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A digitally enabled circular economy for mitigating food waste: Understanding innovative marketing strategies in the context of an emerging economy

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ABSTRACT

Within the context of the circular economy, this article analyses how supermarkets can reduce food waste by implementing appropriate marketing strategies underpinned by digital technologies, such as Big Data predictive analytics. Little is currently known of the potential role of the emerging digital technologies in furthering the sustainability of supermarket chains in emerging economies. Thus, an original multiple case study has been conducted, involving six supermarket chains operating in Brazil and six farming distributors that produce fruit and vegetables (F&V). The findings show that actions towards food waste reduction based on the principles of the circular economy begin with an understanding of F&V stages of deterioration. Through such an understanding, a number of actions can be undertaken to reduce the negative effects of this deterioration. These include (among others) the management of prices, sales, operations, and purchases, all of which can be underpinned by such technologies as sensors and augmented reality in order to manage dynamic pricing, storage, and item display. The findings contribute to demonstrating how digital technologies can help supermarkets' marketing departments in driving corporate sustainability while also benefiting both consumers and societal well-being.

1. Introduction

The reduction of food waste is considered vital for successfully implementing the principles of the circular economy (Pagotto and Halog, 2016). In Latin America and the Caribbean (LAC) alone, over 30 million people could be fed with the food wasted by local retailers/supermarkets; that is, 64% of those suffering from hunger in the region (FAO, 2020). Brazil, for instance, is one of the ten largest producers of food waste in the world. Approximately 30% of all food produced (roughly 40,000 tons) goes to waste (FAO, 2020). In terms of F&V, the loss is estimated at 9.5 tons per week, and is predominantly composed of bananas, papayas, tomatoes, peppers, and lettuce (Santos et al., 2020). The financial losses from F&V disposal are estimated at USD 510 million per year.

However, the role played by recently developed digital technologies in unlocking sustainability-related actions in supermarket chains in emerging economies has been somewhat underexplored. Waste from the final stages of food supply chains causes almost 60% of the total climatic impact of food waste. This is due both to the large quantities of food lost at this stage as well as the more significant effects created per kilogram of product during this phase of the process (Beretta et al., 2017). F&V represent the most commonly discarded items. In Sweden, for instance, 85% of the total food wasted by supermarkets were F&V (Scholz et al., 2015), thus demonstrating the importance of this consideration.

A portion of F&V waste in supermarkets can be attributed to purchasing problems, calculation of quantities, the frequency of resupplying (Filimonau and Gherbin, 2017; Santos et al., 2020; Teller et al., 2018), communication problems between suppliers and retailers

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(Richter and Bokelmann, 2016), and the consumer propensity for rejecting imperfect items. Imperfect F&V tend to be rejected by customers, leading to their disposal, despite the application of discounts.

Environmental marketing may be one strategy with which to address these aforementioned problems (Chen et al., 2015). Previous findings indicate that ecological marketing positively affects companies' operational and commercial performance, which in turn improves their financial results (Fraj-Andrés et al., 2009). Despite the size and power of the food supply chain, the orchestration of large market actions by supermarkets has received scant academic attention. For instance, while the management of price-quality-sustainability compensation has been mentioned (e.g., Choi and Ng, 2011; Ross and Milne, 2020) more study is needed to comprehensively understand this aspect. The use of digital technologies may also be used to solve problems related to food waste. These technologies include using Big Data to analyse large volumes of data (Iqbal et al., 2020; Jabbour et al., 2019; Kumar et al., 2019) or AI to support decision-making (Goli et al., 2019; Manita et al., 2020). The Internet of Things (IoT) can also help reduce waste from the food industry (Jagtap et al., 2019; Jagtap and Rahimifard, 2019). In terms of F&V waste, these same technologies could also be used to improve marketing or purchasing management.

Considering that F&V are the most discarded items in supermarkets, and that these companies are the link between agricultural distributors and final consumers, the following research question is proposed:

RQ: How can proactively sustainable supermarkets located in a developing country reduce the wastage of fruits and vegetables?

Investigating marketing strategies to be readily applied by supermarkets would likely reduce the waste of F&V still fit for human consumption, thereby minimising the unnecessary depletion of scarce natural resources (da Costa Maynard et al., 2020). Such reductions may also help 'end hunger, achieve food security and improved nutrition and promote sustainable agriculture' (UNDP, 2016), as well as meet the UN's sustainable development goals (SDGs) (Giannetti et al., 2020; UNDP, 2018). The research question will be addressed through a multiple case study with six supermarket chains operating in Brazil and six farmers' distributors who provide these retailers with F&V.

The investigation of the role of supermarkets in F&V waste will be based on the Natural Resource Dependence Perspective (NRDP) (Tashman, 2020). NRDP extends the Resource Dependence Theory (RDT) (Pfeffer and Salancik, 1978) into the natural world by explaining how organisations directly depend upon ecology for natural resources and face uncertainty because of the dynamics of socio-ecological systems. We opted for the NRDP as a theoretical background because of how production, transport, handling, marketing, and even F&V disposal, all makes use of scarce ecological resources. This paper projects that the improved use of these resources may be made possible by increasing the consumption of F&V that would otherwise be discarded. However, little is currently known about how the use of these resources could be enhanced.

