Health of cultivated oysters: a literature review

Sanidade de ostras cultivadas: uma revisão de literatura

Abstract: Oysters pose a high risk to public health because, as filter-feeding organisms, they accumulate large quantities of microorganisms present in contaminated water. Thus, we aim in this work, conducting research on the presence of fungi, yeast and bacteria isolated from cultivated oysters, through an extensive literature review in the last ten years. We carried out a bibliographical in February 2023, using the descriptors: "bivalve mollusc", "oyster farming", "oyster farming", "fungi", "yeasts" and "bacteria". The studies selected include articles related to the health of oysters cultivated in Brazil and in the world. We collected a total of 719 articles distributed in the Science Direct (395), Scielo (06), Google Scholar (127) and PubMed (191) databases. Only 20 articles met the criteria for inclusion in the research. The papers surveyed were mostly published in Korea, India, and the Philippines, in the year 2020. The study reveals the scarcity of aspect involving fungi and yeasts isolated from cultivated oysters. The selected authors identified bacteria of the genus *Vibrio* spp., *Escherichia coli* and *Salmonella* sp. in most of their works. Thus, it is necessary to increase studies that can assess the risks that such pathogenic organisms may cause in cultivable oysters and prevent damage to human and animal health.

Keywords: Fungi; bacteria; oyster farming.

Resumo: Ostras representam um alto risco à saúde pública, pois, como organismos filtradores, acumulam grandes quantidades de microrganismos presentes em águas contaminadas. Assim, objetivamos neste trabalho, realizar pesquisas sobre a presença de fungos, leveduras e bactérias isoladas de ostras cultivadas, através de uma extensa revisão de literatura nos últimos dez anos. Realizamos levantamento bibliográfico em fevereiro de 2023, utilizando os descritores: "molusco bivalve", "criação de ostras", "criação de ostras", "fungos", "leveduras" e "bactérias". Os estudos selecionados incluem artigos relacionados à saúde das ostras cultivadas no Brasil e no mundo. Coletamos um total de 719 artigos distribuídos nas bases de dados Science Direct (395), Scielo (06), Google Scholar (127) e PubMed (191). Apenas 20 artigos atenderam aos critérios de inclusão na pesquisa. Os artigos pesquisados foram publicados em sua maioria na Coreia, Índia e Filipinas, no ano de 2020. O estudo revela a escassez de aspectos envolvendo fungos e leveduras isolados de ostras cultivadas. Os autores selecionados identificaram bactérias do gênero *Vibrio* spp., *Escherichia coli* e *Salmonella* sp. na maioria de suas obras. Assim, faz-se necessário incrementar

estudos que possam avaliar os riscos que tais organismos patogênicos podem causar em ostras cultiváveis e prevenir danos à saúde humana e animal.

Palavras-chave: Fungos; bactérias; cultivo de ostras.

INTRODUCTION

Aquaculture is an important source of mollusk production, mainly bivalves. These are species that have a positive environmental impact and bring significant nutritional benefits to consumers (FAO, 2020). The latest edition of the report “The State of World Fisheries and Aquaculture 2024” indicates that global fisheries and aquaculture production in 2022 amounted to 223.2 million t, 4.4% more than in 2020; production included 185.4 million t of aquatic animals and 37.8 million t of algae. Latin America and the Caribbean achieved 17.7 million t of fisheries and aquaculture production, 8% of the world total, rising to 9% when only aquatic animal production is considered (FAO, 2024).

The cultivation of oysters is linked to the environmental conditions of the cultivation area, being subject to the abiotic and biological characteristics (CHAGAS et al., 2021) and the type of management/cultivation (BANNISTER et al., 2019; VALE et al, 2020). Oysters are filter feeders and bioaccumulators, which feed on microalgae, organic and inorganic matter found in the water and retained by the gills, an organ also responsible for absorbing oxygen (SANTOS, BARRETO, SILVA, 2014). Due to the filter feeding habit of oysters, the diet of these animals is based on particles suspended in water, which can cause pathogenic microorganisms present in the production environment to accumulate in the tissues of the bivalve (TROMBETA, NORMANDE, 2017). Therefore, they can accumulate both viruses and bacteria when cultivated in places with the presence of these microorganisms (ABDELZAHER et al., 2009).

