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WASTE MANAGEMENT IN THE PERUVIAN FISHERY INDUSTRY BEFORE AND AFTER COVID-19. BIBLIOMETRIC ANALYSIS PERIOD 2001-2021

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Waste Management in the Peruvian Fishery Industry before and after COVID-19: Bibliometric Analysis Period 2001-2021

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Abstract

The research performs an analysis of waste management in the fishing industry and its relationship with the Peruvian industry through a systematic review of the literature and the use of the VOSviewer software to generate a network of co-occurrences with the aim of identifying the most relevant topics of interest in the scientific community. The present work is analyzed in three periods of time that explain the evolution of the Peruvian fishing industry: 2001-2011, 2012-2019 and 2020-2021, in addition to the collection of articles related to the subject of study, a selection of the best articles is made in relation to the number of citations and the prominence percentile for the most impactful topics of waste management in the fishing industry, finally it is discussed how it could generate a broader vision of the new opportunities of waste management through implement in the Peruvian fishing sector.

Keywords
Fishing industry, Fishing waste, Residual water and Environmental pollution.

1. Introduction
In Peru, the fishing industry has had an evolution in its development during the last two decades. In the economic aspect, between the years 2001 and 2010, the latter had a considerably lower level of capture compared to previous years, which resulted in a decrease in the level of production by 37% (Peruvian Export Promotion Commission and Tourism [PROMPERU] 2011). On the other hand, between 2012 and 2019, capture fishing levels remained in the range of 89.5 and 96.4 million tons (Food and Agriculture Organization [FAO] 2018), this last one dates from 2018 in which the FAO highlights the 10 main world producers of capture fisheries for this high amount of fishing achieved during this period, of which the seven main countries represent about 50% of the total fishing production catch worldwide where Peru ranked third (FAO 2020). Finally, during these last two years in which the impact caused by the COVID-19 pandemic is known, the reduction of activities led to a decrease in exports and imports, as a consequence, the GDP fell by 11.1% during the 2020 (Central Reserve Bank of Peru [BCRP] 2020). The fishing sector, in particular, has been strongly affected since the quarantine was declared as the fishing fleets stopped their operations. This event generated a negative impact on the Peruvian economy (Aroni 2020). However, by the end of 2020, the fishing sector improved its economic situation compared to other industries. According to the National Institute of Statistics and Informatics of Peru (INEI 2020), this sector grew by 108.54% due to the reduction of restrictions on economic activities and thanks to these results, as well as the operation of other activities in the construction and manufacturing sector, the GDP increased in December by 0.51%.

Now, regarding the social context, for the year 2011 the fishing industry through the promotion of Direct Human Consumption (DHC) generated 20,000 jobs directly and more than 57,000 jobs for artisanal fishermen (National Fishery Society of Peru [SNP] 2012). Until 2017, regarding its per capita consumption (CPC), the sector obtained an average annual rate of positive variation of 3.1%, in addition to mentioning that for 2018 it had a value of 20.5 kg (FAO 2020). In addition, the pandemic also affected this social sector, since the employment of people in this industry decreased in 2020 by 21.4% compared to the previous year (National Society of Industries of Peru [SNI] 2021); however, according to Cayetana Aljovín, president of the SNP, she mentioned that "the fishing sector contributes 700,000 jobs. Of these, more than 112,000 jobs are generated by the extraction and fishing industry" (SNP 2020).

However, in relation to the environmental aspect, the SNP mentions that in the last years analyzed until 2012, the Peruvian fishing industry had innovated in technology, minimizing emissions and energy consumption. In addition, between 2009 and 2012, the private sector invested close to $500 million in environmental improvements in order to be more efficient in its processes and generate less pollution. Likewise, effective measures were taken in favor of the environment through the establishment of deadlines for the execution of the Maximum Permissible Limits (MPL) for effluents to the sea, carrying out voluntary environmental projects and the establishment of regulations in DHC plants (SNP 2012). At a global level, when analyzing up to the year 2017, it is commented that during the last 45 years there was a decrease from 90% to 65.8% of the amount of fish that belonged to a biologically sustainable level; however, it was estimated that the recovery of the stability of this overexploited population could contribute to the well-being of nearby communities, as well as increase fish production and improve food security (FAO 2020). In Peru, its fishing is characterized by its informality and disorder, the presence of a weak infrastructure as well as a poor environmental, business and health culture (Ministry of Production [PRODUCE] 2015). In this context, the National Program for Innovation in Fisheries and Aquaculture (PNIPA) was created, which consists of promoting innovation for economic development with inclusion and sustainability (PNIPA 2021). Between 2020 and 2021, PRODUCE prioritized the abundance of marine species for the future since the food and employment of many citizens depend on the sustainability of these resources. These measures were carried out together with the interest groups since it is essential to involve them in the process. Likewise, to combat illegal fishing, high-speed patrols have been implemented to monitor marine areas through a group that seeks to improve inter-institutional coordination, this generated an investment of S/. 16 million (PRODUCE 2021).

