WHEY IN THE INDUSTRY: ENVIRONMENTAL AND VALORIZATION IMPACTS

REVIEW ARTICLE

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ABSTRACT

Whey is a costly and environmentally harmful co-product. Coming from the activities of dairy industries, especially cheese production, whey cannot be discarded directly into the environment because it has a high content of organic matter, which can become an environmental and economic problem, since its treatment for subsequent disposal is time consuming and laborious. In recent decades, however, much research has been developed in search of viable alternatives for the use of whey, instead of just discarding it. One alternative to this is the valorization of whey. The valorization of whey is, therefore, of great interest for economic-environmental reasons and is essential to meet the requirements of Agenda 2030, especially with regard to ODS 6, 9 and 12 (Drinking Water and Sanitation; Industry, Innovation and Infrastructure; Responsible Consumption and Production, respectively). This article

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sought to present a characterization of the production of whey, through a literature review using bibliometric techniques, in order to highlight some alternatives for the reuse and valorization of whey in the industry and its relationship with the environment and the environmental impacts correlated to the disposal and improper handling. Pointing out industrial sectors that can insert whey in production with a view to sustainability and reduction of environmental impacts. With the review of the selected articles to compose this work, it was possible to identify that the valorization of whey is an excellent alternative that should be implemented in industries and that provides gains in both economic and environmental issues.

Key words: Whey, Valorization, Sustainability.

1. INTRODUCTION

The food industry is one of the largest industrial sectors in the world. Even though it is not the one that causes most damage to the environment, food manufacturing and processing can cause damage and major environmental impacts when the pollution generated by this industry is not properly treated.

The high production of the dairy industries, the volumes, the environmental impacts involved, and the nutritional value of the co-products, make it an important subject for valorization. Valorization allows one to explore possibilities for reusing the nutrients in the production of main products, and therefore highlights the potential gains that can be achieved and the minimization of environmental impacts.

Dairy industries, especially those that produce cheese, have supplied large amounts of whey as the main co-product of milk processing into cheese or caseins. Although whey has a high nutritional value and functional properties, it has not had its real value and use in the industries.

Studies show that about 40% of the whey produced in Brazil is improperly discarded, mainly by small and medium-sized enterprises, becoming a harmful industrial waste

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to nature that causes a high negative environmental impact, due to the damage it offers to fauna and flora, because its Biochemical Oxygen Decomposition (DBO) is about 100 times higher than that of domestic sewage (HARAGUCHI et al., 2006; ROHLFES et al, 2011; GAJO et al., 2017; NUNES et al., 2018).

It is estimated that to produce 1kg of cheese, an average of 10kg of raw milk is needed and an average of 9 liters of whey is generated, which is a co-product of high nutritional value and highly harmful to the environment, and above all is not valued or reused by the industry.

The reuse of whey is a topic that has already been debated by several researchers from different areas of knowledge around the world, mainly due to its high nutritional value, which enables its processing and transformation into products with high added value (SLAVOV, 2017; MOR et al., 2018; NUNES et al., 2018).

Whey proteins can be widely used in food formulations due to their nutritional and functional properties. And because it contains essential amino acids and is a source of bioactive peptides, which have health-promoting potential, leading to its use in food supplementation and pharmaceutical products (HARAGUCHI et al., 2006).

And when whey is not reused in the industry, or for animal feed, or when there is no treatment for its subsequent disposal, it is inappropriately discarded in water courses, resulting in environmental impacts.

There are many ways to valorize whey and reuse it in the industry, enabling its use in various segments, such as food, pharmaceuticals, energy, agriculture, among others.

The challenge for dairy industries is to correctly manage the whey produced, and after a theoretical survey the main factors of environmental impact are presented, as well as alternatives for the reuse/valuation of whey as a raw material in the manufacture of new products.

