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Origin of twenty proteinogenic amino acids

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Abstract. "Protein structure alphabet" – that is a name of L-configuration amino acids, which always or frequently occur in protein hydrolysates. Discovery of proteinogenic amino acids was a quite long process and took many years from 1806 to1935.

According to Wicker and Schmidt a presence of amino acids in protein hydrolysate is considered to be established if at least two researchers derived them independently of each other and if its structure is confirmed by synthetic pathway [1]. Even today these requirements are valid in relation to newly discovered amino acids. Each amino acid, except for a name foreseen by the international nomenclature has its trivial (conventional) name, which points either at the source, from which this amino acid was derived first, or notes some of its special characteristics.

The presented work provides chronological review of the history of discovery of twenty proteinogenic amino acids.

Key Words: *Amino acids, Proteinogenic amino acids, Natural materials*

Introduction

Amino acids play an important role in our organism, they normalize and concentrate our attitude (mood), regulate and adjust aggression, attention, sleep mode, as well as sexual activity. Right after entering the organism proteins break down to amino acids, then liberated amino acids are used as proteins and enzymes necessary for organism.

"Protein structure alphabet" – that is a name of L-configuration amino acids, which always or frequently occur in protein hydrolysates. Discovery of proteinogenic amino acids was a quite long process and took many years from 1806 to1935.

According to Wicker and Schmidt a presence of amino acids in protein hydrolysate is considered to be established if at least two researchers derived them independently of each other and if its structure is confirmed by synthetic pathway [1]. Even today these requirements are valid in relation to newly discovered amino acids. Each amino acid, except for a name foreseen by the international nomenclature

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In 1806 French chemists Vauquelin and Robiquet [2] derived the amino acid – asparagine (α-aminosuccinic acid β-amide) from asparagus juice using acid hydrolysisof proteins (proteolysis).

In opinion of Hlasiwetz and Habermann [3], ammoniac, which is contained in acid hydrolysates of protein, is generated from amido groups of asparagine and glutamine.

In 1932, Damodaran et al. derived asparagine from enzymatic hydrolysate of edestin (kind of protein) and ultimately confirmed presence of this amino acid in proteins [4].

L-cystine or β β′-dithiodi(α-aminopropionic acid) was first isolated from urolith (kidney stone) by Wollaston in 1810 [5], and later – by Moerner [6] from keratin (horny) hydrolysate. Cystine is in large quantities in keratin and many other proteins. L-cysteine (α-amino-β-mercaptopropionic acid) enters into composition of proteins, as well, but only cystine – a product of cysteine oxidation is discovered in acid hydrolysatesof proteins. It was established later that large quantities of amino acid tryptophan in proteins lead to cysteine formation during an acidic hydrolysis process, as well [7]. Both cystine and cysteine disintegrate resulting from alkali treatment. Cysteine presence in protein is confirmed by red color formedin mix with nitroprusside. In neutral or alkali solutions, especially in presence of metal ions, cysteine is oxidized to cystine. At the same time, it was discovered that cystine is restored to cysteine by hydrogen evolved as a result of interaction of hydrochloric acid and stannum [8].

In 1903 Erlenmeyer [9, 10]derived cysteine and cystine by a synthesisroute and established the structure of these amino acids.

Cysteine generates carboxylic acid when interacting with formaldehyde. This reaction is not peculiar to cystine, so it is used for cysteine identification [11].

In order to detect cysteine, they use Sullivan highly specific reaction: in highly reducing environment with sodium 1,2-naphthoquinone-4-sulphonate cysteine forms a characteristic red-brown color [12].

L-leucine (α-aminocaproic acid) was derived first from cheese by Prust in 1813 [13]. The same compound was isolated in crystalline form by Braconnot from acid hydrolysates of muscle and wool, and called leucine [14]. Leucine was derived by a synthesisroute from isovaleraldehyde using Strecker reaction and it turned to be similar to racemized natural compound [15].

Glycine (aminoacetic acid) was isolated in 1820 by Braconnot from acid hydrolysate of gelatin [14]. Scientist drew attention to the sweet taste of this compound and called obtained “gelatin sugar” first glycocoll, and then glycine (from Greekglukos – sweet). Later studies made it possible to identify glycine structure, while its synthesis was conducted through interaction of monochloroacetic acid and ammoniac [16, 17].

Glycine is a common amino acid, it is contained inmany proteins, occurs in oxytocin and vasopressin in the form of amide: it is a component part of glutathione, hippuric acid, glycolic acid and other substances. Sarcosine – a product of tissue metabolism in mammals is a methyl-derivative of

glycine. In 1951 was isolated from peanut protein [18], and afterwards – from hydrolysates of some antibiotics.

Taurine is a biologically active substance, which was first isolated from ox gall in 1827 and was named so due to Latin Taurus – bull. Taurine is synthesized in the organism based on methionine and cysteine.

