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Registry of saprolegniose in fish cultivated in the world: a compilation of data

Registro de saprolegniose em peixes cultivados no mundo: uma compilação de dados

Registro de saprolegniose en peces cultivados en el mundo: una compilación de datos

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Abstract

Saprolegniosis is a mycological disease that causes significant economic losses in fish culture and can be considered an obstacle to the development of world fish farming. Thus, we aimed to identify which species of fish cultivated in the world have been associated with fungi of the genus *Saprolegnia*. The research deals with a bibliographical survey that contemplates articles published between 2007 and July of 2017. We found a relationship of saprolegniose with fish

species: *Oncorhynchus mykiss*, *Salmo trutta*, *Oncorhynchus tshawytscha*, *Labeo rohita*, *Pterophyllum scalare*, *Ctenopharyngodon idella*, *Sander lucioperca*, *Pelteobagrus fulvidraco*, *Oreochromis niloticus*, *Odonthestes bonariensis*, *Odonthestes humensi* e *Catla catla*. The oomycetes found were: *Saprolegnia ferax*, *Saprolegnia parasitica*, *Saprolegnia australis*, *Saprolegnia diclina*, *Saprolegnia delica*, *Saprolegnia glomerata*, *Saprolegnia terrestres*, *Saprolegnia uliginosa*, *Saprolegnia unispora*, *Saprolegnia hypogyna* and *Saprolegnia longicaulis*. The species *S. ferax* and *S. parasitica* were the fungi that presented the highest infection register, mainly in salmonids. *O. mykiss*, *S. salar* and *S. trout* were the fish with more studies related to saprolegniose, because they are species that have great market importance in the world fish farming scenario. Despite the great importance of the species *O. niloticus* in the world fish culture, we observed the specie in only one article in this research, which may be related to the high resistance of the species to diseases and to the lack of research funding to identify this type of infection. It was not possible to compare the host - etiological agent among the fish, since many of the studies considered in the research did not have the purpose of identifying the pathogen.

Keywords: Pathology; Fish; Fish farming; *Saprolegnia sp.; Saprolegniosis*.

Resumo

A saprolegniose é uma doença micológica que causa perdas econômicas significativas na piscicultura e pode ser considerada um obstáculo para o desenvolvimento da piscicultura mundial. Dessa forma, objetivou-se identificar quais espécies de peixes cultivadas no mundo têm sido associadas a fungos do gênero Saprolegnia. A pesquisa trata de um levantamento bibliográfico que contempla artigos publicados entre 2007 e julho de 2017. Encontramos uma relação da saprolegniose com as espécies de peixes: *Oncorhynchus mykiss*, *Salmo trutta*, *Oncorhynchus tshawytscha*, *Labeo rohita*, *Pterophyllum scalare*, *Ctenopharyngodon idcerca*, *Sandiopercaer fulvidraco*, *Oreochromis niloticus*, *Odonthestes bonariensis*, *Odonthestes humensi* e *Catla catla*. Os oomicetos encontrados foram: *Saprolegnia ferax*, *Saprolegnia parasitica*, *Saprolegnia australis*, *Saprolegnia diclina*, *Saprolegnia delica*, *Saprolegnia glomerata*, *Saprolegnia terrestres*, *Saprolegnia uliginosa*, *Saprolegnia unispora*, *Saprolegnia unispora*, *Saprolegnia longoglypregnia* e *Saprolegnia hippora*. As espécies *S. ferax* e *S. parasitica* foram os fungos que apresentaram o maior registro de infecção, principalmente em salmonídeos. *O. mykiss*, *S. salar* e *S. truta* foram os peixes com mais estudos relacionados à saprolegniose, por serem espécies de grande importância mercadológica no cenário mundial da piscicultura. Apesar da grande importância da espécie *O. niloticus* na piscicultura mundial,

observamos a espécie em apenas um artigo desta pesquisa, o que pode estar relacionado à alta resistência da espécie a doenças e à falta de financiamento de pesquisas para identificação este tipo de infecção. Não foi possível comparar o hospedeiro - agente etiológico entre os peixes, uma vez que muitos dos estudos considerados na pesquisa não tiveram o objetivo de identificar o patógeno.

Palavras-chave: Patologia; Peixes; Piscicultura; *Saprolegnia* sp.; Saprolegniose.

