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Protein C-phycocyanin, structure, physicochemical and biological properties, methods of extraction

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C-phycocyanin (phycocyanin) is a pigment-protein complex of the lightharvesting phycobiliprotein family that takes part in the primary phase of photosynthesis in lower plants. The phycocyanin content depends on such factors as the species of microalgae, physical state of biomass, extraction techniques, *etc.* The main methods for obtaining phycocyanin from biomass include chemical, physical and enzyme treatments with the following purification by such methods as precipitation with ammonium sulfate, ion exchange chromatography, and gel filtration chromatography. The commercial value of phycocyanin is directly related to the methods of its obtaining, purification and purity. The ratio of absorbances A_{620}/A_{280} indicates the grade of phycocyanin and is the principal index of its purity. If the ratio of A_{620}/A_{280} is greater than 4, phycocyanin can be used for pharmaceutical and analytical studies; at not less than 0.7, phycocyanin can be used for the food industry and at not less than 3.9 phycocyanin can be used as a reagent. The purified phycocyanin has some absorption maxima at the wavelengths of 610–625 nm, 353 nm and 277 nm. Its molecular mass ranges from 110 to 220 kDa. The search for extraction methods is aimed at obtaining a high yield of phycocyanin of an appropriate purity in industrial scale. This will allow a wider introduction of phycocyanin into the food,

cosmetics and pharmaceutical industries as a safe product with many positive biological properties, in particular, antioxidant, antitumor, antiplatelet, antibacterial, hypotensive, anti-inflammatory, *etc.*

Keywords: C-phycocyanin, phycobiliproteins, purity

Scientific interest to the study of phycobiliproteins and especially C-phycocyanin (phycocyanin) is steadily growing. From 1909 to 2020, scientists from 86 countries published the papers related to the theoretical issues of the molecular mechanisms of the biosynthesis of phycocyanin, deciphering its structure and properties; the expression of genes responsible for its biosynthesis; the development of methods of its production, purification and use; the aspects of its application in medicine, the food, pharmaceutical, perfumery and cosmetics industries, in modern molecular immunological methods of analysis, *etc.* [1].

Structure and physicochemical properies of C-phycocyanin

Microalgae are a group of photosynthetic microorganisms, which embraces both prokaryotic and eukaryotic forms that convert sunlight, water, and CO_2 to algal biomass [2]. Microalgae are a rich source of proteins, similar to traditional protein sources such as eggs, meat, milk and soybeans [3]. Microalgae can be also a source of minerals, carbohydrates, and other essential nutrients, including omega fatty acids and vitamins (B_1, B_2, B_3, B_6, B_9, B_{12}, C, D and E) [2–5]. Among such microalgae are *Nostoc, Arthrospira*, *Aphanizomenon, Geitlerinema*, *Thermoleptolyngbya* sp., *Thermosynechococcus vulcanus* NIES 2134, *Synechocystis* sp. PCC 6803, *Limnothrix* sp. NS01 [3, 6–9].

Arthrospira platensis dry biomass powder from Mexico contained 60 % of proteins, 28.5 % of carbohydrates, and 2.65 % of fats [3]. The protein content of Spirulina is 50–70 % of dried weight. Spirulina is the general name of filamentous, multicellular, blue-green microalgae that belong to two genera, namely *Spirulina* and *Arthrospira*, which consist of 15 species. *Spirulina platensis* is the most commonly available and widely used species [4]. The high protein content means that algae could be used as food products and animal feed, including aquaculture, farm animals, and pets [3]. Some of them are used in the human diet for thousands of years [3].

Photosynthetic organisms like microalgae, including cyanobacteria, and plants are the main source of pigments [1]. It is worthy that *Cyanobacteria* (cyanoprokaryotes) are an especially challenging group for classification (species, genera, families, orders) as it has undergone extensive restructuring and revision in recent years with the incoming phylogenetic analyses based on molecular sequence data [10].

