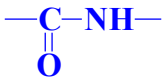
## 2. AMINO ACIDS, PEPTIDES AND PROTEINS

### amino acids

functional groups: $NH_2$ COOH



amino acids bound by amide (peptide) bond

### peptides

2-100 amino acids

### proteins

> 100 amino acids

### AMINO ACIDS

~ 700 amino acids

- free compounds
- structural units of peptides, proteins and other compounds

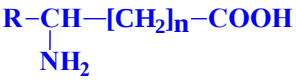
### structure

amino group $NH_2$ free, substituted

- carboxylic group -COOH
- additional functional groups
  - hydroxyl -OH
  - thiol -SH
  - sulfide -S-R
  - guanidyl 
  - phenyl etc. 

### classification

- **according to distance of amino group from carboxylic group**

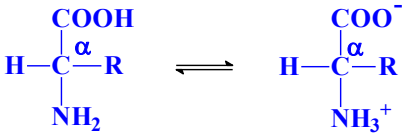


| | | **n** |
|---|---|---|
| 2-amino acids | α-amino acids | 0 |
| 3-amino acids | β-amino acids | 1 |
| 4-amino acids | γ-amino acids | 2 |
| 5-amino acids | δ-amino acids | 3 |
| 6-amino acids | ε-amino acids | 4 |

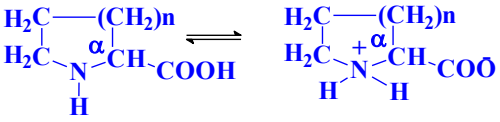
- **according to their occurrence**
  - found in all organisms (invariable), basic (proteinogenic), 21 amino acids
  - found in only some organisms (variable), many amino acids

### basic amino acids

**20 α-amino acids with primary amino group -$NH_2$**



1 α-amino acids with secondary amino group -NH-



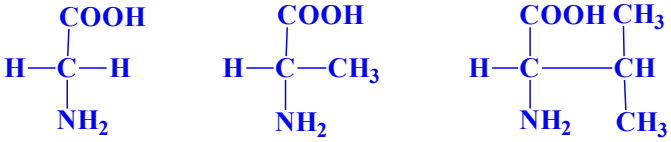
n=0, pyrrolidine

20 amino acids = chiral compounds groups, L-amino acids

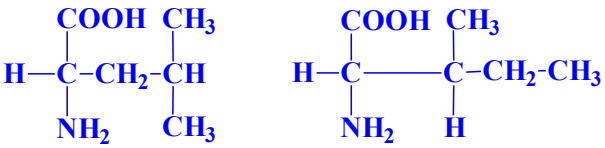
**trivial names systematic names, symbols (tree letters, one letter),** (book 1, table 2.1.)

**classification of basic amino acids according the structure of side-chain and functional groups**

**aliphatic with nonsubstituted chains**

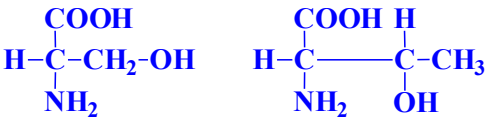


glycine alanine valine



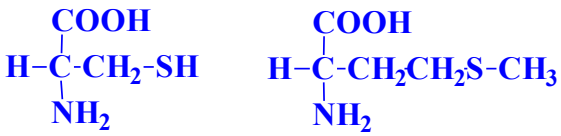
leucine isoleucine

**aliphatic hydroxyamino acids**



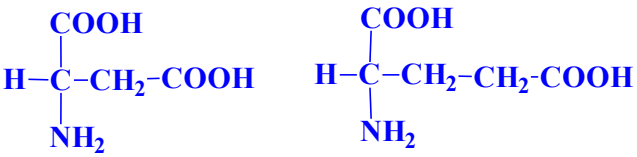
serine threonine

**aliphatic sulphur (selenium)-containing amino acids**
**(*Se*-analogue of cysteine: selenocysteine)**



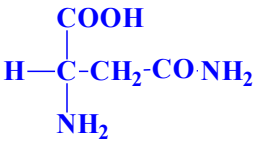
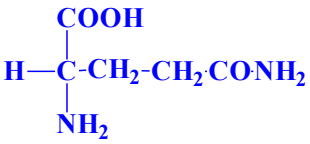
cysteine methionine

**with another carboxyl group in the side-chain (monoaminodicarboxylic, acidic)**



aspartic acid glutamic acid

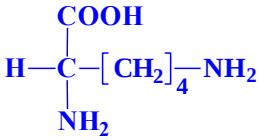
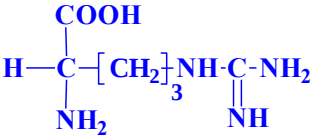
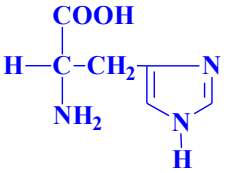
**their monoamides (with carboxamides group in the side-chain)**

asparagine glutamine

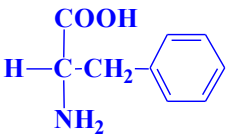
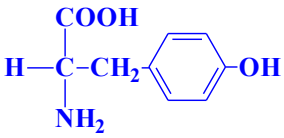
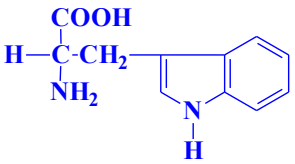
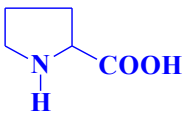
**with basic groups in the side-chain**