In order to know what norms and rules the operations of the Peruvian fishing sector are based on, it is necessary to comment on the political context. Today there are more than 30 international fisheries management organizations that aim to manage cooperation between states in fisheries matters (Vázquez 2022). In the Peruvian industry, there are four entities belonging to PRODUCE that are in charge of seeing specific aspects of fishing policy and management. These are: the National Fisheries Health Agency (SANIPES), the National Fund for Fisheries Development (FONDOPES), the Institute of the Sea of Peru (IMARPE) and the Technological Institute of Production (ITP) (Mitma et al. 2020). However, despite the presence of these regulatory bodies, the existence of illegal fishing within the sector continues to be a factor that generates problems for the Peruvian marine ecosystem in economic and environmental terms, due in most cases to the lack of management government to control such activities (Matos 2020).

Finally, the fishing industry, being considered huge in commercial terms, has always had the capacity to make large investments in the development or obtaining of technology that can optimize its production processes (Molina 2017). For the past five years, FAO has been driving the adoption and innovation of new technologies such as disruptive technology: technology that can bring about dramatic change by changing the way people work, do business, and participate in the economy, such as consequence more sustainable businesses will be obtained, as well as greater resource efficiency and a change in the economic organization of fisheries (FAO 2018). On the other hand, through the PNIPA, the use of Big Data is being promoted, a data collection system to establish fishing patterns, create models that generate improvement opportunities for the competitiveness and sustainability of fishing, among others (PNIPA 2021).

1.1 Objectives

The objective of this research is to identify the current topics of interest in waste management in the fishing industry through a systematic literature mapping, as well as to classify the articles by their age in the most relevant subtopics of published scientific articles and how these are related to the Peruvian industry.

2. Literature Review

2.1 Fishing industry

It is based on two main activities: the extraction (primary activity) and the transformation (secondary activity) of the different hydrobiological resources (INEI 2015), in addition, it constitutes a source of great importance of food, jobs, recreation and trade for populations of all over the world (FAO 1995). Its production can be oriented to Direct Human Consumption (DHC) or Indirect Human Consumption (IHC) (Escobedo 2020). The DHC focuses on the production of canned, frozen, cured, fresh and sausage products (Kleeberg and Nieto 2001), while the IHC is based on the processing of fish species for the production of fish flour and fish oil (Martinez 2018).

2.2 Fishery waste

There are two types of waste: solid and liquid. Solids are all those parts of the fish to be processed that have no commercial value, such as: head, leather, viscera, fins and gills (Agudelo et al. 2007) and that can represent an average of 70% of the total volume of fish to be processed (Olsen et al. 2014). On the other hand, effluents or liquid waste are those waters with the presence of solid or liquid waste that are emitted by industries (Luján 2019) and can be of three types: bailwater, bloodwater and stickwater (Kleeberg and Nieto 2001). These are characterized by their high content of organic substances in the form of suspended particles (Cristóvaõ et al. 2015). This organic matter generates alterations in the sea since it generates instability in the chemical, physical and biological characteristics (García et al. 2009). These two components, when not treated properly, generate a negative impact on the marine ecosystem (Coronado 2018).

2.3 Marine environment

The inefficient solution to the waste generated has been one of the problems with the greatest environmental impact for this industry (Arvanitoyannis and Kassaveti 2008), with the marine environment being the main scenario for these waste discharges. However, in the last two decades these residues have received considerable attention to convert them into commercial products due to economic and environmental reasons (Olsen et al. 2014). These residues have the potential to recycle raw materials or to become useful products of higher value (Jayathilakan et al. 2012) through the proposal of environmentally friendly processes (Vázquez et al. 2013).

