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ECODESIGN: CASE STUDY IN A PUPUNHA PALM HEART AGROINDUSTRY

ECODESIGN: ESTUDO DE CASO EM UMA AGROINDÚSTRIA DE PALMITO PUPUNHA

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Abstract
Sustainable development in the organizational context grows in social relevance due to its importance for the preservation of the environment and for providing better living conditions for humanity. In this scenario, ecodesign is strengthened as a practice that aims to develop products and processes that consider the environmental impacts and reduce harmful environmental effects. Faced with this context, the present study aimed to evaluate the environmental impacts of the processing and commercialization of pupunha heart of palm by applying Ecodesign strategies. The tool chosen for the application was the Ecodesign Strategies Diagram. The work is characterized as a case study, and data collection methods were semi-structured interviews and non-participant observation. The company studied is located in the Ribeira Valley – Brazil, and operates in the processing and commercialization of pupunha heart of palm. As a result, it was possible to identify some environmental impacts caused by the agroindustry studied and to suggest some mitigating measures, such as improving the standardization and automation of processes, use of clean energy, rational use and reduction of waste of process water, and creation of a program of reverse logistics for packaging.

Keywords: Ecodesign. Pupunha palm heart. Product development. Reverse logistic. Packaging.

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Resumo
O desenvolvimento sustentável no contexto organizacional cresce em relevância social em razão de sua importância para a preservação do meio ambiente e por proporcionar melhores condições de vida para a humanidade. Neste cenário, o ecodesign se fortalece enquanto prática que visa desenvolver produtos e processos considerando os impactos ambientais envolvidos e com o intuito de reduzir os efeitos nocivos ao meio ambiente. Frente a este contexto, o presente estudo objetivou avaliar os impactos ambientais decorrentes do processamento e comercialização do palmito pupunha por meio da aplicação de estratégias do Ecodesign. A ferramenta escolhida para a aplicação é o Diagrama de Estratégias do Ecodesign. O trabalho caracteriza-se como um estudo de caso e os métodos de coleta de dados foram a entrevista semiestruturada e a observação assistemática. A empresa estudada localiza-se no Vale do Ribeira – Brasil e atua no processamento e comercialização de palmito pupunha. Como resultado, foi possível identificar alguns impactos ambientais causados pela agroindústria estudada, e sugerir algumas medidas atenuantes, como melhorar a padronização e automatização dos processos, uso de energias limpas, uso racional e redução do desperdício de água do processo e criação de um programa de logística reversa para as embalagens.

Palavras-chave: Ecodesign. Palmito pupunha. Desenvolvimento de produtos. Logística reversa. Embalagem.

1 Introduction

Sustainable development is a concept that is gaining more and more relevance in contemporary society, as its application allows us to envision better living conditions for humanity, especially in a scenario where it is necessary to consider aspects such as the limitations of nature, the context of scarcity of natural resources and the growing demand for consumption (Fonseca, Domingues, & Dima, 2020; Ramzy, El Bedawy, Anwar, & Eldahan, 2019; Scur & Alliprandini, 2023). Sustainable development should be seen as more than just a deliberation of decisions at the management level or mandatory regulations to be complied with due to current legislation. It should be part of the company's strategic vision, which results in ethical and environmental implications in business choices.

The organization can decide to engage in sustainable development for economic purposes or ethical purposes: from an economic point of view, the objective is to increase corporate profitability and competitiveness; from an ethical point of view, companies decide to adopt sustainable development due to their sensitivity to this topic (Pimenta, Rosa & Pimenta, 2023). Regardless of the motivating factor, sustainable practices provide several advantages for organizations, such as reducing the consumption of raw materials or natural resources, improving the company's image before society, customer retention, employee engagement, and adherence to ecological pressures – internal and external (Thomas, Scandurra, & Carfora, 2022; Farias, Coelho, & Coelho, 2019).

In Brazil, the scenario of sustainable development is set back since there is ongoing denialism concerning science that results in the worsening of deforestation in the Amazon, obscurantism concerning the climate and global warming, and even about education for a sustainable way of life (Sorrentino & Nunes, 2020; Rego & Faillace Júnior, 2024). This context highlights the relevance and need for initiatives to reduce the environmental impacts of industries.

To improve this scenario and promote sustainable development, organizations must manage a portfolio of eco-efficient products and services (Pereira, Cunha & Pereira, 2018; De Brito & Oliveira, 2014). A widely suggested path is the industry's adoption and integration of ecodesign in all stages of new product development, from generating ideas to selecting viable projects (Lewandowski, 2016; He, Li, Cao, & Li, 2020). The integration of ecodesign in the industry is based on the design of products for which the minimization of environmental impact is considered throughout their life cycle, contributing to the creation of environmentally sustainable products (Pinheiro et al., 2018). Ecodesign is based on fundamental issues associated with profit, functionality, quality, ergonomics, image, and aesthetics, always to reduce resource consumption, negative impacts, and damage to the environment, in addition to improving energy efficiency (Relich, 2023; Rau, Lagapa, & Chen, 2021).

One way to ensure a product is sustainable is to include ecodesign principles in its design to consider the end-of-life process from the beginning (Furferi, Volpe, & Mantelassi, 2022). Ecodesign solutions for products consider all life cycle stages, from the extraction of raw materials to manufacturing, considering packaging, use, recycling, and reuse (Pinheiro et al., 2018). For this level of implementation, it is necessary to use methods and tools that support ecodesign (Rau et al., 2021).

Among the industries that can improve their environmental performance by applying the principles of sustainable development, the agri-industry is under the most pressure to meet expectations regarding environmental issues (Florini & Pauli, 2018; Luhmann & Theuvsen, 2016). In this context, applying ecodesign can be an effective strategy to stimulate knowledge sharing and the development of products and processes with less environmental impact (Rouault et al., 2020).

In agri-industry, ecodesign manifests itself both in the preservation of nature and in the improvement of quality of life, with a focus on reducing energy consumption and water resources and establishing a waste management system at each stage of the life cycle (Topleva & Prokopov, 2020). It is essential to highlight that the relationship between agribusiness and the food industry is very close and interdependent, based on the supply of raw materials (Wajszczuk, 2016), processing value addition (Bryceson, 2011), logistics and distribution (Yadav et al., 2022), innovation and sustainability (Testa et al., 2022), and food regulation (Behringer & Feindt, 2019), constituting a continuous cycle that is supported by the production, processing, and distribution of food, and playing essential complementary roles for the economy and food security (Christiaensen, Rutledge & Taylor, 2021). From this relationship emerges the agri-food industry (Cook & Chaddad, 2000). Although there are few studies on ecodesign in the food industry, life cycle analysis is one of the most widely used tools considering aspects related to ingredients, packaging, transportation, energy, and water (Thomas et al., 2020).