The findings of this study contribute to the existing literature by highlighting how emerging technologies can help effectively manage the ever-increasing uncertainty associated with dependence on natural resources (Deng and Gibson, 2019; Tashman, 2020; Zhan et al., 2019), how to direct technological progress towards sustainable purpose (Capasso et al., 2019; Centobelli et al., 2020; Wiener et al., 2020), and how retail managers can enhance their organisations' strategy and positively affect consumers' (and societal) well-being (Hofenk et al., 2019; Painter-Morland et al., 2017; Schaltegger and Hörisch, 2017). Other contributions include shedding light on how marketers can focus on consumers' positive traits in order to encourage sustainable consumption (de Moraes et al., 2020; Song and Kim, 2018) and influence sustainable choices (Ross and Milne, 2020).

The remainder of this article is structured as follows. The next section describes its theoretical foundations in terms of the waste generated by supermarkets and customers, as well as the use of digital technologies in mitigating this. The research method is then described, covering the framing, and description of the data collection and analyses. Next, we present our findings regarding how supermarkets can try to reduce food waste. Finally, the study's theoretical and managerial implications are discussed, along with its limitations and our suggestions for future research.

Table 1
. Causes of food waste in supermarkets.

Cause	Summary	References
Operational problems	Greater variety and quantity of items offered by large supermarkets.	(Filimonau and Gherbin, 2017; Teller et al., 2018)
	Problems in refrigeration, storage, transportation, and handling of items.	(Filimonau and Gherbin, 2017; Jagtap and Rahimifard, 2019; Kumar et al., 2020; Santos et al., 2020)
	Store managers having little autonomy.	(Filimonau and Gherbin, 2017)
	Lack of skilled personnel or effective leadership.	(Mithun Ali et al., 2019; Yetkin Özbük and Coşkun, 2020)
	Failure to observe best management practices.	(Lebersorger and Schneider, 2014; Yetkin Özbük and Coşkun, 2020)
Resupply problems	Problems regarding the size of purchases and the frequency of deliveries.	(Filimonau and Gherbin, 2017; Santos et al., 2020; Teller et al., 2018)
	Lack of commitment to environmental issues from suppliers.	(Filimonau and Gherbin, 2017)
	Communication problems within the supply chain.	(Richter and Bokelmann, 2016)

2. Theoretical background

2.1. The circular economy, food waste, and supermarkets

In the context of most optimally adhering to the principles of the circular economy, it is essential to recognise that food waste is a major contemporary issue (Pagotto and Halog, 2016), and one which supermarkets seriously contribute to. Analysis of the relevant literature indicates ways in which retailers can also mitigate this waste. Details of a number of such problems in the retail sector and potential mitigation strategies are presented below.

Within the retail sector, the primary causes of waste can be attributed to problems in the management of operations and store resupplies. Problems related to the former may be associated with the organisation's size. The literature indicates that larger supermarkets, with their increased variety and quantity of items, tend to have higher levels of food waste (Filimonau and Gherbin, 2017; Teller et al., 2018). Waste can also arise from problems of infrastructure or hygiene and food handling, such as in the refrigeration, processing, transport, and receipt of products (Jagtap and Rahimifard, 2019; Kumar et al., 2020; Santos et al., 2020). These problems can be aggravated by the particular store manager's lack of autonomy (Filimonau and Gherbin, 2017), a scarcity of skilled personnel or effective leadership (Mithun Ali et al., 2019), and the non-adherence to the best management practices used among other, similarly-structured organisations (Lebersorger and Schneider, 2014).

Problems with managing resupply tend to be related to the retailer's focus. According to the literature, supermarkets prioritise bulk purchasing, which creates issues regarding the size and frequency of deliveries (Filimonau and Gherbin, 2017). This type of purchasing allows many bargains to be offered to the consumer, as well as a heightened level of regular demand experienced (Santos et al., 2020; Teller et al., 2018). Resupply problems seem to be aggravated by suppliers' lack of commitment to positive environmental action (Filimonau and Gherbin, 2017) or by poor communication between all actors in the supply chain (Richter and Bokelmann, 2016). Table 1 summarises the causes of food waste within retail.

Table 2
. Mitigation strategies for food waste in retail.

Mitigator	Summary	References
Commercial management	Selling surplus food.	(Teigiserova et al., 2020)
	Reduction in the variety of products offered.	(Teller et al., 2018)
	Offering items in line with customer demand.	(de Hooge et al., 2018; Willersinn et al., 2017)
	Selling to people who regularly cook and shop.	(de Hooge et al., 2017)
	Price reduction near the end of the consumption point.	(Filimonau and Gherbin, 2017; Santos et al., 2020; Teller et al., 2018)
	Use of communication to indicate the stage of the food or remind customers of their responsibility to combat food waste.	(Aschemann-Witzel et al., 2019; Lebersorger and Schneider, 2014; Loebnitz et al., 2015; Teller et al., 2018; Thompson et al., 2018)
	Use of opinion-leaders to encourage consumption of sub-optimal items.	(Aschemann-Witzel et al., 2019; Filimonau and Gherbin, 2017)
Operational and supply management	Improvements to transport, handling, and storage.	(Krishnan et al., 2020; Mena et al., 2011; Papargyropoulou et al., 2014; Santos et al., 2020)
	Allocating more time/ resources to workers who handle F&V.	(Mattsson et al., 2018)
	Flexibility of prevention actions, as used in alternative food networks.	(Poças Ribeiro et al., 2019)
	Increase in stock turnover or reduction in quantities purchased.	(Eriksson et al., 2014)
	Promotion of cooperation in the chain, exchange of information, arrangement of joint promotions, or improvement in forecasts and orders in the chain.	(de Moraes et al., 2020; Halloran et al., 2014; Mena et al., 2011; Wesana et al., 2019; Wu and Huang, 2018)
	Requirement that suppliers adjust their sales to reduce returns.	(Spada et al., 2018)
Social actions	Donations or incentives to encourage consumption by employees.	(Bilska et al., 2018; Filimonau and Gherbin, 2017; Lebersorger and Schneider, 2014; Santos et al., 2020)
	Partnerships with food aid organisations.	(Holweg et al., 2016; Pirani and Arafat, 2016)
	Use of technology to increase circularity.	(Ciulli et al., 2019)

