Adoption of cleaner production in a pupunha palm heart factory: a systematic literature review and a case study

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Abstract

The pupunha (peach palm) palm heart production in the Vale do Ribeira (southern region of the State of São Paulo-Brazil) brings economic benefits to the region, and environmental risks with the generation of a large amount of waste. The Cleaner Production adoption in the pupunha palm heart factories is a strategy for reducing environmental impacts and generating profit, with consequent rational use of raw material, reuse of waste, and new equipment installation. This research aims to evaluate the Cleaner Production adoption's environmental and economic benefits in the reuse of waste generated in pupunha palm heart processing. The case study was carried out in a factory, using direct observation, interviews, and documentary data. The calculation of ROI was an adequate tool for economic evaluation, and the adoption of gondolas in the stages of material separation and waste treatment provided improvements in the production processes. The Cleaner Production application increased the theoretical knowledge about the treatment and use of the waste, reduced the environmental impact, allowed the development of a new business, and generated economic gains through the creation of employment and increase of income.

Keywords: economic and environmental evaluation; cleaner production; solid waste; pupunha (Peach Palm).

Practical Application: Cleaner Production in pupunha palm heart factory resulted in sustainability.

1 Introduction

In recent years, the world population's growth has forced an increase in food production, which causes greater consumption of natural resources, energy, and water and changes the environmental, social, and economic conditions (Elliot, 2006). Therefore, initiatives for managing water use (Goap et al., 2018), energy (De Laurentiis et al., 2016), and best practices for integrated resource management (Mannan et al., 2018) are essential for sustainable development (Chen et al., 2019).

According to Ramos et al. (2018), sustainability practices that allow for increased process efficiency in industries with mitigation and reduced risks to the environment and society are the focus of Cleaner Production.

According to Ianovali et al. (2018), in the 1990s, quilombola farmers from Vale do Ribeira, a region located on the south coast of the São Paulo State-Brazil, started to extract the palm heart from the peach palm (Bactrisgasipaes Kunth), as the juçara (Euterpe Edulis Martius) became an endangered species. Several factories of pupunha palm heart processing were installed in the region, generating employment and income.

According to Kapp et al. (2003), the pupunha palm heart has simple processing, starting with the peeling process, which generates large amounts of waste, followed by filling in pots, and finally, the cooking of these pots in tanks, a stage in which large amounts of water are discarded.

The Cleaner Production (CP) can be classified as a set of rules and preventive actions that allows the continued application of a system aimed at financial and environmental results through the rational use of raw materials and the reuse of natural or industrialized residual resources (Jabbour, 2010). The CP seeks to promote means to improve industries' operational efficiency through waste reduction, processes optimization, and an environmentally correct view (Hamner, 1996). Developed through a joint effort by the United Nations Environment Program (UNEP) and the United Nations Industrial Development Organization (UNIDO), the CP represents an essential method to promote the sustainable development of society (Massote & Santi, 2013). According to Oliveira et al. (2016), CP was introduced in Brazil in 1995 by creating the *Centro Nacional de Tecnologias Limpas* (CNTL) or National Center for Clean Technologies.

A literature review on CP use in food industries presents several initiatives for the treatment of residues generated in the production processes, such as the production of chemicals, materials, and fuels from residues (Sáez-Martínez et al., 2016), generation of biogas through anaerobic digestion from residues rich in organic matter (Ingrao et al., 2018), and use of residues from the cider industry to generate value-added chemicals and fuel (Sette et al., 2020).

In anaerobic digestion processes in lactic acid fermentation, through CP, wastewater from the production processes is transformed into biogas and reused in the processes (Zhang et al., 2019).

According to Dvarionienė et al. (2012), in milk production, CP improves the process efficiency by acquiring equipment for the treatment of wastewater, allowing energy reduction, time, washing materials, and water consumption. Willers et al. (2014) implemented CP initiatives in a dairy farm, reducing water consumption when using pressurized water and dry cleaning of surfaces.

