Journal of Cleaner Production 266 (2020) 121954

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Sustainable business models and eco-innovation: A life cycle assessment

Renata Barbieri [a], David Ferreira Lopes Santos [b, *]

[a] Paula Souza Center, Technology College of Presidente Prudente, Rua Teresina, 75, Uep6-S.2, Presidente Prudente, São Paulo, Brazil
[b] São Paulo State University (UNESP), School of Agricultural and Veterinarian Sciences, Jaboticabal, Via de Acesso Professor Paulo Donato Castellane s/n, Jaboticabal, São Paulo, Brazil

ARTICLE INFO

Article history:
Received 9 April 2019
Received in revised form
11 February 2020
Accepted 27 April 2020
Available online 3 May 2020

Handling Editor: Tomas B. Ramos

Keywords:
Agribusiness
Sustainable development indicators
Organizational innovation
Veterinary medicine

ABSTRACT

Eco-innovative business models are prominent elements of the development of sustainable production and consumption systems in organizations of all sizes, especially for small and medium enterprises, where a key challenge is to direct eco-innovation strategies toward the goals of their business model. Therefore, using product life cycle assessment, this research analyzed the alignment between the sustainable business model and the eco-innovative strategies of a Brazilian company in the veterinary homeopathy pharmaceutical industry. Disregarding the controversial discussion about homeopathy, this activity has shown significant growth, having a representative economic importance in the animal protein production chain. The research adopted a case study method for one of Brazil's leading companies in this activity. Data were collected through interviews, process analysis and company records. The results were built through quantitative and qualitative techniques that demonstrated that the eco-innovations developed by the company are directed toward the creation of new production methods and, above all, new products. The management model was framed in the "adopt a management role" archetype, in accordance with the literature. It was found that eco-innovation strategies are important for the development of the company's business model and that this alignment is possible only when there is a management system and investments in the company's ability to eco-innovate in product, process and organizational structure.

1. Introduction

Coping with environmental, social and economic issues at the local, regional, national and international levels requires the transition to more sustainable economic systems and industrial processes (Ghisellini et al., 2016). In this context, the circular economy is an emerging and alternative concept, compared to the linear industrial production-consumption-disposal model, which is based on the generation of value for all stakeholders along the production chain (MacArthur, 2013; Ghisellini et al., 2016; Geissdoerfer et al., 2017a; Manninen et al., 2018).

The need to identify bottlenecks in productive chains and invest in resources capable of generating business models and eco-innovation solutions are emerging business challenges, especially for small and medium-sized enterprises (SMEs), whose challenge is to achieve a competitive position in markets that operate using investments that allow the longevity of this type of organization (Triguero et al., 2013; Johnson, 2015; Klewitz and Hansen, 2014; Geissdoerfer et al., 2017a).

SMEs have increasingly gained relevance for sustainable development, especially in promoting innovation, creativity and decent work (Klewitz and Hansen, 2014; Bocken et al., 2014a). Although much research has focused on eco-innovation development in large companies, social and environmental impacts account for approximately 70% of the global pollution generated by SMEs. However, the environmental impacts of SMEs are minimized by the polluting actions of these organizations and the impacts of large multinational corporations, which have captured the attention of society (Johnson, 2015).

Given the above, empirical studies on eco-innovation have focused their efforts on analyzing their impact on the sustainability of specific innovations and the factors that determine eco-

* Corresponding author. São Paulo State University (UNESP), School of Agricultural and Veterinarian Sciences, Jaboticabal, Via de Acesso Professor Paulo Donato Castellane s/n, Jaboticabal, São Paulo, Brazil.
E-mail addresses: renata.barbieri@fatec.sp.gov.br (R. Barbieri), davidflsantos@gmail.com (D.F.L. Santos).

https://doi.org/10.1016/j.jclepro.2020.121954

innovation (Triguero et al., 2013; Hojnik and Ruzzier, 2016), eco-innovation relationships with business models (Bocken et al., 2014b; Manninen et al., 2018), strategy or performance (Cheng et al., 2014; Przychodzen and Przychodzen, 2015), and bibliometric research on the topic (Bossle et al., 2016).

Organizations and institutions, such as the European Union, underline the importance of solutions and businesses eco-innovations in promoting sustainable development (Colombo et al., 2019). In contrast, there is a limited amount of research in the literature that addresses eco-innovation as a corporate strategy and how it is developed and implemented in companies, especially SMEs (Bocken et al., 2014a). From the perspective of the circular economy, whose approach is directed toward the economic system, social benefits are implicit, and the literature remains inconclusive about the extent and distribution of positive impacts (Geissdoerfer et al., 2017a; Manninen et al., 2018).

Given the theoretical and applied gap of empirical studies that seek to understand how companies can incorporate innovation and sustainability into purposes and processes, this study aimed to analyze the alignment between the sustainable business model and eco-innovative strategies of a pharmaceutical industry that produces homeopathic veterinary medicines.

The analysis was performed from the perspective of life cycle assessment (LCA) using the gate-to-gate approach. The scope of LCA was defined to explore eco-innovation opportunities (realized or potential) as well as to understand the adherence of the company's business model to those established in the literature defined by Bocken et al. (2014b). This methodology was chosen because preliminary studies indicated a positive relationship between LCA and the generation of eco-innovation in the industrial environment (Piekarski et al., 2013), and it is considered "a valuable methodology in the environmental sustainability of industry" (Motta et al., 2018, p.1103).

The present study was developed in a Brazilian SME, a leader in its field whose main market is beef cattle production, one of the most representative sectors in the emission of greenhouse gases (GHG) (Dick et al., 2015) and one of the most important for the food security of the planet (Delatour et al., 2018). The Brazilian market for animal health products was valued at approximately $1.4 US billion in 2018, according to the National Union of Animal Products Industry (SINDAN), and the relevance of the issue is considerable in the country, one of the main producers and suppliers of beef cattle, because the dynamics of the global pharmaceutical veterinary market are closely related to production animals, especially livestock (SINDAN, 2018).

This study made theoretical and managerial contributions, providing evidence that eco-innovation is not an isolated or specific strategy of the researched field because its performance depends on the sustainable business model adopted and on production processes whose opportunities for investments in sustainable eco-innovations are effective.

In Brazil, industrial laboratories for veterinary pharmaceuticals (homeopathic and allopathic) are regulated by the Ministry of Agriculture, Livestock and Supply (MAPA). These pharmaceuticals should comply with the standards set forth in the Good Manufacturing Practices for Veterinary Products (BPFPV) manual (SINDAN, 2018). Many raw materials used in the formulation of homeopathic and allopathic veterinary medicines are similar, as are the resources (water and energy) used in production processes. Given the above, this study focused on the investigation of eco-innovations and the management and business model, excluding discussions about pharmacopoeias and medicine efficiencies. Thus, it is understood that the field is relevant for research purposes.

To better present the results of the study, this paper is organized in three sections. First, the theoretical foundation outlined the assumptions of the literature that directed our empirical research. The second section presents the materials and methods used to obtain the results. The results and discussions are presented and analyzed in the third section. In the conclusions, the contributions of LCA are presented as a source of subsidies for the development of strategies that promote improvements in sustainable performance. It also presented a definition of the business model of the company based on its performance and direction in the development of eco-innovations.

1.1. Background

The use of circular strategies combined with sustainable strategies is considered beneficial in equating positive impacts in the three dimensions of sustainability (Geissdoerfer et al., 2017a). In the circular model, industrial economics is "restorative by intention and design" (MacArthur, 2013, p. 14).

The composition of materials is designed to adapt to upcycling, in which the quality and the life cycle of these resources are extended through various actions, such as maintenance, reuse/redistribution, reconditioning/remanufacturing and recycling. Resources are preserved through effective techniques to optimize their use and minimize waste generation, emissions and leaks by closing or narrowing service and production cycles and generating synergy between ecological and economic systems (MacArthur, 2013; Ghisellini et al., 2016; Geissdoerfer et al., 2017a).

Circular strategies were identified and categorized by Bocken et al. (2014b) into sustainable business model archetypes. These archetypes have been joined to sustainable contributions and practices according to their nature and application, that is, the way companies propose, create, deliver and capture value. Business models are important structures to drive and direct the development of sustainable innovations (Bocken et al., 2014b), which are treated in this article as eco-innovations.

