



# Improving startups through excellence initiatives: addressing circular economy and innovation

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## Abstract

This study analyses how startups implement circular business models supported by innovation and Industry 4.0, in which strategic stakeholders for value creation are to be found in this specific business ecosystem. The theoretical framework of circular business models supported by innovation was used for analysing the startups based on some assumptions of stakeholder theory. Fifty-one startups were selected, which correspond to the unit of analysis for this study on the improvement of supply chains through circular business models supported by innovation aimed at sustainability in organizations. We conducted a multiple case study whose results suggest that: (i) circularity is strategic for the business to assume its commitment to a sustainable development agenda, especially regarding pollution prevention and proactive action; (ii) visionary entrepreneurs are actively engaged with circular economy practices and technological innovation to promote a circular flow for their business ecosystem; (iii) Industry 4.0 is still incipient, but it is synergistic and beneficial for a successful circular economy in startups; and (iv) primary stakeholders are the activators of circular cycles in the startups surveyed. The present study contributes to the literature in four ways by: (i) presenting a framework which brings together exploratory theoretical propositions on strategic stakeholders for startups, innovative capabilities and assumptions of circular business models; (ii) validating exploratory theoretical propositions with 51 startups; (iii) providing lessons learned so far by the startups which are in line with the assumptions of circular business models for triggering their innovation capabilities and promoting Industry 4.0; (iv) providing an original typology of circular economy assumptions and technological innovations adopted by startups. The originality of this study lies in presenting useful insights for motivating managers to: (i) invest in circular business to become one of the first entrants and earn extra profits; (ii) make investments in circular business and technological innovations to obtain efficiency, practicality and process optimization; (iii) internalize Industry 4.0 technologies concomitantly with technological innovations and circular economy to generate systemic effects; (iv) integrate relevant stakeholders of the business ecosystem to generate a synergistic and effective effect for sustainable development.

**Keywords** Sustainability · Circular economy · Stakeholder theory · Innovation · Industry 4.0

## 1 Introduction

In this study we address the excellence in innovation interfaces and circular business models (Sehnem et al., 2021a). Research reveals that emerging companies, called startups (Rok & Kulik, 2021), whose business models are based on acceleration and rapid growth, are already more likely to adhere to sustainable practices as well as to disruptive and radical innovations, including engagement of the different stakeholders of supply chain in this form of action (Sehnem et al., 2021b). Circular business models (Bocken & Ritala, 2022) have gained scientific and social notoriety in recent years (Pavan et al., 2021). They are a relatively young field of research, but they encompass a set of elements already present in organizations for a long time, such as regeneration of materials through technical and biological cycles, circularity, optimization, and more recently, sharing, virtualization, multiple actors and collaborative environments and exchanges (Boldrini & Antheaume, 2021). This collection of practices contributes to the creation of innovative companies closely aligned with suppliers and customers (Huynh, 2022). In this perspective, other elements of the society such as social inclusion, respect for diversity, environmental causes, climate movements and global health crisis can also affect the practices inserted in the daily lives of companies.

The structuring of companies becomes emblematic at a time when we are beset by climate crisis, pandemic and issues related to finitude of natural resources. These pressing imbalance issues demand innovative business models to make it possible to produce and offer more sustainable products and services which can be manufactured with less emission of waste throughout the production process and also after their consumption. Circular business models can greatly contribute to organizational excellence and generation of sustainable supply chains (De Angelis, 2021), especially if their assumptions are based on innovative alternatives and digital transformations provided by Industry 4.0 (Belhadi et al., 2022). Such movements greatly contribute to the companies' strategic stakeholders to act in synergy (Rok & Kulik, 2021), communicate frequently by using shared channels, establish shared strategies and develop resources and strategic capabilities important for the success of the business and consumer satisfaction (Brown et al., 2021).

Considering the above, this article focuses on circular business models supported by Industry 4.0 innovations from the perspective of the stakeholder theory. The justification for carrying out the study is associated with the urgent need to manage the impacts and externalities generated by companies (Salnikova et al., 2021), in addition to the need to act by respecting diversity and inclusion, valuing people and providing well-being at work. Finally, cost management with an emphasis on process improvement, optimization, production efficiency and establishment of synergies in the value chain becomes relevant to society in the current moment. In this context, circular economy can provide managers with a concept for optimizing resources and contributing to managing carbon emissions, thus minimizing externalities. Therefore, circular economy practices and business models are widely explored topics (Guerra et al., 2021; Dahmani et al., 2021; Nag et al., 2021; Wralsen et al., 2021).

However, the role played by stakeholders for circular economy to thrive in continuous, integrated and balanced flows between the different links of a production chain remains unexplored. In line with this, organizational managers and leaders are also discovering the importance and complexity of dealing with circular economy on a daily basis, whether due to lack of organizational culture to work with the assumptions of circular economy, fragile infrastructure or even regulatory frameworks not yet

available or still being structured. All these do not provide the ideal legal support necessary for success and excellence in sustainable and circular operations.

Furthermore, innovation capabilities focused on sustainability are essential to create value for companies, thus increasing efficiency, improving resilience and reducing ecological impact (Sehnm et al., 2021b). Circular economy, currently a buzzword, includes sustainable practices (Kanda et al., 2021) through innovative business models (Moggi & Dameri, 2021) and which are internalized in supply chains according to the consumption logic. Innovation and digital transformation are important items (Pereira & Vence, 2021) supporting the assumptions of circular economy in different business models (Rok & Kulik, 2021). Hence, concerns on design and planning of circular products, life cycle analysis, life cycle extension, remanufacturing, redistribution, reuse, recycling, sustainable consumption, attitude and purpose, culture for purchasing remanufactured products, among others were irrelevant until then (Sehnm et al., 2019a, b). In order to achieve such goals, companies need to engage with different internal and external stakeholders to generate innovative strategies capable of delivering value. This stakeholder engagement creates an ecosystem for efficiently activating circular flows of materials and resources. This is often due to stakeholder pressure, the technological evolution fueling the Industry 4.0, and the digital transformation (Bocken & Ritala, 2021).

This study seeks to offer an analysis using emerging companies, that is, startups, which are organizations having a potential of accelerated growth and capable of becoming strategic players in their industry. These are companies with resilience to pivot and adaptability and agility to reposition themselves in the market. In the Brazilian context, startups have gained notoriety due to several national programs and movements aimed at stimulating their creation, such as legal frameworks for startups to generate innovative entrepreneurship, promotion of incubators, pre-incubators and innovation observatories, support to encourage the creation of these companies, hackathons, initiatives through collective disputes for emergence of ideas which can turn into business, among others. Considering the information presented so far, this study raises two research questions:

RQ1: How are startups implementing circular business models supported by innovation and Industry 4.0?

RQ2: Who are the relevant stakeholders for startups to work with circular business models that are leveraged via innovation and Industry 4.0?

In addition to this first section, Sect. 2 presents the theoretical foundation of this study, which alludes to circular economy, innovation, stakeholder theory and Industry 4.0. This results in a theoretical framework and exploratory theoretical propositions. Section 3 describes the methodological procedures. Section 4 presents analyses and discusses the results of the study. Lastly, Sect. 5 presents the final considerations regarding the search for information and correlations demonstrating the originality of this study, which proposes to present useful insights for motivating managers to: (i) invest in circular businesses to become one of the first entrants and obtain extra profits; (ii) make investments in circular business and technological innovations to obtain efficiency, practicality and process optimization; (iii) internalize industry 4.0 technologies concomitantly with technological innovations and circular economy to generate systemic effects; (iv) integrate the relevant stakeholders of the business ecosystem to generate a synergistic and effective effect for sustainable development.

## 2 Theoretical background on circular economy, industry 4.0 and innovation

Environmental problems, climate change and natural instabilities are raising concern over the environment (Sehnem et al., 2021a, 2021b). In addition to this uncertain environmental scenario, some serious social problems emerged and worsened during the COVID-19 pandemic due to a higher unemployment rates over the last two years. This social crisis is represented by informal work, which provides no protection for the worker, hostile work culture, asymmetries between rich and poor increasing every year, and increase in inequalities regarding different dimensions of life, in which the poor often have neither the right to have opportunities nor to dream of progressing in life (UN, 2021).

All these problems point to an imbalance which contrasts with the global purposes, such as eradication of poverty, proposed by the Sustainable Development Goals. Thus, the circular economy becomes a theoretical framework aimed at contributing to the redesign of production systems, including the dynamics of the society by placing it on a new level (Siderius & Poldner, 2021). This requires engagement, attitudes, significant behavioural changes and people's awareness and commitment to 10Rs of resource management (Reike et al., 2018). The perspective of managing scarce, finite and valuable resources leads us to an understanding of the people's role in the reusing, reducing, recycling, remanufacturing processes (Sehnem et al., 2019b). Adherence to less polluting energy sources capable of self-regeneration (Basile et al., 2021) and energy extraction from waste are mechanisms which are beginning to integrate the business agenda in order to reduce costs, optimize processes and create more sustainable operations (Palmié et al., 2021).