The microbiota of oyster meat is directly related to the environment in which it operates. Therefore, these molluscs pose a great risk in their consumption because they are filter feeders and bioaccumulators of microorganisms, which is why they are widely used as bioindicators (SALLES et al., 2017; PHAM et al., 2020). The risks associated with the consumption of molluscs, in many countries, determined the development of a set of own standards in the commercialization process, based on microbiological analyzes of the culture water and/or its meat (SILVA et al., 2004).

According to data from the Ministry of Health's Information and Notifiable Diseases System (SINAN), outbreaks involving fish in Brazil account for 2.1% of cases (SINAN, 2019). The presence of fungi in products of biological origin represents a risk factor for human and animal health, given the potential for producing mycotoxins with carcinogenic, hepatotoxic, neurotoxic and

nephrotoxic properties (MONTEIRO, 2018). Thus, oysters are seen as high-risk foods, being largely associated with cases of food poisoning and infection, probably because of increased environmental pollution (NASCIMENTO et al., 2011). The microbiota of most bivalve molluscs is quite diverse and may include viruses and bacteria (Staley et al., 2012). All these pathogens can be transmitted from the environment to humans at the time of ingestion of the mollusk, for this reason, contaminated oysters present a high potential risk to the health of consumers (BRASIL, 2012).

Periodic microbiological analyzes of water from crops and bivalve mollusks make up an excellent parameter indicator of contamination by pathogenic microorganisms. Although the quality of mollusks is dependent on many factors, such as pollution discharge, which can carry toxic substances and various microorganism, toxin -producing microscopic algae and inadequate post-harvest management, water quality is undeniably one of the most important factors (JENKINS et al., 2009).

Several pathogens can be associated with bivalve mollusks causing damage and diseases, with the main organisms belonging to the protozoa group *Sphenophrya* sp., *Trichodina* sp., *Ancistrocoma* sp., *Nematopsis* sp., *Perkinsus* sp., *Tylocephalum* sp. (RLOS) and *Ostracobable implexa* fungus (SCARDUA et al., 2017)

Oysters pose a great risk to consumers, because among marine animals captured in environments contaminated by microorganisms, bivalve molluscs are those that pose the greatest risks to Public Health, as they are filter-feeding and bioaccumulating organisms (FIGUEIREDO et al., 2015). Fungi are dispersed in the environment, in vegetables, atmospheric air, soil, water, in food, in general debris, in animals and in man; mostly, fungi are strict aerobic organisms, except for certain optional anaerobic fermenting yeasts, which can develop in a reduced oxygen environment or even in their absence (MANOHARACHARY et al., 2016).

Given the above, one realizes the importance of a literary basis that assists in the knowledge of the possible organisms acting in the health of oysters. Thus, we aim in this work, conducting research on the presence of fungi, yeast and bacteria isolated from cultivated oysters, through an extensive literature review in the last ten years.

MATERIAL AND METHODS

We conducted a bibliographic survey in the Science Direct databases, periodic portal of the Higher Education Personnel Improvement Coordination (CAPES) and Scientific Electronic Library Online (Scielo), Google Scholar and PubMed in February 2023 using the combination of six Descriptors: “Mollusco Bivalve”, “ostreiculture”, “oyster cultivation”, “fungi”, “yeast” and “bacteria”. The intersection of the descriptors occurred through the boolean operators “or” and “and”. The articles published from 2013 to February 2023 were considered. The studies selected to

compose this research include articles related to the health of oysters cultivated in Brazil and worldwide. Articles were excluded in which the studies were not conducted from the collection of oysters from cultivation.

