11. COMPOUNDS INFLUENCING FOOD COLOUR

perception visual colour

pigments (colouring matters, colourings)

formation

- primary compounds
  natural food components
  natural components of other materials (microorganisms, algae, higher plants), used as additives
- secondary compounds
  enzymatic reactions (non-enzymatic browning reaction)
  chemical reactions
- synthetic compounds
  used as additives

colour defects

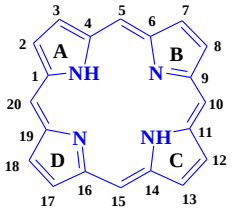
natural colours

important groups

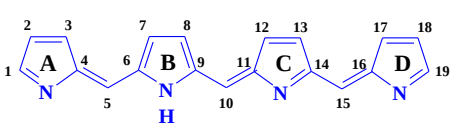
- tetrapyrrole colours — plants, animals
  hem colours
  chlorophyll colours
- betalain colours — plants
  betacyans
  betaxanthins
- flavonoid colours — plants
  anthocyanins
  anthoxanthins
- phenolic and quinoid colours — plants, animals
  phenols
  quinones
- carotenoid colours — plants, animals
  carotenes
  xanthophylls

TETRAPYRROLE PIGMENTS (TETRAPYRROLES)

- **porphyrin pigments** (porphyrins) — cyclic
  hem pigments (hems)
  chlorophyll pigments (chlorophylls)
- biline pigments (bilines) — linear
  phycobilins



porphyrins

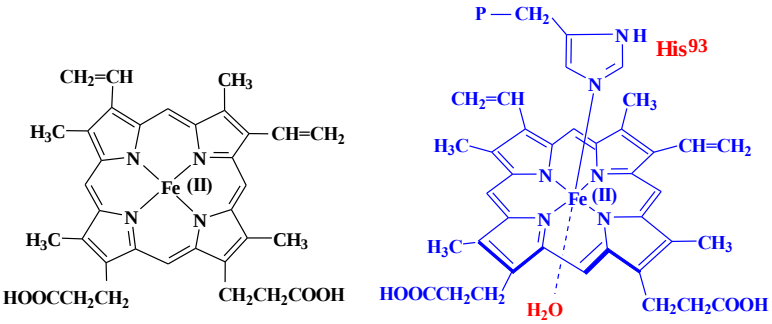


bilines

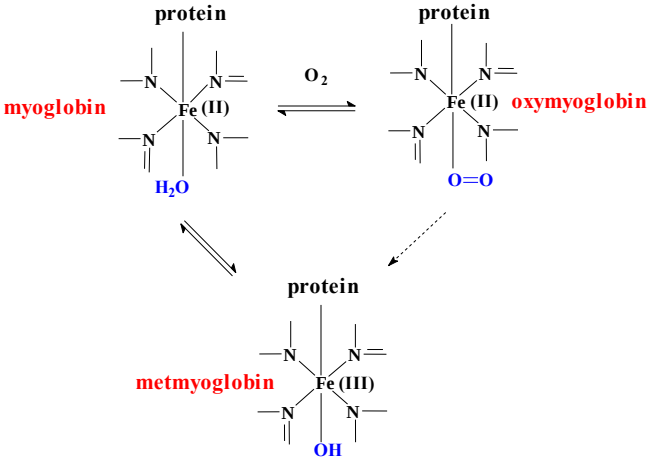
hem pigments

meat, meat products

nomenclature (book 3, tab. 9.1)
content (book 3, tab. 9.2, 9.3, 9.4, 9.5)



hem (reduced haematin, Fe^{2+}), hemoglobin
hematin (Fe^{3+}), myoglobin (P = globin residue,16,8 kDa)



myoglobin (Mb)	dark red
oxymyoglobin (MbO_2)	scarlet
metmyoglobin (MMb)	red to brown

reaction of MMb during temperature processing of meat

metmyoglobin
↓
globin denaturation (70-80°C)
↓
globin hydrolysis
↓
hematin or hem
↓ (loss of Fe^{3+} or Fe^{2+})
linear tetrapyrroles

stabilisation of meat and meat products colour

microorganisms in meat: $NO^{3-} \rightarrow NO^{2-}$
spontaneous reaction: $2\ Mb + NO_2^- \rightarrow 2\ MMb + NO + H_2O$

$$Mb + NO \rightarrow MbNO + H_2O$$

heating: $$MbNO \rightarrow Mb(NO)_2 + globin$$

MbNO = nitroxymyoglobin
$Mb(NO)_2$ = nitroxyhemochrom (nitrosylhemochrom, nitroxymyochromogen)

