Hindawi Publishing Corporation
Interdisciplinary Perspectives on Infectious Diseases
Volume 2012, Article ID 465717, 7 pages
doi:10.1155/2012/465717

Review Article

Epidemiology of *Rhodotorula*: An Emerging Pathogen

Fernanda Wirth and Luciano Z. Goldani

Section of Infectious Diseases, Hospital de Clínicas de Porto Alegre, Universidade Federal do Rio Grande do Sul Ramiro Barcelos 2350, 90640-002 Porto Alegre, RS, Brazil

Correspondence should be addressed to Luciano Z. Goldani, lgoldani@ufrgs.br

Received 7 August 2012; Accepted 7 September 2012

Academic Editor: Mary E. Marquart

This is an updated paper focusing on the general epidemiological aspects of *Rhodotorula* in humans, animals, and the environment. Previously considered nonpathogenic, *Rhodotorula* species have emerged as opportunistic pathogens that have the ability to colonise and infect susceptible patients. *Rhodotorula* species are ubiquitous saprophytic yeasts that can be recovered from many environmental sources. Several authors describe the isolation of this fungus from different ecosystems, including sites with unfavourable conditions. Compared to *R. mucilaginosa*, *R. glutinis* and *R. minuta* are less frequently isolated from natural environments. Among the few references to the pathogenicity of *Rhodotorula* spp. in animals, there are several reports of an outbreak of skin infections in chickens and sea animals and lung infections and otitis in sheep and cattle. Most of the cases of infection due to *Rhodotorula* in humans were fungemia associated with central venous catheter (CVC) use. The most common underlying diseases included solid and haematologic malignancies in patients who were receiving corticosteroids and cytotoxic drugs, the presence of CVC, and the use of broad-spectrum antibiotics. Unlike fungemia, some of the other localised infections caused by *Rhodotorula*, including meningeal, skin, ocular, peritoneal, and prosthetic joint infections, are not necessarily linked to the use of CVCs or immunosuppression.

1. Introduction

Rhodotorula is a common environmental yeast that is found in air, soil, lakes, ocean water, milk, and fruit juice. *Rhodotorula* species, part of the Basidiomycota phylum, colonise plants, humans, and other mammals. The genus *Rhodotorula* includes eight species, of which *R. mucilaginosa, R. glutinis, and R. minuta* are known to cause disease in humans [1]. *Rhodotorula* produces pink to red colonies and blastoconidia that are unicellular lacking pseudohyphae and hyphae. Several authors have isolated *Rhodotorula* in different ecosystems and environments as well as described infections in animals. *Rhodotorula* spp. have been recognised as emerging yeast pathogens in humans in the last two decades. While no cases of *Rhodotorula* infection were reported in the medical literature before 1985, the number of infections increased after that time, most likely because of the wider use of intensive treatments and central venous catheters (CVCs) [2].

This is an updated concise paper focusing on the general epidemiological aspects of *Rhodotorula* in humans, animals, and the environment.

2. *Rhodotorula* in the Environment and Nonhumans

Rhodotorula species are ubiquitous saprophytic yeasts that can be recovered from many environmental sources. This yeast has a strong affinity for plastic, having been isolated from various medical equipments, such as dialysis equipment, fibre-optic bronchoscopes, and other environmental sources, including shower curtains, bathtubs, and toothbrushes [3–5].

Several authors describe the isolation of this fungus from different ecosystems, including sites with unfavourable conditions, such as the depths of the Baltic Sea, the high-altitude Lake Patagonia, the soil and vegetation of Antarctica and

aquatic, hypersaline, and high-temperature environments such as the Dead Sea (Israel), Lake Enriquillo (Dominican Republic), the Great Salt Lake (USA), and beaches located in northern Brazil. In this study, *R. mucilaginosa* was the third most isolated yeast in seawater. Two other studies have reported the occurrence of *Rhodotorula* species in marine waters polluted by household waste [6–10].

R. mucilaginosa is commonly isolated from foods and beverages. Several studies have reported the presence of *R. mucilaginosa* in peanuts, apple cider, cherries, fresh fruits, fruit juice, cheese, sausages, edible molluscs, and crustaceans [11–17]. Although the consumption of food contaminated with yeast may not have a direct role in causing opportunistic infections, there is growing concern that food may be an underestimated source of environmental pathogens [18]. Compared to *R. mucilaginosa, R. glutinis* and *R. minuta* are less frequently isolated in natural environments. These species have been detected in air, seawater (including deep environments), freshwater, and goat's milk [19–21]. Environmental studies have documented the presence of *Rhodotorula* sp. in tropical fruits, sugar cane, and shrimp in the waters of Sepetiba Bay in Brazil [22–24]. Tomsíková reported, *Rhodotorula* sp. contamination of food that is provided to immunocompromised patients in hospitals. [25]. In addition, environmental monitoring of yeasts in specific areas of two tertiary local hospitals revealed the presence of *Rhodotorula* species in a substantial amount of air samples [26]. As a direct consequence of the wide exposure to *Rhodotorula* in the hospital environment, patients who have a depressed immune system can develop Rhodotorulosis, causing a variety of systemic infections. In fact, *Rhodotorula* spp. is the most common microorganism isolated from the hands of hospital employees and patients [27]. Further studies are needed to clarify the role of food contamination by *Rhodotorula* and the development of opportunistic fungal infections. These future studies should focus on the survival and growth of *Rhodotorula* in the gastrointestinal system and its potential ability to transfer from the gastrointestinal tract to bloodstream and should seek to better understand the ecology of *Rhodotorula* in hospitals and healthcare environments [28]. In this aspect, *Rhodotorula* spp. have been isolated from stool samples, indicating that these yeasts can survive in the extreme conditions of the gastrointestinal tract, and it is still uncertain whether *Rhodotorula* is capable of passing from the gastrointestinal tract into the bloodstream [29, 30].