The research carried out by Thomas et al. (2020) on the spirulina-based food industry is an example of the importance of ecodesign in the food industry. This research showed that in the early stages of product development, it is crucial to determine the main characteristics of a product, and it is essential to include environmental criteria in the company's decisions. Therefore, ecodesign tools have also been used to mitigate impacts on agricultural systems related to food and beverage production, logistics, and supply chains, as in the case of research carried out by Perrin et al. (2022), who developed a framework that addresses environmental and economic dimensions during participatory ecodesign workshops in viticulture.

Azzaro-Pantel, Madoumier, and Gésan-Guiziou (2022) indicate three main approaches to ecodesign strategies in food industries that still need to be widely implemented: comparative environmental assessment of different processes, minimization of material flows (water and energy) during the process, and the simulation-optimization approach. Comparative environmental assessment uses life cycle assessment (LCA) to identify the most environmentally harmful processes and thus improve them. Minimizing material flows seeks to modify the operational conditions of the process to reduce both environmental impact and costs. The simulation-optimization approach combines process modelling, simulation, and optimization to minimize the use of inputs (water, energy, and chemicals), contributing to both impact and cost reduction.

Specifically, about the subject of study of this research, waste is generated from collection to packaging disposal in the peach palm agroindustry. In addition to the waste generated in the peach palm harvest, liquid waste is generated in the processing: brine, water from sterilizing containers, water from washing equipment, and water from cooking in a bain-marie; and solid waste: biomass from debarking (Santos, Bolanho, & Danesi, 2021). For each stem that arrives at the industry - after removing the leaves and other residues left in the field - 85% of this material can be considered residue (Santos et al., 2021). The leaves decompose faster, while the sheaths take longer to degrade, becoming an environmental problem (Bayão et al., 2020). Currently, the destination of this solid waste is exposure to the open air, animal feed, and fertilizer. There are also other solid wastes in smaller quantities: cardboard, plastics, glass, and aluminum (Santos et al., 2021).

Given this scenario, with a robust environmental impact promoted by the peach palm processing industry, the present study aimed to evaluate these impacts arising from the processing and commercialization of pupunha heart of palm by applying Ecodesign strategies. We also sought to identify possible improvements in the processing and marketing of this product, considering the importance of environmental preservation.

2 Materials and methods

The methodological procedures used in this study aimed to evaluate the environmental impacts of processing and marketing pupunha palm hearts by applying Ecodesign strategies. To this end, the Ecodesign Strategy Diagram tool was applied in the agroindustry that produces pupunha palm hearts. The tool allowed the analysis of the company's environmental aspects by assigning scores to each of the dimensions of the eight ecodesign strategies. The researcher assigned the scores based on the responses to the questionnaire and the company's unsystematic observation. The evaluation included two dimensions: applicability and relevance for the company. Applicability was associated with its ability to be applied within the production process. Relevance was related to the importance of such practice, action, or the ideal to be achieved.

The Ecodesign Strategies Diagram tool corresponds to a graphic representation covering 33 areas where a product can improve its environmental performance, considering the entire product life cycle. These 33 areas (Table 1) are grouped into eight groups of ecodesign strategies (@, 1, 2, 3, 4, 5, 6, 7), which, in turn, are grouped into three levels of product development (level of product components, product structure level and product system level (Van Hemel & Cramer, 2002; Frazão, Peneda, & Fernandes, 2003). This tool is focused on design standards for sustainability, allowing for a systematic review of the product life cycle (Alves et al., 2016) and allows for comparing current performance with desirable performance (Diehl, Soumitri, & Mestre, 2001; Obrecht, El Haddad, Abd Elbary, Lukman, & Rosi, 2019).

Table 1.

Ecodesign Strategies

<table>
<tr><th>Levels</th><th>Strategies</th><th>Areas of improvement</th></tr>
<tr><td>-</td><td>@. New concept development</td><td>1. Dematerialization
2. Shared use of the product
3. Integration of functions
4. Functional optimization of the product (components)</td></tr>
<tr><td rowspan="2">Product componente level</td><td>1. Selection of low-impact materials</td><td>1. Cleaner materials
2. Renewable materials
3. Lower energy content materials
4. Recycled materials
5. Recyclable materials</td></tr>
<tr><td>2. Reduction of materials usage</td><td>1. Reduction of weight
2. Reduction in (transport) volume</td></tr>
<tr><td rowspan="3">Product structure level</td><td>3. Optimization of production techniques</td><td>1. Alternative production techniques
2. Fewer production steps
3. Lower / cleaner energy consumption
4. Less production waste
5. Fewer / cleaner production consumables</td></tr>
<tr><td>4. Optimization of distribution system n</td><td>1. Less / cleaner / reusable packaging
2. Energy-efficient transport mode
3. Energy-efficient logistics</td></tr>
<tr><td>5. Reduction of impact during use</td><td>1. Lower energy consumption
2. Cleaner energy source
3. Fewer consumables needed
4. Cleaner Consumables
5. No waste of energy/consumables</td></tr>
<tr><td rowspan="2">Product system level</td><td>6. Optimization of initial lifetime</td><td>1. Reliability and durability
2. Easier maintenance and repair
3. Modular product structure
4. Classic design
5. Strong product-user relation</td></tr>
<tr><td>7. Optimization of end-of-life system</td><td>1. Reuse of the product
2. Remanufacturing
3. Recycling of materials
4. Safer incineration</td></tr>
</table>

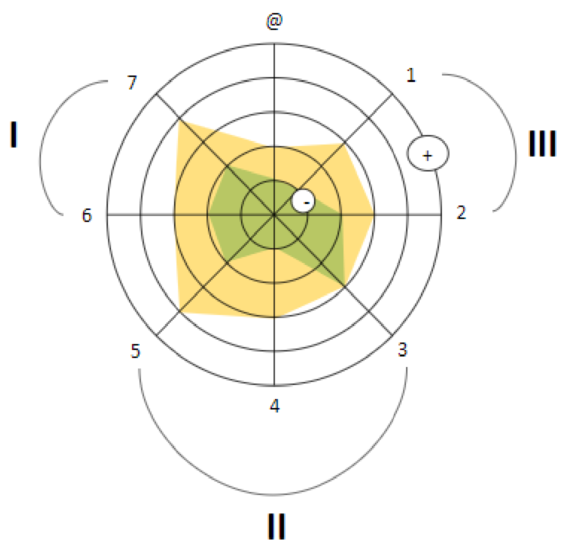
Source: Adapted from Van Hemel and Cramer (2002).