- amino group
- guanidylic group
- imidazole cycle

lysine arginine histidine

**with aromatic (heterocyclic) side-chain**

fenylalanine tyrosine tryptophan proline

**according to polarity of the side-chain and its ionic forms (in neutral medium)**

- **nonpolar, hydrophobic**
  Val, Leu, Ile, Phe, Tyr, Met, Pro; to some extent Gly, Ala, Trp
- **polar, hydrophilic**
  Ser, Thr, Cys, Asp, Glu, Asn, Gln, Lys, Arg, His

hydrophilic (according ionic form of side chain in neutral medium)

- neutral (without electric charge): most amino acids
- acidic (negative electric charge): Asp, Glu
- basic (positive electric charge): Lys, Arg, His

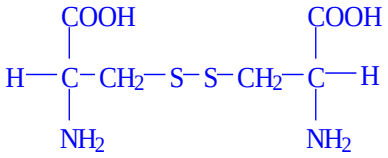
**according to importance in human nutrition**

- essential: Val, Leu, Ile, Thr, Met, Lys, Phe, Trp
- semiessential : Arg, His
- nonessential: others

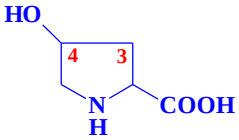
**limiting amino acids**

**DERIVATIVES OF PROTEINOGENIC AMINO ACIDS**
**(formed by posttranslational modifications)**

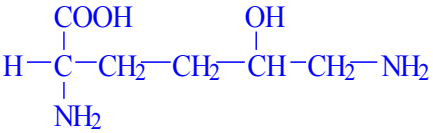
L-cystine (CySSCy)



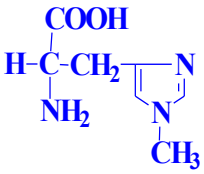
4-hydroxy-L-proline (Hyp)



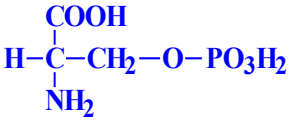
5-hydroxy-L-lysine (Hyl)



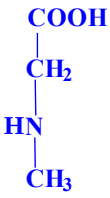
3-methyl-L-histidine



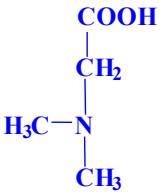
*O*-fosfo-L-serine



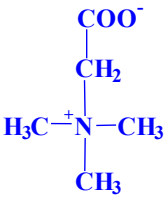
***N*-substituted amino acids (nonproteinogenic)**



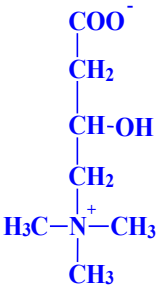
*N*-methylglycine (sarkosine)



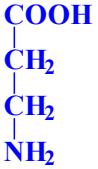
*N*,*N*-dimethylglycine



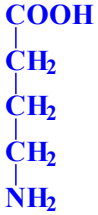
*N*,*N*,*N*-trimethylglycine



L-carnitine (3-hydroxy-4-trimethylaminobutyrate, vitamin $B_t$)

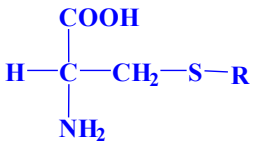


β-alanine (3-aminopropionic acid)

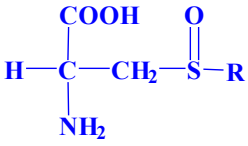


γ-aminobutyric (4-aminobutyric) acid (GABA)

**sulphur-containing amino acids**

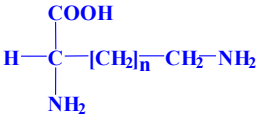


*S*-alk(en)yl-L-cysteines

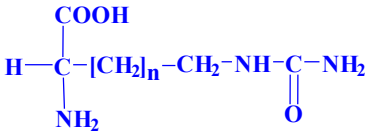


*S*-alk(en)yl-L-cysteine sulfoxides

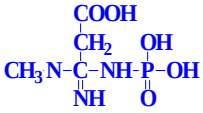
**basic amino acids and related compounds**



L-ornithine (n = 2)

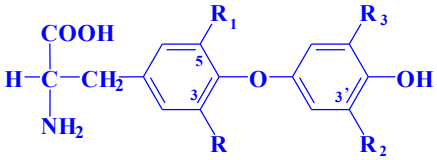


L-citrulline (n = 2, carbamoylderivative of ornithine)

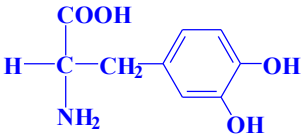


creatine-phosphate

**aromatic amino acids**



tetrajodthyronine (thyroxine), R = $R^1$ = $R^2$ = $R^3$ = I



3,4-dihydroxy-L-fenylalanine (DOPA)

**essential amino acids**

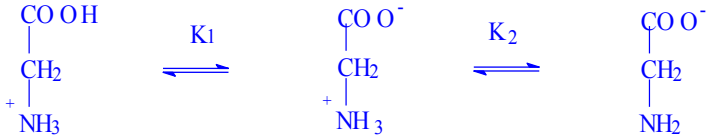
foods with limiting amino acids

- Lys cereals (generally vegetable proteins)
- Met milk, meat
- Thr wheat, ray
- Trp casein, corn, rice

**physical-chemical properties of amino acids**

- acidobasic properties (pK a pI ) (book 1 table 2.3).
- optical activity
- sensory properties