Lightharvesting complexes are composed of proteins, which bind pigments (chlorophylls, bilins or carotenoids) in specific positions [11, 12]. Photosynthetic pigments in cyanobacteria are divided into two classes: water-soluble proteins, which are named phycobiliproteins, and carotenoids and chlorophyll that are insoluble in water and have

small molecular mass [2, 12]. There are four types of phycobiliproteins. Phycocyanin, allophycocyanin, and phycoerythrin found in phycobilisomes, which are attached to the outer surfaces of thylakoid membrane of cyanobacteria, red algae, and glaucophytes [11–14]. Phycobilisomes are the largest protein complexes in the living world and the major light harvesting complex in cyanobacteria and red algae. Their calculated molecular mass is equal to approximately 16.8 megadaltons. Phycobilisomes demonstrate an efficient energy transfer due to an elegant antenna-like assembly [14]. Phycobilisomes consist of hundreds of seemingly similar chromophores, which are protein bound and assembled in a fashion enabling highly efficient unidirectional energy transfer to reaction centers. In phycobilisomes, the complex is assembled from two large substructures, rods and core. The core contains 2–5 cylinders surrounded by 6–8 rods. One of the most critical steps in the functionality of phycobilisomes is the energy transfer from the rod substructures to the core substructure [11]. Phycobilisomes contain also unpigmented proteins called linker proteins [11, 14].

Allophycocyanin, phycocyanin and phycoerythrin consist of α and β protein subunits and different isomeric linear tetrapyrrole prosthetic groups (bilin chromophores) [14, 15]. These bilin chromophores differ in the arrangement of their double bonds. The bilin groups are attached to the polypeptides through thioether linkages to cysteinyl residues [16].

The specific blue color of cyanobacteria and other crytophytes, red algae is related to phycocyanin pigment [7]. Phycocyanin usually appears dark cobalt blue in the powder form [3, 7, 13]. It has a covalent bond that binds to prosthetic groups, which are the same as billins [1]. Phycocyanin has an apparent molecular mass of 110–220 kDa depending on its form (monomer, dimer, trimer, hexamer, octamer, *etc.*) [5, 6, 8]. The monomers of phycobiliproteins assemble into trimers, hexamers, and further rods or cores, and finally form a complete phycobilisome molecule [9].

Song *et al.* determined the molecular weight of purified phycocyanin. It was 115 kDa, which indicated that phycocyanin was trimer $(\alpha\beta)_3$. The fundamental unit of the trimer consisted of α and β subunits with the mollecular mass of 17 and 21 kDa, respectively [8, 17]. The crystallization of the phycocyanin isolated from a filamentous thermophilic cyanobacterium *Thermoleptolyngbya* sp. O-77 was studied under various crystallization conditions, which resulted in the formation of blue single crystals. The initial screening of X-ray crystallographic analyses established that the single crystals were in the conventional hexameric $(\alpha\beta)_6$ state [18].

The phycocyanin content can reach 60–70 mg/g in cyanobacteria [3]. This content depends on the species of microalgae, physical state of biomass (dry, wet, or frozen weight of cells), extraction technique, *etc.* The phycocyanin yield from *Geitlerinema* sp. TRV57 was 30–45 mg per gram of the wet weight of the cells [7]. The yield of phycocyanin from *Spirulina platensis* was in the range of 0.57 mg/g (sonication) to 43.75 mg (sonication with glass pearls) and depended on the extraction techniques [19]. The extraction of phycocyanin from *Arthrospira platensis* (Mexico) gave a crude phycocyanin content of 0.286 g/g and purity of 0.46 [3].