2.4 Waste treatment

The treatment to be used will depend on the type of waste generated; however, all of them will have to find a way to overcome certain difficulties such as biological stability and potential growth of pathogens, high water content, rapid autoxidation, and changes due to the enzymatic activity of such residues (Jayathilakan et al. 2012). In addition, Cristóvaõ et al. maintain that these treatments used to manage the waste generated during production must be associated with optimal and profitable costs, since in this way economic and environmental benefits will be generated (Cristóvaõ et al. 2015). Another aspect to consider is the consumption of water in the production of wastewater (effluents), this consumption can be reduced if an efficient strategy is applied that maximizes its management (Chowdhury et al. 2010). Finally, energy consumption can be mentioned as another important factor to keep in mind when treating the waste generated (Cristóvaõ et al. 2015), since choosing a correct treatment with less energy consumption would generate greater benefits (Chowdhury et al. 2010).

2.5 Waste management

The fishing industry can adopt, mainly, two profiles in relation to the management of its waste. With respect to the first, management can be adopted based on mitigating and controlling the amount of such waste with the sole purpose of contributing to the environment (Ministry of the Environment of Peru [MINAM] 2015). On the other hand, management based on the circular economy can also be adopted (MINAM 2020). The United Nations Industrial Development Organization (UNIDO) defines it as "a sustainable development approach, in which resources are used more efficiently, as a consequence of being used more than once" (PNIPA 2020).

3. Methods

The research has a qualitative approach with an exploratory and descriptive scope. Likewise, it is characterized by being of a non-experimental type with longitudinal design since it collects data from the Peruvian industry through certain periods of time.

The research strategy is analyzed in three periods of time that explain the evolution of the Peruvian fishing industry: 2001-2011, 2012-2019 and 2020-2021, in addition to the collection of articles related to the subject of study, a selection is made of the best articles in relation to the number of citations and the prominence percentile for the most impactful topics of waste management in the fishing industry, finally it is discussed how it could generate a broader vision of the new opportunities of waste management residues to be implemented in the Peruvian fishing sector.

The search is based on secondary information made up of scientific articles published in journals indexed in the Web of Science-Clarivate Analytics, Scopus -Elsevier, and Crossref. The methodology begins with the search and establishment of the research topic; subsequently, the criteria to be used for the selection of articles are decided, where the bibliographic review is carried out, which includes the search, selection, processing, and technical review of the scientific articles. Next, the best articles are selected from the total collected through previously defined criteria. Then, this information is exported to the VOSviewer software to generate a network of co-occurrences that show the most important topics about the studied topic. Finally, these issues are analyzed and how it would contribute to other research in the Peruvian fishing industry is discussed.

4. Results and Discussion

4.1 Analysis of results

Through a systematic mapping in different databases through certain keywords, 102 articles related to waste management in the fishing industry were obtained between 2001 and 2021. Table 1 shows it by year.

Table 1: Quantity of articles related to waste management in the fishing industry between 2001 and 2021

Year	Number of articles published
2021	10
2020	18
2019	9
2018	8
2017	8
2016	4
2015	6
2014	5
2013	9
2012	5
2011	6
2010	3
2009	2
2008	1
2007	1
2006	2
2005	1
2004	1
2003	1
2002	1
2001	1
Total	102

Table 1 presents 3 horizon periods, and they are discussed below.

4.1.1 Long-term horizon

For the years 2001 and 2011, the research topic has been valid in the scientific community since each year it has at least one scientific article, with 2011 being the year with the largest number of articles published in the period.

4.1.2 Medium-term horizon

During the 2012-2019 period, a greater trend and consistency of publications related to the research topic was generated. This can be explained based on the growing environmental awareness previously explained, which generates a higher level of search and investigation on this global problem.

4.1.3 Short-term horizon

Lastly, during the last two years (2020 and 2021); that is, after the pandemic situation experienced by the whole world, it can be mentioned that they were the years with the highest number of publications. In addition, the year 2020 significantly exceeded previous years, this fact is possibly due to the new sanitary measures that arose from COVID-19 as well as new strategies to deal with this problem and improve the industry in the economically, environmentally, etc.

After the collection of articles related to the object of study, the selection of the 20 best is made to analyze them and, subsequently, determine the most relevant topics for the scientific community. The criteria for their selection were based on the number of citations and their respective prominence percentiles. Regarding the first criterion, citations found in the Web of Science, Scopus and Crossref databases were used. Likewise, with respect to the second criterion, this indicates the current relevance of the subject matter within its specialty. Table 2 shows these articles with their respective parameters.