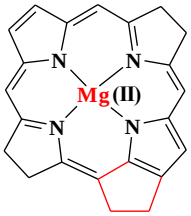
use of ascorbic acid: $MMb + H_2A \rightarrow Mb + A$

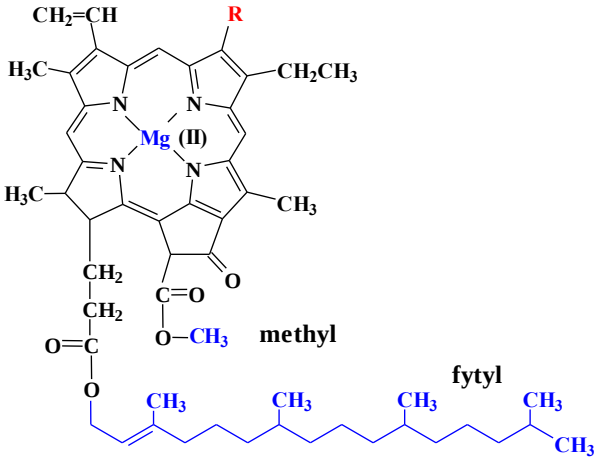
fuscous up to green colours (sulphomyoglobin, verdochrom, cholemyoglobin)

chlorophyll pigments

green parts of fruits and vegetables

content (book 3, tab.9.7)
colour (book 3, tab.9.8)

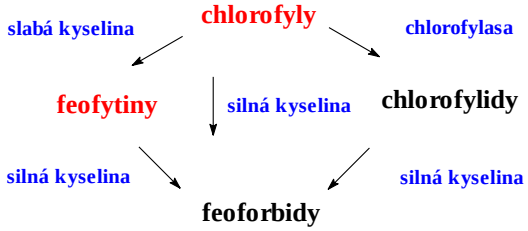




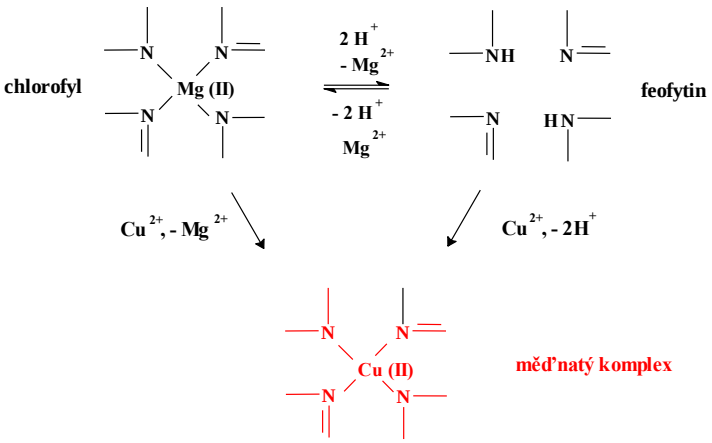
porphyrins chlorophylls

Mg (II) complex	chlorophylls	R = CH_3	chlorophyll a	yellow-green
		R = CH=O	chlorophyll b	blue-green
without Mg (II)	pheophytin			
without phytol	chlorophyllide			
without Mg (II) and phytol	pheophorbide			

reactions of chlorophylls during processing (acids, enzymes)



colour changes during processing (book 3, tab. 9.9, 9.10 **)**
colour stabilisation



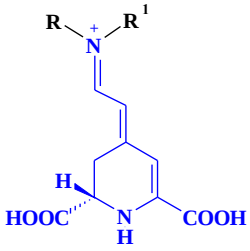
- chlorophylin Cu (chlorophylid Cu)