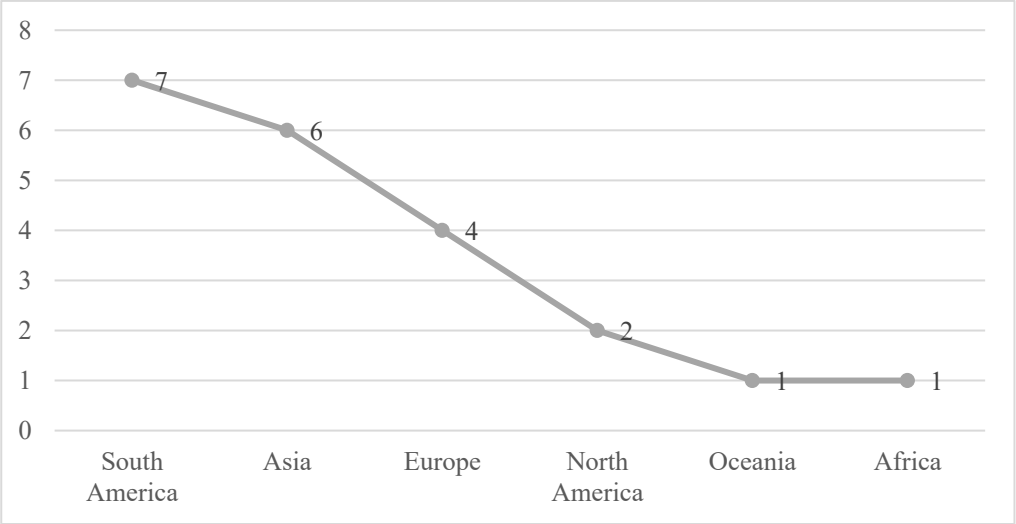
After the electronic search procedure in the mentioned databases, the title and summary were read to identify if the articles met the established criteria for inclusion in the research. Then we selected the articles to identify those who composed the final sample of this bibliographic review. Therefore, this study is an exploratory research and, from the point of view of technical procedures, is classified as bibliographic research prepared from material already published (KAUARK, MANHÃES, MEDEIROS, 2010).

RESULTS

Published studies

Overall, we found 719 articles distributed in Science Direct (395), Scielo (06), Google Academic (127) and Pubmed (191) databases. Of the total articles raised, only 20 met the criteria for inclusion in the research. There were no articles that met the inclusion criteria for this research in the Scielo database. Although Asia, with emphasis on Korea, India and the Philippines, concentrated most of the studies in 2020, South America, especially Brazil, also contributed significantly to research in the area, as seen in graph 1. The research focused mainly on the pathogenic bacteria *Vibrio parahaemolyticus* and *Escherichia coli* (graph 2). Only one article reported fungi and yeasts isolated from oysters cultivated in three of the four databases where the research took place. Oysters of the genus *Crassostrea* sp. were the main genus used for the isolation of fungi and bacteria for identification purposes, especially of bacteria of the genus *Vibrio* sp., followed by *Escherichia coli* and *Salmonella* (Table 1 and table 2).

Grafic 1. Continental distribution that the studies were reported.



Grafic 2. Etiological agents reported in the studies found.

