Studies in Fungi

REVIEW

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https://doi.org/10.48130/SIF-2023-0013

Studies in Fungi **2023**, 8:13

Oudemansiella (Physalacriaceae) mushrooms: A status review on the distribution, cultivation, composition and bioactivity profile

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Abstract

Oudemansiella of Physalacriaceae, Agaricomycetes, Basidiomycota is widely distributed in tropical and subtropical regions, and are known as saprophytic macrofungi. Species of this genus are edible, flavorful, nutritious, and medicinal. Hence, there is increasing attention to the value of these under-utilized myko-resources. In this context, this status review aimed to provide a species checklist of *Oudemansiella* and their distribution worldwide, cultivation requirements for growth and production, nutritional and bioactive compositions, and biological properties. A total of 25 species of *Oudemansiella* was recorded in 31 countries in Asia, North and South America, Australia, Africa, and Europe. *O. canarii* was found to be the most widely distributed, followed by *O. platensis*, *O. cubensis*, *O. melanotricha*, *O. submucida,* and *O. australis*. China had the greatest number of reported *Oudemansiella* species. *O. canarii* was the most commonly cultivated species using agro-industrial wastes such as sugarcane bagasse, eucalyptus sawdust, cotton seed hull, corncob, sawdust, and rice straw. *Oudemansiella* species contain carbohydrates, protein, amino acids, crude fiber, crude fat, minerals, and bioactive compounds such as oudemansin A and B, dihydroxerulin, xerulinic acid, and strobilurin C. Extracts and isolated bioactive compounds from *Oudemansiella* were reported to exhibit antioxidant, antifungal, antimicrobial, cytotoxic properties, and anti-trypanosomatid infection. To the best of our knowledge, this review establishes the most comprehensive checklist of *Oudemansiella* species. The presented data can be used as valuable information for further exploration and exploitation of the maximum profitability of *Oudemansiella* species. This review also provides status, challenges, and research opportunities that will ignite attention among researchers and scientists worldwide.

Citation: Dulay RMR. 2023. *Oudemansiella* (Physalacriaceae) mushrooms: A status review on the distribution, cultivation, composition and bioactivity profile. *Studies in Fungi* 8:13 https://doi.org/10.48130/SIF-2023-0013

Introduction

Mushrooms are edible or poisonous, epigeous or hypogeous, Basidiomycetous or Ascomycetous macrofungi. They can be grouped into an edible, medicinal, poisonous, and miscellaneous groups including under-utilized and undiscovered species. Mushrooms act as saprophytic, parasitic, and symbiotic (mycorrhiza), making them essential in the decomposition of massive forest litters, cycling of nutrients and maintenance of ecological balance[1]. As food, mushrooms are very nutritious and highly medicinal. They are a rich source of proteins, carbohydrates, dietary fiber, ergosterol, minerals such as calcium, copper, iron, magnesium, manganese, phosphorus, potassium, selenium, and zinc, and vitamins like thiamin, riboflavin, niacin, pantothenic acid and pyridoxine[2]. Bioactive proteins such as lectins and enzymes immunomodulatory fungal proteins have been widely reported to exhibit antibacterial, antifungal, antiviral, antitumor and immunoenhancing properties[3]. Phenolic compounds (quercetin, catechin, myricetin, pyrogallol and caffeic acid), carotenoids, ergosterols, tocopherols, ascorbic acid, terpenes and polysaccharides present in the mycelia and fruiting bodies of edible mushrooms showed antioxidant, anti-inflammatory and anticancer activities[4]. Active ingredients of mushroom, such as polysaccharides, terpenoids, proteins, fatty acids, nucleotides, sterols, steroids and vitamins showed antidiabetic, anti-oxidant, anticancer, anti-atherosclerotic, anti-inflammatory, antimicrobial, antiangiogenic, anti-arthritic, anti-herpetic, anti-nociceptive, anti-androgenic, antiaging, antiulcer, anti-fibrotic, anti-osteoporotic, hepatoprotective, hypolipidemic, chemopreventive, analgesic, immunomodulatory and estrogenic activities[5].

