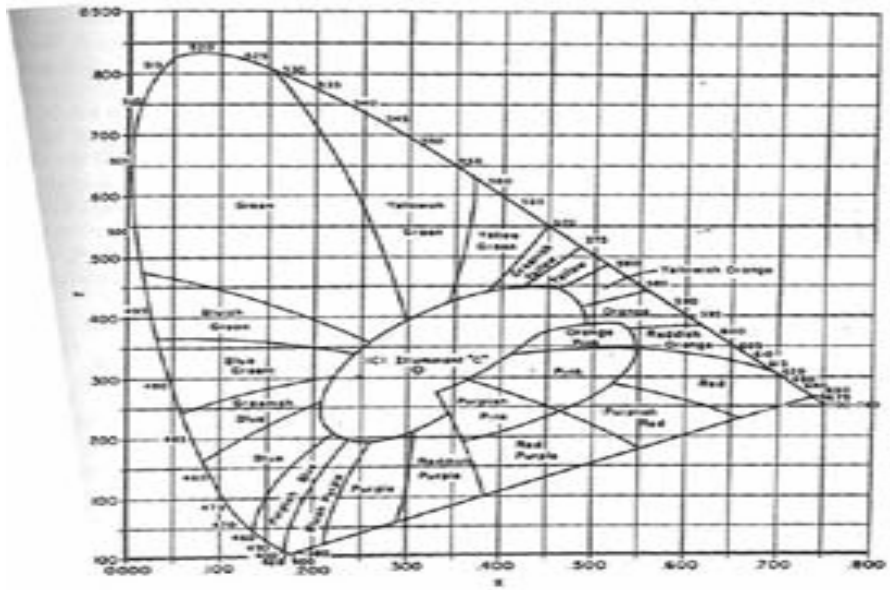


Figure 6-8 Spectral Energy Distribution of Sunlight (S), CIE Illuminant (A), Cool White Fluorescent Lamp (B), and Sodium Light (N)

Color measurement systems

- **Trichromatic CIE XYZ** –component spectral features of light- all colors can be matched by 3 primaries (red,green,blue)



Chromaticity Diagram

Color measurement systems

- **Munsell** – all colors expressed as hue, value and chroma. All colors can be expressed on a ‘color space’
- Hue= 10 hues arranged in a circle-red (R), yellow (Y),green(G),blue(B), purple (P);yr, gy,bg,pb
- Value=lightness(0=black) and 10=white on line perpendicular to hue circle
- chroma-=measure of difference of a color of grey of same lightness (purity of color)-0=central grey

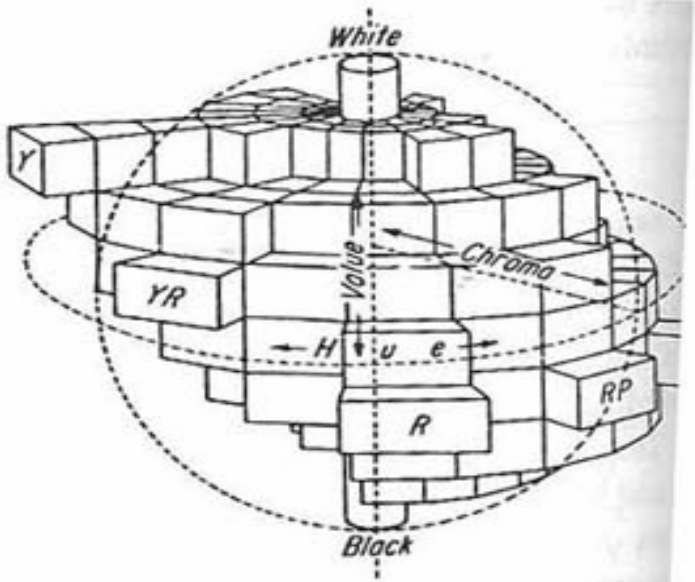


Figure 6–9 The Munsell Color Space

Color measurement systems

- Hunter system- eye has red, green, blue color receptors. Includes factors for perceived color ‘color dimensions’-of red/green (a) and blue/yellow(b)
- Factor for lightness (L)
- All colors expressed as single measurement and differences calculated

