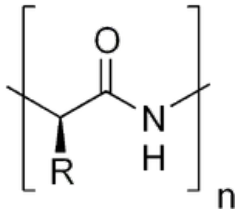
Proteins (1. LF UK, NT)

Proteins, or polypeptides, are organic macromolecular substances. Their molecular weight exceeds 10,000. They consist of amino acids in numbers greater than 100. A typical protein contains 200-300.

Construction

amino acids in the peptide are bound to each other by peptide binding. **Peptide binding** combines with simple covalent binding amino group of one amino acid and a carboxylic group of the other amino acid. The Gibbs energy value of this reaction is equal to G = 10 kJ/mol.



peptide binding

Polycondensation produces an arbitrarily long chain of amino acids. The end of the chain, which has a free (unreacted) amino group, is called **the N-end**. On the opposite side of the chain, on the other hand, we find a free carboxyl group. This end is called **the C-end**.

Structure

The structure of proteins is based on the arrangement of amino acids in the chain. Protein structure is very important for their function.

Primary structure

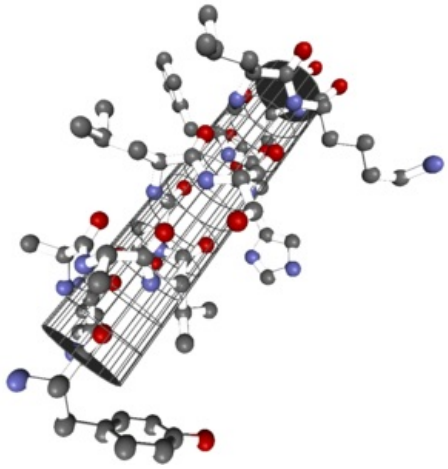
The primary structure is defined by **the exact** sequence of amino acids in the chain.

Secondary structure

Secondary structure means **the spatial arrangement of amino acids** in a chain and stabilization by hydrogen bonds.

They are two basic secondary structures:

1. α-helix: The string is curled into **a right-hand helix**. The length of a single screw thread is equal to 3,6 amino acid residues. The structure of α-helix is found primarily in fibrous proteins (keratins) or muscle proteins.
2. β-folded sheet: Two **parallel and antiparallel** chains resembling a folded sheet of paper.


α-helix

Tertiary structure

The tertiary structure is characterized by other **intramolecular binding interactions**. For example, **disulfide bridges**, ionic bonds and van der Waals forces. Other H-bridges may also form in the molecule.

Quarternary structure

The quaternary structure is formed in proteins consisting of two or more polypeptide chains. Their connections provide **extramolecular binding interactions** with each other. The quaternary structure is found, for example, in hemoglobin. In contrast, myoglobin does not possess quaternary structure.


β-folded sheet

Protein denaturation

Protein denaturing is the process by which secondary and tertiary structures change. The protein thereby loses its biological activity. Denaturation can be achieved, for example, by heating or changing the pH.

Main nutrients

- peptide bonds
- other bindings
  - disulphide -S-S-
  - ester
  - amide
- Ingredients other than amino acids (physically or chemically)
  - water
  - inorganic ions lipids
  - lipids, sugars, nucleic acid, colored compounds

Clasification

Division

By origin

- animal (meat, milk, eggs) - 60% of food protein
- vegetable (cereals, legumes, fruits, vegetables) - 30% of food protein
- non-traditional food protein (seaweed, micro-organisms)

By function

- structural (cell building components, collagen)
- catalytic (enzymes, hormones)
- transport (transfer of compounds, myoglobin)
- motion (muscle proteins, actin, myosin)
- defence (antibodies, immunoglobulins, lectins)
- stock (ferritin)
- sensory (rhodopsin)
- regulating (histones, hormones)
- nutritional (source of essential amino acids, source of nitrogen, mass to build and restore tissues)

By structure

(the presence of a non-protein component)