Among the few references about the pathogenicity of *Rhodotorula* spp. in animals, there are several reports of an outbreak of skin infections in chickens and a report of a lung infection in sheep, both caused by *R. mucilaginosa* [31, 32]. *Rhodotorula* was reported as the causative agent of epididymitis, skin lesions in a sea lion, and dermatitis in a cat that had crusted lesions and mastitis [33–36]. Interestingly, this fungus can also be found in pools where sea animals are kept in captivity [37]. Duarte et al. have shown the presence of fungi in the ear canal of 45 cattle with external parasitic otitis. The 45 cultures in Sabouraud dextrose medium revealed the growth of the genus *Malassezia* in 31 (68.9%) of the 45 cultures, seven (15.5%) yeasts of the genus Candida, five (11.1%) *R. mucilaginosa*, and two (4.4%) fungi of the genus *Aspergillus* [38]. Some authors have reported the *Rhodotorula* genus as a colonising agent in the oropharynx and cloaca of ostriches, in faecal samples and the cloaca of wild birds and pigeons in urban and suburban areas, in the ear canals of adult cattle with parasitic otitis, in healthy rhesus monkeys, genital tract of healthy female camels, and in healthy cats [39–44].

Animal models have been used to study the mechanisms of pathogenesis of different human fungal diseases. Recently, Wirth and Goldani conducted the first experimental study in an animal model of disseminated *Rhodotorula* infection described in the literature [45]. Organs such as lungs, spleen, and especially the liver were the most affected organs presented severe degree of infection. Considering that the animals were highly immunocompromised, histopathology of the involved organs revealed few epitelioidcellsand multinuclear giant cells in association with abundant yeast forms with occasional granuloma formation.

3. *Rhodotorula* in Humans

Previously considered nonpathogenic, *Rhodotorula* species have emerged as opportunistic pathogens with the ability to colonise and infect susceptible patients. Recent studies have demonstrated that the incidence of fungemia caused by *Rhodotorula* was between 0.5% and 2.3% in the USA [46, 47] and Europe [48]. Most cases of infection with *Rhodotorula* fungemia are associated with central catheters in patients with haematologic malignancies. [46, 47, 49–52]. Considering that *Rhodotorula* is an ubiquitous and saprophytic fungus, the isolation of *Rhodotorula* from nonsterile human sites, especially from the mucous membranes, has often been of questionable clinical significance. Localised infections without fungemia including endophthalmitis, onychomycosis, meningitis, prosthetic joint infections, and peritonitis (usually associated with continuous peritoneal dialysis) have been reported in immunocompromised and immunocompetent patients.

The first report of fungemia caused by *Rhodotorula* was made by Louria et al. in 1960 [47]. Subsequently, an increasing number of cases have been published, especially in the last two decades. However, this increase may be a publication bias after recognition of *Rhodotorula* as a pathogen [52]. Another possible explanation is the dramatic expansion of new treatment modalities related to critical care medicine and transplantation.

From 1970 until 1985, no cases of *Rhodotorula* infection were reported in haematological patients, but the number of cases of *Rhodotorula* infection in these patients increased after 1985. The increase of *Rhodotorula* fungemia related to catheters was associated with an increase of more aggressive treatment modalities, which include intensive care units admissions, use of central venous catheters, short- and long-term parenteral nutrition, broad-spectrum antibiotics, organ transplants, and chemotherapy [51]. Most of cases reported in the literature date back to after 1994, when CVCs and intensive therapies were widely available. Table 1 shows

Table 1: Summary of reports of *Rhodotorula* fungemia (2000–2011).

Reference	Number of described cases	Species	Underlying disease
[46]	7	*R. mucilaginosa*	Hematological-solid malignancies
[52]	10	*R.mucilaginosa* *R.glutinis*	SBD; LT; AIDS
[48]	25	*R. mucilaginosa*	Hematological-solid malignancies; LC; SCA; SBD; CLD
[53]	2	*R. glutinis/R. mucilaginosa*	Lymphoma; solid tumor
[54]	1	*R. mucilaginosa*	Lymphoma
[55]	1	*R. mucilaginosa*	Lymphoma
[56]	2	*R. mucilaginosa*	Acute myeloid leukemia
[57]	1	*R. glutinis*	Nasopharyngeal carcinoma
[58]	1	*R. mucilaginosa*	SBD
[59]	3	*Rhodotorula* spp.	Hematological-solid malignancies
[60]	4	*R. mucilaginosa*	Prematurity
[61]	1	*R. mucilaginosa*	Acute myeloid leukemia
[62]	1	*R. mucilaginosa*	SCA
[63]	2	*R. glutinis*	Broad spectrum antibiotics
[64]	1	*R. glutinis*	Systemic lupus erythematous
[65]	1	*R. glutinis*	Solid organ transplant
[66]	1	*R. glutinis*	Liver cirrhosis
[67]	1	*R. glutinis*	Acute lymphoid leukemia
[68]	1	*R. mucilaginosa*	MS/BMT
[69]	1	*R. mucilaginosa*	Multiple abdominal surgeries; ovarian cancer; bowel necrosis