Moreover, circular economy becomes a strategic agenda for organizations (Warwas et al., 2021) as it is associated with the status of being a provider of solutions and alternatives considered more adequate in the context in which humanity currently is (Bocken & Ritala, 2021). It is considered a significant agenda for a sustainable development, as it promotes productive ecosystems and reduces waste generation. Its implementation becomes more agile through the development of innovation capabilities (e.g. eco-innovations), that is, alternatives capable of reducing environmental risk, pollution, waste and negative impacts of the use of resources, in addition to reducing negative externalities emitted by productive processes (Pietro-Sandoval et al., 2018). Circular economy also encourages the use of clean energy, process virtualization, exchanges, sharing, optimization and continuous improvement. These practices are essential for improving the ecological performance of the companies (Agyemang et al., 2019).

Disruptive innovations, as generators of tools for leveraging the competitiveness of organizations, can be used to increase the circularity of resources, retain value in production cycles and increase the value of the product or service provided to the customer (Menelau et al, 2019; Sehnem et al, 2021b). These innovations are directly associated with cost reduction, increased productivity, mitigation of water consumption, reduced energy consumption, nutritious food supply and healthy living. They also contribute to the management of large volumes of data and microdata to increase productivity and efficiency in the organizations (Sehnem et al, 2021b). Industry 4.0 is to be found in this new business scenario, where it is possible to find the emergence and consolidation of several new technologies, namely, internet of things (IoT), cloud computing, additive manufacturing, cyber security, cyber-physical systems (CPS), blockchain, augmented reality, artificial intelligence (AI), big data, among others. These technologies can generate practical solutions to be applied to circular value chains (Chauhan & Singh, 2019; Yadav et al., 2020).

Industry 4.0 is characterized by data-based digital systems (Angelopoulos et al. 2020) and operates in the transformation and digitization of manufacturing and business processes. Through the exploration of new advanced technologies, it aims to improve the traditional organizational processes with the implementation of automated and data-oriented processes (Alkhazaleh et al., 2022; Angelopoulos et al., 2020). Industry 4.0 connects machines, people and information technology systems intelligently, horizontally and vertically to create highly digitized and connected environments. Thus, it brings numerous advantages for the organizations, such as improved production processes, efficiency gains, flexibility, optimization of operational performance and improvements in the supply chain (Veile et al., 2019; Zheng et al., 2020).

Additionally, the study on circular economy and waste (Di Vaio et al., 2021) points out that disruptive innovations can be adopted together with circular economy to promote discounts and incentives for those who contribute to improvements in production cycles and to apply higher tariffs to those on the edge of the model through reliability and transparency driven by the accounting methods. This reliability must also be evidenced in the sustainability reports, so that they are credible, verifiable and irrefutably true in order to reflect the organization's commitment to sustainability and good practices (DiVaio et al., 2023).

## 2.1 Stakeholder theory: an overview

Stakeholders are individuals who affect or are affected by the company's strategies and the achievement of the company's goals (Freeman, 1984). These individuals correspond to all stakeholders who are considered strategic in the field of business and business management (Mani et al., 2020). They have different behaviours, which can be cooperative, competitive or coercive, and consequently affect the organizational performance (Mani & Gunasekaran, 2018). Currently, emphasis is placed on the multi-stakeholder perspective (Ji et al., 2015).

Dependence and influence in the relationships among the stakeholders of an organization can vary (Roy et al., 2020), which implies heterogeneous relationships between these various stakeholders (Truong & Pinkse, 2019). Stakeholder integration has been proven to be a relevant and successful strategy (Venkatesh et al., 2021) as it provides unlimited possibilities for group connections with internal and external interests. According to Freitas et al. (2012), the levels of stakeholder engagement can be classified as the following: (i) primary, in which participation and support by individuals and groups are essential for the organization's survival, and (ii) secondary, in which stakeholders affect and are affected by the organization, but they are not engaged in its transactions, being considered less essential for its perpetuity (Clarkson, 1995).

Prioritizing key stakeholders (Glover et al., 2014a, b) and building solid relationships and commitment (Wanke et al., 2021) are essential to successfully manage and control a company (Hannibal & Kauppi, 2018). However, identifying and prioritizing stakeholders are not an easy task and gives rise to paradoxes (Erthal et al., 2020). In the context of circular economy, for instance, the engagement of multiple stakeholders is encouraged (Bai et al., 2021).

More importance will be given to the stakeholder when all the three attributes, namely, power, legitimacy and urgency, are perceived by the manager (Zhu et al., 2016). This is how the manager identifies stakeholders who are really essential for the organization (Wanke et al., 2021). At the same time, they establish relationships, reciprocity and a relationship of dependence among themselves (De Vries, 2009), in which interest and

reciprocity between them occur due to the fact that they affect one another, leading to benefits or causing harm (Yang et al., 2020).

The role played by stakeholders is crucial for the development of production chains, as evidenced in the agri-food system by means of technological evolution, sustainable evolution or development of advanced management models capable of supporting the technological and technological food supply on a sustainable basis. The importance of promoting a sustainable development agenda, especially in startups who understand the stakeholders' role as internal collaborators, supply chain partners, suppliers, customers and social organizations, allows these businesses and their surroundings to create new spaces aimed at bringing together innovative, responsible and sustainable solutions (Di Vaio et al., 2020).

The theoretical framework of this study was developed on the basis of the stakeholder theory, circular economy, Industry 4.0 and technological innovations, as shown in Fig. 1.

### 3 Methodological procedures

This study aims to analyse how startups implement circular business models supported by innovation and industry 4.0. To make this proposal viable, a database containing around 400 startups associated with Liga Ventures (2021) was accessed. Next, an invitation was made to a random sample of startups to participate in the study. One-hundred 100 companies were invited, corresponding to one-quarter of the total of startups, but only 51 accepted the invitation to participate and be interviewed.

This study presents an original integration between the stakeholder theory's assumptions and business models stemming from circular economy, technological innovations and industry 4.0. Startups are organizations representing sustainable entrepreneurship initiatives in the Brazilian context and they were used as unit of analysis. The search for articles on the present subject reveals that a few studies have a similar scope, namely, building of competitive advantage with sustainable products by using the stakeholder theory (Kahupi et al., 2021), innovative business models, circular economy and sustainable performance in organizations (Jabbour et al., 2020) and innovation strategies geared towards circular

Circular Economy Assumptions (CE)	Strategic Stakeholders (ST)	Technological Innovations (TI)	Industry 4.0 (I4.0)
<p><u>Circular Economy Practices</u></p> <p>CE01 - Restoring, reducing and avoiding</p> <p>CE02 - Recirculating parts and products</p> <p>CE03 - Recirculating material</p> <p>CE04 - Re-inventing</p> <p>CE05 - Rethinking and reconfiguring</p> <p>CE06 - Acting with purpose</p> <p><u>Circular Economy Business Models</u></p> <p>CE07 - Circular supply</p> <p>CE08 - Waste as a resource</p> <p>CE09 - Second life</p> <p>CE10 - Sharing platform</p>	<p>ST01 - Suppliers</p> <p>ST 02 - Producers</p> <p>ST 03 - Distributors and wholesalers</p> <p>ST 04 - Customers</p> <p>ST05 - Employees</p> <p>ST06 - Banks</p> <p>ST07 - Government</p> <p>ST08 - Regulatory entities</p> <p>ST09 - Unions</p> <p>ST10 - NGOs</p> <p>ST11 - Shareholders</p> <p>ST12 - Social networks and media</p> <p>ST13 - Local community</p> <p>ST14 - Class associations</p> <p>ST15 - Community associations</p> <p>ST16 - Opinion makers</p> <p>ST17 - Technical partners</p> <p>ST18 - Universities</p>	<p>TI01 - Incremental innovation</p> <p>TI02 - Radical innovation</p>	<p><u>Industry 4.0</u></p> <p>IN01 - Wireless sensors</p> <p>IN02 - IoT</p> <p>IN03 - Big data</p> <p>IN04 - Cloud computing</p> <p>IN05 - Remote control/monitoring</p> <p>IN06 - 3D printing</p> <p>IN07 - Collaborative robots</p> <p>IN08 - Machine/deep learning</p> <p>IN09 - Augmented reality/simulation</p> <p><u>Industry 4.0 design principles</u></p> <p>IN10 - Technical assistance</p> <p>IN11 - Service orientation</p> <p>IN12 - Decentralized decision</p> <p>IN13 - Interconnection</p> <p>IN14 - Information transparency</p> <p>IN15 - Systems integrations</p> <p>IN16 - Virtualization</p> <p>IN17 - Modularity</p> <p>IN18 - Interoperability</p> <p>IN19 - Artificial intelligence</p> <p>IN20 - Geolocation</p>

Fig. 1 Framework connecting stakeholder theory, CE, TI and I4.0

economy in the organic olive oil industry (Galati et al., 2018). This shows that there is still an opportunity to carry out further exploratory, qualitative studies with this scope. Based on the multiple case-study strategy and cross-comparison units, we developed the present study. Figure 2 presents the theoretical propositions of this study.