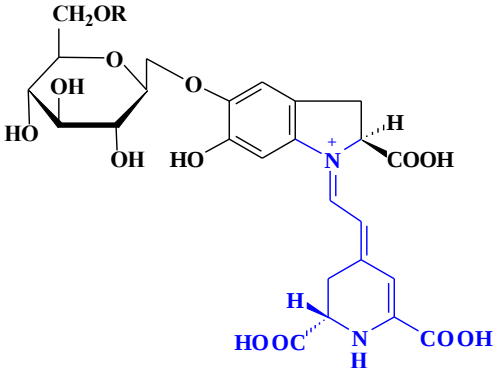
betalain pigments

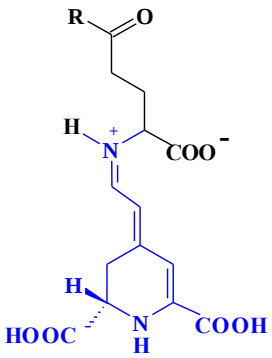
beetroot, prickly pear, amaranth, flowers

betacyanins	red, orange
betaxanthins	yellow, orange

basic structure







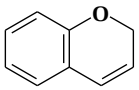
betanin (R = H) 95 % vulgaxanthin I (R = NH_2) 50 %

flavonoid pigments

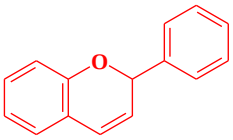
fruits, vegetables, flowers

- anthocyanins red, violet, blue
- anthoxanthins yellow, orange

basic structure



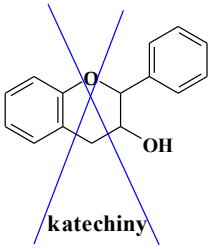
2*H*-chromene



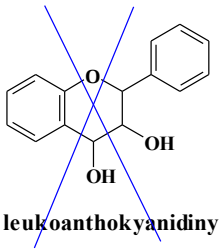
A B C

flavan

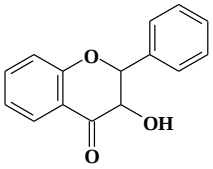
- oxidation of 3C chain (ring B)
- OH groups in rings A, B, C
- aglycones, glycosides