Table 2. Articles on waste management in the fishing industry with the highest impact factor

Title	Year	Authors	Number of citations	Prominence percentile
Treatment of organic pollution in industrial saline wastewater: A literature review	2006	Lefebvre, O. and Moletta, R.	1260	87.56%
Utilization of byproducts and waste materials from meat, poultry and fish processing industries: A review	2012	Jayathilakan, K. et al.	1130	99.31%
Fish industry waste: Treatments, environmental impacts, current and potential uses	2008	Arvanitoyannis, I.S. and Kassaveti, A.	531	99.31%
Applications of chitosan in the seafood industry and aquaculture: A review	2012	Alishahi, A. and Aïder, M.	422	98.24%
Ensiling of fish industry waste for biogas production: A lab scale evaluation of biochemical methane potential (BMP) and kinetics	2013	Kafle, G.K. et al.	407	99.91%
Biological treatment processes for fish processing wastewater - A review	2010	Chowdhury, P. et al.	402	87.56%
Chondroitin sulfate, hyaluronic acid and chitin/chitosan production using marine waste sources: Characteristics, applications and eco-friendly processes: A review	2013	Vázquez, J.A. et al.	376	74.52%

Title	Year	Authors	Number of citations	Prominence percentile
Efficient use of shrimp waste: Present and future trends	2012	Kandra, P. et al.	269	98.24%
Challenges and realistic opportunities in the use of by-products from processing of fish and shellfish	2014	Olsen, R.L. et al.	259	91.85%
A review of anaerobic treatment of saline wastewater	2010	Xiao, Y and Roberts, D.	254	87.56%
Fish processing wastes as a potential source of proteins, amino acids and oils: A critical review	2013	Ghaly, A. E. et al.	188	99.31%
Environmental assessment of canned tuna manufacture with a life-cycle perspective	2006	Hospido, A. et al.	168	9.13%
Waste loading in shrimp and fish processing effluents: Potential source of hazards to the coastal and nearshore environments	2004	Islam, M. S. et al.	149	81.51%
Simultaneous methanogenesis and denitrification of pretreated effluents from a fish canning industry	2001	Mosquera-Corral, A. et al.	141	94.71%
Fish canning industry wastewater treatment for water reuse - A case study	2015	Cristóvaõ, R. O. et al.	140	87.56%
Treatment of fish processing wastewater with microalgae-containing microbiota	2011	Riaño, B. et al.	138	99.77%
Trypsins from fish processing waste: cha racteristics and biotechnological applicati ons - comprehensive review	2013	Bougatef, A.	130	76.73%
Evaluation of the biomethane potential of solid fish waste	2012	Eiroa, M. et al.	127	99.91%
Optimization and characterization of hydrochar produced from microwave hydrothermal carbonization of fish waste	2017	Kannan, S. et al.	110	99.41%
Biological treatment of fish processing saline wastewater for reuse as liquid fertilizer	2017	Chen, Yun and Redzwan, G.	101	87.56%

4.2 Graphics of results

In this section, the network of co-occurrences generated by the VOSviewer tool in each database will be detailed to identify the most relevant topics of interest.

4.2.1 Web of Science

In this database, 14 of the 20 best articles were on that platform. In addition, 2 of the 14 articles did not have a co-occurrence relationship with the other scientific articles, so they were divided into two different networks. Next, Fig.1 is shown in which the previously mentioned networks are displayed.

