Flavour-active compounds

sensory quality
organoleptic properties

perception

♦ olphactoric	smell	odorous compounds
♦ gustative	taste	gustatory compounds
♦ visual	vision	colour compounds (colourants)
♦ auditorial	hearing	
♦ haptic	tactile	

perception of smell + perception of taste = perception of aroma

odorous compounds + gustatory compounds = aroma compounds

Odorous Compounds

olfactoric perception

~10 000 compounds, 50 – 1000 different compounds in individual foods

properties

- **low polarity or non-polar compounds**
- **little soluble and unsoluble in water**
- **volatile**

main groups

hydrocarbons, alcohols, ethers, carbonyl compounds (aldehydes, ketones), acetals (ketals), acids, functional derivatives of acids (esters, lactones), phenols, S- a N-aliphatic compounds, O-, S-, N-heterocycles

food	content in mg / kg
Beef meat	34
Bread (without ethanol)	6-10
Strawberry	2-8
Banana	12-18
Cocoa	100

Commodity	Type of aromatic substance
fruit ,vegetable	terpenes, alcohols, ketones, esters
alcoholic beverage	acids, esters, aldehydes, alcohols, acetals
roasting, frying product	Heterocyclic compounds

formation

- primary compounds

  bound as glycosides, esters

  free

- secondary compounds

  enzymatic reactions (damage of tissues on storage and processing)

  chemical reactions (storage, processing)

  non-enzymatic browning reactions

  fermentation processes

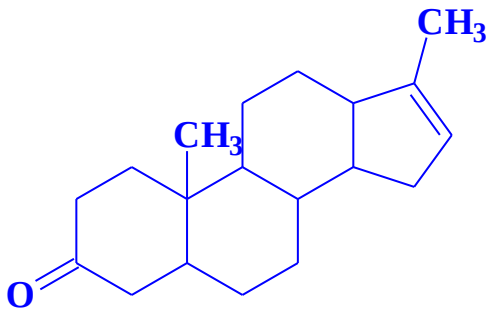
  oxidative reactions

  thermal reactions (Maillard reaction)

Type of aromatic substance	% of the identified substances in total	
	alcoholic beverage	roasted coffee
hydrocarbons	8	11
alcohols	13	10
aldehydes	6	4
ketones	5	8
acetals	8	0
acids	11	4
esters	24	5
lactones	4	2
O-heterocycles	4	23
N-heterocycles	8	20
S-heterocycles	2	8

factors influencing aroma perception

- **tresholds of perception**
- **stimuli threshold**
- **threshold of recognition**



5α-androst-16-en-3-on
feel 71% of women, 63% of men

- **concentration**
- **synergism, antagonism of compounds**
- **sensitivity of individuals**

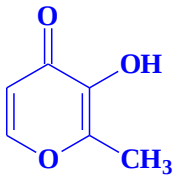
  age, sex, physiological and pathological conditions

  adaptation

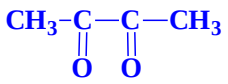
  anosmia

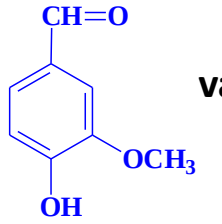
Compound	Occurence	Odour detection threshold (mg/l)
Ethanol	Alcoholic beverage	100
Maltol	Caramel	35
Acetic Acid	Vinigar	25
Biacetyl	Butter	2
Trimethylamine	Fish	2
Butyric acid	Rancid butter	0.2
Vanillin	Vanilla	0.02
2-Isobutyl-3-methoxypyrazine	Bell pepper	0.000 002
(+)-(*R*)-*p*-Menth-1-en-8-thiol	Grapefruit	0.000 000 02
Bis(2-methyl-3-furyl)disulfide	Thiamine photolytic product	0.000 000 002

maltol

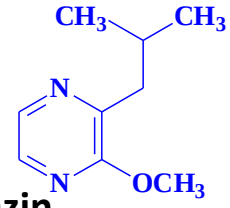


biacetyl

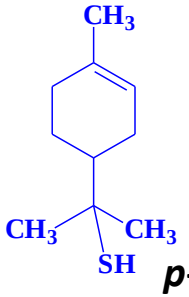




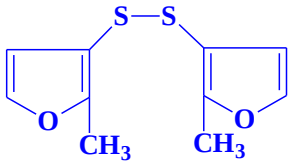
vanillin



2-isobutyl-3-methoxypyrazin



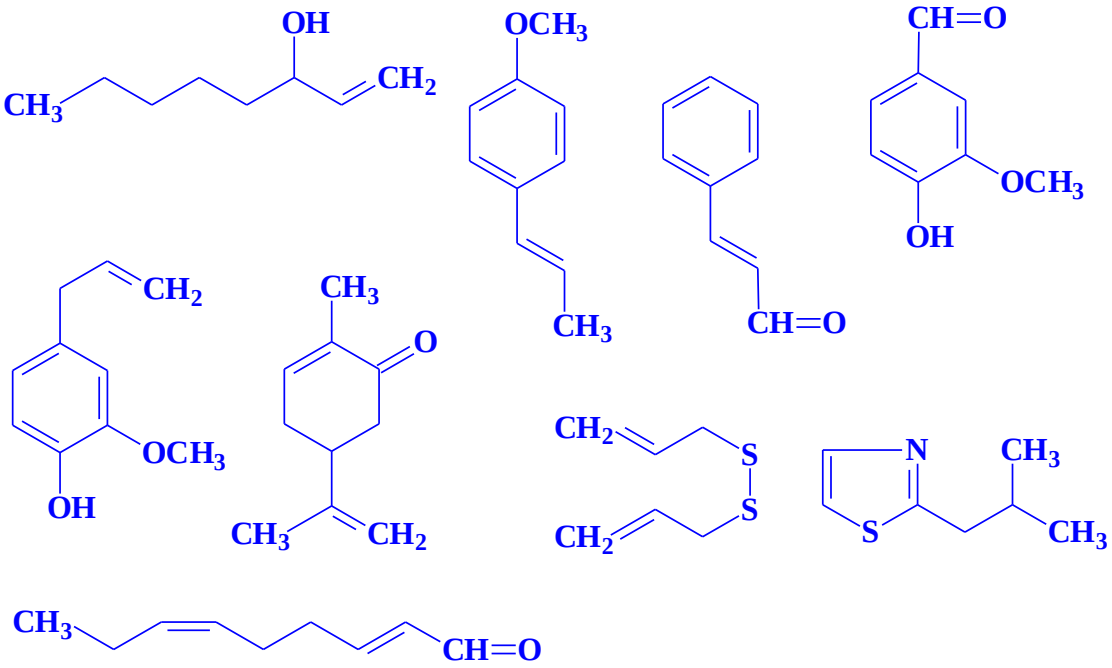
p-menth-1-en-8-thiol



bis(2-methyl-3-furyl)disulfide

Key odor components

Compound	Description	Occurrence
(*R*)-Oct-1-en-3-ol	Mushroom-like	Mushrooms, molds
Anethole	Anise-like	Anise seeds
Cinnamaldehyde	Cinnamon-like	Cinnamon bark
Vanillin	Vanilla-like	Dry vanilla beans
Eugenol	Clove-like	Clove plant fruits
(+)-(*S*)-Carvone	Caraway-like	Caraway and dill seeds
Diallyl disulfide	Garlic-like	Garlic
(2E,6Z)-Nona-2,6-dienal	Cucumber-like	Fresh cucumber
2-Isobutylthiazole	Tomato-like	Tomato leaves, fresh fruits

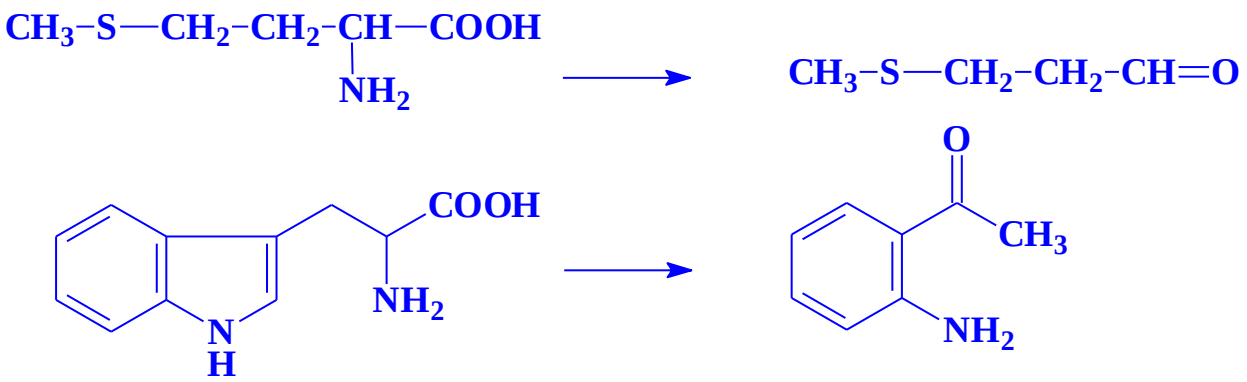


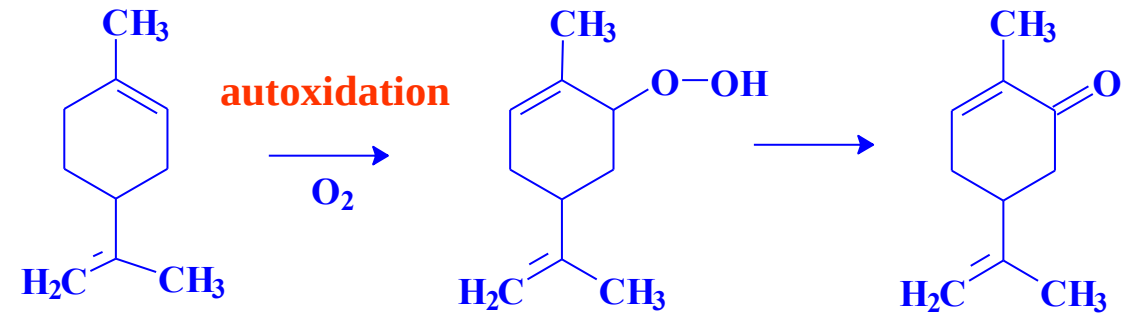
off-flavours

- processing (undesirable fermentation, preservation, thermal operation)
- storage (microbial contamination, reaction of components, oxidation, packaging material)
- animal source foods (feed)
- foods of Plant Origin (contamination of environment)

example

food	defect	source
milk	sun off-flavour	methional (Met, riboflavin)
orange juice	terpenic off-flavour	carvon (oxidation of limonene)
beer	sun off-flavour	Photolysis of isohumulone, reaction with H_2S (3-methylbut-2-en-1-thiol)