**acidobasic properties (Gly)**



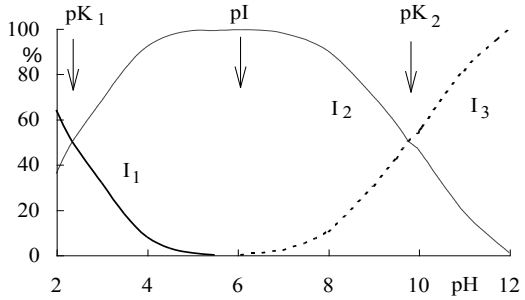

ion $I_1$ (cation)
free charge +1
pH < 2

ion $I_2$ (amfion)
free charge 0
pH ≈ 6

ion $I_3$ (anion)
free charge -1
pH > 10

Gly ionic forms dependence on pH

——— = cation ($I_1$) - - - = amphion ($I_2$) ..... = anion ($I_3$)



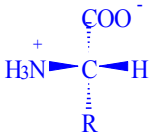

**optical properties**

- Gly = exception
- majority = chiral atom $C_\alpha$
  2 optical isomers (enantiomers)
- some = two 2 chiral centres (Ile, Thr, Hyp, CySSCy)

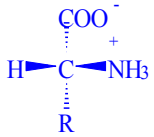
**L- and D-amino acids**

L-amino acids = (*S*)-stereoisomers, exception: L-cysteine = (*R*)-stereoisomer
D-amino acids = (*R*)-stereoisomers

content (book 1, table 2.25)

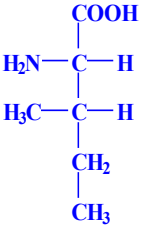



L-amino acid
(*S*)-amino acid

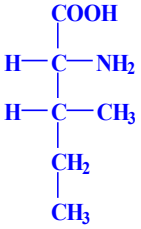



D-amino acid
(*R*)-amino acid

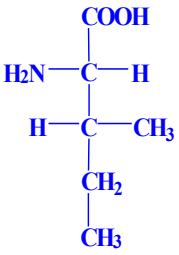
**diastereoisomers**



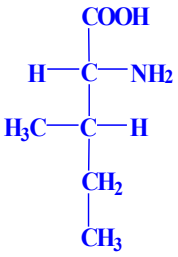

L-isoleucine
(2*S*, 3*S*)-isoleucine




D-isoleucine
(2*R*, 3*R*)-isoleucine




L-*allo*-isoleucine
(2*S*, 3*R*)-isoleucine

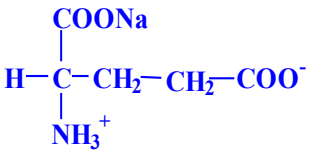



D-*allo*-isoleucine
(2*R*, 3*S*)-isoleucine

**sensory properties**

- sweet — Gly, Ala, Thr, Pro
- sour — Asp, Glu
- bitter — Leu, Ile, Phe, Tyr, Trp
- indifferent — all the other

special properties = **umami** taste



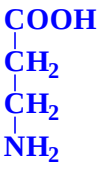

natrium-hydrogen-glutamate

**PEPTIDES**

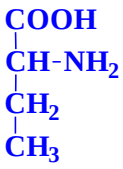
**structure**

condensation of 2 amino acids (linear and cyclic dipetides)

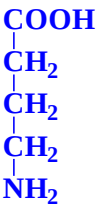
- **uncommon binding of some amino acids**
  distal COOH group of Glu = γ-peptide bond
- **biding of D-amino acids**
- **biding of uncommon amino acids**



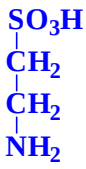
β-alanine (3-aminopropionic acid )



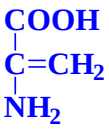
α-aminobutanoic acid 2-aminobutanoic acid)



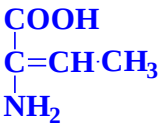
γ- aminobutanoic acid 4-aminobutanoic acid )



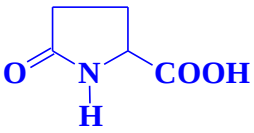
taurine



2-aminoacrylic acid (dehydroalanine)



(*E*)-2-aminocrotonic acid (dehydrobutyrine**)**



pyroglutamic acid

**classification**

**number of bound monomers (amino acids)**

- oligopeptides (2-10 amino acid)
- polypeptides (11-100 amino acid**)**

**chain character**

- linear
- cyclic

**bond type**

- homodetic (peptide bonds only)
- heterodetic (peptide bonds and other bonds)
  disulfide -S-S-
  esters (depsipeptides) -CO-O-R

**bound components**

- homomeric amino acids only
- heteromeric amino acids and other compounds

nucleopeptides phosphopeptides
lipopeptides chromopeptides
glycopeptides metalopeptides

**occurrence**

- product of metabolism, natural peptides
- product of proteolysis, enzymatic and nonenzymatic

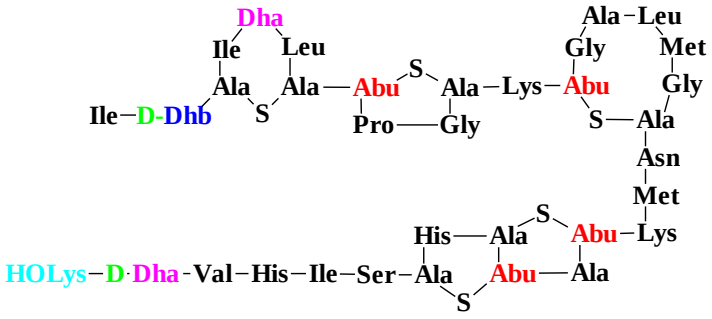
- synthetic peptides, artificial sweeteners etc.

