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Sustainable Resilience Degree assessment of the textile industrial by size: Incremental change in cleaner production practices considering circular economy

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ABSTRACT

The textile industry is highly polluting as it extracts natural resources for production, consumes much energy, generates a large volume of post-consumer waste, and uses chemical products for the dyeing process. However, the textile industry has achieved sustainable resilience due to the pressures of the 2030 agenda to promote sustainable development, demanding incremental changes in cleaner production practices considering the circular economy to reduce the environmental problem. In this context, it is supposed that small textile companies face more difficulties when compared to medium and large companies to achieve sustainable resilience in response to market pressures. Thus, this study aims to assess the degree of sustainable resilience by the size of the textile industry to drive incremental changes in cleaner production practices considering the circular economy. The research method adopted was a survey with 100 responses and data analysis using ANOVA. The theoretical contribution of this study was to assess the textile industry's sustainable resilience by considering its size to drive incremental change in Cleaner Production Practices considering the Circular Economy. For instance, it was found that companies' degree of sustainable resilience is related to the environmental requirements of the market in which they operate. Important practical conclusions were presented that can help shareholders and managers when intending to supply foreign market; guidance is needed on investment in circular economy actions in production, small and medium-sized textile companies would require government subsidies for the investment in product projects and processes with circular economy principles. In contrast, large textile industries can make significant investments, aiming to be recognized by customers/consumers as a brand that invests in sustainability. Regarding society, adopting the circular economy at the micro-level can contribute to eliminating the company's environmental impacts, bringing benefits for the health and safety of employees and the local community.

1. Introduction

The textile industry is highly polluting due to the high volume of chemicals and water used for dyeing and the high energy consumption and volume of post-consumer waste. Thus, the textile industry needs to adopt environmental actions in the production system to eliminate pollution. The Cleaner Production Practices (CPP) is an essential tool for adoption in the textile industry (Silva et al., 2021). In 1989, the United Nations Environment Program (UNEP) defined CPP as a conceptual and procedural approach to production, preventing or minimizing risks to humanity and the environment, considering the product life cycle applied to industrial processes, products, and services provided to society (Baas, 1995),. In addition, CPP influences the continuous application of environmental strategies in textile processes, products, and

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services to improve efficiency and minimize risks to people and the environment (Alkaya and Demirer, 2014).

It is noteworthy that companies have come under institutional pressure from stakeholders (consumers and government) to the detriment of the environmental emergency prevailing in the 2030 agenda, mainly related to the loss of the company's reputation, which could lead to loss of contracts (Oliveira Neto et al., 2021a). Thus, minimizing or mitigating the environmental impacts using CPP is no longer enough. However, CPP is the primary and most important step toward Circular Economy (CE) at the micro-level. Thus, it is necessary to adopt CE, which focuses on the regeneration and recovery of waste in the production system, preservation of natural capital, and use of renewable resources for the system's efficiency (Ellen Macarthur Foundation, 2017a).

The adoption of CE by the company promotes an improvement in the capacity of the economic, environmental, and social systems, turning the company more resilient and, consequently, more capable of recovering from changes such as economic crises or natural disasters (Ellen Macarthur Foundation, 2015a). The CE has sustainable development as its goal, providing benefits to the environmental, economic, and social dimensions.

This can only be achieved through a paradigm shift by replacing a linear view of the product's useful life with the adoption of reduction, reuse, recycling, and recovery of materials in production and distribution processes, made possible by new business models (Kirchherr et al., 2017). Therefore, CPP is a relevant tool for adopting CE, allowing the maximization of the use of more valuable resources, components, and materials in the production system (Ghisellini et al., 2018; Sousa-Zomer et al., 2018).

In this context, companies that have adopted CPP practices can consider CE a relevant strategy to face market pressures, which demand greater environmental action to reduce environmental impacts. Thus, contemporary organizations must have sustainable resilience in the practices of their activities to serve the market (Meerow and Newell, 2015; Marchese et al., 2018; Mou et al., 2021) because it allows turning traditional linear production and consumption into CE (Scarpellini et al., 2020), searching for solutions that meet current needs without compromising future sustainability (Mou et al., 2021).

An example is found in Nelson et al. (2019), in which resilience is defined as the ability of a system to adapt and improve the market towards the adversities, simultaneously paying attention to the intra-system and intergenerational distribution of impacts and sustainability capital in the system. In addition, it has been pointed out that companies need to achieve sustainable resilience to deal with problems, adapts to changes, overcoming adversities and persisting environmental pressures (Chiu et al., 2020).

Besides, it has also been pointed out that research on sustainable resilience indicates that it is essential to assess changes both in the main system and in the organization's subsystem, investigating vulnerabilities, together with adaptation strategies to monitor and manage trends of the organization (Gillespie-Marthaler et al., 2019). Therefore, Nelson et al. (2019) mention that companies must achieve sustainable resilience through clear objectives that guide and evaluate goals and processes. Tisserant et al. (2017) concluded that solutions based on sustainable resilience are necessary to reduce waste, increase productivity and material recycling, improving the circularity index.

Ten studies that related sustainable resilience with CPP and/or CE were found. Eight of these mentioned the relationship between CPP and sustainable resilience, concluding that by using multiple case studies in the automotive sector that CPP has a significant impact on sustainable resilience, minimizing environmental risks from products, waste generated, and worker health and safety for the external audience (Govindan et al., 2014). Also, the adoption of CPP made integrating industrial processes in the eco-parks of Kalundborg and Ulsan easier, generating sustainable resilience, and supporting disruptive events in front of stakeholders (Valenzuela-Venegas et al., 2018).

Other studies carried out in the agribusiness sector found by a survey that the CPP adoption generated sustainable resilience due to the minimization of water consumption in the production of cotton and irrigation, an aspect monitored by stakeholders, mainly the government (Imran et al., 2018; Li et al., 2019); in addition to the reduction in energy consumption, carbon and nitrous oxide emissions when compared to conventional agriculture that does not use CPP, denoting greater sustainable resilience of soil health, being the main concern of the farmer (Lal et al., 2019).

On the other hand, another research carried out in Qatar found that implementing CPP in companies boosted sustainable resilience in pursuing successful public policies for sustainable consumption (Sahin et al., 2019). In addition, in the survey carried out in the electronics sector in Malaysia, it was found that the adoption of CPP and industry 4.0 improved the visibility of the supply chain, allowing the planning of sustainable resilience actions to overcome obstacles (Mubarik et al., 2021). Rutitis et al. (2022) conducted a focus group. They found that raw material suppliers are being encouraged by stakeholders and the market to implement CPP for sustainable transition, aiming at the use of biocomposites.

Two studies related sustainable resilience with CPP and CE. Two case studies indicated that the government of Vietnam had pressured the transformation of conventional industrial zones into eco-industrial parks based on CPP and CE to promote the reuse of by-products, waste, and wastewater, denoting an adequate opportunity to achieve sustainable resilience (Stucki et al., 2019). Another case study in Russia concluded that adopting CE and CPP with digital technology increased the recycling of municipal solid waste, minimizing environmental impacts and costs due to the reuse of materials and reduction in the emission of greenhouse gases, promoting sustainable resilience (Maiurova et al., 2022).

In this context, no previous study evaluated the textile industry's sustainable resilience to drive incremental change in CPPs considering CE or the size of the companies considered. Although the criteria for classifying a company by size are subjective, the most used is the number of employees. Most countries consider small companies as those with up to 50 employees, medium companies with up to 250 employees, and large companies (Ayyagari et al., 2003; Lepoutre and Heene, 2006).

It is noteworthy that the theory's duty is to study the market conditions that could affect industrial technical progress, driving incremental changes in processes, considering exogenous pressures (related to public policy, society, and economic agents) and the endogenous influences (referring to technical progress in the industry in terms of innovations). Thus, these exogenous and endogenous pressures drive incremental changes in the industry to continue serving the market and keep it operating (Dosi, 1984).