Resumen

La saprolegniosis es una enfermedad micológica que causa importantes pérdidas económicas en la piscicultura y puede considerarse un obstáculo para el desarrollo de la piscicultura mundial. Así, nuestro objetivo fue identificar qué especies de peces cultivadas en el mundo se han asociado con hongos del género Saprolegnia. La investigación trata de un relevamiento bibliográfico que contempla artículos publicados entre 2007 y julio de 2017. Encontramos relación de la saprolegniosis con especies de peces*: Oncorhynchus mykiss*, *Salmo trutta*, *Oncorhynchus tshawytscha*, *Labeo rohita*, *Pterophyllum scalare*, *Ctenopharyngodon idella*, *Sander luciogrperusca*, *fulvidraco*, *Oreochromis niloticus*, *Odonthestes bonariensis*, *Odonthestes humensi* y *Catla catla*. Os oomicetos encontrados foram: *Saprolegnia ferax*, *Saprolegnia parasitica*, *Saprolegnia australis*, *Saprolegnia diclina*, *Saprolegnia delica*, *Saprolegnia glomerata*, *Saprolegnia terrestres*, *Saprolegnia uliginosa*, *Saprolegnia unprolegnia*, *Saprolegnia hypogyna long* y *Saulispora*. Las especies *S. ferax* y *S. parasitica* fueron los hongos que presentaron mayor registro de infección, principalmente en salmónidos. *O. mykiss*, *S. salar* y *S. trucha* fueron los peces con más estudios relacionados con la saprolegniosis, por ser especies de gran importancia comercial en el escenario piscícola mundial. A pesar de la gran importancia de la especie *O. niloticus* en la piscicultura mundial, solo observamos la especie en un solo artículo de esta investigación, lo que puede estar relacionado con la alta resistencia de la especie a las enfermedades y con la falta de financiamiento para la investigación para identificar este tipo de infección. No fue posible comparar el hospedador - agente etiológico entre los peces, ya que muchos de los estudios considerados en la investigación no tenían el propósito de identificar el patógeno.

Palabras clave: Patología; Peces; Piscicultura; Saprolegnia sp.; Saprolegniosis.

1. Introduction

Fish farming is the most developed branch of aquaculture in the world, but as in all production system, the intensification process can generate stress and immunosuppression causing risks to animal health (Corrêa et al., 2013). Fish diseases are caused by microorganisms distributed in several groups, including bacteria, protozoa, viruses and fungi, which are responsible for significant economic losses and can be considered as an obstacle to the development of world fish farming (Meyer, 1991; Pavanelli and Eiras, 2008; Pinheiro et al., 2015; van West, 2006).

The main mycological disease in pisciculture is saprolegniosis caused by an Oomycete of the order Saprolegniales, composed of the genera *Saprolegnia*, *Achly*a and *Aphanomyces* (van den Berg et al., 2013), being the species belonging to the genus *Saprolegnia* the most registered as parasites in fish and their eggs (Mastan, 2015; van den Berg et al., 2013).

Saprolegniose is a pathology characterized by the appearance of white-gray spots easily visible to the naked eye, looking like cotton, as a result of the development of the mycelium in the skin, gills or eggs of the fish (Burr and Beakes, 1994; Stueland et al., 2005; Tampieri et al., 2003).

The fish naturally have a layer of mucus that coats it externally, being composed of antibiotics, free fatty acids and enzymes. Damage to this layer leaves the animal susceptible to various pathologies. This barrier is altered mainly by some factors such as sudden changes in temperature, loss of scales, stress, hormonal imbalances, lack of hygiene in the nursery, injuries and wounds caused by parasites. Exposure to these factors may favor the invasion, among other pathogens, of the biflagellate zoospore causing saprolegniosis, allowing its fixation and development. The oomycete eliminates toxin causing necrosis and allowing the extension of the mycelium in the epidermis resulting in alterations of this tissue with consequent death of the animal (Paiva, 1997).