BMT: bone marrow transplant; CLD: congenital liver disease; LC: liver cirrhosis; LT: lung transplant; MS: myelodysplastic syndrome; SBD: short bowel disease; SCA: sickle cell anemia; SOT: solid organ transplant.

a summary of reported cases of fungemia related to CVC use between 2000 and 2011 [46–68]. In all cases listed, the patients were using CVC, short- or long-term CAPD, and umbilical catheter. Zaas et al. [52] published a large number of cases of CVC-related fungemia by *Rhodotorula* spp. that occurred in a USA hospital [52]. The most prevalent species was *R. mucilaginosa*, followed by *R. glutinis*. Most of the patients had an underlying disease, such as congenital heart disease, AIDS, cancer, or chronic intestinal disease, and two patients were transplant recipients (one lung and one bone marrow). Two patients were neutropenic at the time of the development of fungemia, and five patients were receiving parenteral nutrition. All the patients received antifungal treatment. Only in three patients the CVC was not removed. There were no reports of death or relapse of infection.

Perniola et al. [60] reported four cases of CVC-related fungemia by *R. mucilaginosa* in a neonatal intensive care unit (NICU) in an Italian hospital [60]. All the newborns infected with fungemia by *R. mucilaginosa* were premature; three had bacteremia prior to fungemia, and 3 received prophylactic fluconazole. All 4 neonates had venous access (a CVC, an umbilical venous catheter, or both) since birth, but early removal or replacement of the catheter followed by confirmation of sepsis by *R. mucilaginosa* was possible in only two newborns. Blood cultures performed at the end of antifungal therapy were negative. Another retrospective study reviewed the demographics, risk factors, treatment, and outcome of seven patients with *Rhodotorula* fungemia over the years from 2002 to 2005 in a Brazilian hospital [46]. Risk factors included solid and haematologic malignancies in patients who were receiving corticosteroids and cytotoxic drugs, the presence of CVCs, and the use of broad-spectrum antibiotics. Three of the seven patients died, with an overall mortality rate of 42%. The result was favourable for patients who had just had the CVC removed. Duboc de Almeida et al. described 25 cases of fungemia by *R. Mucilaginosa* [48]. The majority of patients had a CVC, and 10 patients (40%) had undergone bone marrow transplantation. Amphotericin B deoxycholate was the most commonly antifungal used, and the CVC was removed in 89.5% of patients. Four (17%) patients died [55].

In a recent paper covering the cases of fungemia by *Rhodotorula* spp. associated with catheters between the years 1966 and 2006, Tuon et al. analysed 66 patients with *Rhodotorula* fungemia. *R. mucilaginosa* was responsible for most of the cases, followed by *R. glutinis* [50]. The most prevalent underlying diseases were haematologic malignancies and solid tumours. AIDS, chronic renal failure, cirrhosis, and gastrointestinal disorders as well as the use of CVCs for parenteral nutrition were also considered predisposing factors.

A recent literature review published in 2010 by García-Suárez et al. analysed 29 cases of *Rhodotorula* fungemia in patients with haematological disorders [51]. This study showed that 100% of patients who developed fungemia by *Rhodotorula* had some form of central venous access, such as a Hickman catheter. In 2008, Tuon and Costa performed the first systematic review of infections caused

Table 2: Summary of reports of *Rhodotorula* infections other than fungemia from 2000 to 2011.

Reference	Species	Underlying disease	Infection site	Outcome
[70–73]	*R. rubra; R. minuta*	HIV; HCV; NU	Endophthalmitis; keratitis	Alive
[74–78]	*R. rubra; R. glutinis; R. mucilaginosa*	HIV; NU	Meningitis	Alive/Death
[79–81]	*R. mucilaginosa; R. minuta*	HIV; NU	Prosthetic joint	Alive
[82–86]	*R. mucilaginosa*	HIV, SOT; chronic renal failure	Peritonitis	Alive/Death
[87]	*R. mucilaginosa*	NU	Onychomycosis	Alive
[88, 89]	*R. mucilaginosa*	HIV,	Oral ulcers, dermatitis	Alive
[90]	*R. mucilaginosa*	NU	Arotic homograft endocarditis	Alive
[91]	*R. mucilaginosa*	HIV	Lymphadenitis	Alive

HCV: chronic hepatitis C; NU: no underlying disease described; SOT: solid organ transplant.

by *Rhodotorula* in 128 patients [49]. The authors analysed all papers about *Rhodotorula* infections published until January 2006 [46]. The most common *Rhodotorula* species found by the authors was *R. mucilaginosa*, followed by *R. glutinis* and *R. minuta*. Immunosuppression was found in 40% of patients, and the most common underlying condition associated with *Rhodotorula* infection was the use of CVCs. In a recent paper, Spiliopoulou et al. described a patient who developed *Rhodotorula* fungemia in an intensive care unit. The authors reviewed the risk factors associated with the development of disseminated *Rhodotorula* infection published in several reports including presence of central venous catheters, solid organ neoplasm, abdominal surgery, and administration of antibiotics. In addition, the authors pointed out that *Rhodotorula* is reliably resistant to fluconazole and echinocandins [69]. On the other hand, *in vitro* susceptibility studies revealed that *Rhodotorula* is generally susceptible to amphotericin B and flucytosine.

