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Cleaner production in the dairy industry: good practices in a dairy plant in the municipality of Valença – Rio and Janeiro, Brazil

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Abstract

The Brazilian dairy sector has great economic importance and is ranked fourth among world producers. The search for less environmental impact has led to good sustainability practices and the adoption of environmental management instruments, products, and processes with an emphasis on cleaner production (CP). In this sense, this article presents CP adoption in the dairy industry. A case study aiming to propose alternatives associated with CP good practices in the dairy industry was conducted in the municipality of Valença, Rio de Janeiro. Data collection was performed with the help of a form and direct observation. The good practices and CP opportunities previously adopted by the industry were identified. Then, five CP measures were proposed and implemented to improve the sustainability of the Minas Frescal cheese production process. Minas cheese was selected for the study due to its higher sales volume and the best profit margin. Other opportunities for improvement should be considered to continue the proposed actions, which include reduction of raw materials and energy and water consumption during production, increase in the company's profit margin and competitiveness in the national and international markets, access to new market niches, and reduction of environmental-, social-, and health-related impacts.

Keywords: environmental management; cleaner production; dairy industry; Rio de Janeiro.

Practical Application: Improving the sustainability of products and production processes, practices, instruments, and tools aimed to reduce the use of natural resources (raw material, water, and energy) and the generation of pollutants (atmospheric emissions, solid waste, and liquid effluents).

1 INTRODUCTION

Corporate environmental management is emerging as a global trend, driven by sustainable development and increasingly rigorous environmental legislation. Thus, regardless of size or production sector, many companies are adapting to this new reality (Belinky, 2016, 2021). In this context, practices, instruments, and tools have been adopted by companies focused on the sustainability of products and production processes, aimed at reducing the use of natural resources (raw materials, water, and energy) and the generation of pollutants (atmospheric emissions, solid waste, and liquid effluents) (Barbieri, 2016). These instruments include pollution prevention (P2), eco-efficiency, cleaner production (CP), life cycle assessment (LCA), eco-labeling, and design for the environment (DfE).

In Brazil, the dairy industry is numerous and diversified, with small to large companies that are responsible for high consumption of natural resources, with significant impacts on the environment due to the high generation of waste, effluents from production processes, and atmospheric emissions (Santos Júnior, 2016). The current food production model is a major contributor to greenhouse gas (GHG) emissions worldwide, especially in Brazil. In 2018, the sector was responsible for 48.04% of total emissions, followed by the energy sector with 42.35% of emissions (Climate Watch, 2021). In this sense, concern for the environment and increased productivity have led to the search for new inputs and technologies for sustainable production with lower costs and competitiveness.

Optimizing products and processes by implementing environmental management tools can result in improved environmental and social performance for companies. Among these instruments, CP can be an effective alternative in the search for sustainability in the dairy industry. CP seeks to integrate environmental approaches to processes, products, and services, aiming to increase the efficiency of production processes and reduce the related risks posed to the environment and society (Oliveira Neto et al., 2019).

CP has been adopted in many countries, including Brazil, in line with the premises of responsible production and consumption, defined in SDG 12, one of the United Nations' 17 Sustainable Development Goals (SDGs). The goals of SDG 12 include ensuring sustainable management and efficient use of natural resources for society and the planet; significantly reducing pollution to minimize its adverse effects on human health and the environment; substantially reducing waste generation through P2, reduction, recycling, and reuse; and encouraging companies to adopt sustainable practices (UNEP, 2019). Giannetti et al. (2020) discussed the contribution of CP actions to the sustainable development of the United Nations. The authors evaluated recent studies on CP in line with the SDGs and reported the need to expand knowledge and research on the

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main objectives of CP in a multidisciplinary way, considering sustainable development.

Ozbay and Demirer (2007) applied the CP concept to evaluate opportunities for improvement in milk processing. The methodology was carried out in two phases: the analysis of inputs and outputs and a checklist aimed at waste reduction and evaluation of other opportunities, namely, recycling clean water; preventive maintenance on equipment, mainly pasteurization equipment; avoiding leaks in the production line; improved use of whey; correct use of packaging; improvement in management practices with the use of CIP; and reduction of water discharge generated during cleaning procedures, to achieve environmental benefits and economic improvements.

