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Water use, reuse and treatment in the food industry: a theorical study

Uso, reuso e tratamento da água na indústria de alimentos: um estudo teórico

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ABSTRACT

This paper aims to analyze the scientific literature produced on water use, reuse, and treatment, in the food industry during the period between 2008 and 2018. The study considered papers indexed in the Scopus and Web of Science databases, as well as Brazilian theses and dissertations. The research used content analysis to explore the corpus, which was formed by the publications' abstracts, and the software Iramuteq was used to support the analysis. The content was separated into two lexical blocks: (a) "water management," explained by the classes "water consumption indicators," "rational use of water," and "environmental management;" and (b) "wastewater management," explained by the classes "fluent management" and "measurement and monitoring." The study pointed to four emergent research opportunities on the theme: "water conservation;" "water reuse;" "new productive standards," and "empirical studies." The main results show a high interest of Chinese, Indian, and European researchers in water management in all cycles of use, and scarce studies in highly industrialized countries with a strong projection of water stress, such as the USA, Japan, and Russia. Also, it is possible to observe that there is a growing interest in this subject due to the projection of water stress in the near future.

Keywords: Water resources; Food industry; Circular economy; Water; Wastewater

RESUMO

Este artigo tem como objetivo analisar a literatura científica produzida sobre uso, reuso e tratamento da água na indústria de alimentos no período de 2008 a 2018. O estudo considerou artigos indexados nas bases de dados Scopus e Web of Science, bem como teses e dissertações. A pesquisa utilizou a análise de conteúdo para explorar o corpus; formado pelos resumos das publicações e, o software Iramuteq, para apoiar a análise. O conteúdo foi segmentado em dois blocos lexicais: a) "gestão da água", explicada pelas classes "indicadores de consumo de água", "uso racional da água" e "gestão ambiental"; e (b) "gerenciamento de águas residuais", explicado pelas classes "gerenciamento de efluente" e "medição e monitoramento". O estudo apontou quatro oportunidades de pesquisa emergentes sobre o tema: "conservação da água"; "reutilização da água"; "novos padrões produtivos" e "estudos empíricos". Os principais resultados apontaram interesse de pesquisadores da China, Índia e Europa no gerenciamento de água em todos os ciclos de uso e estudos escassos em países altamente

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industrializados e com uma forte projeção de estresse hídrico, como EUA, Japão e Rússia. Além disso, é possível observar que há um interesse crescente nesse assunto devido à projeção do estresse hídrico em um futuro próximo.
Palavras-chave: Recursos hídricos; Indústria alimentícia; Economia circular; Água; Efluentes

1 INTRODUCTION

Brazil is among the world's largest producers of food with extensive and intensive growth in agricultural production. Agriculture is one of the country's most important economic activities regarding production, employment and income generation, export, and technical development of the production chain (SANTANA, 2018). The influence of food production on the economy, the large number of businesses related to this industry, and the inadequate waste management, together with weak law enforcement, are elements that contribute to the increasing problem of water contamination (QASIM; MANE, 2013). According to Meneses, Stratton and Flores (2017), 30% of the water used in industry is consumed in food production. Therefore, the food industry produces a high volume of effluent that needs to be managed wisely, with the support of theoretical and empirical knowledge on water use, reuse, and treatment. The contamination of the water sources by industrial effluents with different toxic substances causes negative externalities, and part of this contamination is a consequence of clandestine networks connected to the fluvial system.