$$\Delta E=(\Delta L)^2+(\Delta a)^2+(\Delta b)^2$$

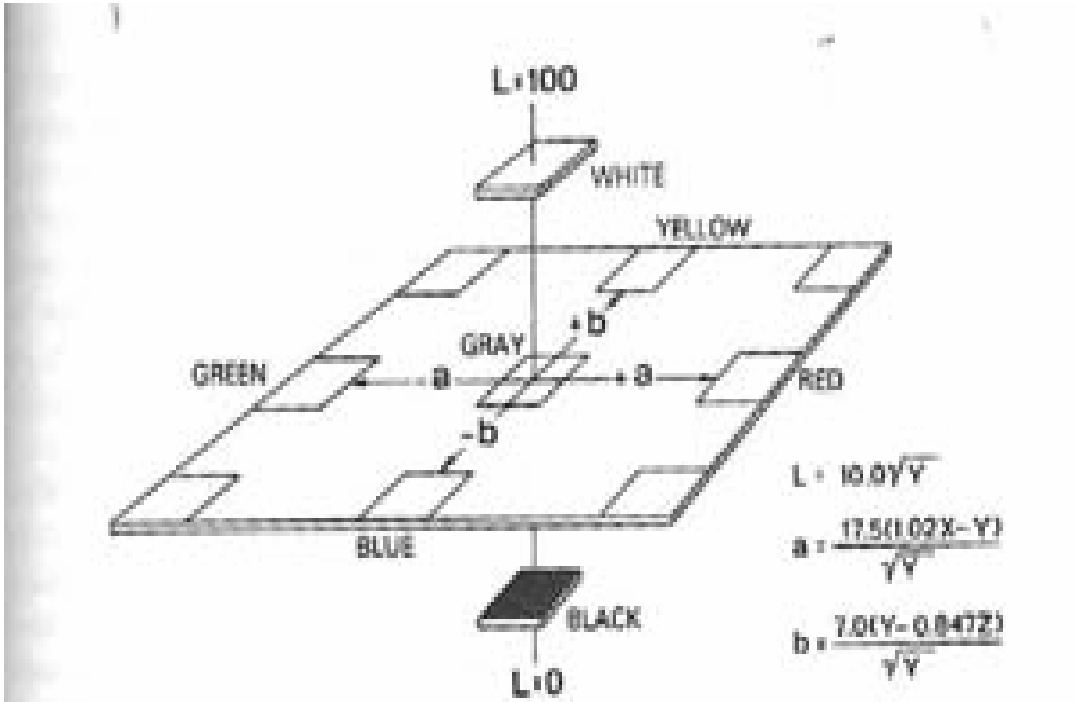


Figure 6–10 The Hunter *L*, *a*, *b* Color Space. *Source:* From Hunter Associates Lab., Inc.