As for physical properties, phycocyanin absorbs light and emits fluorescence at a wavelength of approximately 650 nm [3]. Phycocyanin is sensitive to heat, pH and undergoes changes when exposed to high temperatures [3, 5]. Phycocyanin is stable in the pH range of 4.5 to 8.0 [5]. The purified phycocyanin has the highest absorption at 610–625 nm [2, 3, 5, 6, 9, 12, 15, 17]. The absorption maximum at a wavelength of 610–625 nm is attributed to the absorption of the chromophore [9]. The visible absorption of phycocyanin can show one more maximum at 652 nm [2, 6]. Hovewer, this maximum can be induced by allophycocyanin. Garcia *et al.* and Venugopal *et al.* confirmed that this maximum can be referred to allophycocyanin [12, 20]. The UV absorption of phycocyanin has two maxima at the wavelenghts of 277 and 353 nm [6]. Allophycocyanin and allophycocyanin B have the maximum absorption at the wavelengths of 650–652 and 671 nm, respectively. Some cyanobacteria contain additionally a red protein named phycoerythrin with the maximum absorption at the wavelength of 560–565 nm [13]. Allophycocyanin has a lighter blue color than phycocyanin [12].

Phycocyanin has structural similarity to bilirubin, which strongly inhibits the NADPH oxidase activity in human cell culture [2, 16]. The chemical structures of phycocyanin and bilirubin are shown in Fig. 1.

Extraction of C-phycocyanin

Currently, specification and standard method for the extraction and purification of the phycocyanin form cyanobacteria are not established due to the significant diversity of the extraction methods. Thus, the development of an effective purification process to get phycocyanin of a high purity and adequate commercial value is of great importance [8]. The phycocyanin manufacture is commercially limited because it depends significantly on the biomass quality, culture conditions and extraction. The extraction methods are considered to be the principal factor for the optimum yield and commercialization of phycobiliproteins. In general, the extraction of phycobiliproteins involves cell rupture for releasing these proteins with a safe solvent in order to use these proteins in the food, cosmetics, or pharmaceutical industries without any toxicity and at a lower cost [3].

Different techniques are reported to extract phycocyanin from the biomass of microalgae (dry, wet, and frozen) [3, 7]. The cell walls of some cyanobacteria are quite resistant [3].

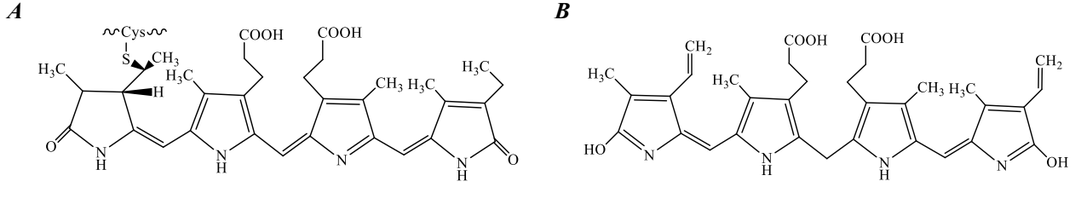

Fig. 1. Comparison of the structures of bilin chromophore of phycocyanin (a) and bilirubin (b) [2, 15, 16, 21]

They consist of four layers: fibrils, peptidoglycans, proteins, and oligosaccharides, similar to Gram-negative bacteria [3]. There are physical, chemical and enzymatic methods of breaking cell walls. Physical methods include homogenization (for instance, in the presence of diatomaceous earth, high pressure homogenization, *etc.*), sonication, ultrasonication, freezing/thawing, microwaving, *etc.* [2, 17]. Chemical methods include the extraction using hydrochloric acid and acetic acid of different concentrations, water, buffer solutions with various values of pH (6, 7), supercritical fluid process, *etc.* The lysozyme treatment refers to enzymatic methods [2, 3, 19]. The combination of above mentioned methods is also used, for example, the combination of the extraction with a buffer solution (pH 7.0) and the lysozyme treatment [22].

The disintegration of cells promotes the phycocyanin release from the cell into the solution [19] and is directly related to the cell rupture. However, *Spirulina* has resistant multilayered cell walls that complicates the extraction procedure [19]. Khandual *et al.* employed several techniques of the phycocyanin extraction. The phycocyanin content was 46.65–54.65 mg/g biomass, 43.13–45.02 mg/g and 35.54–37.88 mg/g, if water, phosphate buffers at pH 7 and 6, respectively, were used [3].

Determination of the concentration and purity of phycocyanin

The concentration of phycocyanin is very important technological index in the processes of its extraction from the biomass of cyanobacteria. To our mind, this index can be used not only for measuring the phycocyanin concentration in crude extracts, but also for the determination of the content of phycocyanin in the powder form.