Minimizing water use can effectively contribute to cost reduction in freshwater acquisition and effluent treatment (KLEMEŠ; VARBANOV; HUISINGH, 2012). According to D. Abu-Ghunmi et al., (2016), it is possible to adopt strategies to close the water cycle on an industrial scale, as well as to attract investments for the wastewater management since, in addition to an obligation, investment in water treatment may bring high returns. The practices of reduction, reuse, and recycling should be applied to industries to minimize the consumption of natural resources and the environmental impact in the BRICS countries, adopting the concept of circular economy. This requires a systematic effort at different levels (WU; GENG; LIU, 2017). The strategy of the circular economy adopted in several countries seeks to reform the linear economic system based on extracting, producing, and discarding, building a regenerative and restorative system. In a circular economy, recovering materials and products is not only a preoccupation at the end of the material's useful life; it is a concern that is present since the service/product's design. Companies develop core competencies in circular products and services to facilitate the elimination, minimization, reuse, recycling and utilization of resources to the maximum (HALOG, 2016). This paper aims to analyze the scientific literature produced during the period from 2008 to 2018 on water use, reuse, and treatment focused on the food industry. The study collects data from papers indexed in the Scopus and Web of Science databases, as well as in Brazilian theses and dissertations. The relevance of such research is based on the rapid population growth, industrial expansion, massive consumption of resources, and large discharges of pollutants that have caused increasing environmental pressures, especially on water resources (BAI et al., 2017).

2 METHODOLOGY

National and international papers, dissertations, and theses published in the period between 2008 to 2018 and dealing directly or indirectly with water use, reuse, and treatment in the food industry were gathered, using keywords related to the topic. Scopus and Web of Science databases were used because they present a broader coverage of the topic and offer useful tools for the consolidation of the research (ARCHAMBAULT et al.,2009). The Scopus database is considered one of the most reliable bibliographic databases (V. GOMEZ-JAUREGUI el al., 2014) and one of the most extensive and consolidated international databases. The Web of Science (WoS) is considered one of the most important regarding scientific journals (ARCHAMBAULT et al., 2009). Metadata on scientific publications (such as title, authors, year of publication, abstract, keywords) were imported using the commands available in the databases to the software Endnote, well used in academic research. The software is used to perform systematic literature reviews because of its practicality for reading and sorting papers, as well as to carry out assessments and comparisons (BRAMER;

MILIC; MAST, 2017). The use of specialized software is increasingly common in data analysis in qualitative research (STAKE, 2016). After importing the metadata and files in PDF format, it was possible to apply successive filters (Table 1) – mediated by the Endnote – until obtaining a comprehensive and aligned portfolio of the topic.

The content analysis was the method used to attribute meaning and representation to the literature analyzed in the study (ABELA, 2002; AIGENEREN, 2009; CHAVES, 2002; LÓPEZ, 2009; SABIOTE; TORRES; QUILES, 2005). The corpus submitted to content analysis was formed by the abstracts of the publications collected in the databases. The decision to use the abstracts is because they are a condensed representation of the relevant points covered in the studies (CROSS; OPPENHEIM, 2006).

Table 1 – Filters and criteria to select the bibliographic portfolio

Filter	Criteria
Importation	Importation of the metadata from the databases (Scopus and WoS) to the Endnote software, using the commands available on the databases websites. Theses and Dissertations were imported from the Capes (Brazilian agency for the improvement of higher education personnel) database.
Duplicity	Automatic identification and exclusion of studies in duplicity eventually indexed in both databases.
Title and abstract	All titles and abstracts of the publications were read, eliminating those that did not contribute to the topic 'water use, reuse, and treatment in the food industry.' This is an important filter because the abstract presents the objective of the article, the methods used, and the study's findings. In some cases, the abstract presents aspects related to originality and relevance of the research portrayed in the publication.
Free access	The research considered only free access publications obtained directly from the database or other websites. There was no funding available to purchase publications with restricted access. In addition, as the title and the abstract alone are not enough to guarantee the relevance of the publication's content, it was not viable to purchase materials that could not be significant to the purpose of the research. Finally, we only considered the publications in the languages we can fully understand: Portuguese, English, Spanish, and French.
Content	The publications were read in order to verify their alignment with the topic addressed in this study and to exclude the works that did not contribute to the purpose of the research. The result of this filter is the bibliographic portfolio.
Bibliographic portfolio	The collection of articles published in scientific journals and theses and dissertations that were selected based on the criteria established for this research: the period of publication and broad keywords, publications that are not duplicated, studies with a title, abstract, and content that are relevant for the research, and available for free access.