1. Simple proteins (they contain only a protein chain - globular, fibrillary proteins)

- globular, spherical proteins (albumins, globulins)
- fibrillary (fibrous), scleroproteins, stromatic proteins (collagen, keratins, elastins)

1. Compound proteins (contain protein chain and non-protein part - prosthetic group - lipoproteins, glycoproteins)

- nucleoproteins (nucleic acids)
- lipoproteins (neutral lipids, phospholipids, sterols)
- glycoproteins (carbohydrates)
- phosphoproteins (phosphoric acid)
- chromoproteins (porphyrin derivatives, flavin)
- metalloproteins (coordinating boud metals)

By solubility

Soluble

- albumins − milk (lactalbumin), egg whites (ovalbumin, conalbumin), wheat (leucosin)
- globulins − meat (myosin, actin), milk (lactoglobulin), eggs (ovoglobulin)
- gliadins, or prolamines − wheat (gliadin), barley (hordein), maize (zein)
- glutelines − wheat (glutenin), rice (oryzenin)
- protamines − soft roe (cyprimin, salmin, klupein, skombrin)
- histones − blood (globins of haemoglobin and myoglobin

Insoluble

- collagen, elastin, keratin

By status

- native (natural, biological functions)
- denatured
- adjusted (modified, additives)

Nutritional aspect

- full-bodied (essential amino acids in optimal quantities)
  - egg and milk
- almost full-bodied (some essential amino acids deficient)

    - animal, muscle
- incomplete (some essential amino acids deficient)
    - all plant, animal connective tissues

Food deficient in certain amino acids

- Lysine − cereals (generally vegetable proteins)
- Methionine − milk, meat
- Threonine − wheat, rye
- Tryptophan − casein, maize, rice

Content in food

- 0–100 % P (in dry matter)
- animal foods > vegetable
- legumes, oilseeds > fruits, vegetables

  eggs – 75 % H_2O, 13 % P (whole), 52 % P in dry matter
  legumes – 12 % H_2O, 24 % P (soya 32-45 %), 27 % in dry matter
  meat (H) – 69 % H_2O, 21% P, 68 % in dry matter
  bread – 38 % H_2O, 7 % P, 11 % in dry matter
  milk – (3,5 % L) 87-90 % H_2O, 3,4 % P, 28 % in dry matter
  potatoes – 78 % H_2O, 2 % P, 9 % in dry matter

Covering energy needs: ~ 10 % **Recommended daily dose:** 1-1,2 g/kg
Nutrient ratio

- protein : lipids : carbohydrates (weight = 1 : 1 : 4)
- energy = < 14 : < 14 : <56 %

Physiology and nutrition

- minimum need for full protein 0,5-0,6 $g \cdot kg^{-1}$
- recommended dose 1,0-1,2 $g \cdot kg^{-1}$ (not used optimally)

  ~ 2,4 $g \cdot kg^{-1}$ growth period, breastfeeding women, recuperation etc.

- nutritional value (nutritional, biological)
- total intake

Availability of peptide bonds to digestive enzymes

Other factors

Previously

- BV (Biological Value) (= g P produced in organism / 100 g P in food)
- NPU (Net Protein Utilization)
- PER (Protein Efficiency Ratio) aj. (animals)

Depends on:

- absolute content of essential amino acids
- relative ratio
- ratio to non-essential amino acids
- digestion

Today

- AAS (Amino Acid Score)
- EAAI (Essential Amino Acid Index) − more accurate

  AAS (%) = 100 A_i /A_{si}

where:

- A_i = essential amino acid content in protein
- A_{si} = same amino acid content in standard (reference) protein

Standard protein = fictitious protein with optimal composition of essential amino acid (AAS = 100%)

$$EAAI = \sqrt[n]{\frac{100A_1}{A_{S1}} \cdot \frac{100A_2}{A_{S2}} \cdot \ldots \cdot \frac{100A_n}{A_{Sn}}}$$