In the Ecodesign Strategies Diagram, the eight groups of strategies are arranged perpendicularly to five concentric circles (Figure 1), in which the radii are configured on a scale of values for each axis. For each strategy, areas that need improvement are presented within the environmental profile, considering the life cycle phases (Frazão et al., 2003). Strategies 1 to 7 correspond to the materials selection and prefabrication phases (strategies 1 and 2), manufacturing (strategy 3), distribution (strategy 4), use (strategy 5), and end of life (strategies 6 and 7). The @ strategy is closely related to creating a concept or designing sustainable product phases (Frazão et al., 2003). To build the diagram, it is necessary to define the scale to be adopted, commonly used from zero to five phases (Frazão et al., 2003).

After dimensioning each axis in the value scale, the profile of a reference product is traced and forms the first polygon of the diagram (area in green in Figure 1). Therefore, the polygon profile is the result of evaluating the environmental performance of the reference product based on all listed areas, which are classified on a scale of zero to five. This representation allows the company to have a holistic view of the environmental problems presented by the product. In the present study, this profile was drawn by evaluating the "applicability" of the improvement areas in the studied company (Van Hemel & Cramer, 2002). The structure of this polygon, as a result of the notes entered, indicates that the larger the area, the better the score of that product, that is, the better its environmental performance, and, consequently, the better it satisfies the needs of customers (Rungyuttapakorn & Wongwatcharapaiboon, 2019).

Figure 1.

Ecodesign Strategies Diagram



Source: Adapted Van Hemel and Cramer (2002).

Subsequently, a second polygon (yellow area in Figure 1) is drawn according to the company's priorities and objectives. This polygon defines the environmental profile of the intended product. In the present study, this profile was drawn, indicating the "relevance" of the proposed improvement areas. In other words, it allowed you to view how much it is possible to apply the improvements in the context of the company studied.

Comparing the polygons makes it possible to visualize the difference between the eco-efficiency profiles of the studied product in its current process (reference product) and a possible intended (improved) process and, consequently, communicate and document the ecodesign strategies that the company would need to use to introduce environmental improvements in the product to be developed, based on established goals, objectives, and priorities. The closer the areas in green and yellow (Figure 1), the better the environmental performance of the intended product in evaluating the team's objectives (Frazão et al., 2003; Agyemang, Jia, Faibil, & Lin, 2021).

The attribution of grades to each improvement area, encompassing the eight ecodesign strategies, was based on a questionnaire applied to people organically involved in the management of the company under study and on the unsystematic observation of the entire company process.

The scores for the analyzed areas of improvement were assigned based on the classifications defined in Table 2. For the analysis of the aspects (areas for improvement) of the axes, the following criteria were defined:

- when it does not apply to the product under study, it receives a score of 0;
- if it has little applicability or relevance, it receives a score of 1;
- if it has reasonable applicability or relevance,
- it receives a score of 2;
- if it has a lot of applicability or relevance, it receives a score of 3;
- if it has high applicability or relevance, it receives a score of 4.

Table 2.

Caption Relates to Evaluation Concepts

Caption		
Score	Application	Relevance
0	None	None
1	Few	Few
2	Reasonable	Reasonable
3	Very	Very
4	Very much	Very much

Source: Adapted from Van Hemel and Cramer (2002).

Then, the arithmetic mean of all improvement areas of the same strategy was calculated so that it was possible to obtain a score for both applicability and relevance, considering each of the eight ecodesign strategies proposed by the tool. The averages obtained in each strategy were classified as low, medium, or high, according to the stratification presented in Table 3.

Table 3.

Stratification of The Averages of Each Strategy

Scores	Rating
0 - 1,5	Low
1,6 - 2,5	Average
2,6 - 4	High

Source: Adapted from Van Hemel and Cramer (2002).

Finally, the Ecodesign Strategies Diagram was built based on the averages obtained, which drew a parallel between the company's current situation (applicability of strategies) and the improvement goal it could achieve (relevance).

The modelling of this article follows the IMRaD model, which proposes a structure organized in sections that aim at a logical exposition of the research results and palatable reading (Pilatti, Cantorani, & Cechin, 2023).

3 Results

3.1 Company characterization

The company has been in the pupunha heart of the palm market for over fifteen years, with operations in several cities in Brazil. The operations branch, which is the object of this study, is located in the state of São Paulo, in the Vale do Ribeira region, which has a large concentration of peach palm plantations. The company sells different types of canned pupunha hearts of palm, sliced, sliced, chopped, salad, heart, band, spaghetti, and aperitif.

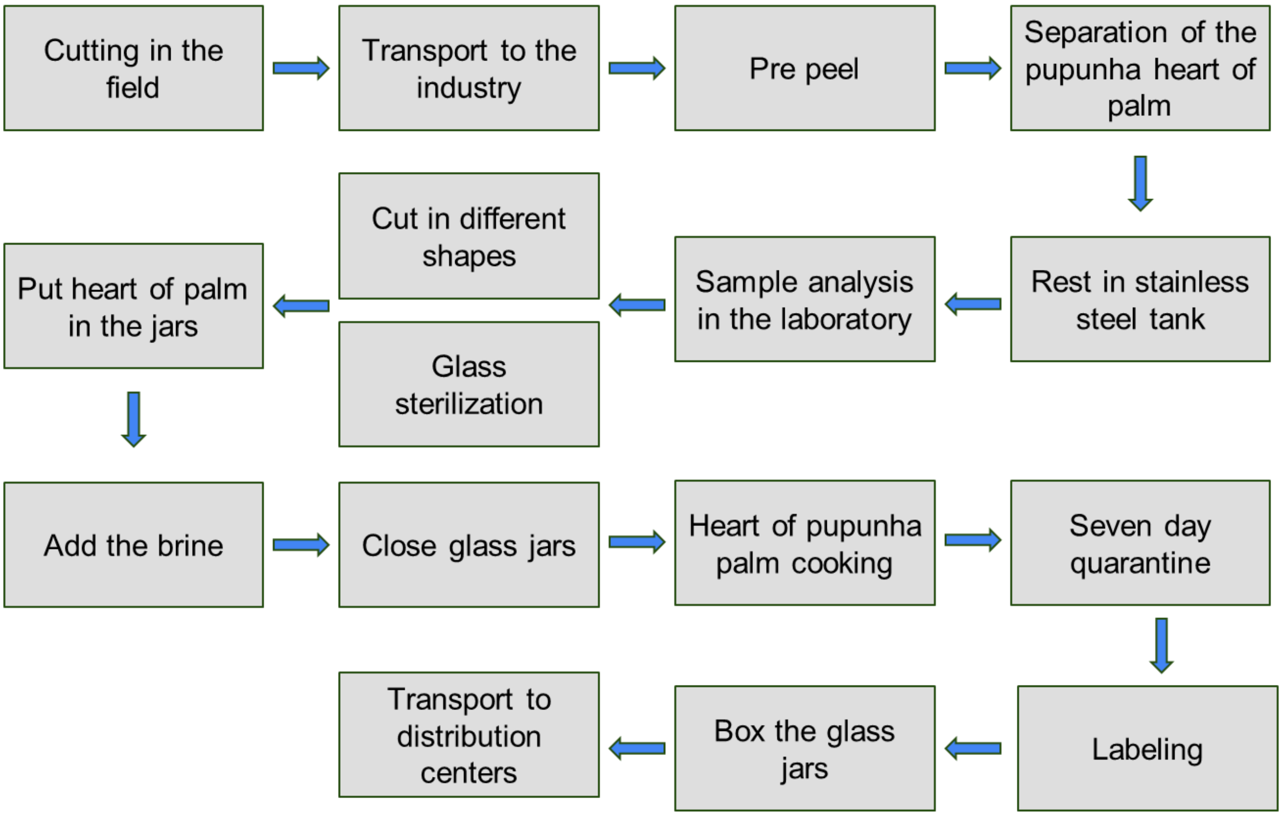
Only 3% of the raw material comes from the company's production. The rest of the raw material is purchased from local and regional producers. The industry produces 2,000 stalks of peach palms per day. Each stem weighs 500 grams, which generates a ton of heart of palm per day. The company produces an average of 30 tons of products sold to large business groups per month.