The most effective measure of control in the treatment of this disease is malachite green use; however, its toxicity represents a risk to the health of professionals (Pottinger and Day, 1999; Stammati et al., 2005). Other measures of control and treatment for saprolegniosis are: formaldehyde, potassium permanganate, acetic acid and iodine (Fuangsawat et al., 2011; Khodabandeh and Abtahi, 2006; Rasowo et al., 2007). Currently phytotherapics have been formulated for the treatment of this pathology, as the one extracted from *Radix sanguisorbae* for the treatment of saprolegniose caused by *Saprolegnia australis* with encouraging results, representing a survival of over 80% (Cao et al., 2014).

Saprolegniose has already been responsible for the loss of 15 to 25% of salmon egg mortality in Chile and has already reached more than 50% of *Salmon coho* production in Japan (Zaror et al., 2004).

In Scotland, the Saprolegnia infection has already resulted in a loss of £ 5 million (Phillips et al., 2008). In many countries, the economic damage caused by this disease has not yet been accounted for, and there has been no compilation of data on which species of fish have been associated with this disease. Thus in this review, we aimed to identify which species of fish cultivated in the world have been related to fungi of the genus Saprolegnia in the last 10 years.

2. Materials and Methods

A bibliographic survey was carried out in the databases *Web of Science*, *Science Direct*, *Portal Periódico da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior* (*Capes*) e *Scientific Electronic Library Online* (*Scielo*) in the month of July 2017 using the combination of four descriptors: “fish farming”, “pisciculture”, “saprolegnia” and “saprolegniosis”. The crossing of the descriptors occurred through the Boolean operators OR and AND. We considered the articles published from 2007 to July 2017.

The studies included in the research should include isolation of *Saprolegnia* performed previously or in the study itself from cultured fish. We excluded articles that identified this genus from other substrates.

After the electronic search procedure in the mentioned databases, we read the title and abstract to identify if the articles met the criteria established for inclusion in the research. Afterwards, we selected the articles to identify the articles that make up the final sample of this bibliographic review. Therefore, this is an exploratory research article and from the point of view of technical procedures it is classified as bibliographic research elaborated from material already published (Kauark, Manhães and Medeiros, 2010).

3. Results

3.1 Published studies

This study collected 226 articles distributed in the databases *Science Direct* (91), *Capes* (105) and *Scielo* (30). The Web of Science database did not present any indexed article

inserted in the subject of this survey. Of the total of articles surveyed, only 22 met the criteria for inclusion in the research (Table 1).

Table 1. List of articles collected, database, periodicals and topics covered.

References	Scientific Journal	Topics Covered
	SCIENCE DIRECT	
De Bruijn *et al.* (2012)	Developmental and Comparative Immunology	Immunology
Rezinciuc et al. (2014)	Fungal Biology	Taxonomy
Minor et al. (2014)	Fungal Biology	Immunology
Sandoval-Sierra et al. (2014)	Aquaculture	Taxonomy
Pereira-Torres et al. (2016)	Fish and Shellfish Immunology	Immunology
Fregeneda-Grandes et al. (2007)	Mycological Research	Taxonomy
Roberge et al. (2007)	Molecular Immunology	Immunology
Vega-Ramírez et al. (2013)	Revista Mexicana de Biodiversidad	Taxonomy
Saha et al. (2016)	Fish and Shellfish Immunology	Immunology
Eissa et al. (2013)	International Journal of Veterinary Science and Medicine	Taxonomy
	PORTAL PERIÓDICO CAPES	
Songe et al. (2016)	Journal of Fish Diseases	Immunology
Yao et al. (2017)	Journal of the World Aquaculture Society	Experiment
Heikkinen et al. (2016)	Aquaculture Research	Treatment
Korzelecka-Orkisz et al. (2016)	Journal of Applied Ichthyology	Treatment
Thoen et al. (2015)	Life Science Weekly	Taxonomy
Ben Khemis et al. (2016)	Journal of Fish Diseases	Experiment
Johari et al. (2016)	Aquacult Int	Experiment

Cao et al. (2012)	Vet Res Commun	Taxonomy
Zahran and Risha (2013)	Zahran and Risha SpringerPlus	Tratament
Valenzuela et al. (2012)	Fish Physiol Biochem	Experiment
Iqbal et al. (2012)	Pakistan journal of zoology	Taxonomy
	SCIELO	
Corrêa et al. (2013)	Ciência Rural	Experiment

Source: Prepared by the authors.