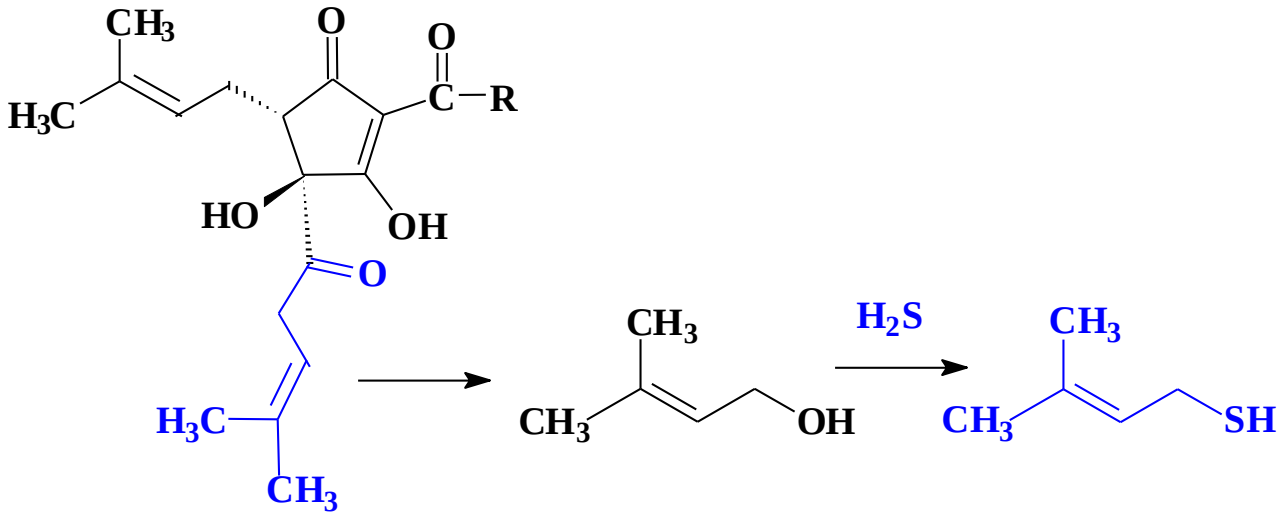




(+)-limonene

(+)-limonene-6-hydroxyperoxide

(+)-carvone

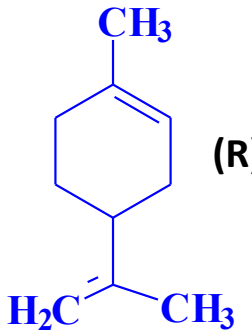


(4*S*,*E*)-isohumulon

prenylalkohol

hydrocarbons

Alicyclic



(R)-limonene citrus essential oil

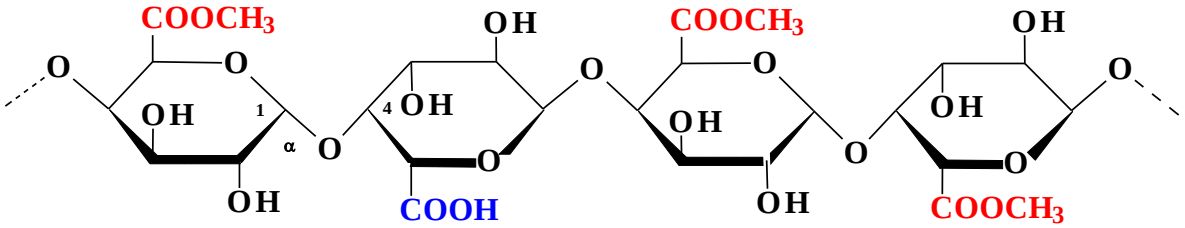
aromatic and polycyclic aromatic (PAU)

benzene, toluene, xylene, benzo[a]pyrene contaminants

Alcohols

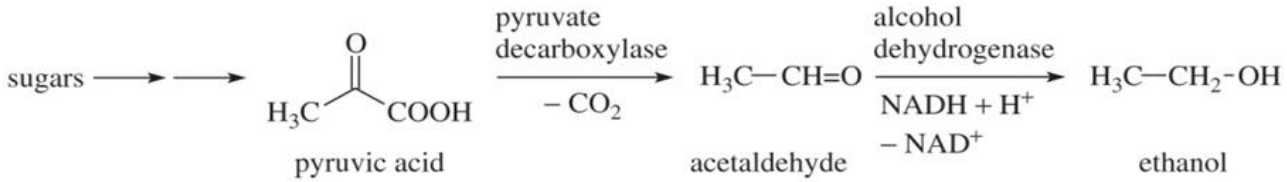
aliphatic saturated

Methanol **hydrolysis of pectin**



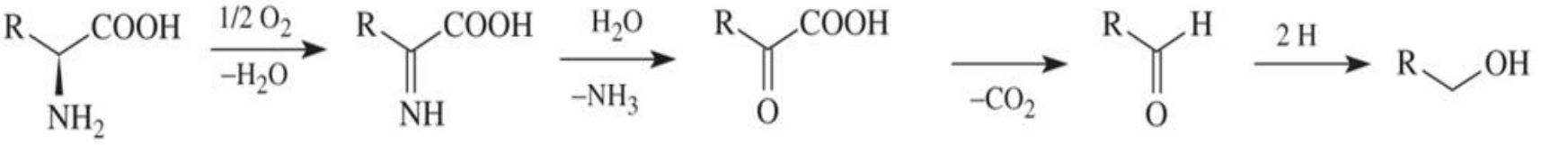
comodity	allowed amount in Czech legislation (g/l ethanol)
spirit (alcohol)	0.8
destillate	12
pomace brandy	15

Ethanol **sugar fermentation**



higher alcohols

transformation of amino acids

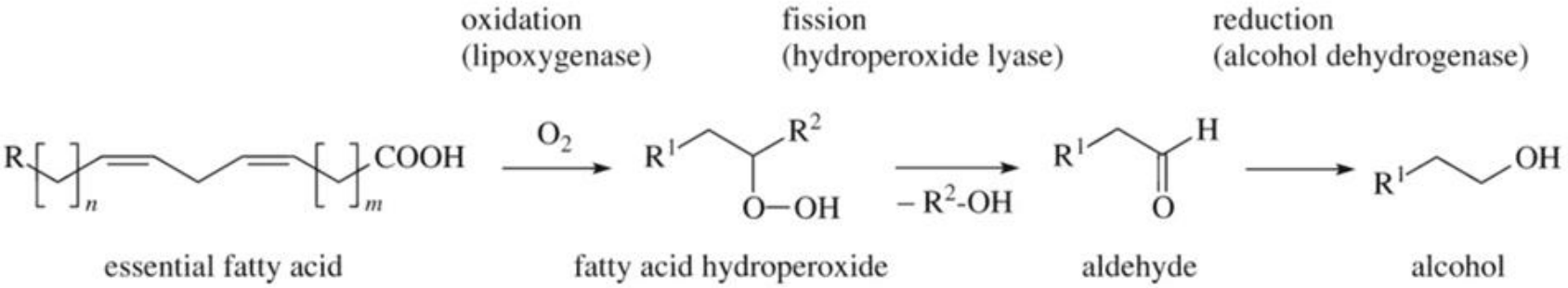


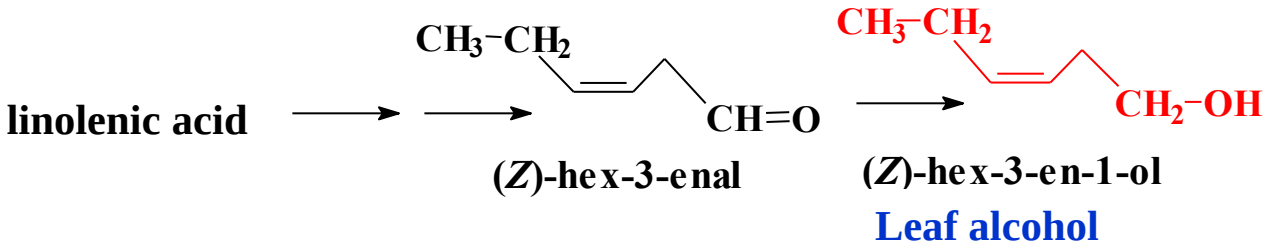
α-amino acid — 2-iminocarboxylic acid — 2-oxocarboxylic acid — aldehyde — primary alcohol