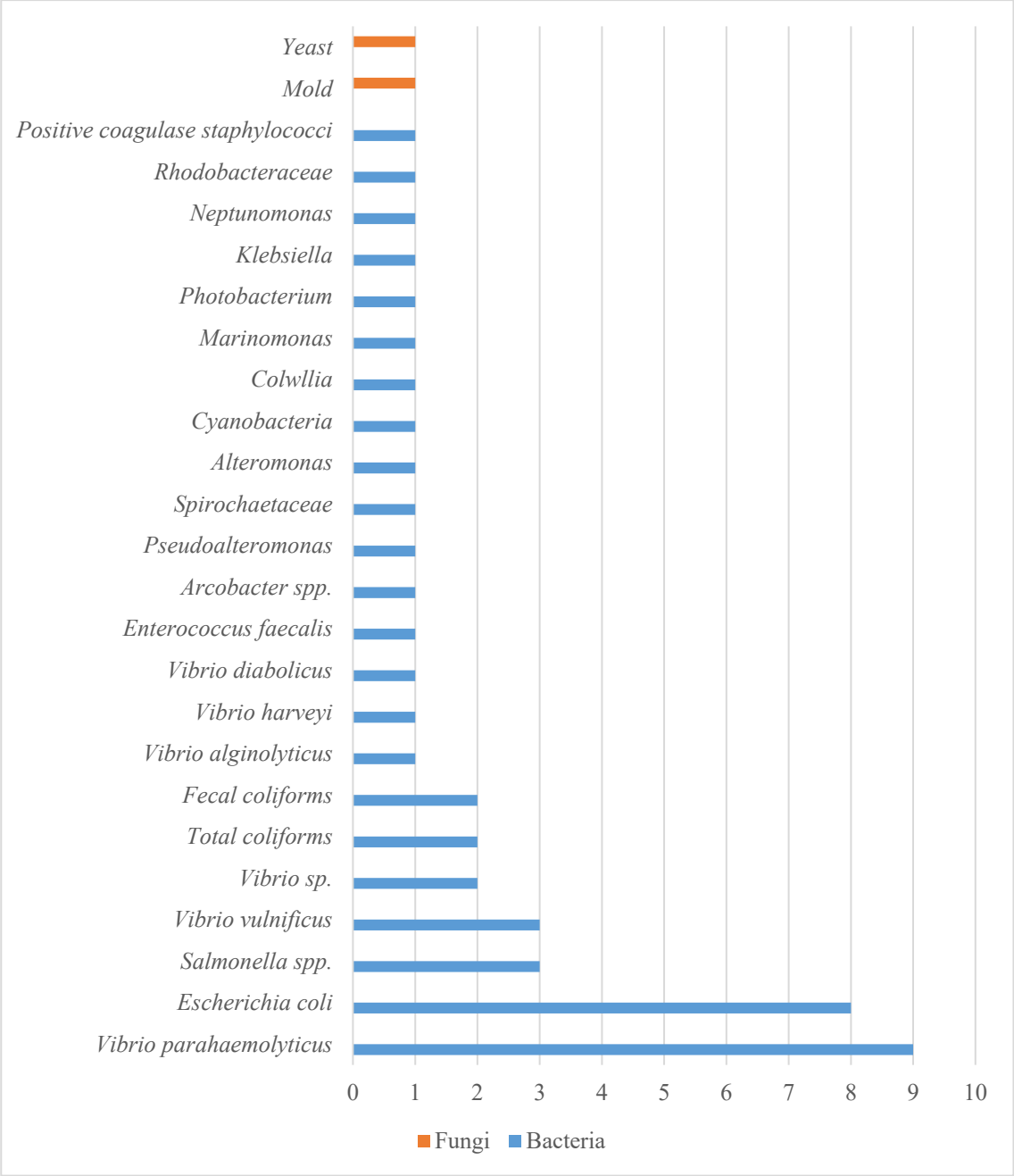


Table 1. Articles found in data survey, highlighting the authors (references) database used, research microorganisms, periodicals, and thematic area.

Microorganisms	References	Journal	Thematic area
		Science Direct	
Fungi and yeast	SILVA et al., 2020a	Aquaculture Reports	Microbiology
Bacteria	BRANDÃO et al., 2017	Journal of Food Protection	Microbiology
	SILVA et al., 2018b	Marine Pollution Bulletin	Biochemistry
	LORENZONI et al., 2021	Journal of Food Protection	Taxonomy and Ecology
	NEETOO et al., 2022	Journal of Food Protection	Microbiology
	PAKINGKING, 2022	Journal of Food Protection	Microbiology
	NUÑAL et al., 2023	Journal of Food Protection	Microbiology
	OYANEDEL et al., 2023	Journal of Invertebrate Pathology	Taxonomy
		Google Scholar	
Bacteria	CHINNADURAI et al., 2016a	Regional Studies in Marine Science	Ecology
	CHINNADURAI et al., 2021b	Aquaculture	Microbiology
	MUDADU et al., 2021	Food Control	Microbiology
		PubMed	
Bacteria	NETA et al., 2015	Genetics and Molecular Research	Microbiology