Unlike fungemia, some of the other infections caused by *Rhodotorula* were not necessarily linked to the use of CVCs or an underlying disease. Table 2 lists a summary of cases of localized *Rhodotorula* infection that did not cause fungemia occurring between the years 2000 and 2011 [70–90]. Meningitis and endophthalmitis by *Rhodotorula* species have been reported as nosocomial infections especially in human immunodeficiency virus- (HIV-) infected persons [70–78]. Prosthetic joint infections caused by *Rhodotorula* sp. have been reported in an HIV-infected patient and patients without any known immunosuppression [79–81]. Goyal et al. described a case of infection caused by *R. mucilaginosa* that had been unionised as a fracture of the femur (the femoral nonunion). The patient was treated with amphotericin B and required a bone graft [79]. Savini et al. reported a similar case, but the patient was seropositive for HIV and had fractured their left femur [80]. The infection manifested as a chronic coxitis after the patient had undergone surgery for internal fixation. Antifungal therapy was performed using liposomal amphotericin B, which eradicated the infection, and a surgical replacement of the femoral prosthesis was indicated. Peritonitis caused *Rhodotorula* species which have been reported in patients undergoing continuous ambulatory peritoneal dialysis [82–86]. Most of the patients were successfully treated with amphotericin B, and fluconazole was continued after catheter removal.

The first case of onychomycosis caused by *R. mucilaginosa* was described by Cunha et al., which shows that these yeasts should also be considered as primary agents that can cause opportunistic onychomycosis [87]. The patient was immunocompetent, and the onychomycosis affected the nail of the hallux. In addition to aortic homograft endocarditis, dermatitis, oral ulcers, and lymphadenitis caused by *Rhodotorula* sp. have been reported in the literature [88–91].

4. Conclusions

Rhodotorula species are ubiquitous saprophytic yeasts that can be recovered from many environmental sources. *R. mucilaginosa* is commonly isolated in foods and beverages. Several studies have reported the presence of *R. mucilaginosa* in peanuts, apple cider, cherries, fresh fruits, fruit juice, cheese, sausages, edible molluscs, and crustaceans. *Rhodotorula* was reported as the causative agent in some papers, including dermatitis in sea lions, chickens, and cats, and lung infections and otitis in sheep and cattle. This fungus can also be found in pools where sea animals are kept in captivity. Previously considered nonpathogenic, *Rhodotorula* species have emerged as opportunistic pathogens with the ability to colonise and infect susceptible patients. *Rhodotorula* in humans primarily cause bloodstream infections that are associated with central venous catheter (CVC) use. Risk factors include solid and haematologic malignancies in patients who receive corticosteroids and cytotoxic drugs, the presence of CVCs, and the use of broad-spectrum antibiotics. Unlike fungemia, localised infections caused by *Rhodotorula*, including skin, ocular, meningeal, prosthetic joint, and peritoneal infections, are not necessarily linked to the use of CVCs or an immunosuppression.

References

[1] D. H. Larone, *Medically Important Fungi—A Guide to Identification*, American Society for Microbiology, Washington, DC, USA, 3rd edition, 1995.

[2] M. H. Miceli, J. A. Díaz, and S. A. Lee, "Emerging opportunistic yeast infections," *The Lancet Infectious Diseases*, vol. 11, no. 2, pp. 142–151, 2011.

[3] T. E. Kiehn, E. Gorey, A. E. Brown, F. F. Edwards, and D. Armstrong, "Sepsis due to *Rhodotorula* related to use

of indwelling central venous catheters," *Clinical Infectious Diseases*, vol. 14, no. 4, pp. 841–846, 1992.

[4] M. E. Hagan, S. A. Klotz, W. Bartholomew, L. Potter, and M. Nelson, "A pseudoepidemic of *Rhodotorula rubra*: a marker for microbial contamination of the bronchoscope," *Infection Control and Hospital Epidemiology*, vol. 16, no. 12, pp. 727–728, 1995.

[5] M. A. Pfaller and D. J. Diekema, "Rare and emerging opportunistic fungal pathogens: concern for resistance beyond *Candida albicans* and *Aspergillus fumigatus*," *Journal of Clinical Microbiology*, vol. 42, no. 10, pp. 4419–4431, 2004.

[6] S. Ekendahl, A. H. O'Neill, E. Thomsson, and K. Pedersen, "Characterisation of yeasts isolated from deep igneous rock aquifers of the Fennoscadian Shield," *Microbial Ecology*, vol. 46, no. 4, pp. 416–428, 2003.

[7] D. Libkind, S. Brizzio, and M. Van Broock, "*Rhodotorula mucilaginosa*, a carotenoid producing yeast strain from a Patagonian high-altitude Lake," *Folia Microbiologica*, vol. 49, no. 1, pp. 19–25, 2004.

[8] K. Pavlova, D. Grigorova, T. Hristozova, and A. Angelov, "Yeast strains from Livingston Island, Antarctica," *Folia Microbiologica*, vol. 46, no. 5, pp. 397–401, 2001.

[9] L. Butinar, S. Santos, I. Spencer-Martins, A. Oren, and N. Gunde-Cimerman, "Yeast diversity in hypersaline habitats," *FEMS Microbiology Letters*, vol. 244, no. 2, pp. 229–234, 2005.

[10] A. N. Hagler and L. C. Mendonça-Hagler, "Yeasts from marine and estuarine waters with different levels of pollution in the state of Rio de Janeiro, Brazil," *Applied and Environmental Microbiology*, vol. 41, no. 1, pp. 173–178, 1981.

[11] V. H. Tournas, J. Heeres, and L. Burgess, "Moulds and yeasts in fruit salads and fruit juices," *Food Microbiology*, vol. 23, no. 7, pp. 684–688, 2006.

[12] M. E. Venturini, R. Oria, and D. Blanco, "Microflora of two varieties of sweet cherries: Burlat and Sweetheart," *Food Microbiology*, vol. 19, no. 1, pp. 15–21, 2002.