Alcohol	Amino acid
propan-1-ol	Thr
butan-1-ol	Thr
2-methylpropan-1-ol	Val
(*S*)-2-methylbutan-1-ol	Ile
3-methylbutan-1-ol	Leu
2-phenylethanol	Phe

aliphatic unsaturated

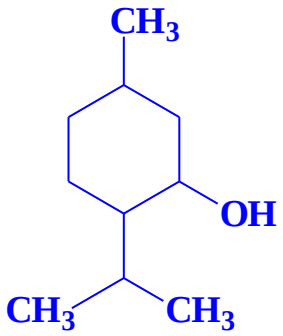
oxidation of higher fatty acids

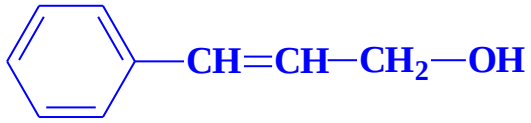




terpenic and aromatic alcohols

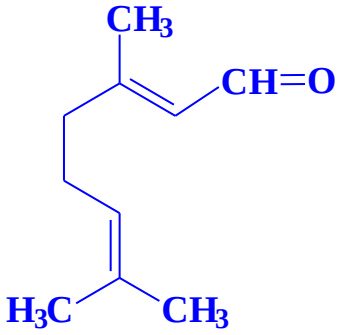
menthol	**mint, chewing gum**
cinnamyl alcohol	**cinnamon**





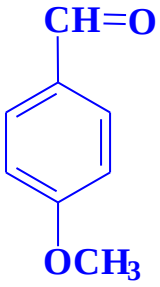
aldehydes

terpenes and aromatics



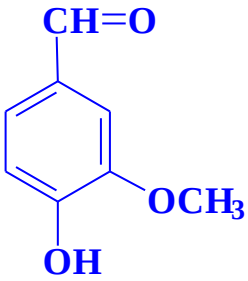
citral and (geranial)

citrus essential oils



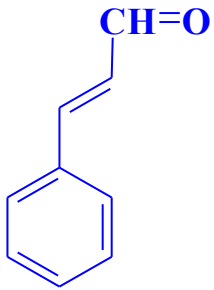
anisaldehyde

anise, star anise, vanilla



vanillin;

vanilla

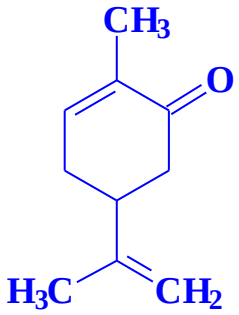


cinnamaldehyde

cinnamon

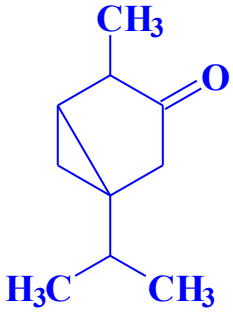
Ketones

terpenes



carvone

caraway

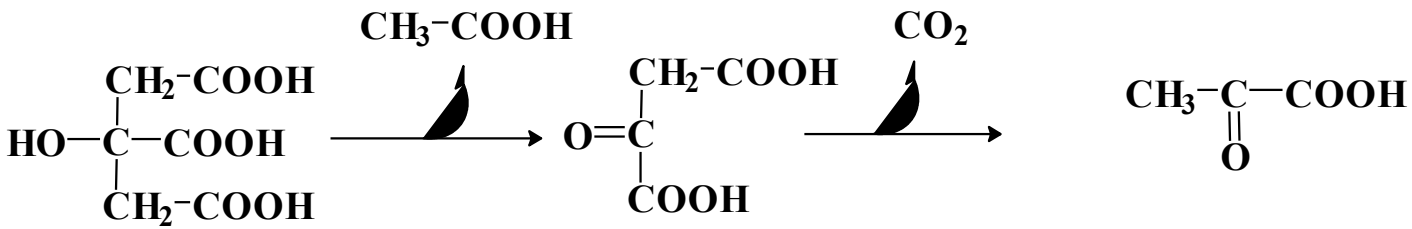


thujone

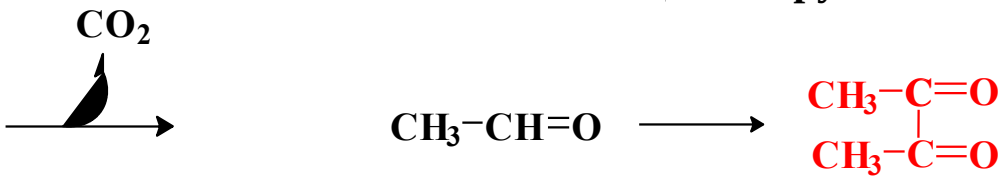
wormwood (absinth)

products fatty acids β-oxidation — **methylketones**

products of saccharides degradation — **diketones**



citric acid — **2-oxaloacetic acid** — **pyruvic acid**



acetaldehyde — **biacetyl**

Butane-2,3-dione (diacetyl, biacetyl) + 3-Hydroxybutanone (acetoin) = aroma of butter

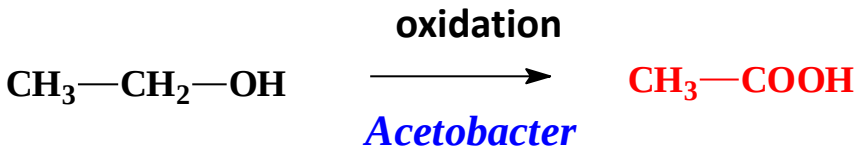
Acids and their functional derivatives

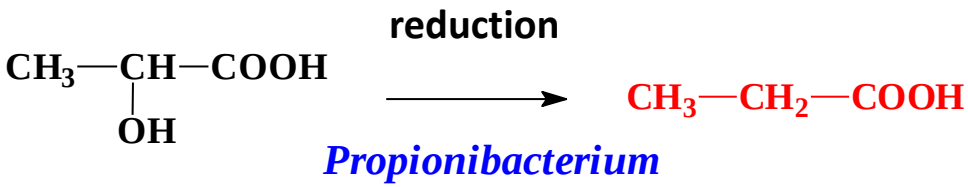
Acids

aliphatic saturated acids

fermentation products

formic, acetic, propionic, higher acids





lactic acid

esters

main compounds:

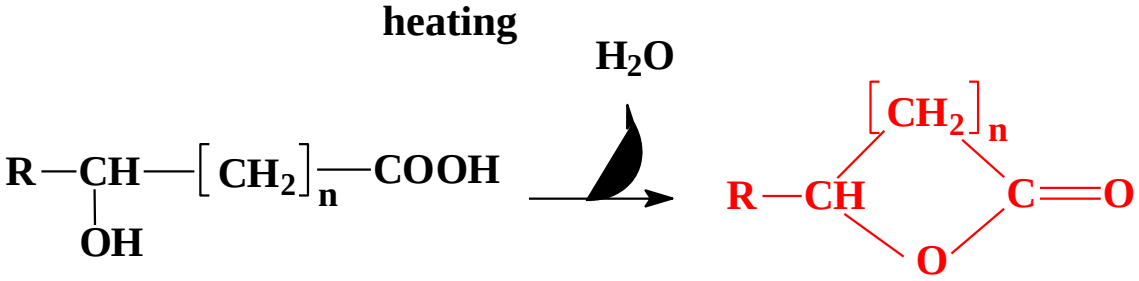
acetic acid	ethanol
formic acid	methanol
propionic acid	butanol
butyric acid	isoamylalkohol
isobutyric acid	(mono)terpenes

fruity and flower aroma

alcoholic beverages	**ethyl acetate**
beer	~ 30 mg/l
wine	10-260 mg/l

fruit	
apple	acetates, butyrates
banana	isoamylacetate
pineapple	ethyl-3-(methylthio)propionate

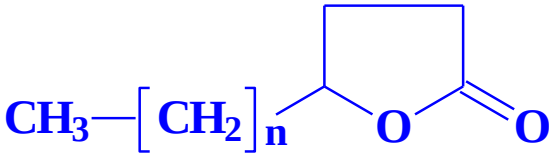
lactones



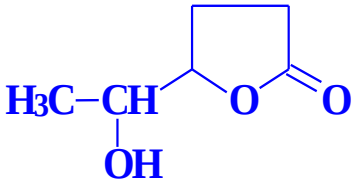
γ-hydroxyl acids → γ-lactones (butano-4-lactones)

δ-hydroxyl acids → δ-lactones (pentano-5-lactones)

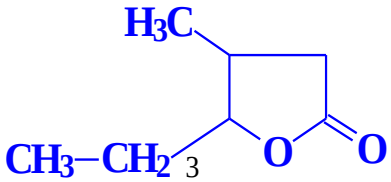
aromatic hydroxy acids → cumarins, phthalides



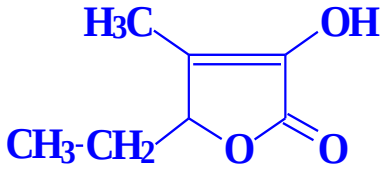
γ-nonalactone	n = 4	coconut aroma
γ-decalactone	n = 5	peaches aroma
γ-dodecalactone	n = 7	butter aroma