Another motivation for this study was that the textile industry has difficulties adopting CPP as it is a highly polluting sector, requiring sustainable resilience through incremental changes. The textile industry manager usually focuses on improving economic and operational performance, aiming at reducing operating costs at the expense of minimizing waste (Oliveira Neto et al., 2021a). However, stakeholders have influenced the textile industry in adopting CPP, mainly economic agents (shareholders) worried about losing the market, as the adoption of CPP practices is a mandatory attribute for supply in the European market (Oliveira Neto et al., 2021b).

With the circular economy approach, the market has become even more demanding for the textile industry, mainly due to its volume of waste generated in production and post-consumption, needing to improve circularity in terms of reuse of shredded waste in production, as well as eliminate toxic materials presented in the composition of textile products, mainly in the dyeing chain (Oliveira Neto et al., 2022a).

Thus, Amindoust and Saghafinia (2016) and Oliveira Neto et al. (2022a) concluded that the textile industry has great challenges regarding the implementation of CE because, first, it is a sector that consumes and pollutes water in the dyeing operation (Chen et al., 2017).

The World Bank estimates that about 20% of all freshwater pollution is due to textile sector activities (Periyasamy et al., 2017) resulting from inappropriate r disposal of chemical materials and toxic metals (San et al., 2018).

In this context, the textile industry needs sustainable resilience to withstand market pressures regarding CE adoption and reconfigure and overcome adversities. However, the small and medium textile company may have more difficulties investing in environmental practices (CPP and CE), despite suffering little pressure from the market because it sells most of the time to the national market. On the other hand, the large textile industry supplies directly to the foreign market, which may require providing the most realistic regulations and certifications on environmental actions, considering the CPP and CE. Thus, the objective of this study is to evaluate the degree of sustainable resilience by the size of the textile industry to drive incremental change in CPPs considering CE.

2. Incremental change in cleaner production practices considering the circular economy

First, the following keywords: “cleaner production” AND “resilience” AND “practices” OR “practices” OR principles” OR “tools” OR “techniques” OR “actions” OR “activities” OR “circular economy” were searched in Scopus, Science Direct; Emerald; Wiley; Taylor & Francis and Scielo Based on the systematic review of the literature, 20 Cleaner Production Practices (CPP) related to Circular Economy Actions based on Cleaner Production (CECP) were identified, as shown in Table 1.

In Table 1, the incremental change in CPPs considering CE is shown. As can be seen, the adoption of CPP is vital to achieving a circular economy at the micro-level, contributing to the improvement of the company’s sustainable performance. Thus, the CE works as a company strategy, which adopts CPP at the micro level to achieve sustainability (Oliveira Neto et al., 2022b). Besides, CPPs are undergoing some incremental changes, as they are specific to promoting the eco-efficiency of a system, aiming at reducing waste and consumption of productive resources. At the same time, CE actions are more focused on the circularity of a system, being related to the elimination of waste and consumption of productive resources, aiming at the regeneration and revaluation of post-consumption waste. The incremental change in CPPs considering CE is related to sustainable business resilience, which consists of the ability of companies to adapt to new market requirements (Meerow and Newell, 2015; Marchese et al., 2018; Mou et al., 2021), as it allows transforming the traditional linear system of production and consumption to CE (Scarpellini et al., 2020).

For example, based on Table 1, CPP3 mentions the efficient use of energy and technologies to minimize energy consumption (Yuksel, 2008; Severo et al., 2018; Sousa-Zomer et al., 2018; Oliveira Neto et al., 2020; Silva et al., 2021), while CECP3 reports on co-generating energy and using clean energy, aiming to eliminate energy consumption from non-renewable sources in the production system (Ghisellini et al., 2016; Gopinath et al., 2018; Suarez-Eiroa et al., 2019).

Another example was found in CPP6, which emphasizes the replacement of materials/components with non-toxic and non-polluting ones, bringing benefits to health and the environment (Yuksel, 2008; Yusup et al., 2015; Oliveira Neto et al., 2020; Silva et al., 2021), while CECP6 mentions the elimination of the use of toxic materials, promoting the reduction of pollutant emission levels in production processes Hens et al., (2018); Sousa-Zomer et al., (2018); Mendoza et al. al. 2019.

Thus, Table 1 was developed based on a systematic review of the literature and showed the incremental change in CPPs considering CE, innovating state of the art.

3. Methods

3.1. Research method and data gathering procedure

The selection of articles was performed as follows: (i) identification and removal of repeated articles; (ii) analysis of the title, abstract, and keywords to select only the works that mention the relationship between cleaner production practices and circular economy actions; and (iii) development of content analysis. Bryman (2003) mentions that this step is vital to define and refine the theoretical constructs and support the work structures. This step made it possible to identify 20 articles. This study was developed in the textile industry and used the survey method to determine the degree of sustainable resilience to drive incremental change in CPPs considering CE. Survey research makes it possible to confirm the study statistically and is suitable for quantitative research (Thietart, 2001; Forza, 2002).

Thus, structured questionnaires were applied to find patterns and relationships between variables. The survey research method’s adoption makes it possible to carry out statistical analyses (Bryman, 2003). In this context, this study followed three steps: first, delimitation of the research domain and determination of the sample size; second, carrying out pre-tests to verify the validity and reliability of the research instrument and data; and third, application of the survey in the domain and the defined sample (Forza, 2002).

The questionnaires considered the 5-point Likert scale to determine the degree of sustainable resilience of each CPP practice considering CE. It is worth noting that companies were categorized into small, medium, and large industries. In this way, the respondents themselves were able to interpret each of the statements and score the intensity of agreement or disagreement (Likert, 1932)

3.2. Data analysis procedure

The validation step of the research instrument was carried out through a face test. Textile sector specialists with CPP and CE knowledge reviewed and validated the variables. The minimum sample size was 64 correctly answered questionnaires; these calculations were performed using the GPower 3.1.9.7 software (Faul et al., 2009). It is worth noting that for these calculations, it was necessary to determine the size of the effect and the power of the test. The determination of the effect size was performed based on the F test. This study considered the guidelines of Hair et al. (2016) and adopted an effect size of 0.15. The determination of the power of the test was performed, considering a confidence level of 95%. This work evaluated the guidelines of Hair et al. (2016) and adopted the test power of 0.80. After an extensive search by companies and professionals adhering to the scope of this research, 281 questionnaires. Otherwise, only 37% were answered correctly; in other words, 104 questionnaires were collected, and only 69 were considered (Fig. 1).

The analysis of the collected data was performed first by observing the data quality. The relationship between variables was analyzed, and, finally, the necessary treatments were performed on the data (Hair et al., 2016). At this point, an imbalance was observed in size, as correctly completed questionnaires were collected from 44 large companies, 37 medium-sized companies, and 23 small companies. Aware that applying statistical tools to unbalanced data requires more steps to obtain the desired results (Good, 2013). Therefore, 23 questionnaires answered by large companies were randomly selected; this same procedure was carried out with the questionnaires of medium-sized companies. Finally, the sample size was reduced from 104 to 69 completed questionnaires. It is worth noting that even after the data balancing step, the minimum sample size calculated remained respected.

The assumption for carrying out the Analysis of Variance (ANOVA) is the confirmation of the normality and homogeneity of the variances of the research variables (Sthle and Wold, 1989). To test for normality, the Skewness and Kurtosis values were evaluated (appendix). A variable is normally distributed when the Skewness values are between −1.0 and +

Table 1
Incremental change in CPPs considering CE.