The literature also discusses a set of retail waste reduction mitigators. For the purposes of this article, these mitigators have been categorised into commercial, operational, and supply management.

The mitigation actions associated with commercial management include selling surplus food (Teigiserova et al., 2020) and reducing the variety of products offered, concentrating instead on such products with repeatedly strong sales (Teller et al., 2018). For this type of reduction to be successful, consumer perception of the associated risks and inconveniences must first be taken into consideration (Willersinn et al., 2017), as well as customers' personal standards, and the consequences of making sub-optimal items available to the customer, e.g., competition, price, costs, logistics, etc. (de Hooge et al., 2018). In addition to these actions, the literature indicates that reducing waste requires a reduction in product prices near the end of their consumption point (Filimonau and Gherbin, 2017; Santos et al., 2020; Teller et al., 2018). The commercial actions indicated here can be complemented by well-orchestrated communication with customers. This communication should clarify the stage of the food available and its acceptability to eat, as well as the retailer's efforts to combat waste (Aschemann-Witzel et al., 2019; Thompson et al., 2018). The literature indicates that placing stickers on products and shelves can increase customers' awareness of their responsibilities in order to leverage sales that reduce food waste (Lebersorger and Schneider, 2014; Teller et al., 2018). Additionally, supermarkets can develop campaigns supported by social opinion-makers; for example, influential people in the community can demonstrate their habit or desire for purchasing sub-optimal fresh food (Aschemann-Witzel et al., 2019; Filimonau and Gherbin, 2017). The literature also suggests targeting consumers who regularly buy fresh items for cooking (de Hooge et al., 2017).

In parallel with these commercial mitigation actions, supermarkets must also enhance their operational and supply management practices. The improvement of operational management focuses on controlling food surpluses (Pirani and Arafat, 2016), as well as considering how best to optimise infrastructure, management, and conservation (Mena et al., 2011; Santos et al., 2020). The managers of large supermarkets could assess the possibility of increasing the flexibility of the actions conducted – as in the case of alternative food networks. In such chains, there appears to be lower levels of waste than in traditional retail outlets (Poças Ribeiro et al., 2019).

The literature suggests that F&V waste can be most significantly reduced at the pre-store stage (Eriksson et al., 2014) – confirms the importance of managing both internal and external supplies. Regarding the former, supermarkets can improve their decision-making regarding the quantities of items purchased, or their increased rotation (Eriksson et al., 2016). To improve the latter, supermarkets can facilitate greater cooperation in their supply chains (Halloran et al., 2014; Wesana et al., 2019; Wu and Huang, 2018), encourage the exchange of information, develop joint promotions, improve the chain's forecasting and orders (Mena et al., 2011), require that suppliers of items with short shelf lives (between 30–50 days) adjust their sales terms in order to reduce future returns (Spada et al., 2018), leverage their power over first-tier suppliers (Devin and Richards, 2018; Spada et al., 2018), or introduce other organisations into their chains that can make use of foods that are no longer likely to be sold (Brancoli et al., 2017). Supermarkets may also engage in improving the allocation of resources to transportation and handling professionals (Krishnan et al., 2020).

Social actions can also mitigate waste. These actions include incentives for consumption by employees (Santos et al., 2020) or food donations to the neediest members of society (Bilska et al., 2018; Filimonau and Gherbin, 2017; Lebersorger and Schneider, 2014). These actions require partnerships with food aid organisations (Holweg et al., 2016; Pirani and Arafat, 2016) and the use of technological resources to provide information that increases circularity (Ciulli et al., 2019). Table 2 summarises the possible mitigators of waste in supermarkets.

2.2. *Waste generated by consumers*

Our literature review indicates that the causes of consumer-generated food waste generated can be divided into three categories: ignorance, consumerism, and preferences/habits. The mitigation of these causes can reduce the most significant damage caused by the waste generated in the chain's final stages (Betz et al., 2015).

Consumers' general lack of knowledge contributes to the generation of waste. Moreover, this knowledge deficiency seems to apply to several age groups. The literature indicates that people are typically unaware of the importance of preventing food waste (Ilakovac et al., 2020; Mattar et al., 2018; Schanes et al., 2018), the risks (real or imagined) associated with consuming sub-optimal food (Loebnitz and Grunert, 2018), and the impacts of food waste (Di Talia et al., 2019; Mattar et al., 2018).

Households with a convenience-based lifestyle increase the generation of food waste (Parizeau et al., 2015). Food waste generation stends to be higher in large households with higher levels of employment, income, and education (Ilakovac et al., 2020; Mattar et al., 2018), or among those who continuously demand perfect food (Tromp et al., 2016). Consumerist habits can also arise from collective lacks of discipline. This type of indiscipline was observed in those families who purchased food in groups (Diaz-Ruiz et al., 2018; Lee, 2018). 'Attractive'

Table 3
. Causes of food wasted by supermarket customers.