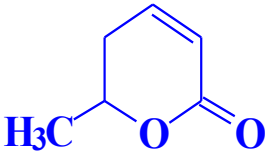
sherry lactone



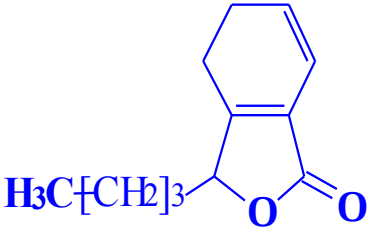
whisky lactone



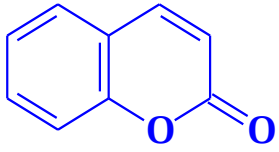
maggi lactone (abhexon)



parasorbic acid

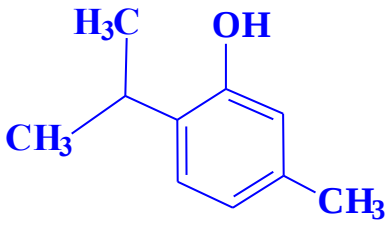


sedanenolid



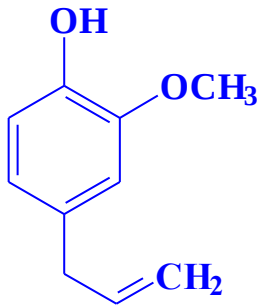
coumarin

phenols



thymol

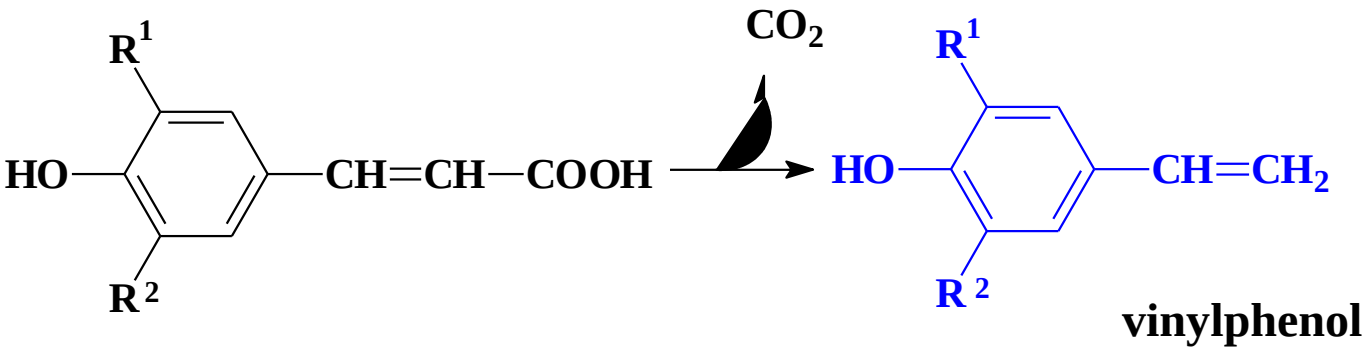
thyme



eugenol

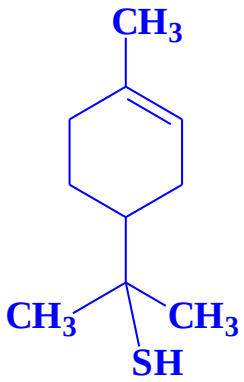
clove

decarboxylation of phenolic acids, lignin degradation



vinylphenol

sulphur containing compounds

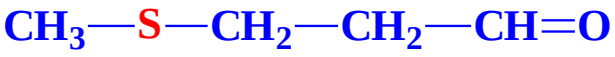


p-meth-1-en-8-thiol

grapefruit

degradation products of sulphur-containing compounds

(sulphur amino acids, glucosinolates)



methional

boiled potato

diallyldisulfide

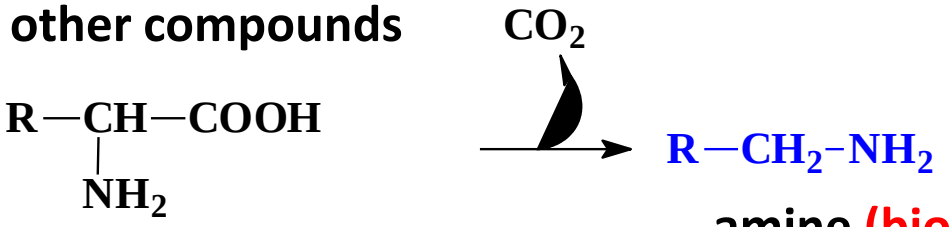
garlic

allylisothiocyanate

mustard, horse radish

nitrogen containing compounds

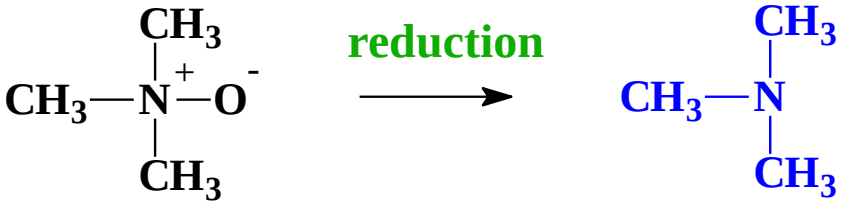
decarboxylation products of amino acids, transformation products of other compounds



amine (biogenic amine)

cheeses, meats, fish, fermentation products

post mortem



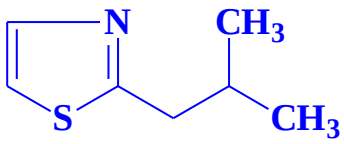
trimethylaminoxide **trimethylamine**

sea fish 40-120 mg/kg
indiferent

fishy smell

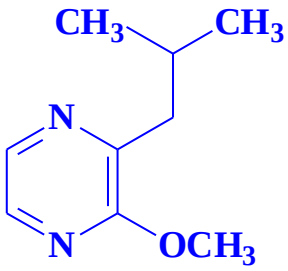
heterocyclic compounds

O-, S-, N-heterocycles



2-isobutylthiazole

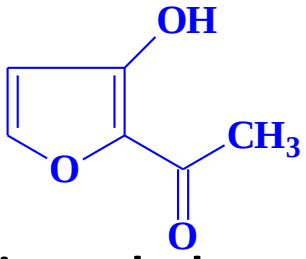
tomato



2-isobutyl-3-methoxypyrazine

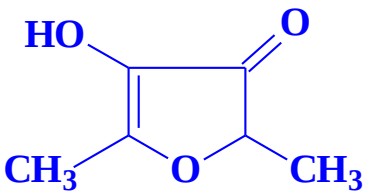
bell pepper

products of Maillard reaction, products of other reactions



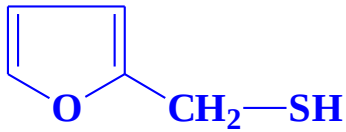
isomaltol

caramel



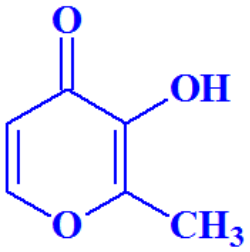
furaneol

strawberry and pineapple fruit

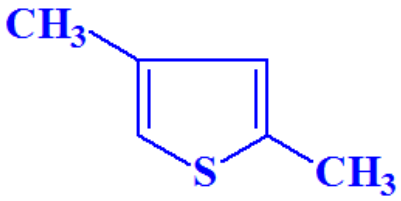


furfurylthiol

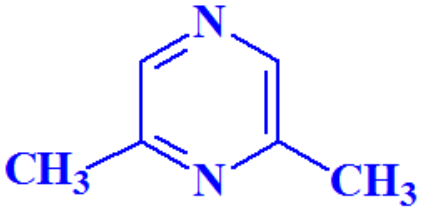
coffee



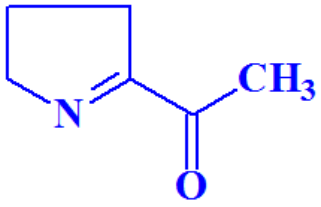
Maltol
caramel



2,4-dimethylthiophene
fried onion



2-acetyl-1-pyrroline
bread



2,6-dimethylpyrazine
chocolate and nuts

obtaining fragrances for flavoring food

75% natural

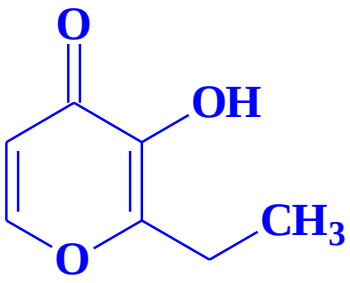
25% syntetic – 99% in nature (naturally identical)

1% not in the nature

materials **essential oils**

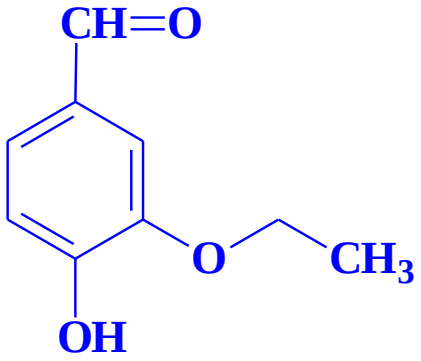
oleoresins

synthetic compounds



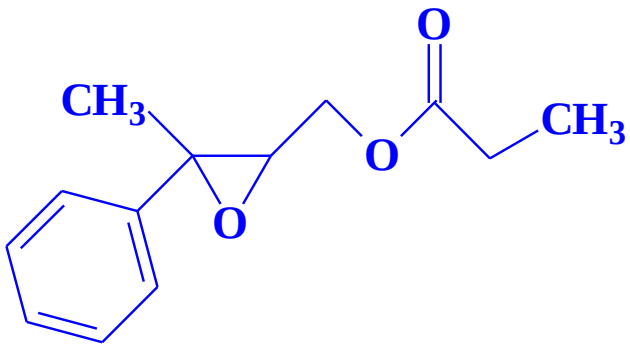
ethylmaltol

caramel



ethylvanillin (bourbonal)

vanilla sugar



ethyl-3-fenyl-3-methylglycidate

strawberry (candies)

biological effect

beneficial effects

bactericidal and anti-inflammatory
(borneol, eugenol, pinene, camphor, thymol, menthol)

spasmolytic or cholinolytic effects
(camphor, camphene, α- and β-pinene)

analeptic effects
(camphene)

antioxidant effects
(essential oils of many kinds of spices: marjoram, sage, thyme)

toxic effects

chronic neurotoxicity (convulsions, damage to the cortex)