Oudemansiella (Physalacriaceae, Agaricomycetes, Basidiomycota) are widely distributed in tropical and subtropical regions and are known as saprophytic fungi that grow in decaying leaves and wood of trees[6]. They are characterized morphologically by their ixotrichodermpileipellis, which are made of filamentous hyphae commonly intermixed with chains of inflated cells[7]. In addition, its pileus is often dry to viscid, with white to off-white lamellae and a central stipe lacking a persistent />annulus[7,8]. Traditionally, *Oudemansiella* has been a broad-based genus that includes *Xerula* Maire and *Mucidula* Pat. species[9]. However, Baekhout & Bass[10] claimed that *Oudemansiella* and *Xerula* are two distinct genera based on morphological differences such as basidiocarp development, pseudorrhiza, spore size, and shape, among others. Meanwhile, Alberti et al.[8] argued in their review that many researchers classified *Oudemansiella*, *Xerula*, and *Mucidula* to be distinct genera. Niego et al.[7] supported this taxonomy and mentioned that the basidiomata of *Oudemansiella* vary from those of *Mucidula* in microscopical parameters by lacking a persistent annulus on the stipe and that the former genus is exclusively found in tropical regions.

The interest on the nutritional and pharmacological properties of wild mushrooms for functional food and alternative drug development is continuously increasing worldwide. The cultivation potentials and the biological activities of *Oudemansiella* species have been explored[11−14]. Herein, we comprehensively reviewed the status in terms of the global records, distribution, cultivation, bioactive compositions and bioactivities of *Oudemansiella* species in order to provide benchmark data for their conservation and maximum utilization.

Species checklist and distribution of *Oudemansiella* species

The distribution of the mushroom is determined by both nutritional and physical factors such as temperature, humidity, substrate composition, elevation, and climatic conditions[1]. Members of the Physalacriaceae mushrooms thrive in a wide range of temperatures, as evidenced by records from both tropical and subtropical regions[6,8,15]. In this review, a total of 25 species of *Oudemansiella* were recorded viz. *O. americana*, *O. andina*, *O. australis*, *O. bii*, *O. canarii*, *O. cephalocystidiata*, *O. crassifolia*, *O. cubensis*, *O. echinosperma*, *O. ephippium*, *O. exannulata*, *O. fanjinshanensis*, *O. globospora*, *O. gloriosa*, *O. haasiana*, *O. indica*, *O. latilamellata*, *O. melanotricha*, *O. munnarensis*, *O. orinocensis*, *O. platensis*, *O. reticulata*, *O. rhodophylla*, *O. submucida*, O. *yunnanensis* (Table 1). The *Oudemansiella* species were reported in 31 countries in Asia, North and South America, Australia, Africa, and Europe. Among species, *O. canarii* was found to be the most widely distributed (14 countries), followed by *O. platensis* (nine countries), *O. cubensis* (seven countries), *O. melanotricha* (five countries), and *O. submucida* and *O. australis* (three countries) (Fig. 1). On the other hand, China had the greatest number of reported species of *Oudemansiella* (eight species), followed by Brazil and Australia (five species each), Argentina (four species), and India, Thailand, and Costa Rica (three species each) (Fig. 2). The geographic distribution of the most widely distributed *Oudemansiella* species in the world is shown in Fig. 3.

Compared to the recent review of Niego et al.[7], they only recorded a total of 14 species of *Oudemansiella*, which includes *O. alphitophylla*, *O. bii*, *O. canarii*, *O. crassifolia*, *O. exannulata*, *O. fanjingshanensis*, *O. gloriosa*, *O. latilamellata*, *O. platensis* var. *orinocensi*, *O. rhodophylla*, *O. reticulata, O. submucida*, *O. turbinospora,* and *O. yunnanensis*. This is significantly lower than the recorded number of species reported in this review. Additionally, based on Species Fungorum, two of the *Oudemansiella* mushrooms mentioned in their review, the *O. platensis* var. *orinocensi* and *O. alphitophylla,* were assigned to another

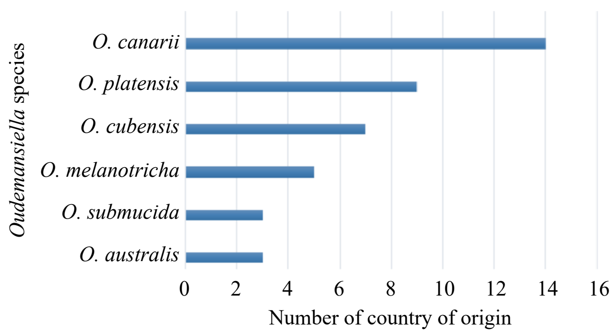


Fig. 1 Most widely distributed *Oudemansiella* species worldwide.