Microorganisms	References	Host	Etiological agent	Study area
	KANG et al., 2016	Environmental Science and Pollution Research		
		Science Direct		
	KIM et al., 2017	Environmental Science and Pollution Research	*Escherichia coli, positive coagulase*	Ecology
Fungi and yeast	VEZZULLI et al., 2017 Silva et al., 2020	*Crassostrea gasar*	Microbial ecology *staphylococci, mold, yeast,* and *Salmonella* spp.	Molecular ecology Pará, Brazil.
	AAGESEN et al., 2018	Microbial ecology		Microbiology
	OSTRENSKY et al., 2018	Journal of applied Microbiology		Microbiology,
Bacteria	BRANDÃO et al., 2017 CANTY et al., 2020 HORODESKY et al., 2020	*Crassostrea rhizophorae*	Environmental Microbiology *Escherichia coli* and *Vibrio parahaemolyticus*	South Coast of Bahia, in the northeast of Brazil
		Anais da Academia Brasileira de Ciências		Taxonomy
	PRUENTE et al., 2020 SILVA et al., 2018	Oyster *Crassostrea rhizophorae* and	International Journal of Food Microbiology *Vibrio parahaemolyticus*	Bahia, Brazil Microbiology

Table 2. Summary of the raised studies that are cultivated in the world, ordered by the database.

	mussel *Mytella guyanensis*)		
LORENZONI et al., 2021	Bivalve mollusks *Mytilus galloprovincialis, Crassostrea gigas* and *Ruditapes decussatus*	*Vibrio parahaemolyticus* and *Vibrio vulnificus*	Sardinia, Italy
NEETOO et al., 2022	Fishes *Scarus ghobban*, *Lethrinus nebulosus*, *Siganus sutor*, *Epinephelus fasciatus*, *Sciaenops ocellatus* and *Dicentrarchus labrax*; oysters *Saccostrea cucullata* [It is cultivated]) and sea urchins *Tripneustes gratilla*	*Vibrio alginolyticus, Vibrio parahaemolyticus, Vibrio harveyi* and *Vibrio diabolicus*	Réduit, Moka
SILVA et al., 2022a	*Crassostrea iredalei*	*Escherichia coli* and *Salmonella*	Province of Capiz, Western Visayas, Philippines
NUÑAL et al., 2023	Mussel *Perna viridis* and oysters *Magallana*	*Escherichia coli, Salmonella spp., Vibrio parahaemolyticus*	Western Visayas, Philippines

		bilineata	and *Vibrio cholerae*	
	OYANEDEL et al., 2023	*Crassostrea gigas*	*Vibrio* sp.	Tongoy Bay, Chile
Google Scholar				
Bacteria	CHINNADURAI et al., 2016	*Crassostrea madrasensis*	Total coliforms, Fecal coliforms, *Escherichia coli*, *Enterococcus faecalis*	Ashtamudi Lake (Kerala, India)
	MUDADU et al., 2021	*Mytilus galloprovincialis, Crassostrea gigas, Tapes decussatus*	*Arcobacter* spp.	Cultivation Farms in Sardinia (Italy)
	CHINNADURAI et al., 2021b	*Crassostrea madrasensis*	Total plate counts, Faecal coliforms, Total coliforms, Faecal *Streptococci*, *Escherichia coli*, *Salmonella* spp., and *Vibrio* spp.	Commercial Farm in Ashtamudi Estuary, Along the Southwest Coast of India
PubMed				
Bacteria	NETA et al., 2015	*Crassostrea rhizophorae*	Coliforms at 35 ° C, Enterobacteriaceae, Aerobic and Psychrotrophic mesophils	Porto do Campo in Camamu Bay - Bahia, Brazil
	KANG et al., 2016	*Crassostrea gigas*	*Vibrio parahaemolyticus*	West Coast of Korea
	KIM et al., 2017	*Crassostrea gigas*	Total and Fecal Coliforms, *Escherichia coli*	Aquaculture Farm, Korea