**properties**

- biological activities
- sensory activities

**products of lactic acid fermentation** =bacteriocines

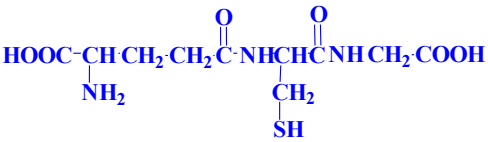
**nisine** *Streptococcus cremoris*, syn. *Lactococcus lactis* ssp. *lactis*
antibiotic properties, preservation agent, stabilisation of lactic acid fermentation products




Abu = 2-aminobutanoic ← Glu
Dha = 2-aminoacrylic (dehydroalanine) ← Ser, Cys
Dhb = 2-aminocrotonic (dehydrobutyrine) ← Thr
HoLys = 5-hydroxylysine, D = D-isomer

**other important peptides**

**glutathione** (G-SH or G-S-S-G)




γ-L-glutamyl-L-cysteinylglycine (γ-amidic bond)
occurrence microorganisms, plants, animals

| | |
|---|---|
| wheat flour | 10-15 mg/kg |
| meat | 300-1500 mg/kg |

**functions**

- detoxification of toxic forms of $O_2$
- transportation of amino acids into cells
- metabolic processes (biosyntheses of leucotriens)
- stabilisation of oxidation state of SH-proteins (peroxidases, glutathione reductases)
- technology (white bread production)

Chorleywood process of white bread production using ascorbic acid

$H_2A + ½\ O_2 \rightarrow A + H_2O$ (ascorbate oxidase)

$A + 2\ G\text{-}SH \rightarrow H_2A + G\text{-}S\text{-}S\text{-}G$ (glutathione dehydrogenase)

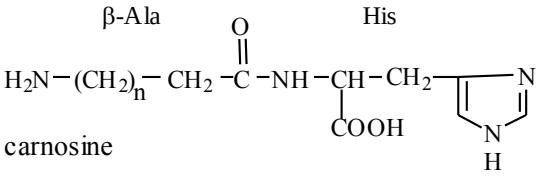
G-S-S-G without influence on rheological properties of dough

G-SH negative influence (depolymerisation of gluten)

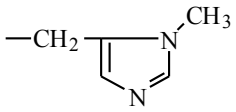
P-S-S-P + G-SH → P-S-S-G + P-SH

**β-alanylhistidine dipeptides**

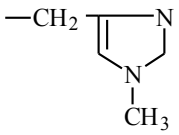
**content in meat** (book 1, table 2.5.)




anserine (n = 1), R =



balenine (n = 1), R =



**function**

- participation on muscle contraction
- buffering capacity of muscle
- sensory properties

**analysis**

- meat origin in meat products

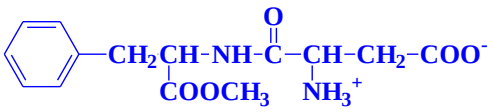
**proteolysis**

- **autolysis**
  desirable meat maturation (consistency, aroma), production of yeast autolyzates (additives)
  undesirable

- **intentional proteolysis**
  cheese production (desirable consistence, aroma)
  malt production (stabilisation of beer foam)
  protein hydrolyzates production
  enzymatic protein hydrolyzates: soya sauce
  acid protein hydrolyzates (hydrolysed vegetable protein)

**bitter peptides of enzymatic hydrolyzates**
hydrophobic amino acids Val, Leu, Ile, Phe, Tyr, Trp (MW < 6000 Da)

**synthetic peptides**
artificial sweetner Aspartam (Asp-Phe-methylester)



**PROTEINS**

polymers of amino acids
> 100 amino acids, $M_r$ ~ 10.000 - milions Da

organized structures
constitution and conformation optimal for their functions

main nutrients
peptide bonds
other bonds
- disulfide -S-S-
- ester
- amide

other compound besides amino acids
- water
- inorganic ions
- lipids, saccharides, nucleic acids, colour compounds (pigments)

**classification according to origin**
- animal (meat, milk eggs, 60% proteins of protein nutrients)
- vegetables (cereals , pulse, fruits, vegetables), 30% proteins of protein nutrients)
- nontraditional (algae, microbs)

**classification according to function**
- structural (components of cells, e.g. collagen)
- catalytic (enzymes, hormones)
- transport (tranport of compounds, e.g. myoglobin)
- motoric (muscle proteins, e.g. actin, myosin)
- defensive (imunoglobulins, lectines)
- storage (ferritin)
- sensory (rhodopsin)
- regulatory (histones, hormones)
- nutritional (source of essential amino acids, source of nitrogen, material for tissues)

**according to structure** (presence of nonprotein components)

simple
- globular spheroproteins(albumins, globulins)
- fibrilar (fibrous), scleroproteins, stromatic proteins (collagens, keratins, elastins)

conjugated
- nucleoproteins (nucleic acids)
- lipoproteins (neutral lipids, phospholipids, sterols)
- glycoproteins (saccharides)
- phosphoproteins (phosphoric acid)
- chromoproteins (porphyrins, flavins)
- methaloproteins (bound metals)