COD	Cleaner Production Practices (CPP)	Concept	Authors	COD	Circular Economy actions considering Cleaner production (CECP)	Concept	Authors
CPP1	Environmental issues are considered during the supplier selection	Establish rules for the development of partnerships between companies and suppliers that result in environmental performance	Yuksel (2008); Zeng et al. (2010); Laforest et al. (2013); Oliveira Neto et al. (2015); Severo et al. (2015); Yusup et al. (2015); Silva et al. (2017); Oliveira Neto et al. (2020); Silva et al. (2021); Oliveira Neto et al. (2021a); Oliveira Neto et al. (2021b).	**CECP1**	Suppliers apply closed cycles for materials and renewable energy flows in their production systems and mainly use back-and-forth packaging (reuse) eliminating waste generation	Suppliers must provide circularity through industrial ecology to provide circularity of material flows, use of clean energy and use of shuttles.	Gao et al. (2006); Hens et al. (2018); Sousa-Zomer et al. (2018); Walmsley et al. (2018); Gupta et al. (2021)
CPP2	Environmental issues are observed in the factory	Opportunity to reduce waste in a preventive way considering all stages of the process, organizing the layout to reduce pollution at source.	Bass (1995); van Berkel et al. (1997); Yuksel (2008); Laforest et al. (2013); Oliveira Neto et al. (2015); Severo et al. (2015); Wasserman et al. (2016); de Guimarães et al. (2017); Silva et al. (2017); Hens et al. (2018); Severo et al. (2018); Sousa-Zomer et al. (2018) Oliveira Neto et al. (2020); Silva et al. (2021); Oliveira Neto et al. (2021a); Oliveira Neto et al. (2021b).	**CECP2**	Develop layout prepared for circularity	Appropriate layout for closed-loop processing aimed at eliminating waste generation and making production systems more flexible for disassembly and reuse of remanufactured components	Hu et al. (2011); Geng et al. (2012); Winans et al. (2017); Shayganmehr et al. (2021); Gupta et al. (2021)
CPP3	Efficient use of energy and technologies to minimize the energy consumption	Minimization of energy consumption in the production system by optimizing waste and adopting clean technologies.	Bass (1995); van Berkel et al. (1997); Yuksel (2008); La Forest et al. (2013); Yusup et al. (2015); Vieira and Amaral (2016); Wasserman et al. (2016); Silva et al. (2017); Adapa (2018); Hens et al. (2018); Matos et al. (2018); Severo et al. (2018); Sousa-Zomer et al. (2018); Oliveira Neto et al. (2020); Silva et al. (2021); Oliveira Neto et al. (2021a); Oliveira Neto et al. (2021b).	**CECP3**	Cogenerate energy and use clean energy	Eliminate energy consumption from non-renewable sources in the production system by the energy cogeneration and the use of clean technology.	Ghisellini et al. (2016); Winans et al. (2017); Gopinath et al. (2018); Suarez-Eiroa et al. (2019); Rajput and Singh (2020); Luthra and Mangla (2018); Oliveira Neto et al. (2022b).
CPP4	Environmental issues are considered in the selection of equipment/ machines for the production	Production is less polluting and more efficient when new machines produce fewer off-spec products	van Berkel et al. (1997); Yuksel (2008); Yusup et al. (2015); Sousa-Zomer et al. (2018); Oliveira Neto et al. (2020); Silva et al. (2021); Oliveira Neto et al. (2021a); Oliveira Neto et al. (2021b).	**CECP4**	Technological optimization in the selection of equipment/ machines for disposal in the generation of waste and gas emissions	Selection of equipment/ machines to promote circularity, aiming at technological optimization for the processes improvement making them more reliable and suitable for elimination in the generation of waste and pollutants.	Hu et al. (2011); Geng et al. (2012); Mendoza et al. (2019); Rajput and Singh (2020); Oliveira Neto et al. (2022b).
CPP5	Possibilities of recycling and reuse of materials and packaging are considered in the proucts design	Consider recycling and reusing of production waste and packaging in product design to improve environmental performance and production efficiency	Yuksel (2008); Zeng et al. (2010); Neto et al. (2014); Oliveira Neto et al. (2015); Sousa-Zomer et al. (2018); Oliveira Neto et al. (2020); Silva et al.	**CECP5**	Product design focuses on closed-loop manufacturing systems to eliminate waste generation through remanufacturing and reuse of materials, supplies and packaging.	It aims to develop products, considering the reuse of yarns/ fabrics/products (leftovers); of inputs and packaging that are generated or used throughout the	Ghisellini et al. (2016); Ghisellini et al. (2018); Hens et al. (2018); Kalmykova et al. (2018); Sousa-Zomer et al. (2018); Walmsley et al.

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Table 1 (*continued*)

COD	Cleaner Production Practices (CPP)	Concept	Authors	COD	Circular Economy actions considering Cleaner production (CECP)	Concept	Authors
			(2021); Oliveira Neto et al. (2021a); Oliveira Neto et al. (2021b); Correia et al. (2021).			manufacturing process, enabling regeneration, reuse or recovery and recycling at the end of their life cycle.	(2018) e Mendoza et al. (2019); Gupta et al. (2021)
CPP6	Materials/ components are replaced by non-toxic and non-polluting	Eliminating product toxicity results in no generation of toxic waste, simplifies effluent treatment and brings benefits to health and the environment.	van Berkel et al. (1997); Yuksel (2008); Yusup et al. (2015); Wasserman et al. (2016); Hens et al. (2018); Sousa-Zomer et al. (2018); Oliveira Neto et al. (2020); Silva et al. (2021); Oliveira Neto et al. (2021a); Oliveira Neto et al. (2021b).	**CECP6**	Elimination of the use of toxic materials, promoting the reduction of pollutant emission levels in production processes, eliminating negative impacts on the health and safety of employees	Eliminate the use of toxic materials in manufacturing processes, as well as replace them with raw materials with a low toxicity level and with properties that do not affect the environment.	Hu et al. (2011); Lieder; Rashid (2016); Hens et al. (2018); Sousa-Zomer et al. (2018); Mendoza et al. (2019); Shayganmehr et al. (2021)
CPP7	Considers the opportunity to reduce the use of packaging in the product design	In the product development, it is suggested to study the possibility of minimizing the use of packaging	Yuksel (2008); La Forest et al. (2013); Oliveira Neto et al. (2015); Yusup et al. (2015); Vieira and Amaral (2016); Wasserman et al. (2016); Silva et al. (2017); Matos et al. (2018); Sousa-Zomer et al. (2018); Oliveira Neto et al. (2020); Silva et al. (2021); Oliveira Neto et al. (2021a); Oliveira Neto et al. (2021b).	**CECP7**	Develop the product design to eliminate the use of inputs and natural resources reusing of packaging in a closed cycle	Companies should eliminate and provide circularity in the use of packaging in order to minimize the use of inputs and natural resources.	Hu et al. (2011); Ghisellini et al. (2016); Ghisellini et al. (2018); Hens et al. (2018); Suarez-Eiroa et al. (2019);Gupta et al. (2021)
CPP8	Environmental issues are considered when selecting manufacturing systems	Using mechanical rather than physico-chemical processes and streamlining the entire production process improves environmental performance	Yuksel (2008); Yusup et al. (2015); Silva et al. (2017); Sousa-Zomer et al. (2018); Oliveira Neto et al. (2020); Silva et al. (2021); Oliveira Neto et al. (2021a); Oliveira Neto et al. (2021b).	**CECP8**	Manufacturing systems keep the added value of products longer and eliminate waste by reuse, repair or recycling	The manufacturing system must ensure the manufacture of durable products. In addition to promoting the circularity of the material in post-consumption through reuse, repair and recycling.	Gao et al. (2006); Ghisellini et al. (2016); Hens et al. (2018); Sousa-Zomer et al. (2018); Walmsley et al. (2018); Rajput and Singh (2020); Gupta et al. (2021)
CPP9	Environmental issues are considered in the material handling	Integrating environmental issues with material handling brings benefits to the health and safety of employees	Yuksel (2008); Yusup et al. (2015); Sousa-Zomer et al. (2018); Oliveira Neto et al. (2020); Silva et al. (2021); Oliveira Neto et al. (2021a); Oliveira Neto et al. (2021b).	**CECP9**	The movement of materials when carried out by equipment that only uses clean energy generated by the energy conversion of waste into electricity or by the use of renewable fuels eliminates negative impacts on the health and the safety of employees	Moving materials internally and externally by environmentally friendly equipment that uses clean energy generated by converting waste energy into electricity or by using renewable fuels.	Winans et al. (2017); Gopinath et al. (2018) e Suarez-Eiroa et al. (2019); Rajput and Singh (2020); Luthra et al. (2021); Shayganmehr et al. (2021)
CPP10	Considers the reduction of the natural resources in the manufacturing process	Improving efficiency in extracting natural resources, choosing renewable sources and using them rationally improves environmental performance	Yuksel (2008); La Forest et al. (2013); Yusup et al. (2015); Hens et al. (2018); Severo et al. (2018); Sousa-Zomer et al. (2018); Oliveira Neto et al. (2020); Silva et al. (2021); Oliveira Neto et al. (2021a); Oliveira Neto et al. (2021b).	**CECP10**	Increasing share of renewable and recyclable resources, as well as reusing materials and components in different streams after the end of the useful lifetime	It emphasizes the regeneration, reuse, recovery and recycling so that these materials at the end of their useful lifetime are the basis for tMendoza et al. (2019) he development of new products, contributing to the circularity of the material.	Ghisellini et al. (2016); Hens et al. (2018); Kalmykova et al. (2018); Sousa-Zomer et al. (2018); Walmsley et al. (2018) e Mendoza et al. (2019); Gupta et al. (2021)
COD		Concept	Authors	COD		Concept	Authors