Physico-chemical qualities

- solubility, hydration and swelling
- dissociation
- optical activity
- formation of gel
- formation of emulsions
- stabilization of foam
- denaturation
  - physical factors − changes in temperature, pressure, ultrasound, penetrating, penetrating electromagnetic radiation
  - chemical factors− salts, changes in pH (acids, bases), surfactants
- concequences
  - more accessible to digestive enzymes of digestive tract
  - denaturalization of antinutritional factors, toxic substances (proteas inhibitors, amylas, lectins)
  - inhibition of undesirable enzymes and microorganisms

Meat, meat products, poultry, fish

Meat, meat products, poultry, fish

4 main tissues types (additional blood)

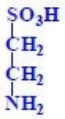
- epithelial
- supporting (connective)
- muscle (transversely striped, smooth)
- neural

Definition

Parts of warm-blooded animals in fresh, processed state
In the narrower sense: skeletal muscle tissue − number of muscles, bone tendrils, blood supply, nerves, skin, cartilage, bone, fat

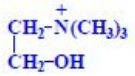
Other components

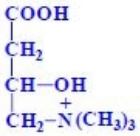
- vitamins
- free amino acids 0,1–0,3 %

  taurine (0,02-0,1 %), bile acid component, nerve excitation transfer 

- quaternary ammonium compounds

  choline 0,02-0,06 %, phospholipids, transmethylation reactions,

  acetylcholine 

  carnitine 0,05-0,2 %, fatty acid transport 

- guanidine compounds
- glycogen
- phosphate sugars and free sugars
- lactic acid and other acids
- purines and pyrimidines

Use for food and non-food purposes.

Myofibrillar proteins

- muscle fiber
- myofibrils (contractile fibers)
- microfilaments (microfibers)
  - myosin
  - actin
  - other proteins

In vivo reaction

🔎 *For more information see Excitation-contraction coupling in skeletal muscle.*

Post mortem reaction

- ATP anaerobic glykolysis from glycogen
- lactic acid › decrease in pH 6,8 to < 5,8
- inhibition of glycolytic enzymes
- Ca2+ / actin reaction with myosin, without ATP › post-mortem stiffening (rigor mortis)

Effect on meat quality

Maturation of meat

- cleaving actomyosin by endogenous proteas (mainly cathepsins)
- cleaving collagen with collagen

Meat defects

- DFD (dry-firm-dark) a DCB (dry-cutting-beef)
  - dark, high binding, low maintenance
  - removal of lactic acid during exsanguination, pH~ 6
- PSE (pale-soft-exudative)
  - light, low binding, grey-green surface
  - increased glycolysis stimulated by hormones, pH~ 5,6

Changes in processing

- ~35° C association of sarcoplasma proteins, reduction in binding, increase in stiffness
- ~45° C visible changes, shortening=denaturation of myosin
- ~50-55° C denaturation of actomyosin
- ~55-65° C denaturation of sarcoplasma proteins, associated structure and gel
- ~60-65° C changes in collagen conformation (shortening 1/3-1/4)
- ~80° C oxidation of SH-groups
- ~90° C gelation of collagen (release of tropocolagen fibres, sol gelatine)
- ~100 ° C elimination NH_3, H_2S, other substances, aromatic substances, change of colour

Milk and milk products

- Nutrient content in milk
- Water by type of milk (origin) 63 - 88 %

Complicated dispersion system

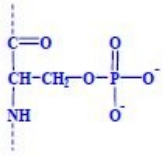
- globular protein of whey − colloidal dispersion
- casein molecule − micellar dispersion
- fat − adipose globule (microsomes, φ 0,1-10 µm): emulsion
- molecules od lipoproteins − colloidal suspension molecular substance (lactose, amino acids, minerals, hydrophilic vitamins)
- molecular substance (lactose, amino acids, minerals, hydrophilic vitamins) − genuine solution