In 1970 its indispensable presence in the form of cat feed component was recognized. In its absence animals experienceddegeneration, which led to blindness, heart diseases. Observations over animals made understand how important is taurine for humans [19], [20].

L-tyrosine (α-amino-β-(p-hydroxyphenyl propionic acid) was isolated in 1846 by Liebig from products of alkaline hydrolysis of casein [21]. In 1848 tyrosine was derived by Rue from cochineal [22], and in 1849 – by Boehm from proteins (albumin, casein, fibrin) [23]. Tyrosine structure was established in 1883 by Erlenmeyer and Lipp. Tyrosine is very hardly soluble in water that simplifies its separation from protein hydrolysate. Tyrosine-O-sulfate is found in fibrinogen and human urine.

In 1850 Strecker derived L-alanine (α-aminopropionic acid) by a synthesis route [24].

His goal was a receipt of lactic acid, for which end he treated the product of acetaldehyde and ammoniac condensation withhydrocyanic acid and hydrochloric acid. Strecker derived lactic acid through crystalline alanine interaction with nitrous acid. He received amino nitrile first, which was transformed into amino acid resulting from hydrolysis. It is possible to produce any amino acid using Strecker reaction, if we use respective aldehyde for reaction.

38 years after Strecker synthesis, Veylisolated alanine from silk protein hydrolysate (silk proteins fibrin and fibroin are especially rich in alanine) [25]. Little later Fischer and Skitaderived alanine from silk and established its structure and configuration through its transition to lactic acid [26].

Valine (α-aminoisovaleric acid) was discovered in 1856 by Gorup-Bezanets in pancreatic gland extract [27,28]. In 1879 Schutzenberger showed that valine is a product of protein (albumin) hydrolysis. Amino acid valine is contained in many proteins, though in relatively small quantities [29].

Valine structure was ultimately established by Fischer in 1906 [30], through identification with one of stereoisomers isolated from amino acid mixture received by a synthesis route.

L-serine (α-amino-β-hydroxy propionic acid) was derived in 1865 by Kremer from silk protein [31]. He noted that according to its structure serine is similar to alanine and cystine and is a hydroxy-amino acid. In 1902 Fischer and Lochs synthesized serine and established its structure [32]. Serine is a common amino acid and is abundant in silk fibroin. Serine occurs in the form of phosphate ester, as well.

L-arginin (α-amino-δ-guanidine valeric acid) was isolated in 1866 by Schultz and Steiger from white (etiolated) sprouts of lupin (Lupinus) [33]. Arginine structure was established through its hydrolysis in alkali environment (resulting from which ornithine and urea were received) [34], as well as from benzoyl ornithine through its synthesis [35]. During acidic hydrolysis of proteins arginine may disintegrate up to ornithine; arginine transformation into citrulline during hydrolysis in alkali medium is reported from literature as well [36]. Arginine is not presented in proteins only, but occurs in free form, too.

L-glutaminic acid (α-aminoglutaric acid) was received by Ritthausen in 1866 from gluten hydrolysate – wheat endosperm [37]. In 1890 Wolf carried out the first chemical synthesis of glutamic acid [38]. Glutaminic acid is one of the most common amino acid. It plays important role in metabolic processes. In the presence of hydrochloric acid glutaminic acid is crystallized in the form of hardly soluble carboxylic acid. Pyrrolidine-α-carboxylic acid (pyrroglutaminic acid, 5-oxo-2-pyrrolidine carboxylic acid) is generated when boiling the aqueous solution of this acid. L-glutaminic acid monosodium salt is used as a spice (flavoring). In 1868 Ritthausen generated asparaginic acid (α-aminosuccinic acid) from protein hydrolysate [39]. Earlier this amino acid was considered as a product of asparagine hydrolysis. Later asparaginic acid was synthesized, too [40]. N-acetyl asparaginic acid is found in cat brain extract at a 100 mg concentration per 100 g of tissue. It is contained in liver, kidney, muscles and urine of rats and cats (1-3 mg per 100 g).

L-phenylalanine (α-amino-β-phenyl propionic acid) was isolated in 1879 by Schultze and Barbieri from white (etiolated) sprouts of lupin (Lupinus) [41]. In 1882 Erlenmeyer and Lipp derived phenylalanine by a synthesis route [42].

Glutamine (α-aminoglutaric acid-γ-amide) was isolated in 1883 by Schultze and Boschard from beetroot juice [43], while Damodaran et al educed it from enzyme hydrolysate ofedestin [44]. Glutamine was synthesized for the first time in 1933 by Bergmann et al. [45]. Glutamine is accumulated in large quantities in some species of higher plants. It is one of the main amino acidic components of mammals' blood. Amido groups are especially labile in glutamine molecule, they easily undergo cyclization and generate pyrrolidine carboxylic acid ammonium salt. Amido groups are relatively stable in peptides, where glutamine γ-amino groups are involved in peptide bonds. Other γ-glutamine derivatives (γ-glutamine peptides, γ-glutaminic acid ethyl ester and homoglutamine) are prone to cyclization. Cyclization process of glutamine and other similar compounds is catalyzed by phosphates and some other anions.