Cause	Summary	References
Ignorance	Importance of waste prevention.	(Ilakovac et al., 2020; Mattar et al., 2018; Schanes et al., 2018)
	Risks or quality of sub-optimal food.	(Loebnitz and Grunert, 2018; Raak et al., 2017)
	Different impacts arising from waste.	(Di Talia et al., 2019; Mattar et al., 2018)
Consumerism	Convenience-based lifestyle.	(Parizeau et al., 2015)
	Higher levels of employment, income, and demand for better products.	(Ilakovac et al., 2020; Mattar et al., 2018; Tromp et al., 2016)
	Collective indiscipline in family purchases.	(Diaz-Ruiz et al., 2018; Lee, 2018)
	Susceptibility to 'attractive' retail offers.	(Abdelradi, 2018; Ilakovac et al., 2020; Lee, 2018; Mattar et al., 2018; Mondéjar-Jiménez et al., 2016; Ponis et al., 2017; Zupancic and Mullner, 2008)
Preferences/habits	Freshness, appearance, and longevity of food.	(Teller et al., 2018)
	Greater product offerings.	(Filimonau and Gherbin, 2017; Teller et al., 2018)
	Lack of care in handling.	(Santos et al., 2020)

retail offers also induce consumerism (Lee, 2018). These offers lead consumers to purchase unnecessary items in order to capitalise upon promotions (Ilakovac et al., 2020; Mattar et al., 2018; Ponis et al., 2017). This context suggests a worrying future trend, as marketing and sales actions also lead young people to make unnecessary purchases (Abdelradi, 2018; Mondéjar-Jiménez et al., 2016).

Customers' preferences or buying habits also increase food waste. This is the case with a fixation on the freshest products, which look more aesthetically appealing and have a longer shelf life (Teller et al., 2018). These preferences seem to be valued more highly among customers with higher expectations, since these customers demand a higher quality and more significant offers (Filimonau and Gherbin, 2017; Teller et al., 2018). Consumers' habits can also increase waste. For instance, a lack of care in handling the most sensitive products can cause damage, leading to an item's waste (Santos et al., 2020). Table 3 indicates the causes of customer-generated food waste.

Successful mitigation of consumer-generated food waste requires attention to be not only paid to the messages conveyed to consumers, but also how these are disseminated.

Messages aimed at mitigating consumer-generated food waste may focus on such aspects as environmental awareness (Katt and Meixner, 2020; Loebnitz et al., 2015), ecological benefits (Abdelradi, 2018; Neubig et al., 2020), understanding 'best before' dates on food items (Thompson et al., 2018), the increased valorisation of social norms that reject waste (Stangherlin and de Barcellos, 2018), or instilling feelings of guilt concerning the wasting of food (Mattar et al., 2018; Richter and Bokelmann, 2018). Additionally, these messages should encourage disciplined shopping behaviour (e.g., buy only what you need, make a list of what you need), valuing the conscious use of food (Diaz-Ruiz et al., 2018; Hebrok and Heidenstrøm, 2019; van der Werf et al., 2020), and also present a positive image of sub-optimal foods (Louis and Lombart, 2018). Other alternatives include providing information about food waste in schools – especially for adolescents (Di Talia et al., 2019) – or teaching people how to effectively assess the quality, use, and appropriate portion sizes of food (Hebrok and Heidenstrøm, 2019).

The messages presented above can be disseminated to supermarket customers by a variety of different means. Among these are television campaigns, religious discourses (Abdelradi, 2018; Wakefield and Axon, 2020), consumer-to-consumer communications (Di Talia et al., 2019; Kim et al., 2020; Närvänen et al., 2018), the inclusion of the topic in school curricula (especially for adolescents), and through mobile applications (Di Talia et al., 2019). Retailers can also contribute to this reduction by delivering messages or offering proposals that positively influence their customers' purchasing decisions (Lee, 2018; Mondéjar-Jiménez et al., 2016) or improve the design of their price tags (Helmert et al., 2017). Table 4 presents the alternatives for mitigating consumer-generated food waste.

Table 4
. Mitigation strategies for waste generated by customers.

Mitigators	Summary	References
Awareness focus	Benefits of not wasting food or environmental awareness.	(Abdelradi, 2018; De Toni et al., 2018; Katt and Meixner, 2020; Loebnitz et al., 2015; Neubig et al., 2020)
	Exploring people's feelings of guilt or their valuing of social norms.	(Mattar et al., 2018; Richter and Bokelmann, 2018; Stangherlin and de Barcellos, 2018)
	Disciplined buying behaviour and conscientious use of food.	(Diaz-Ruiz et al., 2018; Hebrok and Heidenstrøm, 2019; van der Werf et al., 2020)
	Enhancement of the positive image of sub-optimal items.	(Louis and Lombart, 2018)
	Evaluation of quality, storage, portion sizes, and food use.	(Hebrok and Heidenstrøm, 2019)
	Understanding food's longevity.	(Thompson et al., 2018)
	Approaching the theme in schools.	(Di Talia et al., 2019)
Disclosure of messages	Media campaigns or religious speeches.	(Abdelradi, 2018; Wakefield and Axon, 2020)
	Consumer-to-consumer communications.	(Di Talia et al., 2019; Kim et al., 2020; Närvänen et al., 2018)
	Enhanced price tag design.	(Helmert et al., 2017)
	Use of mobile applications.	(Di Talia et al., 2019)
	Marketing actions by retailers to influence the purchasing decision of supermarket customers.	(Lee, 2018; Mondéjar-Jiménez et al., 2016)