A case study protocol was followed, which contained questions on business profile, innovations and sustainable practices aligned with the assumptions of circular economy. To conduct the investigation, the case study assumptions presented by Yin (2010) were followed. As shown in Fig. 1, based on a review of the theoretical framework, four exploratory theoretical propositions were identified for use in the data analysis. They were validated by the empirical evidence of the study. Considering that this is a qualitative exploratory study, we do not intend to generate analytical generalizations. Our work is based on assumptions which were previously adopted by Campos and Vazquez-Brust (2016), Sehnem et al (2019a), Sehnem et al (2019b), and Sehnem et al., (2021a, 2021b). The study’s unit of analysis is represented by startups growing exponentially which have gained notoriety in their operating segments. They were renamed from FT01 to FT51 to maintain their anonymity. They are startups operating in the food, agriculture, livestock, health, well-being, agribusiness, textile, furniture, information technology and biotechnology segments. Interviews lasting 31 min and 54 s were recorded and gathered, totaling 293 transcribed pages. After a fluctuating reading, analytical encoding was performed according to theoretical premises adopted to conduct this study. Categories of analysis were created a *posteriori* by considering the basic theoretical framework of the study on the following themes: circular economy, stakeholder theory, technological innovations and industry 4.0. These categories of analysis were based on Yin (2010), who proposed empirically based patterns of combinational logic and compared it to a predicted pattern (or several alternative predictions). When the patterns match, the results help in strengthening the internal validity of the case study. The principles of triangulation of different data collection sources were also followed, namely, interview content, secondary data from websites, leaflets, flyers and interviews and videos on the companies available on YouTube. With regard to the interview script, it involved questions on the profile of the companies, operating segment, operating time, circular economy practices, strategic stakeholders, innovation practices and industry 4.0 technologies. Data were collected by conducting online meetings, such as Zoom, Teams and Google Meet. Therefore, information was obtained face-to-face from key informants of the startups analysed. The justification for choosing one respondent *per* unit of analysis is that startups are small, usually composed only of the entrepreneur who outsources and hires temporary service providers, in addition to being the decider, planner and main executor of the action plan.

Analytical categorization was used according to the pattern combination recommended by Yin (2010). We adapted the typology of circular economy assumptions and technological innovations described by Kristoffersen et al. (2021) taxonomically:

Theoretical Framework	Exploratory Research Propositions	Methodology Design
CE assumptions	Proposition 1: Based on the cases addressed in this study, companies with a proactive approach towards circularity use technological innovation to support pollution control initiatives.	Exploratory multiple-case study in Brazilian startups.
Strategic stakeholders	Proposition 2: Based on the cases addressed in this study, companies with a proactive approach towards circularity use technological innovation to support pollution prevention initiatives.	Non-generalizable insights using stakeholder theory insights.
Technological innovations	Proposition 3: Based on the cases addressed in this study, companies with a proactive approach towards circularity use technological innovation to support product management initiatives.	Using technological innovation for supporting CE and providing sustainable entrepreneurship.
Industry 4.0	Proposition 4: Based on the cases addressed in this study, companies with a proactive approach towards circularity use technological innovation to support sustainable development initiatives.	Using industry 4.0 for supporting CE and providing sustainable entrepreneurship.

Fig. 2 Exploratory research proposition connecting stakeholder theory, CE, TI and I4.0

*Restore, reduce and avoid* the impact on virgin materials and supply.

*Recirculate* parts and products by extending the existing cycle of use.

*Recirculate* materials by extending the material use cycle.

*Reinvent* the paradigm (i.e. virtualization, digitization, separation of data from physical resources, making data available for easier use, digital supply chains and digital manufacturing).

*Rethink and reconfigure* the business model.

*Purpose* (organizations acting with the purpose of generating significant impact and contributions to society).

With regard to circular economy business models, the typology of Kalmykova et al. (2018) consists of:

- (a) *Circular supply* of renewable energy, fuel and bio-based products.
- (b) *Waste as a resource* with emphasis on recovering useful resources and resource energy by making use of industrial symbiosis.
- (c) *Second life* by extending the life of products through repair, modernization, resale and durable, modular design.
- (d) *Sharing platform* by retaining the producer's property and offering the product as a service, thus contributing to the product-dematerialization process and strengthening the circular design.

With regard to the categories of analysis related to innovations, the premises set by Baptista (1999) for incremental innovation and by Christensen (1997) for disruptive or sustaining innovation were followed, namely:

*Disruptive or sustaining innovation*: it is the innovation aimed at creating a new market, that is, a disruption for generating a transformation in society.

*Incremental innovation*: it generates small improvements in products and processes capable of providing increments to something already existing.

*Relevant stakeholders*: people interested in the company's processes and results who act as individuals or organizations who are affected by the actions of a company (Freeman, 1984).

The resulting data are summarized in the tables below. The existence of mapped practices was signalled with a smiley (☺). In this way, it is possible to carry out a cross-analysis by verifying the existence of practices in each of the cases analysed.

The practices related to the typologies by Kristoffersen et al. (2021) and Kalmykova et al. (2018) were classified from CE1 to CE10, as shown in Fig. 2. Likewise, the practices by Baptista (1999) and Christensen (1997) were classified, respectively, as TI01 and TI02. Their mapping resulted in Table 1.

The stakeholders (Freeman, 1984) were labeled from ST1 to ST18 (Fig. 2), which originated Table 2. In turn, industry 4.0 technologies (Belhadi et al., 2022) were classified from IN01 to IN 20 and are mapped in Table 3.

The startups surveyed have an average age of 6.7 years and most managers have bachelor's degree (29 respondents), postgraduate degree (12 respondents), master's degree (two respondents), PhD degree (five respondents), post-doctoral degree (one respondent) or high school degree (2 respondents). This evidence indicates that this type of company has managers with a higher level of education, which can benefit business management.

We followed the criteria by Gaskel and Bauer (2002) to attest to the validity and reliability of the qualitative study. Thus, data from different sources and different units of



**Table 1** Typology of circular economy assumptions and technological innovations mapped in the startups analysed

	Kristoffersen et al. (2021)				Kalmykova et al. (2018)				Baptista (1999)	Christensen (1997)		
	CE01	CE02	CE03	CE04	CE05	CE06	CE07	CE08			CE09	CE10
FT01				☺								
FT02	☺					☺				☺		
FT03						☺	☺					
FT04												
FT05						☺		☺				
FT06												
FT07						☺		☺				
FT08						☺		☺	☺			
FT09						☺		☺	☺			
FT10						☺		☺	☺			
FT11						☺		☺	☺			
FT12						☺		☺	☺			☺
FT13						☺		☺				
FT14						☺		☺				
FT15						☺		☺	☺			☺
FT16						☺		☺	☺			
FT17												
FT18												
FT19												
FT20												
FT21												
FT22						☺		☺				
FT23												
FT24						☺		☺				

**Table 1** (continued)

	Kristoffersen et al. (2021)			Kalmykova et al. (2018)							Baptista (1999)		Chris- tensen (1997)
	CE01	CE02	CE03	CE04	CE05	CE06	CE07	CE08	CE09	CE10	TI01	TI02	
FT25											☺		
FT26							☺				☺		
FT27						☺					☺	☺	
FT28						☺					☺		
FT29						☺					☺	☺	
FT30											☺		
FT31							☺				☺		
FT32							☺				☺	☺	
FT33								☺			☺		
FT34							☺				☺		
FT35											☺	☺	
FT36							☺				☺		
FT37											☺	☺	
FT38							☺				☺		
FT39											☺	☺	
FT40											☺		
FT41							☺						
FT42											☺		
FT43											☺		
FT44						☺					☺		
FT45							☺				☺		
FT46											☺		
FT47											☺		

**Table 1** (continued)

	Kristoffersen et al. (2021)					Kalmykova et al. (2018)					Baptista (1999)	Christensen (1997)
	CE01	CE02	CE03	CE04	CE05	CE06	CE07	CE08	CE09	CE10	TI01	TI02
FT48									☺	☺	☺	
FT49							☺		☺		☺	
FT50											☺	
FT51										☺	☺	

☺ Existing practices and assumptions of CE and innovation

**Table 2** Stakeholders relevant for the startups analysed (Freeman, 1984)

Startups	ST01	ST01	ST03	ST04	ST05	ST06	ST07	ST08	ST09	ST10	ST11	ST12	ST13	ST14	ST15	ST16	ST17	ST18
FT01	☺										☺							
FT02	☺			☺			☺				☺							
FT03	☺			☺							☺							
FT04	☺			☺							☺							
FT05	☺			☺							☺							
FT06	☺			☺							☺							
FT07	☺			☺			☺				☺							
FT08	☺			☺		☺					☺		☺				☺	
FT09	☺			☺							☺							
FT10	☺			☺							☺							
FT11	☺			☺							☺							
FT12	☺			☺		☺					☺							
FT13	☺			☺							☺							
FT14	☺			☺							☺							
FT15	☺			☺							☺							
FT16	☺			☺							☺							
FT17	☺			☺							☺							
FT18	☺			☺							☺							
FT19	☺			☺							☺							
FT20	☺			☺							☺							
FT21	☺			☺							☺							
FT22	☺			☺							☺							
FT23	☺			☺							☺							
FT24	☺			☺							☺							
FT25	☺			☺							☺							
FT26	☺			☺							☺							
FT27	☺			☺							☺							

Table 2 (continued)

Startups	ST01	ST01	ST03	ST04	ST05	ST06	ST07	ST08	ST09	ST10	ST11	ST12	ST13	ST14	ST15	ST16	ST17	ST18
FT28	☺			☺							☺	☺						
FT29	☺			☺							☺	☺						
FT30	☺			☺							☺	☺						
FT31	☺			☺							☺	☺						
FT32	☺			☺							☺	☺						
FT33	☺			☺							☺	☺						
FT34	☺			☺							☺	☺						
FT35	☺			☺							☺	☺						
FT36	☺			☺							☺	☺						
FT37	☺			☺							☺	☺						
FT38	☺			☺							☺	☺						
FT39	☺			☺							☺	☺						
FT40	☺			☺							☺	☺						
FT41																		
FT42	☺			☺							☺	☺						
FT43	☺			☺							☺	☺						
FT44	☺			☺							☺	☺						
FT45	☺			☺							☺	☺						
FT46	☺			☺							☺	☺						
FT47	☺			☺							☺	☺						
FT48	☺			☺							☺	☺						
FT49	☺			☺							☺	☺						
FT50	☺			☺							☺	☺						
FT51	☺			☺							☺	☺						

analysis were triangulated to reduce the inconsistency and contradictions, which contributed to the generation of convergence (Patton, 2002). The reflexivity process to attest the reliability of the qualitative study was adopted. Clarity in the procedures was used for replicability of the protocol of this case study with multiple units of analysis. The construction of the research corpus through observation, reflection and criticality of multiple players involved, including the use of more than one researcher in the process, was also adopted in this study. Rich, informed description was provided and feedback from the informants (communicative validation) was obtained to enable a valid and reliable process for conducting a qualitative study. Figure 3 summarizes the study design.