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2. LITERATURE REVIEW

2.1 ENVIRONMENTAL ASPECTS AND IMPACTS OF BRAZILIAN DAIRY INDUSTRIES

Before starting the environmental issues of dairy products, it is fundamental to present the definitions of environmental aspects and impacts, in order to obtain a better understanding of the whey disposal problem. According to the NBR ISO 14.001 standard, an environmental aspect is defined as "the element of an organization's activity, products or services that can interact with the environment" (ABNT, 2004).

About environmental impact CONAMA Resolution 001, from January 23, 1986, in its article number 1 defines environmental impact as:

Any alteration of the physical, chemical and biological properties of the environment, caused by any form of matter or energy resulting from human activities that, directly or indirectly, affect: I - the health, safety and welfare of the population; II - the social and economic activities; III - the biot; IV - the aesthetic and sanitary conditions of the environment; V - the quality of environmental resources.

There are several environmental impacts generated by dairy industries. And the main negative impacts are related or correlated to at least one of the following aspects:

- **High water consumption**

High water consumption is directly linked to sanitary quality. This is the natural resource with the greatest use in the sector, and it promotes the guarantee of cleanliness of the work environment (equipment, tools, and facilities), and is directly linked to operations, such as cooling and steam generation.

- **Generation of effluents**

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Characterized by the high concentration of organic matter, the effluents from the dairy industry are the main environmental aspects of the sector. They result mainly from washing and cleaning the fleet that transports milk and products, tanks, machinery and equipment directly involved in the production process, in addition to leaks, spills and inefficient equipment operations, which generate losses in the process and disposal of products and co-products, such as whey;

- **High energy consumption**

Refrigerated and air-conditioned environments, lighting, ventilation, and equipment operation are related to the quality assurance of the sector's products, which requires high energy consumption.

- **Generation of solid residues**

This aspect is characterized not only in the manufacturing process itself, but throughout the manufacturing context, for example: paper, disposables, packaging, material for physical-chemical and microbiological analysis, among others;

- **Atmospheric emissions**

The emission of gases into the atmosphere is directly linked to fuel burning and boiler operations.

In addition to the aspects with polluting potential, mentioned above, the disposal of whey is a waste of nutrients, especially proteinaceous material, considering that on average 55% of the nutrients in milk are present in whey (ALMEIDA et al., 2001; BUSS AND HENKES, 2014).

The liquid effluent generated by these industries and cheese dairies is considered to be the main responsible for pollution. In many industries of this sector, whey is discarded along with other effluents, which is considered an aggravating factor due to

its organic load, making it a highly polluting effluent, especially in the production of small and medium industries, since production is centralized only in the production of cheese (GUEDES et al., 2013; BASSETO et al., 2017)

2.2 WHEY

Whey, also known as whey or even cheese whey, is the liquid portion extracted from the clotting process during cheese making. It is considered the main co-product of the dairy industry, because its generated volume is about 90 to 95% of the volume of milk used for cheese making, and it contains approximately half of the total milk solids, including soluble proteins, salts, and especially lactose. On the industrial side, there are two main types of whey, which are sweet whey and acid whey, classified by their total acidity or by their lactic acid content. Acid whey has a pH of 4.5 to 4.8 and a salt content of 0.8%; sweet whey has a pH of 5.8 to 6.5 and 0.5% salts (SGARBIERI 2004; MORRILL et al., 2012; ALVES et al., 2014; NUNES et al., 2018; HAUSJELL et al, 2019).

When not used, whey is considered the most worrying residue due mainly to the lactose and protein present, which makes the rate of organic matter high, and can cause severe environmental impact if released into the environment without prior treatment. (MORRILL et al., 2012; SILVA et al, 2018; PINHO, 2019).

2.2.1 CHARACTERISTICS (NUTRITIONAL VALUE)

The characteristics and composition of whey depend on the type of processing and the type of cheese to be produced. On average whey contains, 93% water and 7% total solids. Of the whey solids, on average, 73% is lactose, 14% protein, 7% fat, 4% lactic acid and small amounts of vitamins. The protein fraction, contains, on average 50% beta-lactoglobulin, 25% alpha-lactalbumin and 13% other protein fractions, including immunoglobulins (SILVEIRA et al., 2013; HARAGUCHI et al., 2006)

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2.2.2 THE POLLUTING POTENTIAL OF WHEY

One of the main environmental impacts caused by dairy industries is related to the fate of the whey not used for the manufacture of new products, when released directly into waterways, without any treatment (PEREIRA et al., 2018; SILVA et al., 2015; 2018).