2.3. Digital technologies and the mitigation of food waste

There seems to be a considerable amount of information on the large quantities of food wasted in the final tiers of the supply chain (Beretta et al., 2017; Scholz et al., 2015), which can in turn be analysed using Big Data analytics (Iqbal et al., 2020). This analysis can support future decision-making (Fosso Wamba et al., 2015; Manita et al., 2020). The existing literature presents a number of studies dealing with the feasibility of adopting Big Data to improve environmental sustainability (Dubey et al., 2019, 2016; Sivarajah et al., 2019). Other studies have investigated the use of Big Data to assess the benefits provided by enterprise resource planning (ERP) software (Zhang et al., 2017)¸ the aggregation of value between buyers and suppliers (Elia et al., 2019), the circular economy (Jabbour et al., 2019), operations management (Gölzer and Fritzsche, 2017; Matthias et al., 2017; Melnyk et al., 2018), forecasting demand (Kumar et al., 2019), and Industry 4.0 (Ardito et al., 2019; Betz et al., 2019).

Organisations can deploy AI to manage large volumes of information. Indeed, some authors have posited that AI could well replace human intelligence in repetitive activities or in supporting decision-making (Goli et al., 2019; Manita et al., 2020). AI has been used in the analysis and implementation of various renewable energy initiatives (Jha et al., 2017) for calculating a product portfolio's risk (Goli et al., 2019), analysing trading strategies in power markets (Moreno, 2009), and leveraging the use of technologies in manufacturing (Gershwin, 2018; Kusiak, 2018).

Machine learning (ML) uses information to make decisions in real-time; e.g., for identifying patterns in large volumes of data or for aligning demand with supply (Gružauskas et al., 2019; Nilashi et al., 2019; Zhang et al., 2019). Combined with AI, ML can support

Fig. 1. . Research model for improving the use of scarce natural resources through a digitally enabled circular economy.

decision-making with less human involvement (Gutierrez et al., 2015; Jha et al., 2017; Vitorino de Souza Melaré et al., 2017). ML has been used for measuring sustainability (Nilashi et al., 2019), in forecasting or sales management (Gurnani et al., 2017; Syam and Sharma, 2018), for improving the provision of industrial services (Kamp et al., 2017), evaluating sales forecasts (Gružauskas et al., 2019), and improving the digitisation of the retail sector (Simchi-Levi and Wu, 2018).

The IoT connects data, equipment, processes, and people to produce information that enhances decision-making (Ardito et al., 2018; Jagtap and Rahimifard, 2019). As an example, the IoT has been used to determine the status of contents inside a refrigerator, and then notify the user about the condition and quantity of food via an SMS or email (Nasir et al., 2018). Related studies have considered the possibilities of adopting the IoT for reducing food wastage in restaurants (Wen et al., 2018), barriers to the IoT in food retail supply chains (Kamble et al., 2019), its use in warehouse management systems for smart logistics (Lee et al., 2018), in reducing food industry waste (Jagtap et al., 2019; Jagtap and Rahimifard, 2019), for understanding the critical factors for the value creation process in the IoT industry (Metallo et al., 2018), for improving waste collection (Gutierrez et al., 2015), and on the IoT's possible contributions to sustainability in supply chains (Manavalan and Jayakrishna, 2019). The IoT makes use of sensors, which are devices used to collect data (de Sousa Jabbour et al., 2018; Lu and Weng, 2018; Vitorino de Souza Melaré et al., 2017; Wen et al., 2018; Zhang et al., 2019).

2.4. Analysis model

The disposal of wasted F&V in supermarkets increases the unnecessary use of scarce natural resources, and wastes items that could be used to feed those with less purchasing power. As explored above, the causes of this waste are related to both supermarket management problems and consumer attitudes. Some mitigators have also been identified as potential methods with which to reduce waste related to these causes. Another line of thought suggests that digital technologies could contribute to mitigating the remaining problems. This study proposes that understanding the causes of supermarket food waste will reveal options for mitigating F&V waste, thus allowing for a more efficient use of scarce natural resources (the focus of the NRDP). In order to formulate the research model for this study, we considered the sequence presented in Fig. 1 (below).

3. Methodology

3.1. Research design

Given that our research focus is on how supermarkets can reduce F&V waste, we opted for a qualitative approach. The multiple case study methodology is both credible and robust because it allows for individual case analysis and in-depth scrutiny between cases (Eisenhardt, 1989; Patton, 2002). Supermarkets were selected as the sample based on the consideration that large quantities of food are lost at this point in a food supply chain. Indeed, in particular, the waste of F&V at the final stages of food chains are responsible for almost 60% of the total climate impact of food waste (Beretta et al., 2017).

Based on the above literature review, we selected a coding approach for the qualitative text analysis stage (Saldaña, 2015), founded in grounded theory (Corbin and Strauss, 1990). The coding procedure was performed using ATLAS.ti software. The coding itself was used to uncover the causes of F&V waste, as well as its mitigators (as described above).

Table 5
. Profile of supermarkets surveyed.