#### 4 Data presentation and analysis

Table 1 presents the circular economy typologies and innovations mapped in the surveyed startups. Stakeholder theory is well positioned to connect to innovation, Industry 4.0 and circular economy. Since innovation, Industry 4.0 and circular economy are major concepts which are both directly and indirectly relevant to resource-based view, technology diffusion and triple bottom line theories, it is understandable that this basic theoretical framework produces guidelines supporting stakeholder management strategies for a successful sustainability performance. Critical success factors are overcome by a set of elements favouring the management of relevant and strategic stakeholders for successful sustainable management. Therefore, the parsimony of the theory can be determined in the midst of these relevant and intertwined concepts.

Table 2 shows the predominance of incremental innovations in startups, probably because they are less costly, easier to be implemented and cheaper viability. Waste is also notorious as a resource and as a second life one according to the practices adopted by the startups, in addition to the use of sharing platforms in business environment, which optimizes, dilute costs and are quickly implemented. However, there is great unexplored potential alluding to the assumptions of circular economy, which can serve as source of differentiation for business by promoting competitiveness and providing companies with a sustainability status. Thus, Table 2 presents the relevant stakeholders for the startups surveyed.

Table 2 shows that, according to the startups analysed, the most relevant stakeholders are suppliers, customers, shareholders and owners. In general, there is a culture of not naming relevant stakeholders emphatically in documents, reports and on the website. Below, Table 3 presents the technologies and design principles of Industry 4.0 identified in the startups.

Table 3 clearly demonstrates that industry 4.0 technologies are incipient and adopted in isolation. But there is a variety of technologies being used in conjunction with business models of circular economy, which shows the potential this synergy can provide in the construction of sustainable production chains with potential to promote closed cycles, reverse cycles, shorter cycles, circularity of materials and generation of data to encourage dematerialization of products. Table 4 presents the assumptions of circular economy and innovations according to the startups investigated.

**Table 3** Technologies and design principles of Industry 4.0 in the startups analysed (Belhadi et al., 2022)

Startups	IN 01	IN 02	IN 03	IN 04	IN 05	IN 06	IN 07	IN 08	IN 09	IN 10	IN 11	IN 12	IN 13	IN 14	IN 15	IN 16	IN 17	IN 18	IN 19	IN 20	
FT01																					
FT02																					
FT03																					
FT04																					
FT05																					
FT06	☺																				
FT07																					
FT08															☺						
FT09																					
FT10																					
FT11																					
FT12																					
FT13																					
FT14																					
FT15	☺						☺														
FT16																					
FT17																					
FT18																					
FT19																					
FT20																					
FT21																					
FT22																					
FT23																					
FT24																					
FT25																					
FT26																					
FT27																					

**Table 3** (continued)

Startups	IN 01	IN 02	IN 03	IN 04	IN 05	IN 06	IN 07	IN 08	IN 09	IN 10	IN 11	IN 12	IN 13	IN 14	IN 15	IN 16	IN 17	IN 18	IN 19	IN 20	
FT28																					
FT29	☺																		☺		
FT30																			☺		
FT31				☺																	
FT32																			☺		
FT33																					☺
FT34																					
FT35															☺	☺					
FT36																					
FT37		☺																	☺		
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## 4.1 Discussion of results

In this section, the four above-mentioned research propositions will be discussed along with the relevant study results. The results for Proposition 1 (companies with a proactive circularity approach use technological innovation to support pollution control initiatives) and Proposition 2 (companies with a proactive circularity approach use technological innovation to support pollution prevention initiatives) were validated through research evidence. The statements by FT 07, 11, 32, 35, 41, 42, 43 and 44 show the entrepreneurs' concern in creating businesses with profitable and sustainable potential simultaneously while making use of innovation artefacts (i.e., specific technologies) for the sector in which they operate. Therefore, there is evidence of a synergy between circularity, proactivity, technological innovation and pollution prevention potential. This finding is relevant and is in line with the COP-26 debates, which called for the urgency and need for organizations to be more proactive in preventing pollution. In this sense, the stakeholders, especially the most relevant ones (i.e., those who are strategic and active in the value chain), play a unique and valuable role for the sustainability of natural resources. A startup who is a newborn company, who is still conquering its space and customers in the market and who makes such a compromise already signals a differentiated positioning which can captivate enlightened, selected customers purchasing products in a responsible and conscious way. It is well known that sustainability is increasingly occupying a space in the consumer market. And for this to become possible, production needs to adapt to generate a synergy throughout the entire productive chain.

Furthermore, it is notorious that digitization, traceability, use of sensors and generation of a database to control production chains become strategic elements for food safety, health, well-being, prevention and proactivity, which shows that the environmental dimension is not the only one addressed. We have noticed a strong emphasis on social aspects, especially focused on the individual, individuality, well-being and, to a larger extent, on the economic dimension, predominantly regarding efficiency, process optimization, continuous improvement and generation of high production performance. Disruption and proactivity are notorious with the creation of new markets (FT14), sensors in agricultural cultivation (FT29), digital agricultural notebooks (FT29), and shelf life extension of fruits and vegetables through technology for absorption of ethylene gas emitted by them.

Proposition 3 (companies with a proactive circularity approach use technological innovation to support product management initiatives) and Proposition 4 (companies with a proactive circularity approach use technological innovation to support sustainable development initiatives) were validated by the cases analysed herein, as there are elements supporting both propositions. For example, according to FT 43, "all waste from our production undergoes a rigorous recycling process and our raw material is just reforestation wood from sustainable forests", FT 32 "Our on-farm bio-inputs production technology allows producers to reduce their costs by up to 40% in soy, corn, wheat, cotton, sugarcane, coffee and fruit crops", FT 35 "For animal protein producers throughout Brazil, Kayros offers biotechnological solutions that improve the efficiency in the production of animal protein from both terrestrial and aquatic species"; and FT 17 "Internal project 'adopt a mug' = avoid wasting plastic cups and highlight the culture of conscientious consumption; planting of native species = environmental preservation and sustainable development".

These findings show us that circular economy and innovation play a strategic role in the production management, including conception, design and re-signification of the products. At the same time, Industry 4.0 offers an entire strategic arsenal to monitor, track,

follow up and reintegrate obsolete products into new production flows useful and relevant to society. This logic of production and consumption has a decisive role for sustainable development and success of commitments globally assumed at the COP-26. Finally, green product design is an effective way to reach out to circular economy (Li et al., 2021) and can be considered a disruptive innovation for the productive sector. The circular economy impacts the structure and relationships of the supply chain and requires integration and interaction with the business ecosystem. Coordination and sharing of information (Li et al., 2021) are required for the success of circular economy, especially when associated with the buyer–supplier relationship (Lee et al., 2020) based on the following aspects: exchange of information, development of operational links, establishment of legal links, specific adaptations to the relationship, and standard cooperation (Centobelli et al., 2021). Moreover, the startups investigated are committed to implementing business models (Kristoffersen et al., 2021) which can represent the contemporaneity valued by the society.

### 4.2 Lessons learned

The present study indicates some strategic lessons for business:

*Lesson 1:* Turbulent environmental and institutional scenarios can be conducive to creating innovative businesses to surprise customers. This is what happened with several startups analysed herein, such as those created a few months ago, as they bring innovative business proposals which generate value for the customer while incorporating elements of sustainability into their business dynamics.