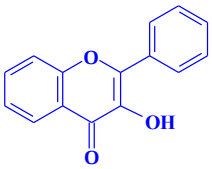
katechiny



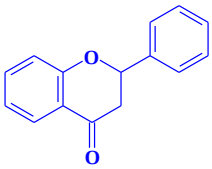
leukoanthokyanidiny



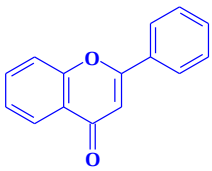
flavanonoly



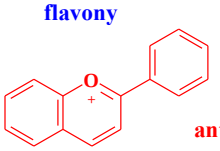
flavonoly



flavanony

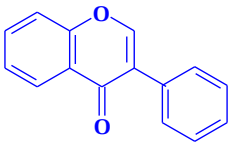


flavony



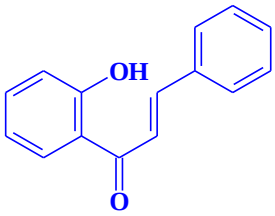
anthokyanidiny

colourless colourless-light pale yellow light yellow-yellow red-blue

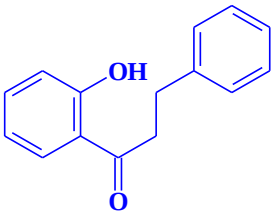


isoflavony

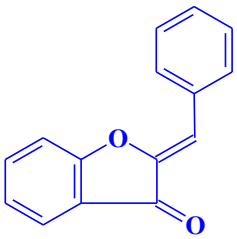
light yellow



chalcones
yellow-orange



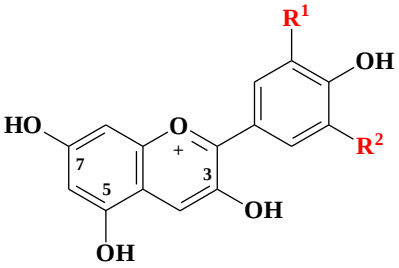
dihydrochalcones
yellow-orange



aurones
gold-yellow

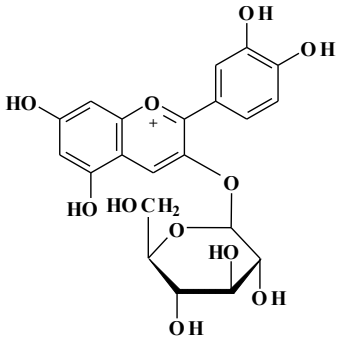
anthocyanins

basic structure

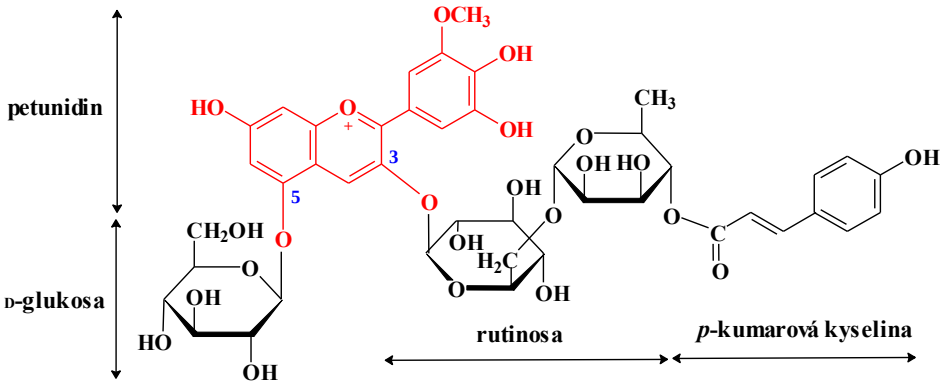


pelargonidin	Pg	R^1 = H	R^2 = H	violet-red
cyanidin	Cy	R^1 = H	R^2 = OH	violet
delfinidin	Dp	R^1 = OH	R^2 = OH	blue-violet
peonidin	Pn	R^1 = H	R^2 = OCH_3	violet
petunidin	Pt	R^1 = OH	R^2 = OCH_3	dark red
malvidin	Mv	R^1 = OCH_3	R^2 = OCH_3	blue-violet

saccharides: Glu, Gal, Xyl, Ara, Rha, always at C-3, often at C-3 and C-5, seldom at C-7
acids: *p*-cumaric, caffeic, ferulic



examples
cyanidin-3-*O*-β-D-glucoside (general occurrence)



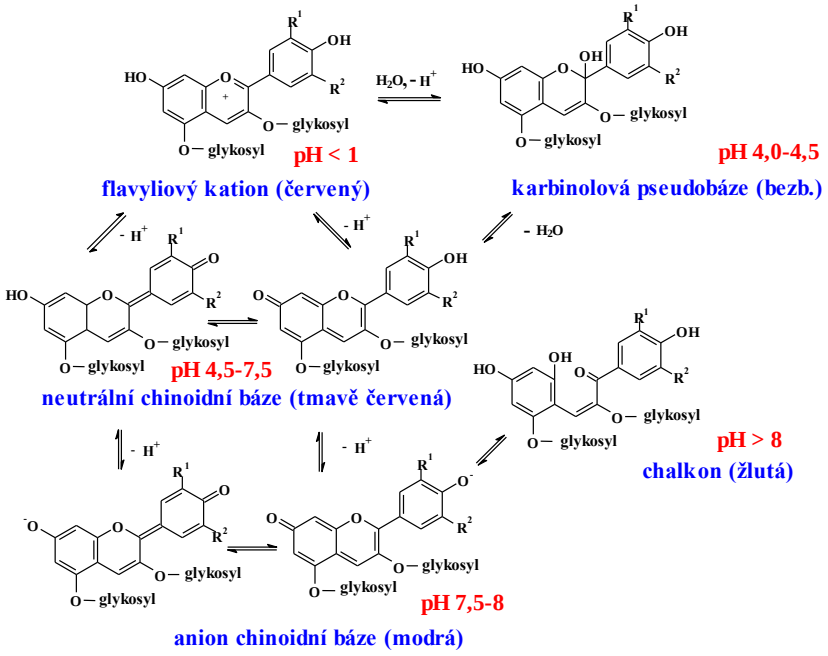
petanine (red coloured potato)
(*E*)-petunidin-3-*O*-[6-*O*-(4-*O*-*p*-cumaroyl-α-L-rhamnopyranosyl)-β-D-glucopyranoside]-5-*O*-β-D-glucopyranoside

anthocyanins fruits and vegetables (book 3,. tab. 9.12)