The table above shows the list of authors selected for the research, the year in which each article was published, the database, the journals, as well as the main topic addressed in each research.

The taxonomy was the topic more discussed in the articles, showing that knowledge about the pathologies caused by fungi in fishes is still at the level of identification of causal agents, even in countries such as China, Norway and Chile that represent the main producers in aquaculture (FAO, 2018). We observed a greater publication in the year 2016 with predominance by taxonomic and immunological approaches.

4. Discussion

The articles surveyed were based on research conducted predominantly in Europe and America. The studies reported the occurrence of saprolegniosis in the following species of fish: *Oncorhynchus mykiss*, *Salmo trutta*, *Oncorhynchus tshawytscha*, *Labeo rohita*, *Pterophyllum scalare*, *Ctenopharyngodon idella*, *Sander lucioperca*, *Pelteobagrus fulvidraco*, *Oreochromis niloticus*, *Odonthestes bonariensis*, *Odonthestes humensi* and *Catla catla* (Table 2).

Table 2. Summary of the studies that have included fish farmed in the world infected with saprolegniose, separated by a database.

Reference	Host	Etiological Aagent	Search Location
	SCIENCE DIRECT		
De Bruijn et al. (2012)	*O. mykiss*	*S. parasitica*	United Kindon
Rezinciuc et al. (2014)	Eggs from *S. trutta*	*S. ferax, S. australis* and *Saprolegnia* sp.	Spain
Minor et al. (2014)	Eggs from *O. mykiss*	*S. parasítica*	Netherlands
Sandoval-Sierra et al. (2014)	Different phases of Salmonidian development *S. salar*, *O. mykiss* and *Oncorhynchus Tshawytscha*	*S. australis, S. delica, S. diclina, S. ferax, S.parasitica* e *Saprolegnia* sp.1 and sp. 2	Chile
Pereira-Torres et al. (2016)	*S. salar*	*S. ferax* e *S. parasitica*	Chile
Fregeneda-Grandes et al. (2007)	*S. trutta*	*S. parasitica*	Spain
Roberge et al. (2007)	*S. salar*	*Saprolegnia* sp.	Canada
Vega-Ramírez et al. (2013)	Eggs and adult fish *O. mykiss*	*S. ferax, S. australis, S. diclina, S. glomerata, S. parasitica, S. terrestris, S. uliginosa, S. unispora,*	Mexico
Saha et al. (2016)	*Labeo rohita*	*S. parasitica*	India
Eissa et al. (2013)	*Pterophyllum scalare*	*S. parasitica, S. hypogyn, S. delica* and *S. Longicaulis*	Egypt
	CAPES PERIODIC PORTAL		
Songe et al. (2016)	Eggs from *S. Salar*	*S. diclina*	United States
Yao et al. (2017)	*Ctenopharyngodon idella*	*Saprolegnia* sp.	China
Heikkinen et al. (2016)	*O. mykiss*	*Saprolegnia* sp.	Finland

Korzelecka-Orkisz et al. (2016)	Eggs from *S. trutta*	*Saprolegnia* sp.	Poland
Thoen et al. (2015)	Eggs from *S. salar* e peixe adulto	*S. diclina*, *S. parasítica*, *S. ferax* and *S. hypogyna*	Norway
Ben Khemis et al. (2016)	Eggs from *Sander lucioperca*	*Saprolegnia* sp.	Tunisia
Johari et al. (2016)	Eggs from *O. mykiss*	*Saprolegnia* sp.	Iran
Cao et al.(2012)	Eggs from *Pelteobagrus fulvidraco*	*S. ferax*	China
Zahran and Risha (2013)	*O. niloticus*	*S. ferax*	Egypt
Valenzuela et al. (2012)	*O. mykiss*	*Saprolegnia* sp.	Chile
Iqbal et al. (2012)	*C. catla* and *C. idella*	*Saprolegnia* sp.	Pakistan
SCIELO			
Corrêa et al. (2013)	*O. bonariensis* and *O. humensis*	*Saprolegnia* sp.	Brazil/RS

Source: Prepared by the authors.