Coloration

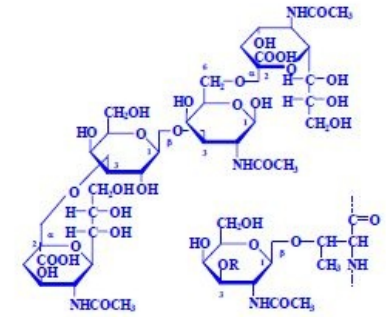
Protein composition of cow's milk

- Protein composition of cow's milk

Amino acid content of milk

- caseins
  - α-caseins = phosphoproteins, α_{S1}, α_{S2}, phospherin 
  - ß-caseins = phosphoproteins
  - γ-caseins = products of ß-caseins degradation
  - κ-caseins = glycoproteins (2 genetic variants, B), sugar = tetra-, tri-, di-, mono-, GalNAc, Gal,

NeuAc, binding to Thr (133)



hlavní složka κ- kaseinů

- caseins − αS-, ß-, κ-caseins aggreation into submicel and micel, casein moleculs › submicel › micel

Changes in storage and processing

Heat treatment

- clumping of fatty globules in raw milk, ~ makroglobulin
- whey causes proteins to thermable, denature, caseins practically don't denature

Pasteurization

- 72-74 °C (20-40 s): denatures about 50-90 % of serum proteins
- > 75 °C:
  - most enzymes are inactivated
  - reduction of disulfide-binding
  - elimination of H_2S (ß-lactoglobulin)
  - sulphides, disulphides simmer ingestion (Met)
  - degradation of thiamine
  - formation of lactones and methyl ketones
- sterilisation 140 °C (4 s)
  - denaturation 100 % of the proteins
  - reaction of lactose with lysine
  - loss of lysine (Maillard reaction), fragrances − raw and pasteurised milk ~ 400 fragrances (1-100 mg/kg)

Casein clotting and proteolysis

- fresh milk − pH 6,5-6,75
- casein precipitation − pH 4,6 (contaminant, culture microbes)

Hard cheeses

- microorganisims (lactic acid), acidifaction (pH 5,5)
- proteolytic enzyme rennin (chymosine, rennet), specific hydrolysis of κ-casein − para-κ-kasein = hydrophobic part, part of micells, κ-caseinmacropeptide = hydrophilic part, coagulation
- curds, (storage › rigidity, acidity, centrifugation of whey, salting, maturation (in the case of Emmental-type cheese, conversion of lactic › propionic acid + CO_2), proteolysis, lipolysis › hard cheese

Soft cheeses, yoghurts

- precipitation, low pH (fermentation of lactose, lactic acid), partial coagulation of caseins, in yoghurts is association of micells (gel structure)

Insoluble acid casein

Sweet casein (rennet clotting)

Caseinates (soluble)

Na, K, NH_4; dispersible: Ca, Mg)

Insoluble coprecipitates

Whey

Egg

Egg

- proteins of white 53 %, yolk 47 %
- nutrient content in hens eggs
- protein composition of hens egg white and yolk

Proteins of egg white

~ 40 proteins (globulins, glycoproteins and phosphoproteins)

- enzymes (lysozyme, N-acetylmuramide activity, murein, cell walls of bacteria)
- protein components of enzymes (flavoprotein/riboflavin, avidine/biotine)
- protease inhibitors (ovomucoid, ovoinhibitor)

Concequences

- viscosity and gel-like consistency of egg white − ovomucoid a ovomucin
- stability of whipped white foam − ovoglobulins G2 a G3
- antimicrobial effects −lysozyme (ovoglobulin G1)
- antinutritional action − avidine

Yolk proteins (emulsion of fat in water)

- 1/3 = proteins, 2/3 = lipids
- glyco-, lipo-, glycophospho- and glycophospholipoproteins
- granules − lipovitellin and phosvitin
- plasma − lipovitellenin and livetin