3.2 Productive process

The production process of canned pupunha heart of palm carried out by the company consists of 16 stages, as shown in Figure 2.

Figure 2.

The Stages of The Company's Production Process



Source: Elaborated by the authors.

The first stage is cutting the pupunha heart of palm in the field, and the rural producers are responsible for this procedure. Then, the peach heart of palm is transported to the factory, where the company picks up the heart of palm cut from the field and transports it to the company using a chartered truck, which travels a distance of up to 30 km, depending on the location of the supplier. When it arrives at the company, the pupunha heart of the palm undergoes pre-peeling, which is the third stage of the process, in which the most rustic parts of the heart of the palm are removed.

Subsequently, the pupunha heart of palm is separated into three parts: one that is discarded because it is of low quality for consumption, another that is the less noble part of the heart of palm (billet), and the other that is the noblest part of the heart of palm (the head), the latter two being those intended for consumption, which is left to rest in water in a stainless steel vat (fifth stage: resting in the stainless steel vat).

The sixth stage is analyzing the sample in the laboratory for pH analysis to determine the amount of acid that should be used to accompany the heart of the palm. In the seventh stage, the heart of the palm is cut into different shapes: slices, pieces, chopped, salad, heart, band, spaghetti, and appetizer.

Simultaneously with the seventh stage, the eighth stage of the process takes place, sterilizing the glass before use. The ninth stage consists of placing the hearts of the palm in already sterilized bottles. In the tenth step (the brine), a mixture of water, salt, and sulfuric acid is placed in the glass. Then, the bottles are closed in step 11.

Step 12 consists of cooking the heart of the palm, which is carried out using a bain-marie, in which the heart of palm jars is cooked in a pan filled with water, which is heated using steam generated by burning wood. Cooking takes 45 minutes, with the water temperature at an average of 95 to 100° C. After cooking, there is a seven-day quarantine (stage 13), in which the heart of the palm is left to rest to check that it will not present any change in quality aspects. If, after quarantine, the heart of the palm is within the expected quality parameters, the product goes to step 14 of the process, labelling.

When packing the bottles (step 15), the glass jars are packed in cardboard boxes with 15 jars. Finally, transport to the distribution centers occurs, an outsourced service to a logistics company responsible for taking the goods to a distribution center in São Paulo and another in Minas Gerais. The product is distributed to other parts of the country from these two points.

3.3 Ecodesign strategies

Table 4 presents the average of each ecodesign strategy according to applicability and relevance in the canned pupunha heart of the palm manufacturing process. The scores are based on the questionnaire responses and the company's unsystematic observation. Two scores were explored for each dimension to compare the company's current situation concerning sustainability with the ideal situation to be achieved. The first score refers to what is applied in the company, that is, "applicability in the company," and the second score refers to the importance of that dimension in the context of the company - "relevance for the company," considering its capacity for application within the production process. The averages of each strategy were obtained by the arithmetic average of the scores of all areas of improvement that make up each strategy. The notes on the dimensions of each ecodesign strategy are presented in Tables 4, 5, 6, 7, 8, 9, 10, 11 and 12.

Table 4.

Average Applicability And Relevance of Ecodesign Strategies

Ecodesign Strategies	Applicability to the company	Relevance to the company
@ - New concept development	0.5	0.5
1 - Selection of low-impact materials	2	2.8
2 - Reduction of materials usage	1	1
3 - Optimization of production techniques	1.3	3.5
4 - Optimization of distribution system	2.2	3.6
5 - Reduction of impact during use	0.0	0.0
6 - Optimization of initial lifetime	1.8	2.4
7 - Optimization of end-of-life system	0	1

Source: Elaborated by the authors.

Table 5 presents the areas for improvement associated with the "Development of new concepts" strategy, the analyzed factors, and the justification for the strengths and weaknesses of the process. The data shows that the company still needs to devise better ways to reduce the materials used in production. New concepts could be considered for packaging, which could be shared, acquire new functions, or be reusable, improving these ecodesign aspects.

Table 5.

Development of New Concepts

Improvement Areas	Analyzed factors	A	R	Justification
Dematerialization	Decreased use of materials in production.	0	0	Does not apply to the product.
Shared use of the product	The product created to be used in a shared way.	0	0	Does not apply to the product.
Integration of functions	The product adds several functions to its performance.	0	0	Does not apply to the product.
Product functional optimization	The product meets the needs of the customer and with components to enhance aesthetics.	2	2	The product is inspected to ensure customer satisfaction.

Source: Elaborated by the authors.

The abbreviation "A" in Table 5 represents the grade referring to the applicability of the improvement area. The abbreviation "R" represents the grade referring to the relevance of the improvement area. After attributing scores for each area of improvement, the arithmetic mean between them was calculated, obtaining an average of 0.5 for the applicability of the strategy in the company and an average of 0.5 for the relevance or goal of the company. In this strategy, only the functional optimization of the product was addressed. At the same time, the other items can hardly be applied since it is impossible to maintain shared use or integrate different functions for canned pupunha heart of palm.