- α and β-thujone= dominant component
- wormwood, sage, clove oil
- absinthism
- Pulegone (essential oils of different varieties of mint)

carcinogenic effects alkenylbenzenes

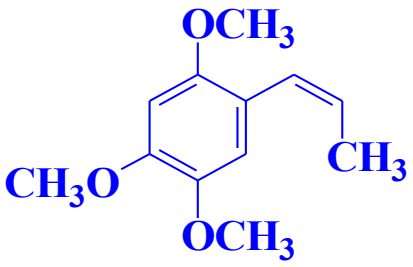
- β-asarone (calamus oil)
- estragole (tarragon oil)
- methyleugenol (clove)
- safrole (essential oils of nutmeg, anise, cinnamon)
- isosafrole (laurel oil, clove)
- myristicin (oil vegetables: carrots, parsley, celery, caraway)

psychomimetic, hallucinogenic and narcotic effects (comparable to the effects of ethanol)

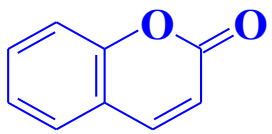
myristicin (nutmeg - flower, hazelnut)

hepatotoxic effects

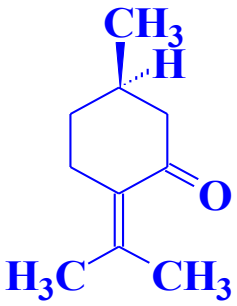
coumarin



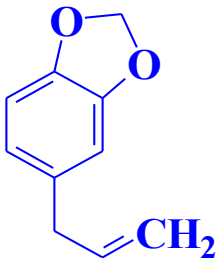
β-asaron



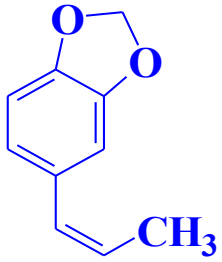
coumarin



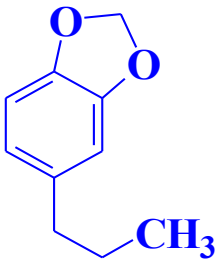
(+)-pulegon



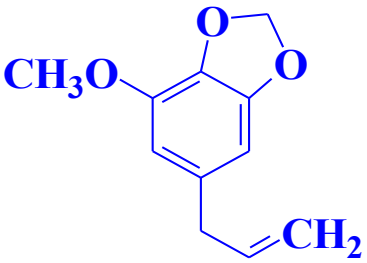
safrole



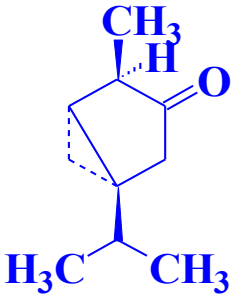
isosafrole



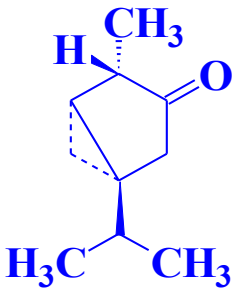
dihydrosafrole



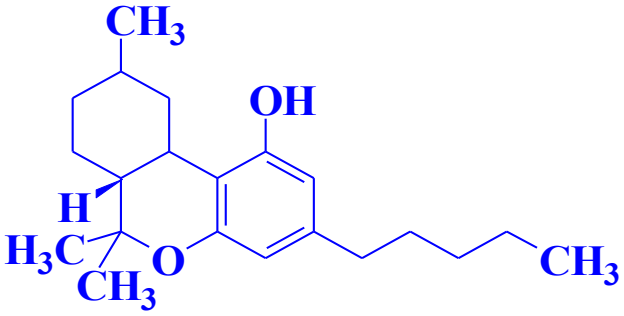
myristicin



α-thujon
(-)-thujon



β-thujon
(+)-isothujon



tetrahydrocannabinol

Compounds influencing food taste

perception of gustation

4 (5) basic tastes

♦ sweet	end of tongue
♦ salty	upper surface of tongue
♦ acid	sides of tongue
♦ bitter	root of tongue, roof of the mouth
umami	whole oral cavity

♦ astringent	whole oral cavity
♦ pungent (burning, hot)	whole oral cavity

other sensations

Properties

- polar
- water-soluble
- non-volatile

Formation

- primary compounds
- secondary compounds
    - enzymatic reactions (damage of tissues on storage and processing)
    - chemical reactions (storage, processing)

factors influencing taste perception

- thresholds of perception
    - stimuli threshold
    - threshold of recognition

Compound	Stimuli threshold (vol. %)	Compound	Stimuli threshold (vol. %)
sweet		acid	
D-glucose	1.17	acetic	0.011
D-fructose	0.24	lactic	0.020
saccharose	0.36	citric	0.015
salty		bitter	
sodium chloride	0.175	limonin	0.0006
umami		quinine	0.001
Glu (Na-H)	0.012	caffeine	0.014

saccharide	stimuli threshold (vol. %)	threshold of recognition (vol. %)
D-glucose	1.17	1.63
D-fructose	0.24	0.94
saccharose	0.36	0.81

SWEET COMPOUNDS

according to origin

- natural
- synthetic, identical with natural
- modified natural and synthetic

according to importance in nutrition (energy value)

- nutrients (source of energy)
- non-nutrients (they are not source of energy)

according to possibility to influence the blood sugar level

- contraindicated to diabetes
- without any influence

according to influence on caries

- cariogenic
- non-cariogenic

Sweetness

Saccharides

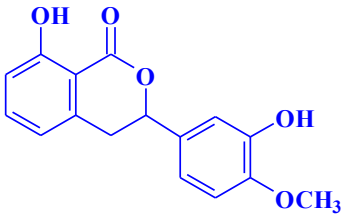
standard = 10% solution of saccharose

compound	Sweetness	compound	Sweetness
D-glucose	0.4-0.8	D-galactose	0.3-0.6
D-fructose	0.9-1.8	maltose	0.3-0.6
saccharose	1.0	lactose	0.2-0.6

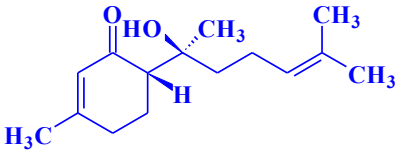
artificial sweeteners – taste quality

natural sweet compounds

Compound	Sweetness	sructure	occurrence
phylloducin	200-800	isocoumarin	*Hydrangea opuloides*
glycyrrhizin	50	saponins	*Glycyrrhiza glabra*
hernandulcin	1250	aromatic ketone	*Lippia dulcis*
monellin	1500-3000	protein	*Dioscorcophyllum comminsii*
osladin	3000	steroidal glycoside	*Polypodium vulgare*
stevioside	100-300	steroidal glycoside	*Stevia rebaudiana*
thaumatin (thalin)	2000-3000	protein	*Thaumatococcus daniellii*

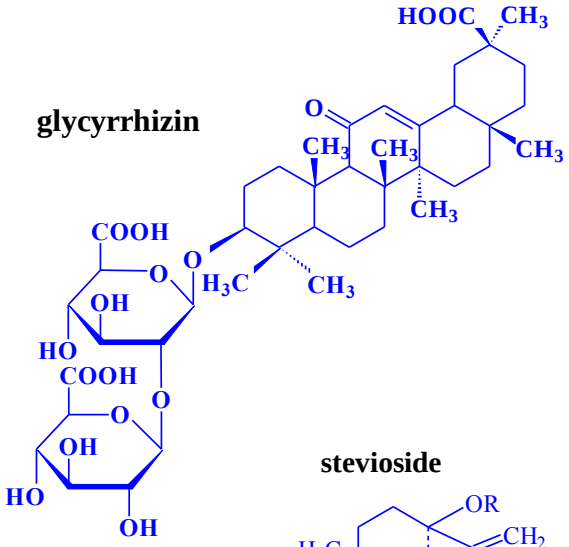


phylloducin

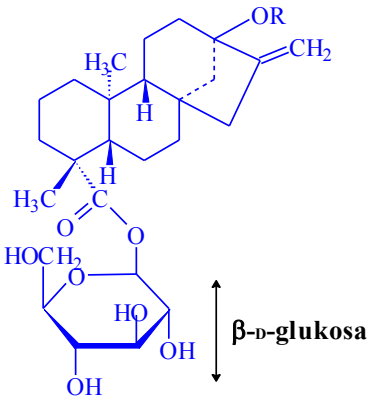


hernandulcin

glycyrrhizin



stevioside



R = β-soforosa
(β-D-Glcp-(1➔2)-β-D-Glcp

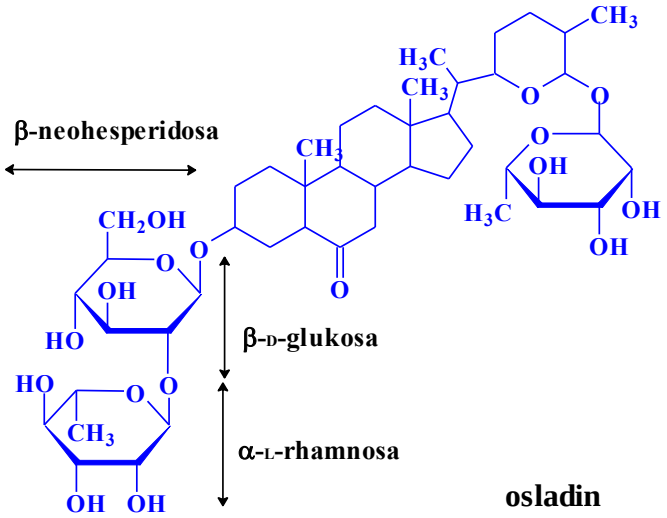
β-D-glukosa

β-neohesperidosa

α-L-rhamnosa

β-D-glukosa

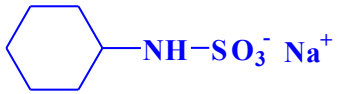
α-L-rhamnosa



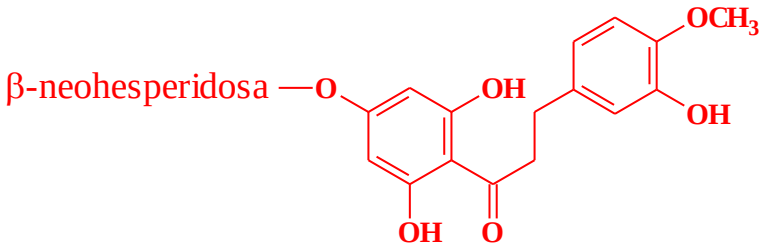
osladin

synthetic compounds

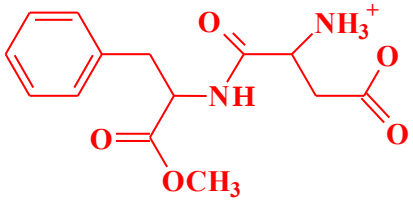
Compound	Sweetness (sucrose = 1)
Cyclamates	30-35
Aspartane	200
Saccharin	300-350
Neohesperidin dihydrochalcon	1100-1500
Acesulfame K	200
Dulcin	110-250