In the scientific literature, no studies were found on the application of CP practices to reuse residues from the pupunha palm heart industry. Based on this gap, this research aims to evaluate the environmental and economic benefits of adopting CP practices in the reuse of waste from a processing factory of pupunha palm heart. The resolution of the environmental liability with the commercialization of waste represents a contribution to the literature and management practice of palm heart processing industries.

This paper contains seven sessions, introduction, literature review, methodology, case study, results, discussion, and conclusion.

2 Literature review

2.1 Application of Cleaner Production in the food industry

Table 1 presents the papers presented in the literature review on CP use for managing wastes of the food industry. Waste and uncontrolled use of natural resources have drawn environmental experts and non-governmental organizations' attention to the need for the government to demand more effective control actions (Giannetti & Almeida, 2006). The agriculture and food sectors are vital to human health and well-being, and food production's sustainability is a significant concern today (Medici et al., 2020).

Food waste is a significant barrier to a sustainable society (Aschemann-Witzel et al., 2020). In 2015, the Japanese food-processing industry generated 9.5 million tons of organic waste annually, of which 25% was composted or used as an intermediate material for the production of animal feed, 25% was dried, 5% was used for energy generation, and 40% was incinerated or landfilled (Liu et al., 2016). Neugebauer & Sołowiej (2017) state that in 2013 only 3% of food wastes are recycled in the USA, and researches analyzing various waste management scenarios demonstrated that up to 27% of waste could be effectively composted.

According to Tesfaye et al. (2018), the disposal of large food waste poses substantial environmental impacts, and there is growing attention to it due to its effect on the environment (Tesfaye et al., 2020). CP is the most effective approach for avoiding waste (Aschemann-Witzel et al., 2020). The generation of waste from the agro-processing industry is continually increasing due to the increasing need for food security. The beneficiation of this waste has both economic and environmental impacts that can be overcome via the implementation of CP technologies (Tesfaye et al., 2020).

Industries that seek to implement CP practices need to pay special attention to the environmentally correct disposal of waste or its reuse. These procedures involve the interaction and interrelation of the industrial departments, which can also be reflected in the scope of economic and social issues (Oliveira et al., 2013).

According to Ingrao et al. (2018), the growing demand for food and the reduced adverse impacts of related supply chains represent a significant challenge in the 21st century. According to the European Union, food waste increased substantially, and it was estimated that 126 million tonnes could be produced in 2020 (Tesfaye et al., 2020). As food waste at the consumer level is a recent research topic, the related factors are still under analysis and discussion, and waste can be a valuable resource for producing chemicals, materials, and fuels (Sáez-Martínez et al., 2016). Recycling of waste from food processing industries can also be in the form of livestock feed or by producing value-added products from the waste, as food wastes contain organic materials that are biodegradable and can be converted to bio-based materials (Tesfaye et al., 2020).

Denham et al. (2016) analyzed the environmental impacts of the fish fillet sector and reported that electricity consumption, leakage of refrigeration gas, and disposal of unused fish portions contributed to the higher greenhouse gas emissions in supply chains. Potential strategies of CP to reduce these impacts included installing solar panels, recycling fish fillet residues through the production of biogas, fertilizers, and hydrolysates, maintaining refrigeration equipment, and replacing gas. Together, these strategies can reduce up to 35% of the total greenhouse gas emissions in the fillet's collection, processing, and retail.

Wu et al. (2016) investigated four filtration treatments that improve the effluent quality of sorting/classification of canned tangerine. The treatment involved a bag filter, an activated carbon filter, and a precision filter, resulting in improved water quality. The efficiency of this process can provide a 34.28% reduction in consumption.

Sette et al. (2020) propose the full, effective, and sustainable use of bio-waste from the regional cider and wine industries as an incentive to CP. The residues were recovered by extracting bioactive compounds and the pyrolysis/gasification of the residual solid to obtain value-added chemicals. One of them is biochar, a product that can be used as a fuel, as a precursor to activated carbon, or as a substitute fertilizer, offering an advanced biological carbon sequestration option.

Adazabra et al. (2016) used instrumental methods to study the adequacy of the use of shea waste in the civil construction sector. Evidence suggested that the waste reused in unburned bricks provided stronger and most resistant walls to waterlogging in traditional buildings.