The phycocyanin concentration and purity are determined by spectrophotometric method as described by Bennet and Bogard in 1973 [3]. The concentration (C−PC) is calculated according to the formula below, using the absorbances at the clue wavelengths of 620 nm and 652 nm [3, 6, 8, 12, 20]:

$$\text{C−PC (mg/mL)} = (\text{Abs}_{620} - 0.474(\text{Abs}_{652}))/5.34$$

Other authors calculated the amount of phycocyanin in the sample, using one more equation of Bennett and Bogorad (1973) [17]:

$$\text{C−PC (mg/mL)} = (\text{Abs}_{620} - 0.7(\text{Abs}_{652}))/7.38$$

For computing the concentrations of allophycocyanin (AlloPC), and phycoerythrin (PE) such formulae are used [20]:

$$\text{C-AlloPC} = (\text{A}_{652} - 0.208(\text{A}_{620}))/5.09$$
$$\text{C-PE} = (\text{A}_{562} - 2.41(\text{C-PC}) - 0.849(\text{alloPC}))/9.62$$

The yield of phycocyanin from the algal biomass can be calculated according to the following formula:

$$\text{Yield (mg/g)} = (\text{C−PC} \times \text{Volume})/\text{Biomass}$$

The last formula can be also used for the calculation of phycocyanin in the powder form:

$$\text{Content (\%)} = (\text{C−PC} \times \text{Volume} \times 100\%)/\text{powder},$$

where V is a used volume for dissolving the powder of phycocyanin, powder is a weight of

phycocyanin in mg. From our experience, it is necessary to select appropriate weight and volume of water for the spectrophotometric evaluation of the phycocyanin content in the obtained powder.

The purity of phycocyanin is usually evaluated, using such a ratio of absorbances as A_{620}/A_{280}. This index is very important for setting up the grade of phycocyanin. Moreover, purity is directly related to process costs. In general, the more purified phycocyanin, the more expensive it is [15]. The absorbance at a wavelenght of 620 nm indicates the phycocyanin content whereas the absorbance at a wavelenght of 280 nm is induced by the presence of proteins in the solution, which are rich in aromatic amino acids [3, 12, 15, 23, 24]. The grades of phycocyanin depending on a ratio of A_{620}/A_{280} are shown in table 1.

Additionally, the absorbances ratio of A_{620}/A_{280} less than 4 indicates the presence of proteins in a phycocyanin sample [12]. Therefore, the purification of phycocyanin is a very important step in the process of its obtaining [5, 20]. It is very often carried out by the precipitation with $(NH_4)_2SO_4$, the following centrifugation and dialysis [7]. Various precipitating agents such as polyethylene glycol, ethanol, acetone, trichloroethane and ammonium sulfate can be used. However, ammonium sulfate due to its low heat of solublization and bacteriostatic effect precipitates readily and prevents the protein denaturation [23]. The direct precipitation with $(NH_4)_2SO_4$ of different concentrations (20 %, 30 %, 40 %, 50 %, 60 %, 70 %) and fractional precipitation (20–65 %, 30–65 %), which was maintained overnight at 4 °C, are used for obtaining the purified phycocyanin. The pellet was formed by centrifugation at 4 °C and dissolved again in water for quantification and purity testing [3]. The saturation with ammonium sulfate dissolved in acetate buffer (4.5, 0.1M) eliminates other basic proteins to a remarkable level with the simultaneous improvement in the purity ratio (A_{620}/A_{280}) as well as separation factor (A_{620}/A_{652}). The presence of phycocyanin, allophycocyanin, other proteins, and nucleic acids corresponds to their maximum absorption at the wavelengths of 620 nm, 652 nm, and 280 nm, respectively [20]. The main role of dialysis is to remove the small molecular weight components from the sample and to increase the ratio of the absorbances A_{620}/A_{278} [5, 20, 24]. Sarada *et al.* pointed out that 50 % (w/v) ammonium sulphate solution precipitated phycocyanin whereas 30 % (w/v) solution precipitated other proteins. The crude phycocyanin fractions obtained were respectively chromatographed on a DE 52 column. The absorbances ratio (A_{620}/A_{280}) was 4.69 [25].