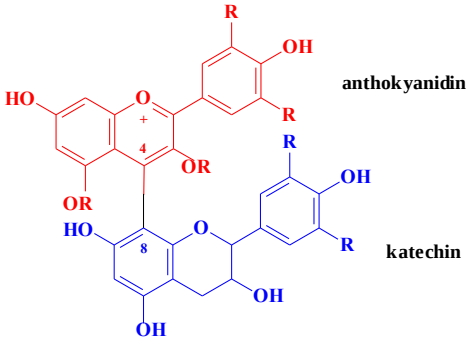
colour changes due to different factors

- pH
- co-pigmentation, eventual transformation into other pigments
- SO_2
- H_2O_2

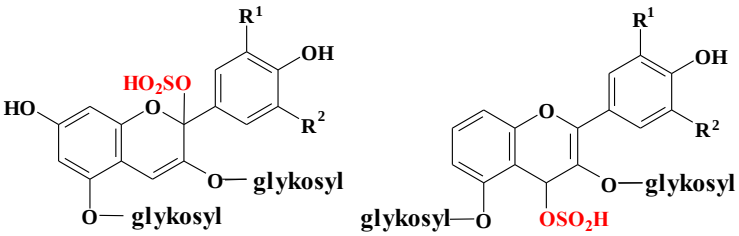
pH



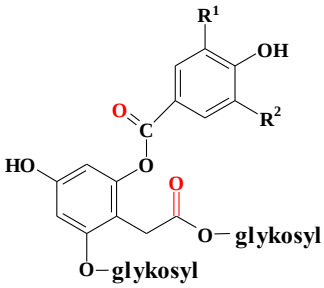
- copigmentation
  interaction with procyanidinins (catechins = copigments) → coloured complexes
- transformation into other pigments, coloured complexes → dimers (oligomers), non-soluble condensation products, polymeric compounds



SO_2→ colourless sulfonic acids



H_2O_2→ colourless products



anthoxanthins
flavanones

- pigments of low importance
- bitter compounds of grapefruits

naringin = naringenin + neohesperidose
neohesperidin = hesperetin + neohesperidose

flavanonols

- pigments of low importance

flavones

- important anthoxanthins

flavonols

- important anthoxanthins
- antioxidant activity, rutin = kvercetin + rutinose, bioflavonoids

isoflavones

- pigments of low importance (e.g. in soybeans)
- estrogenic activity

chalcones and aurones

- important pigments of flowers

dihydrochalcones

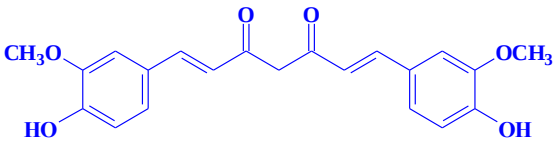
- pigments of low importance
- neohesperidindihydrochalcone (synthetic sweet compound)

quinoid pigments

lichens, mushrooms, higher plants

- phenols
- quinones

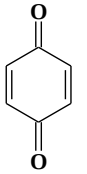
phenols
curcuminoides (diarylheptanoides)



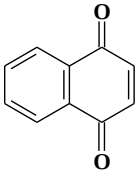
curcumin (curcuma, curry)

quinones

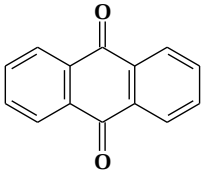
- benzoquinones
- naphtoquinones
- anthraquinones



benzo-1,4-quinone

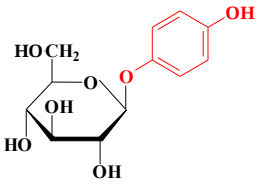


naphto-1,4-quinone



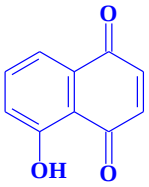
anthra-9,10-quinone

benzoquinones



arbutin (cranberry leaves, antiseptic activity)
(related terphenylquinones and pulvic acids in mushrooms)

