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MICROSCOPIC FUNGI OF LITHOBIONT COMMUNITIES OF ARGENTINE ISLANDS REGION: DATA FROM THE 22ND UKRAINIAN ANTARCTIC EXPEDITION

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The identification of the diversity of microscopic fungi of lithobiont communities of the Argentine Islands in specimens collected during the 22nd Ukrainian Antarctic Expedition was the purpose of this work. Samples of rock, soil, mosses and lichens of rock micro-habitats of "Crustose lichen sub-formation and fruticose lichen and moss cushion sub-formation" were used in the work. These samples were used for extracting and cultivation of filamentous fungi on dense nutrient media. Determination of physiological and biochemical characteristics and identification of yeast-like fungi were performed using a microbiological analyser 'Vitek-2' ('Bio Merieux', France). Cultivation of microorganisms was carried out at temperatures from +2 to +37 °C. In results cultures of microscopic fungi of Zygomycota (*Mucor circinelloides*), Ascomycota (species of the genera cf. *Thelebolus*, *Talaromyces*), representatives of the Anamorphic fungi group (*Geomyces pannorum,* species of the genera *Alternaria*, *Acremonium*, *Aspergillus*, *Penicillium*, and *Cladosporium*) were isolated from Antarctic samples. Microscopic fungi *Penicillium* spp. were dominated after the frequency in the studied samples (54.5%). *Rhodotorula rubra* and *Candida* sp. among isolated yeast fungi, and dark pigmented fungi represented by *Aureobasidium pullulans* and *Exophiala* spp. were identified. The biological properties of a number of isolated fungi (the potential ability to synthesise important biologically active substances: melanins, carotenoids, lipids) are characterised. Mycobiota of rock communities of Argentine Islands is rich on filamentous and yeast fungi similarly to other regions of Antarctica. A number of fungi investigated are potentially able to synthesise biologically active substances. The dark pigmented species of the genera *Cladosporium*, *Exophiala*, *Aureobasidium pullulans*, capable of melanin synthesis; 'red' yeast *Rhodotorula rubra* (carotenoid producers and resistant to toxic metals); *Mucor circinelloides* and *Geomyces pannorum*, lipid producers, are among these fungi. Yeast-like fungi assimilated a wide range of carbohydrates, which will allow them to be further used for cultivation in laboratory and process conditions. The collection of technologically promising strains of microorganisms, part of the Culture Collection of Fungi at Taras Shevchenko National University of Kyiv (Ukraine), is updated with isolated species (strains) of filamentous fungi and yeast – potential producers of biologically active substances, obtained within this study.

Key words: Argentine Islands, lithobiont communities, microscopic fungi, species diversity

INTRODUCTION

The organisms exhibit various adaptive mechanisms under the conditions of action of various extreme environmental factors (high or low temperature, pH, ultraviolet radiation, humidity, salts, metals, etc.). For example, their metabolic processes are directed towards the synthesis and accumulation of individual metabolites. An active strategy for the adaptation of microorganisms allows them to evolve under such conditions, in particular through their ability to potently produce important biologically active compounds (BAC) (Cary *et al.* 2010).

Finding out the biological characteristics of microorganisms in extreme habitats, including Antarctica, finding biologically active compound producers among them, harnessing the potential of microorganisms in obtaining BAC for biotechnology, medicine, pharmaceuticals, agriculture, etc. is a priority area of research in many countries (Buzzini and Margesin 2014, Deming 2009, Dimitrova *et al.* 2013). Fungi, in particular yeasts and filamentous fungi, are now regarded as sources for the production of biologically active compounds, which can be used as adaptogens, immunostimulants, anticarcinogens, etc. (Dembitsky 2015, El-Gendy and Rateb 2015).

Numerous studies have shown that Antarctic microscopic fungi are potential sources of metabolites with antimicrobial and antifungal activity. The latter may be objects of the pharmaceutical industry. Henríquez *et al.* (2014) found that metabolites of filamentous fungi of Antarctica are capable of exhibiting antimicrobial, antitumor, antioxidant activity. Swedish researchers S. K. Svahn with colleagues (Svahn *et al.* 2015) characterised an antifungal metabolite, amphotericin, produced by the Antarctic filamentous fungus *Penicillium nalgiovense* Laxa.

Yeast-like fungi, adapted to low ambient temperatures, have enormous biotechnological potential and can be used as a source of cold-active enzymes and biopolymers. This provides benefits for the use of these biologically active compounds in food microbiology, bioremediation and biocontrol processes. Antarctic yeast *Candida antarctica* is recognised as one of the most useful microorganisms for the effective method of synthesis of indolysin, derivatives of which are used as anti-cancer, anti-tuberculosis, analgesic, antioxidant agents, etc. (Dinica *et al.* 2013, Ferreira *et al.* 2012). The usage of Antarctic microorganisms or isolated enzymes allows them to develop environmentally friendly biotechnologies, an alternative to known chemical processes. The practical use of cold-adapted microorganisms may constitute a separate progressive direction in terms of energy savings.

Antarctic microorganisms are capable of synthesis and accumulation of lipids, since in the composition of lipid inclusions, a large proportion is unsaturated fatty acids. The latter is a consequence of low ambient temperatures. It is the lability of the ratio of saturated and unsaturated fatty acids that underlies the phase transitions in the cell membrane. It favours the use of Antarctic species of microorganisms in biotechnology (Robinson 2001). The ability of microorganisms not only to synthesise but also to accumulate lipids indicates the economic feasibility of using such technologies.