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Table 1 (*continued*)

COD	Cleaner Production Practices (CPP)	Concept	Authors	COD	Circular Economy actions considering Cleaner production (CECP)	Concept	Authors
	Cleaner Production Practices (CPP)				Circular Economy actions considering Cleaner production (CECP)		
CPP11	Environmental issues are considered in the production planning and control processes	The integration of environmental issues with production planning and control results in the rational use of materials and in the reduction of rework and waste	Yuksel (2008); Zeng et al. (2010); La Forest et al. (2013); Oliveira Neto et al. (2015); Severo et al. (2015); Yusup et al. (2015); Silva et al. (2017); Oliveira Neto et al. (2020); Silva et al. (2021); Oliveira Neto et al. (2021a); Oliveira Neto et al. (2021b).	**CECP11**	The production planning and control sector changes the linear and/or semicircular flows to closed flows (cycles)	Production planning and control must include in operations the use of circular flows for the reuse of regenerated, reused, recovered or recycled materials in the manufacturing system, ensuring the circularity of materials as much as possible	Suarez-Eiroa et al. (2019); Shayganmehr et al. (2021); Gupta et al. (2021)
CPP12	Considers in the production program the schedule for solving environmental problems	Conducting an environmental risk analysis integrated to the production schedule allows preventive actions to be taken and increases environmental awareness	Yuksel (2008); Oliveira Neto et al. (2015); Oliveira Neto et al. (2020); Silva et al. (2021); Oliveira Neto et al. (2021a); Oliveira Neto et al. (2021b).	**CECP12**	It considers in the production program the focus on the premise of closing cycles, on the actions to solve problems, promoting the elimination of environmental impacts	Considering in the production program the elimination of environmental impacts through recycling, reuse and recovery of materials in the production system. And based on the production plan, it is suggested to control these processes through performance indicators to eliminate environmental impacts.	Lieder; Rashid (2016); Sousa-Zomer et al. (2018) e Mendoza et al. (2019); Shayganmehr et al. (2021); Gupta et al. (2021)
CPP13	Considers in capacity decisions the possibility of using clean and efficient energy technologies	Using clean technology and investing in innovation minimize the environmental damage, reduce the waste and improves the operational efficiency	Van Berkel et al. (1997); Yuksel (2008); Zeng et al. (2010); La Forest et al. (2013); Oliveira Neto et al. (2015); Yusup et al. (2015); Vieira and Amaral (2016); Wasserman et al. (2016); de Guimarães et al. (2017); Hens et al. (2018); Severo et al. (2018); Sousa-Zomer et al. (2018); Oliveira Neto et al. (2020); Silva et al. (2021); Oliveira Neto et al. (2021a); Oliveira Neto et al. (2021b).	**CECP13**	Considers the use of technologies that use clean energy, as well as the process materials from renewable sources	Use of renewable energy, originating from natural resources, such as thethe the sun, wind, rain, tides and geothermal energy. With this, companies could stop using energy obtained by uranium (atomic), coal and oil. It is noteworthy that searching for technologies that use renewable resources is not an easy task for organizational managers, mainly because they are more expensive than the conventional ones, but promoting the circular economy at the micro level (production) is inevitable.	Geng et al. (2012); Rajput and Singh (2020); Luthra et al. (2021); Shayganmehr et al. (2021); Oliveira Neto et al. (2022b).
CPP14	Considers the possibilities of using renewable resources to select raw materials and energy	The use of renewable resources contributes to the reduction of environmental impact.	Yuksel (2008); Zeng et al. (2010); Oliveira Neto et al. (2015); Yusup et al. (2015); Wasserman et al. (2016); Oliveira Neto et al. (2020); Silva et al. (2021); Oliveira Neto et al. (2021a); Oliveira Neto et al. (2021b).	**CECP14**	Use of biological renewable raw materials and clean energy	Pursuing raw materials and energy from renewable sources, eliminating the use of non-renewable raw materials and energy obtained from fossil fuels. With this, the main focus is the promotion of processes with lower rates of generation of pollutants and residues.	Hu et al. (2011); Winans et al. (2017); Gopinath et al. (2018); Mendoza et al. (2019) e Suarez-Eiroa et al. (2019); Rajput and Singh (2020)
CPP15	Minimizes the generation of waste and emissions in the production system	Preventive actions that stimulate the rational use of productive resources, which include reducing: in the	Yuksel (2008); La Forest et al. (2013); Oliveira Neto et al. (2015); Severo et al. (2015); Yusup et al.	**CECP15**	Develop the product design for reuse of wastewater and solid waste generated in a closed cycle	Promote the reuse of wastewater and solid waste in a closed cycle to eliminate as much as possible the waste and	Hu et al. (2011); Ghisellini et al. (2016); Kalmykova et al. (2018); Walmsley et al.

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Table 1 (*continued*)