Source: Elaborated by the authors

The software Iramuteq (Interface de R pour lês Analyses Multidimensionnelles de Textes et de Questionnaires) was used to support the content analysis. The software is one of the many possibilities for qualitative data analysis available in the market, and it was chosen because it is open access and delivers good results when performing content analysis (RAMOS; ROSÁRIO; AMARAL-ROSA, 2018), such as the hierarchical descending classification (HDC) presented in this paper. The HDC groups and organizes the words according to their frequency, after the fragmentation of the transcribed material into text segments (CAMARGO; JUSTO, 2013). The process aims to classify text segments, clustering those that, at the same time, present similar vocabulary to each other, and different vocabulary in comparison to other text segments grouped in another cluster (CAMARGO, 2005). It reduces the text segments to sets of terms, which are classified by the software according to the frequency and the association to a specific cluster (HOCHDORN et al.,2018). The software calculates and provides the results enabling the description of each of the clusters based on a characteristic vocabulary (CAMARGO; JUSTO, 2013).

3 RESULTS

The data collection resulted in a bibliographic portfolio with 138 scientific publications from the Scopus and Web of Science databases and the Capes theses database (Table 2).

Table 2 – Bibliographic portfolio

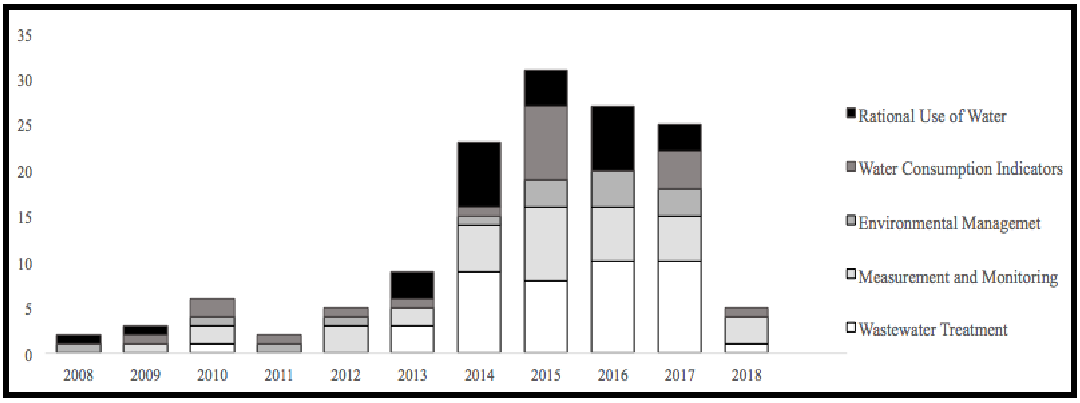
Frequency	Filter				
10098	Importation				
1117	Duplicity				
895	Title and Abstract				
254	Free Access				
197	Content				
155	**Bibliographic Portifolio**				
	Year	**Paper**	**Master's Thesis**	**PhD Dissertation**	**Total**
	2008	2			2
	2009	3			3
	2010	5		1	6
	2011	1	1		2
	2012	4	1		5
	2013	9			9
	2014	23			23
	2015	31		1	32
	2016	26			26
	2017	25			25
	2018	2	3		5
	Total	**131**	**5**	**2**	**138**

Source: Elaborated by the authors

For the content analysis, the software divided the abstracts of the bibliographic portfolio into 1014 text segments, using 965. Two main categories were generated with five clusters of distinct text segments, there were 35,125 words, of which 4,491 are distinct words, and 1,947 are hapaxes (occurring only once). From the HDC, it was possible to produce interpretations about the formations of each cluster and understand the approximations and distances between them (RAMOS; LIMA a ROSA, 2018). After assessing the words of each cluster and the context in which they were used, the two main categories were named as "water management" and "wastewater management" each with their clusters.

Since 2014 the academic production on the topic increased, with greater emphasis in the clusters "wastewater treatment," "rational use of water," and "measurement and monitoring," as shown in Figure 1. The literature addresses the water crisis based on different perspectives.

Figure 1 – Scientific production per class



Source: Elaborated by the authors

In the sections below we detail and provide the foundations for each of the clusters, using the literature in the bibliographic portfolio. It is worth clarifying that studies related to a cluster may be used to support another, because the clusters are interconnected, and the topic demands such cross-fertilization.