A separate aspect of the problem of finding microorganisms producing biologically active compounds is their ability to synthesise and accumulate various pigments, in particular melanin. It is known that melanin has a broad spectrum of biological effects: antioxidant, cytoprotective, photo- and radioprotective. Melanin can be used as sorbent of a number of radionuclides and heavy metals (Eisenman and Casadevall 2012). A significant number of new species of dark pigmented microscopic fungi and yeasts is described from extreme habitats (Boo *et al.* 2013, Turchetti *et al.* 2013).

Therefore, the development of biotechnology, which is based on the use of the potential of microorganisms in the production of BAC, is as one of the strategic directions of modern world science. It is relevant to search for producer organisms (bioprospecting), in particular in the extreme conditions of our planet, such as Antarctica.

Antarctic microbiota studies are also of great ecological importance, as the terrestrial ecosystems' mycocomponents remain poorly explored, and some regions of the Antarctic are generally unexplored. This is relevant for the Argentine Islands area, located in the central part of maritime Antarctic. At the same time, the microscopic fungi that can be a significant component of the diversity of open rock wall communities, such as "Crustose lichen subformation, fruticose lichen and moss cushion sub-formation", namely "Bryophyte and lichen assemblages of rock micro-habitats" (Parnikoza *et al.* 2018). The above characteristic of biological activity of microscopic fungi of the region also allows to understand the adaptation mechanisms of mycobiota in extreme conditions of the region.

The identification of the diversity of microscopic fungi of lithobiont communities of the Argentine Islands in specimens collected during the 22nd Ukrainian Antarctic Expedition (UAE) was the main aim of this work.

MATERIALS AND METHODS

Samples of rock, soil, mosses and lichens obtained during the 22nd Ukrainian Antarctic Expedition 2017/18 from lithobiont communities of the Argentine Islands region, namely islands: Irizar, Copepoda Island (Roca Is), Pitermann, Skua, Galindez, Winter (Table 1, Figs 1–3), affected by rigid physical and chemical factors (low temperature and humidity, ultraviolet radiation, etc.), were used as the material for this research.

Table 1
Characteristics of collection points for micromycetes of lithobiont communities in the Argentine Islands. No = sample number.

No	Sampling location, coordinates, sampling time	Sample and lithobiont community characteristics
1	Irizar Island, S 64.197222°, W 64.197222°, 26.02.2018	*Umbilicaria* sp. and black crustose lichens on rock wall; Crustose lichen sub-formation and fruticose lichen and moss cushion sub-formation
2	Irizar Island, S 64.197222°, W 64.197222°	*Umbilicaria* sp., together with brown crust *Protoparmelia* sp., and *Lecanora* sp. on rock wall; Crustose lichen sub-formation and fruticose lichen and moss cushion sub-formation
3	Roca Is, Copepoda Island, S 65.178889°, W 64.491667°, 01.02.2018	*Dermatocarpon* aff. *polyphyllizum* and other crustose lichens on rock wall; Crustose lichen sub-formation
4	Roca Is, Copepoda Island, S 65.178889°, W 64.491667°, 01.02.2018	*Dermatocarpon* aff. *polyphyllizum* and other crustose lichens on rock wall; Crustose lichen sub-formation
5	Skua Island, Finger Point, S 65.254722°, W 64.273333°, 20.02.2018	*Umbilicaria* sp. growing together with dark crustose lichens on rock wall; Crustose lichen sub-formation and fruticose lichen and moss cushion sub-formation
6	Pitermann Island, South Part, S 65.176389°, W 64.138889°, 25.02.2018	Dark crustose lichens on rock wall; Crustose lichen sub-formation
7	Pitermann Island, South Part, S 65.176389°, W 64.138889°, 25.02.2018	Brown crustose *Protoparmelia* sp. and other crustose lichens on rock wall; Crustose lichen sub-formation
8	Galindez Island, Govorucha dome slope, rock wall, S 65.248170°, W 64.245029°, 08.04.2018	*Umbilicaria* sp., *Pseudophebe* sp. and crustose lichens *Huea* aff. *grisea*, *Caloplaca* sp., on rock wall; Crustose lichen sub-formation
9	Galindez Island, Govorucha dome slope, rock wall, S 65.248170°, W 64.245029°, 08.04.2018	Dark crustose lichens, *Pseudophebe* sp. on rock wall; Crustose lichen sub-formation and fruticose lichen and moss cushion sub-formation
10	Galindez Island, Govorucha dome slope, rock wall, S 65.248170°, W 64.245029°, 08.04.2018	*Huea* aff. *grisea* and other crustose lichens, *Pseudophebe* sp. on rock wall; Crustose lichen sub-formation and fruticose lichen and moss cushion sub-formation
11	Galindez Island, Govorucha dome slope, rock wall, S 65.248170°, W 64.245029°, 08.04.2018	*Andreaea regularis* and crustose lichens on rock wall; Crustose lichen sub-formation and fruticose lichen and moss cushion sub-formation

Table 1 (continued)