Jin et al. (2016) developed a systematic biotechnological approach to select suitable fungi for bioconversion of the winery biomass wastes (grape marc and lees) into animal feed, aiming to improve protein contents, and the digestibility of the grape marc. Bioconversion of organic waste materials, such as the grape marc and wine lees, to value-added products, offers an opportunity for the reuse of abundant waste materials from agro-industrial processes and can be an excellent process to improve the nutrition content and digestibility of the organic wastes, making them as protein-rich animal feedstock.

Table 1. Application of CP in the food industry.

Author(s)	Country	Factory	Waste Type	Percentage of solid waste	Waste Treatment	Economic Gain	Environmental Gain
Denham et al. (2016)	Australia	Fish fillet	CO_2	---------------	Biogas production	Decrease in water and energy costs	Reduction of 35% in greenhouse gas emissions
Wu et al. (2016)	China	Canned tangerine	Wastewater	---------------	Installing activated carbon filters	Water treatment cost savings	Decreased water consumption
Sette et al. (2020)	Argentina	Grape and apple wine	Green apple pomace, grape pomace	100% of discarded fruits	Extraction of bioactive compounds, gasification of the residual solid and obtaining added value chemicals	Activated carbon production for use in fuel and reinforcement applications in the soil structure	Elimination of accumulation of organic waste from industries
Adazabra et al. (2016)	Ghana	Shea production	Spent shea	50 to 75%	Use in the manufacture of clay bricks	Bricks used in building stronger walls	Reduction of disposal and non-use of waste
Jin et al. (2016)	Australia	Wine industry	Grape marc and lees	Not mentioned	Extraction of fungi for producing protein-rich animal feedstock	Increased protein and digestibility of animal feedstock	Reduced carbon emission of landfills in Australia.
Tesfaye et al. (2018)	Ethiopia	Mango juice-making industry	Solid waste (mango seeds)	15 to 25% of the fruit	Manufacturing of starch from mango seeds	Accounting rate of return of 83%	Reduction in the environmental loads in traditional processing
						59% reduction of unit production cost compared to maize	Use of small amounts of chemicals in the processing
Tesfaye et al. (2020)	Ethiopia	Avocado farm	Solid waste (avocado seeds)	20 to 25% of the fruit	Manufacturing of starch from avocado seeds	Accounting rate of return of 75%	Reduction in the amounts of chemicals used in the starch extraction process
						40% reduction of selling price compared to corn starch	Processing of wastes generated
Zhang et al. (2020)	China	Wheat starch	Wastewater	---------------	Nutrient extraction from wastewater	Production of vitamin K_2 using Bacillus from compounds present in wastewater	
Abou-Elela et al. (2008)	Egypt	Confectionery	Wastewater	---------------	Chemical and biological treatment	Saving financial resources for the construction of a water treatment plant	Elimination of untreated wastewater discharge into the public sewage system
Dvarionienė et al. (2012)	Lithuania	Milk processing	Wastewater	---------------	Use of water treatment equipment	Reduction of 40% in energy consumption, 68% in washing materials, and 57% in electricity	Reduction of 9% in pollutant emissions, and 31% in water consumption
Willers et al. (2014)	Brazil	Dairy farm	Wastewater	---------------	Training in water use and replacement of cleaning equipment	Reduction of additional water and equipment costs	Reduction of water consumption and final amount of polluting waste

Tesfaye et al. (2018) analyzed mango seeds as an alternative resource for starch production in Ethiopia. The results showed that starch extraction from mango seeds was facile, a good quality product was obtained, the unit production cost is 0.33 US$/kg, while the cost of starch from maize is 0.81 US$/kg, the project is financially viable with an accounting rate of return of 83% and a break-even analysis of 78% with a payback period of 2 years.

Tesfaye et al. (2020) analyzed avocado seeds as an alternative resource for starch production in Ethiopia. The results showed that starch extraction from avocado seeds is economically feasible, as it does not need sophisticated technology, has an accounting rate of return of 75%, and a break-even analysis of 82% with a payback period of 2 years.