*Lesson 2:* Entrepreneurship is risky and those who carry it out need to create a plan allied to trends and potential market disruptions. Industry 4.0, combined with technological

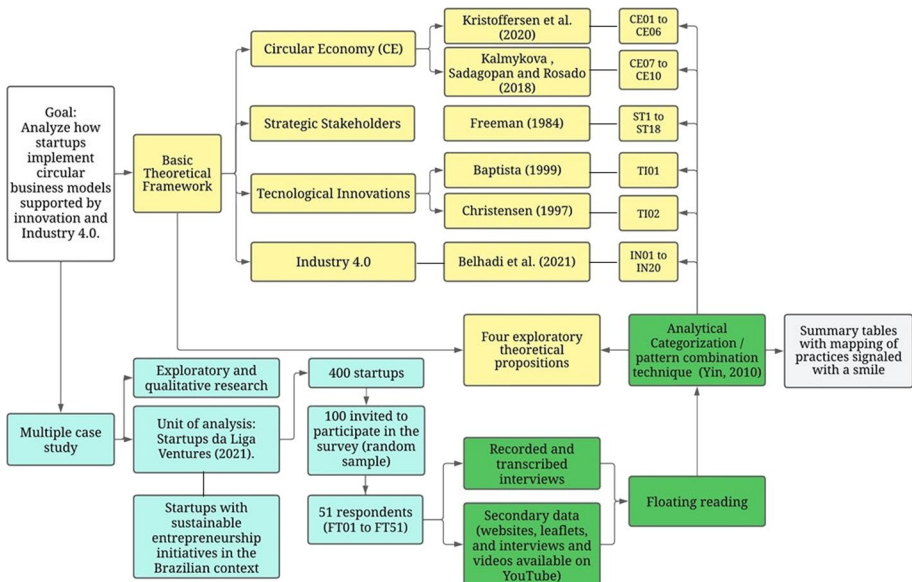


Fig. 3 Research design. \*Nota do tradutor: Não foi possível acessar o conteúdo da figura

innovation and circular economy, offers a series of possibilities to break boundaries, create new markets and generate new commercial transactions.

*Lesson 3:* Sustainable development cannot be a global discourse only. It should start as a homework assignment for an enterprise starting in the backyard, in a university classroom or in a hackathon team. All these spaces should serve as potential environments for creating and stimulating sustainable movements and businesses.

*Lesson 4:* The unexpected often surprises and captivates the customer. Combining elements and joining technological artefacts towards simplicity can generate something innovative and capable of attracting a legion of customers. Therefore, creativity is essential to articulate a circular business.

## 5 Final remarks

The startups surveyed are implementing circular business models with the help of primary stakeholders, namely, suppliers, customers, shareholders, owners, social networks and media, and by using incremental technological innovations and some artefacts from Industry 4.0.

The main practical contribution of the study is the empirical validation of four theoretical propositions of the framework proposed herein. It presents an original typology of circular economy assumptions adopted by the startups as well as by Industry 4.0 technologies. In addition, a brief overview of the profile of entrepreneurs located in an emerging country shows the entrepreneurial behaviour of Brazilians in situations of external pressure, climate change and extremisms caused by the current global situation, such as forest fires, excessive rain, antagonism associated with Amazon, absence of government policy for sustainability, need to develop entrepreneurship for survival, and role of innovation to generate solutions for plural situations arising locally.

The theoretical contribution is associated with the evidence of synergy between circular economy, innovation and industry 4.0 to achieve sustainable development. Orchestrating these concepts synergistically can produce fruitful results in the most diverse sectors and contribute to having a healthier, more sustainable and more circular society. Stakeholder theory plays an important role for the strategic management of relevant stakeholders, that is, engagement of all to obtain superior performance in the business ecosystem.

The results of the study can be useful for managers by contributing to their perception of the relevance of investing in circular business models and by making use of industry 4.0 technologies concomitantly with technological innovations. Investments in circular businesses supported by innovation are a tendency to create new markets while generating greater efficiency, practicality and optimization of organizational processes, thus producing extra profits. The study reveals to managers the importance of integrating relevant stakeholders of the business ecosystem, especially the primary ones, to build a synergistic and effective effect for sustainable development.

Study limitations are associated with the access of only one respondent *per* unit of analysis, since multiple respondents would have complemented the data. For future research, we suggest to increase the number of respondents *per* unit of analysis and also to re-read the data from the perspective of systems theory. Another opportunity for future research is to carry out studies to validate the theoretical propositions from a

**Table 4** Assumptions of circular economy and innovation mapped in the startups analysed

Startups	Interview excerpts		Secondary data	
	Excerpts referring to circular economy	Excerpts referring to technological innovation	Excerpts referring to circular economy	Excerpts referring to technological innovation
FT01	<p>“...medicine shows that the diseases cause the most deaths in the world, they could be avoided if people had a healthier lifestyle”</p> <p>“...the purpose of the startup is to raise awareness that we have to take a step back before treating the disease, how about not having the disease? How about living in a different way? Then they show that cancer, diabetes, dementia, cardiovascular disease, Alzheimer’s disease, hypertension, obesity, all scientifically proven, in which 80% should not exist. If people had a healthier lifestyle, then for me it was very much a turning point, you know, and this medicine does not work only with prevention, quite the opposite, it works with the treatment of diseases through lifestyle changes, it doesn’t mean that medicine is against medication, but it basically says that if medication is really necessary, it should also be accompanied by a change in habits because while you don’t eat better, while you don’t practice physical activity, don’t sleep better, not having all this self-care, the medication will not solve the problem, so that’s what we do, it’s a very complex process because it’s something very new for the popular culture, we work a lot with content, with countless ways to first change people’s awareness of this</p>	<p>“It is the first health-tech startup to work with life style medicine”</p> <p>“The startup was born in the pandemic, so we only work from home”</p> <p>“We were born with the digital mindset”</p> <p>“It’s 100% telemedicine”</p>	<p>“The humanized consultation is a differential.”</p>	<p>“Integrative preventive treatment, health coach, nutritionist and doctors, Reike therapists”</p> <p>“Health insurance plans and online care (telemedicine)”</p>

**Table 4** (continued)

Startups	Interview excerpts		Secondary data	
	Excerpts referring to circular economy	Excerpts referring to technological innovation	Excerpts referring to circular economy	Excerpts referring to technological innovation
FT02	<p>“Smart food designed to make your day more practical and healthier”</p> <p>“We seek to act sustainably in all our processes”</p>	<p>“Our products seek to balance health and flavor in each recipe, taking advantage of everything that nature offers here”</p> <p>“Frozen foods, low glyce-mic index, organic and functional”</p> <p>“Delivery, online order, 24 h service”</p>	<p>“Dish made organic”</p>	<p>“We plan everything to bring more quality of life, health, weight loss, flavor, color and aroma to your daily life”</p>
FT03	<p>“Healthy, practical, delicious”</p>	<p>“Delivery, online order, 24 h service”</p>	<p>“Organic food”</p>	<p>“Power detox dishes, fast slimming combo, low carb combo, power immunity”</p>
FT04	<p>“...Systemic analysis through human genetics”</p> <p>“Focuses on disease prevention”</p>	<p>“Human genomic and metagenomic analysis for preventive treatment of human health”</p> <p>“Telemedicine service with nutritionists and doctors who can serve customers”</p>	<p>“Improvement of sports performance based on your DNA”</p>	<p>“Focus on disease prevention, but using food and physical activity as a way”</p> <p>“interactive dashboard to give feedback to the customer”</p>

**Table 4** (continued)

Interview excerpts		Secondary data	
Startups	Excerpts referring to circular economy	Excerpts referring to technological innovation	Excerpts referring to circular economy
FT05	<p>“Implementation of social and environmental responsibility projects with systematic collection and analysis of data”</p>	<p>“Best social, environmental and governance practices”</p> <p>“Incorporation of sustainable actions and practices related to environmental preservation and regeneration, promotion of a responsible and fair world for people and the use of the best administrative processes.”</p> <p>“...information transmitted in real time”</p>	<p>Excerpts referring to technological innovation</p> <p>“Technical guidance for online producers, I use Whats.App”</p> <p>It incorporates ESG practices in the supply chain, generating social and environmental improvements in rural communities that supply raw materials and quantifying the results in a reliable and systematic way”</p>
FT06	<p>“...avoid waste”</p>		<p>“Competitive, sustainable and innovative agribusiness”</p> <p>“...real-time connection and agility...”</p>

**Table 4** (continued)

Interview excerpts		Secondary data		
Startups	Excerpts referring to circular economy	Excerpts referring to technological innovation	Excerpts referring to circular economy	
FT07	<p>“It selects natural ingredients with high nutritional power, offering super-foods with more flavour and energy for your daily life.”</p> <p>“We promote the preservation of the Amazon, teach about agroforestry and respect the environment, work together with riverside dwellers, encourage local economy and support projects with a positive impact”</p>	<p>“It develops innovative foods and promotes well-being among consumers, the Amazon people and the forest”</p> <p>“...use of green technologies and innovative education models to work together in favour of valuing socio-biodiversity and the standing Amazon Forest”</p>	<p>“Focus on reducing waste in poultry farming”;</p> <p>“Focus on reducing waste in poultry farming”;</p> <p>Ongoing actions: Regenerative agriculture and nursery to catalyze new chains of fruit trees and native Amazon species;</p> <p>Demonstration of the use of green technologies (solar, bio-digesters and bamboo);</p> <p>Innovative educational partnerships with universities and civil society organizations to serve riverine people (long-term suppliers);</p> <p>Social and environmental education and agroforestry training;</p> <p>Academic support: technical visits, internships and scientific research (UFPA/IFPA/EARTH)</p> <p>Production and supply of seeds and seedlings</p>	<p>Excerpts referring to technological innovation</p> <p>“Two points that stand out: the issue of fibres and sustainability, they don’t have any dyes and no chemicals in them. I always recommend it for energy replacement and immunity strengthening”</p> <p>“Social learning and local identity for a healthy and peaceful country. We encourage teaching and exchange of knowledge between riverside communities and students from institutions in the Amazon. We promote scientific research and collaborative practices in favour of agroforestry systems and we rely on cross-sector partnerships in the implementation and development of the eco-farm”</p>
FT08	<p>“Vegetables without pesticides, always harvested on time”</p>	<p>“Our urban farms are spread throughout the city and we only harvest at the time of delivery”</p>	<p>“Network of urban farms”</p> <p>“Vegetables without pesticides, harvested on the spot, generate income for people living on the outskirts (to produce vegetables on slabs and empty land)”</p>	