No	Sampling location, coordinates, sampling time	Sample and lithobiont community characteristics
12	Winter Island, base of old flagstock, S 65.25116°, W 64.25469°, 07.04.2018	Crustose lichens *Huea* aff. *grisea*, *Candelariella* and others, as well as *Usnea antarctica*; Crustose lichen sub-formation and fruticose lichen and moss cushion sub-formation
13	Winter Island, rock near Wordie House, S 65.25109°, W 64.25487°, 07.04.2018	Dark crustose lichens; Crustose lichen sub-formation
14	Galindez Island, Karpaty Ridge, S 65.24607°, W 64.24998°, 08.04.2018	*Schistidium antarctici* and *Ceratodon purpureus*; Fruticose lichen and moss cushion sub-formation
15	Galindez Island, Karpaty Ridge, S 65.24607°, W 64.24998°, 08.04.2018	*Usnea antarctica*; Fruticose lichen and moss cushion sub-formation
16	Galindez Island, Karpaty Ridge, S 65.24607°, W 64.24998°, 08.04.2018	*Polytrichum strictum*; Moss turf sub-formation
17	Galindez Island, Karpaty Ridge, S 65.24607°, W 64.24998°, 08.04.2018	*Umbilicaria* sp.; Fruticose lichen and moss cushion sub-formation
18	Galindez Island, Karpaty Ridge, S 65.24607°, W 64.24998°, 08.04.2018	*Lepraria* sp., *Cladonia* sp. and black crustose lichens on rock wall; Crustose lichen sub-formation
19	Galindez Island, Govorucha dome slope, S 6524823°, W 6424467°, 08.04.2018	*Umbilicaria* sp. and dark crustose lichens (*Trapeliopsis* sp.) on rock wall; Crustose lichen sub-formation
20	Galindez Island, Govorucha dome slope, S 65.24823°, W 64.24467°, 08.04.2018	*Cladonia* sp., crustose lichens *Ochrolechia* sp., *Trapeliopsis* sp. and moss on rock wall; Crustose lichen sub-formation
21	Galindez Island, rock near end of Cemetery Ridge, S 65.246839°, W 64.248966°, 08.04.2018	Fruticose lichen *Usnea antarctica* and some other lichens; Fruticose lichen and moss cushion sub-formation
22	Galindez Island, rock near end of Cemetery Ridge, S 65.246839°, W 64.248966°, 08.04.2018	Black crustose lichens on rock wall; Crustose lichen sub-formation

Lithobiont micromycetes from rock, soil, moss and lichen samples were the object of this study.

The isolation of pure cultures of microscopic fungi from the Antarctic specimens was carried out using standard mycological methods of cultivation on agar nutrient media: Malt extract agar (MEA, Merck KGaA, Germany),

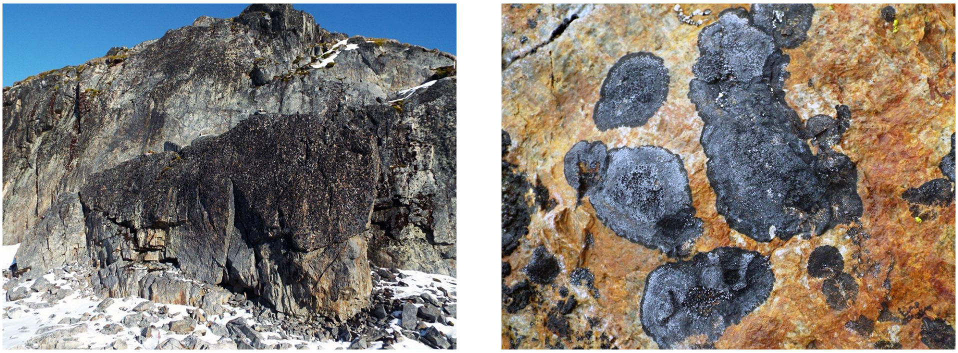

Fig. 1. Crustose lichen sub-formation and fruticose lichen and moss cushion sub-formation, on rock outcrops of Galindez Island, Govorucha dome slope

Fig. 2. Fruticose lichen and moss cushion sub-formation, on rock outcrops of Winter Island, rocks near old flagstock

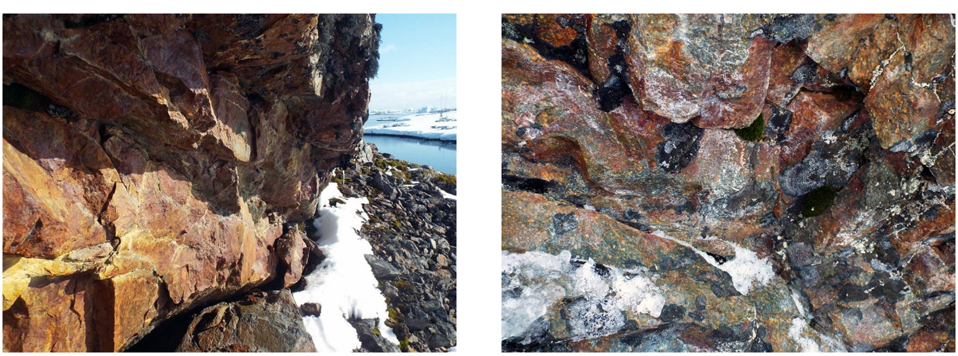

Fig. 3. Crustose lichen sub-formation and fruticose lichen and moss cushion sub-formation, on rock outcrops of Galindez Island, Karpaty Ridge

Chapek-Dox agar, Potato-Dextrose Agar (PDA), Sabouraud Agar (SDA) (Hi-Media Laboratories) (Samson *et al.* 2004).