Table 6 presents the dimensions that correspond to the strategy "Choosing materials with low associated impact," as well as the factors that were analyzed and the justification for the strengths and weaknesses of the process.

Table 6.

Strategy - Choice of Materials With Associated Low Impact

Improvement Areas	Analyzed factors	A	R	Justification
Clean materials	Use of environmentally friendly materials.	2	2	The company would need to acquire raw materials from sustainable agroindustries.
Renewable materials	Use of raw materials and renewable materials.	3	4	Raw materials are renewable, but water is wasted.
Materials with low energy content	Use of materials that require little energy in their transformation.	2	2	Production with few transformations, and the main energy is the burning of firewood.
Recycled materials	Use of recycled materials in production.	0	3	The company does not use recycled material.
Recyclable materials	Use of materials that can be recycled in production.	3	3	The pupunha heart of palm cannot be recycled, the other inputs are recyclable.

Source: Elaborated by the authors.

After awarding scores for each area of improvement, the arithmetic mean between them was calculated. Thus, it was concluded that the average for the applicability of the strategy evaluated in the company is 2, and the relevance for the company is 2.8. This strategy is related to using low-impact materials – non-aggressive, from renewable sources, recyclable, and that minimize energy use. The pupunha heart of palm comes from a renewable source, with materials that can be recyclable. Therefore, regarding the applicability, some points need to be improved, such as using sustainable raw materials, reducing water waste, and using another energy source different from burning firewood. These actions could result in less impact.

Table 7 presents the dimensions that correspond to the "Reduction in the use of materials" strategy, the analyzed factors, and the justification for the strengths and weaknesses of the process. In this strategy, the reduction of materials appears, considering the reduction of weight and volume with a focus on facilitating transport and reducing waste production. However, weight and volume reductions do not apply to the test item since the quantity of items sold and transported cannot be reduced. Nevertheless, the rationalization of transport has applicability and relevance since prioritizing local inputs to reduce the distances between cultivation and processing is an essential strategy. The arithmetic means between them were calculated, with the applicability 1 and relevance of 1.

Table 7.

Strategy - Reduction in the Use of Materials

Improvement Areas	Analyzed factors	A	R	Justification
Weight reduction	Ways to reduce the weight of the product.	0	0	Does not apply to the product.
Reduction in volume	Ways to reduce product volume.	0	0	Does not apply to the product.
Transport rationalization	Prioritization of local inputs to reduce the distance to the factory.	3	3	Prioritization of local pupunha heart of palm. Purchase from other regions when not available.

Source: Elaborated by the authors.

Table 8 presents the dimensions that correspond to the "Optimization of production techniques" strategy, the analyzed factors, and the justification for the strengths and weaknesses of the process. In this strategy, there is a search for alternative processes, eliminating unnecessary processes and reducing waste in production (inputs, energy, water, and other resources).

Table 8.

Strategy - Optimization of Production Techniques

Improvement Areas	Analyzed factors	A	R	Justification
Alternative production techniques	Use of technologies that avoid risks to the environment.	2	4	Use of wood burning in cooking.
Reduction in production stages	Optimization of production steps.	2	4	Lack of standardization and automation.
Reduction of consumption and rational use of energy	Optimization of production energy use.	0	2	Few steps use energy and there are no measures to reduce consumption
Use of cleaner energies	The company prioritizes the use of renewable energy sources.	0	3	The company uses electricity and firewood.
Reduction in the production of waste/rejects	Production process generates low amounts of waste	3	4	Peach palm heart residues are reused as fertilizer.
Rational use of production inputs	Procedures that allow the reduction of inputs.	1	4	There are no waste reduction measures.

Source: Elaborated by the authors.

After attributing scores for each area of improvement, the arithmetic mean between them was calculated, making an average of 1.3 for the strategy's applicability and 3.5 for relevance for the company. Regarding applicability, some points need to be improved, such as burning firewood in cooking, lack of standardization of processes, lack of measures to reduce energy consumption, and lack of measures to reduce waste. On the other hand, the company reuses heart-of-palm residues as fertilizer. Concerning relevance or goal, applying the improvements would benefit the processing agroindustry.

Table 9 presents the dimensions that correspond to the "Distribution system optimization" strategy, the factors that were analyzed, and the justification for the strengths and weaknesses of the process.

Table 9.

Strategy - Distribution System Optimization

Improvement Areas	Analyzed factors	A	R	Justification
Packaging reduction	Use of minimal packaging.	0	4	There are no strategies to reduce packaging.
Cleaner packaging	Recycled, biodegradable or renewable packaging.	2	4	There is no recycled packaging, but it contains renewable raw materials.
Reusable packaging	Use of packaging that can be reused and recycled.	4	4	Packaging can be reused or recycled.
Energy-efficient means of transport	Low-cost shipping and measures to prevent damage in transit.	3	4	Product transport is outsourced to reduce costs and there is no loss of product.
Energy efficient logistics	Use of the full capacity of the means of transport and route planning.	2	2	Transport is outsourced. There is no influence on the choice of routes.

Source: Elaborated by the authors.

After assigning scores for each area of improvement, the arithmetic mean between them was calculated. Thus, it was concluded that the average applicability of the strategy evaluated in the company is 2.2, and its relevance is 3.6. This strategy seeks to use minimal, clean, reusable, or recyclable packaging, adequate means of transport, and efficient logistics. In this agroindustry, there is no concern with reducing the use of packaging or recyclable or reusable packaging. Concerning transport, this is carried out by outsourced services, with no influence on the equipment and routes used.

Although there is no intensive concern with packaging in this agroindustry, this issue is quite impactful and has become a serious environmental problem due to the amount of waste generated (Ortega et al., 2021).

Table 10 presents the dimensions that correspond to the "Impact reduction in the use phase" strategy, the analyzed factors, and the justification for the strengths and weaknesses of the process. This strategy aims to minimize the consumption of energy and inputs and ensure that energy and inputs are considered clean.

Table 10.

Strategy - Impact Reduction in The Use Phase

Improvement Areas	Analyzed factors	A	R	Justification
Ensure lower energy consumption	Reduction of energy consumption.	0	0	Does not apply to the product.
Use of cleaner energy source	Use of cleaner energy when consuming the product.	0	0	Does not apply to the product.
Need for fewer consumables	Use of less inputs by the product.	0	0	Does not apply to the product.
Cleaner consumables	Use of cleaner inputs by the product.	0	0	Does not apply to the product.
Prevent waste through design	The design allows replacement of components and the product has characteristics that encourage its consumption.	0	0	Components cannot be replaced. There are tests to ensure the quality of the product.