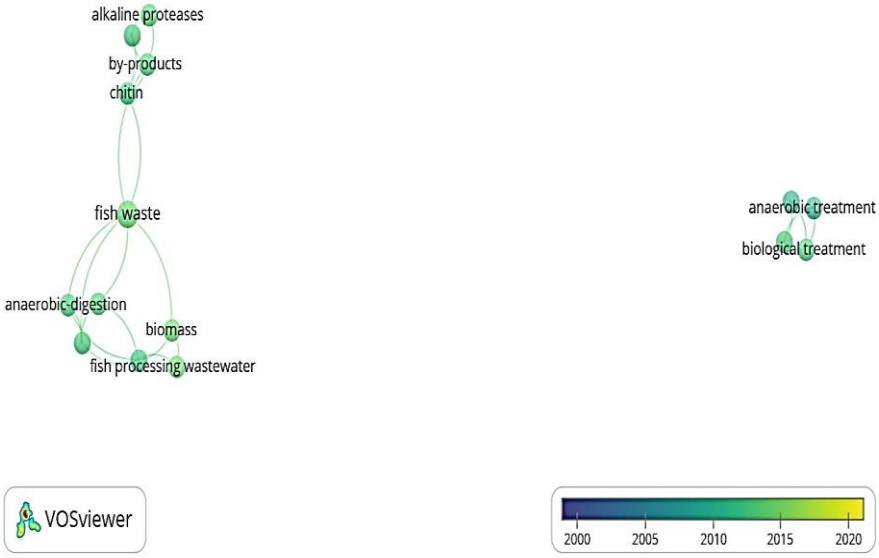

Figure 1. VOSviewer co-occurrence network of the best Web of Science articles.

From the Figure 1 it can be seen that 15 were the most relevant topics in the articles published in the Web of Science, highlighting anaerobic and biological treatment as topics of articles that were unrelated to the others. In addition, due to the range of years shown, it can be seen that most of the topics are between 2005 and 2020.

4.2.2 Scopus y Crossref

The reason why these two databases are shown together is because the top 20 articles are present in both databases, so the co-occurrence network graph shown by the VOSviewer is the same.

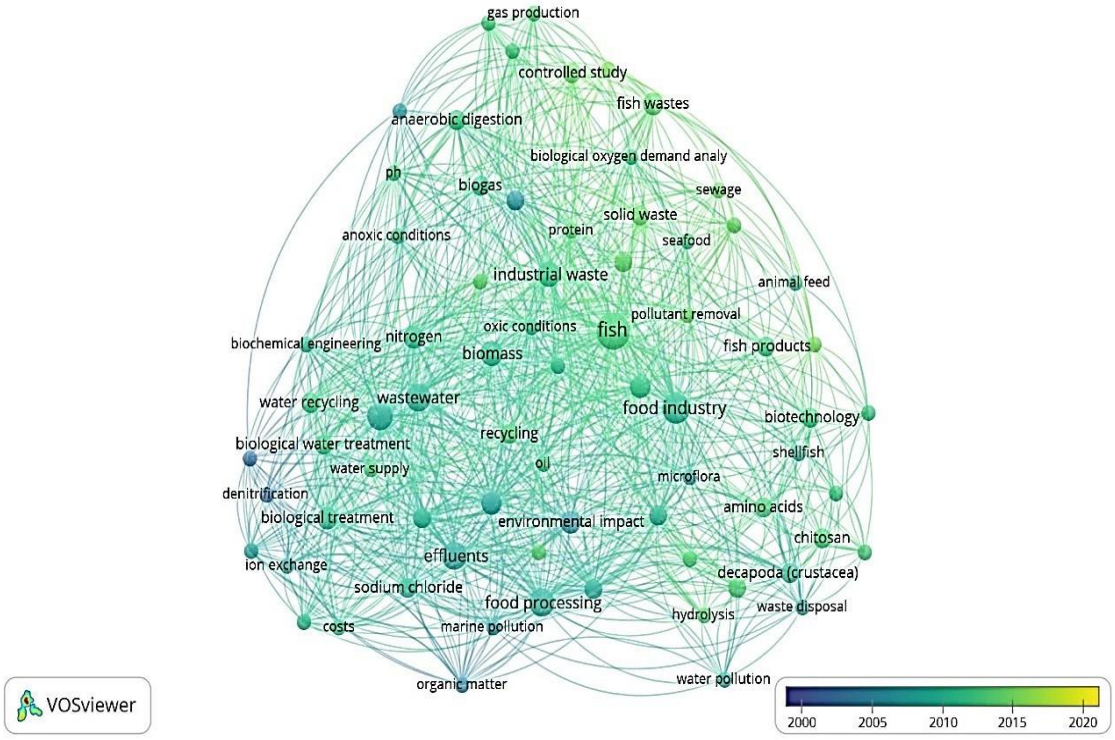

Figure 2. VOSviewer co-occurrence network of the best Scopus and Crossref articles.