[13] F. J. Las Heras-Vazquez, L. Mingorance-Cazorla, J. M. Clemente-Jimenez, and F. Rodriguez-Vico, "Identification of yeast species from orange fruit and juice by RFLP and sequence analysis of the 5.8S rRNA gene and the two internal transcribed spacers," *FEMS Yeast Research*, vol. 3, no. 1, pp. 3–9, 2003.

[14] S. Senses-Ergul, R. Ágoston, Á. Belák, and T. Deák, "Characterization of some yeasts isolated from foods by traditional and molecular tests," *International Journal of Food Microbiology*, vol. 108, no. 1, pp. 120–124, 2006.

[15] F. Gardini, G. Suzzi, A. Lombardi et al., "A survey of yeasts in traditional sausages of Southern Italy," *FEMS Yeast Research*, vol. 1, no. 2, pp. 161–167, 2001.

[16] T. Kajikazawa, T. Sugita, M. Takashima, and A. Nishikawa, "Detection of pathogenic yeasts from processed fresh edible sea urchins sold in a fish market," *Nihon Ishinkin Gakkai Zasshi*, vol. 48, no. 4, pp. 169–172, 2007.

[17] M. W. Eklund, J. Spinelli, D. Miyauchi, and H. Groninger, "Characteristics of yeasts isolated from Pacific crab meat," *Applied Microbiology*, vol. 13, no. 6, pp. 985–990, 1965.

[18] G. H. Fleet, "Yeasts in fruit and fruit products," in *Yeasts in Food. Beneficial and Detrimental Aspects*, T. Boekhout and V. Robert, Eds., p. 267, Behr, Hamburg, Germany, 2003.

[19] T. Nagahama, M. Hamamoto, and K. Horikoshi, "*Rhodotorula pacifica* sp. nov., a novel yeast species from sediment collected on the deep-sea floor of the north-west Pacific Ocean," *International Journal of Systematic and Evolutionary Microbiology*, vol. 56, no. 1, Article ID 63584, pp. 295–299, 2006.

[20] D. Libkind, S. Brizzio, A. Ruffini, M. Gadanho, M. van Broock, and J. P. Sampaio, "Molecular characterization of carotenogenic yeasts from aquatic environments in Patagonia, Argentina," *Antonie van Leeuwenhoek*, vol. 84, no. 4, pp. 313–322, 2003.

[21] C. Callon, F. Duthoit, C. Delbès et al., "Stability of microbial communities in goat milk during a lactation year: molecular approaches," *Systematic and Applied Microbiology*, vol. 30, no. 7, pp. 547–560, 2007.

[22] R. C. Trindade, M. A. Resende, C. M. Silva, and C. A. Rosa, "Yeasts associated with fresh and frozen pulps of Brazilian tropical fruits," *Systematic and Applied Microbiology*, vol. 25, no. 2, pp. 294–300, 2002.

[23] L. A. I. de Azeredo, E. A. T. Gomes, L. C. Mendonca-Hagler, and A. N. Hagler, "Yeast communities associated with sugarcane in Campos, Rio de Janeiro, Brazil," *International Microbiology*, vol. 1, no. 3, pp. 205–208, 1998.

[24] F. G. Pagnocca, L. C. Mendonça-Hagler, and A. N. Hagler, "Yeasts associated with the white shrimp *Penaeus schmitti*, sediment, and water of Sepetiba Bay, Rio de Janeiro, Brasil," *Yeast*, vol. 5, pp. S479–S483, 1989.

[25] A. Tomsíková, "Risk of fungal infection from foods, particularly in immunocompromised patients," *Epidemiologie, Mikrobiologie, Imunologie*, vol. 51, no. 2, pp. 78–81, 2002.

[26] R. A. Cordeiro, R. S. N. Brilhante, L. D. M. Pantoja et al., "Isolation of pathogenic yeasts in the air from hospital environments in the city of Fortaleza, Northeast Brazil," *Brazilian Journal of Infectious Diseases*, vol. 14, no. 1, pp. 30–34, 2010.

[27] L. J. Strausbaugh, D. L. Sewell, R. C. Tjoelker et al., "Comparison of three methods for recovery of yeasts from hands of health-care workers," *Journal of Clinical Microbiology*, vol. 34, no. 2, pp. 471–473, 1996.

[28] G. H. Fleet and R. Balia, "The public health and probiotic significance of yeasts in foods and beverages," in *Yeast in Food and Beverages*, A. Querol and G. H. Fleet, Eds., p. 381, Springer, Berlin, Heidelberg, 2006.

[29] J. O. Silva, S. A. Franceschini, M. A. S. Lavrador, and R. C. Candido, "Performance of selective and differential media in the primary isolation of yeasts from different biological samples," *Mycopathologia*, vol. 157, no. 1, pp. 29–36, 2004.

[30] N. Van Uden, "Intestinal yeasts of man and domestic animals," in *Proceedings of the 6th International Congresses on Tropical Medicine and Malaria*, p. 612, 1958.

[31] S. K. Aruo, "Necrotizing cutaneous rhodotorulosis in chickens in Uganda," *Avian Diseases*, vol. 24, no. 4, pp. 1038–1043, 1980.

[32] D. P. Monga and D. N. Garg, "Ovine pulmonary infection caused by *Rhodotorula rubra*," *Mykosen*, vol. 23, no. 4, pp. 208–211, 1980.