3.1 Wastewater Management

3.1.1 Wastewater Treatment

The wastewater treatment cluster is the largest, with 262 text segments (27.15%). It presents the factors related to wastewater generation, pollutants, and toxic elements, as well as the importance of the treatment of liquid effluents to remove these unwanted components (AMARAL-SILVA et al., 2016; ARIONO; PURWASASMITA WENTEN, 2016; QASIM; MANE, 2013).

The food industry generates high pollutant effluents (AMARAL-SILVA et al., 2016) and the treatment corroborates for the mitigation or elimination of environmental impacts. In Brazil, many rivers and lakes receive domestic sewage and industrial effluents without treatment, compromising the quality of the water (MORAES; JORDÃO, 2002). For Costa and Barros Junior (2005), the treatment required for wastewater recovery is closely related to the specifications applied for water reuse. The main objective of wastewater treatment is to obtain high-quality effluents, but the selection of the type of treatment involves several factors, such as the type of pollutant, the infrastructure for treatment, the desired quality of the effluent, and the system's operating costs (BHATNAGAR; SILLANPAA, 2010).

For Hespanhol (2015), the concept of reuse for drinking purposes, as well as being the economic and environmentally correct solution, provides safe water – which is not currently provided by the conventional treatment systems that deal with the water from polluted springs. The processes or systems that can be used to compose advanced reuse treatment systems are the membrane systems, the biological activated carbon, and advanced oxidation process (AOP) that is a technology for industrial wastewater containing organic contaminants that are difficult to biodegrade (KRZEMIŃSKA; NECZAJ; BOROWSKI, 2015).

In the food industry, effluents are generally characterized as highly biodegradable and non-toxic, with a high number of suspended solids, high COD (Chemical Oxygen Demand) and BOD (Biochemical Oxygen Demand), as well as oils and greases (MOUSSA et al.,2017). Therefore, it is financially viable and technically efficient to provide a variety of solutions according to the type of contaminant, some of them with the use of the wastewater in the business itself (HEALY, 2016). The adoption of various simultaneous treatments is recommended for organic waste to achieve better economic and environmental performance (KACPRZAK et al., 2017).

3.1.2 Measurement and Monitoring

Natural phenomena (such as volcanic eruptions, earthquakes, and tsunamis) as well as the anthropogenic interference, impact in the case of water security, making water scarce, polluted, unavailable, altering water-related ecosystems and interfering with climate, especially in industrialized countries with vulnerable and depleted water systems, as a consequence of the high consumption and high discharge of effluents (CLARK; HAKIM, 2014). "Measurement and monitoring" of wastewater reveal factors related to the characterization of wastewater through physical-chemical and microbiological analyzes, which are compared to appropriate technical and legal parameters.

It was also evidenced that the main parameters used to evaluate the water quality for use, reuse, and discharge in the food industry include biochemical oxygen demand (BOD) and chemical oxygen demand (COD), total organic carbon, total nitrogen, nitrate , nitrite, acidity, conductivity, ammonia, total solids, turbidity, coliforms and microbiological analyzes (JACOB; CHINTAGUNTA;BANERJEE, 2016; MENESES; STRATTON; FLORES, 2017; MORITA, 2010; SANTANA, 2018).

The identification, quantification, and characterization of the effluents generated in an industry are essential to protect waters from pollution, as well as for the definition of the strategies for capturing, routing, and treatment of the different types of effluent generated (MIERZWA, 2002). The effluents from the food industry are characterized by high concentrations of oil and grease, sulfate, nitrate and phosphate. Thus, they have high COD and BOD, and inadequate discharge and the lack of treatment cause significant environmental impacts. Compared to domestic sewage, the effluent generated by the food industry pollutes 10 to 100 times more (NOUKEU et al., 2016).