Willers et al. (2014) evaluated water consumption during the milking of dairy cattle in the state of Bahia, Brazil, to assess the environmental impact during milk production associated with high water consumption. They found that milking and cleaning professionals lacked knowledge of CP actions. Actions such as training and maintenance of cleaning equipment were aimed at preventing water waste during milking.

Berton et al. (2021) identified opportunities in farm management resources to target mitigation measures in the production phase. A model was used to evaluate the life cycle of animal husbandry and the milk production steps in the dairy industry, aimed at analyzing the main environmental impacts.

Cortés et al. (2021) studied environmental indicators and eco-efficiency related to milk production on farms. The study provided data on the most efficient parameters required in the dairy sector to meet the objectives of sustainable development.

Rotz et al. (2021) evaluated regional dairy production in the United States and defined strategies to reduce NH3 emissions. The study identified more sustainable economic solutions and reported that avoiding the generation of pollutants remains a challenge for the dairy industry.

Pantoja et al. (2022) studied the dairy cow and buffalo industries and found the possibility of recovering waste in the buffalo milk production chain, aimed at increasing income and reducing waste generation.

Silva et al. (2023) evaluated the life cycle of Minas Frescal cheese and matured Minas cheese. Matured Minas cheese had greater impacts when compared to Frescal, due to the greater volume of milk used in the manufacturing process. The study suggests mitigation measures to reduce the environmental impacts generated by GHG emissions.

Although previous studies have analyzed environmental actions and good practices in the dairy industry, only two studies have investigated the adoption of CP. No recent publications using CP in the sector were identified in the literature. Therefore, the motivation for this study arises once the dairy industry has significant economic and social relevance in Brazil, with high production and market share (Hajmohammadi et al., 2020; Lopes et al., 2020; Messias et al., 2022).

Brazilian dairy technology has expanded in both the field and the industry. According to the InfoMoney (2022), Brazil created 277,018 formal jobs in the dairy industry in May 2022, which is considered a strong increase when compared to April (196,966), above market expectations. According to the Embrapa's report (Embrapa Gado de Leite, 2020), there has been an increase in the number of producers in Brazil who have been attracted by new research mechanisms and companies in the sector. The technologies have improved management efficiency, increased productivity indicators, and reduced working hours.

Brazil produced 5.2 million tons of milk in 2020 and reached 35.5 million tons in 2021. This increase is due to the rise in job creation in the dairy sector, which is very important for the Brazilian economy, especially for the economy of the state of Rio de Janeiro.

In this context, this study aims to present the environmental management tool CP and propose CP opportunities for a medium-sized dairy industry located in the municipality of Valença, in the southern region of the state of Rio de Janeiro, focused on improving environmental performance. Good practices and CP opportunities were identified, and new opportunities were proposed and implemented in partnership with the company's quality sector.

Minas Frescal cheese was selected as the product of reference for this study, as it is a product with the highest sales volume and the best profit margin.

2 CLEANER PRODUCTION AND ITS APPLICATIONS

SENAI (2003) defines CP as the application of a technical, economic, and environmental strategy integrated into processes and products to increase efficiency in the use of raw materials, water, and energy through the non-generation, minimization, or recycling of waste and emissions generated, with environmental, occupational health, and economic benefits.

According to Kiperstok et al. (2002) and Pimenta and Gouvinhas (2012), CP has an environmental approach, with the prevention of losses and waste of raw materials, reducing water and energy expenditure, and the generation of industrial waste and effluents. By improving manufacturing processes and implementing CP, the industry can gain more technical knowledge, which generates economic, social, and environmental improvements (Silva, 2020).

CP techniques can be used for products, services, and processes (Gasi & Ferreira, 2013). The main function is to make the production process more efficient in the use of inputs, generate more products and less waste (solids, liquid effluents, or atmospheric emissions), or create means for reusing or recycling the waste (Fernandes et al., 2015). CP consists of a series of methods and processes used to promote a company's progress, improving and innovating thoughts and actions to increase efficiency and the use of raw materials, water, and energy, in addition to reducing waste generation and obtaining an economic and environmental gain (Nunes Junior, 2002; Santos, 2013).

It is a proactive management system that includes environmental responsibility in the corporate structure in addition to complying with standards. The CP demands a change in

attitudes and commitment from managers to employees, leading to a change in the company's culture (Kiperstok et al., 2002).