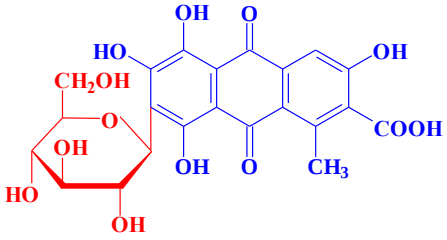
naftoquinones

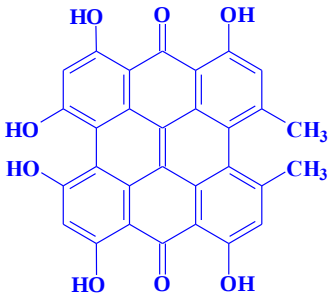


juglone (leaves of walnut, 4-β-D-glucosid 1,4,5-trihydroxynaphtalene)
(relative gossypol in cotton seeds, related coenzymes Q, vitamins K)

anthraquinones

related emodins, bianthrons





carminic acid (cochineal, dried bodies of female beatles *Coccus cacti*) hypericine (St. John's wort)

carotenoid pigments

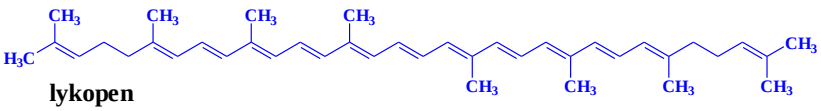
yellow, orange, red up to violet pigments of plants and microorganisms (in mammals)

composition and content in fruits and vegetables (book 3, tab.9.14)

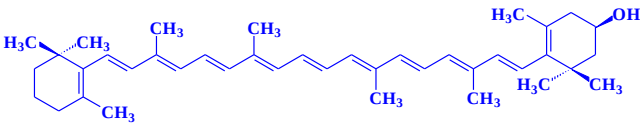
- carotenoids (tetraterpenes, 40 C atoms, *trans*-isomers)
  - hydrocarbons — carotenes
  - *O*-derivatives — xanthophylls
  - neocarotenoids (*cis*-isomers)
  - degradated carotenoids (30, 20, 15, 13, 10 C atoms)

carotenes

acyclic and alicyclic hydrocarbons



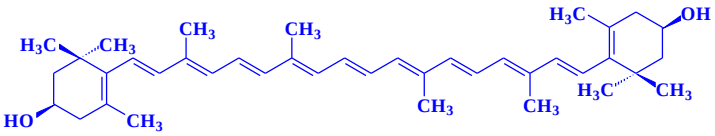
lykopen



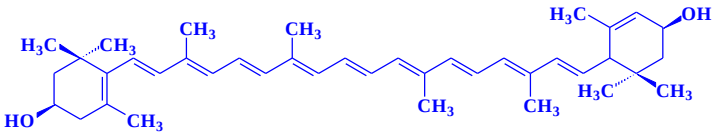
β-karoten

lycopene: tomato, rose-hip, β-carotene: carrot, apricot, mango

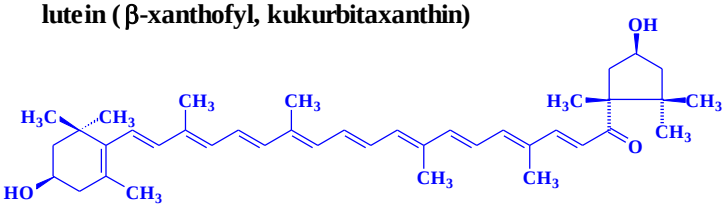
xanthophylls
alcohols, ketones, epoxides
free, bound (glycosides, fatty acids esters, carotenoproteins)