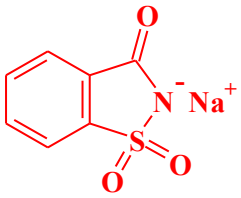
cyclamic salt



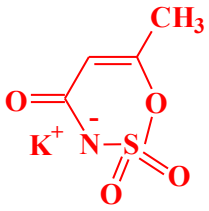
neohesperidin dihydrochalcone



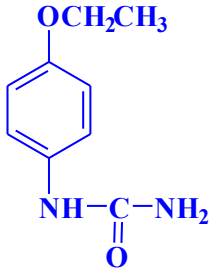
aspartame



saccharin



acesulfame K



dulcin

List of currenst EU approved sweeteners and their E-codes

E code	
E420	Sorbitol and sorbitol syrup
E421	Mannitol
E950	Acesulfame K
E951	Aspartame
E952	Cyclamic acid and its Na and Ca salts
E953	Isomalt
E954	Saccharin and its Na and Ca salts
E955	Sucralose
E957	Thaumatin
E959	Neohesperidin dihydrochalcone
E960	Steviol glycoside
E961	Neotame
E962	Salt of aspartane-acesulfame
E965	Maltitol and maltitol syrup
E966	Laktitol
E967	Xylitol
E968	Erythritol

SALTY COMPOUNDS

Inorganic salts, mostly NaCl

some salts of organic acids

taste quality, further attributes (bitter, metallic)

food classification

- with very low content — < 0.4 g/kg Na ~ < 1 g/kg NaCl
  milk, fruits, vegetables
- with low content — 0.4-1.2 g/kg Na
  meat, poultry, fish
- with high content — 1.2-4.0 g/kg Na
  bread, some bakery products, pickled vegetables
- with very high content — > 4.0 g/kg Na
  some meat and fish products, olive, salty condiments

ACIDIC COMPOUNDS

non-dissociated carboxylic acids

♦ aliphatic monocarboxylic	volatile	aroma, taste,
♦ aliphatic dicarboxylic	non-volatile	taste
♦ aliphatic hydroxy acids	non-volatile	taste
♦ alicyclic	non volatile	taste
♦ aromatic	some non-volatile	aroma, taste

mineral acids, H_3O^+ (pH)

taste quality, further attributes (fruity)

food classification

♦ very sour	pH < 4,0	fruits
♦ little sour	pH 4,0-6,5	vegetables (fruits),cereals
♦ neutral	pH > 6,5	meat, milk, egg

	pH
1. Vinegar 8%	2,53
2. 100% juice from sicilian citron - Lemon d´or	2,57
3. Coca Cola	2,87
4. Grapefruite nectar 50%	3,16
5. Sour cabbage	3,59
6. Pickled cucumber	3,80
7. Yogurt	4,12
8. Tomato juice100%	4,30
9. Mineral water Vincentka	6,75
10. Milk	6,86
11. Mineral water Magnesia	8,05
12. Egg – white	8,70

Lemon	**citric acid**	**4.0-4.4%**
Grapefruit	**citric acid**	**1.2-2.1%**
Tomato	**citric acid**	**0.9-2.0%**
Vinegar	**acetic acid**	**8.0%**
Pickled cucumber	**acetic acid**	**1.0%**
Sour cabbage	**lactic acid**	**2.0%**
Yogurt	**lactic acid**	**1.0%**
Coca Cola	**phosphoric acid**	**0.08%**

fruits	citric, malic, quinic, ascorbic
vegetables	citric, malic, oxalic
meat	lactic
milk (vegetables) fermented products	lactic

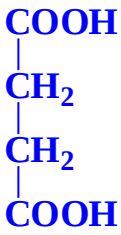
apple unripe	quinic
apple ripe, pulp	malic
apple ripe, skin	citric, malic

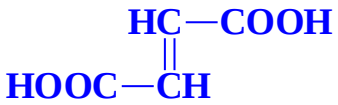
aliphatic monocarboxylic acids

formic	side product of fermentation, degradation of saccharides, preservative compound
acetic	acetic acid fermentation (*Acetobacter*), vinegar preservative compound
propionic	propionic acid fermentation (*Propionibacterium*) preservative compound

aliphatic dicarboxylic acids

oxalic	**metabolisms, antinutritive compound**
succinic	**metabolisms**
fumaric, (E)-but-2-enic	**metabolisms**





content in carrot

- **Oxalic** **0-0,06%**
- **Succinic** **0,002-0,013%**
- **Fumaric** **0,0005-0,0008%**
- **Quinic** **0,004-0,006%**
- **Malic** **0,4-5,2%**
- **Citric** **0,034-0,093%**

Food	Content of oxalic acid in %
Orange	0.004
Tomato	0.010
Spinach	0.54-0.98
Rhubarb	0.23-0.96
Tea	0.65-0.70

aliphatic hydroxyacids

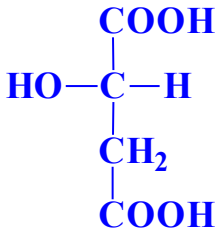
lactic milk fermented products (Lactobacillus and others), meat

D-(-)-lactic (*R*)-2-hydroxypropionic

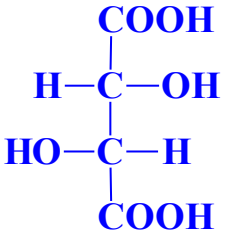
L-(+)-lactic (*S*)-2-hydroxypropanic

milk fermented products	0.5-1.0%
Sour cabbage	1.5-2.5%
sour olive	0.8-1.2%
meat	0.2-0.8%

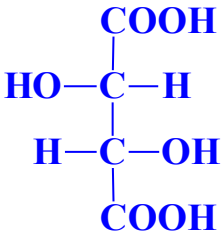
L-malic acid fruits, vegetables, additives (acidulant)



tartaric acid fruits, vegetables, additives (acidulant)



L-tartaric, (2R,3R)-tartaric, L-threaric

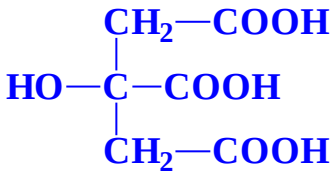


D-tartaric

grapy acid (racemic mixture, racemate, K-H salts = tartar),

mesotartaric (erythraric)

citric acid fruits, vegetables, additives (acidulant)

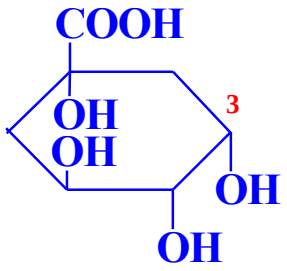


Content of main acid in fruit (%)

Fruit	Malic	Citric	Tartaric
Apple	0.2-1.3	0.0075-0.01	-
Orange	0.06-0.2	0.56-0.98	-
Lemon	0.17-0.30	4.0-4.4	-
Grapes	0.7-1.5	0.03-0.1	0.4-1.4

alicyclic acids

L-quinic fruits, vegetables (free, depsides)



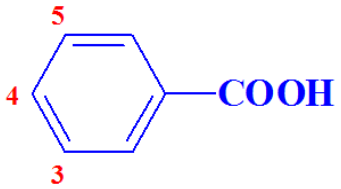
aromatic acids

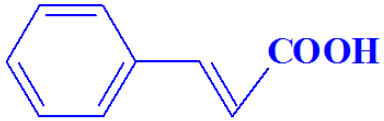
fruits, vegetables, cereals, (free, esters, glycosides)

seeds germination inhibition, antibacterial properties

sensory properties (phenols, non-enzymatic browning reactions)

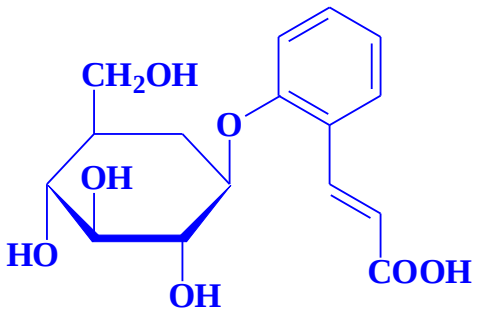
benzoic acid, cinnamic acid and derivatives



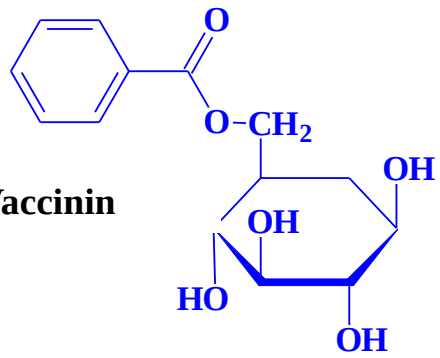


	benzoic	cinnamic
4-OH	*p*-hydroxybenzoic	*p*-cumaric
3,4-diOH	protocatechuic	caffeic
4-OH, 3-MeO	vanillic	ferulic
4-OH, 3,5-diMeO	syringic	sinapic
3,4,5-triOH	gallic	