According to Varella et al. (2022), the introduction of CP in industry contributes to reducing environmental impacts and controlling the use of raw materials, water, energy, and waste management. In addition, CP can contribute to innovations to improve production processes and environmental performance, leading to financial gains.

The implementation of a CP program begins with a technical visit to the industry. This visit provides the basis for an environmental diagnosis of the production processes (environmental aspects and impacts, mass and energy balance — inputs and outputs, and establishment of indicators), followed by the analysis of the process stages. CP options are then identified, taking into account the applicable legislation, associated risks, costs, and economic and environmental benefits (Senai, 2003).

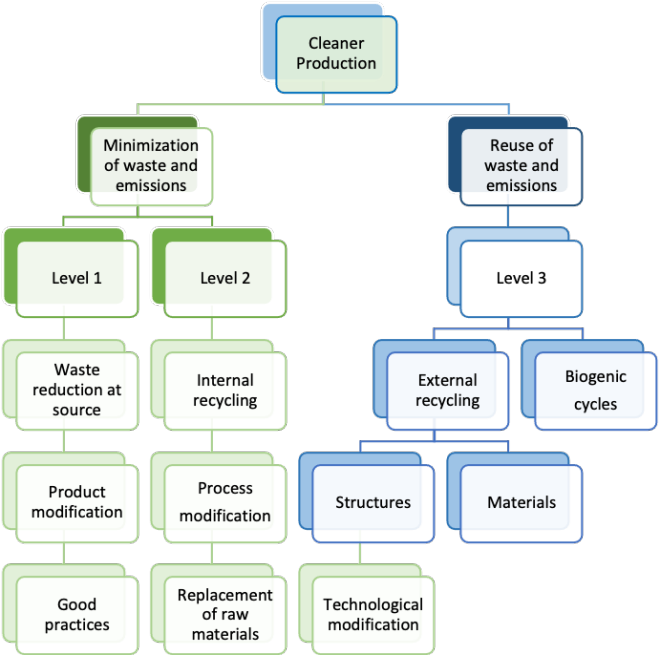
The CP options can be grouped into three levels. Level 1 consists of modification to the production process and/or product according to its efficiency, while Level 2 corresponds to internal recycling by minimizing waste and emissions within the company. It is worth emphasizing that both Levels 1 and 2 are measures to solve the problem at the source of generation, i.e., within the company. In turn, Level 3 consists of external recycling, focused on reusing or reintegrating the waste into the biogenic cycle (composting). Figure 1 shows the order of priority for implementing PC (Senai, 2003).

3 MATERIALS AND METHODS

The methodology used in this study is in line with the methodology developed by UNEP (2019) for implementing a CP program and consists of a bibliographical, documentary, experimental, and descriptive review. Technical visits were carried out for individual observation and application of a form (Supplementary Material) with the industry's employees. This practice aimed to identify, assess, and guide employees in adopting good CP practices, minimizing resource consumption and the environmental impacts associated with the production process, as well as assessing the potential for new actions.