Reusing is to use again materials, products or components for the same purpose for which they were designed (CASTELLANI; SALA; MIRABELLA, 2015). In order to evaluate the viability of reusing energy and material resources in the food production chain, the literature recommends various methods for measurement and monitoring, including mathematical modeling, material flow analysis (such as ecological/water footprint), mass balance and energy, and life cycle assessment (LCA). These methods, however, are not enough to capture the differences between resource flows or the complexity of the interactions between the environmental and socioeconomic aspects (CASTELLANI; SALA; MIRABELLA, 2015; KACPRZAK et al., 2017; MARACAJÁ et al.;, 2012; MENESES;STRATTON; FLORES, 2017; SEIXAS, 2011; SILVA, 2018; SILVA et al.,2013; WU; GENG;LIU, 2017; YU et al., 2009).

3.2 Water Management

3.2.1 Rational Use of Water

The second largest cluster was the rational use of water, with 241 text segments (24.97%). It is part of the water management category and comprises words associated with water resources, preservation and conservation practices that indicate the feasibility of water reuse and the sustainability of this resource in a safe way. Countries with high economic development, such as China, face a severe water crisis involving other neighboring countries that share the same water sources. They have conservation and water transfer plans but are not sure that sustainability targets are met and do not control the generation of negative externalities (CLARK; HAKIM, 2014). There are two directions regarding saving water resources: changing consumption behavior and using the strategy of virtual water trade, which is the value of water in the agricultural commodities, incorporated in the commercial activities. Countries with water shortages save water by importing food, ensuring food security without worsening the local water crisis (ZHAO; CHEN; YANG, 2009).

The term water reuse is defined as the use of treated or untreated effluents for beneficial purposes such as irrigation, industrial use, and non-potable urban purposes. It is the use of the treated effluents in stations or treatment units or the direct use of effluents to replace the customarily exploited water source (MIERZWA, 2002). However, CONAMA (2005) establishes that the water reuse activity should be informed, when required, to the water resources management agency, for registration purposes. The register should include at least the identification of the producer, distributor, or user; the geographical location of the origin and destination of the reuse water; specification of the purpose of water production and reuse; the daily flow rate and volume of reuse water produced, distributed, or used.

In Brazil, the first regulation providing on water reuse nationwide was the technical rule NBR-13696, issued in September 1997. The rule was supported by Law 9433 in the same year, which provided on the National Water Resources Policy and implemented the tax based on the use of water resources as a management tool (WEBER; CYBIS; BEAL, 2010). According to the National Water Resources Council (CNRH), water reuse constitutes a practice of rationalization and conservation of water resources, according to the principles established in the action plan Agenda 21 (CONAMA, 2005). Rationalization consists of using water most efficiently and effectively to allow maintaining and optimizing the water supply to multiple uses and users.

Therefore, the best quality water sources are preserved to be used for the noblest purposes, besides allowing the entrepreneur to save on costs and to potentiate their production process, obtaining economic and environmental benefits (RYGAARD; ALBRECHTSEN; BINNING, 2011). Rainwater, for instance, is most often discarded and it is a resource that when better exploited could solve the problem of lack of water in some regions – knowing that rainwater, although not presenting a high level of contamination, is not potable, thus requiring adequate treatment (SILVA; PRZYBYSZ, 2014).

3.2.2 Water Consumption Indicators

The cluster "water consumption indicators" presented 176 text segments (18.24%). It is in the water management category and refers to the water used to produce goods and services, i.e., the 'water footprint.' The cluster also refers to the interaction with the ecology, considering the provision of water intake and the water used in the products' consumption, which justifies the use of the 'water footprint' in the legislation (SILVA, 2018; SILVA et al., 2013).

In the industry, water is used in several ways such as for human consumption, as raw material, as an auxiliary fluid, in the generation of energy, and as heating and cooling fluid. The quantity and quality of water required for the development of industrial activities depend on the characteristics of the business, given the different levels of quality and production capacity that can be used (MIRRE et al.,2012).

Indicators are required to measure the volume of water used in each organization. In past studies, the concept of water footprint was used as an indicator of the water consumed both by people and products (ZHAO, CHEN and YANG, 2009). Identifying the water footprint allows quantifying the total water consumption along the production chain (YU et al., 2010). In this way, the players involved in the production can quantify the freshwater appropriation and contribute to reduce consumption and apply mechanisms for compensation when there are conflicts of water use and environmental degradation in river basins (SEIXAS, 2011).