Pieces of rock, soil, moss, and lichen were used for the accumulation of fungal cultures, which were deposited on the surface of dense nutrient media. Isolated pure cultures of microscopic fungi were identified using appropriate manuals (Ellis 1989, Samson *et al.* 2004). Taxonomic analysis was performed with the usage of the ninth edition of the Dictionary of fungi (Kirk *et al.* 2001). Current species names of fungi were clarified using the Index Fungorum and MycoBank (www.speciesfungorum, www.mycobank.org/quicksearch.aspx) resources.

The morphological features of the study objects were determined using a Carl Zeiss binocular microscope by Primo Star Company.

Determination of physiological and biochemical characteristics and identification of pure yeast cultures were performed using a microbiological analyser 'Vitek-2' ('Bio Merieux', France), as well as the corresponding ID-cards (YST).

Cultivation of Antarctic microorganisms was carried out at different temperatures – from +2 to +37 °C, using dense nutrient media.

Fat inclusions, neutral, acidic lipids in cells of microscopic fungi isolated from Antarctic specimens were detected using appropriate cytological methods and staining.

In addition to traditional morphological-anatomical and biochemical methods of lichen identification (Kondratyuk 2008, Øvstedal and Lewis Smith 2001), we have used nuclear DNA extraction and amplification techniques, followed by molecular phylogenetic analysis using the sequences obtained (Kondratyuk *et al.* 2019*a*, *b*, *c*).

RESULTS AND DISCUSSION

Cultures of microscopic fungi of Zygomycota (species of genus *Mucor circinelloides* Tiegh.), Ascomycota (species of genera cf. *Thelebolus* Tode, *Talaromyces* C. R. Benj.) were isolated from the samples obtained in the 22nd Ukrainian Antarctic Expedition. Representatives of the Anamorphic fungi group (species of the genera *Alternaria* Nees, *Acremonium* Link, *Aspergillus* P. Micheli ex Haller, *Penicillium* Link, *Cladosporium* Link, *Geomyces* Traaen), Coelomycetes (species of the genus *Phoma* Sacc.) were also found in the studied samples (Fig. 4). Microscopic fungi of *Penicillium* spp. found to be dominated by frequency (54.5%) in the samples tested.

The species of the genus *Penicillium* and representatives of Ascomycota, identified by us in the studied samples, were distinguished by us and in the previous studies from the samples of the 19th to 21st Ukrainian Antarctic Expedition. Part of Ascomycota fungi (in specimens from Irizar, Copepoda Island (Roca Is), Skua, Pitermann, Galindez locality numbers 2–6, 12, 17, and 22, respectively Table 1) found to form substrate mycelium with wrinkles (with radial clear depressions) on the surface of which air mycelium, a different colour (from dark grey to red), and which barely protrudes above the surface of the substrate mycelium, is formed depending on the composition of the nutrient medium (Fig. 5).

The isolated fungi are the subject of our further research to establish their taxonomic identity. Ascomycota fungi nowadays have a large proportion of non-identified specimens. Identification can be extremely difficult due to the specific morphological changes associated with the need to adapt to harsh environmental factors in Antarctica (Chávez *et al.* 2015). Their further study is advisable and promising, given the ability of these fungi to produce pig-

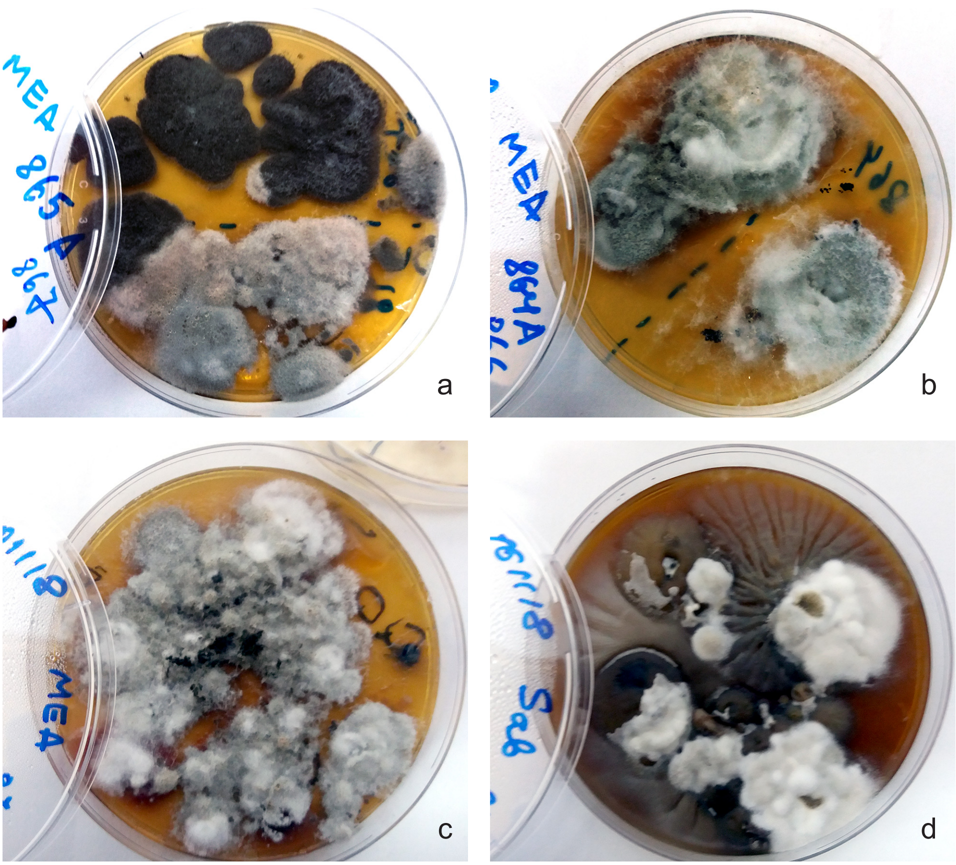

Fig. 4. Filamentous microscopic fungi from Galindez Island in cumulative cultures (sample numbers 9 (a), 10–11 (b), 14 (c), 22 (d) hereafter referred to in Table 1)