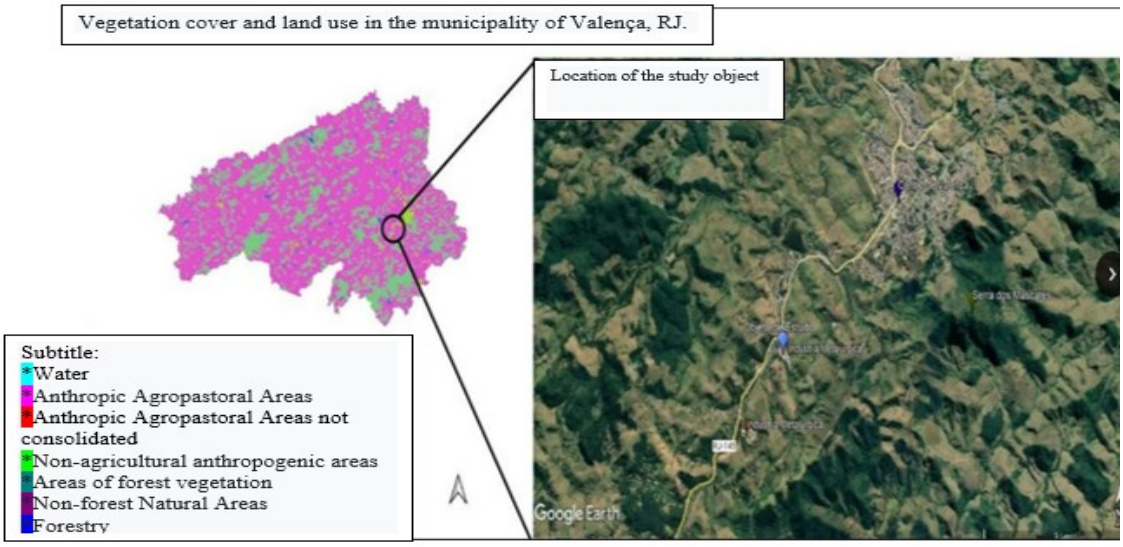
3.1 Area of study

The main criterion for selecting the dairy industry was the identification of proactive actions in the search for sustainability and new markets. The industry selected for the study is concerned with buying its main raw material (milk) from producers who care about animal welfare, guaranteeing the quality of the product offered to the end consumer. Figure 2 shows the location of the industry in the district of Varginha, in the municipality



Source: SENAI (2003).

Figure 1. CP Implementation levels.



Source: Google Earth (2021).

Figure 2. Varginha neighborhood with vegetation cover and land use, municipality of Valença, state of Rio de Janeiro.

of Valença, Rio de Janeiro state, 28 km northeast of Barra do Piraí. Valença occupies an area of 1,304.8 km² at an altitude of 551 m, and its geographical coordinates are latitude 22° 14' 46" South and longitude 43° 42' 11" West.

The dairy industry under study is a medium-sized company that processes approximately 1,200 L of milk per month for the production of various dairy products, including pasteurized milk, Minas cheese, yogurt, and butter. Other selection criteria were the company's growth in the consumer market in the state of Rio de Janeiro, the use of traditional Italian techniques to produce the products with the guidance of an Italian master cheese maker, and strict parameters to select suppliers.

3.2 Technical visits

On the first visit, the managers were asked about the availability of data needed for the study and their interest in implementing good practices and technological innovations. They were informed about reducing environmental impacts and introducing improvements in production with a view to environmental, economic, and social gains (CETESB, 2008).

On the second visit, data were collected in the field using a form (Figure 3).

The purpose of the questionnaire was to collect information about the origin of the raw material, the amount of raw material used in the production process, the source of energy and water used, the waste generated during manufacture, the industry's operational processes, and other processes involved in making dairy products.

Dairy industry technical visit checklist
1) How many farms does the industry receive milk from?
2) Is the end consumer interested in knowing the herd's origin?
3) Is the industry monitored by an inspection service?
4) Does the industry meet the regulatory requirements for good manufacturing practices and related procedures?
5) Does the industry have management standards in place?
6) Does the industry adopt selective waste collection?
7) Is there an environmental education policy in the organization?
8) Are there direct sales to recycling companies?
9) Is the packaging produced in-house or purchased?
10) Does the organization evaluate the packaging life cycle?
11) Which dairy products are produced in the industry?
12) How much raw material (cow's milk) is produced per day?
13) What raw materials are used in the manufacture of Minas Frescal cheese?
14) What equipment is used in the manufacture of Minas Frescal cheese?
15) Which is the final destination of the effluents?
16) Which varieties of Minas cheese are produced?

Figure 3. Guidance form for the technical visit to the dairy industry.

The amount of milk used in the production of Minas Frescal cheese was obtained from production control spreadsheets. The electricity costs were obtained from the electricity bills of the establishment, and the average of the last 12 months was considered. It was found that the water used in the manufacturing process comes from artisanal wells, which are then treated on-site using an automatic chlorination device with a standard of 1 ppm of chlorine. The quality of the water is monitored by microbiological and physicochemical parameters by the requirements of the Federal Inspection Service (SIF). The daily water consumption is 72,000 L for the daily production of 40,000 L of milk.

Regarding the characterization of liquid effluents, the volume of water used in the cheese manufacture was considered. Both the farming inputs used and the waste from animal husbandry were quantified based on data reported by the veterinarian in charge. On the third and fourth visits, good CP practices adopted by the dairy industry were analyzed and the potential for implementing new actions was assessed.

4 RESULTS AND DISCUSSION

4.1 Data collection

Table 1 shows data obtained from the technical visits and the guidance form.

Figure 4 presents the industry's floor plan, showing the production sectors, raw material reception, utensil washing, handling room, and equipment.