The high polluting power of whey is due to the high amount of organic substances present in its composition represented mainly by proteins and lactose. Thus, when discharged into waterways, whey can cause the destruction of flora and fauna due to biochemical oxygen demand (DBO), which has high concentrations. It is estimated that the DBO of whey is approximately 100 times more than the DBO of domestic sewage.

For this reason, environmental legislation prohibits the disposal of whey without efficient treatment. Law n° 9.605, of February 12, 1998, provides for criminal and administrative sanctions derived from conducts and activities that are harmful to the environment, and makes other provisions, provided in its Art. 33:

Causing, through the emission of effluents or the transportation of materials, the perishing of aquatic fauna specimens existing in rivers, lakes, ponds, lagoons, bays or Brazilian jurisdictional waters: Penalty - detention, from one to three years, or a fine, or both, cumulatively. (p 11).

Thus, dairy products agribusinesses must obligatorily perform the treatment of their effluents before final disposal in waterways. Industries in this sector, must follow Resolution No. 430, of May 13, 2011, which provides on the conditions and standards for effluent discharge, complements and amends Resolution No. 357, of March 17, 2005, of the National Council of the Environment - CONAMA (BRASIL, 2011). However, each state in Brazil has its own legal specifications governing standards and conditions for effluent discharge.

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As the generation of whey is on average nine times the amount by weight of cheese produced, it can be seen that its contribution in the final effluent from dairies is very relevant, both in qualitative and quantitative terms. The treatment of these effluents for small and medium-sized industries is a very challenging issue, because it requires high-cost investments, which makes them end up acting illegally, or wasting this valuable product, whey (SILVA et al., 2015; 2018; PEREIRA et al., 2018).

2.3 ALTERNATIVES FOR WHEY PROCESSING.

In the past, whey was not used or was only used in animal feed, such as pigs and cattle, but the knowledge of its composition and technological advances led it to be considered an ingredient of great value for the food and pharmaceutical industry. There are numerous applications for whey, including dairy, pharmaceutical, meat, chocolate, snacks and beverages, dry mixtures (for seasoning), baking etc., (MARTINS et al., 2013; BANASZEWSKA et al., 2014).

2.3.1 FOOD PRODUCTION AND HEALTH BENEFITS

Whey can be used as a raw material for other products, or be part of their formulation. In the industry, it is already known to be used in the production of foods such as yogurt, dairy drinks and desserts, some types of cheese, such as ricotta, bakery products, supplements, food for athletes and individuals with dietary restrictions, among other uses. Besides having nutritional properties, whey also has highly significant functional properties that promote health benefits. And due to the functional properties, mainly by the proteins present, these confer to the products better characteristics and provide better quality. (ALMEIDA et al., 2001; TERRA et al., 2009; ROHLFES et al., 2011; GUEDES et al., 2013; SIQUEIRA et al., 2013; ROHLFES et al., 2014; NUNES et al., 2018; BARUKČIĆ, 2019; KOPSAHELIS AND KACHRIMANIDOU, 2019).

In figure 1, we can see some applications of whey in the food industry, related to the characteristics that it gives to products and the protein percentage.

Figure 1: Example of whey applications attributed to the characteristics and protein percentage.

Feature	Food sector	Protein Percentage	Applications
Viscosity	Desserts	35	Chocolates, Marshmallow,
Solubility, Colloidal Stability	Drinks	35	Fortified protein, isotonic, aerated and food replacement beverages; Piña colada, teas, juices and yoghurts.
Emulsification	Soups, children's foods	85	Low or zero fat soups, Sauces and processed cheeses
Foam Formation	Confectionery	35	Icing, Sour Cream, Whipped Cream,
Gelation	Dairy products	65	Yogurt, Frozen Yogurt, Ice Cream
Elasticity	Bakery	65	Brownie, Cake, Cookies, Bread,
Water and fat absorption	Meat Products	8	Sausage, Burger Steak, Ham, Nuggets and Sausages.