ments of dark and red hues (on different nutrient media). It is known that pigmented microorganisms deserve special attention because they are able to synthesise a variety of pigments, in particular melanins, carotenoids and their derivatives, which are characterised by high biological activity (Jagannadham *et al.* 2000).

A significant number of dark pigmented microscopic fungi of the 22nd UAE capable of producing melanin and melanin-like pigments were detected by us in the samples tested, as in previous studies. Such fungi in the Argentine Islands exist in the biotope of exposed insolated rock walls that are significantly affected by ultraviolet light. Dark pigmented microscopic fungi were represented by *Alternaria* sp., *Cladosporium* spp., *Aureobasidium pullulans* (de Bary) G. Arnaud, and *Exophiala* spp. These fungi were discovered in lithobi-

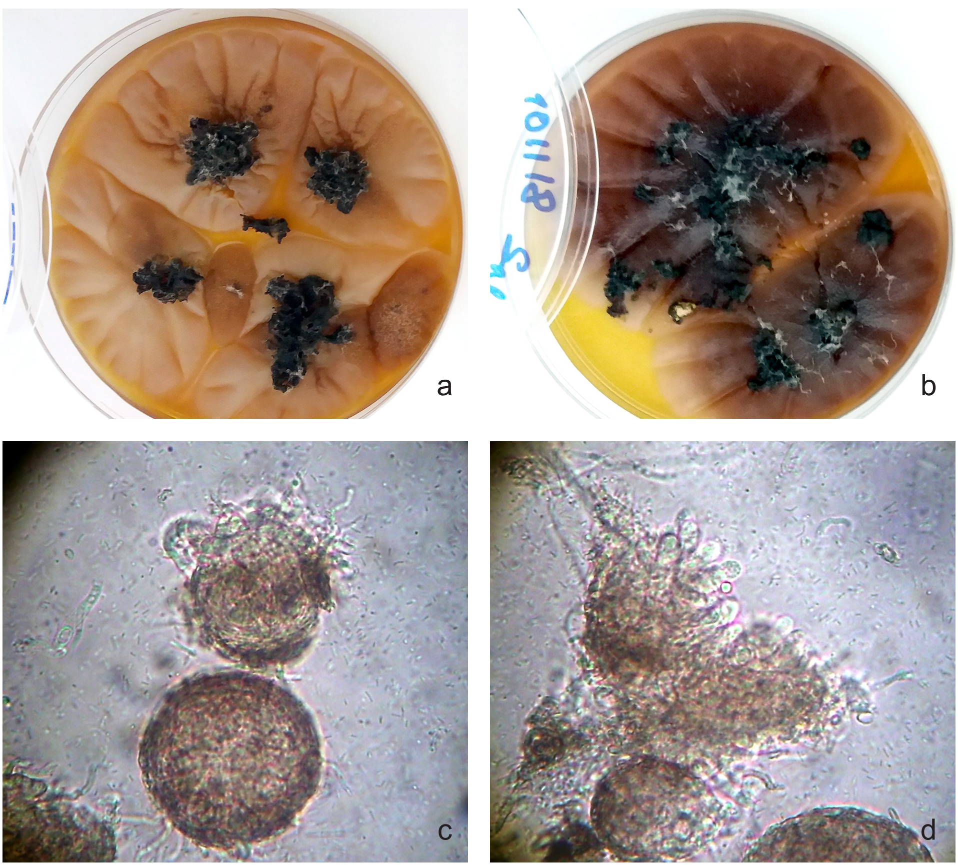

Fig. 5. Filamentous microscopic fungi (representatives of the Ascomycota) in specimens of the 22nd Ukrainian Antarctic Expedition: a = MEA medium, sample number 4; b = Sabouraud medium, sample number 6; c, d = fruiting bodies, asci and ascospores (×400)

ont communities from Irizar Isl., Roca Isl., Pitermann Isl. (sample numbers 1) and Galindez Isl. (sample numbers 8, 10, 13, 14, 18, 20, and 22) (Fig. 6). Representatives of black yeast fungi of the genus *Exophiala* were found in only three samples selected on Irizar Isl. (sample number 1) and on Galindez Isl. (sample numbers 8 and 18). Pigmented forms of microorganisms, in particular black yeast, synthesising coal-black melanin-like pigments were also earlier found by Ukrainian researchers in the terrestrial biotopes of the western coast of the Antarctic Peninsula, as well as in the islands of the Argentine archipelago (Romanovskaya *et al.* 2009, Tashyrev *et al.* 2012). It is known that the melanin of microorganisms has a wide range of biological effects: antioxidant, cytoprotective, immunomodulating, photo- and radioprotective, they can be used