**according to solubility**

soluble

- albumins
  milk: lactalbumin
  egg white: ovoalbumin, conalbumin
  wheat: leucosin
- globulins
  meat: myosin, actin
  milk: laktoglobulin
  egg: ovoglobulin
- gliadins (prolamins)
  wheat: gliadin
  barley: hordein
  corn: zein
- glutelins
  wheat: glutelin
  rice: oryzenin
- protamins
  fish: cyprimin, salmin, clupein, scombrin
- histones
  blood: haemoglobin and myoglobin

insoluble
collagen, elastin, keratin

**according to origin**

- native (natural, they have various biological functions)
- denaturated
- modified (additives)

**according to nutritive value**

- nutritionally balanced (essential amino acids in optimal amount)
  egg and milk
- almost nutritionally balanced (shortage of some essential amino acids)
  muscle proteins of animals
- nutritionally disbalanced (some amino acids in shortage)
  all vegetables from animals connective tissues,

foods with shortage of some essential amino acids

| | |
|---|---|
| Lys | cereals (generally plant proteins) |
| Met | milk, meat |
| Thr | wheat, rye |
| Trp | casein, corn, rice |

**content in foods** (book 1, tables 2.9 and 2.10)

protein (P) content generally 0-100% (in dry matter)
animal proteins > plant proteins
pulses, oilseed plants > fruit, vegetables

| | | | |
|---|---|---|---|
| eggs | 75% $H_2O$<br>13% P (whole)<br>52% P in dry matter | pulses | 12% $H_2O$<br>24% P (soya 32-45 %)<br>27% in dry matter |
| meat (beef) | 69% $H_2O$<br>21% P<br>68% in dry matter | bread | 38% $H_2O$<br>7% P<br>11% in dry matter |
| milk<br>(3.5 % fat) | 87-90% $H_2O$<br>3.4% P<br>28% in dry matter | potatoes | 78% $H_2O$<br>2% P<br>9% in dry matter |

**structure see biochemistry books**

**physiology and nutrition**

coverage of total requirement of energy: ~ 10%
ratio of nutrients:
proteins : lipids : saccharides
mass = 1 : 1 : 4
energy = < 14 : < 14 : <56%
minimum need of nutritionally balanced proteins: 0.5-0.6 $g.kg^{-1}$
advisable need of nutritionally balanced proteins : 1.0-1.2 $g.kg^{-1}$ (not digested optimally)
~2.4 $g.kg^{-1}$ during growth, reconvalescents etc.

**nutrition value (biological)**

- total intake
-
- composition of amino acids (book 1, tables 2.12 a 2. 13)
- availability of peptides bound by digestive enzymes
- other factors

**formerly**

- BV (*Biological Value*, g of P retained by body / 100 g P in food)
- NPU (*Net Protein Utilization*)
- PER (*Protein Efficiency Ratio*) etc.

depends on:
absolute content of essential amino acids
relative relations
nonessential amino acids
digestibility

**today**

AAS (*Amino Acid Score*)
EAAI (*Essential Amino Acid Index*), better results

$$AAS(\%) = \frac{100\ A_i}{A_{si}}$$

$A_i$ = content of essential amino acid in protein
$A_{si}$ = content of the same amino acids in standard (reference) protein

Standard protein = fictional protein, optimal composition of essential amino acids (AAS=100%)

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

**physical-chemical properties**

- solubility, hydratation, swelling
- dissociation
- optical activity
- gel formation
- emulsion formation
- foam stabilisation
- denaturation

  physical factors: temperature, pressure, ultrasound, irradiation

  chemical factors: salts, pH , surface active compounds

  consequences

  better access of digestive enzymes

  denaturation of antinutritive factors, toxic compounds (inhibitors of proteases, amylases, lectins, decomposition of toxic compounds)

  inhibition of undesirable enzymes and microorganisms

**meat, meat products, poultry, fish**

4 main types of tissue (another one is blood)

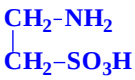
- epithels
- connective tissue
- muscle tissue
- neural

**definition**
parts of warm-blooded animals in natural or processed state

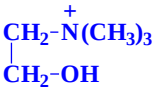
mainly skeletal muscle tissue

components

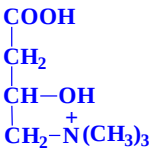
- free amino acids 0.1–0.3%
- vitamins
- taurine (0.02-0.1%)



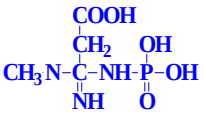
- quaternary ammonium compounds
  choline 0.02-0.06%, phospholipids, transmethylation reactions, acetylcholine, sinapine



  carnitine 0,05-0,2%, transport of fatty acids



- creatine phosphate, creatine, creatinine)



- glycogen
- sugar phosphates and free sugars
- lactic acid and other acids
- purines and pyrimidines

**myofibrillar proteins**
muscle fibrilles
myofibrilles (contractible fibrilles)
microfilaments (microfibrilles)
myosine
actine
other proteins

reactions *in vivo*
reactions post mortem

- ATP by anaerobic glycolysis from glycogen
- lactic acid → decrease of pH from 6.8 to < 5.8