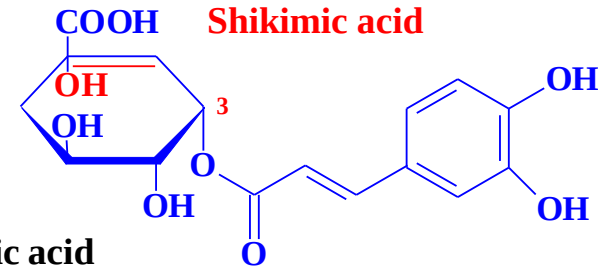
benzoic, p-hydroxybenzoic	food preservative
caffeic	substrate oxidoreductases
vanillic	component of alkaloids
gallic	component of tannins



Melilotoside



Vaccinin



Chlorogenic acid

apple, potato, coffee — **chlorogenic = caffeic + quinic**

dates — **dactylipheric = caffeic+ shikimic**

BITTER COMPOUNDS

primary compounds

- characteristic compounds of plants

secondary compounds

- formation during processing and storage

  (reaction products, metabolites of microorganisms)

Ilex

additives

alkaloids

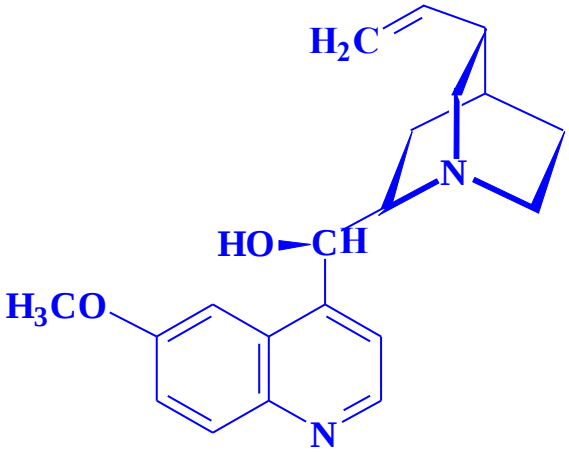
quinine (true alkaloids, quinolinic alkaloids),

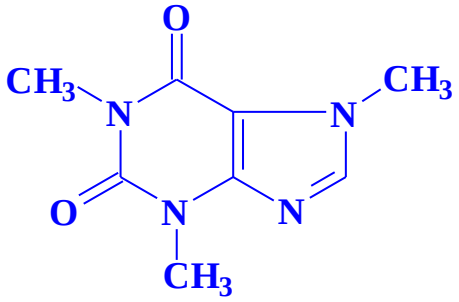
tonic water

caffeine (protoalkaloids, purine alkaloids)

coffee, tee, cocoa, guarana, cola drinks

mate - prepared by steeping dried leaves of yerba mate (*Ilex paraguariensis*), "national infusion" in Argentina





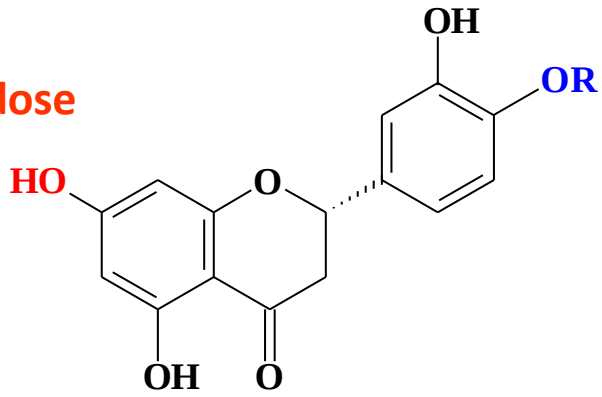
mg/kg	quinine	caffeine
nonalcoholic beverages	75	250
spirits	300	

fruits

grapefruits (bitter oranges)

flavonoids (flavanones)

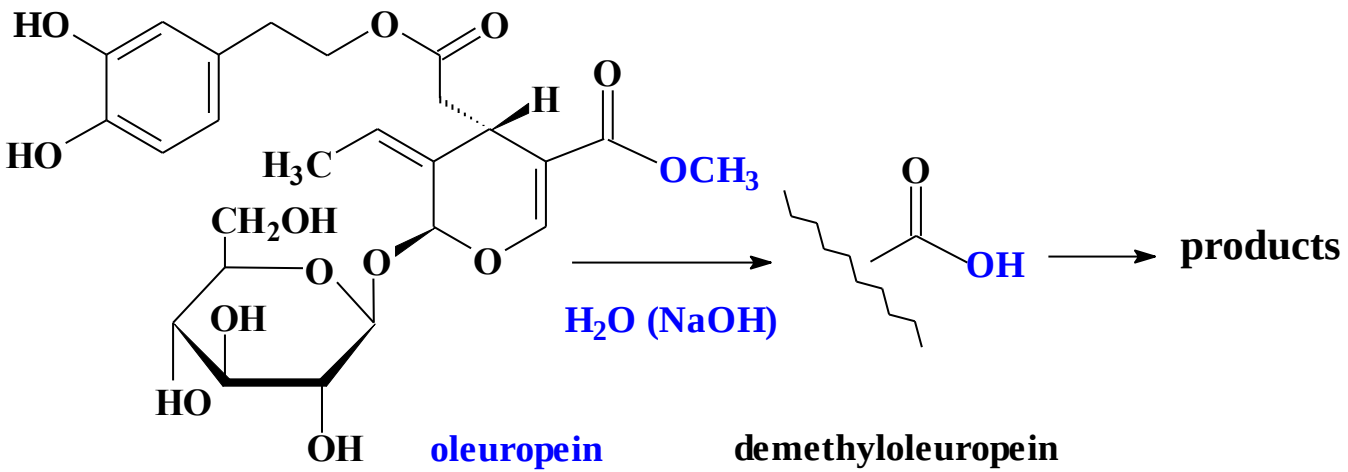
neohesperidose



naringin = naringenin (R = H) + **neohesperidose**, α-L-Rha-(1→2)-β-D-Glc
neohesperidin = hesperetin (R = CH_3) + **neohesperidose**
sweet neohesperidin dihydrochalcon

olive

phenols



oleuropein demethyloleuropein

vegetables

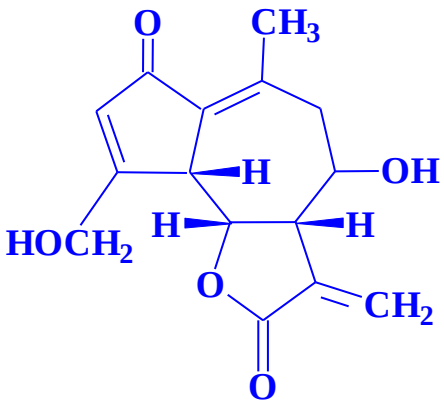
lettuce, endive, chicory (lactucin)

terpenes

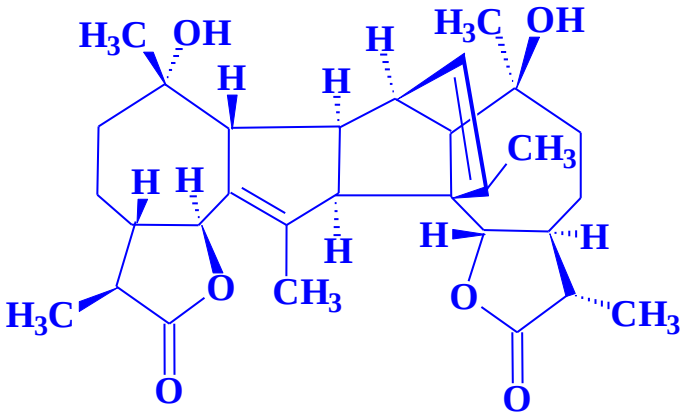
spices and other plant materials

wormwood (absinthin)

terpenes



lactucin



absinthin

hops

derivatives phloroglucinol (1,3,5-benzenetriols)

bitter acids (18% dry matter)