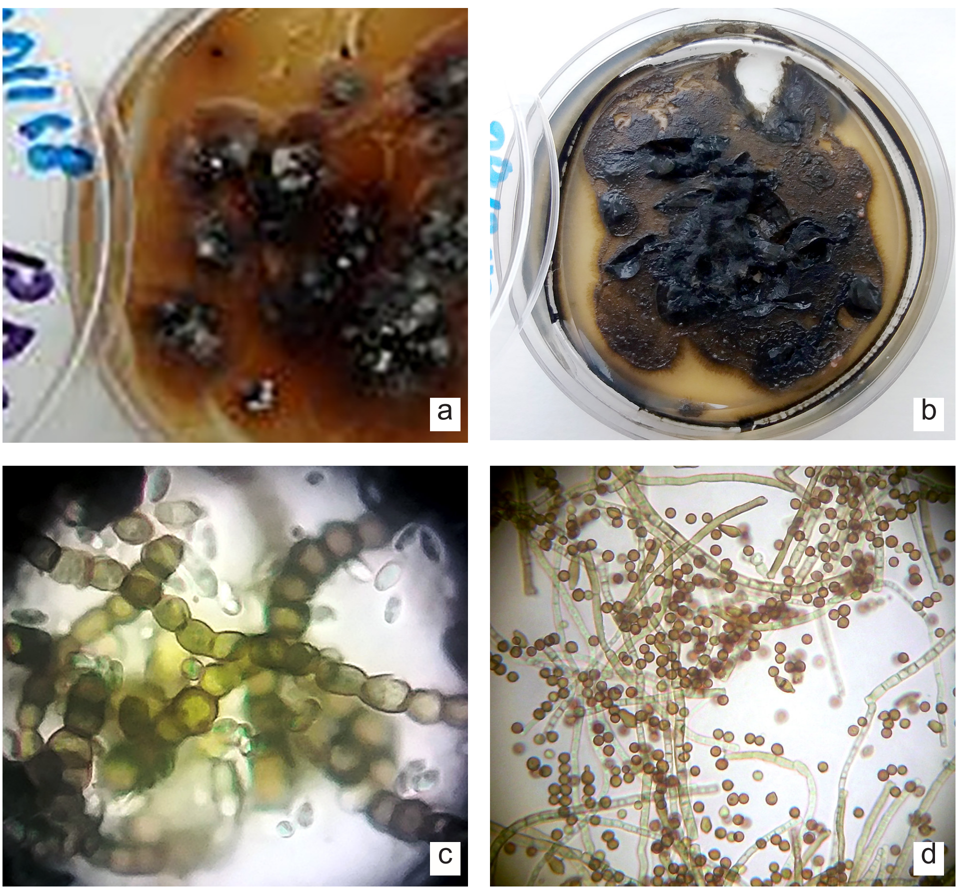

Fig. 6. Dark pigmented micromycetes in the specimens from Irizar Isl. (numbering according to Table 1; a = *Exophiala* sp., sample number 1) and Galindez Isl. (b, c = *Aureobasidium pullulans*, c = ×400, sample number 20); d = *Cladosporium* sp., ×400, sample number 22)

as sorbents of a number of radionuclides and heavy metals, etc. (Plonka and Grabacka 2006).

Microscopic fungi of *Geomyces pannorum* (Link) Sigler et J. W. Carmich. are identified in one sample from Irizar Isl. (sample number 1), *Mucor circinelloides* Tiegh. are identified in 4 samples of the 22nd Ukrainian Antarctic Expedition (consequently sample numbers 8, 14, 18, 22), as well as they were found in our previous studies of the Antarctic samples of the 18–20 Ukrainian Antarctic Expeditions, and in the 21st UAE. These fungi have the ability to synthesise and accumulate lipids in hyphae in the form of lipid inclusions (Kondratiuk *et al.* 2016). Lipid inclusions contain important saturated and unsaturated fatty acids, first of all, myristic, palmitic, stearic, oleic, linoleic, linolenic. Biosynthesis processes of unsaturated fatty acids are the most important types of modulation of fatty acid content in microorganisms, which are adapted to development in low ambient temperatures (Taha *et al.* 2013). Fungal lipids can be used in biotechnology, medicine (for medicine lipids containing essential fatty acids and ubiquinone Q-10), in the technical fields. An increased lipogenic activity has been shown for microscopic filamentous fungus *Geomyces pannorum* isolated from Antarctic biotopes. Such a feature of metabolism of these micromycetes is associated with a strategy of survival in the face of extreme environmental factors (Konova *et al.* 2009). Indeed, the conditions of their existence on Galindez Island are among the most exposed to the effects of ultraviolet light, and high and low temperatures. The ability to cultivate these microorganisms on agricultural and food waste makes their use convenient and cost-effective (Bhanja *et al.* 2014, Feofilova *et al.* 2010, Tauk-Tornisielo *et al.* 2009).

The yeast-like fungi were isolated of the two samples selected on Irizar Isl. (sample numbers 1, 2), and from the samples of Galindez Isl. (sample numbers 8, 9, 14, 16, 18, and 20). As a result of our research we have found out their cultural-morphological and physiological-biochemical features (Table 2).

Taxonomic affiliation of isolated yeast fungi to the sections Basidiomycota (*Rhodotorula rubra* (Schimon) F. C. Harrison – in 3 specimen numbers 1, 2, 16), Ascomycota (*Candida* sp. – specimen numbers 9, 14) and to the Anamorphic fungi group (dark pigmented *Aureobasidium pullulans* specimen number 20, *Exophiala* spp. specimen numbers 1, 8, 18) was established owing the combination of results of cultural and morphological studies and data of physiological and biochemical features.