Zhang et al. (2020) studied the wheat starch sector, where wastewater was used to produce vitamin K_2, using Bacillus subtilis W-17, in order to reduce its production cost. The vitamin production through the extraction of nutrients from wastewater and its reuse can offset the sector's disposal costs.

Abou-Elela et al. (2008) studied wastewater management in a confectionery that produces chocolates, chewing gum, and lollipops, using cocoa butter, powdered milk, starch, sugar, flavors, and coloring compounds. The CP measures applied involved good cleaning, recovery of spent chocolate, modification of floor cleaning, and suction devices installation to remove sugar and powdered starch. With these initiatives, the money destined for the construction of a treatment plant wastewater has been spared.

Dvarionienė et al. (2012) demonstrated the application of CP and Ecological Design as sustainable production tools to improve a milk processing industry's environmental efficiency. Through more sophisticated equipment to deal with wastewater management, it was possible to achieve a 40% reduction in thermal energy consumption, 40% in time, 68% in washing materials, 57% in electricity, 9% in pollutant emissions, 31% in water consumption, and 9% in natural gas consumption.

Willers et al. (2014) studied the milking sector of a medium-sized dairy farm. CP actions implemented involved pressurized water, dry cleaning, and foam to clean surfaces; training employees to use water; replacing equipment cleaning; effluent decontamination; and fertilizer irrigation with wastewater.

Worldwide, Brazil stands out in the industrialization of acidified and pasteurized canned palm heart, both for the quantity processed and the product's quality (Berbari et al., 2008). Brazil is the world's largest producer and consumer of palm heart and is the second-largest exporter of this item (Belniaki et al., 2020).

According to Ormenese et al. (2016), concerning the palm trees that can be used in palm heart production, the species that stand out are juçara (*Euterpe Edulis Martius*), açaí (*Euterpe Oleraceae Martius*), pupunha/peach palm (*Bactrisgasipaes Kunth*), and several species of Australian royal palms (*Archontophoenix Alexandrae* and *Archontophoenix Cunninghamiana* are the most cultivated).

The Australian royal palm is an endemic tree in eastern Australia; however, it has developed well in Brazil, as the country's tropical climate provides an ideal temperature range (between 20 and 30 °C) for plant germination (Zanini et al., 2020). This specimen can reach up to 25 meters in height, producing viable seeds, having good resistance to diseases, and providing high-quality palm heart.

Pupunha is a multi-stemmed palm species used in the consumption of palm heart and the production of drinks, sweets, flour, among other products (Mossanek et al., 2014). Peach palm is a palm tree of tropical climate, is highly valued, as all its parts can be used, with the palm heart and the fruits having the highest added economic value (Clement & Bovi, 1999).

When analyzing the agribusiness exploitation and the processes related to the industrialization of the pupunha palm heart, it is possible to observe the residual generation of large quantities of barks and their respective external sheaths, which, if not adequately cared for and discarded, can cause environmental problems (Silva et al., 2009).

According to Zanini et al. (2020), high palm production results in significant amounts of waste during palm heart extraction. For each palm, approximately 400 g of commercial palm heart is collected. The residue constitutes 80 to 90% of the palm's total weight, with some variation depending on the species. In the palm heart extraction process, the leaves are left at the cut site, and the stem is taken to the palm heart factory. The sheath has a high carbon/nitrogen ratio. Therefore, it takes time to decompose, causing environmental problems due to the accumulation of waste.

Palm residues are found in large quantities in several countries, mainly in Brazil, and are considered low-cost, biodegradable, and easy to handle waste (Zanini et al., 2020). Besides, pupunha palm heart can be sold through simplified processing steps. So, the peach palm is a palm highly valued in Brazil because, in addition to providing alternatives for sustainable cultivation, it generates employment and income for small and medium-sized farmers (Ferreira et al., 1982; Ianovali et al., 2018).

3 Research method

This research used case study as a method to understand facts and relationships (Gil, 2009), and according to Yin (2009), case study adoption aims to answer questions of "how" and "why", and in real situations where boundaries between the subject and the context are indistinct. Such conditions fit this research and confirm that the case study is the most appropriate method.