Table 1. Checklist of different species of *Oudemansiella* and their country of origin.

Oudemansiella species	Country of origin	Ref.
1. *Oudemansiella americana* (Mitchel & A.H.Sm.)	US	[16]
2. *Oudemansiella andina* (Speg.) T. Lebel & T.W.	Australia	[17]
3. *Oudemansiella australis* G. Stev & G.M. Taylor	Papua New Guinea	[18]
	Australia	[18]
	Philippines	[19]
4. *Oudemansiella bii* Zhu L. Yang & Li. F. Zhang	China	[7]
5. *Oudemansiella canarii* (Jungh.) Höhn.	Argentina	[8]
	Brazil	[20]
	China	[21]
	India	[13]
	Philippines	[12]
	Colombia	[22]
	Thailand	[23]
	Mexico	[24]
	Costa Rica	[18]
	Puerto Rico	[18]
	Cuba	[25]
	Cameroon	[26]
	France	[27]
	Bolivia	[28]
6. *Oudemansiella cephalocystidiata* (R.H. Petersen & Aime) Wartchow	Brazil	[29]
	Bolivia	[30]
7. *Oudemansiella crassifolia* Corner	China	[8]
	Thailand	[23]
8. *Oudemansiella cubensis* (Berk. & M.A. Curtis) R.H. Petersen	Argentina	[8]
	Dominican Republic	[31]
	Puerto Rico	[31]
	Brazil	[32]
	Guyana	[33]
	China	[34]
	Costa Rica	[35]
9. *Oudemansiella echinosperma* Singer	Brazil	[36]
10. *Oudemansiella ephippium* (Fr.) M.M. Moser	Greece	[37]
	Iran	[38]
11. *Oudemansiella exannulata* (Cleland & Cheel) R.H. Petersen	Australia	[7]
12. *Oudemansiella fanjingshanensis* M. Zang & X.L. Wu	China	[7]
13. *Oudemansiella globospora* (R.H. Petersen & Nagas.) Zhu L. Yang, G.M. Muell., G. Kost & Rexer	China	[39]
14. *Oudemansiella gloriosa* (D.A. Reid) T. Lebel & T.W. May	Australia	[40]
15. *Oudemansiella haasiana* Raithelh.	Argentina	[8]
16. *Oudemansiella indica* Sathe & S.D. Deshp.	India	[41]
17. *Oudemansiella latilamellata* Mizuta	Japan	[42]
18. *Oudemansiella melanotricha* (Dörfelt) M.M. Moser	Spain	[43]
	Czech Republic	[44]
	Turkey	[45]
	Poland	[46]
	Bulgaria	[47]
19. *Oudemansiella munnarensis* Sathe & J.T. Daniel	India	[48]
20. *Oudemansiella orinocensis* (Pat.) Speg.	Paraguay	[49]
21. *Oudemansiella platensis* (Speg.) Speg.	Argentina	[50]
	Brazil	[50]
	Colombia	[50]
	Costa Rica	[50]
	Cuba	[50]
	Dominican Republic	[50]
	Ecuador	[50]
	Panama	[51]
	Paraguay	[52]
22. *Oudemansiella reticulata* (J.W. Cribb) T. Lebel & T.W. May	Australia	[40]
23. *Oudemansiella rhodophylla* Mizuta	Japan	[42]
24. *Oudemansiella submucida* Corner	China	[53]
	Thailand	[23]
	Malaysia	[54]
25. *Oudemansiella yunnanensis* Zhu L. Yang & M. Zang	China	[55]

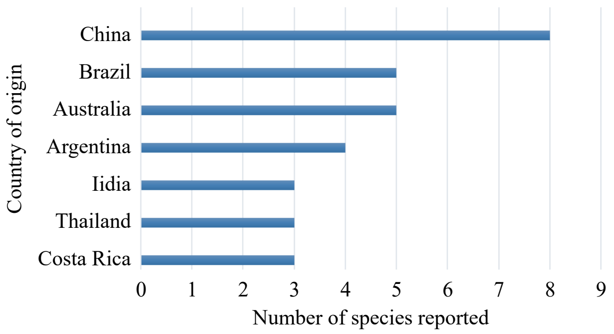


Fig. 2 Top countries with the greatest number of reported *Oudemansiella* species.

species (*Oudemansiella orinocensis*) and genera (*Chamaemyces alphitophyllus*), respectively. Therefore, it is safe to conclude that the present review provides a comprehensive checklist and the distribution of *Oudemansiella* species worldwide.