- inhibition of glycolytic enzymes
- $Ca^{2+}$ / reaction of actine with myosine, ATP is missing → (*rigor mortis*)

influence on meat quality
ripening of meat
- splitting of actomyosin by endogenous proteases (mostly cathepsins)
- splitting of collagen (collagenases)

defects of meat
- DFD (*dry-firm-dark*) a DCB (dry-cutting-beef)
  dark, high water holding capacity, low stability, remotion of lactic acid during blooding, pH~ 6
- PSE (*pale-soft-exudative*)
  pale, low water holding capacity, grey-green surface, increased glycolysis stimulated by hormones, pH~ 5.6

changing during processing

| | |
|---|---|
| ~35°C | association of sarcoplasmatic proteins, decrease of water holding capacity, increase of firmness |
| ~45°C | visible changes, shrinkage =denaturation of myosin |
| ~50-55°C | denaturation of actomyosin |
| ~55-65°C | denaturation of sarcoplasmatic proteins, association, gel structure |
| ~60-65°C | changes of collagen conformation (shrinkage by 1/3-1/4) |
| ~80°C | oxidation SH-groups |
| ~90°C | gelatinisation of collagen (loosening of tropocollagenic fibres, sol, gelatine) |
| ~100°C | elimination $NH_3$, $H_2S$, other compounds, aroma formation, changes in colour |

**milk and milk products**

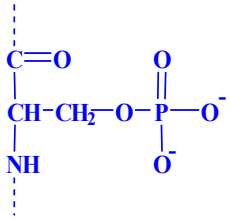
content of nutrients in milk (book 1, table 2.14)

water according to type of milk: 63-88%

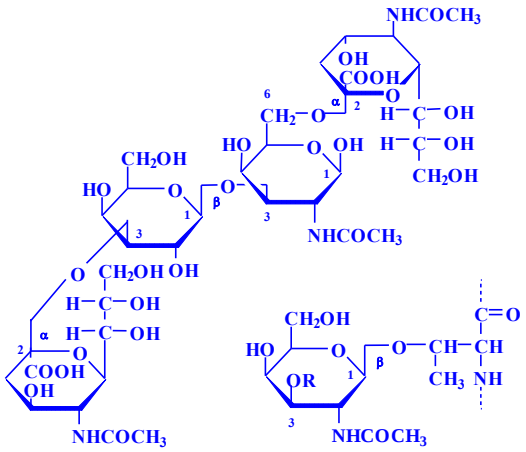
complex disperse system
- globular whey proteins: colloidal disperse
- casein molecules: micellar disperse
- fat: fat globules (microsomes, ϕ 0.1-10 μm): emulsion
- particles of lipoproteins: colloidal suspension
- low molecular weight compounds (lactose, amino acids, minerals, vitamins: solution
- colour

composition of cow milk proteins **(**book 1, table 2.16**)**
content of amino acids in milk **(**book 1, table 2.15**)**

**caseins and whey proteins**
α-caseins = phosphoproteins, $\alpha_{S1}$, $\alpha_{S2}$, phosphoserine



β-caseins = phosphoproteins
γ-caseins = β-caseins degradation products
κ-caseins = glycoproteins (2 genetic variants, B), sugar = tetra-, tri-, di-, mono-, GalNAc, Gal, NeuAc, binding on Thr 133)



main components of κ- caseins

$\alpha_S$-, β-, κ-caseins: aggregation into submicells and micells

**changes during storage and heat processing**

- agglomeration of fat globules in fresh milk, ~ makroglobulin
- whey proteins thermolabile, denaturation, caseins thermostable, practically do not denaturate

pasteurisation

| | |
|---|---|
| 72-74°C (20-40 s): | denatured appr. 50-90% whey proteins<br>most of enzymes are inhibited |
| > 75°C: | reduction of disufide bonds<br>$H_2S$ elimination (β-lactoglobulin)<br>sulfide, disulfide, taste changes (Met)<br>thiamine degradation<br>lactones and methylketones formation |

sterilisation

| | |
|---|---|
| 140°C (4 s) | 100% proteins denatured<br>reaction of lactose with whey proteins, Lys losses (Maillard reaction), aroma compounds, fresh and pasteurised milk ~ 400 aroma compounds (1-100 mg/kg) |

**precipitation and proteolysis of caseins**

| | |
|---|---|
| fresh milk: | pH 6,5-6,75 |
| precipitation of caseins : | pH 4,6 (due to microorganisms) |

hard cheese

- microorganisms (lactic acid), (pH 5,5)
- proteolytic enzyme rennin (chymosin,), specific hydrolysis of κ-casein: *para*-κ-casein = hydrophobic part, component of micells, κ-casein makropeptid = hydrophilic part,
- coagulation (storage→ firmness, whey centrifugation, addition of NaCl, ripening (at Emmental cheese conversion of lactic acid → propionic acid + $CO_2$), proteolysis, lipolysis → hard cheese

soft cheese, youghurt

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

other products

- unsoluble acid casein
- sweet casein (precipitated by enzymes)
- caseinates (soluble:Na, K, $NH_4$; dispersable: Ca, Mg)
- soluble coprecipitates
- whey

**eggs**

white egg protein 53 %, yolk 47 %
content of nutrients in eggs **(**book 1, table 2.17**)**
composition of egg white protein and egg yolk protein **(**book 1, tables 2.18 and 2.19**)**

**white egg poroteins**
~ 40 proteins (globulins, glycoproteins and phosphoproteins)

- enzymes (lysozyme, activity of *N*-acetylmuramides, murein, cell walls of bacteria)
- protein components of enzymes (flavoprotein/riboflavin, avidin/biotin)
- proteases inhibitors (ovomucoid, ovoinhibitor)

consequences

- viscosity and gel consistence of egg white: ovomucoid a ovomucin
- foam stabilisation of whipped egg white: ovoglobulins $G_2$ a $G_3$
- antimicrobial effects: lysozyme (ovoglobulin $G_1$)
- antinutritive effect: avidin