For this research, a single case study was carried out. The authors followed the following selection criteria:

1) To operate in the processing segment of pupunha palm heart;

2) To have adopted or to be in the process of implementing CP;

3) To allow researchers access to company information;

4) To make available a person responsible for supporting researchers on the CP adoption.

It is noteworthy that the systematic literature review was initially developed to verify whether the case presented in this study would contribute to the scientific literature, demonstrating novelty. The procedures for data collection and data analysis adopted in the case study presented were explained.

3.1 Systematic literature review

In order to assess the economic and environmental benefits of using CP in the pupunha palm heart industry, exploratory research was carried out in the literature review in order to help understand subjects and events where there is little or no control (Marconi & Lakatos, 2010). For that, a research protocol was elaborated using the terms "Cleaner Production" AND "Waste" OR "Residue" AND "Food", consulted in the databases Scopus and Web of Science. As criteria for selecting papers, filters were applied (papers published in journals, written in English, and with full text available). The criteria for rejection of papers were not to be applied CP with a focus on food production and waste reuse environments. However, although bibliographic research in the Scopus and Web of Science databases revealed 81 papers on wastes in the food sector was published, a detailed analysis presented five papers are related to solid wastes and six papers are related to liquid wastes in the food industry.

3.2 Procedure for data collection

The action of collecting data for case studies indicates that the semi-structured interview is the most appropriate in quantitative research, according to Bryman (1995) and Collins & Hussey (2007). A visit to the factory was made to learn about the manufacturing process of pupunha palm heart. The factory manager and the administrative director were interviewed, and they answered a questionnaire and presented documents related to production. The documentary data survey made it possible to confirm the data provided in the interview (Yin, 2009).

The data survey involved the following questions:

1) How has the CP adoption in the processing factory of pupunha palm heart contributed to increase economic gains and reduce environmental impacts with waste disposal?

2) How much raw material enters the process?

3) What quantity of raw material is used in palm heart processing?

4) How much waste is generated?

5) What is the selling price of the processed waste?

3.3 Procedure for data analysis

The analysis of the data collected in the collection stage uses a quantitative approach since the variables analyzed, in their majority, are identified as measurable (Martins, 2012; Paoli et al. 2013). In the interview, the values related to the investment in a crushing machine of the pupunha bark and the calculation of the annual costs (expenses with the machine's maintenance and consumption of electric energy) were raised. Thus, to evaluate the annual economic gains from the sale of waste, the Return on Investments (ROI) and the return period on invested capital were calculated. According to Martins (2000), the ROI calculation represents the most effective way of measuring an enterprise's degree of success. The ROI calculation and the payback period can be calculated using the equations shown in Table 2.

The mass balance calculation was used to evaluate the amount receivable from the sale of residues generated in the processing of pupunha palm heart. It is calculated by: Mres = Ment – Mpalm (Equation 1).

$$M_{res} = M_{ent} - M_{palm} \qquad (1)$$

Where: M_{res} – mass of bark residue

M_{ent} – input mass of raw material

M_{palm} – mass of pupunha palm heart

4 Case study

The processing factory of pupunha palm heart is located in Juquiá, located 150 km from São Paulo City and 250 km from Curitiba City. The company's primary customers are specialized food distributors and supermarket chains.

The processing process of palm heart is divided into the following steps:

- Collection of trunks in the farms, carried out mainly by small producers pre-registered by the company.

- Unloading the pupunha trunks, transported by trucks, forwarding to the debarking process, separating the residual material (pupunha bark), and the primary product (palm heart billet).

- According to the order requests, cut the palm heart billets (into strips or slices) and fill them in glass pots.

- Cooking, with subsequent storage and sending the product to quarantine, for quality control steps.

- Labeling and shipping of products.

Figure 1 illustrates the processing of pupunha palm heart and the residual generation

With the adoption of CP practices, the processing of residues from palm heart barks was added to the production process, as shown in Figure 1. In this way, the residues are stored for later crushing and transformation into natural fertilizers.

Table 2. Equations for calculating ROI.

ROI Evaluation and Payback Period	% ROI = half-yearly net income / investment ROI Period = investment / half-yearly net income

5 Results and discussion

In this section, the case study results are presented in terms of analysis of the mass balance and evaluation of environmental gains, and the analysis of investments and financial evaluation.