VEZZULLI et al., 2017	*Crassostrea gigas*	*Vibrio* sp., Pseudoalteromona, Spirochaetaceae, Alteromonas, Cyanobacteria, Colwllia, Marinomonas, Photobacterium, Klesbiella, Neptunomonas, Rhodobacteraceae	Seafood Farm, Gulf of La Spezia, Italy
AAGESEN et al., 2018	*Crassostrea gigas*	*Vibrio parahaemolyticus*	Oregon Oysters Farm, Newport, Oregon
OSTRENSKY et al., 2018	*Crassostrea gasar*	Bacterial microbiota of the philos: Acidobacteria, Actinobacteria, Armatimonadetes, Bacteroidetes, Caldithrix, Chlamydiae, Chlorobi, Chloroflexi, Crenarchaeota, Cyanobacteria, Elusimicrobia, Euryarchaeota, Fibrobacteres, Firmicutes, Fusobacteria, Gemmatimonadetes, Lentisphaerae,	Marine farms in Guaratuba Bay, on the coast of the state of Paraná, Brazil

		Planctomycetes, Proteobacteria, Spirochaetes, Tenericutes, Verrucomicrobia	
CANTY et al., 2020	*Crassostrea virginica*	*Vibrio vulnificus* and *Vibrio parahaemolyticus*	Bay of Cedar Island, Jarrett Bay, and the Newport River estuary
HORODESKY et al., 2020	*Crassostrea* sp.	Bacterial microbiota	Macau and Tibau do Sul in Rio Grande do Norte, Marking (Paraíba), Passo do Camaragibe and Barra de São Miguel in Alagoas, Brejo Grande and Indiaroba in Sergipe, Brazil
PRUENTE et al., 2020	*Crassostrea virginica*	*Vibrio vulnificus* and *Vibrio parahaemolyticus*	Cowell, Australia

DISCUSSION

The study reveals the scarcity of research focused on ecology, microbiology, taxonomy or any other aspect involving fungi and yeasts isolated from cultivated oysters. The research conducted by Silva et al. (2020), mentions the isolation of fungi and yeast in *C. Gasar* cultivation in the state of Pará, in Brazil; however, microorganisms were not identified at a specific level, attributing to the taxonomic group co-company as sporadic and unusual in mollusks.

Fungi produce mycotoxins that are secondary metabolic considered harmful to both human and animal health (EISENMAN, CASADEVALL, 2012; IARC, 1993), and some types of these molecules have carcinogenic action and may also interfere with the replication of affected DNA (WHO-IARC, 1993; MAKUN et al., 2011; ISMAIEL, PAPENBROCK, 2015). By ingesting products containing high concentrations of Aflotoxin B1 (AFB1), secondary metabolics produced by some species of fungi of the genus *Aspergillus* sp., the effects may be immunosuppressors, mutagenic, teratogenic, carcinogenic, and hepatotoxic (EISENMAN, CASADEVALL, 2012). Fumonisins, mycotoxins produced by *Fusarium* sp. and ochratoxin A (AO), toxin produced by fungi of *Aspergillus* and *Penicillium* genres are currently classified by IARC (1993) as class 2B, designated to probable carcinogenic agents for humans. Still, shyness is observed when referring to the study of this isolated taxonomic group of cultivated oysters that, in most cases, are consumed in natura. Borzykh and Zvereva, 2018 identified fungi of the genus *Fusarium* sp. and *Penicillum* sp. in oysters Crassostrea gigas on Rikord Island, Sea of Japan. The isolation of the genera was also carried out from the scallop *Nodipecten nodosuns* in Angra dos Reis Bay, RJ, Brazil (Santos et al., 2016) and in scallop *Mizuhopecten yessoensis* in Rikord Island, Sea of Japan (Borzykh and Zvereva, 2018). The genus *Penicillium* was also found in gill arches, intestine and muscle of the scallop *Nodipecten nodosuns* in Brazil (Santos et al., 2016), in the mantle, adductor muscle, kidneys, gills, hepatopancreas, and gonads of mussels *Modiolus modiolus* and *Crenomytilus grayanus* in Ussuriiskii Bay, Peter the Great Bay, Sea of Japan (Zvereva and Vysotskaya, 2005), scallop *Mizuhopecten yessoensis* and mussel *Mytilus trossulus* in Rikord Island, Sea of Japan (Borzykh and Zvereva, 2018). The genus *Aspergillus* has already been identified in Brazil isolated from other mollusks such as scallop *Nodipecten nodosuns* (Santos et al., 2016), in Japan in scallop *Mizuhopecten yessoensis* (Borzykh and Zvereva, 2018) and in mussels *Modiolus modiolus* and *Crenomytilus grayanus* also in Japan (Zvereva and Vysotskaya, 2005).