The water footprint is divided into three components: blue, green, and gray water footprint, all of which are expressed in water volumes. According to Hoekstra et al., (2010), the blue water footprint of a product refers to the consumption of surface and groundwater along the production chain. The green water footprint refers to the consumption of rainwater, provided it does not drain. The gray water footprint refers to pollution and is defined as the volume of fresh water required to assimilate the pollution related to the production process, based on the natural concentrations and existing water quality standards. For Chapagain and Tickner (2012), the concept of blue water footprint is represented by an indicator of consumptive use, ‘surface water’ and ‘groundwater,’ i.e., when there is water evaporation; when water is incorporated into the product; when the water does not return to the basin of origin but flows into another basin or the ocean; when the water does not return in the same period, for example, when it is withdrawn in a drought period and returns in a rainy season.

According to Souza and Vieira (2012), the green water footprint is an indicator of the human’s use of water. For the authors, the green water is the precipitation on the continent that does not drain or replenish groundwater but is stored in the soil or remains temporarily on the surface of the soil or vegetation. The green water footprint is particularly relevant for agriculture and forestry production. The gray water footprint indicates the degree of freshwater pollution associated with the production process. Hoekstra et al. (2010) define this component as the volume of fresh water required to assimilate the pollution based on natural concentrations and existing water quality standards.

Empinotti and Jacobi (2012) emphasize that the water footprint is a multidimensional indicator representing the volumes of water consumption in terms of space, dividing the water resources according to the different sources used, such as water present in the soil (green water footprint) and irrigation water (blue water footprint). The water footprint can also subsidize the measurement of contamination of freshwater resources resulting from pollution (gray water footprint). In comparison to other industries, food production requires large volumes of water, which are mainly used in plant operations, such as production, cleaning, sanitation, refrigeration and transportation of materials (MAVROV; BÉLIÈRES, 2000). The water footprint can be used to control water consumption in industry, as it is a water management tool that allows governments, companies, and civil society to observe the amount of water needed along the production chain (SILVA, 2018).

3.2.3 Environmental Management

The environmental management cluster presented 130 text segments (13.47%), is part of the water management category, and refers to environmental performance. In this sense, the environmental management system based on ISO 14001 (which provides environmental certification) stands out. The system can be considered as an indicator of commitment to the environment and nature resources. Also, the environmental management cluster refers to the environmental license, a legal requirement for environmental control (COLARES et al.,2015).

As for certification, D'Avignon (2001) states that a management system linked to a specific process, when correctly certified, may induce the adoption of increasingly clean technologies as well as the improvement of the final product. The civil liability of the organization for damages to the environment and defects in the products is also more transparent. The system can be applied to all types and sizes of organizations, adapting to different geographic, cultural, and social conditions. The overall purpose of ISO 14001 is to balance environmental protection and pollution prevention with socio-economic needs (MORETTI; SAUTTER; AZEVEDO, 2008). In addition, the organization’s administration must design the environmental policy, which will become the central axis of the environmental management system.

For Silva and Przybysz (2014), environmental management corresponds to a set of policies, plans, and organizational, administrative and technical procedures so that a company can obtain the adequate environmental performance. Environmental performance indicators need to be reviewed because it is common for companies to create indicators that are difficult to measure, ambiguous, redundant, misaligned with strategic policies and objectives, or that do not provide adequate information to the manager, as well as not considering the singularity of each sector of the economy and each company (CAMPOS; MELO, 2008).

Reuse as well as recycling, bioremediation, energy efficiency, and landfill are options that reduce the amount and toxicity of solid and liquid waste, but public and business policies are needed to show benefits and encourage resource substitution practices. The objective is to eliminate the use of non-renewable resources from the supply chain, and to increase the circularity of products and services by analyzing and improving the flow of materials in the life cycle stages of products and services, considering the interdependence between consumption, environmental protection, and economic performance. It is possible to observe that companies are increasingly aware of the strategic importance of the environment for business. However, only 3% of the businesses in the food industry in Brazil have the ISO 14000 certification. Certified companies usually seek certification to meet environmental legislation.