The climatic condition of the geographic origin of *Oudemansiellla* species is one of the major factors that affects their distribution and diversity. Based on the data gathered, *Oudemansiella* species could grow in a wide range of temperatures, from tropical to temperate conditions of different countries. This supports the claims by Niego et al.[7] who reported that *Oudemansiella* can be found worldwide, primarily in tropical and subtropical regions. Given that the majority of these mushrooms are wood-rotting and leaf litter macrofungi, another possible reason for the wide distribution of the *Oudemansiella* is the rich vegetation in the rainforest of the cited countries. Rainforests offer a great substratum that is suitable as a growing medium for wild mushrooms like *Oudemansiella*. Furthermore, in a recent study by Lopez & Undan[19], they successfully identified the first species of *Oudemansiella australis* in the Philippines using a molecular approach, wherein its last records were found in Papua New Guinea and Australia in 2001. Hence, continuous efforts on the myco-expedition and mycodiversity assessment in the wild by mycologists, mycotaxonomists and researchers are imperative to reveal more *Oudemansiella* species that remain to be explored.

Altogether, the climatic conditions of geographical origin and vegetation have significant impact on the diversity and distribution of *Oudemansiella*. The recent findings on the new records of *Oudemansiella* species in different countries[7,8,19,28,32,34] strongly indicate that there are still more *Oudemansiella* species in the wild waiting to be discovered and harnessing of their various promising potential.

Cultivation of *Oudemansiella* mushroom

In the present review, the different technologies for the cultivation of *Oudemansiella* species were also gathered (Table 2). It can be seen that only two *Oudemansiella* species were evaluated for their fruiting body cultivation, and *Oudemansiella canarii* was the most commonly evaluated for cultivation. Several agro-industrial wastes such as sugarcane bagasse, eucalyptus sawdust, cotton seed hull, corncob, sawdust, and rice straw were used as basal substrates in the production of *Oudemansiella* fruiting body[12,20,21,56]. In terms of the biological efficiency, *O. canarii* showed significantly varied biological efficiencies depending on the substrate used and most likely on the origin of the mushroom strains used in the individual study.

Silveira Ruegger et al.[20] used sugarcane bagasse and eucalyptus sawdust supplemented with wheat bran for the fruiting body cultivation of *O. canarii* strain CCB179. They found out that growing *O. canarii* in sugarcane bagasse incorporated with 50 g wheat bran, incubated at 25 °C, resulted in higher biological efficiency (55.66%), productivity (4.47%), and compost consumption (38.78%). Fruiting bags containing eucalyptus sawdust supplemented with wheat bran recorded 19.51% only. Xu et al.[21] cultivated *O. canarii* fruiting bodies using lignocellulosic wastes such as cotton seed hull, sawdust, corncob, and their combinations supplemented with 18% wheat bran and 2% lime incubated at 25 °C and 70% relative humidity in dark condition. Substrate with 80% cotton seed hull, 18% wheat bran and 2% lime produced the greatest yield of 7,955.1 g and recorded the highest biological efficiency of 113.64%. However, this was not significantly different to the yield and biological efficiency of mushroom cultivated in substrate containing 40% cotton seed hull, 40% corncob, 18% wheat bran and 2% lime.

Dulay & Damaso[12] successfully domesticated and cultivated a wild strain of *O. canarii* BIL 9137 from Lingap Kalikasan of Central Luzon State University, Science City of Munoz, Nueva

Fig. 3 Geographical distribution of *Oudemansiella* species worldwide.

Table 2. Substrate used in fruiting body production and biological efficiencies of *Oudemansiella* species.