Therefore, one of the most important requirements for obtaining phycobiliproteins of

Table 1. **Grades of phycocyanin depending on a ratio of A_{620}/A_{280}**

№	The absorbance ratio of A_{620}/A_{280}	Type of grade
1	0.7≤	food grade [3, 12, 15, 17, 22]
2	3.9≤	reactive grade [15, 17, 22]
3	4.0<	analytical grade [15, 17], for biochemical studies [20], medical studies [5]

appropriate grade is the selection of a suitable extraction protocol.

Song *et al.* used a combination of the methods for purification, which involved ammonium sulfate precipitation, hydrophobic interaction chromatography, ion exchange chromatography and gel filtration chromatography. As a result, they obtained phycocyanin with a very high purity ratio (A_{620}/A_{280}) of 5.32 [17].

Antioxidant activity of C-phycocyanin

Excessive generation of the oxygen free radicals plays a key role in the destruction of biologically active molecules, such as DNA, proteins, lipids, carbohydrates. Antioxidant molecules are reported to have an ability to lessen the production of reactive oxygen species or at least to halt their progression and, respectively, to delay or inhibit the oxidation process and to mitigate a toxic effect of reactive oxygen species [7, 26]. Exogenous antioxidants are derived from the natural sources like bacteria, algae, plants and beekeeping products [7, 27]. Among exogenous antioxidants, there are carotenoids (beta carotene), phenolic acids (gallic acid, protocatechuic acid, *p*-coumaric acid, ferulic acid, *etc.*), flavonoids (quercetin, kaempferol, catechins, *etc.*), vitamin C and E, *etc.* [2, 7, 27, 28]. In general, antioxidants are the substances protecting cells from the harm induced by the unstable molecules known as free radicals [7, 22, 29]. The oxidative stress is a major source of inflammation [17].

1,1-Diphenyl-2-picrylhydrazyl (DPPH) is often employed as a reagent to evaluate the free radical scavenging activity of antioxidants and their mixtures, including herbal preparations and beekeeping products [22, 27, 29, 30]. DPPH is a stable free radical, which accepts an electron or hydrogen radical from an antioxidant to become a stable diamagnetic molecule, nonradical form DPPH-H. In the hydrogen atom transfer mechanism, the free radical DPPH takes one hydrogen atom of an antioxidant, and the antioxidant itself becomes a radical. This reduction is visualized by the colour change of reaction mixtures from purple to light purple or even yellow, depending on the concentration of DPPH and antioxidants, and colour of reaction mixtures. These changes in colour are determined by a decrease in the absorbance at a wavelength of 514–517 nm [22, 27, 28]. According to our unpublished data, the absorption maximum of DPPH in 50 % aqueous solution of ethanol was observed at a wavelength of 525–526 nm. This

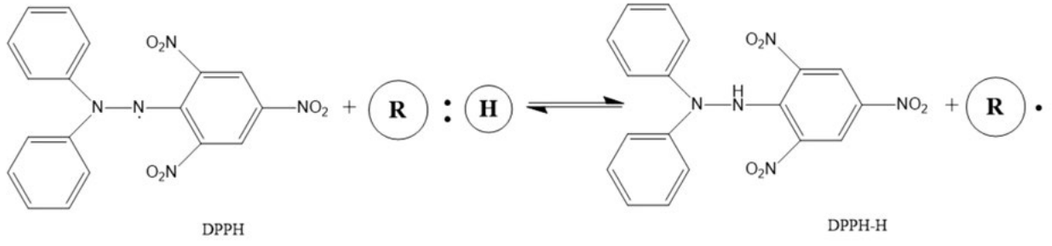

Fig. 2. The mechanism of interaction of DPPH with an antioxidant (R:H — antioxidant radical scavenger; *R* — antioxidant radical) [28].

peak is due to the resonance of the radical [29]. The mechanism of interaction of DPPH with an antioxidant is presented in Fig. 2.