Source: Elaborated by the authors.

After assigning scores for each area of improvement, the arithmetic mean between them was calculated. Thus, it was concluded that the average for the applicability of the strategy evaluated in the company is 0.0, and the relevance for the company is 0.0. These scores were low because the company needs help to see ways to change how consumers use the product since it is a ready-to-use food product. Furthermore, since it is an item for consumption in its natural state, it does not require other inputs or clean energy, nor can the components be replaced since it is a perishable product.

Table 11 presents the dimensions that correspond to the "Optimization of the product's lifetime" strategy, the factors that were analyzed, and the justification for the strengths and weaknesses of the process. This strategy indicates the lifetime, which can be improved with an extended duration under suitable conditions. To that end, they include items designed to facilitate maintenance and repairs.

Table 11.

Strategy - Product Lifetime Optimization

Improvement Areas	Analyzed factors	A	R	Justification
Reliability and durability	Product retains taste and quality as designed	4	4	Quality tests are performed on the product.
Easy maintenance and repair	Ease of repairing product failures	0	0	Does not apply to the product.
Product modular structure	Product can be manufactured in modules	0	0	Does not apply to the product.
Classic design	The design and quality of the product guarantee appreciation by the user.	3	4	Product quality is guaranteed, but it is necessary to invest in more attractive and sustainable packaging.
User care for the product	The product presents differentials in relation to competitors and conservation information.	2	4	The company could invest in a sustainable product as a differential.

Source: Elaborated by the authors.

After awarding scores for each area of improvement, the arithmetic mean between them was calculated. Thus, it was concluded that the average for the strategy's applicability is 1.8, and the relevance for the company is 2.4. As it is a food product, quality tests are carried out to guarantee the desired standard. However, there is a need to invest in more attractive and sustainable packaging.

Table 12 presents the dimensions corresponding to the "Post-use Optimization" strategy, the analyzed factors, and the justification for the strengths and weaknesses of the process. This strategy is concerned with the impact that is caused to the environment.

After attributing scores for each area of improvement, the arithmetic mean between them was calculated. Thus, it was concluded that the mean for the applicability of the strategy evaluated in the company is 0, and the relevance for the company is 1. Note regarding the application was zero because the product cannot be reused, remanufactured, recycled, or refurbished. However, packaging can be recycled or reused, indicating relevant measures that could be implemented. In this way, a reverse packaging logistics program could be undertaken.

Table 12.

Strategy - Post-use Optimization

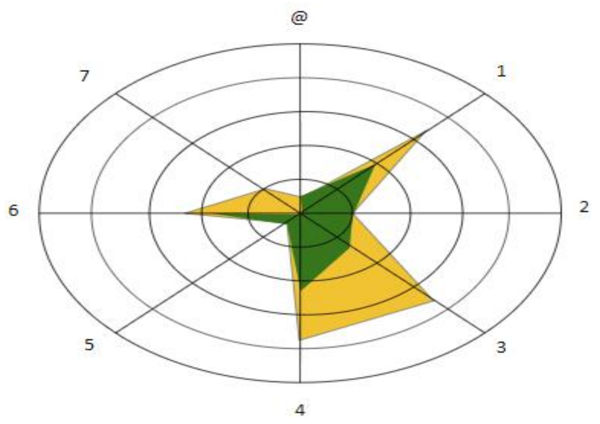
Improvement Areas	Analyzed factors	A	R	Justification
Reuse of the product (or components)	It is possible to reuse the merchandise or its components.	0	2	It is possible to reuse the packaging, but there are no measures implemented.
Remanufacturing	The product may be remanufactured or refurbished.	0	0	Does not apply to the product.
Material recycling	The materials used can be recycled.	0	3	Packaging can be recycled, but there is no reverse logistics program.
Safe incineration	Hazardous waste that needs to be incinerated.	0	0	Does not apply to the product.
Energy reuse	Use of methods and processes to recover part of the energy contained in solid waste.	0	0	Does not apply to the product.

Source: Elaborated by the authors.

Figure 3 presents the diagram of ecodesign strategies built based on the data collected in the company object of this study. The green polygon represents the averages the company received in the applicability of each of the eight ecodesign strategies proposed by the tool. The yellow polygon represents the average relevance of each of the eight ecodesign strategies for the company; that is, it suggests the goal the company should achieve in applying strategies to be more sustainable.

Figure 3.

Diagram of Ecodesign Strategies For The Canned Heart of Palm Factory



Source: Elaborated by the authors.

Based on Figure 3, it is possible to observe that in the strategies development of new concepts (@), reduction in the use of materials (2), and reduction of the impact in the use phase (5), the applicability in the company received the same average as the relevance of the strategies. This fact points out that the organization already does what is possible in these strategies and reaches the desired goal. As for the strategies of choosing materials with low associated impact (1), optimization of production techniques (3), optimization of the distribution system (4), optimization of the product's lifetime (6), and optimization of post-use (7), the application in the company did not reach the desirable goal, which was determined through the relevance of each strategy. Therefore, with these strategies, it is necessary to rethink processes and apply measures to improve the company's environmental performance.

In developing a new concept strategy (@), the company's applicability and relevance score was low (0.5). This result is because the dimensions evaluated by the strategy are not very applicable to the product since the company considers that a food product does not integrate several functions, does not allow shared use, and does not allow the reduction of its components during its manufacture.

In choosing materials with low associated impact (1), relevance to the company received a high score (3.2). In this case, the evaluated dimensions directly apply to the product, as they are related to the types of materials used in production. The company did not reach the desired goal in this strategy, receiving an average score of 2 for applicability. This fact is mainly due to not using recycled material in production.

Regarding the strategy to reduce the use of materials (2), the applicability and relevance reached a low score (grade 1). The reason is that the weight reduction and volume dimensions are aspects considered unalterable by the manufacturer due to the nature of the product.

As for the strategic optimization of production techniques (3), the relevance for the company received a high score (3.5). This result was due to the fact that the evaluated dimensions were directly applicable to the product. Regarding applicability, the company received a low score (1.33), as it does not use cleaner energy sources or apply techniques that reduce consumption and rational use of energy.

Concerning the distribution system optimization strategy (4), the relevance for the company is high (grade 3.6) since the analyzed dimensions apply to the product. As for applicability, the company did not reach the target, as it obtained an average score (2.2) since it does not apply measures to reduce the amount of packaging and does not use packaging produced from recycled materials.