Supermarket	Region of operation	2018 Revenue (USD)	Details
Supermarket A	Global	0.15 billion	27 branches
Supermarket B	Global	0.15 billion	23 branches
Supermarket C	Brazil	1.90 billion	68 branches
Supermarket D	Brazil	0.29 billion	41 branches + 1 e-commerce platform
Supermarket E	Brazil	7.00 billion	438 branches
Supermarket F	Brazil	0.45 billion	47 branches

Table 6
. Profile of supermarket respondents.

Company	Position	Code	Experience
Supermarket A	Regional Manager	RMSA	23 years
	Store Manager	SMA1	17 years
	Store Manager	SMA2	24 years
	Store Manager	SMA3	20 years
Supermarket B	Regional Manager	RMSB	18 years
	Store Manager	SMB1	18 years
	Store Manager	SMB2	22 years
	Store Manager	SMB3	25 years
	Store Manager	SMB4	27 years
Supermarket C	Regional Manager	RMSC	20 years
	Store Manager	SMC1	17 years
	Store Manager	SMC2	19 years
Supermarket D	Regional Manager	RMSD	22 years
	Store Manager	SMD1	19 years
	Store Manager	SMD2	21 years
Supermarket E	Regional Manager	RMSE	17 years
	Store Manager	SME1	19 years
Supermarket F	Regional Manager	RMSF	19 years
	Store Manager	SMF1	24 years

Table 7
. Profile of F&V distributors surveyed.

F&V distributor	Founded in	Main customers
Distributor 1	1985	Supermarkets
Distributor 2	2001	Supermarkets and small restaurant chains
Distributor 3	1999	Supermarkets and local F&V resellers
Distributor 4	2010	Supermarkets
Distributor 5	2004	Supermarkets and industrial restaurants
Distributor 6	2013	Supermarkets

Table 8
. Profile of F&V distributor respondents.

F&V distributor	Position	Code	Experience	Interview duration
Distributor 1	General manager	D1	15 years	67 min
Distributor 2	General manager	D2	13 years	53 min
Distributor 3	Owner	D3	21 years	45 min
Distributor 4	Owner	D4	16 years	67 min
Distributor 5	General manager	D5	26 years	60 min
Distributor 6	Owner	D6	17 years	43 min

3.2. Data collection

We began the data collection process by defining the profile of companies to be investigated. We used a stratified purposeful sampling method to select the supermarkets we would focus upon (Palinkas et al., 2015; Patton, 2002). Six supermarkets that take actions to reduce F&V losses were selected. The number of cases selected falls within the appropriate range as indicated in the literature for this type of study – that is, 6 to 10 (Yin, 2009). Table 5 presents the main characteristics of the supermarkets investigated.

On this basis, the selected supermarkets were asked to indicate those employees responsible within their organisation for processes focused on reducing food waste. All of the nominated employees agreed to participate in the survey. These respondents also included those employees who held decision-making power over waste mitigation actions in local F&V supply chains. The profile of interviewees is shown in Table 6.

These respondents further indicated 12 distributors of farm produce involved in waste reduction actions. 10 of these distributors sell to all the supermarkets investigated. The researchers then contacted these 10 distributors, of which 6 agreed to participate. This number of distributors is within the appropriate range indicated in the literature (6 to 10; Yin, 2009). Table 7 presents prominent aspects of the contributing distributors.

The profile of the individual respondents from the F&V distributors is shown in Table 8.

We created two groups of questions for the data collection process – both of which were based on the above literature review. These questions focused on the causes and mitigators of F&V waste. The sets of questions (proposed to both the supermarket respondents and the representatives of the distributors) can be found in Appendix A.

All interviews were conducted between January 2020 and March 2020. The interview process began with a pilot study involving supermarkets A and B and distributors 1 and 2. These pilot studies aimed to test and validate the research instruments. These companies were subsequently interviewed in full. The data collection involved semi-structured interviews and document analysis. The meetings were scheduled personally by the authors. Since audio recordings were not authorized, the authors conducted the interviews and recorded all information manually. We then transferred these records to Microsoft Word for text editing. The interviews were considered complete when two conditions were met: all research protocols had been applied, and no new evidence was being provided by each interviewee (Corbin and Strauss, 2007). Once we were satisfied with these conditions, the documents were submitted and coded using ATLAS.ti.

Table 9
. Secondary data (documents collected).

Group	Company	Documents
Supermarkets	Supermarket A	Sales Reports, Internal Food Waste Reports
	Supermarket B	Sales Reports, Internal Food Waste Reports
	Supermarket C	Sales Reports, Internal Food Waste Reports
	Supermarket D	Internal Food Waste Reports
	Supermarket E	Internal Food Waste Reports
	Supermarket F	Internal Food Waste Reports
Distributors	Distributor 1	Sales Reports, Internal Food Waste Reports
	Distributor 2	Sales and Loss Reports
	Distributor 3	Sales and Loss Reports
	Distributor 4	Sales and Loss Reports
	Distributor 5	Sales and Loss Reports
	Distributor 6	Sales and Loss Reports

At the end of each interview, we asked the participants to provide any relevant documents relating to the topics discussed, such as public and management reports from the companies investigated. We also considered results from publicly available electronic documents identified online, allowing for some triangulation between interviews and documents. The secondary documents collected are shown in Table 9.