[33] K. Kadota, K. Uchida, T. Nagatomo et al., "Granulomatous epididymitis related to *Rhodotorula glutinis* infection in a dog," *Veterinary Pathology*, vol. 32, no. 6, pp. 716–718, 1995.

[34] S. Alvarez-Perez, A. Mateos, L. Dominguez, E. Martinez-Nevado, J. L. Blanco, and M. E. Garcia, "Isolation of *Rhodotorula mucilaginosa* from skin lesions in a Southern sea lion (*Otaria flavescens*): a case report," *Veterinarni Medicina*, vol. 55, no. 6, pp. 297–301, 2010.

[35] P. Bourdeau, B. Hubert, and J. P. Magnol, "Suspicion de dermatomycose à Rhodotorula mucilaginosa chez un chat infecté par le FeLV et le FIV," *Recueil de Médecine Veterinaire*, vol. 168, no. 2, pp. 91–96, 1992.

[36] E. O. Costa, C. R. Gandra, M. F. Pires, S. D. Coutinho, W. Castilho, and C. M. Teixeira, "Survey of bovine mycotic mastitis in dairy herds in the State of São Paulo, Brazil," *Mycopathologia*, vol. 124, no. 1, pp. 13–17, 1993.

[37] J. D. Buck, "Occurrence of human-associated yeasts in the feces and pool waters of captive bottlenosed dolphins (*Tursiops truncatus*)," *Journal of Wildlife Diseases*, vol. 16, no. 1, pp. 141–149, 1980.

[38] E. R. Duarte, J. C. P. Resende, C. A. Rosa, and J. S. Hamdan, "Prevalence of yeasts and mycelial fungi in bovine parasitic otitis in the state of Minas Gerais, Brazil," *Journal of Veterinary Medicine*, vol. 48, no. 8, pp. 631–635, 2001.

[39] P. A. Melville, B. Cogliati, M. B. B. C. D. Mangiaterra et al., "Determinação da microbiota presente na cloaca e orofaringe de avestruzes (*Struthio camelus*) clinicamente sadios," *Ciência Rural*, vol. 34, no. 6, pp. 1871–1876, 2004.

[40] A. T. K. Lord, K. Mohandas, S. Somanath, and S. Ambu, "Multidrug resistant yeasts in synanthropic wild birds," *Annals of Clinical Microbiology and Antimicrobials*, vol. 9, article 11, 2010.

[41] A. K. F. Costa, J. J. C. Sidrim, R. A. Cordeiro, R. S. N. Brilhante, A. J. Monteiro, and M. F. G. Rocha, "Urban pigeons (*Columba livia*) as a potential source of pathogenic yeasts: a focus on antifungal susceptibility of *Cryptococcus* strains in Northeast Brazil," *Mycopathologia*, vol. 169, no. 3, pp. 207–213, 2010.

[42] H. Shokri, A. Khosravi, A. Sharifzadeh, and Z. Tootian, "Isolation and identification of yeast flora from genital tract in healthy female camels (*Camelus dromedarius*)," *Veterinary Microbiology*, vol. 144, no. 1-2, pp. 183–186, 2010.

[43] T. L. Brotto, M. C. R. Andrade, M. A. B. Gonçalves, F. Gimenis, and A. Pina, "Identification of fungi microflora in the ear conducts of rhesus macaques (*Macaca mulatta*) kept in captivity," *Brazilian Journal of Veterinary Research and Animal Science*, vol. 42, no. 6, pp. 459–464, 2005.

[44] R. C. Amaral, J. F. Ibanez, E. M. Mamizuka, W. Gambale, C. R. de Paula, and C. E. Larsson, "Microbiota indígena do meato acústico externo de gatos hígidos," *Ciência Rural, Santa Maria*, vol. 28, no. 3, pp. 4441–4445, 1998.

[45] F. Wirth and L. Z. Goldani, "Experimental Rhodoturolosis in rats," *Acta Pathologica, Microbiologica et Immunologica*, vol. 120, pp. 231–235, 2012.

[46] L. W. Lunardi, V. R. Aquino, R. A. Zimerman, and L. Z. Goldani, "Epidemiology and outcome of *Rhodotorula* fungemia in a tertiary care hospital," *Clinical Infectious Diseases*, vol. 43, no. 6, pp. e60–e63, 2006.

[47] D. B. Louria, S. M. Greenberg, and D. W. Molander, "Fungemia caused by certain nonpathogenic strains of the family *Cryptococcaceae*," *The New England Journal of Medicine*, vol. 263, pp. 1281–1284, 1960.

[48] G. M. Duboc de Almeida, S. F. Costa, M. Melhem et al., "*Rhodotorula* spp. isolated from blood cultures: clinical and microbiological aspects," *Medical Mycology*, vol. 46, no. 6, pp. 547–556, 2008.

[49] F. F. Tuon and S. F. Costa, "*Rhodotorula* infection. A systematic review of 128 cases from literature," *Revista Iberoamericana de Micologia*, vol. 25, no. 3, pp. 135–140, 2008.

[50] F. F. Tuon, G. M. Duboc de Almeida, and S. F. Costa, "Central venous catheter-associated fungemia due to *Rhodotorula* spp.—a systematic review," *Medical Mycology*, vol. 45, no. 5, pp. 441–447, 2007.

[51] J. García-Suárez, P. Gómez-Herruz, J. A. Cuadros, and C. Burgaleta, "Epidemiology and outcome of *Rhodotorula* infection in haematological patients," *Mycoses*, vol. 54, no. 4, pp. 318–324, 2011.