As for the impact reduction strategy in the use phase (5), relevance and applicability received a low score (0.0). These notes indicate that consumers cannot implement these improvement actions in the use phase.

Regarding the optimization strategy of the product's lifetime (6), the relevance for the company is medium (grade 2.4) since, for the company, the dimensions of easy maintenance and repair and the modular structure of the product do not apply to the heart of palm canned. The applicability does not reach the desirable goal, as it obtained an average score (1.8). To reach the goal, it would be necessary to invest in differentials for the product in relation to the competition, such as developing a sustainable product.

Concerning the post-use optimization strategy (7), the relevance for the company could be higher (grade 1) since the dimensions of remanufacturing, safe incineration, and energy reuse do not apply to canned hearts of palm. The applicability in the company received a low score (0) since the company does not have a reverse logistics program that allows the reuse and recycling of product components after use.

3.4 Measures for implementing environmental performance

Table 13 presents suggestions for measures the company can implement to improve its environmental performance. In Table 13, the suggested measures are arranged in such a way as to present them in their relationship with the ecodesign strategies and also with the dimensions. Nevertheless, the expected results after the implementation of the measure and the Sustainable Development Goals (SDGs) proposed by the UN related to each measure are presented.

Table 13.

Suggested Measures to Improve The Company's Environmental Performance

Strategy	Improvement area	Mode	Expected outcome	SDGs
Choice of materials with associated low impact	Clean materials Use of recycled materials	Look for suppliers who are committed to environmental management.	Insert recycled materials into production that were produced respecting the environment.	SDG 12 - Sustainable consumption and production.
Optimization of production techniques.	Alternative production techniques Use of cleaner energies	Replacing wood burning as fuel to power the cooking boiler with a cleaner source of energy.	Insert more sustainable energy sources into production.	SDG 9 - Industry, innovation and infrastructure.
Optimization of production techniques.	Reduction in production steps.	Standardize production steps.	Optimize production time and reduce waste.	SDG 9 - Industry, innovation and infrastructure.
Optimization of production techniques	Rational use of production inputs.	Reduction of water consumption in production.	Decrease water consumption during the production process.	SDG 6 - Drinking water and sanitation
Distribution system optimization Product lifetime optimization	Use of cleaner packaging Classic design	Start using packaging made from recycled materials (sustainable packaging).	Insert more sustainable packaging into production.	SDG 12 - Sustainable consumption and production.
Product lifetime optimization.	User care for the product.	Achieve green seal certification.	Introduce the green seal on product packaging to gain credibility in the market as a sustainable product.	SDG 13 - Action against global climate change.
Post-use optimization.	Reuse of the product (or components) Material recycling.	Reverse logistics program for glass bottles used to package the product.	Reuse glass bottles after proper sterilization, or send them for recycling when necessary.	SDG 12 - Sustainable consumption and production.
-	-	Training of the company's management in environmental management and/or the hiring of someone specialized in the area.	Increase the company's environmental awareness.	SDG 9 - Industry, innovation and infrastructure.

Source: Elaborated by the authors.

These proposed measures aim to be implemented in the company, as knowledge about environmental management is essential for these practices to be put into practice and for the company to learn to adapt to the necessary standards.

4 Discussion

The study discusses the concept of sustainable development and its relevance in contemporary society, particularly in industries that have a significant environmental impact. It emphasizes the importance of incorporating sustainable practices in business strategies to reduce resource consumption, minimize negative environmental impacts, and improve energy efficiency. The case study focuses on the application of ecodesign strategies in the pupunha palm heart agroindustry in Brazil.

The research highlights the environmental challenges faced by the agroindustry, specifically the waste generated throughout the processing and packaging of pupunha palm hearts. Ecodesign strategies can be incorporated to reduce the environmental impact of agri-food packaging (Ortega et al., 2021). Consolidated companies, such as Nestlé, for instance, have adopted a simplified approach to packaging ecodesign, using life cycle assessment to support product design decisions (Adams, Schenker, & Loerincik, 2015).

Topleva and Prokopov (2020) showed that achieving ecodesign is not a one-dimensional business activity but an integrated process of managing and redesigning the company's production, distribution, and consumption functions. In the industry, environmental aspects are increasing and cumulative in all phases of the product life cycle. Some activities need to be reviewed, such as raw materials grown with the use of pesticides, high water consumption, intense use of energy, and a high volume of waste generated from the extraction of the raw material to the disposal of the packaging by the consumer. Thus, achieving sustainability in the industry is increasingly challenging.

The study reveals that a significant portion of the material used in the industry, such as stems, leaves, and solid waste, is considered residue. The disposal methods currently employed include exposure to the open air, animal feed, and use as fertilizer. The study underscores the need for initiatives to reduce environmental impacts and promote sustainability in the industry.

To address these challenges, the research proposes the adoption of ecodesign strategies in the agroindustry. Ecodesign involves considering the environmental impact of a product throughout its entire life cycle, from the generation of ideas to the selection of viable projects.

The application of ecodesign principles aims to create environmentally sustainable products, minimize resource consumption, and improve energy efficiency. The research utilizes the Ecodesign Strategies Diagram, a tool that assesses the environmental performance of a product based on 33 areas grouped into eight ecodesign strategies.

The results of the study indicate the applicability and relevance of each ecodesign strategy in the pupunha palm heart agroindustry. According to Florini and Pauli (2018) are under pressure to address environmental issues, which indicates a latent need to improve sustainable performance. Topleva and Prokopov (2020) addressed regulatory demands and growing consumer demand for environmentally friendly products. The studies by Santos, Bolanho and Danesi (2021) also demonstrated that in the peach palm agroindustry, the heart of the palm production process generates residues throughout the life cycle, including the stages carried out in the field until the disposal of the packaging. Other residues are generated in the processing stage, such as brine, water from sterilization containers, water from washing equipment, and water from cooking in a bain-marie, in addition to biomass from debarking. Thus, the strategies related to developing new concepts, reducing the use of materials, and reducing the impact in the use phase received high relevance scores, indicating that the company already incorporates these practices and achieves the desired goals. On the other hand, strategies such as choosing materials with low associated impact, optimizing production techniques, optimizing the distribution system, optimizing the product's lifetime, and optimizing post-use showed lower applicability and relevance scores, indicating the need for improvement in these areas.

Another measure to implement environmental performance is to relate the strategies with the expected results after implementation and also present the Sustainable Development Goals (SDGs) proposed by the UN that would be achieved with each measure (Table 8).

The first suggested measure is to look for suppliers committed to environmental management, aiming to prioritize recycled materials that were produced respecting the environment. This measure is related to SDG 12, which aims to ensure sustainable consumption and production, with recycled materials being a vital pillar to make the industry more sustainable.