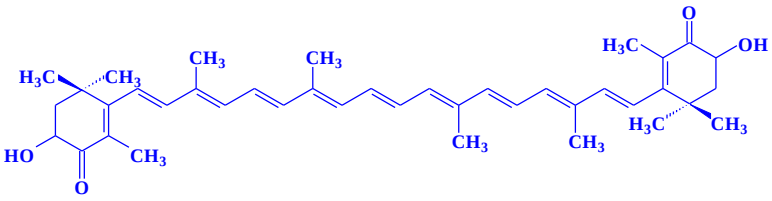
zeaxanthin



lutein (β-xanthofyl, kukurbitaxanthin)



kapsanthin



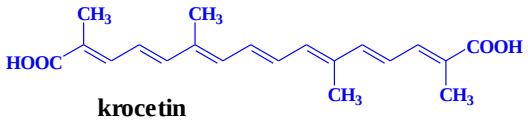
astaxanthin

zeaxanthin, lutein: generally wide-spread
kapsanthin: red bell pepper
astaxanthin: fish, shellfish (α-crustacyanin)

retinoids

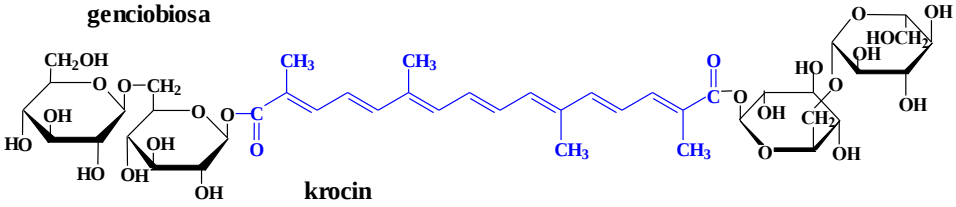
degradated carotenoids

crocin (18 C)
saffron (*Crocus sativus*), spice



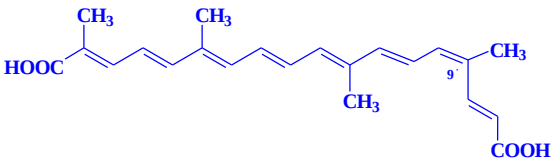
krocetin

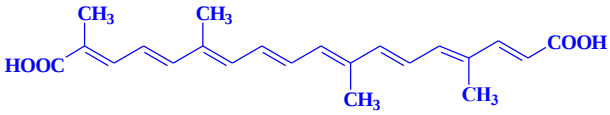
genciobiosa



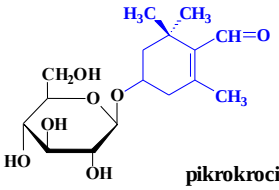
krocin

annato (20 C)
bixin (*Bixa orellana*)
extract 0,2-0,5 % = mixture *cis/trans*-isomers, cheese and margarine colouring

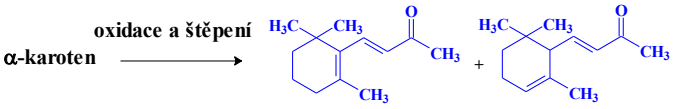




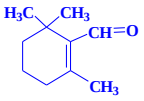
aromatic and gustatory compounds formed from carotenoids



pikrokrocin

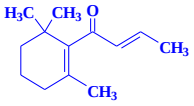


β-jonon α-jonon

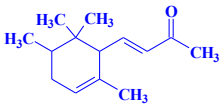


β-cyklocitral

dihydroaktindiolid



β-damaskon



α-iron

reactions

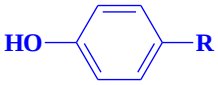
- hydrolysis of esters, glycosides
- dehydration of alcohols to hydrocarbons
- *cis/trans* isomeration (neocarotenoids, low colour intensity)
- autooxidation (low colour intensity, even decolourisation)
- antioxidants

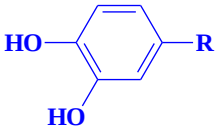
consequences

- flour bleaching
- colour changes of orange juices
- food flavour
- beneficial food components

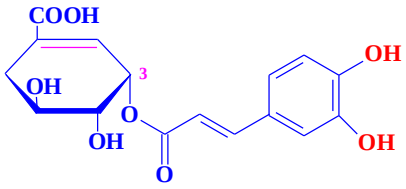
Enzymatic browning reactions

substrates (book 3, tab. 9.15)

