The Absorption and Fluorescence Spectra of the Cyanobacterial Phycobionts of Cryptoendolithic Lichens in the High-Polar Regions of Antarctica

L. G. Erokhina, A. V. Shatilovich, O. P. Kaminskaya, and D. A. Gilichinskii

Institute of Fundamental Problems of Biology, Russian Academy of Sciences,
Pushchino, Moscow oblast, 142290 Russia

Institute of Physicochemical and Biological Problems of Soil Science, Russian Academy of Sciences,
Pushchino, Moscow oblast, 142290 Russia

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Abstract—The algologically pure cultures of the green–brown cyanobacterium Chroococcidiopsis sp. and three cyanobacteria of the genus Gloeocapsa, the blue–green Gloeocapsa sp.1, the brown Gloeocapsa sp.2, and the red–orange Gloeocapsa sp.3, were isolated from sandstones and rock fissures in the high-polar regions of Antarctica. These cyanobacteria are the most widespread phycobionts of cryptoendolithic lichens in these regions. The comparative analysis of the absorption and the second-derivative absorption spectra of the cyanobacteria revealed considerable differences in the content of chlorophyll a and in the content of composition of carotenoids and phycobiliproteins. In addition to phycocyanin, allophycocyanin, and allophycocyanin B, which were present in all of the cyanobacteria studied, Gloeocapsa sp. also contained phycocerythrocyanin and Gloeocapsa sp.3 phycocerythrin and C-phycocerythrin (the latter pigment is typical of nitrogen-fixing cyanobacteria). The fluorescence spectra of Gloeocapsa sp.3 and Gloeocapsa sp.1 considerably differed from the fluorescence spectra of the other cyanobacteria as well. The data obtained suggest that various zones of the lichens may be dominated either by phototroph or photoautotrophic cyanobacterial phycobionts, which differ in the content and composition of photosynthetic pigments.

Key words: high-latitude regions of Antarctica, cyanobacterial phycobionts of cryptoendolithic lichens, pigments, absorption spectra, second-derivative absorption spectra, low-temperature fluorescence spectra.

The aim of the present work was to isolate cyanobacterial phycobionts from the cryptoendolithic lichens of the high-polar regions of Antarctica and to study the content and composition of photosynthetic pigments in these cyanobacteria based on their absorption spectra, second-derivative absorption spectra, and low-temperature fluorescence spectra.

MATERIALS AND METHODS

Rock samples with distinct algal zones of lichens, violet–green in color, were collected from the Beacon permafrost sandstones and from rock fissures in the high-polar regions of Antarctica. The samples were ground aseptically and placed in petri dishes with mineral BG-11 medium [2]. The dishes were incubated for 60 days either at 8°C under illumination with the white light from luminous lamps at an intensity of 400–600 lx or at 20°C under 15 000 lx illumination. The cyanobacterial cells and colonies grown under these conditions did not differ in size and color, although the number of colonies was greater in the second case. Some sandstone samples gave rise to green, brown, and red–orange cyanobacterial colonies, which might rep-
resent different species of the genus Gloeocapsa [1, 3]. These cyanobacteria were designated Gloeocapsa sp.1, Gloeocapsa sp.2, and Gloeocapsa sp.3, respectively. Some samples from rock fissures gave rise to green–brown colonies of the cyanobacterium Chroococcidiopsis sp. To obtain cyanobacteria in algologically pure cultures, colonies grown in enrichment cultures were transferred to the liquid BG-11 medium and incubated at 20°C at 15 000-lx illumination in an atmosphere containing 2% CO₂ for 30 days. The laboratory cyanobacterial cultures Gloeocapsa alpicola CALU 743 and Chroococcidiopsis thermalis CALU 758 grown under the same conditions were also investigated for the sake of comparison.

The low-temperature fluorescence spectra of cyanobacteria were recorded at the liquid nitrogen temperature (~196°C) using a Hitachi 850 spectrophotometer (Japan). The optical density of the samples in this case did not exceed 0.1–0.2 optical units.

The absorption and the second-derivative absorption spectra of cyanobacteria were recorded at room temperature using a Shimadzu UV-1601 PC spectrophotometer (Japan). For this purpose, cell suspensions were dried in a flow of compressed air to give films about 0.5 mm in thickness. The content of chlorophyll a was estimated from the ratio of cell absorbance at 680 nm (the maximum of the major absorption peak of chlorophyll a) to cell absorbance at 730 nm. The relative content of the other photosynthetic pigments in cyanobacterial cells was estimated with reference to the content of chlorophyll a [4]. All the spectra were recorded in triplicate. Since the difference between such spectra did not exceed 10%, the figures show typical spectra.

RESULTS

Figure 1 shows the absorption spectra of the new isolates Gloeocapsa sp.1, Gloeocapsa sp.2, Gloeocapsa sp.3, and Chroococcidiopsis sp. and the laboratory cyanobacterial cultures Gl. alpicola CALU 743 and Chr. thermalis CALU 758. According to the spectral data available in the literature [5], the absorption peaks at 680 and 620 nm belong to chlorophyll a and phycocyanin, respectively. Absorption in the region 450–500 nm was due to carotenoids. The broad band at 400–440 nm, which resulted from the overlapping of two peaks of chlorophyll a (at 418 and 438 nm), was observed only in the spectra of Gl. alpicola and Chr. thermalis.

The content of chlorophyll a, estimated from the height of the peak at 680 nm, was minimal in Gloeocapsa sp.3 and Chroococcidiopsis sp. cells and maximal in Gloeocapsa sp.1 and Gloeocapsa sp.2 cells (Fig. 1). In the two latter species, the content of chlorophyll a was comparable with that of Gl. alpicola and Chr. thermalis. The isolates also differed in the relative content of carotenoids. Namely, the ratio of absorbance at 490 nm, which is due to the total carotenoids, to the absorbance of chlorophyll a was more complex. The second-derivative absorption spectra of the cyanobacterial cultures showed distinct peaks of chlorophyll a at 415–420 and 430–438 nm in the blue spectral region and at 681–682 and 715–720 nm in the red spectral region (Fig. 2 and the table), which agrees with the data of Bekasova et al. [5]. The situation with carotenoids was more complex. The second-derivative absorption spectra of Gl. alpicola, Chr. thermalis, Gloeocapsa sp.1, and Chroococcidiopsis sp. exhibited two peaks of carotenoids, at 488 and 515–525 nm. The respective spectrum of Gloeocapsa sp.1 had six peaks, at 460, 488, 500, 525, 532, and 540 nm. The heights of the major peaks (at 488 and 525 nm) of this cyanobacterium were comparable with those of the cyanobacteria Gloeocapsa sp.1, Chroococcidiopsis sp., Gl. alpicola, and Chr. thermalis. The second-derivative spectrum of Gloeocapsa sp.3 had seven peaks, at 444, 450, 488, 500 (shoulder), 515, 522, and 530 nm. The height of the peak at 488 nm of this cyanobacterium was twofold