In 1898 Drexler educed amino acid lysine (α, ε-diamino carboxylic acid) from casein hydrolysate [46]. By Drexler's presumption lysine should be a diamine. In 1902 Fischer and Weigert synthesized lysine [47]. Lysine mainly occurs in animal proteins and either is not presented or available in negligible amount in vegetable proteins (zein, gliadin). When treated with protein nitrous acid free ε-amino groups of lysine transform into hydroxylic groups that is a sign that the major part of ε-amino groups entering protein, if not each of them, is in free state.

Histidine (α-amino-β-imidazole propionic acid) was discovered by Kossel in 1896 [48] in acidic hydrolysate of sturin (sturgeon sperm protamine). Pauly established a presence of imidazole ring in histidine molecule and showed that red color is formed during histidine interaction with diazotized sulphanilic acid in alkali medium (Pauly reaction). Histidine molecule structure was ultimately established through its synthesis in 1911 by Pyman[49]. Relatively much histidine is contained in hemoglobin.

L-proline (pyrrolidine-2-carboxylic acid) was generated by a synthesis route in 1900 by Willstätterfrom dibromopropylmalone acid ester [50], while in 1901 Fischer isolated L- and D.L-proline from casein hydrolysate [51]. Proline is an amino acid soluble in alcohol. It forms yellow color

at paper chromatogramm when interacting with ninhydrin and blue color – with isatin. Proline is available in collagen, gelatin and other proteins.

L-tryptophan (α-amino-β^3-indole propionic acid) was isolated in 1901 by Hopkins and Coli from products of casein hydrolysis by pancreatic gland juice [52]. Tryptophan structure was established in 1907 by Ellinger and Flamand [53]. This amino acid occurs in many proteins, though usually in small quantities. Animals' demand for tryptophan is relatively less compared to other amino acids.

L-isoleucine (α-amino-β-methylvaleric acid) was isolated in 1904 by Ehrlich from sugar beet molasse, and little later – from fibrin hydrolysate, which was produced by treatment of pancreatic gland juice, as well as from wheat gluten, egg albumin and meat [54]. On Ehrlich's observations, chemical composition of the separated product was similar to leucin's composition, but isoleucine itself differs from leucin according to several properties (solubility, melting temperature, copper salt dissolubility). Ehrlich was able to decompose L-isoleucine to d-amylamine, as well as to receive isoleucine epimer from d-isovaleraldehyde.

L-carnitine is frequently called vitamin-like substance, since human organism can synthesize itindependently. It was detected in 1905 by Russian scientists: V. Gulevich and R. Krimberg. In 1962, the physiological role of carnitine was established – it provides fatty acids transportation to mitochondria, where their burning and energy release take place [55]. L-carnitine is synthesized in liver and kidney, from where it is transported to other tissues and organs.

L-carnitine – amino acid derived from lysine was named so due to the fact that it was isolated first from meat (carnis).

Methionine (α-amino-γ-mercaptobutyric acid) was discovered in 1922 by Moeller when studying streptococci growth factors [56]. In 1928 Barger and Coyne [57] synthesized methionine using Strecker method. Natural objects contain methionine sulfoxide, which presumably is a product of nonenzymatic oxidation.

Threonine (α-amino-β-hydroxybutyric acid) was derived in 1935 by Rose et al. from acid hydrolysateof fibrin [58]. Researchers set a goal of separating the necessary factor of rat growth from protein hydrolysate. Threonine discovery made it possible to establish for the firsttime that rat growth is possible through their putting on a cleaned amino acid diet, as well. Rose et al derived α-aminobutyric acid through threonine reduction and D-butyric acid – via its oxidation. Threonine was synthesized by Carter [59]. Further, West and Carter divided this amino acid into four stereoisomeres. Similar to serine, threonine is widespread in the form of phosphate ester. Serine and threonine reacts with iodic acid with formation of glyoxalic acid, ammoniac, and respectively, formic or acetic aldehydes. This reaction is usually used for quantification of serine and threonine.

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ოცი ცილოვანი ამინომჟავის წარმოშობის შესახებ

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აბსტრაქტი.

„ცილის სტრუქტურის ანბანი“ - ასე უწოდებენ იმ კონფიგურაციის ამონომჟავებს, რომლებიც ყოველთვის ან ხშირად გვხვდება ცილის ჰიდროლიზატებში. ცილოვანი ამინომჟავების აღმოჩენა, რომელიც საკმაოდ ხანგრძლივი პროცესი იყო, მოიცავს 1806-1935წწ.

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