COD	Cleaner Production Practices (CPP)	Concept	Authors	COD	Circular Economy actions considering Cleaner production (CECP)	Concept	Authors
		generation of waste, in water consumption and emissions in the production system.	(2015); Vieira and Amaral (2016); Wasserman et al. (2016); de Guimarães et al. (2017); Adapa (2018); Hens et al. (2018); Matos et al. (2018); Severo et al. (2018); Sousa-Zomer et al. (2018); Oliveira Neto et al. (2020); Silva et al. (2021); Oliveira Neto et al. (2021a); Oliveira Neto et al. (2021b).			the emissions generation in the product design.	(2018); Mendoza et al. (2019);Gupta et al. (2021)
CPP16	Efficient use of raw materials and inputs, avoiding waste	The rational use of raw materials is also related to the continuous improvement practices and reduction of process variations, in addition to environmental performance.	Bass (1995); van Berkel et al. (1997); Yuksel (2008); La Forest et al. (2013); van Hoof and Lyon (2013); Oliveira Neto et al. (2015); Severo et al. (2015); Yusup et al. (2015); Vieira and Amaral (2016); Wasserman et al. (2016); de Guimarães et al. (2017); Silva et al. (2017); Hens et al. (2018); Matos et al. (2018); Severo et al. (2018); Sousa-Zomer et al. (2018); Oliveira Neto et al. (2020); Silva et al. (2021); Oliveira Neto et al. (2021a); Oliveira Neto et al. (2021b).	**CECP16**	Eliminate waste of raw materials and inputs to minimize the use of inputs and natural resources	It aims to promote the circularity of materials, by eliminating the waste of raw materials and inputs with the concern of the regeneration of natural resources.	Hu et al. (2011); Kalmykova et al. (2018); Ghisellini et al. (2018); Sousa-Zomer et al. (2018); Walmsley et al. (2018); Mendoza et al. (2019); Suarez-Eiroa et al. (2019);Rajput and Singh (2020); Gupta et al. (2021)
CPP17	Considers the Cleaner Production intrinsic to the environmental management system, with periodic audits, aiming at continuous improvements	The application of CP practices collaborates with the implementation of the Environmental Management System, with audit programs	Yuksel (2008); Zeng et al. (2010); Oliveira Neto et al. (2015); Yusup et al. (2015); Wasserman et al. (2016); Oliveira Neto et al. (2020); Silva et al. (2021); Oliveira Neto et al. (2021a); Oliveira Neto et al. (2021b).	**CECP17**	Conducting periodic audits leads to greater sustainable value by optimizing the use of materials, equipment and goods for as long as possible, in closed cycles and powered by clean sources or cogeneration with environmental benefits.	It emphasizes the use of environmental audits in the production system with a focus on optimizing material and physical resources as much as possible in a closed loop.	Geng et al. (2012); Suarez-Eiroa et al. (2019); Rajput and Singh (2020); Luthra et al. (2021)
CPP18	Increase the employee environmental awareness by training	Environmental education requires the training of all employees and activities related to environmental impacts, environmental management and recycling	Bass (1995); Yuksel (2008); Zeng et al. (2010); Oliveira Neto et al. (2015); Yusup et al. (2015); Vieira and Amaral (2016); Adapa (2018); Oliveira Neto et al. (2020); Silva et al. (2021); Oliveira Neto et al. (2021a); Oliveira Neto et al. (2021b).	**CECP18**	Train and increase the awareness among employees to create value for the product through circularity, considering its life cycle extension.	It aims at training and raising awareness among employees to create value in the product to extend its life cycle.	Geng et al. (2012); Lopez et al. (2019); Suarez-Eiroa et al. (2019);Luthra et al. (2021); Shayganmehr et al. (2021);Gupta et al. (2021)
CPP19	Improve the working conditions to reduce the waste	Conducting training related to ergonomics and environmental issues improves occupational health and	Bass (1995); Yuksel (2008); Zeng et al. (2010); Severo et al. (2015); Yusup et al. (2015); de Guimarães et al.	**CECP19**	Maximize the working conditions that guarantee closed-loop manufacturing processes, eliminating	Training on environmental management needs to be extended to all employees, being an important step towards	Walmsley et al. (2018); Suarez-Eiroa et al. (2019); Luthra et al. (2021); Shayganmehr et al. (2021)

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Table 1 (*continued*)

COD	Cleaner Production Practices (CPP)	Concept	Authors	COD	Circular Economy actions considering Cleaner production (CECP)	Concept	Authors
		safety, in addition to reducing the waste	(2017); Hens et al. (2018); Matos et al. (2018); Oliveira Neto et al. (2020); Silva et al. (2021); Oliveira Neto et al. (2021a); Oliveira Neto et al. (2021b).		waste and waste generation	maximizing the working conditions to eliminate waste.	
CPP20	Efficient use of water	Preventive actions that promote the rational use of water make it possible to identify opportunities for reuse and mitigate risks of effluent pollution, reducing the environmental impacts	Yuksel (2008); La Forest et al. (2013); Oliveira Neto et al. (2015); Severo et al. (2015); Yusup et al. (2015); Vieira and Amaral (2016); Wasserman et al. (2016); de Guimarães et al. (2017); Adapa (2018); Hens et al. (2018); Matos et al. (2018); Severo et al. (2018); Sousa-Zomer et al. (2018); Oliveira Neto et al. (2020); Silva et al. (2021); Oliveira Neto et al. (2021a); Oliveira Neto et al. (2021b).	**CECP20**	Optimization of the water use and increased effectiveness of wastewater treatment, enabling the circularity in industrial processes	Practice CP to promote efficient use of water in the production system, with a focus on reducing consumption, reuse, conservation and preservation.	Gao et al. (2006); Hu et al. (2011); Geng et al. (2012); Ghisellini et al. (2018); Kalmykova et al. (2018); Sousa - Zomer et al. (2018); Lopez et al. (2019); Gupta et al. (2021)

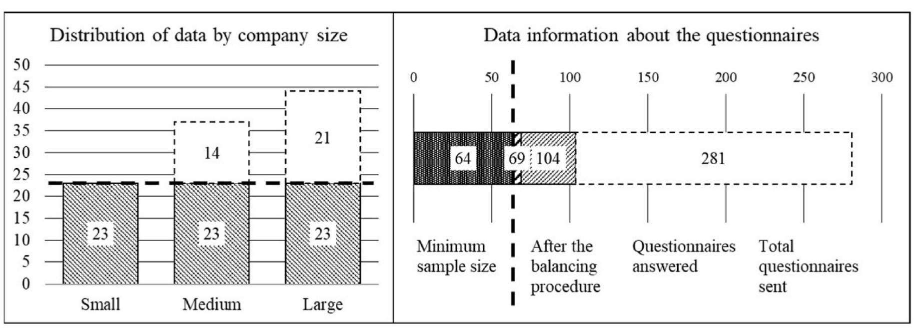

Fig. 1. *Sample size.*

1.0 and the Kurtosis values are below 2.0. It is worth mentioning that the normality of the data was analyzed before and after the balancing step and the expected result was normality maintenance.

ANOVA application made it possible to test the equality of two or more population means from the analysis of sample variance. Thus, the interpretation of the results can be performed directly (Triola, 2008), considering the range from 1 to 5. Via the ANOVA test, the relationship between the degree of sustainable resilience and the size of the industries was verified.

It is important to emphasize that there are different ways of applying ANOVA in the literature, depending on the problem to be analyzed. For example, Tucci and Neto (2019) used, in addition to ANOVA, Student's t-test, and the Process Control Chart (PCC) to assess the reduction in flight delays after changes in aircraft maintenance procedures.

In this study, Levene's test was performed by comparing groups (Levene, 1960; Zaiontz, 2022), that is, large & medium, medium & small, and finally, large & small. Levene's test revealed that the values of the large group stood out compared to the medium and small companies. Furthermore, the Tamhane test was applied following the ANOVA, which allowed the identification of possible pairings. This test compared each of the 20 practices regarding company size to verify the existence or absence of relationships. In the appendix, it is possible to observe relationships through the symbol * and the lack of relationships through the acronym N.S., referring to non-significant. The comparison of the degree of sustainable resilience according to the company's size was also tested in a multivariate way.

The results of the Pillai Test performed on the entire data sample were equal to 0.0017, considering an F equal to 2.4812, confirming the relationship as a function of size. It is important to highlight that the Pillai trait was chosen because it is the most suitable for evaluating events in which the groups are of different sizes. Therefore, the f-value was used to validate the significance of the model (Field, 2013).

This result emphasizes that there are significant differences between the groups. The descriptive statistics of the degree of sustainable resilience according to size are shown in Table 2. It is worth noting that the degree of sustainable resilience is calculated by the number of practices implemented divided by the total number of practices. Therefore, one can see that large industries showed a higher degree of sustainable

Table 2
Sustainable Resilience Degree by size.