Source: Alves et al., 2014, adapted from UDESC, 2014.

Embedded foods, such as bologna, when in its manufacturing process had the water replaced by whey, there was no negative influence on the characteristics such as: sensory, pH, color and stability. This is a suitable alternative for the reuse of whey (TERRA et al., 2009; ALVES et al, 2014).

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Due to its nutritional values, and because it is considered an excellent source of protein, and promotes nitrogen retention, with biological improvement and prevention of metabolic stress of the organs, whey has been widely inserted in the diet of athletes of various modalities and degrees of effort (HARAGUCHI et al., 2006).

There are many studies on the benefits of whey in the human diet, especially for some specific groups, such as obese people, where the essential amino acids of whey proteins benefit the metabolic processes in order to reduce body fat, control blood glucose and insulin, and preserve muscle mass during weight loss (ALMEIDA et al, 2001; SCARBIERI, 2004; OLIVEIRA et al., 2012).

Due to the functional properties of the proteins present in whey, there have been significant improvements in the immune system of patients with HIV virus when they are subjected to a supplementation of protein concentrates and anti-cancer activities in cancer cell cultures, antibacterial and antiviral, anti-ulcer and protection of the cardiovascular system (SGARBIERI, 2004).

The immunomodulatory power of whey proteins is another important functional property, as they play an important role in health promotion, for example in controlling blood pressure and as a cardiac risk-reducing agent (HARAGUCHI et al., 2006).

2.3.2 INDUSTRIAL PRODUCT DEVELOPMENT AND ENERGY PRODUCTION

While the use of whey is most visible in the food industry, it is also used in the chemical and energy industries. Lactose is an energy source for microorganisms, so it is possible to use whey as a substrate for fermentation to obtain ethanol, biomass, biogas, lactic acid, etc. (KOSSEVA, 2009; DINIZ et al., 2012; PARACHAR et al., 2016).

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A very interesting application of whey, is that whey proteins can be used in the manufacture of invisible, biodegradable and even edible packaging, which are thin films used to extend shelf life and ensure food quality (EÇA et al., 2014; SANTOS et al., 2015; RYAN and WALSH, 2016).

Significant efforts are being made worldwide to find ways to use whey to produce value-added products. As whey has high nutritional value and the Lactose present can act as the main carbon source for the growth and formation of various biotechnological processes, ethanol and biogas production becomes a promising and viable alternative, as well as reducing environmental impact, not only by avoiding contamination from the whey, but also by producing clean energy (FLORÊNCIO et al, 2013; MURARI et al., 2013, 2017 and 2019; RODRÍGUEZ et al., 2016; PEREIRA et al., 2018; ANTONELLI et al., 2019).

3. MATERIAL AND METHOD

This research consists of an exploratory-descriptive research, which sought to outline the main means for valorization of whey in the industry, by means of a systematic review of the literature on the studied subject, sought to outline the main avenues for valorization of whey in the industry. The systematic review, as well as other types of review studies, consists of a research that uses a source of data from the literature on a specific subject, in order to group and consolidate the results of primary studies on the subject. This type of research provides a summary of related evidence, strategies, methods, synthesis and criticism (SAMPAIO and MANCINI, 2007).

The methodological strategy used for the development was the steps presented in figure 2.

Figure 2: Steps for the systematic literature review process.

Source: The Authors (2021).

The scientific question is based on the situation that many companies in the dairy industry find themselves in, faced with an increasingly competitive scenario and environmental demands. What to do with whey in the dairy industry?

The Capes Periodicals portal < <http://www.periodicos.capes.gov.br/>> was used as the indexing database. The search was made by subject in an advanced manner, with the objective of obtaining results from several databases, such as Scopus (elsevier) and Scielo. And the search was restricted to peer-reviewed journals.