3.3. Trustworthiness, credibility, and reliability

We asked experts to review this study so as to guarantee the reproducibility of our results (Eisenhardt, 1989). A set of usage restrictions was used to ensure credibility and proper use. These criteria cover the extent of companies' suitability with our study's objectives, understanding, generalization, control (Corbin and Strauss, 2007), transferability, reliability, and integrity (Corbin and Strauss, 2007; Hirschman, 1986; Wallendorf and Belk, 1989).

Throughout the process of conducting this study, examinations of the interviewees' responses conveyed an understanding of the topic, while generalizability was achieved by selecting professionals whose work environments were of a similar size. The validation of results and transferability of participants with integrated control refers to our selection of professionals who worked for companies that have developed actions to mitigate the waste of F&V items. Reliability involved a focus on the benefits of these actions in reducing food waste, while confirmability related to the individual analysis of each case. This analysis – in which any and all evidence relating to the investigated companies' actions – was conducted over a three-day period. After analysing each case individually, a cross-case analysis was performed using the ATLAS.ti software. These analyses sought to identify similarities and differences between the interviewees, and the reasons behind them. In both analyses, the results were coded in order to compare and contrast them with the elements identified within the literature. This codification was based on grounded theory (Corbin and Strauss, 1990; Strauss and Corbin, 1998). The revised documents were then presented to the interviewees. Aspects of integrity included anonymity and adherence to ethical standards.

A range of strategies based on diversity, negation, and abstraction were used to mitigate the effect of potential biases (Bonaccorsi et al., 2020). The diversity-based strategy combined the opinion of each individual expert with those of a diverse range of professionals and laypersons. For this purpose, interviewees were frequently asked about the specialist areas of other interviewees, as well as their own (supermarkets x supermarkets, supermarkets x farmers' distributors, and farmers' distributors x farmers' distributors). We adopted this approach in order to expand on the perspective of individual experts, thus helping to mitigate cognitive biases. The negation strategy aimed to lead the experts to systematically consider opposing views, in order to overcome or mitigate framing and anchoring biases, as well as the social desirability, false consensus, and planning fallacy biases. To do this, we presented the interviewees with several opposing views. The abstraction strategy aimed to help experts consider several – possibly conflicting – options at

Table 10
. Summary of findings.

Code	Group	Suggested actions / Notes
Understanding deterioration	What to analyse	Observe changes in colour or odour.
	How to use the analysis results	Classification of F&V into: Perfect (can be sold at premium price due to the absence of damage), Intermediate (suitable for sale, but less than perfect), Imperfect (can be sold to bargain hunters), and Disposable (no chance of commercialisation).
Price management	How to manage prices	Offering dynamic discounts to reduce the transformation of intermediate stage items into imperfect items.
	What to consider when pricing F&V	Note that intermediate items with prices equal to perfect ones are generally rejected.
	What hinders better pricing	Managers are unaware of the best time to reduce prices. Managers are unaware of the amount to discount at each stage of deterioration.
Sales management	Who buys intermediate or imperfect F&V and where	Bargain hunters buy intermediate or imperfect items. Bargain hunters also visit stores which generally serve higher income customers.
	What hinders a higher sale of intermediate or imperfect items	In most cases, sales to bargain hunters are reactive. Managers are unaware of the habits and preferences of bargain hunters.
Operational management	When to expose F&V	The gradual exposure of F&V throughout the day leverages the sale of intermediate items.
	What hinders better operations management.	Managers do not have time to guide their employees. High employee turnover prevents the adoption of best practices. Small number of employees compromises the management of items on display or in stock.
Purchasing Management	Why supermarkets over-buy F&V	To reduce the rate of disposal by farmers if they did not sell all of their production. To reduce the losses that farmers would incur if they did not sell all of their production. To attract consumers.
	How to reduce excess purchases	Increasing farmers' knowledge about demand fluctuations in order to help them improve the accuracy on the quantities to be planted.

once, while exploring all of their potential implications. Posing questions about alternative options to reduce unsolved causes of waste helped to implement this strategy.

4. Findings

Our data analysis focused on exploring how supermarkets and agricultural product distributors can reduce food waste. The findings of our interviews and documentary analysis indicate that one must first understand the stages of food deterioration before being able to create effective reduction strategies. This understanding relates to a set of activities that can be implemented so as to reduce the negative impacts of product deterioration. Such actions include the management of prices, sales, operations, and purchases. These actions are aligned with certain constructs revealed by the literature review. Expanding this topic further, this study details how these constructs can satisfy customer demand (from a variety of income groups) while concurrently reducing waste of resources. Table 10 presents a summary of these findings. It is important to note that the actions identified appear to be limited by certain residual problems (discussed in greater detail below).

4.1. Deterioration analysis

The deterioration of F&V can be identified based on changes colour (e.g., melon, banana, pineapple, tomato, papaya, peach, mango, avocado, lettuce, watercress, rocket, cabbage, spinach, etc.), odour (e.g., melon and potato), or texture (e.g., tomato, papaya, green leaves, pumpkin, strawberry, and passion fruit). These indicators can be used to classify F&V into 4 stages of deterioration: "Perfect" items (ideal for sale); "Intermediate" items (items without damage, but with lower indicators than the items in the "Perfect" stage); "Imperfect" items (items with some deterioration, but still with parts suitable for human consumption); and "Disposable" items (no chance of commercialisation.) It should be noted that supermarkets only accept F&V at the intermediate stage or above. If left unsold, these F&V deteriorate inside supermarkets. According to both supermarket and distributor interviewees, the sale of intermediate items is the best option for reducing waste:

The banana goes from yellow to black, or from the perfect stage to disposal. (D5)

Colours, odours, and textures indicate the stage of deterioration and trigger mitigating actions. (SMB4)

4.2. Prices

Intermediate F&V tend to be rejected by the majority of customers when offered at a price equal to perfect items. Our observations further confirmed this assertion from participants. This preference seems to encourage the conversion of intermediate items into imperfect items. For both supermarket managers and distributors, only the sale of intermediate items at more attractive prices can make it possible to reduce waste while still generate some profits (or reducing losses). We found that 16 of the 19 supermarket branches reduce F&V prices on display when there are few perfect items available. Both our observations and interviewees' assertions indicated that such discounts are offered before displaying new perfect items. This practice seeks to leverage the sale of intermediate stage items, avoiding their conversion into imperfect ones.