5.1 Mass balance analysis and environmental gains evaluation

The factory processes 15 tons of pupunha a day for palm heart production, generating an average of 7.34 tons of waste (pupunha barks), which represents a residual percentage of 48.9% concerning the total daily value processed in the company. In the researched literature, the solid waste rates found ranged from 50 to 75% in the Shea production (Adazabra et al., 2016), 15 to 25% in the Mango Juice Industry (Tesfaye et al., 2018), 100% of the fruit discarded in the Grape and apple wine industry, and 20 to 25% in the Avocado farm (Tesfaye et al., 2020).

Considering 220.2 tons of waste are generated monthly, it is possible to state that 2,642.4 tons of waste are generated annually.

The pupunha bark can be used in several agriculture sectors and can be reused as a natural fertilizer to improve the cultivation of different plantations. For this reuse, the main applicable primary process refers to the crushing of the pupunha bark.

Table 3 shows the mass balance calculations of the raw material used and their respective quantities of waste generated after processing the company's product.
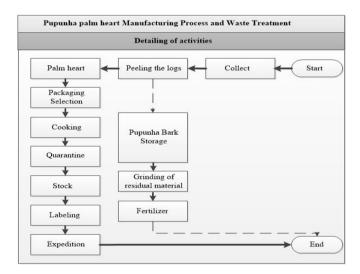

Figure 1. Manufacturing process of pupunha palm heart and residual generation.

Table 3. Mass Balance of Raw Material and Waste Generated.

Material	Daily amount (ton)	Monthly amount (ton)	Annual amount (ton)	%
Stalks of pupunha processed	15	450	5,400	100
Pupunha bark (residue)	7.34	220.20	2,642.40	48.9
Palm heart billets	7.66	229.80	2,757.60	51.1

The reuse of this residual material corroborates the study of Franco et al. (2019), who prescribe that pupunha has a rapid growth cycle, making it advantageous for productive activities (food products), in addition to the reuse of waste (material with high added value), creating alternatives for mitigation of inadequate disposal.

5.2 Investment analysis and economic evaluation

Considering the calculations related to financial gains, the kilogram of processed waste (pupunha bark) receives a value of US$ 0.0137, representing a gross annual return of US$ 44.920,80. The annual expenses with electricity were US$ 8,487.39, with the maintenance of the area US$ 1,529.52, and US$ 4,996.04 was spent with labor. The net annual revenue was US$ 29,907.85 through a reduction in annual costs, which are related to the maintenance of the area and expenses with electricity. The investment for acquiring the machine was measured at US$ 857.14 in order to validate waste crushing processes (pupunha bark).

Given the findings presented, it was possible to calculate the ROI of 2,445.5% per year and return on invested capital over 0.06 years or 0.72 months (equivalent to 21.6 days). Table 4 shows the details of the calculations made on the ROI, having as input the investment values about equipment acquisition, the depreciation of 10 years, and the value obtained in the sale of solid waste, after deducting the costs with electricity and maintenance of the area. With these data, taxes had been calculated and discounted, resulting in the value of Annual Cash, and Table 5 shows the period on the return on invested capital.

The processing industries of pupunha palm heart receive the raw material in small batches. It is brought from the farms in trucks that park at the factory in a bay. There, the factory's employees already separate the barks and the palm heart. This procedure keeps the truck stuck, causes congestion at the entrance, and places waste in an inappropriate location. With the adoption of CP strategies, the first modification was made at the entrance of raw materials, using gondolas, where the raw material is unloaded, and the truck is released. Another modification was made in the trunk's debarking, with the barks placed in a gondola, for processing the waste.

Table 4. Calculation of Return on Investment (ROI).

Investment in the implementation of Cleaner Production	US$ 857.14
Depreciation term (years)	10
Annual depreciation	US$ 85.71
Annual Cost Reduction achieved	US$ 29,907.85
Annual depreciation	- US$ 85.71
Basis for calculating Income Tax (IR)	**US$ 29,822.14**
TILP + SCNI (Social Contribution on Profit)	30%
Annual IT + SCNI value	- US$ 8,946.64
Annual Net Cost Reduction	**US$ 20,875.50**
Annual Depreciation	US$ 85.71
Annual Cash Generation	**US$ 20,961.21**

TILP = Tax on Income of Legal Persons; SCNI = Social Contribution on Net Income; IT = Income Tax.