Table 4 (continued)

Interview excerpts		Secondary data	
Startups	Excerpts referring to circular economy	Excerpts referring to technological innovation	Excerpts referring to circular economy innovation
FT09	<p>“Subscribers enjoy exclusive discounts and benefits”</p> <p>“Book your table, avoid lines and pay less for it”</p>	<p>“The biggest platform for eating out with more than 2,500 restaurants across Brazil.”</p> <p>“You can buy an exclusive menu in advance or use the credits to earn extra credits and consume whenever you want”</p>	<p>“The more you use, the more you save. Did you know that our subscribers save on average R\$120 per month? It can be used in Japanese restaurant, hamburger shops, bakery and even that romantic restaurant: all this without limits, for you to enjoy every day, as often as you like”</p> <p>“Book your table and avoid lines. You know that restaurants have huge lines to get in. By making a reservation in the app, you can plan ahead and ensure that the restaurant will be ready to receive you, and the best part: paying less!”</p>
FT10	<p>“Cooking has never been easier. Inside each package there are the ingredients necessary to prepare your meals. Just add a few ingredients that we always have on hand: water, oil or butter. And you cook. The finishing touch is yours! Very practical but with freedom of choice”</p>	<p>“When I idealized the Cook It products, I wanted people to go back to the kitchen and prepare their own meal. There they could participate in the transformation of the ingredients into their food. I expected this transformation to impact people and transform them too.”</p>	<p>“Delivery with free shipping throughout SP”</p> <p>“Technologies for relationship with suppliers and customers”</p>
FT11	<p>“Transforms production residue into shredded tow, generating one more product and less waste.”</p>	<p>“Dry depigmentation of fibres”</p>	<p>“Transforms waste into raw material, recycling textile waste, reduces environmental liabilities”</p> <p>“We are agents of change and we encourage actions that implement good environmental practices, implementation of P + L”</p> <p>“Dialogue with customers and suppliers via Facebook, LinkedIn and WhatsApp”</p>



**Table 4** (continued)

Interview excerpts		Secondary data	
Startups	Excerpts referring to circular economy	Excerpts referring to technological innovation	Excerpts referring to circular economy
FT12	<p>The equipment must be connected to the house's electrical network to control lighting, irrigation and ventilation for the plants automatically, ensuring that they grow healthy and tasty. Everything that is collected from the Plantário is free of pesticides and has an incomparable flavour and freshness! In addition, as in the Plantário the plants are always in an ideal environment, protected from the lack or excess of water, sun and nutrients, with development being up to twice as fast as in the conventional plantations</p> <p>"[...] makes use of the compost barn system..."</p>	<p>"It is a line of appliances that create organic gardens inside houses and apartments and connect our urban world with the beauties, flavours and pleasures of life linked to nature"</p>	<p>The equipment is manufactured with high quality materials, has a minimalist design, and brings the green of nature and the sophistication of technology to any environment. They can be manufactured in different colors and come complete, including an organic substrate and a selection of seeds to start the garden</p>
FT13	<p>"Bio-based products are used in the manufacture of the products and in the treatment of waste."</p>	<p>"100% of the whey is used"</p>	<p>"...use of the most modern technologies in the sector"</p>
FT14		<p>"We use digital platforms, digital signature, business intelligence"</p>	<p>"Handcrafted production process, focusing on quality and standardization of processes"</p> <p>"Initially produced through an artisanal process, the production began to take on a larger scale in 2015 [...]. The industrialization of the current factory began, thus achieving more quality and standardization in the processes. NOTE The only information that could "induce" you to think about process innovation"</p>

Table 4 (continued)

Interview excerpts		Secondary data		
Startups	Excerpts referring to circular economy	Excerpts referring to technological innovation	Excerpts referring to circular economy	
FT15	<p>“Management of internal waste to turn it into inputs to feed your company’s or another company’s production processes”</p>	<p>“the part of IoT (Internet of Things) [...], we hardly ever set foot in projects that don’t have IoT. [...] we realize the value of this data, big data. Artificial intelligence is a kind of gray area for me, because an algorithm is already an artificial intelligence. So, if we use it a little, we’ll feel like using more. [...] We tried to do this, but it is very difficult for you to have a good AI and it is very expensive, but today we are able to deliver a dashboard to the client”</p>	<p>“The ChoppUP beer coolers eliminate the main sources of waste in bulk services. The beer cooler and specialized services reduce common waste from 25 to 1%”</p>	<p>“Values: continuous innovation”  “Big data, IoT, automation, intelligent sensors, data intelligence, dashboard, systems that can be integrated with POS’s, artificial intelligence, machine learning”</p>
FT16	<p>“All waste generated by breweries, such as malt bagasse, instead of discarding it, we encourage them to donate it for animal feed manufacturing process, shelters, NGOs, etc., or for use to make bread, more in that sense.”</p>	<p>“So, we are trying to automate it more and more, putting artificial intelligence in some cases, running away from bots. Today we work with robust digital platforms such as AWS, Google’s GSuit.”</p>	<p>“Yes, there is an ideal glass designed for each style, which helps preserve and highlight the flavours and aromas of each beer.”</p>	<p>“Uestbeer, Marketing Brewer, Hopoh, Abrasel, Maria Cevada”</p>

**Table 4** (continued)

Interview excerpts		Secondary data	
Startups	Excerpts referring to circular economy	Excerpts referring to technological innovation	Excerpts referring to circular economy innovation
FT17	<p>“Adopt a mug” campaign (elimination of plastic cups); Use of disposable lunchboxes (returnable, to eliminate the generation of disposable waste); Zero Plastic (to eliminate the use of disposables in works)”</p>	<p>“All files are stored in the cloud”</p>	<p>“Internal project ‘adopt a mug’ = avoid wasting plastic cups and highlight the culture of conscientious consumption. / Planting of native species = environmental preservation and sustainable development”</p>
FT18	<p>“The wood used to generate energy is 100% reforested. In the manufacturing process virgin raw materials are not used, all material is recycled [...]”</p>	<p>“Scanning and processes are used for storing documents in the cloud (data storage is 100% in the cloud)”</p>	<p>“Reference in the sector, being considered one of the best in the country in the segment of production of paper with 100% recycled material”</p>
FT19	<p>“Since it is a technology company, it only does the normal separation of recyclable items in the office”</p>	<p>“Big data yes, but artificial intelligence not yet, the company has been carrying out studies on the advantage of this technology. Cloud computing is present in 100% of the company’s activities, this technology the company develops itself, when it is not enough it will have more space in the market”</p>	<p>“Delivery solutions that revolutionize your sales”</p> <p>“It is part of InovAativa Brasil 2020.1: a national acceleration program of innovative business for companies throughout Brazil. / Amo is awarded in the Innovation category at the 2<sup>nd</sup> Best of the Year Award Hackathon Shift Community Innovation (category ‘Donation and fostering society during the pandemic’ = brands that promoted social and economic impact during the pandemic).”</p>
FT20	<p>“Virtualization of processes”</p>	<p>“The use of big data and artificial intelligence is already part of the business”</p>	<p>“Focus on agility, availability and friendliness”</p> <p>“...resolvability and agility...”</p>

**Table 4** (continued)

Startups	Interview excerpts		Secondary data
	Excerpts referring to circular economy	Excerpts referring to technological innovation	
FT21	<p>“...it’s reverse logistics, our supplier produces scraps from fabric leftovers, and we bring them through our trucks to deliver them into our factory and process them to make a new product [...] Like polyols, which are derived from petroleum, some raw materials we already use, like bamboo fabric, a certain ecological appeal [...]”</p>	<p>“[...] we use BI (Business Intelligence) aimed at serving and understanding this segment.”</p>	<p>“Health, well-being and sustainability” “Eco-products, focus on well-being and safe materials”</p>

**Table 4** (continued)

Interview excerpts		Secondary data	
Startups	Excerpts referring to circular economy	Excerpts referring to circular economy	Excerpts referring to technological innovation
FT22	<p>“We are still trying to reuse these recyclable products [...] leftovers from the refrigerator waste”</p> <p>“Innovation is very strong, today there are 11 people in R&amp;D working on research and development for innovation all the time, we look at our market.”</p>	<p>“Flexível is a pioneer in adapting to the use of HFO as a blowing agent in the polyurethane industry. HFO is the ideal product to replace HCFC in a sustainable and commercially advantageous way. HFO offers high performance, low flammability, and minimal global warming potential. = take care of the planet.”</p>	<p>“We believe that innovation is in the company’s DNA. Therefore, we are investing more and more in new possibilities to be ahead of the market. / [...] we have a total structure of 6,000 m<sup>2</sup> dedicated to research, development, production and distribution of technologies by a team of specialists focused on innovation. From the information on the website, it is clear that the company invests, year after year, in new market segments and in the launch of new product lines. To innovate and contribute to the creation of new products on the market, our structure has the capacity to develop customized and specific projects, according to the client’s objective and needs. Investment in vehicles and logistics technologies is also part of the strategic growth plan. /To support Flexível’s new moment, with the consolidation of the group and the new areas of activity that are to come, we are expanding our plant in Jaraguá do Sul/SC and modernizing our processes.”</p>
FT23	<p>“We just built our factory with some principles of using sunlight, big windows, big doors and the factory’s heat-controlled ventilation system.”</p>	<p>“Use of patches, exploitation...”</p>	<p>“Consumption of foam derivatives for making women’s clothing, with sustainable appeal for retail delivery”</p>