Cleaner Prodution Practices (CPP)	Circular Economy actions considering Cleaner Production (CECP)	Small	Medium	Large
CPP3 - Efficient use of energy and technologies to minimize the energy consumption	CECP3 - Cogenerate energy and use clean energy	1.8	3	3.95
CPP7 - Considers the opportunity to reduce the use of packaging in the product design	CECP7 -Develop the product design to eliminate the use of inputs and natural resources reusing of packaging in a closed cycle	2.4	2.65	4.1
CPP15 - Minimizes the generation of waste and emissions in the production system	CECP15 - Develop the product design for reuse of wastewater and solid waste generated in a closed cycle	2.55	3.2	4.45
CPP16 - Efficient use of raw materials and inputs, avoiding waste	CECP16 - Eliminate waste of raw materials and inputs to minimize the use of inputs and natural resources	3.4	3.6	4.1
CPP19 - Improve the working conditions to reduce the waste	CECP19 - Maximize the working conditions that guarantee closed-loop manufacturing processes, eliminating waste and waste generation	3	3.2	3.65
CPP17 - Considers the Cleaner Production intrinsic to the environmental management system, with periodic audits, aiming at continuous improvements	CECP17 - Conducting periodic audits leads to greater sustainable value by optimizing the use of materials, equipment and goods for as long as possible, in closed cycles and powered by clean sources or cogeneration with environmental benefits.		2.95	3.8
CPP18 - Increase the employee environmental awareness by training	CECP18 - Train and increase the awareness among employees to create value for the product through circularity, considering its life cycle extension.		3.35	3.9
CPP20 - Efficient use of water	CECP20 - Optimization of the water use and increased effectiveness of wastewater treatment, enabling the circularity in industrial processes		3.85	4.35
CPP1 - Environmental issues are considered during the supplier selection	CECPP1 - Suppliers apply closed cycles for materials and renewable energy flows in their production systems and mainly use back-and-forth packaging (reuse) eliminating waste generation			3.3
CPP2 - Environmental issues are observed in the factory	CECP2 - Develop layout prepared for circularity			3.55
CPP4 - Environmental issues are considered in the selection of equipment/machines for the production	CECP4 - Technological optimization in the selection of equipment/ machines for disposal in the generation of waste and gas emissions			4.4
CPP5 - Possibilities of recycling and reuse of materials and packaging are considered in the proucts design	CECP5 - Product design focuses on closed-loop manufacturing systems to eliminate waste generation through remanufacturing and reuse of materials, supplies and packaging.			3.75
CPP6 - Materials/ components are replaced by non-toxic and non-polluting	CECP6 - Elimination of the use of toxic materials, promoting the reduction of pollutant emission levels in production processes, eliminating negative impacts on the health and safety of employees			3.8
CPP8 - Environmental issues are considered when selecting manufacturing systems	CECP8 - Manufacturing systems keep the added value of products longer and eliminate waste by reuse, repair or recycling			4.2
CPP9 - Environmental issues are considered in the material handling	CECP9 - The movement of materials when carried out by equipment that only uses clean energy generated by the energy conversion of waste into electricity or by the use of renewable fuels eliminates negative impacts on the health and the safety of employees			4.2
CPP10 - Considers the reduction of the natural resources in the manufacturing process	CECP10 - Increasing share of renewable and recyclable resources, as well as reusing materials and components in different streams after the end of the useful lifetime			4.05
CPP11 - Environmental issues are considered in the production planning and control processes	CECP11 - The production planning and control sector changes the linear and/ or semicircular flows to closed flows (cycles)			4.05
CPP12 - Considers in the production program the schedule for solving environmental problems	CECP12 - It considers in the production program the focus on the premise of closing cycles, on the actions to solve problems, promoting the elimination of environmental impacts			3.7
CPP13 - Considers in capacity decisions the possibility of using clean and efficient energy technologies	CECP13 - Considers the use of technologies that use clean energy, as well as the process materials from renewable sources			3.55
CPP14 - Considers the possibilities of using renewable resources to select raw materials and energy	CECP14 - Use of biological renewable raw materials and clean energy			3.8

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Table 2 (*continued*)

Cleaner Prodution Practices (CPP)	Circular Economy actions considering Cleaner Production (CECP)	Small	Medium	Large
	Sustainable Resilience Degree	5/20 = 0.25	8/20 = 0.40	20/20 = 1

resilience when compared to SMEs.

4. Results and discussion

The degree of sustainable resilience of small textile companies is low, 0.25, as only five cleaner production practices promoted incremental changes, considering circular economy actions, while the mid-sized textile companies' degree is 0.40, with eight gradual changes. However, the large textile industries have achieved the degree of sustainable resilience 1, by migrating all CPP's actions to CE, according to Table 2.

This finding points out that the degree of sustainable resilience is related to the demands and pressures received from the market by a company to adapt to environmental practices. Small textile companies serve the Brazilian market, producing part of the chain. Most small companies are service providers for medium and large companies in the sector, not receiving pressure to adopt CE actions. In contrast, some medium-sized textile companies carry out the dyeing operation, providing services to national and multinational companies. As a result, it receives a little more pressure for environmental compliance than the small company.

On the other hand, large textile industries are usually multinational or sell products abroad, driven by the environmental legislation of more demanding countries, such as the European countries, which are focused on fulfilling the 2030 agenda. They operate on the assumption of promoting incremental changes in CPPs, considering the CE principles in agreement with sustainable development, and considering the circular economy as a business strategy for producing goods and services.

Some research already reported about this subject indicates that large companies suffer institutional pressures from the market to the detriment of the environmental emergency prevailing in the 2030 agenda, mainly concerning the loss of the company's reputation, leading a company to have to terminate the supply of goods and services (Oliveira Neto et al., 2021b). Thus, the more pressure from the market for environmental compliance, the greater the degree of resilience, which consists of the system's ability to adapt and improve the market (Nelson et al., 2019), considering the adoption of CE as a relevant strategy to face the challenges market pressures (Mou et al., 2021). This leads the traditional linear system of production and consumption into CE at the micro-level (Scarpellini et al., 2020).

This result contributes to the scientific literature because this is the first study that assesses the degree of sustainable resilience of the textile industry by size to drive incremental change in CPPs considering CE. It also contributes to organizational practice, as it can guide shareholders and managers that, when seeking to get into the European market, must invest in CE actions to migrate from minimization practices to environmental elimination. In addition, the adoption of CE at the micro-level contributes to eliminating the company's environmental impacts, bringing benefits to the health and safety of employees and the local community.

4.1. Small textile industry

As mentioned before, the Sustainable Resilience Degree of small textile companies is low, only 0.25, according to Table 2, mainly because the small textile companies have adopted CPP practices to reduce waste of raw materials and inputs to obtain economic gain (CECP16/3.40). As a result, they promoted the readjustment of performance indicators related to the consumption of raw materials and inputs, the amounts of waste generated and emissions, as well as the recycling and reuse of waste for the production of articles from recycled or reprocessed raw materials within the process itself, collection and reuse of water, generated in a closed cycle. These aim to eliminate the waste of raw materials and inputs and minimize the use of these inputs and natural resources, as indicated by Kalmykova et al. (2018) and Mendoza et al. (2019).

Consequently, these improvements maximized working conditions as they considered manufacturing in closed cycles, eliminating the generation of waste and waste itself (CECP19/3.0). Walmsley et al. (2018) and Suarez-Eiroa et al. (2019) emphasized that environmental performance indicators have undergone incremental changes, previously, the focus was on minimizing pollution, and currently, processes must provide circularity, eliminating waste.

In this way, small companies have adopted CPP to obtain economic gain, but they have difficulties investing in technologies for energy cogeneration (CECP3/1.8). The studies by Ghisellini et al. (2016), Winans et al. (2017), and Gopinath et al. (2018) pointed out that the installation of medium and small solar power plants can be a good alternative for small companies, generating clean energy for production while reducing costs, with medium-term return on investment. Small textile companies also began to design products aimed at minimizing the generation of waste and emissions in the production system and reducing the use of packaging.

Besides, incremental changes were observed, considering the development of products with a focus on the circularity of waste (solid and liquid) in the production and post-consumption system (CECP15/2.55), in addition to designing products without the need for packaging and in extreme cases promote reuse as much as possible in a closed cycle (CECP7/2.4). This finding shows that an incremental change is taking place, which considers the CE premises in the development of the product and process design, promoting the circularity of waste (solid and liquid) in the production system and adequacy of the reuse of packaging in a closed cycle, as presented by Hens et al. (2018) and Ghisellini et al. (2018).