According to Macarthur et al. (2013), the transition to the circular economy is supported by innovation and system design. Innovations are not limited only to the development of new technologies, but they apply to the formulation of new business models that incorporate sustainability into "their business purposes and processes" (Bocken et al., 2014b, p.42), changing the logic of how companies propose, create and deliver, and capture value, promoting systemic changes in institutions, culture and society (Cheng et al., 2014; Bocken et al., 2014b; Ghisellini et al., 2016; Geissdoerfer et al., 2017b).

Under the aegis of the sustainable development narrative, this study used the concept of eco-innovations proposed by Reid and Miedzinski (2008, p. I), defined as the "creation of goods, processes, systems, services and procedures designed to meet the needs and to provide a better quality of life for all with a minimum use of natural resources throughout the life cycle (materials, including energy and territory) per unit of production and minimum release of toxic substances." This study considered innovations that generate environmental and social benefits as eco-innovations in the evaluation of the results.

The classification of eco-innovation used in this study was supported by Hellström (2007) using the taxonomy of Schumpeter (1934): I) new products; II) new methods of production; III) new sources of supply; IV) new market practices; and V) new forms of business organization (Hellström, 2007).

For eco-innovations to result in positive impacts, it is essential that they be conceived under relevant social structures and can also influence such structures by shifting "from an anthropocentric approach to a more eco-centric approach" (Hofstra and Huisingh, 2014, p.459). Industries of all sizes and in all fields should act collaboratively, incorporating life-cycle thinking into their business models and promoting the interaction among the process, environment, and economy in which they are embedded (Cheng et al., 2014; Bocken et al., 2014b; Ghisellini et al., 2016).

Life cycle approaches, such as LCA, which is used to assess the impacts of sustainable business models along the value chain, can contribute to the promotion of the circular economy and the achievement of sustainable development goals (Manninen et al., 2018). Standardized by ISO 14040 and ISO 14044, LCA can be used as a business tool to support sustainable management, especially in the areas of business processes and operations; act as a facilitating agent in the creation of technological eco-innovations; and assist in the selection of indicators to measure the socio-environmental performance of companies, among other applications (Piekarski et al., 2013).

In the pharmaceutical industry, measuring impacts is a latent need in developing sustainable practices (Li and Hamblin, 2016). The activity generates several environmental impacts, which are especially caused by the high consumption of drinking water used in the formulations, as well as by the emissions of wastewater in the natural environment as a result of the manufacturing process and formulations (Bártíková et al., 2016).

In Brazil, innovative activities developed by companies are measured through the Research for Technological Innovation (PINTEC) managed by the Brazilian Institute of Geography and Statistics (IBGE), which is based on the conceptual and methodological references in the third edition (2005) of the Oslo Manual (IBGE, 2014). However, there are no measurement indicators for eco-innovation. To fill this gap, this study used the theoretical model of eco-innovation indicators proposed by Santos et al. (2015), which allowed, among other contributions, observation of the innovative performance of companies that publish information based on the Global Reporting Initiative, as observed in Santos et al. (2017).

The indicators are internal to the company and evaluate the impacts of investments in eco-innovation, allowing us to distinguish among economic, social and environmental results, in line with the eco-innovation classification proposed by Hellström (2007). Economic indicators contemplate factors related to monetary flows and investments. Environmental indicators are represented by aspects that can impact the natural environment, such as energy consumption, water consumption, GHG emissions and waste. Social indicators refer to measures that promote quality of life at work, as well as equality of and access to social resources (Santos et al., 2017).

2. Materials and methods

In view of our intended objectives, quantitative-qualitative research was carried out using a single case as a methodological research strategy.

2.1. Materials

Empirical research occurred during the period from August 2017 to June 2018 in an SME in the state of São Paulo, Brazil. It is a small pharmaceutical industry and a leader in the veterinary homeopathic field. The pertinence and relevance of the choice of study object were supported by sustainable actions developed by the company, which has been recognized by several awards and publications in the Brazilian press. Its excellence was confirmed in four national competitions from 2014 to 2017, recognized by representative areas of industry and specialized media. To maintain the company's anonymity, this study decided not to disclose details of the awards.

HBR®, the fictitious name given to the investigated medicinal product, is intended to serve the market of farm animals (cattle and horses). It represents approximately 19% of revenue and is the main product in the company's portfolio. The product is commercialized in the internal and external markets (South America and Europe).

2.2. Methods

The planning and development of the present research were adapted to the phases proposed by Eisenhardt (1989) to carry out case studies, as shown in Fig. 1.

1st Stage - Definition of research questions: The thematic and research questions were defined, observing the relevance of and adherence to the phenomenon under analysis.

2nd Stage - Case selection: The analysis unit was selected: the industry in the animal health sector. The period of analysis was August 2017 to June 2018; the data source, a single case; and the research cut, gate-to-gate.

3rd Stage - Elaboration of instruments and protocol: The research action plan (protocol), the orientation of the research (quanti-qualitative), the timeline for data collection, methods and investigative techniques, the types of data, and the questions and the data sources to be searched were defined.

4th Stage - Data collection: The primary data were obtained using different instruments, such as on-site observations, interviews, structured questionnaires, and LCA. The secondary data were obtained mainly through bibliographic sources and digital files. The on-site observations were carried out on 5 occasions, with an average duration of 2 h, which aimed to investigate the eco-innovations implemented in all sectors of the company. These observations were also performed in the different stages of the production process of the medicine investigated to perform the LCA. Interviews were carried out with managers, as well as with employees who performed operational functions in various sectors of the company. These were carried out in the second half of 2017 and in the first half of 2018. The questionnaires approved by the director general and the chief financial officer comprised objective questions, addressing the management model and the economic and social aspects of the company. The data collected through these instruments refer to the 2017 period.

5th Stage - Data analysis and literature analysis: Due to the use of multiple sources, the analysis was based on a triangulation of data. To interpret the qualitative data investigated, conventional content analysis was performed based on theoretical propositions. This step was performed in sequential phases, outlining and implementing coding processes, data comparison and treatment of results, following guidelines by Hsieh and Shannon (2005). In the quantitative analysis of the data obtained in the LCA, the inputs and outputs of materials and residues were measured in the main and elementary flows of the production process. The evaluation of the numerical results allowed the identifications of the main hotspots that generated the most significant environmental impacts in the production of the HBR® drug. The results were challenged and discussed using the existing literature. Finally, quantitative and qualitative data were organized and categorized according to the theoretical model proposed by Santos et al. (2015).

6th Stage - Report: A report on the results of the research and elaboration of this article was written.

3. Results

The results of the LCA were presented in the economic, environmental and social dimensions, according to the theoretical model proposed by Santos et al. (2015). The presentation of the results aimed to identify the eco-innovations developed, the positive returns they generated, and the new opportunities to implement them in the production process of the homeopathic

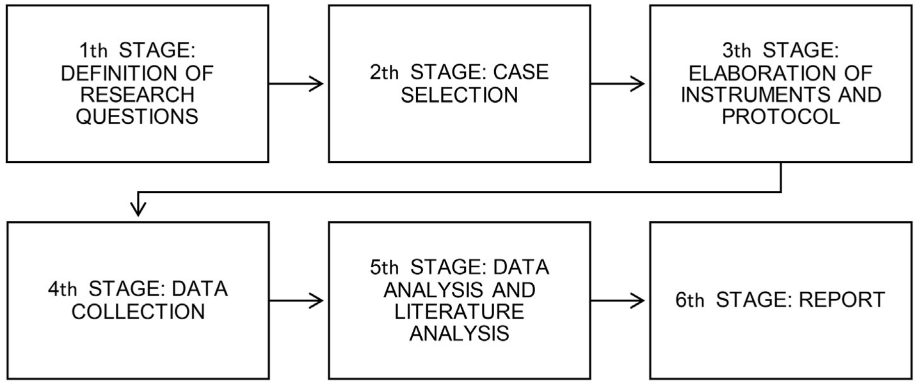

Fig. 1. Planning of the data collection and processing phases to elaborate this research. Adapted from Eisenhardt (1989).

veterinary medicine HBR®. The analysis of the results made it possible to trace the innovative profile of the company according to the archetypes of the sustainable business model proposed by Bocken et al. (2014b).