**Table 4** (continued)

Startups	Interview excerpts		Secondary data
	Excerpts referring to circular economy	Excerpts referring to technological innovation	
FT24	<p>“The company does use biological products. .... more sustainable. .... transforms the unused product into biomass...”</p>	<p>“Data Center Usage”</p>	<p>“[...] Blue converts environmental liabilities into highly efficient bioactive compounds.”</p> <p>It uses technologies such as fertilization biotechnology to develop innovative and green solutions for the pesticide and fertilizer market. It offers solutions such as active organic ingredients for pest control and aims to improve the performance and quality of customers' crops</p>
FT25	<p>“We don't have our own factory, we outsource”</p>	<p>“We use cloud computing for data storage”</p>	<p>“We have great experience in developing innovative projects that deliver a solution to the market.”</p> <p>It uses technologies such as nanotechnology, intelligent materials and biotechnology to bring more health to Brazilians. It offers solutions such as silver nanowires and silver nanoparticles and aims at the quality and reliability of the customers. It operates in the medical, pharmaceutical, cosmetic, chemical and food sectors</p>
FT26	<p>“Use of rainwater and solar energy ...”</p>	<p>“We want to create a seal of wood recovered from reforestation before a fire or loss of area for reforestation processes. ... and also use plywood... in addition to some innovations based on bamboo”</p>	<p>“Brazilian company that innovates in wooden furniture production processes using recycled/reused wood from renovations, demolitions, wood chips and all sorts of disposed wood”</p>

**Table 4** (continued)

Interview excerpts		Secondary data	
Startups	Excerpts referring to circular economy	Excerpts referring to technological innovation	Excerpts referring to circular economy
FT27	"Proposes the development of innovative products for application in the agro-technological park based on research and, with this, intends to collaborate in the expansion of sustainable alternatives that are economically viable in the Brazilian agriculture"	"Transfers technology from Brazilian research to the farmer"	"Amino acid for agriculture"
FT28	"Create connections between players"	"Seeks to deepen the connections between digital commerce and productive sector"	"We are a bridge between university and market for development, application and pivoting of products with biological action for human health. We will use all available scientific tools to co-develop products with customers that improve people's daily lives, bringing biotechnology closer to those who really need it."
FT29	"From field equipment to traceability to the consumer's table, it promotes the productive chain"	"Accessible technologies to develop the entire agricultural chain" "Digital field notebook" "It makes enables agribusinesses to control the supply chain and manage agricultural activities and processes in one place, ensuring more quality, food safety, sustainability and traceability"	Environmental protection: we support the best use of our green area, encouraging more and more sustainable and ecological crops" "Allows the entire monitoring of stock management to be more organized, reducing time and costs."
			"We fight the COVID-19 virus. We validate, develop and improve viral and pandemic-fighting products."  "We believe in challenging the traditional model of agriculture on the planet by uniting the old with the new. Our mission is to develop people and technologies for agribusiness capable of positively affecting society through socially just solutions that are economically viable and ecologically correct"

Table 4 (continued)

Startups	Interview excerpts		Secondary data	
	Excerpts referring to circular economy	Excerpts referring to technological innovation	Excerpts referring to circular economy	Excerpts referring to technological innovation
FT30	Artificial intelligence solution specialized in identifying consumption patterns to reduce breakages and surplus	We built customized big data and business analytics solutions aimed at the most varied market segments	"Sustainability Report in 2018 and 2019"	"Delivery of shares. You and your team will receive real-time actions to make the right decision"
FT31	"Technology applied to generation of business solutions"	"Software focused on business efficiency"	"Sustainable solutions for the transport sector, clinics, corporate environments"	"Creative and innovation laboratory space for creating solutions and also avoiding mistakes"
FT32	"Bio-inputs production on the farm" "Automated bio-factories are the equipment used for multiplication of 100% stainless steel bio-inputs, customized according to your needs"	"Our on-farm bio-inputs production technology allows producers to reduce their costs by up to 40% in soy, corn, wheat, cotton, sugarcane, coffee and fruit crops"; "We deliver sterilized culture media, with an anti-foam system and bio-inputs."	"We serve more than 1,000,000 ha of crops with the integrated management system"	"We develop the entire project for your farm taking advantage of our experience with a high-standard automated industrial laboratory and our development of intellectual property."
FT33	"We are a marketplace performing with intelligence in geo-location of agricultural machinery and implements"	"Agricultural leasing by geo-location for soil preparation, planting, spraying and harvesting throughout Brazil"	"Renting and offering the entire portfolio of products related to agribusiness, with this we will take technology, productivity, profitability, and economy to the rural producer"	"We want to professionalize and innovate the agricultural machinery and implement rental market in Brazil."
FT34	"All the flavour of fresh fruit, without added sugar, honey, preservatives, colorings or any other additives"	"100% natural dehydrated fruit"	"Receive your product anywhere"	"Only separate production from packaging, with third parties"



**Table 4** (continued)

Interview excerpts		Secondary data	
Startups	Excerpts referring to circular economy	Excerpts referring to technological innovation	Excerpts referring to circular economy
FT35	<p>“The ideal environmental biological promoter for high-yield shrimp farming”</p>	<p>“Biological sanitizers for domestic and industrial use”;</p> <p>“Biotechnological solutions that improve the efficiency of animal protein production from both terrestrial and aquatic species”</p>	<p>“For animal protein producers throughout Brazil, Kayros offers biotechnological solutions that improve the efficiency in the production of animal protein from both terrestrial and aquatic species”</p> <p>“For the production of aquatic animals such as fish, shrimp, lobsters, frogs, algae and mussels, it offers a complete line of bio-remediators, accelerators and biological promoters that create and regulate all the environmental conditions in the nursery to adapt it to the specific needs of each species, promoting creation of biofilm, cleaning the tank, improving water quality, and improving the oxygenation of the environment through the reduction of toxic compounds, such as waste and other by-products, in a natural, fast, efficient and economical way”</p>
FT36	<p>“Biotechnology-based company that operates in animal reproduction for increasing productivity and reducing costs in livestock farming, especially regarding the use of artificial insemination and embryo transfer procedures as tools for technification and investment in agribusiness</p>	<p>It also has in its portfolio a pet line with products for canine reproduction, such as extenders for cooling semen and sending it over long distances, increased volume, and fresh insemination</p>	<p>“It presents products with vegetable origin (soy) instead of egg yolk (animal), preventing the spread of diseases to the freezing environment”</p> <p>“Soy lecithin, absence of egg yolk (no products of animal origin)”</p>

Table 4 (continued)

Interview excerpts		Secondary data		
Startups	Excerpts referring to circular economy	Excerpts referring to technological innovation	Excerpts referring to circular economy innovation	
FT37	<p>The app that simplifies your routine</p> <p>Practicality that adapts to your rhythm</p> <p>You choose the best time for collection or delivery. You can book in advance as the app lets you know when everything is ready!</p> <p>Change of plans?</p> <p>No problem! Just reschedule using the app</p>	<p>The first step is to choose the nearest store or the one that stands in your way</p> <p>You can filter to see only markets or restaurants and the type of delivery: drive-thru or delivery</p>	<p>In a very practical way, choose the products you want to add to the cart</p> <p>With a few clicks, you can find what you are looking for, define quantities and add or remove items</p> <p>Sections organized as in the physical store</p> <p>Find a specific product using the search tool</p> <p>Make observations to choose the product according to what you need</p> <p>Place a special order for a product not listed in the sections</p>	<p>“Order for natural products at nearby stores, picking them up or getting them delivered at home.”</p>
FT38	<p>Technology for smart buildings</p> <p>Spiri technology: air quality management</p> <p>Fluxi technology: optimization of the use of spaces</p> <p>Piscari Technology: digitalization of physical retail</p> <p>Fluo technology: water quality management</p>	<p>Our purpose is to remove barriers to interaction between people and the environments they occupy, thus enabling productive spaces that promote well-being in our daily lives</p>	<p>“Constant monitoring of the quality of indoor environments for mitigating risks of air contamination, with data collection and analysis without the need of Wi-Fi”</p>	<p>“Use of multi-parameter databases with online dashboards combined with real-time data collection environments”</p>

**Table 4** (continued)

Interview excerpts		Secondary data	
Startups	Excerpts referring to circular economy	Excerpts referring to technological innovation	Excerpts referring to circular economy
FT39	"It monitors the temperature and humidity of any perishable product in real time and at all stages of the distribution chain"	"Reports in accordance with current legislation, facilitating processes during audits" "Real-time monitoring. Online monitoring for fixed points serves both environments, chambers, freezers, shelves or any fixed structure that needs evaluated parameters. It can be used with internet connection, Wi-Fi network, cable or even GPRS"	"Temperature and humidity monitoring of any perishable product in real time. (Fixed Points, Transportation)"
FT40	"Solutions to prolong the life of fruits, vegetables and vegetables" "To improve the producer's yield, efficiency, productivity and profitability"	"For retailers, innovative technologies to reduce food waste on the shelves"	"Develops a product that, when placed in the middle of food (blue strawberry – by absorbing the ethylene gas exhaled by them), triples their duration."