Species	Substrate used	Biological efficiency (%)	Ref.
O. canarii	Sugarcane bagasse + wheat bran	55.66	[20]
O. canarii	Eucalyptus sawdust + wheat bran	19.51	[20]
O. canarii	Cottonseed hull + wheat bran + lime (80:18:2)	113.64	[21]
O. canarii	Sawdust + wheat bran + lime (80:18:2)	85.49	[21]
O. canarii	Corncob + wheat bran + lime (80:18:2)	105.65	[21]
O. canarii	Cotton seed hull + sawdust + wheat bran + lime (40:40:18:2)	83.26	[21]
O. canarii	Cotton seed hull + corncob + wheat bran + lime (40:40:18:2)	110.11	[21]
O. canarii	Sawdust + corncob + wheat bran + lime (40:40:18:2)	75.79	[21]
O. canarii	Pure rice straw	12.08	[12]
O. canarii	Rice straw + sawdust (8:2)	18.94	[12]
O. canarii	Rice straw + sawdust (6:4)	15.88	[12]
O. canarii	Rice straw + sawdust (4:6)	13.56	[12]
O. canarii	Rice straw + sawdust (2:8)	7.14	[12]
O. canarii	Pure sawdust	5.70	[12]
O. submucida	Sawdust + cotton seed hull	140.36	[56]
O. submucida	Oak sawdust with 20% rice bran	n.r.	[57]

n.r., not reported.

Ecija, Philippines. They also reported that malt extract agar (64.83 mm) and potato broth sucrose agar (84.17 mm) showed the widest mycelial diameter with very thick mycelia. Sorghum seeds and cracked corn were found to be most suitable grain spawn materials, which showed the lowest incubation period of 11.33 d. Rice straw and sawdust at 8:2 ratio was identified as the best substrate formulation for the fruiting body cultivation of *O. canarii*. The mycelia and fruiting bodies of *O. canarii* grown in their most suitable medium are shown in Fig. 4. The stages of fruiting body development of *O. canarii* from primordial initiation to fruiting body maturation were also documented.

In comparison with other Physalacriaceae species such as *Flammulina velutipes*, Harith et al.[58] also utilized agro-industrial waste such as rubber wood sawdust, paddy straw, palm empty fruit bunches, and palm-pressed fiber supplemented with spent brewer's yeast and rice bran as nitrogen sources at the ratios of 3:1, 1:1, and 1:3 for fruiting body cultivation of *F. velutipes*. Similarly, agro-industrial waste shows excellent substrate material resulting in excellent biological efficiency (BE). Based on their findings, the best substrates were paddy straw + palm empty fruit bunches (25:75 substrate formulation) with 185.09% BE, paddy straw + palm-pressed fiber (50:50) with 150.89% BE, and palm-pressed fiber (100) with 129.06% BE.

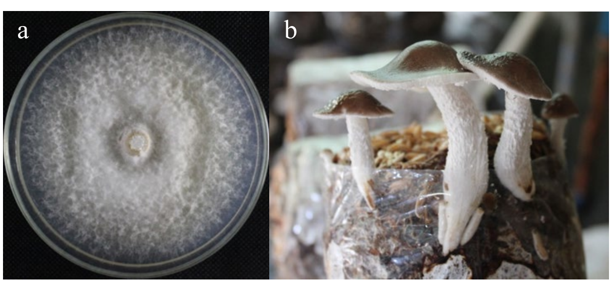


Fig. 4 (a) Mycelia and (b) fruiting bodies of *O. canarii*[12].

Given the limited studies on the cultivation of *Oudemansiella* species, this unlocks important research topics and efforts on the optimization studies, enriched cultivation, and submerged cultivation, which are necessary to develop more production technologies for this group of mushrooms in order to ensure conservation and sustainability.