3.1. Life cycle assessment

The intended application of this LCA study is an attributional one and aimed to map the main critical points, identifying opportunities for eco-innovations in the production process of the HBR® drug in 2017. The study adhered to the guidelines of ISO 14040/14044. The target audience for this research is the scientific community and the managers of the investigated company. The function, functional unit and reference flow that comprise the study scope are shown in Table 1.

The industrial processes investigated were based on a linear relationship, that is, there was no coproduct generation. Therefore, no allocation procedures were performed. For the evaluated processes, the criterion was the exclusion of processes whose inputs were less than 1% of the product.

The system of the investigated product comprised five main processes, as shown in Fig. 2. The delimitation of the study was performed in the manufacturing process unit of the product system in a gate-to-gate approach. The elementary processes analyzed were homeopathic formula production, impregnation, packing and packaging.

In the delimited product system, the main inputs used in the manufacture of HBR® are 96% (v/v) ethanol, sucrose, mother tincture, plastic packaging and cardboard packaging. The explanation of these inputs and the production flows shown in Fig. 3 are justified to denote the limitations of this research, as well as to provide a holistic view of the value chain of the investigated product and its potential environmental aspects from the life cycle perspective.

The manufacturing process unit of the product system includes four main steps. Breaking down these stages (see Fig. 4) illuminates the human and material resources required in each phase of the production process.

In the topics presented below, the calculations of the consumption of resources used in the production process are presented, considering that the daily productive capacity of the HBR® product is 16,000 units.

3.1.1. 1st stage: production of the homeopathic formula

The production of the HBR® drug begins with the preparation of the homeopathic formula. To produce it, the mother tincture is diluted in solvent and subsequently energized. The dynamization process consists of dilutions followed by mechanical succussions. The process is performed until the desired power is reached on the Hahnemann Centesimal scale. It is emphasized that, in this stage, the number of dynamizations executed was not known because it is an industrial secret. The production of the HBR® drug is shown in Fig. 5.

To produce a 400-g (gram) package, based on the reference flow set forth in Tables 1 and 1% (4 mL (ml)) of homeopathic formula is added to the sucrose granules. The solvent used in the formula is composed of 30% distilled water (1.2 ml of water) and 70% alcohol (2.8 ml). Note that 72 ml of potable water is required to obtain 1.2 ml of distilled water, generating 70.8 ml of waste water.

The emissions of liquid effluents and residues resulting from the packaging used to store the mother tinctures and ethanol are present at the outlet of the main flow, as shown in Fig. 6. In the elementary flow, the energy consumption is cited but not considered because it meets the exclusion criterion.

3.1.2. 2nd stage: impregnation

Impregnation implies a process wherein the homeopathic formula is mixed with the sucrose granules used as carriers of the medicament. The mixture is stirred in a spiral motion for 15 min or a longer period until all the moisture is extracted from the granules. The equipment has the capacity to impregnate 800 kg (kg) of sucrose every 45 min. It has two electric motors that together consume 22 kW (kW) of energy per hour worked. To meet the daily production capacity, the equipment is used for a period of 2 h, consuming 44 kWh of energy.

To calculate the amount of kilowatt hours per hour worked per piece of equipment, the following formula was used:

$$\text{kilowatts hours (kWh)} = \text{Power [kw] x Hours}$$

In the flow of incoming materials described in Fig. 7, the homeopathic formula and sucrose, the raw materials used to manufacture bulk medicine, are present.

Table 1
Function, functional unit and reference flow of the HBR® drug.

Function	Functional unit	Reference Flow
Treat infestations of endo and ectoparasites in adult bovines.	Treat an adult bovine of approximately 600 kg within 120 days.	A package of 400 g of the drug.

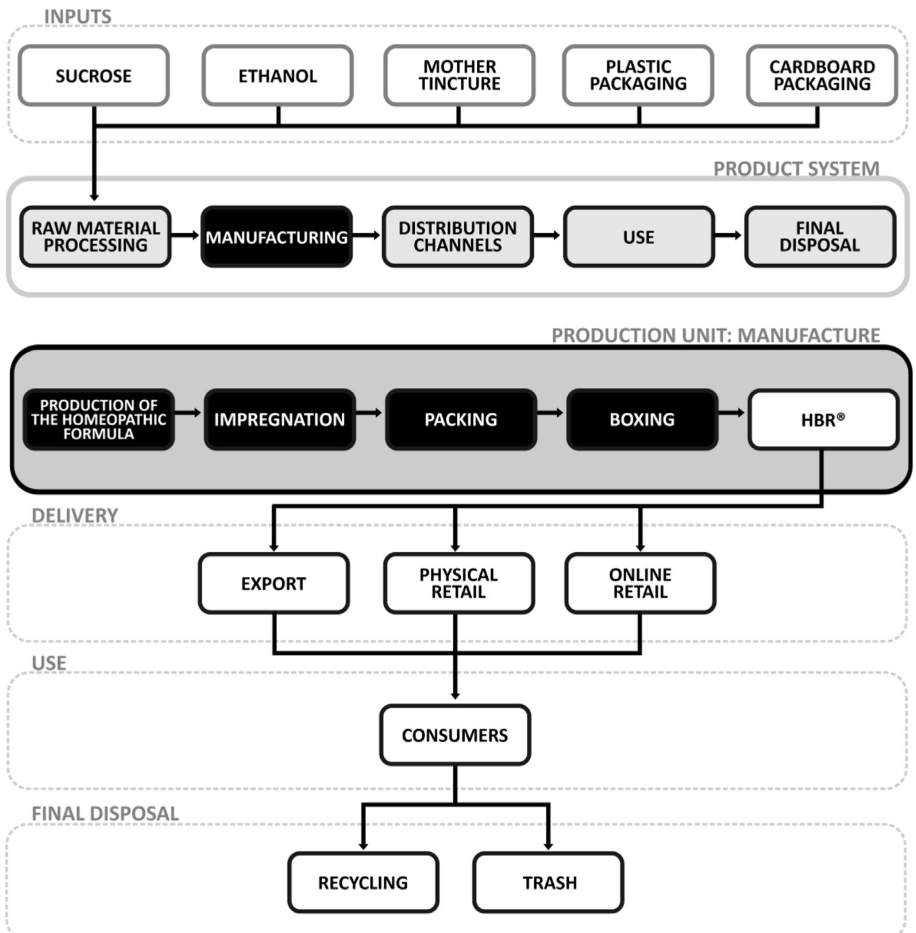

Fig. 2. HBR® supply chain with an expanded view of the manufacturing process unit, which makes up the product system.

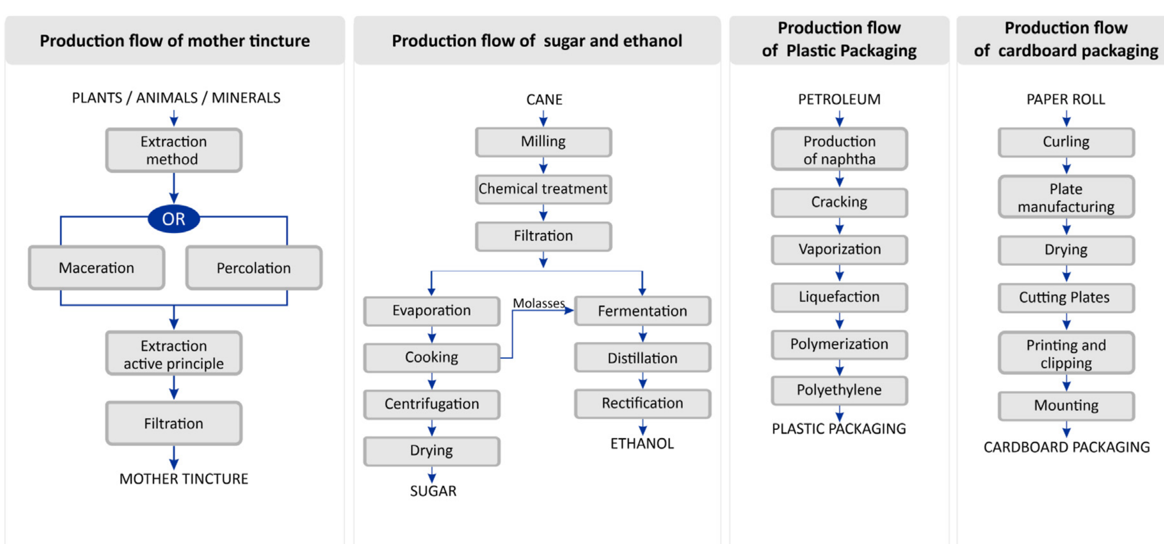

Fig. 3. Production processes of the main raw materials used in the formulation of the HBR® drug.