Results obtained are summarised in Table 3. The 'red' yeast of the genus *Rhodotorula* deserves special attention. In addition to biosynthetic activity, they can develop on various sources of hydrocarbons, such as paraffins of oil, low molecular weight alcohols, etc. It is also shown that yeasts of the genus *Rhodotorula* are resistant to heavy metals and used in soil bioremediation (Biloivanenko and Bukhtiyarov 2013).

Table 2
Physiological and biochemical features of the yeast fungi (D) of the lithobiont communities of the Argentine Islands

Formation of enzimes	Isolated cultures of yeast-like fungi (number of isolate)					
	D 857	D 858	D 865	D 870	D 872	D 874
Urease	+	+	–	–	+	–
β-xylosidase	±/–	±/–	–	–	±/–	–
β-glucosidase	±/–	±/–	+	–	±/–	–
γ-glutamyl transferase	–	–	–	+	–	+
Phosphatase	–	–	±/–	+	–	+
Ability to assimilate substrate						
Inositol	–	–	–	–	–	±/+
D-xylose	+	+	–	±/+	+	–
D-glucose	+	+	+	+	+	–
D-mannitol	–	–	+	–	–	+
D-trehalose	–	–	–	+	+	–
D-mannose	–	+	+	–	–	+
Cellobiose	+	+	–	+	+	–
Arabitol	–	–	–	+	–	±/–
D-ribose	+	+	–	+	–	+
Starch	–	–	±/–	+	–	+

It should be mentioned that well development of micromycetes isolated from rock, soil and almost all lichen samples of the genera *Caloplaca*, *Candelariella*, *Lecanora*, *Lepraria*, *Umbilicaria* and others. However, in the case of attempts to isolate microscopic fungi from *Usnea antarctica*, the growth of microorganisms (both microscopic fungi and bacteria) in the nutrient media was absent. That confirms the previously established phenomenon of antibacterial and antifungal action of usnic acid contained by lichens of this genus (Cocchietto *et al.* 2002, Kartsev *et al.* 2018, Paudel *et al.* 2010).

Lichen substances exhibit antibiotic, anticancer, antimutagenic, antifungal, antiviral properties (Elix 1996, Huneck and Yoshimura 1996). Therefore, lichens are a potential source for obtaining useful and important compounds that can be used in medicine, pharmaceuticals, and agriculture (Boustie and Grube 2005, Dayan and Romagni 2001, Huneck 1999, Molnár and Farkas 2010, Muller 2001).

The data from the samples obtained during wintering in the 22nd Ukrainian Antarctic Expedition, regarding the taxonomic affiliation of (predominating in samples) genera (species) of micromycetes of lithobiont communities, are largely in agreement with those of other authors investigating the Antarctic and Arctic microbiota (Held *et al.* 2005, Kochkina *et al.* 2011, Newsham *et al.* 2016). Among the Antarctic micromycetes there are those that require further research to clarify their species affiliation and ability to produce biologically active compounds.

It should be especially emphasised that in the previously studied samples of soil, mosses, lichens of the 18–20th Ukrainian Antarctic Expeditions species of the genus *Aspergillus* (Anamorphic fungi group) did not occur to us. Species *Aspergillus niger* and *A. ochraceus* were discovered by us in the study of samples of the 21st Ukrainian Antarctic Expedition. Single colonies of the genus *Aspergillus* were found by us in two samples obtained during wintering in the 22nd Ukrainian Antarctic Expedition (Table 3).

On the one hand, fungi of the genus *Aspergillus* are recognised as powerful producers of a number of enzymes and other biologically active compounds, which are widely used in various industries, medicine, agriculture. Secondly, the above species of microscopic filamentous fungi may exhibit pathogenic and toxigenic properties. Recently, the problem of increasing the share of opportunistic and pathogenic microorganisms in the Antarctic region has been discussed in the scientific literature (Gonçalves *et al.* 2017, Panin *et al.* 2014). The authors attribute this fact, in particular, to the problem of anthropogenic transformation of the environment, which affects the conditions of existence of microorganisms. These publications analyse the grouping of microscopic fungi of Antarctic soils and the potential risk of individual mycobiota representatives to humans.

Attention is also drawn to the fact that, as Antarctica is one of the major regions of the planet that is vulnerable to global climate change, the study of the species diversity of microorganisms is relevant and urgently needed. Microorganisms are among the first to respond to climate change, recognised by indicator systems that respond to changes in their habitat and signal changes in the environment (Poma *et al.* 2012). These changes are particularly noticeable in the isolated and deserted oasis of Antarctica, which occupy only 2% of its total area. The rest of the territory of the sixth continent is covered with ice the whole year. The temperature factor and humidity of the habitat are one of the decisive points for the development and growth of microorganisms. Therefore, changes in micro biocoenoses that are determined by microbiological monitoring may be an objective prognostic factor (predictor of risk) of climate change in polar regions of the Earth that are negative.

Collection of live cultures of microscopic fungi in a viable state, a part of the Culture Collection of Fungi at Taras Shevchenko National University of Kyiv, is recently created and maintained at ESC 'Institute of Biology and Medicine'. It has own acronym FCKU and is registered in the World Microbial Collections Database at the Institute of Biology and Medicine under the

Table 3
Microscopic fungi of lithobiont communities of Argentine Islands from samples of 22nd Ukrainian Antarctic Expedition. No = sample number, UnI = unidentied species.