Natural Colors- Tetrapyrrole Based

- 4 pyrrole joined together (porphyrin ring)
- Central metal ion

- Chlorophyll- Mg; Myoglobin- Fe

Chlorophyll

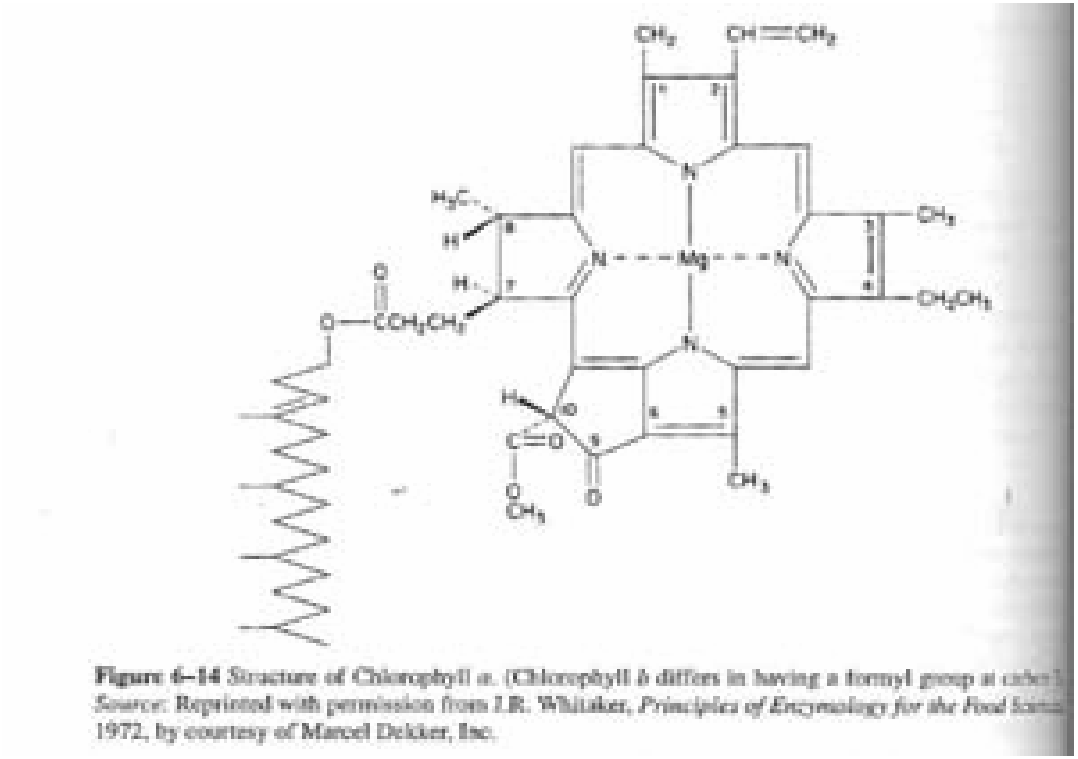


Figure 6–14 *Structure of Chlorophyll a.* (Chlorophyll *b* differs in having a formyl group at carbon 7.)
Source: Reprinted with permission from J.R. Whitaker, *Principles of Enzymology for the Food Sciences*, 1972, by courtesy of Marcel Dekker, Inc.

Chlorophyll breakdown

- Alkaline stable
- Cholorophyll bound to lipoprotein, somewhat protected from acid.
- Removal of Mg with acid - >pheophytin – olive brown

Hemoglobin and myoglobin

- Myoglobin, hemoglobin
- Fe is central metal ion
- Protein component (globin)
- Oxymyoglobin (red) – myoglobin (purple/red)-metmyoglobin (brown)
- Heat –denature globin, oxidize iron (hemichrome)
- Add nitrite – nitrosomyoglobin-> pink nitrosylhemochrome

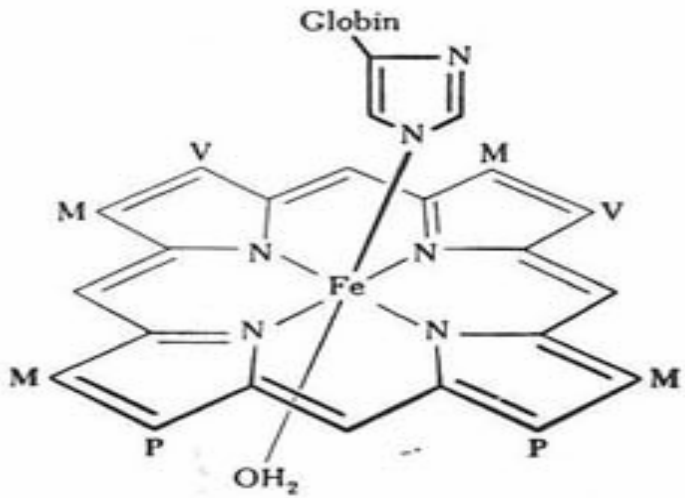
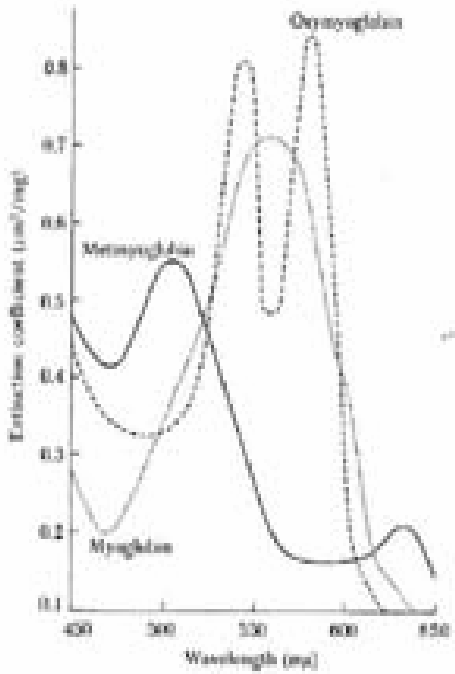


Figure 6–11 Schematic Representation of the Heme Complex of Myoglobin. M = methyl, P = propyl, V = vinyl. *Source*: From C.E. Bodwell and P.E. McClain, Proteins, in *The Sciences of Meat Products*, 2nd ed., J.E. Price and B.S. Schweigert, eds., 1971, W.H. Freeman & Co.



gure 6-12 Absorption Spectra of Myoglobin, Oxymyoglobin, and Metmyoglobin. *Source*: From E. Bodwell and P.E. McClain, Proteins, in *The Sciences of Meat Products*, 2nd ed., J.E. Price and B. Schweigert, eds., 1971, W.H. Freeman & Co.