According to Figure 4, the manufacture of Minas Frescal cheese can be briefly described. First, the milk is pasteurized in a jacketed tank, using a boiler to heat the water and a chiller to cool the material. After pasteurization, milk is placed in a cheese-making tank for coagulation, with the addition of the ingredients responsible for transforming milk into cheese. A harp and a paddle stirrer are used to cut the cheese curd, which is then packed in plastic molds for pressing and draining the whey. After the technological process, the cheeses are placed in plastic bags, vacuum-packed, and stored in cooling chambers for processed products at 0 to 4°C.

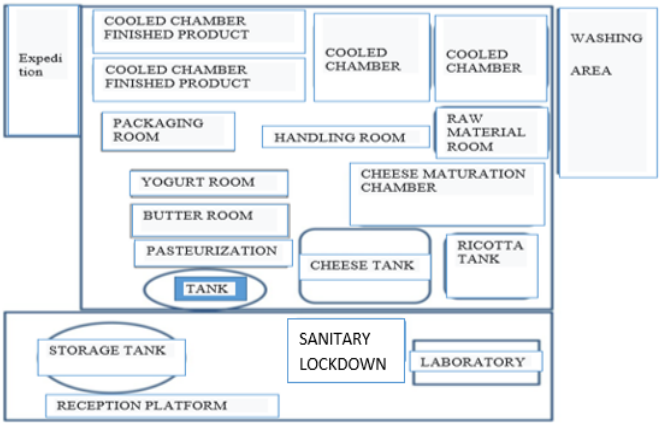
Table 1. Characteristics of the dairy industry.

Location	Municipality of Bom Jardim, state of Rio de Janeiro.
Organization	1995, in a dairy cooperative
Objective	Industrialization and sale of milk and dairy products.
Origin of milk	Family farming by small producers in the mountainous region of the state of Rio de Janeiro (300 registered agricultural properties and industry partners), located in the municipality of Valença and neighboring municipalities such as Rio das Flores, Rio Preto, and Vassouras.
Production	40,000 L of milk per day, corresponding to 1,200,000 L per month for the manufacture of cheese, yogurt, butter, processed cheese, and milk cream.
Monitoring of the manufacturing process	Operational and environmental quality programs; certificates
Product transportation	Own refrigerated vehicles, thus ensuring the food safety of the products.

Monitoring the manufacturing process of Minas Frescal cheese allows for assessing the environmental aspect of production, the manufacturing process, and the CP measures used.

4.2 The dairy industry and the CP Program

Currently, society is concerned about sustainability and animal welfare (Gameiro, 2017). The company under study is aware of the animal's grazing conditions and a balanced and healthy diet, which are necessary factors for a good-quality product. Hygiene in the process is essential for product quality. It is worth emphasizing the company's strategy and partnership with small producers and local farmers, who are responsible for supplying milk, representing a source of income for the local community and thus bringing social, economic, and environmental gains. Some CP actions previously adopted by the industry are shown in Table 2.



Source: technical visitation (2021).

Figure 4. Industry's floor plan.

As previously discussed, the technical visits allowed for collecting information to identify CP opportunities. In this context, five CP opportunities were suggested:

- Reducing the cost of cleaning materials by using dual-action sanitizers: chlorinated detergent and sanitizer, along with the implementation of a chemical dilution plant aimed at reducing waste generation;
- Reducing the amount of paper used in the administrative sector to create and monitor self-control programs, as required by the supervisory body. A whiteboard with self-control spreadsheets was suggested, as well as digitizing the spreadsheets. Reducing the cost of sheets used to create control spreadsheets for the self-control programs required by the SIF. A photo of the table on a whiteboard was suggested, as well as a scanned file of the spreadsheets;

Table 2. CP actions previously adopted by the dairy farm.