Bacteria of the genus *Vibrio* spp. were identified in most of the work. Probably this factor is associated with the epidemiological importance of the genre (AUSTIN, 2010), as some species are considered pathogenic for human health such as *V. pahaemolyticus* and *V. vulnifus* (AUSTIN, 2010; SOUSA, 2004; SILVA et al., 2018). These organisms were the most reported in the studies

tabulated in the present research. Both species cause infections commonly related to ingestion of raw or poorly cooked animals (OLIVER, 2013).

The bacterium *Vibrio parahaemolyticus* was isolated in 45% of studies, being detected in a variety of marine organisms and geographic regions. Among the hosts, fish (such as *Scarus ghobban*, *Lethrinus nebulosus*, *Siganus sutor*, *Epinephelus fasciatus*, *Sciaenops ocellatus* and *Dicentrarchus labrax*), bivalve molluscs (oysters of the genera *Saccostrea*, *Crassostrea* and *Magallana*, mussels of the genera *Mytella*, *Perna* and *Mytilus*) and sea urchins (*Tripneustes gratilla*) stand out. The presence of *V. parahaemolyticus* has been confirmed in different regions, including the Indian Ocean (Réduit, Moka), the Atlantic Ocean (Southern coast of Bahia, Brazil; Cedar Island Bay, Jarrett Bay and Newport River estuary, United States; West coast of Korea; Oregon Oyster Farm, Newport, Oregon; Cowell, Australia) and the Pacific Ocean (Western Visayas, Philippines; Sea of Japan; Sardinia, Italy), as shown in Table 2. *V. parahaemolyticus* is considered a zoonosis with more frequent cases of infections, although lighter; in humans can generate diarrhea with abdominal cramps, nausea, vomiting and fever (DRAKE., DEPAOLA, JAYKUS, 2007; JONES, OLIVER, 2009), besides to find marine animals (VASEEHARAN, RAMASAMY, 2003). *V. vulnifus* cases are considered less frequent, however, their effects may be more severe, especially in immunocompromised individuals, and as symptoms of infection can cause fever, hypotension, and chills (YEUNG, BOOR, 2004), while *Salmonella* sp. and *E. coli*, if found in animals, are indicative of fecal contamination (LEES, 2000), but all species are constantly associated with food transmitted diseases that can raise risks to human health (LEES, 2000; OLIVEIRA et al, 2011). The results obtained in this study reveal a high prevalence of pathogenic bacteria in oysters and reinforce the importance of continued research to understand the ecology and epidemiology of these bacteria, as well as to develop effective strategies for the control and prevention of foodborne diseases.

The constant frequency of studies with oysters of the genus *Crassostrea* sp. It is directly related to its source of nutrients (SOLETCHNIK et al., 2002) and ease of cultivation (FAO, 2014), which guarantee their broad marketing worldwide (FAO, 2014). These factors can be unfeasible when oysters become susceptible to the presence of pathogens when cultivated, and this reflects the need for increased studies and consequently measures that may minimize the risks to human health in the consumption of products originating from aquaculture (CHINNADURAI et al., 2021).

CONCLUSION

The study reveals that there is a scarcity of research aimed at identifying fungi and isolated yeasts from cultivated oysters, even considering the aggravation that these microorganisms are producing toxins potentially carcinogenic to man, especially because oysters are consumed mainly in raw form.

Bacteria of the genres *Vibrio* spp. and *Salmonella* sp., and the *E. coli* species are commonly associated with cultivation oysters and are configured in the main pathogenic organisms that cause concern for public health.

Ostreculture is growing significantly and is accompanied by the need to obtain research that aims at the broader knowledge of the health of these organisms, especially because oysters have bioaccumulation potential, making them an important reservoir of pathogens.

PATENTS

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