Carotenoids

- Color – from conjugated double bonds. More double bonds – more red
- Need 7 for perceptible yellow color
- Cis and trans are both yellow to red. Trans are deepest color.
- Carotenoids in foods are mostly trans
- Change trans to cis by adding light, heat, acid

Carotenoid compounds: 1- Lycopene, 2,3,4- carotenes

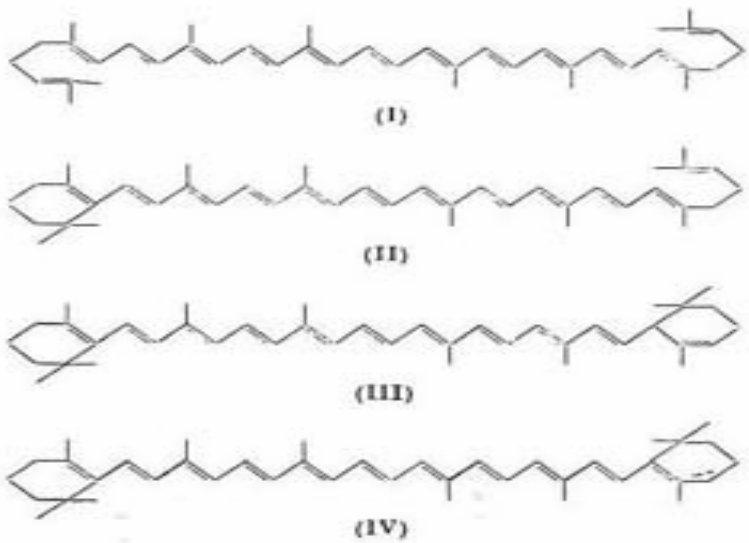


Figure 6–16 The Carotenoids: (I) Lycopene, (II) γ-carotene, (III) α-Carotene, and (IV) β-Carotene. *Source*: From E.C. Grob, The Biogenesis of Carotenes and Carotenoids, in *Carotenes and Carotenoids*, K. Lang, ed., 1963, Steinkopff Verlag.

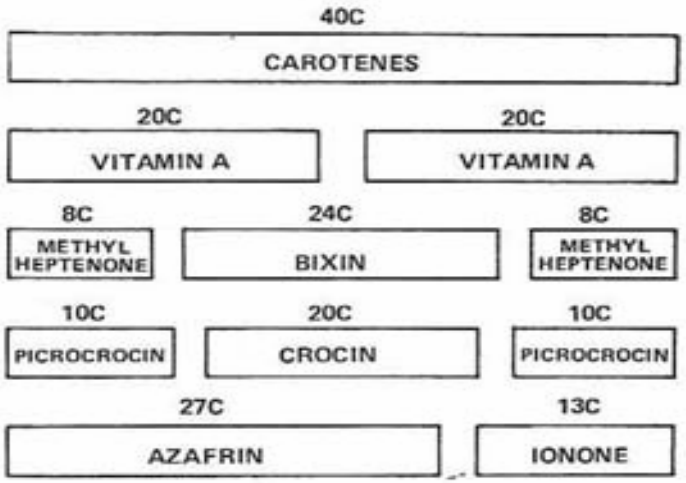


Figure 6–18 Relationship Between the Carotene and Carotenoids with Fewer than 40 Carbons