Changes in storage and processing

- partial denaturation of white proteins when whipped
- denaturation by heat
  - 57 °C − beginning
  - 60-65 °C − most proteins denature (not ovomucoid)
  - 65-70 °C − most yolk proteins (not phosvitin)

Foods of vegetable origin

Foods of vegetable origin

- main sources − plant seeds
- limited sources − fruits, leaves, tubers and other parts of plants (fruits, vegetable, root crop)

Cereals and pseudocereals

- Basic chemical composition of cereals
- Cereal proteins and their composition

Wheat proteins

Flour 7-13 (up to 15) % of proteins

- 15 % albumins (water soluble) leucosin
- 7 % globulins (0,4 M-NaCl) edestin
- 33 % prolamines (70 % ethanol) gliadine
- 46 % glutelines (remainder) glutenin

  prolamine/gluteline ratio = 2 : 3

1. Strong flour = bread (12-14 %)

- (dough elastic, stiff, necessary intense mixing, retains carbon dioxide, air, bulkier products)

1. Weak flour= biscuit production, confectionery (< 10 %)

Dough

- gluten = viscoelastic mass, 2/3 of water, 1/3 hydrated gluteline (viscosity),
- gliadines (elasticity), gluten solids = 90 % of proteins, 8 % of lipids, 2 % of

sugars

Gluten-free products

- allergic disease - celiac disease (~ 0,05 % of children in Europe)
- changes in the epithelial cells of the intestinal wall, impaired absorption of nutrients
- prolamine fraction of wheat, rye, barley, sequence: Pro-Ser-Gln-Gln a Gln-Gln-Gln-Pro

  limits < 100 mg gliadine/kg (dry matter)

Rye proteins

- no gluten
- bakery properties: pentoses, certain proteins (bottling in an acidic environment)
- formation of acids by microorganisms (*S. cerevisiae*, *S. minor*, *L. plantarum*, *L. brevis*)

Legume and oilseed proteins

- high in globulins, germination function

🔎 *For more information see amino acid content in legumes.*

Utilization of non-traditional protein sources

Textured herbal proteins

Protein-rich preparation

Reactions

Reactions

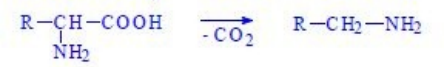
- elimination, isomerization, additive, oxidation
- complex reaction
- influence of food composition, conditions: temperature, pH, O2, other substances

Concequences

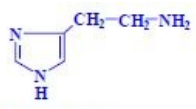
- impairment of biological value
  - breakdown of essential amino acids
  - formation of non-metabolizable products
  - reduction of digestion
  - formation of antinutritional and toxic substances
- formation of aromatic substances
  - mainly Cysteine, Methionine, Ornitine, Proline
  - amines, aldehydes, alcohols, S-compounds

Elimination reaction

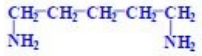
- dekarboxylation (elimination of carbon dioxide)



aromatic substances
biologically active substances (biogenic amines)

- - histamine (His)  , cadaverine (Lys)

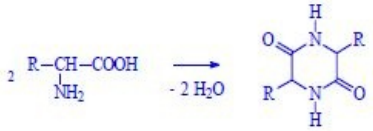
histamin (His)



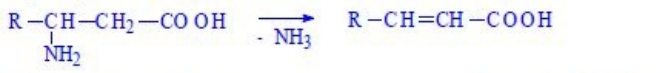
kadaverin (Lys)

Elimination of ammonia and water

- formation of 2,5-dioxopiperazines (cyclical dipeptides)