[52] A. K. Zaas, M. Boyce, W. Schell, B. A. Lodge, J. L. Miller, and J. R. Perfect, "Risk of fungemia due to *Rhodotorula* and antifungal susceptibility testing of *Rhodotorula* isolates," *Journal of Clinical Microbiology*, vol. 41, no. 11, pp. 5233–5235, 2003.

[53] C. Alliot, B. Desablens, R. Garidi, and S. Tabuteau, "Opportunistic infection with *Rhodotorula* in cancer patients treated by chemotherapy: two case reports," *Clinical Oncology*, vol. 12, no. 2, pp. 115–117, 2000.

[54] N. Kiraz, Z. Gulbas, and Y. Akgun, "Case report: *Rhodotorula rubra* fungaemia due to use of indwelling venous catheters," *Mycoses*, vol. 43, no. 5, pp. 209–210, 2000.

[55] V. Petrocheilou-Paschou, H. Prifti, E. Kostis, C. Papadimitriou, M. A. Dimopoulos, and S. Stamatelopoulos, "*Rhodotorula* septicemia: case report and minireview," *Clinical Microbiology and Infection*, vol. 7, no. 2, pp. 100–102, 2001.

[56] J. W. Chung, B. N. Kim, and Y. S. Kim, "Central venous catheter-related *Rhodotorula* rubra fungemia," *Journal of Infection and Chemotherapy*, vol. 8, no. 1, pp. 109–110, 2002.

[57] P. R. Hsueh, L. J. Teng, S. W. Ho, and K. T. Luh, "Catheter-related sepsis due to *Rhodotorula glutinis*," *Journal of Clinical Microbiology*, vol. 41, no. 2, pp. 857–859, 2003.

[58] V. Lo Re, N. O. Fishman, and I. Nachamkin, "Recurrent catheter-related *Rhodotorula rubra* infection," *Clinical Microbiology and Infection*, vol. 9, no. 8, pp. 897–900, 2003.

[59] G. C. Pasqualotto, F. A. Copetti, C. F. Meneses, A. R. Leal Machado, and A. L. Brunetto, "Infection by *Rhodotorula* sp. in children receiving treatment for malignant diseases," *Journal of Pediatric Hematology/Oncology*, vol. 27, no. 4, pp. 232–233, 2005.

[60] R. Perniola, M. L. Faneschi, E. Manso et al., "*Rhodotorula mucilaginosa* outbreak in neonatal intensive care unit: microbiological features, clinical presentation, and analysis of related variables," *European Journal of Clinical Microbiology and Infectious Diseases*, vol. 25, no. 3, pp. 193–196, 2006.

[61] E. Luckman, "*Rhodotorula mucilaginosa*," *The Johns Hopkins Microbiology Newsletter*, vol. 26, no. 16, 2007.

[62] D. Neofytos, D. Horn, and J. A. De Simone Jr., "*Rhodotorula mucilaginosa* catheter-related fungemia in a patient with sickle cell disease: case presentation and literature review," *Southern Medical Journal*, vol. 100, no. 2, pp. 198–200, 2007.

[63] D. Kofteridis, E. Mantadakis, A. Christidou, and G. Samonis, "*Rhodotorula glutinis* fungemia successfully treated with fluconazole: report of two cases," *International Journal of Infectious Diseases*, vol. 11, no. 2, pp. 179–180, 2007.

[64] U. Pamidimukkala, S. Challa, V. Lakshmi, A. Tandon, S. Kulkarni, and S. Raju, "Sepsis and meningoencephalitis due to *Rhodotorula glutinis* in a patient with systemic lupus erythematosus, diagnosed at autopsy," *Neurology India*, vol. 55, no. 3, pp. 304–307, 2007.

[65] D. J. Riedel, J. K. Johnson, and G. N. Forrest, "*Rhodotorula glutinis* fungemia in a liver-kidney transplant patient," *Transplant Infectious Disease*, vol. 10, no. 3, pp. 197–200, 2008.

[66] F. Pulvirenti, P. Pasqua, E. Falzone, F. Maffeo, C. Gugliara, and L. Guarneri, "Sepsi da *Rhodotorula glutinis*. Descrizione di um caso clinico," *Le Infezioni in Medicina*, vol. 18, no. 2, pp. 124–126, 2010.

[67] I. Al-Obaid, Z. U. Khan, S. Ahmad et al., "Persistent catheter-related Rhodotorula mucilaginosa fungemia in a leukemic child," *Journal de Mycologie Medicale*, vol. 21, no. 2, pp. 134–137, 2011.

[68] T. Mori, Y. Nakamura, J. Kato et al., "Fungemia due to *Rhodotorula mucilaginosa* after allogeneic hematopoietic stem cell transplantation," *Transplant Infectious Disease*, vol. 14, no. 1, pp. 91–94, 2012.

[69] A. Spiliopoulou, E. D. Anastassiou, and M. Christofidou, "*Rhodotorula* fungemia in an intensive care unit patient and

review of published cases," *Mycopathologia*, vol. 174, no. 4, pp. 301–309, 2012.

[70] A. Pinna, F. Carta, S. Zanetti, S. Sanna, and L. A. Sechi, "Endogenous *Rhodotorula minuta* and *Candida albicans* endophthalmitis in an injecting drug user," *British Journal of Ophthalmology*, vol. 85, no. 6, p. 759, 2001.

[71] A. B. Merkur and W. G. Hodge, "*Rhodotorula rubra* endophthalmitis in an HIV positive patient," *British Journal of Ophthalmology*, vol. 86, no. 12, pp. 1444–1445, 2002.