- **α-bitter acids (homologues humulone)**
- **β- bitter acids (homologues lupulone)**

beer

isobitter acids

- **iso-α-bitter acids (isohumulone)**
- **iso-β- bitter acids (isolupulone)**

ADSTRINGENT COMPOUNDS

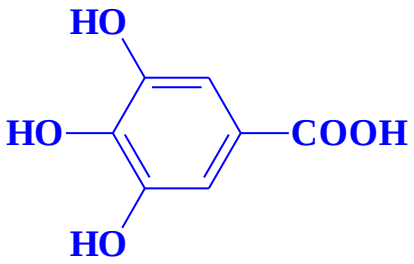
perception = protein interaction of saliva with polyphenolic compounds → denaturation (loss of protective role)

tannins

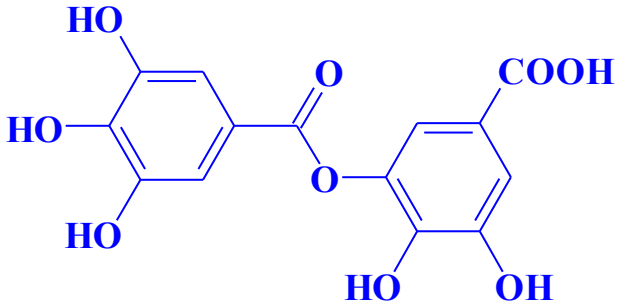
- **hydrolysed** **polymers of gallic acid esters**
  additives, little in food
- **condensed** **polymers of flavan-3-ols (3,4-diols)**
  food (fruits, wine)

hydrolysed tannins

gallotannins

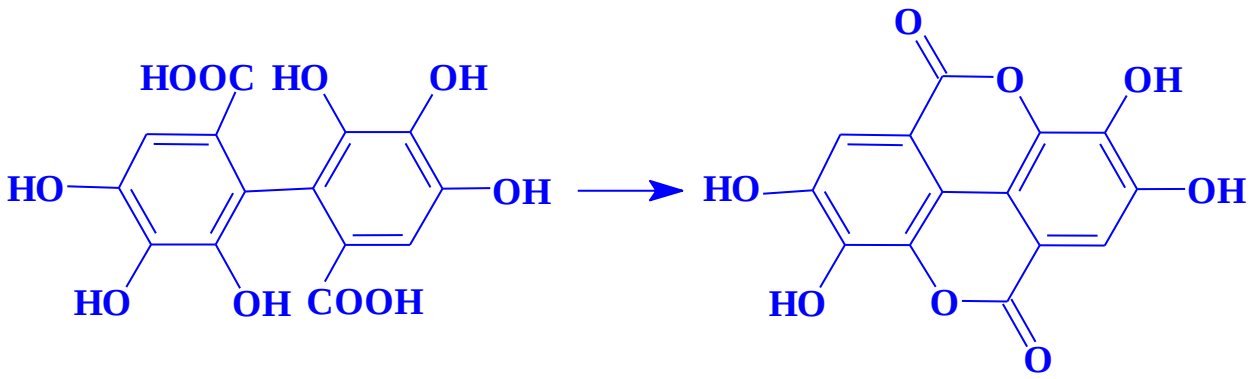


gallic acid



m-digallic acid (depside)

- **ellagotannins**



hexahydroxybiphenylic acid (C-C dimer) **ellagic acid (lactone)**

gallotannins

Chinese tannin

mixture of galloylesters and m-digalloylesters D-glucose

elimination of turbidity caused by proteins (vinegar, beer, wine)

Ellagotannins

corilagin

cranberries leaves

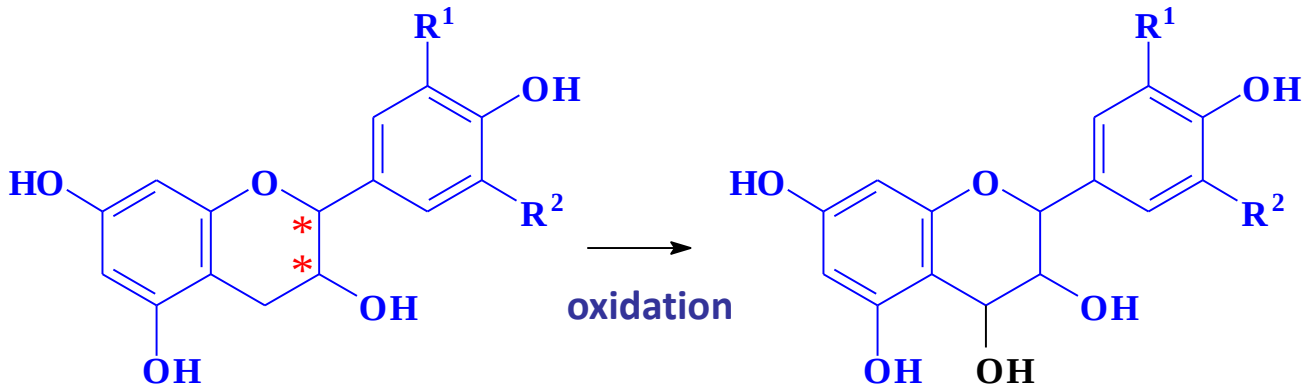
condensed tannins (proanthocyanidins, flavolans)

dimers and higher oligomers (2-10 unites)

- **flavan-3-ols (catechins)**
- **flavan-3,4-diols (leucoanthocyanidines)**

monomers do not have the properties of tannins

oxidised oligomers are coloured



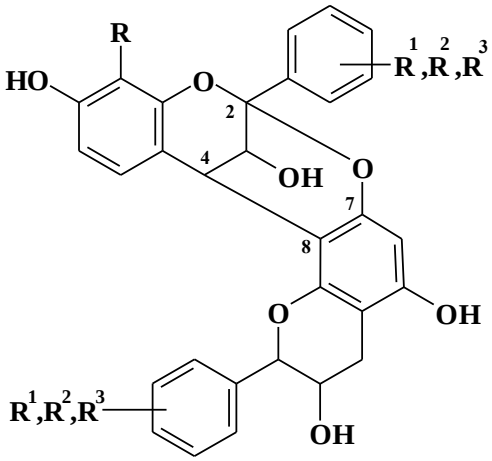
afzelechins (R1 = R2 = H)	***p*-hydroxybenzoic**	**leucopelargonidin**
catechins (R1 = H, R2 = OH)	**protocatechuic**	**leucocyanidin**
gallocatechins (R1 = R2 = OH	**gallic**	**leucodelphinidin**

Examples

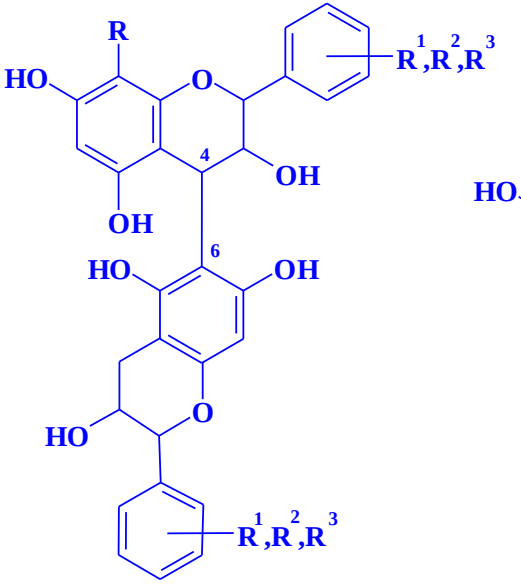
fruit and wine tannins

tea tannins

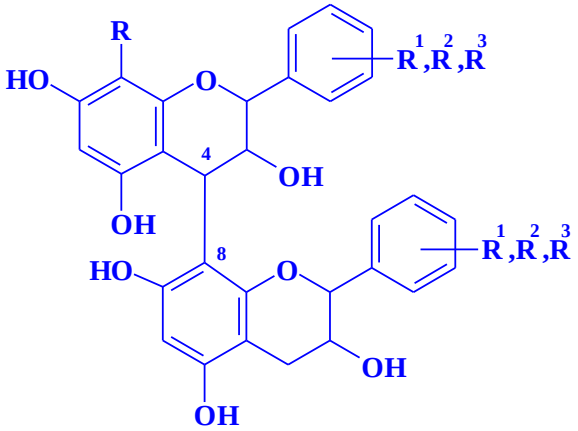
non-enzymatic browning reaction



type A (C-4→C-8, C-2→O → C-8)



type B (C-4 → C-6)



type B (C-4 → C-8)

PUNGENT SUBSTANCES

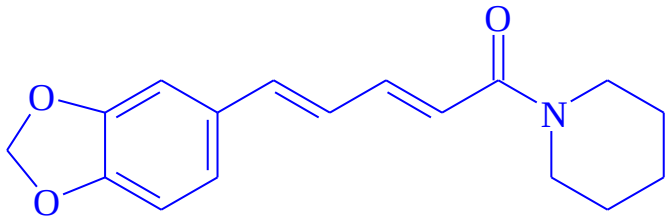
primary compounds

- characteristic components of plants

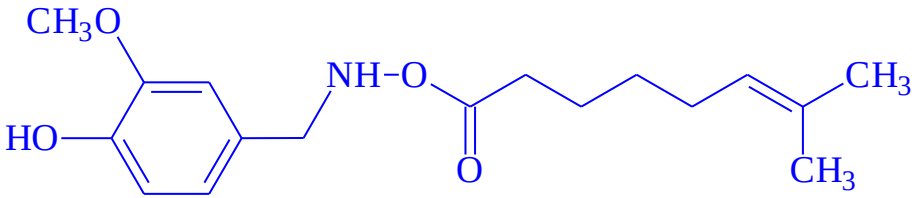
secondary compounds

- enzymatic reactions

Alkaloids

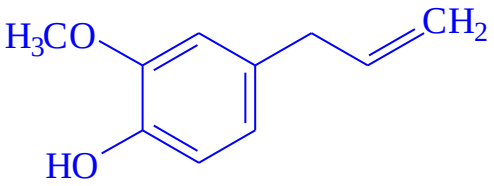


true alkaloids: **piperine** (black pepper)

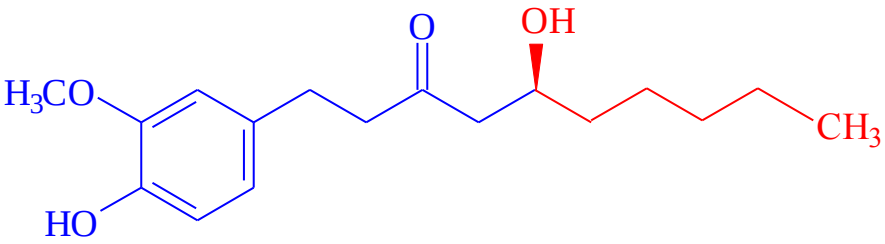


protoalkaloids: **capsaicin** (bell pepper, chilli)

phenols

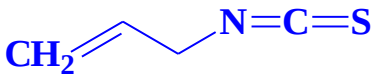


eugenol (clove)



gingerol (ginger)

isothiocyanates



allylisothiocyanate (mustard, horse radish)

formation