Table 5. Cash Flow presented over the five-year period.

Cash flow	Year 0 (US$)	Year 1 (US$)	Year 2 (US$)	Year 3 (US$)	Year 4 (US$)	Year 5 (US$)
Investment	- 857.14					
Annual Cash		20,961.21	20,961.21	20,961.21	20,961.21	20,961.21
Cash Flow Total	- 857.14	20,961.15	20,961.15	20,961.15	20,961.21	20,961.21
ROI or IRR		**2,445.5% per year**				
PayBack minus 15% per year		**0.06 year**				

IRR = Internal Rate of Return.

The novelty at this point of adoption of CP in the processing factory of pupunha palm heart was gondolas' placement for the entry of raw material and gondolas for placing the barks' residues. The practical advantages were reducing truck times at the factory, better allocating waste, and reducing accidents. Another critical point was the increase in the daily processing capacity of pupunha palm heart, and this corroborates Abou-Elela et al. (2008) and Willers et al. (2014), who introduced changes in the process to increase production.

The use of CP in the processing factory of pupunha palm heart presented an environmental gain with a decrease of 229.80 tons of waste per month, previously thrown into the environment in a disorderly manner. The reuse of this waste allowed creating a new structure at the factory, with a crushing, packaging, and commercialization unit. This process generated environmental and social gains, with new jobs in a region lacking opportunities.

Adazabra et al. (2016), Denham et al. (2016), Sette et al. (2020), and Zhang et al. (2020) created new activities with the use and processing of waste. This study innovates the state of the art because the adoption of CP practices solved a large amount of waste (in the form of barks) discarded in the environment, generating significant environmental impacts and fines by regulatory agencies. The purchase of a crushing machine allowed the sale of waste as fertilizers for other crops or as nutrients for animal feed. The introduction of equipment or alteration of processes for the treatment and use of waste is efficient, as can be seen in Adazabra et al. (2016), Dvarionienè et al. (2012), and Zhang et al. (2019).

The treatment of waste generated in pupunha palm heart and the CP adoption required investment in new equipment. The use of ROI calculation can provide more security for managers to invest in new equipment. The novelty in this CP adoption project was the calculation of ROI, and it is in line with Sette et al. (2020), Wu et al. (2016), and Zhang et al. (2020), who used the economic return to evaluate the implementation of CP practices and the acquisition of new equipment.

6 Conclusion

CP adoption practices in a processing factory of pupunha palm heart, with changes in the entry process of raw material and the treatment of palm heart barks waste, provided economic and environmental gains by reducing the disposal of waste in the environment. This strategy gave managers the conditions to make more proactive decisions.

Many processing factories of pupunha palm heart installed in Vale do Ribeira are small companies, with a production process without automation, and even inadequate waste treatment, without clear criteria for a destination.

The contribution of this research to the theory was the introduction of ROI calculation as a financial management strategy to support investments that provide environmental gains; for business practice, the placement of gondolas to receive raw material and waste processing; and for the social area, the creation of jobs and the generation of income. The CP adoption practices in the processing factories of pupunha palm heart added innovation in the production process, increased production, waste use, and economic and environmental gains.

Furthermore, the CP adoption in the processing sector of pupunha palm heart enables new businesses, such as the development of natural fertilizers, animal feed, raw material for the furniture and handicraft industry.

This study has some limitations. Thus, it is essential to emphasize that the case study was carried out in a single factory that was starting to adopt CP, so the results cannot be generalized for the segment. Additionally, as the focus was on the economic gain generated by using the pupunha bark waste, the reuse of water in the production process was not evaluated.

As a suggestion for future research, evaluating how the wastewater from the production process can be analyzed, treated, and reused is indicated. Furthermore, the realization of multiple cases about the CP adoption in the processing factories of pupunha palm heart can bring more significant contributions to the study field.

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