3.1.3. 3rd stage: packing

After impregnation, the sucrose granules are sent by pipeline to the packaging apparatus of the medicament in plastic packages, as shown in Fig. 8.

The packing machine has the capacity to pack 2000 units in 45 min. This equipment is pneumatic, so for it to work, it must be connected to a high-pressure industrial air compressor and to an air filter. The compressor used has a 15-hp motor. The electric motors

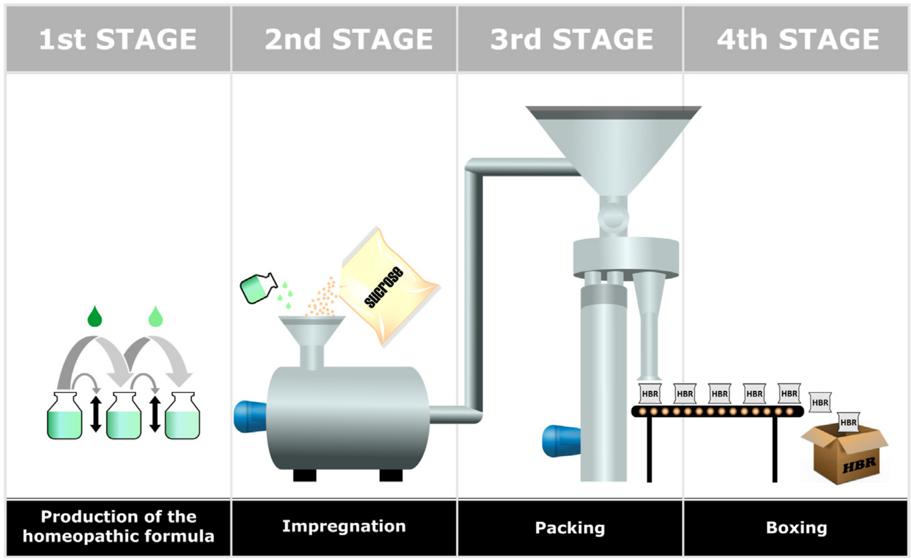

Fig. 4. The steps (production of the homeopathic formula, impregnation, packing and boxing) that make up the production process of the HBR® drug.

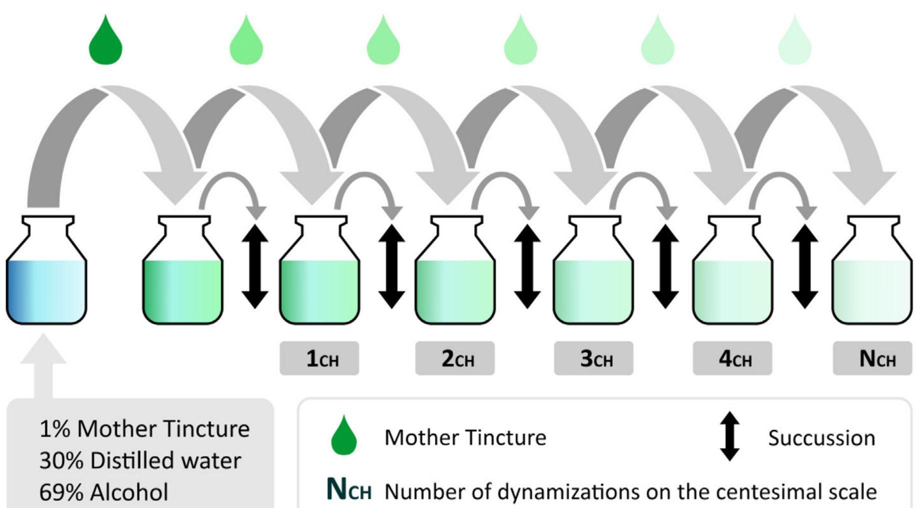

Fig. 5. Steps in the process of dynamizing the homeopathic formula of the HBR® drug on the Hahnemann Centesimal scale.

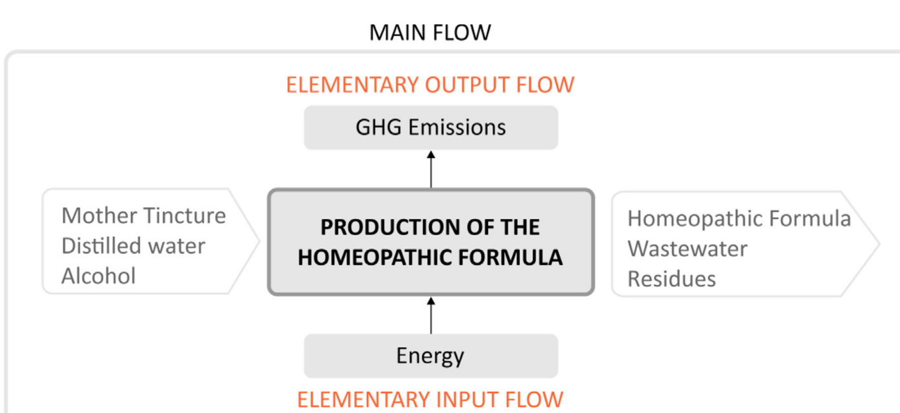

Fig. 6. Input-output material flow generated in the production of the homeopathic formula.

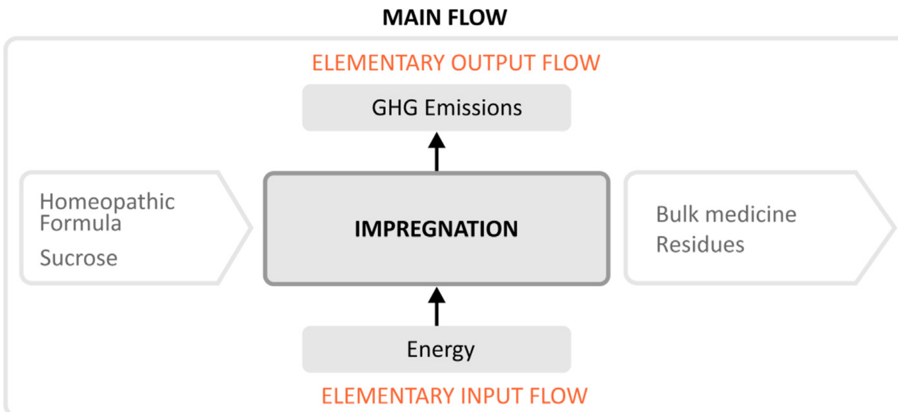

Fig. 7. Elementary process: input-output of the material flow generated in the impregnation process.

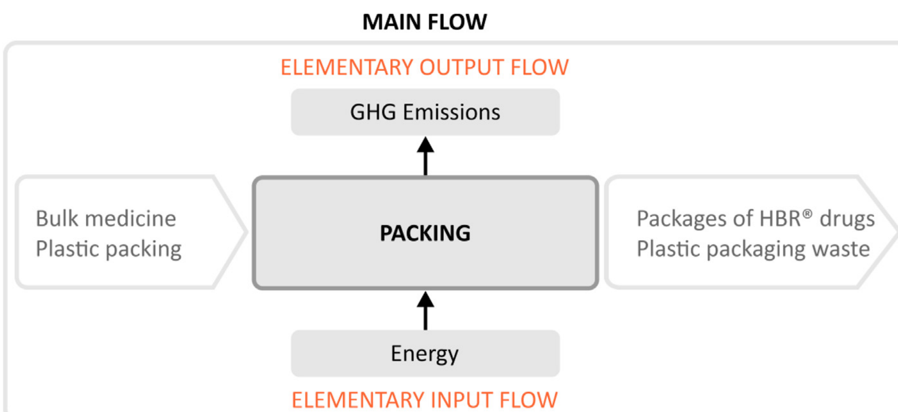

Fig. 8. Elementary process: input-output of the material flow generated in the packing process.

in the packing machine and the filter have 5 hp of power each.

Considering that the impregnation process is performed in 15 min and the packaging process in 45 min, the total time for the production of a batch of medicines is 1 h. Thus, during the 6 h of activities in which equipment is connected, the daily energy consumption of the three pieces of equipment [66 kWh (air compressor) + 22,08 kWh (packing machine) + 22,08 kWh (filter)] totals 110,16 kWh.