The percentage scavenging effect of phycocyanin extracted from marine filamentous cyanobacteria *Geitlerinema* sp TRV57 in the concentrations 5 μg/mL and 200 μg/mL was 68.75 % and 78.75 %, respectively [7]. Phycocyanin extracted from *Oscillatoria minima* in the concentration of 1mg/ml showed 44 % of DPPH radical scavenging activity [20]. Phycocyanin from *S. platensis* had high antioxidant activity *in vitro* [22].

The results of the DPPH assay depend on the ratio of DPPH radical to the antioxidant [27, 29]. Therefore, it is impossible to compare the results of different authors if they use various ratios of a DPPH solution to phycocyanin and, what is more important, without a positive control. However, it can be declared that phycocyanin has an antioxidant potential.

Phycocyanin attracts an attention of the researchers in different fields due to its nutritional and medicinal properties and the role of colorant in the food and medicinal products [3, 12]. Phycocyanin pigment, as a bioactive component of phycobiliprotein complexes, possesses antioxidant [26], anticancer [8, 15, 31, 32], antiplatelet [23, 33], antibacterial [25, 34], antihypertensive [35], anti-inflamation [36] activities.

Biological activity of C-phycocyanin

It seems that phycocyanin causes apoptosis in cancer cells due to impaired mitochondrial function, reducing the expression of anti-apoptotic proteins such as Bcl2 and Stat3, as well as the ratio of glutathione to its oxidized form, and increasing the expression of pro-apoptotic proteins [8], downregulating the NF-kB pathway [31]. Phycocyanin suppressed the *in vitro* proliferation and induced apoptosis in non-small cell lung cancer cell lines because of the inactivation of the NF-kB pathway [31]. Aditionally, phycocyanin induces the tumor cell cycle G0/G1 arrest, promotes the tumor cell apoptosis through the cell membrane surface death receptor (exogenous) pathway, inhibits the COX-2 expression and tumor cell metastasis, down-regulates the extracellular signal-regulated kinase signaling pathways and up-regulates the JNK and p38 mitogen activated protein kinase signaling pathways to induce the tumor cell death [32]. Therefore, phycocyanin could be regarded as a potential drug candidate for the further nonclinical and clinical studies in the cancer treatment.

Arsenic-induced oxidative stress in the rats was attenuated by phycocyanin. The elevated liver enzyme levels AST and ALT reduced. The increased serum AST and ALT levels are the markers of liver dysfunction [37].

Phycocyanin is an inhibitor of platelet aggregation that may be associated with such mechanisms as the inhibition of thromboxane A2 formation, intracellular calcium mobilization and platelet surface glycoprotein IIb/IIIa expression, increasing cyclic AMP formation and platelet membrane fluidity [33].

The long-term administration of phycocyanin can reduce systemic blood pressure by enhancing eNOS expression in aorta that is stimulated by adiponectin. Therefore, phycocyanin may be beneficial for preventing endothelial the dysfunction-related diseases in metabolic syndrome [35].

Phycocyanin significantly reduced Kupffer cell phagocytosis and the associated respiratory burst activity, while the latter effect may contribute to the suppression of the oxidative stress-induced tumor necrosis factor-*a* (TNF-*a)* response and NO production by hyperthyroid state. Moreover, the thyroid hormone treatment increased the levels of TNF-*a* in the serum by 82 times over control values. This effect was suppressed when the rats were pretreated with either C-phycocyanin, *a*-tocopherol, or $GdCl_3$. Thus, such activity of phycocyanin supports its anti-inflammatory potential [36] .

Phycocyanin inhibited the growth of drug resistant bacteria *Escherichia coli*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa* and *Staphylococcus aureus* [25].