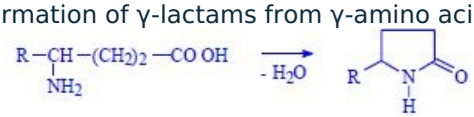


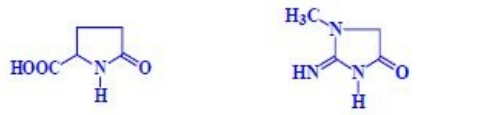
- formation of alc-2-enoic acids



β-aminokyselina (Asp) alk-2-enová kyselina

- formation of γ-lactams from γ-amino acids, γ-amino acid Glu, creatine





2-oxopyrrolidin-2-karboxylová kyselina kreatinin

Elimination of function groups of side chains

- reaction in an acidic environment or thermal reactions
  - protein deamideation, hydrolysis
- reaction in neutral environment or thermal reactions
  - formation of unusual bindings
- reaction in alkaline environment or thermal reactions
  - formation of unusual binding, unusual amino acids, D-amino acids (abiogenic)

Concequences

- reduction of digestion
- reduction in the nutritional value
- formation of potentially toxic amino acids
- formation of aromatic substances

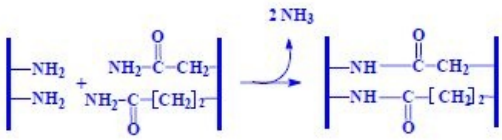
Acidic environment

- Production of protein hydrolysates
  - enzymes ofautolysis, yeast autolysates, food hydrolysates, soy sauce
  - acids of food hydrolysates

Neutral environment

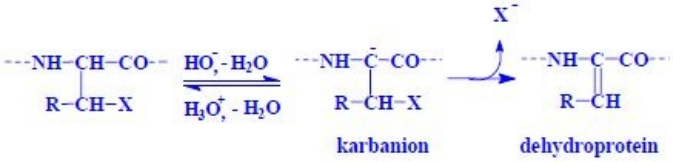
- formation of transverse bindings and unusual amino acids

  ε-amino group Lys, the carboxamide group Asn, Gln



Alkaline environment

- loss of Lysin, Cystein, Serin, Threonin, Arginin aj.
- 1,2-elimnation of H-X (Ser, Thr, Cys, SySSCy) and hydrolysis



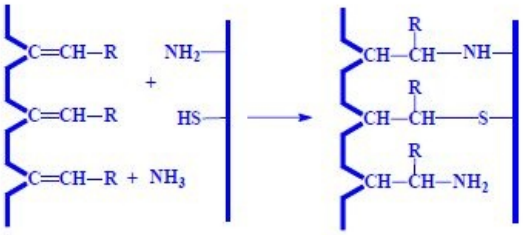
karbanion dehydroprotein

X = OH, SH, SR, SSR etc.

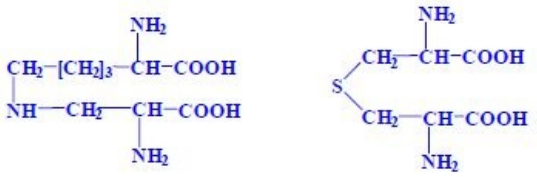
Cys, Ser›2-aminoacrylic acid (dehydroalanine), Thr › 2-aminocrotonic acid

(dehydrobutyrine) 

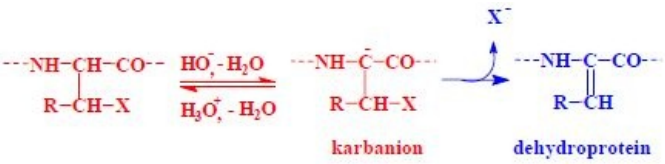
- addition of functional groups of amino acids (intra- and intermolecular transverse bindings)



- hydrolysis of cross-linked protein and formation of unusual amino acids, lysinoalanine, lanthionine

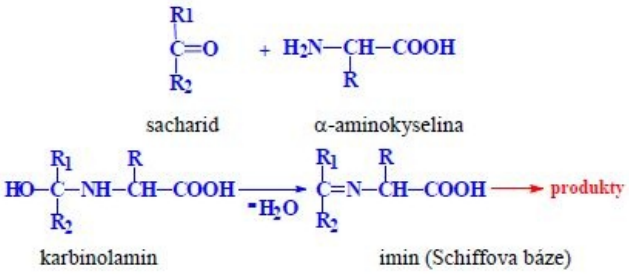


- isomerisation and formation of D-amino acids, reduced reusability



Additive reactions

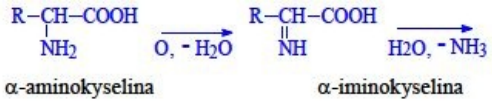
- carbohydrate reaction (aldehydes, ketones), Maillard reaction