Formation of Vitamin A from β-carotene

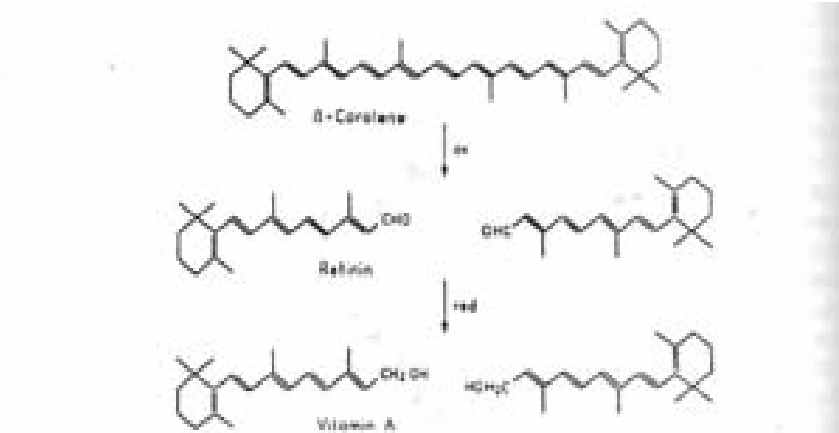


Figure 6–19 Formation of Retinin and Vitamin A from β-Carotene. *Source:* From E.C. Grob, The Biogenesis of Carotenes and Carotenoids, in *Carotenes and Carotenoids*, K. Lang. ed., 1963, Steinkopff Verlag.

Food sources

- Yellow and orange vegetables (carrots, tomatoes), leafy green vegetables
- Salmonids, crustaceans (caroteno-protein)
- Palm oil (lost during processing)
- Milkfat (grass fed cows)
- Eggs

Provitamin A content of various foods

Table 6–3 Provitamin A Value of Some Fruits and Vegetables

Product	*IU/100 g*
Carrots, mature	20,000
Carrots, young	10,000
Spinach	13,000
Sweet potato	6,000
Broccoli	3,500
Apricots	2,000
Lettuce	2,000
Tomato	1,200
Asparagus	1,000
Bean, french	1,000
Cabbage	500
Peach	800
Brussels sprouts	700
Watermelon	550
Banana	400
Orange juice	200

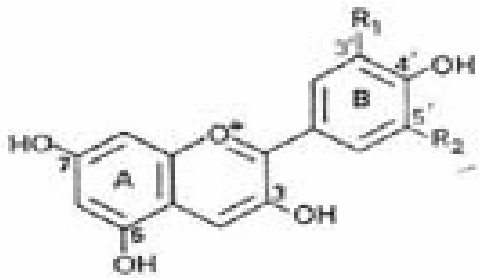
Source: From B. Borenstein and R.H. Bunnell, Carotenoids: Properties, Occurrence, and Utilization in Foods, in *Advances in Food Research*, Vol. 15, C.O. Chichester et al., eds., 1967, Academic Press.

Maintaining carotenoid content in foods

- Blanching – destroys enzymes responsible for carotenoid oxidation
- Stable in frozen and commercially stable foods, poor in dehydrated foods

Anthocyanins

- Plant sap – red, blue, violet
- Sugar (1 or 2 glucose, galactose, or rhamnose) + anthocyanidin group
- Can contain metal ions (Fe, Al, Mg) or organic acids
- Acid stable
- Strong color in acid – fade in neutral/basic, presence of sulfite
- Destroyed by high temperature, high pH, increased sugar concentration



$R_1 = H$	$R_2 = H$	PELARGONIDIN
$R_1 = OH$	$R_2 = H$	CYANIDIN
$R_1 = OH$	$R_2 = OH$	DELPHINIDIN
$R_1 = OCH_3$	$R_2 = H$	PEONIDIN
$R_1 = OCH_3$	$R_2 = OH$	PETUNIDIN
$R_1 = OCH_3$	$R_2 = OCH_3$	MALVIDIN