**egg yolk proteins** (emulsion of fat in weater)
1/3 = proteins, 2/3 = lipids
glyko-, lipo-, glycophospho- a glycophospholipoproteins
granules: lipovitellin a fosvitin
plasma: lipovitellenin a livetin

**changes during storage and processing**

- partial denaturation of egg white protein during whipping
- heat denaturation
  57°C: beginning
  60-65°C most of proteins denaturate (ovomucoid does not)
  65-70°C most of yolk proteins denaturate (phosvitin not)

**cereals and pseudocereals**
basic cereals chemical composition (book 1, table 2.21)
cereals proteins and their composition (book 1, tables 2.22 and 2. 23)

wheat protein
flour proteins: 7-13% (to 15%)

- 15% albumins (soluble in water) leukosin
- 7% globulins (0.4 M-NaCl) edestin

- 33% prolamins (70% ethanol) gliadin
- 46 % glutelins (rest) glutenin

ratio: prolamins / glutelins = 2 : 3
strong flour = bread flour (12-14%, dough elastic, firm, essential intensive mixing during preparation, hinder $CO_2$, air, voluminous products)
week flour = crackers production (< 10 %)

dough
gluten = viscoelastic matter, 2/3 water, 1/3 hydrated glutelins (viscosity), gliadins (elasticity), dry matter of gluten = 90 % proteins, 8 % lipids, 2 % sugars

products without gluten
alergenic celiac disease (~ 0,05 % children in Europe)
changes of epithelial gut cells, improper resorption of nutrients, responsible: prolamine fraction of wheat, rye, barley, sequences: Pro-Ser-Gln-Gln and Gln-Gln-Gln-Pro, limits < 100 mg gliadins/kg (dry matter)

rye proteins
- gluten is not present
- backer´s properties: pentosans, some proteins, (swell in acidic medium)
- acid formation due to activity of *S. cerevisiae*, *S. minor*, *L. plantarum*, *L. brevis*

**legumes and oil seeds proteins**

high content of globulins, function during germination
content of amino acids (book 1, tab. 2.24)

**utilisation of nontraditional protein sources**
texturised plant proteins, protein rich products

**Reactions**

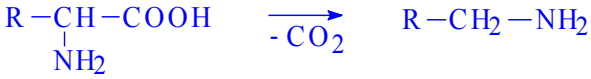
elimination, isomeration, addition, oxidation reaction

influence of food composition, reaction conditions: temperature, pH, $O_2$, other compounds

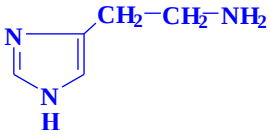
**consequences**

- decrease of nutritive value
  - decomposition of essential amino acids
  - formation of unmetabolised products
  - decrease of digestibility
  - formation of antinutritive and toxic compounds
- formation of flavour compounds
  - mostly Cys, Met, Orn, Pro (amines, aldehydes, alcohols, *S*-compounds)

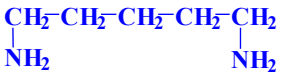
**elimination reactions**
**decarboxylation** (elimination of $CO_2$)



flavour compounds
biologically active compounds (biogenic amines)

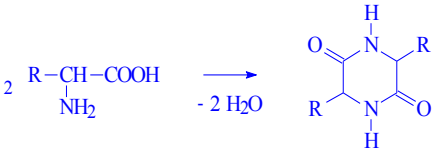


histamine (His)

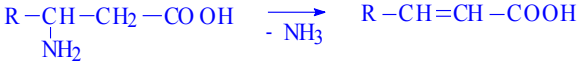


cadaverine (Lys)

**elimination of ammonia and water**
formation of 2,5-dioxopiperazines (cyclic dipeptides)

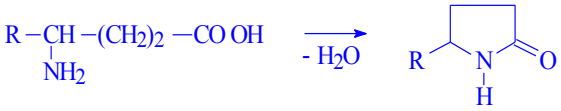


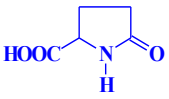
formation of alk-2-enic acids



β-amino acid (Asp)  alk-2-enon acids

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





2-oxopyrrolidin-2-carboxylic acid

creatinine

**elimination of functional groups of side-chains**

- reaction in acid medium or by thermal reaction

- deamidation of proteins, hydrolysis
- reaction in neutral medium or by thermal reaction
  - formation of unusual bounds
- reaction in alkaline medium or by thermal reaction
  - formation of unusual bounds, unusual amino acids, D-amino acids (abiogenic acids)

**consequences**

- decrease of digestibility
- decrease of nutritive value
- formation of potentially toxic amino acids
- formation of flavour compounds

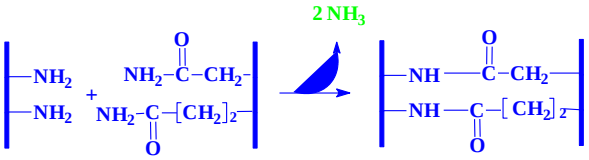
**acid medium**

production of protein hydrolysates

- enzymes autolysis, yeast autolysates, soya souce
- acid protein hydrolysates

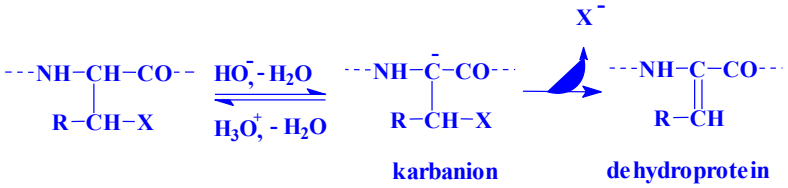
**neutral medium**

formation of cross-binding and unusual amino acids
ε-amino groups of Lys, carboxamide group of Asn, Gln