**Table 4** (continued)

Startups	Interview excerpts		Secondary data
	Excerpts referring to circular economy	Excerpts referring to technological innovation	
FT41	<p>"We have the project to purchase solar energy plates and we will achieve a 75% reduction in energy costs"</p> <p>"Due to the development of the chemical products we use, there is a reduction in processes and contact with solvents"</p>	<p>"Our processes make it possible to save resins and paints, which generate a good reduction in costs. We developed an automated sander that made the work much easier. In this activity, we reduced the number of employees by 50%."</p>	<p>"Focus on sustainable wood and demolition wood."</p>

**Table 4** (continued)

Startups	Interview excerpts		Secondary data
	Excerpts referring to circular economy	Excerpts referring to technological innovation	
FT42	<p>“Our wood residues are used in the group’s refrigerator and in the boiler that heats water to pluck the birds”</p> <p>“The wood shavings are sold in m<sup>3</sup> to aviaries to cover the floor. The residual wood goes to the fertilizer company, to our fridge and to feed the boilers. The paints must be collected by CETRIC, which changes for the disposal of this residue”</p>	<p>“We innovated in the finishing standards, which after the spread of our furniture were incorporated by other factories throughout most of Brazil. It was an application we made. No one had it, just us. Now everyone uses it. We also replaced plastic handles with wooden handles of the same color as that of the furniture.”</p> <p>“Our modern machinery comes from Italy and optimizes the cutting of wood and there is even a more recent one that reads the wood and detects where there are imperfections and, according to the knots and cracks, optimizes the cut of the pieces. It makes a reading with cameras and minimizes losses”</p>	<p>Excerpts referring to circular economy</p> <p>“All the residues from our production go through a rigorous recycling process and our raw material is just reforestation wood, which comes from sustainable forests.”</p> <p>Excerpts referring to technological innovation</p>

**Table 4** (continued)

Startups	Interview excerpts		Secondary data
	Excerpts referring to circular economy	Excerpts referring to technological innovation	
FT43	<p>“Our wood residues are cut, packaged and sold to wood-fired pizzerias. Part of the wood not good for this is used by a company that produces fertilizers, in the boiler and the sawdust chips, the wood shavings are sold to be used in aviaries. We practically have no waste to be disposed of”</p> <p>“We purchased solar energy plates and achieved a 75% reduction in energy costs.”</p>	<p>“The difference is that it is a more durable product”</p>	<p>“Durable products”</p> <p>“Green chemistry”</p>
FT44	<p>“My term paper was on process optimization and we eliminated 38% of the losses. There was also the acquisition of an Italian cutting machine that, through very precise software, reduces the losses with part cuts to almost zero.”</p> <p>“We still had incentives of a government program called Brasil Mais Produtivo and achieved a 68% reduction in waste. There was also an optimization of the movement of the parts and this generated greater efficiency in the assembly”</p>		<p>“Concern with renewable energy and cost reduction”</p> <p>“Focus on customer satisfaction with innovations in the architecture industry”</p>

**Table 4** (continued)

Interview excerpts		Secondary data	
Startups	Excerpts referring to circular economy	Excerpts referring to technological innovation	Excerpts referring to circular economy innovation
FT45	<p>“We focus on reducing losses. Our plates are obtained from certified companies”</p>	<p>“State-of-the-art technological equipment. Our parts come out of the machines cut and are already labeled, indicating the name of the customer, environment, furniture, and part. This eliminates assembly errors. We can obtain a high production with low labour. We can also design projects by literally knowing how the customer wants them. Our machines allow this.”</p> <p>/ “Yes, both in terms of productivity and innovative concepts of architecture and design”</p>	<p>“Re-signify wood”</p> <p>“Modern and sustainable architecture”</p>
FT46	<p>“Agility, practicality and customer satisfaction are our priorities”</p>	<p>“Before, we took the parts to assemble everything on site, but now we take what is already assembled because it reduces the time spent with the customer and optimizes the work”</p>	<p>“Machined and prefabricated blocks”</p> <p>“Focus on functionality, natural lighting and spaciousness”</p>

Table 4 (continued)

Startups	Interview excerpts		Secondary data
	Excerpts referring to circular economy	Excerpts referring to technological innovation	
FT47	<p>“We thought all about this as a sustainable issue, right, rainwater, solar energy” [company headquarters]</p>	<p>“Man, we have a gamification scheme here that is interesting, people like it a lot, this thing about getting points to do good is something very different from other applications”</p>	<p>Excerpts referring to circular economy innovation</p> <p>With every purchase you earn points and can exchange them for products, services, and coupons!</p>
FT48	<p>“...fermentation of organic compounds in the transformation of cooking gas”</p> <p>“In addition to extracting surprising flavours from the combination of plants, we use traditional techniques such as ‘cachaça preservation’, ‘anaerobic fermentation’, ‘live feeding’, grain germination and a combination of other techniques that make our products deliciously nutritious and unique.”</p>	<p>“What we brought as an innovation is the agricultural production model, which is highly scalable with several associations of micro minors, family farming. (...) The other innovation is the use of these plants themselves, which have different flavours, right?, but the techniques that we use, we are also patenting some, right, so it is a matter of innovation also in the processing technique”</p>	<p>100% plant-based, rich in nutraceutical properties and revolutionary PANC are rich in nutrients and because they have therapeutic benefits (as in diabetes care, blood pressure, hormonal regulation...) they are seriously recommended by many nutritionists</p> <p>“We managed to combine haute cuisine, nutraceutical ingredients, environmental and social awareness in a unique and pioneering product line (...) Respecting our social and environmental values of species preservation and maintenance of native areas, such as the Atlantic Forest (...) It's sustainable. It's bio-diverse. (...) More than 80% the ingredients are local/traceable”.</p>



**Table 4** (continued)

Interview excerpts		Secondary data	
Startups	Excerpts referring to circular economy	Excerpts referring to technological innovation	Excerpts referring to circular economy
FT49	<p>“We try to apply energy recovery as a by-product to biogas generation”</p>	<p>“Technology to treat highly complex effluents and thus looking at a market aimed at industrial effluents, which therefore requires treatment technologies because conventional ones normally require a lot of space and even limit the expansion of companies, right, depending on the treatment extension”.</p>	<p>“Brings solutions for the treatment of effluents, sewage and slurry, working on the project, product, implementation and operation of the system”</p>
FT50	<p>“We encourage the use of biodegradable packaging, whether cardboard or paper, many have already changed to paper, craft paper”</p>	<p>“We are looking, from the perspective of the consumer, to make them have a shopping experience, even when buying small things, with a structure of large companies, right, so with this purchase technology plus logistics services, we seek to provide services that he/she would have from any large company.”</p>	<p>The electrocoagulation and electro-flocculation process consists of bringing an electrical current adjusted through metallic electrodes to the effluent, causing reactions, where the coagulant is generated <i>in loco</i> through electrolytic oxidation of the anode, thus obtaining control in the release of the coagulating agent and forming flakes that will float or settle down</p> <p>Benefits</p> <ul style="list-style-type: none"> <li>• Immediate efficiency;</li> <li>• Low sludge generation;</li> <li>• Reduced deployment area;</li> </ul> <p>“We are an online fair of artisanal, local, typical, organic and agro-ecological food producers. Cultivating a better world, valuing the small producer, local food production, diversity, regional cultures and conscious consumption is what moves us daily”</p>

**Table 4** (continued)

Startups	Interview excerpts	
	Excerpts referring to circular economy	Excerpts referring to technological innovation
FT51	<p>“Organic, vegan and natural products”</p> <p>“Online sales platform. “The fact that many people can’t go to fairs doesn’t mean they don’t want to have access to organic food from local cooperatives. Due to lack of time, they end up settling for what is more affordable, like going to the nearest supermarket. The cool thing about offering a fully online service is to show people that they can have access to fresh food. And, by making a purchase through our website, they will have a wide variety of products delivered in the comfort of their homes, or even at work.”</p>	<p>Secondary data</p> <p>Excerpts referring to circular economy</p> <p>Excerpts referring to technological innovation</p> <p>“Organic production does not harm the soil, water or vegetation, being totally sustainable and very beneficial to the environment”</p> <p>E-commerce with the option of weekly or biweekly subscriptions</p>

quantitative perspective. Studies on the perspective of networks, synergy and integration of strategic players are also welcome to understand sustainability between systems. Finally, we suggest that similar studies should analyse medium-sized organizations.

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## Declarations

**Conflicts of interest** The authors whose names are listed immediately below certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript. The authors whose names are listed immediately below report the following details of affiliation or involvement in an organization or entity with a financial or non-financial interest in the subject matter or materials discussed in this manuscript. Please specify the nature of the conflict on a separate sheet of paper if the space below is inadequate.

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