Figure 6–23 Chemical Structure of Fruit Anthocyanidins

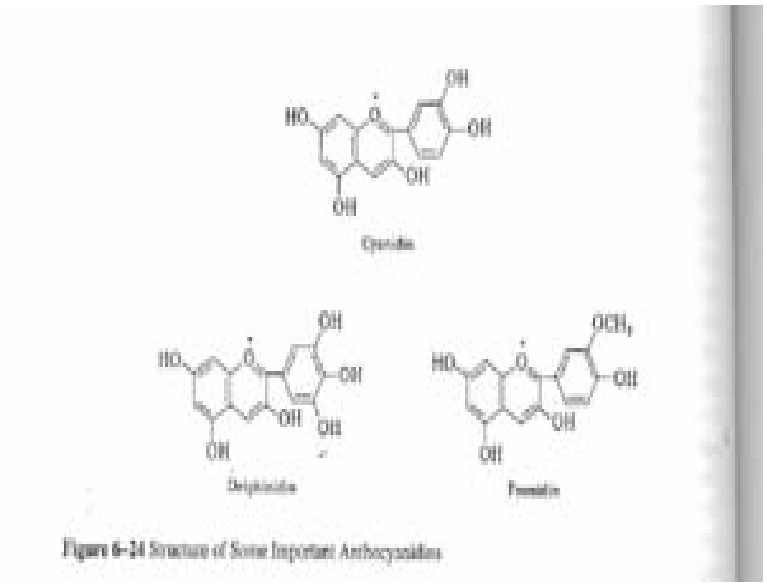


Figure 6-24 Structure of Some Important Anthocyanidins

Fruit or Vegetable	*Anthocyanidin*
Apple	Cyanidin
Black currant	Cyanidin and delphinidin
Blueberry	Cyanidin, delphinidin, malvidin, petunidin, and peonidin
Cabbage (red)	Cyanidin
Cherry	Cyanidin and peonidin
Grape	Malvidin, peonidin, delphinidin, cyanidin, petunidin, and pelargonidin
Orange	Cyanidin and delphinidin
Peach	Cyanidin
Plum	Cyanidin and peonidin
Radish	Pelargonidin
Raspberry	Cyanidin
Strawberry	Pelargonidin and a little cyanidin

Source: From P. Markakis, Anthocyanins, in *Encyclopedia of Food Technology*, A.H. Johnson and M.S. Peterson, eds., 1974, AVI Publishing Co.

Flavonoids

Blue or green with Fe

Browning reactions

Antioxidants

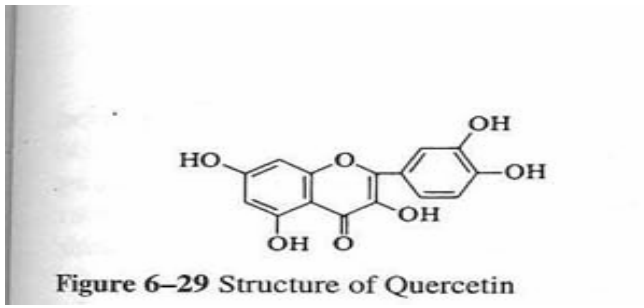


Figure 6–29 Structure of Quercetin

Tannins
Polyphenols
Color (red or brown), astringent

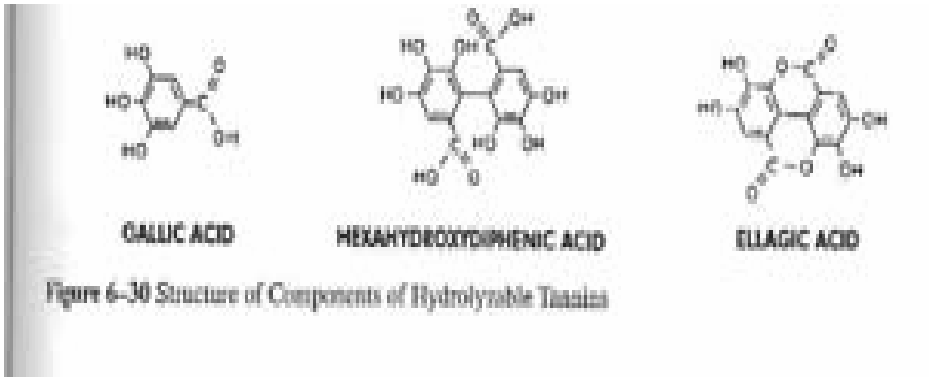


Figure 6-30 Structure of Components of Hydrolyzable Tannins

Artificial colorants

- Artificial or synthesized – certified color additives
- FD&C dyes (water soluble, <300ppm)
- FD&C lakes (insoluble, alumina complexes w/ 20-25% dye)

Table 6–7 Color Additives Not Requiring Certification

Colorant	*Restriction*
Annatto extract	—
Beta-apo-8′-carotenal	33 mg/kg
Beta-carotene	—
Beet powder	—
Canthaxanthin	66 mg/kg
Caramel	—
Carrot oil	—
Cochineal extract (carmine)	—
Ferrous gluconate	Ripe olives only
Fruit juice	—
Grape color extract	Nonbeverage foods only
Grape skin extract (enocianina)	Beverages
Paprika and its oleoresin	—
Riboflavin	—
Saffron	—
Titanium dioxide	1%
Turmeric and its oleo-resin	—
Vegetable juice	—