This Figure 2 shows the large number of topics and co-occurrences generated by the 6 additional articles that complete the total of 20 articles. This generated a network of relationships with a total of 75 keywords related to multiple topics about waste management in the fishing industry. With respect to the range of years shown in the graph, it can be seen that topics such as biological treatment and the organic composition of waste have a trend between the years 2000 and 2010, while topics such as gas production, the use of waste for animal feed and the use of crustacean waste have been relevant during 2010 and 2020.

4.3 Final results

After the general analysis commented by the result of the VOSviewer, a detailed analysis is carried out which was based on the level of co-occurrence of the keywords, the higher the value of that parameter, the more important the topic. In this way, it was possible to determine that, of the 20 best published articles, 16 articles related to the management of fishery residues investigated the treatment of wastewater. The authors comment, in a general way, that there are many treatments focused on wastewater, in addition to confirming the fact that wastewater from industrial fish plants has not received the necessary attention to generate a good level of environmental awareness for a long time, which means that they do not have a specific role in the environment. Likewise, the characteristics of these wastewaters are discussed, such as, for example: the high content of organic matter, the small particles of meat, the soluble proteins, and carbohydrates. These characterizations are generated with the aim of providing the correct destination, disposal, or reuse of those waters through correct treatment.

In a little more detail, 9 articles commented on anaerobic treatment, in which anaerobic processes such as the UASB reactor, the anaerobic filter (AF) and the anaerobic fluidized bed (AFB) can achieve great removal of organic materials (80-90 %) in the treatment of effluents and apart from producing biogas. In addition, this treatment helps large plants to have low treatment costs, little space requirements and valuable gas production.

On the other hand, biological treatment is a topic that is mentioned in 8 articles and the authors comment that it is probably the best option for wastewater. This is because most of the contaminants in aquatic products from these

industries are organic, so they are compatible with most biological treatments to treat them. However, some methods such as activated sludge are not efficient, since they involve a high use of energy associated with the use of oxygen and do not allow recycling of the nutrients present in the wastewater.

There is also a lot of research about managing wastewater, through its reuse. For this topic, the authors mention in 7 articles that the reuse of water can be considered to treat effluents without damaging product quality and hygiene, although sometimes this method is not accepted due to public health problems. The main factor in the reuse of wastewater is that the effluent from the process unit meets the influence requirements of another unit process. In addition, the articles state that fish processing factories, after their respective biological treatment, generate wastewater that can be reused in agriculture as liquid fertilizer, being able to promote plant growth since the main components are organic and nutritious substances, as well as they do not have the presence of toxic substances or known carcinogenic materials.

Just as waste treatments are discussed, production can also be chosen, in this case, 5 articles investigated the production of chitin. Chitin is a component found in the exoskeletons of crustaceans, containing 15-20% of dry weight. The production of this component in the fish industries has turned out to be environmentally attractive and economically feasible. Likewise, chitosan, which is derived from chitin, has become a highly regarded product for treating spoilage fish industry products, as the substance is non-toxic, biocompatible, and biodegradable. In addition to this, it has antibacterial and antioxidant properties, serves as a gel enhancer, coagulating agent, etc. Therefore, it can be implemented in these industries to improve the quality of products and human nutrition.

Finally, during the last few years, considerable research has been done on biogas production. In 7 articles, the authors comment that biogas can be used to produce thermal energy through a burner or also as fuel to produce thermal, mechanical, or electrical energy within a treatment plant. In the fishing industry, biogas can be produced at the time of using fish waste silage, the latter being obtained from a fish processor. It should be added that the best quality of fish waste silage was obtained through a mixture of these with waste from bread production.

5. Conclusion

The fishing industry in Peru is considered of great importance for all the results that it generates annually both economically, socially, technologically, etc. However, to this day the environmental problem prevails based on the way in which companies manage their waste, as well as the presence of informality that delays the formal development of this sector.

During the last two decades, the worldwide scientific community has been researching and proposing methods and strategies to manage the waste generated in the fishing sector. The use of the VOSviewer tool allowed knowing these methods through the topics that cover them. It was learned that the topics are diverse in each scientific community; however, there are common themes between them which generates a greater intrigue to know what they propose and why it is so much discussed today.