Chemical composition and bioactivities of *Oudemansiella* mushrooms

Mushrooms are widely utilized as a source of food and/or traditional medicine worldwide. Edible mushrooms are an excellent source of nutritious and unique umami-tasting food. They are rich in carbohydrates, proteins, fibers, vitamins, minerals, and low-fat content[59,60]. The dry matter of mushrooms, in general, contains 50%-65% carbohydrate, 19%–35% protein, and 2%–6% fat[61]. The approximate composition of *O. canarii* and *O. submucida* and the most commonly cultivated edible mushrooms in the world are summarized in Table 3. Zhou et al.[53] revealed that *O. submucida* contains 27.41% total carbohydrate, 3.95% fiber, 14.70% protein, and 7.10% fat. The carbohydrate compositions include arabitol (15.95%), mannitol (2.90%), glucose (0.97%), soluble polysaccharides (4.00%), and fiber (3.95%). This mushroom also contains 15 amino acids including alanine, arginine, aspartic acid, glutamic acid, glycine, histidine, isoleucine, leucine, lysine, phenylalanine, proline, serine, threonine, tyrosine, and valine with a total of 18.09%. On the other hand, *O. canarii* contains 33.39% carbohydrates, 16.65% protein, 33.52% fiber, 1.64% fats, 8.13% ash, essential and non-essential amino acids[21]. Accordingly, the amount of chemical compositions of mushroom varies depending on the species. Carbohydrates are the major components of the six mushrooms (Table 3). The major carbohydrate content of mushrooms include glucose, fructose, sucrose, maltose, arabinose, rhamnose, mannitol, trehalose, and xylose[61,62]. Lipids are the lowest composition of mushrooms. However, the major fatty acid content of mushrooms include linoleic acid, oleic acid, palmitic acid, and stearic acid[63]. Linoleic acid has been reported to exhibit anti-obesogenic, anti-carcinogenic, and anti-atherosclerotic properties[64]. Moreover, tocopherol is known as an effective antioxidant[65], whereas ergosterol is known as a precursor of vitamin D2[66].

Edible mushrooms have been exploited for a very long time as natural alternative remedies for various diseases. The therapeutic values and medicinal properties of edible mushrooms have found to stem from numerous biologically active compounds or metabolites[70]. The crude extracts and bioactive compounds and the corresponding biological activities of *Oudemansiella* species are summarized in Table 4. Among *Oudemansiella* species, only two species namely, *O. canarii* and *O. melanotricha*, have been evaluated for biological properties, which are reported in six separate studies. Crude extracts of *O. canarii* extracted using ethyl acetate, ethanol and methanol as extracting solvents have been found to exhibit antifungal, antioxidant and cytotoxic activities and inhibit trypanothione reductase (TryR)[11,13,14,71]. Moreover, bioactive compounds such as oudemansin A, dihydroxerulin, xerulinic acid, oudemansin B and strobilurin C have been successfully isolated from *Oudemansiella* species, and have been shown to display antimicrobial activities[11,72,73]. The chemical structures of the five mentioned bioactive compounds of *Oudemansiella* obtained

Table 3. Comparison of proximate composition (% of dry matter) of the two *Oudemansiella* species and the most commonly cultivated edible mushrooms worldwide.

Mushrooms	Carbohydrate	Protein	Fiber	Fat	Ash	Ref.
Agaricus bisporus	71.53	15.43	n.r.	1.67	11.36	[67]
Pleurotus ostreatus	69.86	21.14	6.11	2.02	7.02	[68]
Lentinula edodes	70.62	22.61	9.38	0.78	5.99	[68]
Flammulina velutipes	n.r.	13.50	32.30	1.47	8.24	[69]
Oudemansiella canarii	33.39	16.65	33.52	1.64	8.13	[21]
Oudemansiella submucida	27.41	14.70	3.95	7.10	n.r.	[53]

n.r., not reported.

from Pubchem (https://pubchem.ncbi.nlm.nih.gov/) are presented in Fig. 5. Accordingly, *Oudemansiella* species could be valuable natural resources of extracts and bioactive compounds that possess pharmacological and nutraceutical properties.