[72] A. M. Bawazeer and W. G. Hodge, "*Rhodotorula* infection in a corneal graft following penetrating keratoplasty," *Canadian Journal of Ophthalmology*, vol. 38, no. 3, pp. 225–227, 2003.

[73] T. Lifshitz and J. Levy, "*Rhodotorula rubra* keratitis and melting after repeated penetrating keratoplasty," *European Journal of Ophthalmology*, vol. 15, no. 1, pp. 135–137, 2005.

[74] V. P. Baradkar and S. Kumar, "Meningitis caused by *Rhodotorula mucilaginosa* in human immunodeficiency virus seropositive patient," *Annals of Indian Academy of Neurology*, vol. 11, no. 4, pp. 245–247, 2008.

[75] R. S. Shinde, B. G. Mantur, G. Patil, M. V. Parande, and A. M. Parande, "Meningitis due to *Rhodotorula glutinis* in an HIV infected patient," *Indian Journal of Medical Microbiology*, vol. 26, no. 4, pp. 375–377, 2008.

[76] M. Lanzafame, G. De Checchi, A. Parinello, M. Trevenzoli, and A. M. Cattelan, "*Rhodotorula glutinis*-related meningitis," *Journal of Clinical Microbiology*, vol. 39, no. 1, p. 410, 2001.

[77] O. H. Gyaurgieva, T. S. Bogomolova, and G. I. Gorshkova, "Meningitis caused by *Rhodotorula rubra* in an HIV-infected patient," *Journal of Medical and Veterinary Mycology*, vol. 34, no. 5, pp. 357–359, 1996.

[78] K. Thakur, G. Singh, S. Agarwal, and L. Rani, "Meningitis caused by *Rhodotorula rubra* in an human immunodeficiency virus infected patient," *Indian Journal of Medical Microbiology*, vol. 25, no. 2, pp. 166–168, 2007.

[79] R. Goyal, S. Das, A. Arora, and A. Aggarwal, "*Rhodotorula mucilaginosa* as a cause of persistent femoral nonunion," *Journal of Postgraduate Medicine*, vol. 54, no. 1, pp. 25–27, 2008.

[80] V. Savini, F. Sozio, C. Catavitello et al., "Femoral prosthesis infection by *Rhodotorula mucilaginosa*," *Journal of Clinical Microbiology*, vol. 46, no. 10, pp. 3544–3545, 2008.

[81] A. F. Cutrona, M. Shah, M. S. Himes, and M. A. Miladore, "*Rhodotorula minuta*: an unusual fungal infection in hip-joint prosthesis," *American Journal of Orthopedics*, vol. 31, no. 3, pp. 137–140, 2002.

[82] A. Soylu, F. Demircioglu, M. Turkmen, M. Yucesoy, and S. Kavukcu, "Unusual cause of peritonitis during peritoneal dialysis. *Rhodotorula rubra* and amphotericin B," *Pediatric Nephrology*, vol. 19, no. 12, pp. 1426–1428, 2004.

[83] J. R. de Zoysa, M. Searle, K. L. Lynn, and R. A. Robson, "Successful treatment of CAPD peritonitis caused by *Rhodotorula mucilaginosa*," *Peritoneal Dialysis International*, vol. 21, no. 6, pp. 627–628, 2001.

[84] A. Alothman, "*Rhodotorula* species peritonitis in a liver transplant recipient: a case report," *Saudi Journal of Kidney Diseases and Transplantation*, vol. 17, no. 1, pp. 47–49, 2006.

[85] A. Ünal, A. N. Koc, M. H. Sipahioglu et al., "CAPD-related peritonitis caused by *Rhodotorula mucilaginosa*," *Peritoneal Dialysis International*, vol. 29, no. 5, pp. 581–582, 2009.

[86] A. Unal, I. Kocyigit, M. H. Sipahioglu, B. Tokgoz, O. Oymak, and C. Utas, "Fungal peritonitis in peritoneal dialysis: an analysis of 21 cases," *International Urology and Nephrology*, vol. 43, no. 1, pp. 211–213, 2011.

[87] M. M. L. da Cunha, L. P. B. dos Santos, M. Dornelas-Ribeiro, A. B. Vermelho, and S. Rozental, "Identification, antifungal susceptibility and scanning electron microscopy of a keratinolytic strain of *Rhodotorula mucilaginosa*: a primary causative agent of onychomycosis," *FEMS Immunology and Medical Microbiology*, vol. 55, no. 3, pp. 396–403, 2009.

[88] R. Kaur, A. Wadhwa, and S. K. Agarwal, "*Rhodotorula mucilaginosa*: an unusual cause of oral ulcers in AIDS patients," *AIDS*, vol. 21, no. 8, pp. 1068–1069, 2007.

[89] A. D. Means, K. Sisto, V. Lichon, D. Monaghan, P. O'Keefe, and R. Tung, "Cutaneous Rhodotorula treated with photodynamic therapy," *Dermatologic Surgery*, vol. 38, no. 7, part 1, pp. 1100–1103, 2012.

[90] M. Maeder, P. R. Vogt, G. Schaer, A. von Graevenitz, and H. F. Günthard, "Aortic homograft endocarditis caused by *Rhodotorula mucilaginosa*," *Infection*, vol. 31, no. 3, pp. 181–183, 2003.

[91] H. B. Fung, C. A. Martyn, A. Shahidi, and S. T. Brown, "*Rhodotorula mucilaginosa* lymphadenitis in an HIV-infected patient," *International Journal of Infectious Diseases*, vol. 13, no. 1, pp. e27–e29, 2009.