3.1.4. 4th stage: boxing

In this process, the packaged products are transported by an electric conveyor to the storage section. They are packed in cardboard boxes with a capacity of 50 units of medicine per box. This process has energy consumption as an elementary input flow, according to Fig. 9.

The daily energy consumption of the electric treadmill is 3 kWh. Given the productive capacity of 6 h, the consumption is 18 kWh.

The daily energy and water consumption identified in the LCA is summarized and presented in Table 2. It should be noted that the values are estimated according to the daily productive capacity of the HBR® drug.

The results show the phases that have the most significant environmental impacts in the production process of the investigated drug. The monthly energy consumption (23 working days) generated by the equipment is responsible for the emission of 6.44 tons of CO2e. The packing stage is the most important because it alone consumes 64% of the total energy used in the process. The production formula stage produces the greatest amount of wastewater; during this stage, approximately 26,055 L of wastewater are generated per month.

It should be noted that in this research, the energy consumption of the equipment was measured from the online channel of the manufacturers (WEG, 2018). CO2e emissions were calculated through an online tool provided by the Green Initiative organization (Iniciativa Verde, 2019).

3.2. Eco-innovative and sustainable performance

The results obtained from the LCA study made it possible to evaluate and measure sustainable performance through the sustainability indicators proposed by Santos et al. (2015).

3.2.1. Environmental performance

a) Ecopatents: In Brazil, although the number of patents has increased, the technological performance in the development of climate change mitigation technologies falls far short of international trends (Feitosa, 2016). The industry studied filed several applications with the National Institute of Industrial Property (INPI). However, it did not obtain any concessions. The difficulty in patenting products, according to the managers, is the absence of specific legislation for the production of homeopathic veterinary medicines.
b) Emission of liquid effluents in the production process: In the study of LCA, it was observed that these emissions are one of the main pollutants in the production process. To ease this problem,

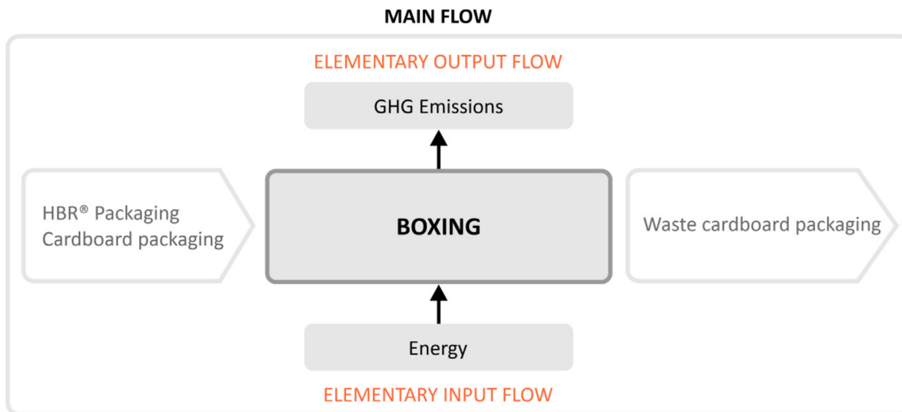

Fig. 9. Elementary process: input-output of the material flow generated in the boxing process.

Table 2
Water and energy consumption in the production process of the HBR® drug.

Stages	Resources consumed			
	Water resources		Energy resources	
	Resources	Environmental aspect	Resources	Environmental aspect
	Potable water *(liters)*	Wastewater *(liters)*	Energy (*kilowatt-hour*)	Emissions (*Tons of CO2 equivalent*)
Production formula	1.152 l	1.133 l		–
Impregnating	–		44 kWh	0,7 tCO_2eq
Packing	–		110,16 kWh	0,18 tCO_2eq
Boxing	–		18 kWh	0,03 tCO_2eq
Total daily:	1.152 l	**1.133 l**	172,16 kWh	**0,28 tCO2eq**
Total monthly:	26.496	**26.059**	3.959,68 kWh	**6,44 tCO2eq**
Total annual:	317.952	**312.708**	47.516,16 kWh	**77.26 tCO2eq**

the company installed a storage system, shown in Fig. 10, to reuse the wastewater resulting from the distillation process in cleaning external areas.

The eco point warehouse is also used to capture recyclables generated by the community of the municipality, as well as to store materials coming from awareness campaigns promoted by the company in favor of sustainability. Periodically, the material collected is taken to a recycling cooperative in the municipality. Electronic waste, household appliances, energy storage batteries and fluorescent light bulbs are disposed of at appropriate collection sites or intended for companies specializing in recycling when manufacturers of related products do not have a reverse logistics system. It should be emphasized that the drug in our study of LCA offers no risk of contamination to the environment. Its packaging is made from biodegradable and nontoxic materials, in compliance with the Brazilian Standards approved by the Brazilian Association of Technical Standards ABNT NBR's - 15448-1 and 15448-2.

g) Consumption of material: To promote sustainability and reduce socioenvironmental impacts, whenever possible, the company has chosen to acquire recyclable and/or biodegradable consumer materials that are inserted in a sustainable production chain, prioritizing local suppliers and adopting selection criteria of sustainable practices. This study observed the rational consumption of office supplies to deal with the use of consumer materials: the use of durable utensils, such as cups and packaging, to replace disposable items, as well as the use of renewable fuels to supply the company's vehicles.

3.2.2. Social performance

a) Absenteeism and rotativity: To reduce absenteeism rates and turnover, actions are periodically taken to promote the physical and emotional well-being of employees. Motivational lectures, social gatherings, work-based gymnastics, and the practice of collective sports through sponsorships for regional competitions and partnerships with clubs for physical and leisure activities, guarantee employees a number of benefits, expanding access to health, leisure, culture and entertainment. According to the data provided by the company, the efforts made yielded satisfactory results in reducing absenteeism by more than 80% in 2017. Turnover rates have been positive. In the analyzed period, a 13% departure rate of company employees was registered. However, the increase in the number of hired employees was approximately 26%. The figures show that the turnover rate of the company was 19.73%, lower than the national average in the field (DIEESE, 2016).
b) Accidents at work: The pharmaceutical industry is one of the most regulated productive sectors in Brazil (Nishida et al., 2017). According to Decree No. 5.053 of 2004, the facilities and equipment of the establishments that manufacture, manipulate, fraction, package, label, and control the quality of products for themselves or for third parties must comply with the BPFPV established by the MAPA, as well as the health and safety standards established by competent official bodies. The activities carried out in the pharmaceutical industry offer numerous risks to the health of the worker. However, in the case analyzed, compliance with the BPFPV and regulations imposed by the regulatory bodies were decisive for the absence of records of

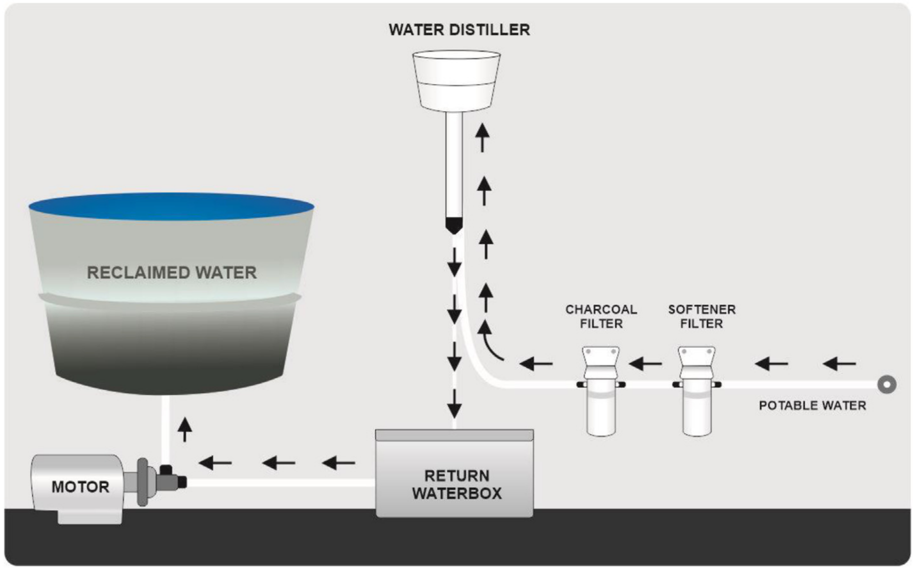

Fig. 10. Exploded view of the wastewater reuse system generated in the production process of the homeopathic formula.