Issue	Process/Stage/Action	CP measure
Electric energy	Ensuring food safety (heat treatment, cooling, and storage in refrigerated chambers)	Optimization of natural lighting
Raw material	Control and reception of raw materials	Control and receipt of raw materials Cooling chamber, control and separation of stocks, monitoring of shelf life, and production to prevent losses.
Thermal energy	Partnership with eucalyptus reforestation producers authorized by Ibama to supply firewood (energy for the boiler)	Installation of a filter to retain particulate matter (PM) aimed at reducing atmospheric emissions. Under normal conditions, the dairy industry saved 40% on the amount spent on electricity
Water use	High water consumption with no knowledge about the actual consumption. The volume of water used in industrial processes is monitored daily at around 72,000 L of water per day, when compared to the daily production of milk and 40,000 L of milk, equivalent to 1.8 L of water to process 1 L of milk.	Training in good practices and raising awareness among employees and collaborators. Implementation of infrastructure to capture, store, and use rainwater to sanitize the trucks. Use of well-granted water by INEA for milk processing and other hygiene processes in the industry. Introduction of new equipment: the *filatrice* (mozzarella-making equipment), which allows water recirculation from the molding process, i.e., all hot salted water is recirculated throughout the production of fresh mozzarella, as energy-saving strategies when compared to the previous process.
Effluents	Approximately 20,000 L of water are used per day to sanitize the dairy industry.	Reduction of organic load through effluent treatment.
Whey	It is the main by-product generated in the manufacture of dairy products.	Partnerships with rural producers of the region. All volume of whey generated in the manufacture of Minas cheese and ricotta is sold for animal feed as a supplement, mainly pigs.
Residues	Cutting machine for hard cheese.	Equipment purchased to increase cutting precision for hard cheese, preventing waste production.
Preventive equipment maintenance	Control of energy consumption.	Introduction of transparent walls in the handling area, allowing more natural light in and preventing energy losses between the storage area, which consists of a cold room and expedition area with direct communication to the refrigerated transport truck
Packaging	Product storage	Hiring a freelance branding and packaging designer for the dairy products with a clean label appeal.

- Organizing and controlling the raw material reception, refrigerated storage, stock control and separation, shelf-life control, and production;
- Carrying out preventive maintenance on equipment;
- Controlling energy consumption by installing exhaust fans with millimeter grids in the handling room.

The implementation of these CP opportunities is the technically and economically practicable initiative for the company to implement in the short term, resulting in economic, environmental, and social gains.

However, an analysis of the technical and economic viability of these actions is required, which can be implemented in stages if there is not enough capital available for the project.

In addition to the five CP actions suggested, another four CP opportunities were suggested in the long term to continue the action plan and make the manufacture of Minas Frescal cheese more sustainable, as follows:

- Maximizing local reuse. Reducing the volume of water and the time spent by employees cleaning milk storage tanks. Constructing a water reservoir with a capacity of 20,000 L to capture rainwater to meet the hygiene demands of these utensils and reduce the time spent by employees;
- Introducing solar energy, using solar panels;
- Improving the product and the cost of packaging and disposing of packaging burrs. Heat-shrink packaging with the industry's emblem is suggested to reduce the high cost of packaging, which has been developed by the quality control department. The evaluation should be carried out together with the packaging supplier, who can customize the packaging according to the product size, eliminating the need to dispose of packaging burrs;

Implementing an equipment preventive maintenance plan. Although this plan has been developed in the industry's self-control program to meet the requirements of the Federal Inspection Service, equipment should be associated with environmental performance.

These actions, even in the long term, can lead to economic, environmental, and social gains for the company, as well as improving operational processes.

5 CONCLUSION

This study presented the CP environmental management tool and its adoption in the dairy industry. As a case study, an industry located in the district of Varginha, in the municipality of Valença, state of Rio de Janeiro, was selected. Technical visits were carried out to gather information and data, enabling suggestions for improvements and CP opportunities. The study presented economically and environmentally viable proposals for the industry. Shortcomings were identified, and opportunities for applying CP and strategies were suggested, as well as process improvements in the dairy industry. The critical points identified were: water consumption in the industry's sanitizing processes; electricity consumption; reduction and recycling of waste generated; and packaging costs.

Several difficulties were identified for the development of the study, including economic aspects and employee awareness to successfully implement improvements.

Five CP improvement actions were suggested in the short term, and four other CP actions were recommended in the long term to make the Minas Frescal cheese production process more sustainable. The suggested actions are expected to result in minimized use of raw materials; reduced energy and water consumption in production; increased company profit margins; competitiveness in the national and international markets; access to new market niches; reduced environmental and social impacts, especially those related to health; and reduced pollution.

The CP opportunities identified took into account the technical, environmental, and economic aspects that meet the premises of the industry's management, aiming at ensuring the integration of CP into the decision-making process and the business strategy of the company.

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