Therefore, small textile companies in Brazil are still in the early stage of CE actions in production, as they do not suffer pressure from the Brazilian market to adopt them. For this reason, sustainable resilience is very low. Still, they gradually realize the opportunity to increase economic benefits at the expense of eliminating waste of raw materials and energy, maximizing closed-loop working conditions, and starting the development of product designs and processes to stop waste generation and the use of packaging.

This finding contributes to the theory as it shows the opportunity for small textile companies to increase economic gains through adopting CE actions in production, and searching for sustainable resilience with an economic focus. It also collaborates with organizational practice, encouraging the manager and the entrepreneur to design products and processes with CE principles for economic gain. It is noteworthy that it would be important to develop specific legislation for implementing CE actions to pressure small companies, including financial support to eliminate the pollution that can lead to the reduction of local pollution.

4.2. Medium-sized textile industry

It was also found that the degree of resilience of medium-sized textile companies is 0.40, as in this group, eight cleaner production practices underwent incremental changes, considering circular economy actions, according to Table 2. The biggest concern of medium-sized textile companies is the optimization of water consumption and the adoption of wastewater circularity, considering reuse in the company (CECP20/3.85). Thus, these companies are designing products and processes aimed at the closed-cycle reuse of liquid and solid waste in industrial plants (CECP19/3.2). This finding can be justified because medium-sized textile companies usually have the dyeing process in the chain, which in many cases provides services to small companies. The dyeing process uses chemicals diluted in water, generating highly polluting liquid waste, requiring reuse in a closed cycle.

Thus, some studies have indicated the need to promote sustainable resilience aiming at the circularity of wastewater, considering the need to reuse water in the process (Kalmykova et al., 2018; Sousa-Zomer et al., 2018; Lopez et al., 2019), mainly in agribusiness, with the maximum possible optimization of water consumption in cotton production and irrigation, an aspect monitored by stakeholders, primarily the government (Imran et al., 2018; Li et al., 2019). Another example is the government of Vietnam, which is pushing to transform conventional industrial zones into eco-industrial parks to reuse waste and wastewater (Stucki et al., 2019).

Another important finding related to the medium-sized textile company is the concern with the elimination of waste of raw materials and inputs (CECP16/3.6), processing in a closed cycle, eliminating the generation of waste, in addition to consequently improving working conditions (CECP15/3.2). Thus, companies recover fabric residues through defibration, which returns the fabric to cotton, making it possible to produce the product again. With this, waste is eliminated, which in addition to recovering tissue residues generated in manufacturing, can also consider post-consumer tissue residues in the defibration, which is in good agreement with Oliveira Neto et al. (2022a)

It is noteworthy that adopting training/capacitation to improve employee awareness of environmental issues in the CPP implementation process generated the revaluation of waste in a closed cycle, regeneration, and useful life extension driven by the circular economy approach (CECP18/3.35). As a result, sustainable training processes began to consider CE in CPP, aiming at sustainable resilience in terms of value creation, regeneration, circularity, and extension of the useful life of tissue waste, which is in good agreement with Lopez et al. (2019) and Suarez-Eiroa et al. (2019) considering that the application of periodic audits promotes and encourages continuous improvements through an integrated training of employees on CE in production.

As such, when considering CE at the micro-level of medium-sized textile companies, incremental changes are taking place in the activities of audits of the environmental management system, which are currently audited with a focus on circularity and elimination of waste of raw materials, inputs, and electricity (CECP19/2.95). The adoption of CE in the environmental management system in the company can be an excellent channel to offer training to employees, generate their awareness, and train auditors based on the actions of the CE.

Also, one of the main concerns of the medium textile company is the search for energy efficiency due to the excessive consumption of electricity in the chain. However, companies are currently adopting clean energy cogeneration processes (CECP3/3.0). A study by Lal et al. (2019) in the agribusiness sector concluded that the reduction in energy consumption using clean energy had been demanded by public organizations, denoting the need for sustainable resilience.

Another meaningful action was the elimination of product packaging and, in extreme cases, the reuse of packaging in a closed cycle (CECP7/2.65). In this context, the textile industry is reducing (eliminating) excess packaging from products. Also, they are using more durable and reusable packaging to avoid the use of cardboard or plastic packaging, corroborated by the studies by Hens et al. (2018) and Ghisellini et al. (2018). The latter indicated the opportunity to optimize as much as possible in the use of packaging of products.

Thus, medium-sized textile companies are being implemented (between 3 and 3.99) in the CPPs and CE aiming at the circularity of wastewater defragment of fabric waste, elimination of product packaging, and adoption of clean energy because there are many service providers of dyeing and weaving for small and large companies located in Brazil. As a result, they are applying sustainable training/training to employees for the revaluation of waste, regeneration, circularity, and extension of the useful life of tissue waste, as well as inviting suppliers to explain and propose technologies for the cogeneration of clean energy implementation.

As such, this study contributes to the theory, showing that medium-sized company still suffers little pressure from some large multinationals, according to Oliveira Neto et al. (2020) and Oliveira Neto et al. (2021a), which require sustainable practices (circularity of wastewater, defibrillation of fabric residues, elimination of product packaging, and adoption of energy clean), as an attribute for the provision of services, denoting that sustainable resilience (0.4), although low, advances as medium-sized textile companies are charged by the homologation requirements.

It also contributes to organizational practice by showing that despite the low demand from large companies, sustainable improvements in the implementation stage is required considering the main villains of environmental pollution in the sector, namely: water pollution, high volume of industrial waste generation, post-consumption, and packaging, as well as the use of clean energy cogeneration. Moreover, the training of the employees can contribute to society, as it can increase the environmental awareness, bringing benefits to the health and occupational safety of employees and reduction of local pollution.

4.3. Large textile industry

It was also identified that the degree of resilience of large textile companies is 1, according to Table 2, denoting the circular economy as a business strategy for producing goods and services, thus generating incremental changes in CPPs, considering the CE principles. The data shows that some large companies have implemented (from 4.00 to 4.99), and others are implementing (from 3.00 to 3.99) CE principles in production.

The CE actions that are implemented in the production and testing stages (from 4.00 to 4.99) advocate the development of the product project for the reuse of wastewater and solid waste generated in a closed cycle (CECP15/4.45, CECP20/4.35) in addition to the elimination of inputs and resources natural resources through packaging reuse (CECP7/4.1). This finding shows that a large part of the large textile industry has the dyeing process, which is the main source of pollution because it uses much water with contaminating chemicals, generating the need to reuse wastewater, according to research by (Kalmykova et al., 2018; Sousa-Zomer et al., 2018; Lopez et al., 2019). Also, these companies are developing products aimed at eliminating waste generation, even though it is a great challenge because the production process generates an excessive volume of waste in production (fabric scraps) and post-consumption (Annaldewar et al., 2021; Oliveira Neto et al., 2022a)

Thus, when developing products considering CE principles, it became necessary to involve the manufacturing process, particularly the production planning and control sector, which had to change linear and/or semicircular flows to circular flows (CECP11/4.05), eliminating material waste raw materials and inputs to minimize the use of inputs and natural resources, considering the revaluation of waste through reuse, repair or recycling (CECP8/4.2/CECP16/4.1). This generates an increase in the share of renewable and recyclable resources, as well as the reuse of materials and components in different flows after the end of their useful life (CECP10/4.05). This finding shows that the large textile industry has been concerned with adopting production practices to eliminate waste generation, and as promoting the circularity of post-consumer waste, denoting an incremental change in terms of minimization towards an elimination approach. This finding is supported by (Sinha et al., 2016; Annaldewar et al., 2021)

Thus, they are investing in technologies (CECP4/4.4) based on digital transformation to eliminate the generation of waste and gas emissions, especially in the process of moving materials, using equipment that uses clean energy generated by the energy conversion of waste into electricity or by the use of renewable fuels (CECP9/4.2). This result indicates that large textile companies are investing in industry 4.0

technologies connected to CE principles and actions (Oliveira Neto et al., 2022b). The join (composition) of the circular economy considering CPPs with industry 4.0 was identified in the studies by Rajput and Singh (2020), Shayganmehr et al. (2021), Gupta et al. (2021), Luthra and Mangla (2018), concluding significant qualitative results on the benefits for sustainability when considering that the adoption of autonomous systems with Industry 4.0 technologies eliminates environmental impacts on the production system, denoting circular economy action.