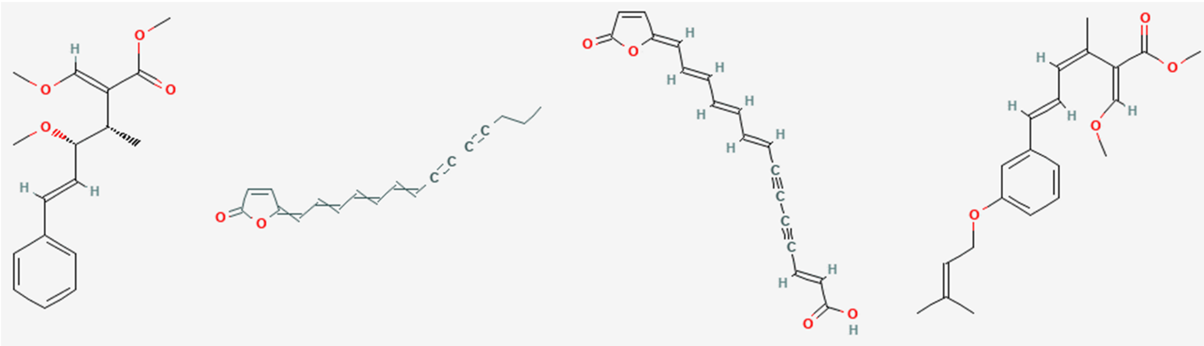
Dulay et al.[14] studied the cytotoxic activities of ethanol extract of wild fruiting bodies of *O. canarii* against nine hematologic malignant cells and the underlying molecular mechanisms. They found out that *O. canarii* extract exhibited cytotoxicity with IC_{50} values of 26.8–66.0 ppm and inhibited cell proliferation by 57.3%–72.5% in all the cancer cell lines used. After 48 h of exposure, extract-treated cancer cells displayed 68.2%–82.5% Annexin-V positive cells, and showed a significant increase of cells in the sub G0/G1 phase from 5.3%–22.5% (control group) to 59.8%–87.5%. The presence of *O. canarii* extract displayed an increase in the production of ROS by 4.32-fold in KBU, 2.96-fold in MOLM13, 7.42-fold in J45.01, 3.73-fold in U937, 7.40-fold in RPMI 8226, and 5.22-fold in MM.1R, and showed a significant increase in the monomer/aggregate ratio between 0.64 and 5.95, which strongly suggest that *O. canarii* extract can induce mitochondrial dysfunction. Activation of apoptosis-related markers and stress-activated protein kinase (SAPK/JNK) signaling pathway is one of the potential mechanisms of the cytotoxicity of *O. canarii* extract against leukemia, lymphoma, and myeloma cells. The bioactive metabolites of *O. canarii* have not yet been identified in their study and it warrants further investigation.

Antioxidants are one of the most important biological/pharmacological properties of *O. canarii*[13]. Most studies have also reported that the bioactive compounds isolated from *Oudemansiella* species have potent antimicrobial activity[72]. Accordingly, studies on the functionality profile of *Oudemansiella* species are very limited. It is therefore of urgent need to popularize this mushroom group through commercial cultivation for industrial application, and increase the number of researchers who will be working on this aspect. More advanced work on bioactivity profiling, product development, and commercialization of the developed functional foods, dietary supplements, and alternative drugs are imperative.

Table 4. Bioactive compounds and biological properties of *Oudemansiella* species.