The results of this research showed that the species *O. mykiss* is the fish with more studies related to pathologies caused by Saprolegnia, being registered in seven of the twenty-two articles raised. As espécies *S. salar* e *S. truta* também são constantemente relacionadas com a saprolegniose (juntos estão presentes em 40% dos estudos levantados). These salmonids were frequently associated with the occurrence of the fungus, the object of this study, probably due to the intense cultivation of these species and their high market importance, since they represent the third largestgroup of fish used in world fish farming (FAO, 2018). According to studies, saprolegniose is responsible for about 10% of the annual economic loss in salmonids, but in some cases this loss may represent up to 50% of the total production, a fact that justifies investments in research to identify this pathology (Hussein and Hatai, 2002; Kishio and Gen-Ichi, 1992; van West, 2006).

The relation of economic importance and intense investment in research is remarkable when one observes the frequency that the species *S. salar* is recorded in the study. This species accounts for 93% of the world's total aquaculture production and research related to the Saprolegnia fungus is funded mainly by Norwegian, Chilean and Canadian institutions

representing the world's major producers of this species (2012). Although Atlantic salmon is very important economically in Europe was found in only a single study (Soon and Baines, 2012).

The species *O. niloticus* (tilapia) represents the second species of fish most produced in the world behind only *Cyprinus carpio* (carp) (Sebrae, 2015). However, there was little presence in the research carried out, which may be associated with the high resistance of this species to diseases and also with the lack of research funding, especially by countries such as Brazil, which has such an expressive species in the aquaculture scenario national (da Silva et al., 2012; IBGE, 2014).

The Brazilian production of tilapia is quite expressive, reaching the mark of 357,639 tons per year (Associação Brasileira de Piscicultura, 2018). However, it is observed that the studies are still insipient, being recorded the occurrence of saprolegniose in tilapia by Martins et al. (2002) in the state of São Paulo and by Pinheiro et al. (2015) in the state of Maranhão. The most recent research registered in Brazil in the databases verified in this research was with the species O. bonariensis and O. humensis (Corrêa et al., 2013), kingfish species that present commercial value in South America (Pacheco-Marino, Suani Giovanna; Salibián, 2010).

The saprolegniose caused by *S. ferax*, together with the species *S. australis*, were the ones that presented the highest infection records in different fish species (6 species), followed by *S. parasitica* (5 species), *S. diclina* (4 species) and *S. delica* (3 species). The S. glomerata, *S. terrestrial*, *S. uliginosa* and *S. unispora* species were identified only in *O. mykiss*. The pathology caused by the *S. hypogna* species was identified only in the *S. salar* species. The fish *C. idella*, eggs of *S. lucioperca*, *O. bonariensis*, *O. humensis* and *C. catla* were recorded with saprolegniose, however there was no identification until the species level (Figure 1).

Within the set of ten fungi of the genus Saprolegnia found on fish, nine were from the species *O. mykiss* and six, from the species *S. salar*, showing the importance of this pathology for the cultivation of both species. It was not possible to compare the host - etiological agent among the fish, since many of the studies considered in the research did not have the purpose of identifying the pathogen. Thus, it is evident that further studies are necessary in the area of biopathology to identify saprolegniosis in fish in order to establish a more consistent relationship between the species that cause this disease and the species of fish cultured.

5. Conclusion

The research shows that infection studies in fish caused by fungi of the genus Saprolegnia were recorded mainly in salmonids *O. mykiss*, *S. salar* and *S. trout* due to the economic importance of these species in the world fish farming scenario.

For tilapia, although it is a very cultivated species in the world, few studies of infection caused by saprolegnia have been found, probably because of the high resistance of this species to diseases or because it presents little investment in research aimed at identifying this pathology. The *S. ferax* and *S. parasitica* oomycetes are the fungi with the highest infection rates in fish, especially salmonids.

The fish farmer, especially of the species that obtained the highest numbers of saprolegniose, must be aware of the clinical signs of this disease and perform some control measures such as good quality of the water of the breeding grounds and adequate management of the fish, avoiding the stress and consequent susceptibility to the diseases. For the confirmation of a precise host-pathogen relationship, further studies are needed, including accounting for the economic damage caused by this disease.

It is worth mentioning that a research carried out an important step to understand the relationship of the genus *Saprolegnia* sp. causing saprolegniosis with parasites in fish and their eggs; and that data cleansing of this relationship with the genera *Achlya* and *Aphanomyces* constitutes an equally important research.

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