The largest food companies, while affirming their concern regarding sustainability, build water management programs to ensure operational efficiency, reduce costs, and perpetuate an unsustainable business model, which endangers the business’ survival. Particularly for water, the integrated water management has the potential to act in ecosystems that are under natural and anthropogenic threats that interfere with the availability, the inadequate use, and climate change, impelling governments and private bodies to be more assertive in the decision-making about this natural resource (CLARK; HAKIM, 2014; COLARES et al., 2015).

3.3 Gaps and Opportunities

The work of reading the papers and the results of the content analysis demonstrate some topics regarding water use, reuse, and treatment in the food industry that were not covered in the literature. Others were dealt with only superficially, and some themes stood out in the last years.

3.3.1 Water Conservation

The culture of waste is predominant both within the population and in corporations, and there is no awareness regarding preservation and sustainability. In Brazil, water is abundant in large urban centers (even though there have been some episodes of scarcity), so there is no concern about rational consumption by the population and public authorities (ALMEIDA, 2011). However, increasing urbanization and industrialization generate a supply and demand problem for water resources. Good quality water, increasingly scarce, became a topic of interest. The Brazilian reality, however, is still contradictory in comparison to other nations that have long suffered from rationing, such as Japan and Israel, which already make more conscious use of water. This awareness has been inserted in their culture through environmental education (BAI et al., 2017). It is observed that there is room for policies to encourage public awareness and participation in environmental decisions and the water's governance and management (HORI, 2014).

Water pollution is an aggravating factor since rivers are polluted by domestic sewage, industrial effluents, medical waste, pesticides, among other elements. It is clear the importance of raising awareness that the problem is not in water availability but the quality of its use, reuse, and treatment. Governments, industries, and the general population should join efforts to develop awareness programs, inform the public about the importance of water conservation and community participation in developing mechanisms of water reuse and conservation. Cost-effective research to deploy a complex yet effective system compared to a simpler yet inefficient and polluting (and therefore costly) system is necessary to mitigate inadequate effluent disposal.

3.3.2 Water Reuse

In the quest for a solution to the problem of water scarcity, reuse of wastewater is becoming an essential tool in water management and environmental policies. In order to fully exploit the significant potential of water reuse, it is necessary to establish institutional arrangements, economic instruments, and more explicit guidelines, as well as prioritizing technological innovation and consolidating best practices (BIXIO et al., 2006). In Brazil, there are no specific norms and standards to regulate and direct the reuse of wastewater, which is a result of the lack of tradition in reusing water in the country. The legislation only establishes maximum impurity limits for each specific water destination (ALMEIDA, 2011).

The rationale for explaining the low reuse rates varies from the lack of norms and legislation to the abundance of water resources, or the deficit in sanitation infrastructure and services (RIBEIRO, 2012). Brazilian legislation allows water reuse only for non-potable purposes, whereas in other countries the reuse as potable water is allowed, after adequate treatment according to the final use. The practice of direct reuse for public supply is already established in several states in the US, in South Africa, Australia, Belgium, Namibia, and Singapore, without associated public health problems (HESPANHOL, 2015).

The concept of reuse observed in the literature is often exposed based on the same examples, guiding the reuse of water for discharges, floor washing, toilets, automobiles, boilers, cooling, garden watering, and irrigation. It is fair to assume that investments from the industry in technology and infrastructure are needed, as well as being crucial that the government establishes clear and objective norms for efficient water reuse.

The abundance of water in Brazil causes the false impression that there is no need to worry about scarcity. The lack of enforcement, stricter laws, and regulations contribute to a general neglection about the issue of improving water use. A critical analysis of the legal framework for water reuse is essential. The regulation of water reuse is underway in Brazil, but it is still necessary to define the standards for the different modalities (MARACAJÁ et al., 2012).

3.3.3 New Productive Standards

The increased demand and the maintenance of the unidirectional linear cycle (extraction, use, and disposal) have rapidly reduced the water supply, culminating in scarcity. The circular economy applied to industries creates and provides higher value for each natural resource used when compared to the linear economy (HUSGAFVEL et al., 2016). Circularity adds value to products for as long as possible, minimizing environmental impacts generated by waste and predatory exploitation of resources (TORRES; PARINI, 2019). In South America, the concept is new, and the incorporation of the circular economy by public policies in industrial production processes is slow.