c) Water consumption: The company has developed several actions to reduce and optimize water consumption, including rainwater harvesting, which is used to clean facilities and gardens; the reduction of waterproofing of sidewalks and floors around the company; regular actions to educate employees and the community about water-conscious consumption; and the use of eco-efficient technologies in taps and toilet valves in all sectors of the company.
d) Energy consumption: This resource is used in all stages of the production process analyzed, especially in the packing stage, in which high consumption is generated by the engines that perform the function of transforming electric energy into mechanical energy.
e) GHG emissions: In the production process observed, GHG emissions are derived primarily from energy consumption. Therefore, the reduction of emissions is directly associated with the decrease in the use of said resources.
f) Solid waste: In Brazilian organizations, waste management must comply with the guidelines of Law No. 12.305 of 2010, which stipulates the shared responsibility of waste generators. Recyclable waste, such as plastics, paper and aluminum, resulting from the production process and other sectors of the company are stored temporarily in a warehouse called ‘eco point’ located on the premises of the company.

occupational accidents since the company’s inauguration date (2000).

3.2.3. Economic performance

a) Market share: In Brazil, the veterinary industry is a branch of the economic market that is constantly on the rise. In 2018, the national market obtained an estimated net revenue of $1.4 US billion, a growth of 8% over the previous period (SINDAN, 2018). The analyzed homeopathic veterinary laboratory dominates approximately half of the national market in the segment of homeopathic products. Compared to manufacturers of allopathic medicines, the company owns approximately 0.1% of the national market. This performance is related mainly to the culture of innovation and pioneering in the segment of homeopathic medicines for veterinary use. Notable international and national competitors include Zoetis (USA), MSD Animal (USA), Health Merial (France), Ouro Fino Agronegócio (Brazil), and Bayer Animal Health (Germany), among others.
b) Return on investment (ROI) and return on sales (ROS): According to the data provided by the company, the percentage of expenses incurred with the acquisition of machinery and equipment associated with environmentally correct products or processes, in relation to the previous year (2016), was 2% of the amount of revenue. The assertiveness of the investments in fixed assets of the company can be verified by examining the profitability of the assets of the company (ROA) in 20% a.a. It is worth noting that, in consultation with the chemical and pharmaceutical industries listed on the official stock exchange in Brazil (B3) in 2016, the industry average was −4.3% for ROA. None of the 11 listed companies presented ROA higher than that achieved by the company in this study. Notwithstanding, the company also reported, in 2017, ROS of 15%, which results for positive profitability considered high compared to the chemical-pharmaceutical sector, which indicated an average negative result of 1.9%. Table 3 summarizes the economic, social and environmental impacts generated in the manufacture of the HBR® drug.

In the analysis of the environmental, social and economic impacts caused by the production process of HBR®, presented in Table 3, it is possible to observe some aspects and consequent positive and negative impacts.

3.3. Analysis of the business model

In Brazil, the industry evaluated is a precursor to the use of population homeopathy for the prevention and treatment of cattle herds. Innovation and sustainability are embedded in the industry’s processes, organizational culture and values. The performance of the industry, according to the classification proposed by Bocken et al. (2014b), is concentrated in the social area and falls within the “adopt a stewardship role” archetype. This business model generates, in the long term, positive social and environmental impacts for all stakeholders: the organization itself, society and the environment (Bocken et al., 2014b, p. 51).

The gate-to-gate approach proposed in this research did not make it possible to analyze the entire value chain, only the industry – specifically, the production of homeopathic medicine. However, it should be noted that the actions of a sustainable business model extend beyond the limits of the organization, requiring a systemic and integrated perspective, to all the stakeholders that make up the value chain, as in Manninen et al. (2018) and Velter et al. (2020). In

Table 3
Environmental, social and economic aspects and impacts from a life-cycle perspective on the HBR® drug.

Stage	Activity	Raw materials used	ENVIRONMENTAL IMPACTS		SOCIAL IMPACTS		ECONOMIC IMPACTS
			Emissions, waste and tailings	Use of resources	Employees	Community	Profitability
PRODUCTION	Production of the homeopathic formula.	- Mother tincture. - Distilled water.	- Wastewater. - CO2. - Plastic gallons of ethanol.	- Water. - Electricity.	- Ergonomics. - Exposure to noise.	- Generation of jobs. - Support for recycling cooperatives (plastic gallons).	- Personnel costs and social charges. - Costs of the purchase of raw material. - Costs of machinery and new technologies. - Reduced costs with the reuse of wastewater.
	Impregnation.	- Sucrose. - Homeopathic formula.	- CO2. - Noise. - Powder/ suspended particles. - Bags.	-Electricity.	- Exposure to noise. - Manual handling of loads. - Risk of intoxication.	- Generation of jobs.	- Personnel costs and social charges. - Costs of the purchase of raw material. - Costs of machinery and new technologies.
	Packing.	- Plastic packages.	- CO2. - Noises. - Powder/ suspended particles.	-Electricity.	- Risk of intoxication.	- Generation of jobs.	- Personnel costs and social charges. - Costs of the purchase of raw material. - Costs of machinery and new technologies.
	Boxing.	- Cardboard boxes.	- CO2. - Noise. - Damaged packaging.	-Electricity.	- Ergonomics. - Exposure to noise.	- Generation of jobs. - Support for recycling cooperatives (damaged packaging).	- Personnel costs and social charges. - Costs of the purchase of raw material. - Costs of machinery and new technologies.

view of the above, this study considers that the identification of the profile of the business model in which the company operates can guide it to carry out more effective actions along the chain to fully adapt its management strategies to the said model, generating value for all parties systemically.

3.4. Opportunities for ecoinovar

The environmental impacts generated in the four stages of the production process expose the main pollutant areas of the analyzed product. In compliance with the ReSOLVE framework, possible Ecoinovar opportunities were identified in the scope of the following actions: Optimize, Regenerate and Replace. The propositions of eco-innovations are based on the collected data and expertise of the researchers.

Optimize: High consumption of water in the first stage of the production process and, consequently, the generation of wastewater can be minimized by replacing a conventional distiller with more efficient water purification systems.

Regenerate: Use renewable energy sources, such as solar energy, given the climatic conditions of the region where the company is located.

Exchange: In steps 2, 3 and 4 of the production process, high-energy consumption generated by obsolete electric motors can be reduced by replacing them with new equipment designs with higher energy efficiency. In other facilities of the company, the consumption generated by air conditioning equipment can be reduced by the application of thermal ink in areas exposed to the sun, such as roofs.

4. Discussion

In the SME studied, sustainability is clearly embedded in the business model and product and process development practices. The alignment between the sustainable business model and the eco-innovation strategies from the LCA demonstrates that sustainability in business activities needs to be understood in an integrated and articulated way that considers both management and operations activities.

The implementation of environmental management systems that use international standards, such as ISO 14001, plays an important role in the development of eco-innovations and contributes to companies' environmental and financial performance, as explained by Przychodzen and Przychodzen (2015). However, although the studied company does not present a certified EMS due to limitations in human and financial resources, it was possible to note that the company tacitly uses environmental management in its processes and in the management model that guides its business. This evidence demonstrates that small and medium-sized companies that do not have the necessary financial and technical structure to obtain certifications can perform their activities in a sustainable way (Klewitz and Hansen, 2014). The importance of these companies was highlighted by intergovernmental organizations such as the United Nations (UN) and authors such as Bocken et al. (2014b) and Johnson (2015), in addition to specific studies in the pharmaceutical sector, such as that carried out by Li and Hamblin (2016).

The investigated industry produced Brazil's first homeopathic medicine for veterinary use and consolidated itself as one of the largest companies in this market with the creation of products aligned with its business model. Thus, based on its business model, the company contributed to the development of a new market (homeopathic veterinary medicines), and its longevity has been maintained through the use of eco-innovative strategies in its production process.