The second measure is to replace the burning of wood as fuel to feed the cooking boiler with a cleaner energy source, aiming to include more sustainable energy sources in production, such as solar energy. This measure is linked to SDG 9, which aims to build resilient infrastructure, promote sustainable industrialization and foster innovation since cleaner energy sources allow for generating energy without pollution, mainly avoiding the emission of greenhouse gases, which is the cause of climate change.

Then, it is suggested to standardize the production steps to optimize operating time and reduce waste, leaving the steps delimited and training employees in specific steps of the process. This measure is linked to SDG 9, which aims to build resilient infrastructure, promote sustainable industrialization, and foster innovation since the standardization of processes allows production to be optimized and waste to be reduced.

The fourth measure would be the reduction of water consumption in production and reusing water in the boiler that cooks the heart of palm flasks since the water left over can be treated and used again in the process. These measures are intended to reduce water consumption during the production process, as this wastage of water was observed. This measure is linked to SDG 6, which aims to guarantee access to water and sanitation for all people, as it will save water during the process.

The fifth proposed measure would be to start using packaging made from recycled materials to introduce more sustainable packaging into production, both about the glass bottles in which the heart of palm is placed in conversation, as well as the cardboard boxes that are used to pack the product. This measure is related to SDG 12, which aims to ensure sustainable consumption and production, as using packaging that causes less impact on the environment is an important pillar to make the industry more sustainable.

The sixth suggested measure is to obtain the green seal certification and introduce it in the product packaging to gain credibility as a sustainable product in the market. This measure is linked to SDG 13, which aims to take urgent and necessary measures to combat climate change and its impacts, as respecting the environment's limits contributes positively to combating climate change. In this way, to obtain certification, the company will have to implement measures that aim to make production sustainable so that a regulatory body can assess the green seal for the company.

The seventh proposed measure is a reverse logistics program for the glass bottles used to package the product, to reuse them after proper sterilization, or to forward them for recycling when necessary. Some actions could be implemented, such as reducing packaging materials through partnerships with manufacturers. Another alternative would be to implement reverse logistics for packaging, although this process is complex. The first major challenge would be to maintain a constant flow of reverse logistics for these packages, which would require awareness among both points of sale and consumers. The system would begin in the post-consumption phase, with delivery of items to points of sale. These items are collected, separated, packaged, and sent to processing locations, where they undergo inspection, separation, and sanitization and are ready for reuse. Damaged packaging would need to be sent for recycling (Oliveira Neto et al., 2014).

Implementing the reverse supply chain involves both operational and infrastructural complexity, requiring a careful analysis of economic viability. In addition, it is necessary to consider the environmental impact generated by the use of new resources such as inputs, water, and energy, as well as the potential for global warming, since glass production has a significant environmental impact (De Feo; Ferrara & Minichini, 2022). On the other hand, reverse logistics is aligned with the requirements of the National Solid Waste Policy (PNRS), ensuring compliance with legal obligations. Furthermore, these actions would promote conscious and sustainable consumption, bringing benefits to the environment and society (Oliveira Neto et al., 2014). This measure is related to SDG 12, which aims to ensure sustainable consumption and production since, with the reuse of glass bottles, the consumption of new glasses will be restricted, which will even help with the problem of the lack of this material for consumption.

The eighth measure proposed would be training the company's management in environmental management and hiring someone who specializes in the area, intending to increase the company's environmental awareness. This measure is linked to SDG 9, which aims to build resilient infrastructure, promote sustainable industrialization and foster innovation since knowledge about environmental management is fundamental for sustainable development. This measure is not related to any of the eight ecodesign strategies proposed by the tool; however, it helps so that the other measures proposed in this topic can be implemented in the company since knowledge of environmental management is fundamental for them to be put into practice, including to learn how to adapt to the norms necessary to earn the green seal.

The study suggests several measures to enhance the environmental performance of the agro-industry. These measures include sourcing materials from environmentally responsible suppliers, replacing wood burning with cleaner energy sources, standardizing production processes, reducing water consumption, using recycled packaging materials, obtaining green seal certification, implementing a reverse logistics program for packaging, and providing environmental management training to the company's management.

The research provides valuable insights into the environmental challenges faced by the pupunha palm heart agroindustry and offers practical solutions through the application of ecodesign strategies. By implementing the proposed measures, the industry can improve its environmental performance, reduce resource consumption, and contribute to sustainable development. The findings of this study can serve as a foundation for further research and encourage other agro-industries to adopt ecodesign principles to minimize their environmental impact.

5 Conclusion

The initial proposal of this research was to analyze the environmental impacts resulting from the processing and commercialization of pupunha heart of palm in agroindustry in Vale do Ribeira, which was accomplished with the application of the Ecodesign Strategies Diagram tool. The tool made it possible to analyze the main environmental impacts caused by the product and draw a comparison with a defined goal so that its environmental performance improves.

It is essential to highlight that according to the grades awarded, the strategies least adopted by the company are @ and 5, which correspond respectively to the development of new concepts and reduction of the impact in the use phase. Regarding the development of new concepts, there are evaluated dimensions that do not apply to the product since a food product does not integrate multiple functions and has the difficulty of shared use. As for the impact reduction strategy in the use phase, these improvement actions could not be implemented in the use phase by consumers.

On the other hand, the best evaluation occurred with strategy 4 - optimization of the distribution system, since the company could create a packaging reuse or recycling system within a reverse logistics program. By analyzing the company's shortcomings in terms of sustainability, it was possible to construct a list of measures to achieve improved environmental performance. Such measures were related to the SDGs to clarify how the suggested actions can contribute to sustainable development.

The main contribution of this research was to evaluate the profile of the environmental performance of a pupunha heart of palm agroindustry present in the Ribeira Valley. In this region where peach palm heart agribusinesses have low automation and low application of measures related to environmental management.

The research has some limitations. The first limiting factor is the absence of applying any quantitative life cycle assessment, which would provide more information for decision-making. Another limiting aspect is related to the number of respondents. It would be interesting to expand the research and analyze other companies in the Vale do Ribeira region and better understand how they deal with these environmental issues.

Thus, as a suggestion for the development of future research, it would be important to apply the Ecodesign Strategies Diagram in other peach palm agro-industries present in the Ribeira Valley region so that it is possible to draw a profile of the main environmental impacts caused by the companies of processing and commercialization of pupunha heart of palm so that a more comprehensive analysis can be carried out. In addition, disseminating the results of these surveys would contribute to sharing good practices and potential adoptions.

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