Financial investments to support projects and research on the subject are necessary, and it is necessary to disseminate knowledge about shifting the paradigm from the current models of capitalist production to a socio-economic and environmental organization of the production of goods and services. Berthelot et al., (2003) studied Canadian ISO 14001 certified companies about potential difficulties in implementing the standard, and respondents listed among the key aspects the employee involvement and the need for employee training.

Gibson and Tierney (2012) identified obstacles of implementing new environmental practices, highlighting the high costs and difficulty of obtaining employees' commitment. Resistance is also presented as difficulty in implementing change, and many efforts have been devoted to overcoming this issue. Employee commitment to the environmental management system must be assessed, in order to verify whether this aspect affects the efficiency of environmental processes (COLARES et al., 2015) and to propose strategies to overcome the resistance to change.

3.3.4 Empirical Studies

A few Brazilian theses and dissertations about the theme were observed in the study (MORITA, 2010; SANTANA, 2018; SEIXAS, 2011; SILVA, 2018). These works dealt with practices for water use and reuse in food industries, focusing on indicators of consumption (SEIXAS, 2011; SILVA, 2018) and measurement and monitoring (MORITA, 2010), which ratifies the opportunity for researchers to delve deeper into the subject. International agriculture supply chains can transform local water crises into global ones, affecting humanity’s food security, and it is, therefore, urgent to study the impact of the food industry on water resources on a broader and transnational spectrum (DUARTE; PINILLA; SERRANO, 2015).

Chinese authors discussing the subject, followed by Italian, Dutch, Indian, and Spanish. European researchers show considerable interest in the subject while in countries like the USA, Russia, and Japan, which are economies with a high index of industrialization, there is little research on the subject.

Brown et al. (2015) guide researchers to focus on empirical studies based on local problems, resulting in more robust and reliable indicators, greater credibility of the approaches to academia and society, and to create a framework for predicting the effects of water management. In this sense, it is noteworthy that the low qualified scientific production in countries with abundant water resources such as those of South America and Australia. Brazilian publications on this subject are all in Portuguese, indicating the need for internationalization of the research on the topic.

4 FINAL CONSIDERATIONS

This study has provided a theoretical approach on the scientific production on water use, reuse, and treatment in the food industry – which is closely linked to global food security and a significant generator of liquid effluents. The study carried out content analysis on abstracts of 140 research works including papers, theses, and dissertations on water use, reuse, and treatment in the food industry, published between 2008 and 2018. The analysis resulted in the separation of the content in two lexical categories, 'water management' and 'wastewater management,' covering from the water extraction until the discharge, divided into 5 clusters. Each cluster was explained and validated theoretically with the selected reference, and it was demonstrated that the water management could be explained by the indicators of water consumption, rational use of water, and environmental management, whereas the wastewater management is explained by the indicators effluent treatment and measurement and monitoring.

It has been shown that studies on water in the food industries have increased since 2014 and are empirical, local or regional, and few papers focus on review. Also, it was not possible to find any specific article on the topic researched. By 2013, studies focused more on water consumption in food industries, with emphasis on the water footprint, life cycle analysis, and sustainability. After 2014, the publications started to portray applied studies on circular economy, efficiency, and improvement of processes and effluents' treatment.

Four research opportunities have been identified in this review. First, water conservation in food industries, which has been the subject of research around the planet, particularly based on water scarcity in the near future. Another opportunity is for further studies on water reuse, for the same reason as scarcity, but also because the food industry is a sector of the economy with high water use and significant generation of effluents. The third is the search for new production standards, stimulated by the concept of circular economy, modifying products and processes throughout the supply chain. Finally, it was observed that the water use, reuse, and treatment in food industries is a topic with an elevated interest in academia. The evidence points to a great interest in water management in all cycles of use from Chinese, Indian, and European researchers. However, the studies are still scarce in other countries with high industrialization and strong projection of water stress.

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