The presented history reinforces the argument that the sustainability-oriented business model and organizational culture contribute to the transformation of the market and society, as discussed by Bocken et al. (2014b), Santos et al. (2015), Geissdoerfer et al. (2017b), Manninen et al. (2018) and Velter et al. (2020). It should be emphasized that business models should incorporate innovation and sustainability at the strategic level (Bossle et al., 2016), using such concepts through the archetypes as proposed by Geissdoerfer et al. (2017b), so that the contributions to sustainable development are more significant.

Eco-innovations of products have been directed to produce homeopathic veterinary medicines, such as HBR, which, due to its formulation, leaves no traces of residue in the animal organism. The product meets the increasing demands of producers, consumers and governments in improving food quality and safety, as analyzed by Delatour et al. (2018). Specifically, mention is made of the production of beef without the presence of residues of veterinary drugs and in accordance with the international standards imposed by the Codex Alimentarius.

The environmental impacts generated in the production process and measured by the LCA reveal that the implemented eco-innovations generated benefits for the natural environment in all stages of the analyzed production process; therefore, the proposition of the positive impacts of the process eco-innovations was supported by the results found.

The process eco-innovations aimed at reusing waste water implemented in the 1st stage proved to be efficient in managing water use, which confirms that eco-innovations bring positive contributions to environmental performance in the pharmaceutical industry, as noted by Li and Hamblin (2016).

The use of water in the manufacture of medicines may lead to the contamination of the natural environment with veterinary drugs in industrial effluents, according to Bártíková et al. (2016, p.2291): “The drugs can reach environment through the treatment processes, inappropriate disposal of used containers, unused medicine or livestock feed, and manufacturing processes”.

However, it is emphasized that the eco-innovations implemented in this stage are directed toward the control of “end-of-pipe” pollution. Thus, it is understood that solutions aimed at developing cleaner and more eco-efficient technologies to minimize resources use would be more beneficial to the industry’s environmental performance (Klewitz and Hansen, 2014).

The high-energy consumption observed in the 2nd, 3rd and 4th stages has a direct impact on the volume of GHG emissions. In Brazil, according to data provided by Eletrobras (Centrais Elétricas Brasileiras S.A.), the industrial sector consumes approximately 42% of the electric energy produced, and 70% of it is consumed by electric motors (SEBRAE, 2016). The energy consumption of the equipment of the investigated industry, which is compatible with the national average, demonstrated the need to eco-innovate industrial parks, replacing old equipment with newer models that have lower energy consumption. These actions will help to obtain positive environmental results and reduce the use of resources, costs and emissions. The action will be beneficial for the company’s eco-efficiency, reducing the use of resources, costs and emissions.

As for the economic impacts, investments in the creation of the innovative product generated profitability and competitiveness for the business. The positioning of the product and the costs inherent in its production also guaranteed the company a financial margin higher than the industry average, demonstrating that the sustainability pillars are not incongruent and that investing and maintaining a structure with greater responsibility toward the environment does not generate losses to the company, as stated by Triguero et al. (2013).

The social impacts generated by eco-innovations demonstrated that the production of the HBR® drug contributes to the generation of employment and income for the local community. These positive returns are also generated indirectly through the availability of the selective collection point and partnerships with recycling co-operatives. In the internal context, the actions carried out promote the social and physical well-being of human capital. The service of the good manufacturing practices (GMP) contributed, above all, to reducing turnover and absenteeism rates, keeping them below the average of previous years.

The feasibility of implementing the LCA methodology to analyze the environmental impacts generated in the 4 stages of the production process demonstrated that there is no “one-size-fits-all” application for carrying out studies of this nature, as stated by Blanco et al. (2015). This methodology proved to be an efficient business tool to investigate eco-innovations and the adherence of the business model to the archetypes defined by Bocken et al. (2014b). It is also worth noting that, according to the theoretical model proposed by Piekarski et al. (2013), given the volume of data obtained, the use of the methodology can contribute to defining strategies and decision making as well as to subsidizing and directing R&D.

The transition to a circular economy in order to achieve sustainable performance requires that companies act interdependently and mutually under the three pillars of sustainability, seeking eco-innovative solutions whose benefits extend to the entire supply chain, as noted by Geissdoerfer et al. (2017a), Manninen et al. (2018) and Colombo et al. (2019). In this context, it was observed that the impacts generated by the economic, social and environmental aspects are positive; however, the majority of the actions developed are concentrated in the internal environment of the SME. Eco-innovations generate benefits, particularly eco-efficiency in the use of resources, the local community and consumers, and it is necessary to foster the generation of value among other stakeholders, such as the relationship with suppliers and business partners, bringing together the dimensions of economic, social and environmental value to effectively constitute the circularity of the observed business model, as directed by Bocken et al. (2014b) and Velter et al. (2020).

5. Conclusion

The formulation of the business model investigated included sustainability as a basic principle to ensure competitive advantages and a value proposition strategy. The performance of the company demonstrated that the main types of eco-innovations developed are focused on the creation of new production methods and, especially, new products, which are typologies proposed by Hellström (2007).

The proposition of the positive impacts of eco-innovations was supported by the results found. Therefore, it is assumed that eco-innovations contribute significantly to the balance between industrial and natural systems, as stated by Ghisellini et al., (2016), Geissdoerfer et al. (2017a) and Manninen et al. (2018). However, the results of this study demonstrate that the development of a sustainable business model requires management and investments in eco-innovations at the product, process and organization levels to make eco-innovative strategies viable.

The theoretical model proposed by Santos et al. (2015) proved to help assess the company’s eco-innovative performance from the main perspectives of sustainability, in addition to being aligned with the metrics of the Global Reporting Initiative, which may allow comparative analysis.

The use of the LCA methodology allowed this study to identify the main critical points of the production process, evaluate eco-innovative performance at the company’s operational and strategic levels and define the company’s business model. However, the limitations of this study and the methodological approach of the research (gate-to-gate) are imposed by the particularity of the object of study, the complexity of the research method, the value chain, and the absence of references of similar business models for more detailed and comparative assessments of their impacts.

Understanding the essence of eco-innovative business models, as well as how eco-innovations are created and how they are presented to the market as value propositions, brings contributions, especially to science and public policy makers, to eco-innovative behaviour in the animal health sector, on which knowledge is still incipient. It is noteworthy that many eco-innovations reported in this research can be operationalized in other companies and industries of different segments and sizes.

The research developed was restricted to a single company, and the results and conclusions obtained in this research may not be generalized to other industries. Therefore, future research is needed to understand how the Brazilian veterinary pharmaceutical industry eco-innovates, as well as eco-innovations in general, are incorporated into business models as a business strategy and how the extent and distribution of the positive impacts of these eco-innovations extend beyond organizational limits, covering the entire chain value, from upstream to downstream.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Renata Barbieri: Conceptualization, Methodology, Investigation, Formal analysis, Resources, Visualization, Writing - original draft. **David Ferreira Lopes Santos:** Conceptualization, Formal analysis, Supervision, Validation, Writing - review & editing.

Acknowledgement

This study was financed in part by the Paula Souza Center [08/2016].