Based on two selection criteria, it was possible to determine the most relevant topics in waste management issues, among which wastewater treatment, anaerobic and biological treatment, wastewater reuse and chitin and biogas production stand out. Through these topics, a discussion could be held about how they could contribute and generate a change in the Peruvian fishing industry. Based on the data analyzed from said industry, it could be suggested that it has the potential to invest, develop and improve these waste management methods since, according to the authors, these issues have the capacity to generate environmental benefits because it has a high effectiveness to treat waste; social benefits because they generate greater sustainability with marine resources as well as greater safety for the community and, finally, economic benefits since in addition to reducing costs and optimizing water and energy consumption, they can provide the option of creating new production lines by reusing and giving a commercial value to certain waste that was previously destined only to be treated and subsequently discarded.

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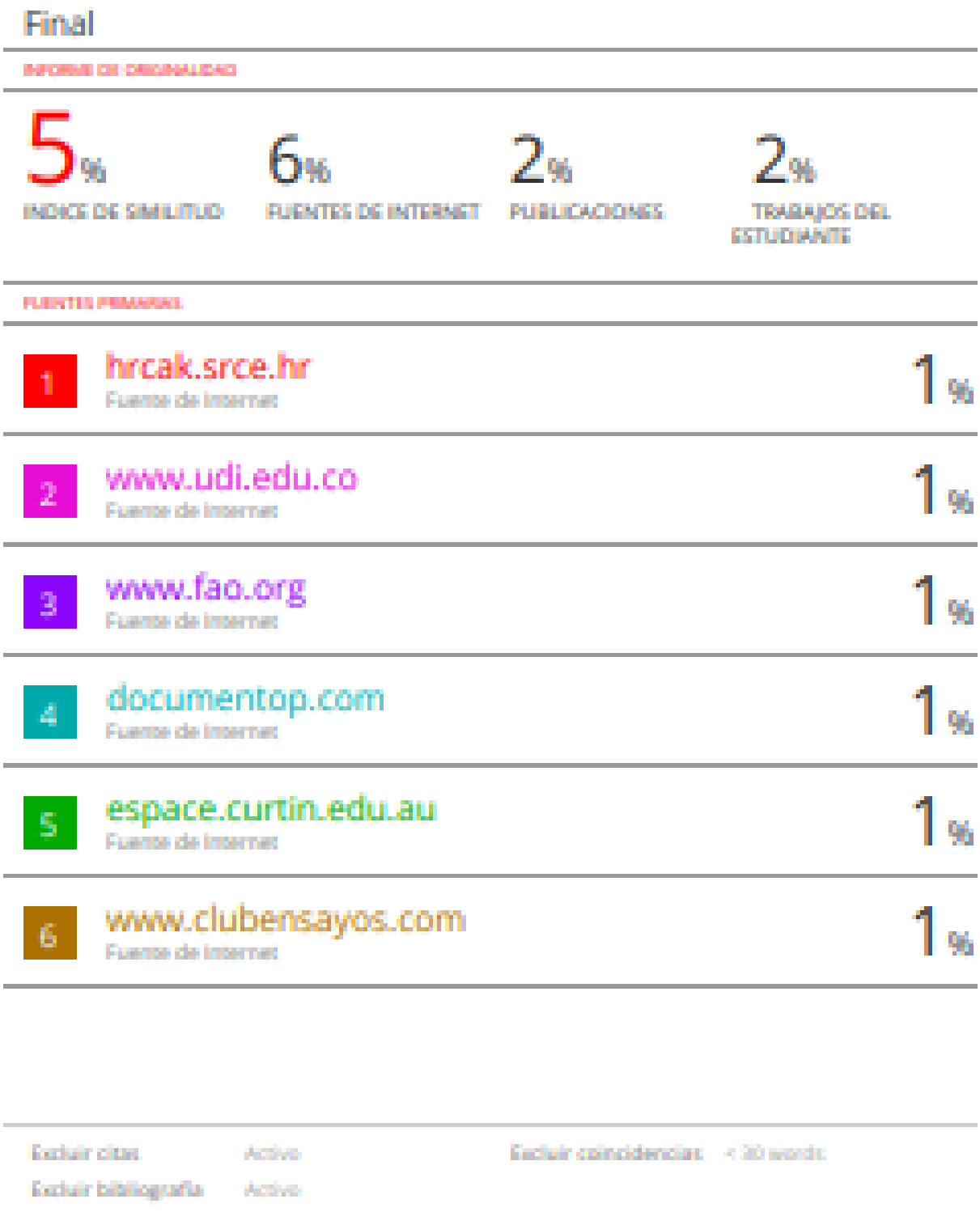

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