The search terms used and the strategies applied are listed in figure. The keywords are associated with the terms used in the search for the journals, which are: cheese whey, whey valorization, environment pollution, sustainable.

The selection criteria for the articles were based on the search for the terms sustainability, valorization, management, and environmental impacts, opting for Brazilian research. The application of the criteria was based on the analysis of the article title, abstract, and discussion/conclusion. After selecting the articles of interest, which contributed to the answer to the scientific question, they were analyzed in their full in order to obtain solid content and information.

Figure 3 shows the results of the search based on the strategy used to select the articles that compose this study. When we searched for material using the term whey, we obtained a large number of articles related to it, so by using Boolean operators it was possible to refine the search and reach the selected articles.

Figure 3: Search strategy

Key-word	Search terms	Found articles	Analysed articles	Selected articles	Authors
Whey	Whey	45.032	162	23	Afonso et al., 2008; Almeida et al., 2001; Alves et al., 2014; 2017; Antonelli et al., 2019; Banaszewska et al., 2014; Basseto, 2017; Barukčić, et al., 2019; Buss and Henkes, 2014; Diniz, et al., 2012; Eça, et al., 2014; Florêncio et al., 2013; Gajo et al., 2017; Gough et al., 2012; Guedes, et al., 2013; Haraguchi et al., 2006; Hausjell et al., 2019; Kopsahelis and Kachrimanidou, 2019; Kosseva et al., 2009; Mor et al., 2018; Morrill et al., 2012; Murari et al., 2013; 2017; 2019; Nunes et al., 2018; Oliveira et al., 2012; Parashar et al., 2016; Pereira et al., 2018; Pinho, 2019; Rodríguez et al., 2016; Rohlfs et al., 2011, 2014; Ryan and Walsh, 2016; Santos et al., 2015; Sgarbieri, 2004; Silva et al., 2015; Silva et al., 2018; Siqueira, 2013; Slavov, 2017; Terra et al., 2009.
	Whey AND Cheese Whey	11.207	147		
	Whey AND Utilization	7.373	43		
	Whey AND Management	6.020	34		
	Whey AND Valorization	438	2		
Environment	Environment AND Whey	9.967	43	17	
	Environmental Impacts AND Whey	1.220	7		
	Environment Pollution AND Whey AND dairy	203	5		
	Whey AND Valorization AND Sustainable	236	11		

Source: The Authors (2021).

4. FINAL CONSIDERATIONS

From the found and analyzed articles, 40 articles were selected to be studied, and to compose this work. These articles, in addition to present the problem which involves the improper disposal and waste of a co-product such as whey, also indicate that it is of fundamental importance to seek alternatives for reuse, mainly due to its nutritional quality and versatility. However, in the current scenario, for small and medium Brazilian dairy industries, economically feasible alternatives for whey recovery are very limited, if considered in isolation. It is important to consider that the solution for the valorization of whey includes issues such as: obtaining quality whey, outflow production, implementation of strategically located units for pre-concentration and forwarding of whey to processing units. This is a challenge, since competitiveness in this sector shows that only companies with efficient production processes and market strength, and with developed environmental programs, can survive and remain productive.

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Scientific discoveries have shown in recent years that whey is a by-product of the dairy industry of great value, and that its multifunctional properties, especially the proteins presented, have varied applications in various industrial sectors. It is necessary to change the perception that whey is just a waste product; it should be treated as a raw material with nutritional, functional and economic value, which enables value addition along the milk production chain and cost reduction with effluent treatment. And so, the processing of whey will provide a significant improvement in preserving the environment.

Developing sustainable methods for dealing with the whey produced in dairies is of great necessity. There are numerous possibilities in the use of its proteins and various products, however, it is still necessary to explore the potential of whey in the industry. Processes and systems must be developed especially in the emerging fields of bioplastics and biofuel production, where whey can be an ally or even an option in replacing fossil fuels.

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