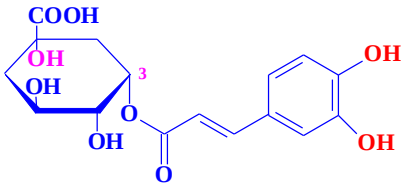




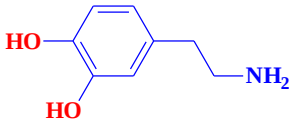
phenols, diphenols (polyphenols), esters (depsides), glycosides



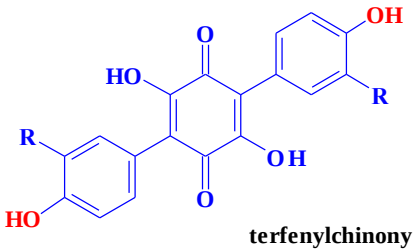
chlorogenová kyselina



daktyliferová kyselina



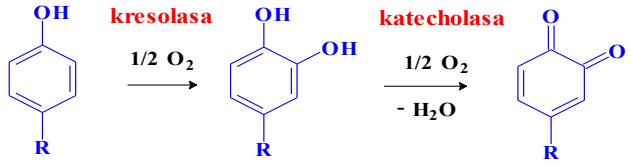
3,4-dihydroxyfenylethylamin



terfenylchinony

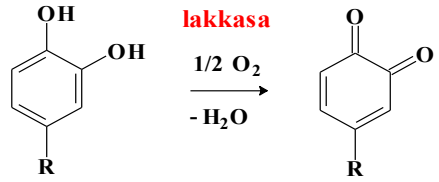
enzymes
polyphenoloxidases

- catecholoxidase

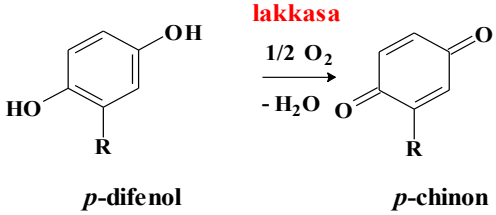


fenol **o-difenol** **o-chinon**

- laccase



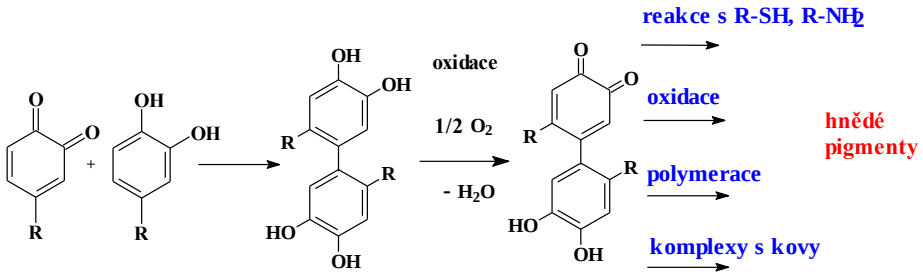
***o*-difenol** ***o*-chinon**



***p*-difenol** ***p*-chinon**

catechin oxidation — yellow quinone
chlorogenic acid oxidation — yellow-orange quinone
DOPA oxidation — orange quinone

mechanisms



inhibition of browning (book 3, tab. 9.16)

- inhibition of enzymes (oxygen elimination , decrease of pH)
- chelatation of metals (Cu^{2+})
- use of reducing compounds (ascorbic acid, SO_2)

desirable reactions

- tee fermentation
- cocoa fermentation
- olive fermentation

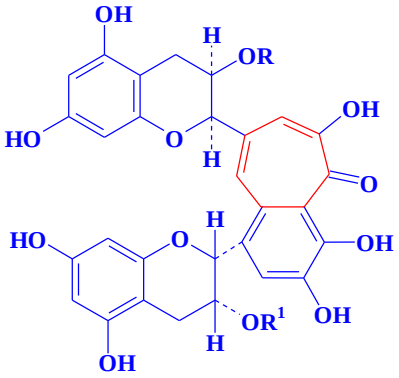
black tea

precursors in green tea

- epigallocatechingallates
- epicatechins
- epicatechingallates
- epigallocatechins

main types of black tea pigments

- theaflavins (oxidised flavonoid dimers), orange-red (seven-carbon tropolone cycles)



- thearubigines (polymers, 700-400 000 Da), red-yellow up to orange-brown