Conclusion

Phycocyanin is a blue colored phycobiliprotein pigment, which is present in plentiful amounts in cyanobacteria. Its content depends on the species of cyanobacterium, and extraction techniques. The basic unit of phycocyanin consists of α and β subunits with the mollecular mass of 17 and 21 kDa, respectively. The concentration and purity of phycocyanin are very important technological and commercial quality indexes. The ratio of absorbances A_{620}/A_{280} indicates the grade of phycocyanin. If the ratio of absorbances A_{620}/A_{280} is more than 4, phycocyanin is considered to be highly pure as pharmaceutical and analytical agents. The purity of not less than 0.7 and 3.9 is considered as a food grade and reactive one, respectively. The review reveals that the phycocyanin pigment possesses numerous biological properties and it can be used as a promising pharmaceutical and nutraceutical active substance. Among biological activities are antibacterial, anti-inflamation, antihypertensive, and anticancer ones.

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Білок С-фікоціанін, його структура, фізико-хімічні та біологічні властивості, методи екстрагування

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С-фікоціанін (фікоціанін) — це пігментно-білковий комплекс із сімейства фікобіліпротеїнів, який бере участь у первинній стадії фотосинтезу нижчих рослин. Уміст фікоціаніну залежить від багатьох чинників, серед яких особливе значення мають вид мікроводоростей, фізичний стан біомаси і методи екстракції. До основних способів одержання фікоціаніну з біомаси відносять хімічну, фізичну і ферментативну обробки, наступне очищення методами осадження, іонообмінної хроматографії і гель-фільтраційної хроматографії. Комерційна цінність фікоціаніну пов'язана з вибором методів отримання й очищення та ступенем його чистоти, яку контролюють за співвідношенням оптичного поглинання за довжин хвиль 620 і 280 нм. Якщо значення співвідношення більше ≥4, фікоціанін вважають високочистим і використовують в аналітичних і фармацевтичних дослідженнях; якщо не нижче 0,7 — для використання у харчових продуктах; не нижче 3,9 — використовують як хімічний реагент. У спектрі поглинання очищеного фікоціаніна є максимуми поглинання за довжин хвиль 610–625 нм, 353 нм і 277 нм. Молекулярна маса є в діапазоні від 110 до 220 кDa. Пошук методів екстракції спрямовано на одержання високого виходу фікоціаніну відповідної чистоти. Це сприятиме ширшому впровадженню цієї біологічно активної сполуки, що володіє антиоксидантними, протипухлинними, антиагрегантними, антибактеріальними, гіпотензивними, протизапальними властивостями в харчову і фармацевичну промисловості.

Ключові слова: С-фікоціанін, фікобіліпротеїни, чистота

Белок С-фикоцианин, его структура, физико-химические и биологические свойства, методы экстракции

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С-фикоцианин (фикоцианин) — пигмент-белковый комплекс из семейства фикобилипротеинов, участвующий в первичной стадии фотосинтеза у низших растений. Содержание фикоцианина в биомассе зависит от вида водорослей, физического состояния биомассы и методов экстракции. Основные способы извлечения фикоцианина из биомассы включают химическую, физическую или ферментативную обработку с последующей очисткой методами осаждения, ионообменной хроматографии, гель-фильтрационной хроматографии. Коммерческая ценность фикоцианина напрямую связана с выбором методов получения и очистки и степенью его чистоты, которую контролируют по соотношению оптического поглощения при длинах волн 620 и 280 нм. Фикоцианин считается высокочистым и используется в аналитических и фармацевтических исследованиях, если значение соотношения больше 4; если не ниже 0,7 — в пищевых продуктах; не ниже 3,9 — в качестве реагента. В спектре поглощения очищенного фикоцианина есть максимумы поглощения при длинах волн 610–625 нм, 353 нм и 277 нм. Молекулярный вес находится в диапазоне от 110 до 220 кDa. Поиск методов экстракции направлен на получение высоких выходов фикоцианина определенной чистоты в промышленных масштабах. Это даст возможность более шире внедрить эту биологически активную субстанцию, обладающую антиоксидантными, противоопухолевыми, антибактериальными, гипотензивными и противовоспалительными свойствами в пищевую и фармацевтическую промышленность.

Ключевые слова: С-фикоцианин, фикобилипротеины, чистота

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