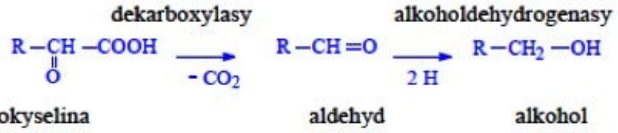


- - coloured substances, aromatic substances, biologically active substances

Oxidative reactions

- oxidative deamination and transamination
  - Enzyme reactions
    - deaminases or transminases, hydrolasses

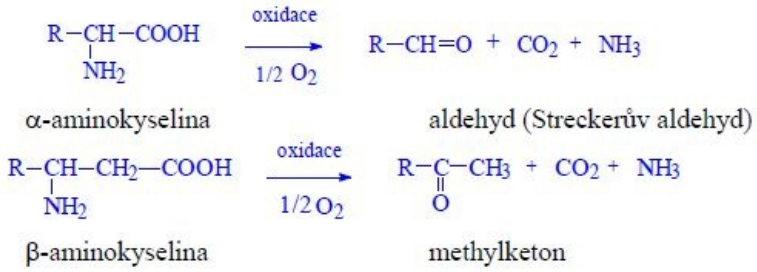




- - - aldehydes − aroma of fruits and vegetables
    - alcohols − aroma of alcoholic beverages (alcohols congeners)

Strecker degradation (oxidative decarboxylation)

- formation of strecker aldehydes
  - non-enzyme reaction



Oxidizing agents

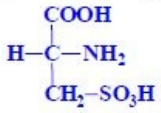
- dicarbonyl compounds
- carbohydrates
- quinones
- inorganic substances (hypochlorites)

Formation of other products

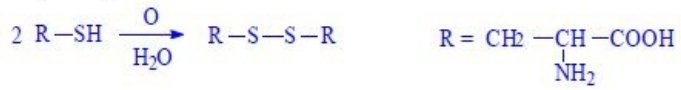
- N- and S-heterocyclical compounds

More oxidations

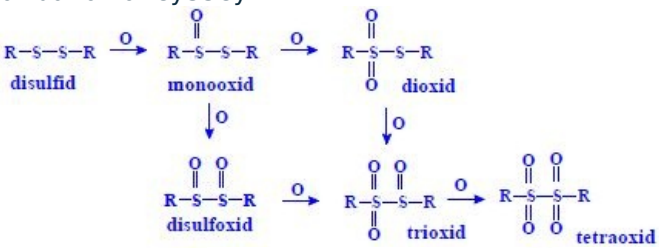
- oxidised lipids and phenols, O_2 (photosensitisers)
- cysteine and cystine
  - oxidation of Cys na sulfenic, sulfinic, sulfonic (cysteic) acid

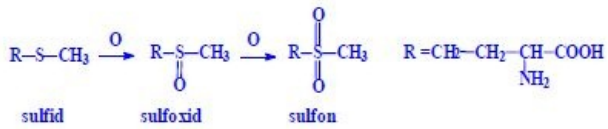
    (unusable) 

  - oxidation of Cys to CySSCy

  - oxidation of CySSCy

- oxidation of Met 

Reaction with food ingredients

- reaction with polyphenols
  - dark colour of scrap isolates
  - unusable products, reduced digestion
- reaction with oxidized lipids
  - unusable products, reduced digestion

References

Related articles

- Peptides (1. LF UK, NT)
- Amino Acids (1. LF UK, NT)
- Amino acids, peptides, protein

Sources

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