As a result of the consideration of CE in the development of product and process design (CECP5/3.75), other CE actions are being implemented in production by large textile companies (from 3.00 to 3.99). Energy cogeneration and the use of clean energy are being implemented due to the high investment value, but with a short-term return on investment (CECP3/3.95). Also, it is necessary to use technologies that use clean energy, as well as process materials from renewable sources (CECP13/3.55).

The large textile industries have economic interests in eliminating energy consumption because they pay very high added value monthly, despite the need to invest in technology to cogenerate clean energy. The studies by Ghisellini et al. (2016), Winans et al. (2017), Gopinath et al. (2018), Suarez-Eiroa et al. (2019), Rajput and Singh (2020), and Luthra and Mangla (2018) in other sectors indicate that the elimination of energy consumption from non-renewable sources in the production system by using energy cogeneration and the use of clean technology is an important action to promote CE in the production.

They are also investing in employee training and awareness, increasing the product value creation through the fulfill and closed-loop use of resources and materials with life-cycle extension (CECP12/3.7, CECP18/3.9), including in the training of auditors of the environmental management system the need for revaluation and circularity of waste, use of equipment and goods for as long as possible and use of clean energy cogeneration (CECP17/3.8). The studies by Lopez et al. (2019), Suarez-Eiroa et al. (2019), Luthra and Mangla (2018), Shayganmehr et al. (2021), and Gupta et al. (2021) mentioned that training generates employee awareness to create value in the product for life cycle extension, migrating from the linear to the circular behavior.

Another important finding is that the elimination of the use of toxic materials has been implemented to reduce the levels of pollutant emissions in production, mainly in the dyeing process (CECP6/3.8). For this, studies are being carried out to consider biological and clean energy renewable raw materials (CECP14/3.8) that can lead to eliminating problems related to the health and safety of employees, maximizing working conditions, and eliminating the generation of waste (CECP19/3.65). Thus, it seeks to select and certify potential suppliers in line with the demands of developing non-toxic and non-polluting materials/components (Hu et al., 2011; Hens et al., 2018), generating an incremental change in the substitution of materials/components. Toxic components for their elimination (Sousa-Zomer et al., 2018; Mendoza et al., 2019; Shayganmehr et al., 2021).

However, to eliminate the generation of waste and waste itself, it was necessary to implement an appropriate layout for closed-loop processing, aiming at flexibilities of the production system for disassembly and reuse of remanufactured components, specifically for tissue recovery (CECP2/3.55), as directed by Winans et al. (2017), Shayganmehr et al. (2021), Gupta et al. (2021). However, Sinha et al. (2016) and Annaldewar et al. (2021) emphasized that the recovery of components and fabrics is a complex activity in the apparel textile sector, requiring a specific approach to remanufacturing.

In addition, large companies are orienting suppliers to use closed cycles in their production systems for materials and renewable energy flows, and especially to use back-and-forth packaging (reuse) eliminating waste generation (CECP1/3.3). It should be noted that the Procurement area approved some suppliers that are certified or that prove the use of renewable and recyclable resources. However, there is a lack of a project with suppliers, intermediary customers in the textile chain up to the final customer for the collection of finished products after the end of their useful life, so that these products return to the production process (recycling, "defibration", new processing).

Large textile industries are usually multinationals or sell products abroad, being driven by the environmental legislation of more demanding countries, such as European countries, which are focused on meeting the 2030 agenda towards sustainable development. Thus, large textile companies are considering CE in CPPs and have implemented (between 4.00 and 4.99) the development of the product project for the circularity of wastewater and solid waste, including packaging waste. A relevant aspect was the implementation of CE actions by the production planning and control sector, which changed the circular linear flows, eliminating waste of raw materials and inputs, resulting in the revaluation of waste through reuse, repair, and recycling, besides the implementation of industry 4.0 technologies for elimination in the generation of waste, emissions, and energy.

As a result of the implementation of CE actions in the development of the product project, other actions have been implemented in the production by large textile companies (from 3.00 to 3.99), starting with technological investment in clean energy cogeneration, investment in training, and awareness of employees, including environmental auditors on CE in production, elimination of toxic materials for dyeing, development of circular layout for waste recovery and approval of suppliers that have a circular process, seeking the formation of industrial ecology.

This finding contributes to the scientific literature, as the large companies can make investments, as well as tend to implement CE practices to become able to supply goods and services to the foreign market. The innovative aspect of this finding is in it being the first study that assessed the degree of implementation of CE practices in the textile industries by size. With this, when large textile companies are adept at CE practices, they could obtain economic advantages, in addition to contributing to society in terms of eliminating pollution.

5. Conclusion

This study evaluated the degree of sustainable resilience of the textile industry and further research may include annual revenues as the criterion to define the company's size, but although the findings can only refer to industries in the textile segment the study can be expanded to other industrial sectors.

Regarding incremental changes in CPPs considering CE.

(i) small companies can benefit adopting CE by eliminating waste, using cleaner energy cogeneration and maximizing closed-cycles. In addition, designing for environment to eliminate waste,
(ii) medium-sized companies should reinforce employeeś training/capacitation on CE, reevaluate the potential of waste regeneration and extend of the useful life of fabric waste, eliminating packaging and adopting cleaner energy cogeneration, and
(iii) large companies must implement CE actions driven by the environmental legislation of countries to meet the sustainable development goals. Thus, CE's premises must be incorporated in product design with investments in industry 4.0 technologies, considering the planning and control of strategic production to achieve circularity.

Regarding organizational practices:

(i) Although small companies still face economic difficulties in implementing CE due to lack of credit access, economic downturns, decision makers' lack of knowledge, economic gains and the opportunity to expand the company can encourage designing products and processes with CE principles;
(ii) Despite large companies require continuous improvements for medium-sized suppliers, most of the improvements are still in the implementation stage. Nevertheless, medium-sized companies

can invest and promote modernization by acquiring innovative technologies

(iii) Large textile industries made incremental changes in the CPP's considering the adoption of CE in production as a strategic attribute for the supply of products and services to the foreign market.

Regarding their benefits to society:

(i) Small companies need specific legislation and financial support for the implementation of CE
(ii) Medium-sized companies may multiply knowledge and generate benefits regarding occupational health and safety;
(iii) Large industries, by making incremental changes to the CPP's promote the increase of productive capacity, contributing to public health. In addition, the generation of indirect jobs may affect local economies by increasing purchasing power stimulating knowledge, skills, values and socio-environmental awareness.

CRediT authorship contribution statement

Geraldo Cardoso de Oliveira Neto: Conceptualization, Methodology, Formal analysis, Writing – original draft. **José Manuel Ferreira Correia:** Conceptualization, Methodology, Formal analysis, Data curation, Investigation. **Henrricco Nieves Pujol Tucci:** Methodology, Software, Validation. **André Felipe Henriquez Librantz:** Methodology, Software, Validation. **Biagio Fernando Giannetti:** Conceptualization, Methodology, Investigation. **Cecília Maria Villas Boas de Almeida:** Conceptualization, Methodology, Writing – review & editing.

Declaration of competing interest

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

Data availability

No data was used for the research described in the article.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2022.134633.

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