Species	Solvent used	Bioactive compounds	Bioactivity	Reference
O. canarii	Ethyl acetate	n.d.	Antifungal activity against *Candida albicans, Candida glabrata, Candida krusei,* and *Candida tropicalis*	[71]
O. canarii	Methanol	n.d.	Showed 12.91 ± 0.26 μM Trolox equivalent/mg of extract antioxidant activity	[13]
O. canarii	Methanol	n.d.	Showed EC_{50} value of 0.912 ± 0.38 mg/ml for radical scavenging activity	[13]
O. canarii	Methanol	n.d.	Exhibited antioxidant capacity of 15.33 ± 0.67μg/mg ascorbic acid equivalent	[13]
O. canarii	Ethanol	n.d.	Cytotoxicity against acute myeloid leukemia (AML), lymphoma, and multiple myeloma with IC_{50} values of 26.8–66.0 ppm, inhibited cell proliferation, increased annexin V positive, cells in sub G0/G1 phase and formation of reactive oxygen species, and reduced mitochondrial membrane potential.	[14]
O. canarii	Ethyl acetate	n.d.	Crude extract at 10 μg/ml inhibited the growth of human melanoma cells (UACC-62) by 47%.	[11]
O. canarii	Ethyl acetate	n.d.	Crude extract at 10 μg/ml inhibited the enzyme trypanothione reductase (TryR) from *Trypanasoma cruzi* by 62%.	[11]
O. canarii	Ethyl acetate	Oudemansin A	Antifungal activity against *Cladosporum sphaerospermum* at a minimum inhibitory concentration of 1.25 μg/spot in the bioautographic assay	[11]
O. melanotricha	Acetone	Dihydroxerulin	Antifungal activity against *Ascochyta pisi*, *Aspergillus ochracens*, *Mucor miehei*, *Phytophthora infestans*, and *Zygorhynchusmoelleri* with 16–30 mm zone of inhibition.	[73]
O. melanotricha	Acetone	Xerulinic acid	Antifungal activity against *Mucor miehei* with 12 mm zone of inhibition	[73]
O. *melanotricha*	Methanol	Oudemansin B	Antimicrobial activity against *Absida glauca* CDS 101.08, *A. glauca* CBS 102.08, *Alternaria porri*, *Ascochyta pisi* CBS 126.54, *Ceratocystis retusi* CBS 100.78, *Cladosporium cladosporiodes*, *Mucor miehei*, *Nematospora coryli*, *Paecilomyces variotii*, *Penicillium notatum*, *Phytophthora infestans* CBS 366.51, *Pleospora herbarum* CBS 714.68, *Pythium debaryanum* CBD 265.38, *Ustilago nuda* CBS 118.19, and *Zygorhyn chusmoelleri* CBS 111.10 with 22–55 mm zone of inhibition	[72]
O. melanotricha	Methanol	Strobilurin C	Antimicrobial activity against *Absida glauca* CDS 101.08, *A. glauca* CBS 102.08, *Alternaria porri*, *Ascochyta pisi* CBS 126.54, *Ceratocystis retusi* CBS 100.78, *Cladosporium cladosporiodes*, *Mucor miehei*, *Nematospora coryli*, *Paecilomyces variotii*, *Penicillium notatum*, *Phytophthora infestans* CBS 366.51, *Pleospora herbarum* CBS 714.68, *Pythium debaryanum* CBD 265.38, *Ustilago nuda* CBS 118.19, and *Zygorhyn chusmoelleri* CBS 111.10 with 11–55 mm zone of inhibition	[72]

n.d., not determined.



Oudemansin A,B Dihydroxerulin Xerulinic acid Strobilurin C

Fig. 5 Chemical structures of bioactive compounds of *Oudemansiella* (National Center for Biotechnology Information (2022). PubChem Compound Summary for CID 6438712 oudemansin A and B, 131569 dihydroxerulin, 6439346 xerulinic acid 76968370, and strobilurin C. Retrieved December 14, 2022, from https://pubchem.ncbi.nlm.nih.gov/.

Conclusions and future perspectives

The geographical distribution, cultivation, composition and bioactivity of *Oudemansiella* species were highlighted in this review. In particular, this paper provides the global distribution of 25 *Oudemansiella* species, cultivation potential with reference to their substrate requirements for fruiting body production, proximate compositions and isolated bioactive com-/>pounds, and biological properties of *Oudemansiella*. It is also revealed that only two species (*O. canarii* and *O. melanotricha*) have been thoroughly studied for bioactivity evaluation, and the bioactivity is limited to anticancer, antifungal, antioxidant, cytotoxicity, and antibacterial activities. Furthermore, the industrial applicability of *Oudemensiella* has not yet been explored.

Based on the information gathered in this study, the following should be considered for future research; (a) wider scope of assessments of the world's mycodiversity particularly those countries with suitable environments for the growth of *Oudemansiella*, (b) accurate identification and characterization of other *Oudemansiella* species through taxonomic and phylogenetic analysis using new molecular techniques to identify new *Oudemansiella* species, (c) mycelial growth optimization, nutrient source optimization, and submerged cultivation in order to establish the full potential of this mushroom group for cultivation and to popularize their utilization in various industrial applications, (d) evaluation of more functional activities in various biological systems or models and establish their mechanism of action, (e) elucidation, characterization, and identification of novel bioactive compounds responsible for the observed bioactivities, and (f) exploration of *Oudemansiella* mushrooms for the development of functional foods, dietary supplements, and pharmaceutical drugs in order to fully realize their importance for the benefits of mankind.

Conflict of interest

The author declares that there is no conflict of interest.

Dates

Received 22 December 2022; Accepted 29 May 2023; Published online 21 July 2023

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