**alkaline medium**

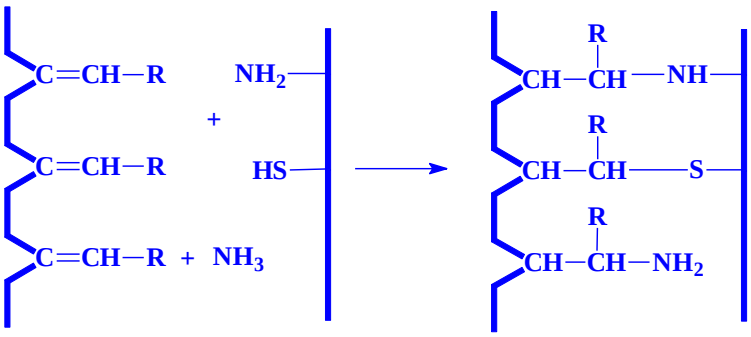
losses of Lys, Cys, Ser, Thr, Arg etc.
1,2-elimination of H-X (from Ser, Thr, Cys, SySSCy) and hydrolysis



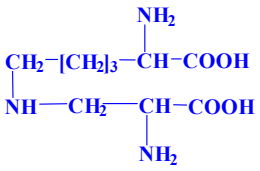

X = OH, SH, SR, SSR etc.

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

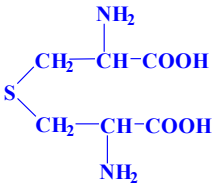

intra- and intermolecular crossbinding



- hydrolysis of cross-linked proteins and formation of unusual amino acids:

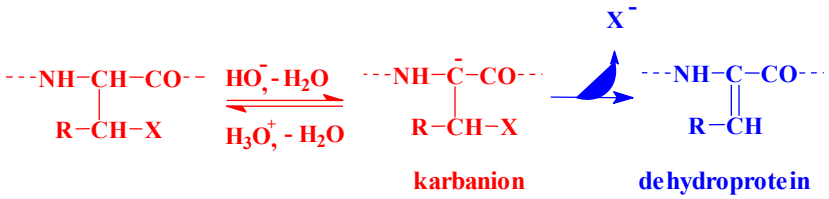


lysinoalanine



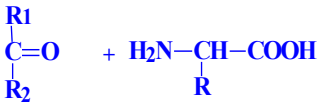
lanthionine

- isomerisation and formation of D-amino acids, decreased utility (book 1, table 2.25)

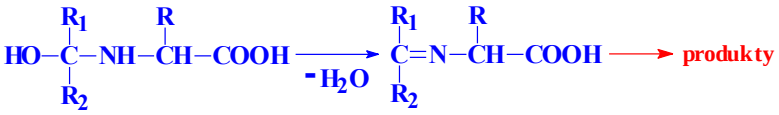


karbanion dehydroprotein

**addition reaction**
reaction with saccharides (aldehydes, ketones), Maillard reaction



saccharide α-amino acid

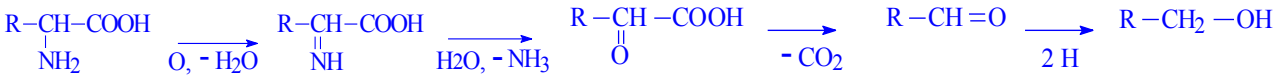


carbinolamine imine (Schiff base)

- coloured products, flavour compounds, biologically active compounds

**oxidation reactions**

**oxidative deamination and transamination**
enzymatic reactions
deaminases or transaminases, hydrolases, decarboxylases, alcoholdehydrogenases

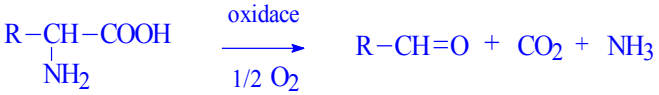


α-amino acid α-imino acid 2-oxo acid aldehyde alcohol

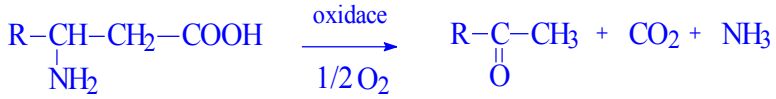
- aldehydes: fruit and vegetable aroma
- alcohols: aroma of alcoholic drinks (fusel oil alcohols)

**Strecker degradation** (oxidative decarboxylation)

Formation of Strecker aldehydes (book 1, table 2.27)
Nonenzymatic reaction



α-amino acid aldehyde (Strecker aldehyd)




β-amino acid methylketone

oxidative agents

- dicarbonyl compounds
- saccharides
- chinones
- inorganic compounds (hypochlorite)

formation of other compounds, *N*- a *S*-heterocyclic compounds

**other oxidation reactions and reactions with food compounds**

- cysteine, cystine, methionine
- reaction of amino acids with oxidised lipids (decrease digestibility or undigestible products)
- reaction of amino acids with oxidised phenols (dark colour of protein isolates, decrease of digestibility or undigestible products)