No	Filamentous fungi											Yeast-like fungi				
	Mucor circinelloides	UnI of Ascomycota	*Alternaria* spp.	*Acremonium* sp.	*Aspergillus* sp.	*Penicillium* spp.	*Cladosporium* spp.	*Geomyces pannorum*	*Phoma* sp.	UnI of nonpigmented fungi	UnI of dark pigmented fungi	*Aureobasidium pullulans*	*Exophiala* spp.	*Rhodotorula rubra*	*Candida* sp.	UnI of yeast-like fungi
1	–	–	–	–	–	+	–	+	–	–	+	–	+	+	–	–
2	–	+	–	–	+	+	–	–	–	–	–	–	–	+	–	+
3	–	+	–	–	–	+	–	–	–	–	–	–	–	–	–	–
4	–	+		–	–	–	–	–	–	+	–	–	–	–	–	–
5	–	+	–	–	–	–	–	–	–	+	–	–	–	–	–	–
6	–	+	–	–	+	–	–	–	–	–	+	–	–	–	–	–
7	–	–	–	–	–	+	–	–	–	+	+	–	–	–	–	–
8	+	–	–	–	–	–	–	–	–	+	+	–	+	–	–	–
9	–	–	–	–	–	+	+	–	–	–	+	–	–	–	+	–
10	–	–	–	–	–	+	+	–	–	–	+	–	–	–	–	–
11	–	–	–	–	–	+	–	–	–	+	–	–	–	–	–	–
12	–	+	–	–	–	+	–	–	–	–	–	–	–	–	–	–
13	–	–	–	–	–	–	+	–	–	–	+	–	–	–	–	–
14	+	–	–	–	–	+	–	–	+	+	+	–	–	–	+	–
15	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
16	–	–	–	–	–	+	–	–	–	–	–	–	–	+	–	–

Table 3 (continued)

No	Filamentous fungi												Yeast-like fungi			
	Mucor circinelloides	UnI of Ascomycota	*Alternaria* spp.	*Acremonium* sp.	*Aspergillus* sp.	*Penicillium* spp.	*Cladosporium* spp.	*Geomyces pannorum*	*Phoma* sp.	UnI of nonpigmented fungi	UnI of dark pigmented fungi	*Aureobasidium pullulans*	*Exophiala* spp.	*Rhodotorula rubra*	*Candida* sp.	UnI of yeast-like fungi
17	–	+	–	–	–	+	–	–	–	+	–	–	–	–	–	–
18	+	–	–	–	–	+	–	–	–	–	+	–	+	–	–	+
19	–	–	–	+	–	–	–	–	–	+	–	–	–	–	–	
20	–	–	+	–	–	+	–	–	–	–	–	+	–	–	–	–
21	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
22	+	+	–	–	–	–	+	–	–	+	–	–	–	–	–	–

number WDCM 1000. The collection contains more than 500 isolates of microscopic (filamentous and yeast) fungi belonging to the Zygomycota, Basidiomycota, Ascomycota and Anamorphic fungi group. The collection was supplemented with isolates of various microorganisms (filamentous fungi, yeast, bacteria) isolated from Antarctic samples and capable of synthesis of biologically active compounds and resistant to toxic metals – technologically promising strains of microorganisms in 2014–2018 (Kondratiuk *et al.* 2017). It is advisable to select among the diversity of the most active strains (species) introduced into the specified Collection of microorganisms – producers of biologically active compounds, which need further research, in particular molecular genetics, in order to clarify the identification, deposition in the relevant depositories of Ukraine and implementation of processes of depositors of Ukraine.

The results of careful analysis of Antarctic samples on the presence and quantity of biologically active compounds producing microorganisms will also help to clarify the nature of the adaptation processes that occur in microorganisms under the influence of extreme environmental conditions and make them resistant to harsh physical and chemical factors of the Antarctic.

Given the relevance of scientific research on the search for technologically promising strains of microorganisms in the Antarctic samples obtained in the Ukrainian Antarctic Expedition, fundamental aspects, the practical value of the results obtained – further research and development on this topic is appropriate and extremely relevant.

CONCLUSIONS

It is shown that the diversity of microscopic fungi of lithobiont communities: insolated rock walls and surfaces of the Argentine Islands area, as well as of other regions of the Antarctic, is characterised by the presence of filamentous and yeast-like fungi. The microscopic fungi *Penicillium* spp. found to be dominated after the frequency in the studied samples (54.5%).

The following potential producers of biologically active compounds are identified among the investigated samples: the dark pigmented species of the genera *Cladosporium*, *Exophiala*, *Aureobasidium pullulans*, which capable of melanin synthesis; 'red' yeast *Rhodotorula rubra* (carotenoid producers and resistant to toxic metals); as well as *Mucor circinelloides* and *Geomyces pannorum* lipid producers. At the same time, the isolated yeast-like fungi have assimilated a wide range of carbohydrates, which can be a substrate for their growth, will allow them to be further used for cultivation in laboratory and technological conditions.

The collection of technologically advanced strains of microorganisms of Culture Collection of Fungi at Taras Shevchenko National University of Kyiv has been expanded with strains of species of filamentous fungi and yeasts potential producers of biologically active compounds isolated from the samples of the 22nd UEA.

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