References

Bártíková, H., Podlipná, R., Skálová, L., 2016. Veterinary drugs in the environment and their toxicity to plants. Chemosphere 144, 2290–2301. https://doi.org/10.1016/J.CHEMOSPHERE.2015.10.137.
Blanco, J.M., Finkbeiner, M., Iniba, A., 2015. Guidance on Organizational Life Cycle Assessment. UNEP Setac, Paris.
Bocken, N.M.P., Farracho, M., Bosworth, R., Kemp, R., 2014a. The front-end of eco-innovation for eco-innovative small and medium sized companies. J. Eng. Technol. Manag. 31, 43–57. https://doi.org/10.1016/J.JENGTECMAN.2013.10.004.
Bocken, N.M.P., Short, S.W., Rana, P., Evans, S., 2014b. A literature and practice review to develop sustainable business model archetypes. J. Clean. Prod. 65, 42–56. https://doi.org/10.1016/J.JCLEPRO.2013.11.039.
Bossle, M.B., Dutra de Barcellos, M., Vieira, L.M., Sauvée, L., 2016. The drivers for adoption of eco-innovation. J. Clean. Prod. 113, 861–872. https://doi.org/10.1016/J.JCLEPRO.2015.11.033.
Cheng, C.C.J., Yang, C., Sheu, C., 2014. The link between eco-innovation and business performance: a Taiwanese industry context. J. Clean. Prod. 64, 81–90. https://doi.org/10.1016/J.JCLEPRO.2013.09.050.
Colombo, L.A., Pansera, M., Owen, R., 2019. The discourse of eco-innovation in the European union: an analysis of the eco-innovation action plan and Horizon 2020. J. Clean. Prod. 214, 653–665. https://doi.org/10.1016/j.jclepro.2018.12.150.
Delatour, T., Racault, L., Bessaire, T., Desmarchelier, A., 2018. **Screening of veterinary drug residues in food by LC-MS/MS**. Background and challenges. Food Addit. Contam. 35, 632–645. https://doi.org/10.1080/19440049.2018.1426890.
Dick, M., Abreu da Silva, M., Dewes, H., 2015. Life cycle assessment of beef cattle production in two typical grassland systems of southern Brazil. J. Clean. Prod. 96, 426–434. https://doi.org/10.1016/J.JCLEPRO.2014.01.080.
DIEESE, 2016. Trade in 2016: a review of key indicators (Comércio em 2016: um balanço dos principais indicadores). Department of Statistics and Socioeconomic Studies. https://www.dieese.org.br/boletimindicadoresdocomercio/2016/boletimIndicadoresComercio09.pdf. accessed 4.7.19.
Eisenhardt, K.M., 1989. Building theories from case study research. Acad. Manag. Rev. 14, 532–550. https://doi.org/10.5465/amr.1989.4308385.
Feitosa, P.H.A., 2016. **Technological structure and climate change in Brazil: an exploratory study from patent statistics** (Estrutura tecnológica e mudanças climáticas no Brasil: um estudo exploratório a partir de estatísticas de patentes). Rev. Bras. Inovação 15, 61–86. https://doi.org/10.20396/rbi.v15i1.8649120.
Geissdoerfer, M., Savaget, P., Bocken, N.M.P., Hultink, E.J., 2017a. The Circular Economy – a new sustainability paradigm? J. Clean. Prod. 143, 757–768. https://doi.org/10.1016/J.JCLEPRO.2016.12.048.
Geissdoerfer, M., Savaget, P., Evans, S., 2017b. The cambridge business model innovation process. Procedia Manuf 8, 262–269. https://doi.org/10.1016/J.PROMFG.2017.02.033.
Ghisellini, P., Cialani, C., Ulgiati, S., 2016. A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. J. Clean. Prod. 114, 11–32. https://doi.org/10.1016/J.JCLEPRO.2015.09.007.
Hellström, T., 2007. Dimensions of environmentally sustainable innovation: the structure of eco-innovation concepts. Sustain. Dev. 15, 148–159. https://doi.org/10.1002/sd.309.
Hofstra, N., Huisingh, D., 2014. Eco-innovations characterized: a taxonomic classification of relationships between humans and nature. J. Clean. Prod. 66, 459–468. https://doi.org/10.1016/J.JCLEPRO.2013.11.036.
Hojnik, J., Ruzzier, M., 2016. What drives eco-innovation? A review of an emerging literature. Environ. Innov. Soc. Transitions. 19, 31–41. https://doi.org/10.1016/J.EIST.2015.09.006.
Hsieh, H.F., Shannon, S.E., 2005. Three approaches to qualitative content analysis. Qual. Health Res. 15, 1277–1288. https://doi.org/10.1177/1049732305276687.
IBGE, 2014. Innovation Research (Pesquisa de Inovação). Brazilian Institute of Geography and Statistics. https://www.ibge.gov.br/estatisticas-novoportal/multidominio/ciencia-tecnologia-e-inovacao/9141-pesquisa-de-inovacao.html?=&t=o-que-e. accessed 3.26.19.
Johnson, M.P., 2015. Sustainability management and small and medium-sized enterprises: managers' awareness and implementation of innovative tools. Corp. Soc. Responsib. Environ. Manag. 22, 271–285. https://doi.org/10.1002/csr.1343.
Klewitz, J., Hansen, E.G., 2014. Sustainability-oriented innovation of SMEs: a systematic review. J. Clean. Prod. 65, 57–75. https://doi.org/10.1016/J.JCLEPRO.2013.07.017.
Li, X., Hamblin, D., 2016. Factors impacting on cleaner production: case studies of Chinese pharmaceutical manufacturers in Tianjin, China. J. Clean. Prod. 131, 121–132. https://doi.org/10.1016/J.JCLEPRO.2016.05.066.
MacArthur, Ellen, 2013. Towards the circular economy. J. Ind. Ecol. 2, 23–44. https://doi.org/10.1007/b116400.
Manninen, K., Koskela, S., Antikainen, R., Bocken, N., Dahlbo, H., Aminoff, A., 2018. Do **circular economy business models capture intended environmental value propositions?** J. Clean. Prod. 171, 413–422. https://doi.org/10.1016/J.JCLEPRO.2017.10.003.
Motta, W.H., Issberner, L.R., Prado, P., 2018. Life cycle assessment and eco-innovations: what kind of convergence is possible? J. Clean. Prod. 187, 1103–1114. https://doi.org/10.1016/j.jclepro.2018.03.221.
Nishida, A.L., Costa, C.K.F., Bondezan, K.L., Ribeiro, V.S., 2017. Regulation of the pharmaceutical industry in Brazil and its consequences on the exports and imports in Brazil between 1997 and 2014. Rev. Espac. 38, 15–22.
Piekarski, C.M., Mendes da Luz, L., Zocche, L., de Francisco, A.C., 2013. Life Cycle Assessment as entrepreneurial tool for business management and green innovations. J. Technol. Manag. Innovat. 8, 44–53. https://doi.org/10.4067/S0718-27242013000100005.
Przychodzen, J., Przychodzen, W., 2015. Relationships between eco-innovation and financial performance – evidence from publicly traded companies in Poland and Hungary. J. Clean. Prod. 90, 253–263. https://doi.org/10.1016/J.JCLEPRO.2014.11.034.
Reid, A., Miedzinski, M., 2008. Eco-innovation. Final report for sectoral innovation watch. Syst. Eco-Innovation Rep. https://doi.org/10.13140/RG.2.1.1748.0089.
Santos, D.F.L., Basso, L.F.C., Kimura, H., Sobreiro, V.A., 2015. Eco-innovation in the Brazilian sugar-ethanol industry: a case study. Brazilian J. Sci. Technol. 2, 1–15. https://doi.org/10.1186/s40552-014-0006-4.
Santos, D.F.L., Lima, M.M. De, Basso, L.F.C., Kimura, H., Sobreiro, V.A., 2017. Eco-innovation and financial performance at companies established in Brazil. Int. J. Bus. Emerg. Mark. 9, 68–89. https://doi.org/10.1504/IJBEM.2017.080783.
Schumpeter, J.A., 1934. The theory of economic development: An inquiry into profits, capital, credit, interest, and the business cycle. Harvard University Press, Cambridge.
SEBRAE, 2016. **Energy Efficiency for Small Businesses: electric Motors (Eficiência Energética para pequenos negócios: motores elétricos)**. Brazilian Service to Support Micro and Small Enterprises. http://sustentabilidade.sebrae.com.br/Sustentabilidade/Parasuaempresa/Publicações/WEB-Cartilha Eficiência Energética_15x21cm4.pdf accessed 5.10.18.
SINDAN, 2018. Total annual revenue of the animal health sector (Faturamento total anual do setor de saúde animal). National Union of the Industry for Products of Animal Health. http://www.sindan.org.br/anuario2018/. accessed 12.26.19.
Triguero, A., Moreno-Mondéjar, L., Davia, M.A., 2013. Drivers of different types of eco-innovation in European SMEs. Ecol. Econ. 92, 25–33. https://doi.org/10.1016/J.ECOLECON.2013.04.009.
Velter, M.G.E., Bitzer, V., Bocken, N.M.P., Kemp, R., 2020. Sustainable business model innovation: the role of boundary work for multi-stakeholder alignment. J. Clean. Prod. 247, 119497. https://doi.org/10.1016/j.jclepro.2019.119497.
Verde, Iniciativa, 2019. **CO^2 calculator (calculadora CO^2)**. http://www.iniciativaverde.org.br/calculadora/index.php accessed 10.03.19.
WEG, 2018 **Energy efficiency (eficiência energética)**. https://www.weg.net/institutional/BR/pt/solutions/energy-efficiency/efficiency-index, 2018. accessed 5.10.18.