However, this action reveals a paradox: leveraging F&V sales in the intermediate stage in this way contributes to perfect F&V being kept in stock, thereby allowing them to deteriorate into the intermediate stage. We also noted that none of the branches displayed imperfect items. In the opinion of supermarket managers, an unexplored alternative would be to sell F&V in the perfect and intermediate stages simultaneously and at differentiated prices. Such an option could reduce the deterioration of F&V from the perfect to the intermediate stage, or from the intermediate to the imperfect stage. Preventing, or decreasing, these transformations would contribute to reducing the future disposal of F&V.

Would you buy something worse for the same price as a perfect item? (D4)

That banana is almost all good [in the intermediate stage], but the consumer will choose the banana to the side [in the perfect stage]. (SME2)

Archive data from the 16 branches which practice price reductions reveals that the related profit margins when using dynamic pricing could vary from 70% (perfect items) to negative (intermediate items). These 16 managers also stated that only dynamic price management could reduce retailers' losses. This variation could be determined automatically based on the level of F&V deterioration at the time of sale. However, the absence of further alternatives makes this pricing binary: either the price offered is for a perfect item, or it is for an intermediate item at the end of its shelf life. We further found that the aforementioned 16 managers seemed doubtful over the most effective times to offer lower prices for intermediate items, or even how much of a discount should be offered (considering the sales/cost/profit ratio). The other three managers declared that they had not adopted dynamic and dual pricing, offering only perfect items at the original full price. This option is related to the lack of knowledge and acceptance that higher-income consumers may select intermediate offerings.

It is better to have less profit than losses. If this is true for a distributor, then it must be true for a supermarket. (D2)

Lower prices are the best way to reduce waste. (RMSB)

4.3. Sales management

The managers interviewed indicated that the sale of intermediate and imperfect items is usually directed at 'bargain hunters' (i.e., supermarket customers looking for lower prices, or owners of small restaurants, sweetshops, and canning factories). The findings also suggest that these supermarket customers can be found even in stores aimed at those with higher incomes (due to the geographical proximity between the supermarket and their homes or businesses). As observed, bargain hunters prioritise attractive prices over aesthetic perfection. Despite the importance of this group of customers for reducing F&V waste, the findings indicate that such sales are made reactively. This means that the realisation of a sale depends on these consumers happening, rather than directly intending, to visit the supermarket. We found that managers are generally unaware of further details about these customers. The interviewees' believed that the proactive selling of these items to these customers could reduce the wastage of intermediate products.

People are not consumers, but bargain hunters. (RMSD)

People with good incomes can be bargain hunters. (SMC2)

4.4. Operational management

The investigation of operational actions that could mitigate waste revealed that the gradual presentation of fresh items throughout the day is a method with which to successfully minimise damage to products and leverage the sale of intermediate items. However, certain elements prevented a more thorough exploration of this option. As our research shows, due to time constraints, managers are typically unable to reorient employees towards this task, or even to check whether this service is being performed satisfactorily throughout the day. This problem becomes more worrying when one considers the high turnover of employees in the F&V sector. This turnover prevents supermarkets from obtaining a better return on investments from training staff in these practices. The benefits of such training would include: a more efficient use and presentation of items in stock or on shelves, the quicker identification of signs of deterioration, and a more refined definition of the identified waste mitigation actions. Another problem seems to be low levels of staffing in this sector. This limitation can lead to supermarkets increasing waste by either display too many items at once or to stop displaying in-stock items entirely. A combination of the above factors can also limit the frequency of temperature control of the display shelves, thereby accelerating deterioration.

High turnover and low training: these are my problems. (SMB2)

My challenge is to train and supervise employees amid other demands. (SMC2)

4.5. Purchasing management

All of the distributors interviewed reported that their companies both buy and resell F&V. This type of operation reduces a company's impact from bumper crops. According to supermarket managers, this leaves distributors in a comfortable position, which may explain their lack of engagement in reducing the waste created by both farmers and supermarkets. If they were interested in mitigating this waste, distributors could cooperate with supermarkets in identifying sale fluctuations (historical or momentary) and sharing this information with farmers. Since they are unaware of these fluctuations, farmers select the quantities to be planted based on intuition or experience. A lack of effective analyses regarding the amounts to be planted can increase the chances of future disposal in the field. This is an uncertainty that adds to climatic fluctuations. As noted, an eventual reduction in waste by farmers would allow more stable prices to be offered, reducing excess purchases by supermarkets and the unnecessary waste of scarce natural resources.

Our business is to sell perfect F&V. (D5)

Distributors do not gain or lose anything by informing farmers about the market. (SMA1)

5. Discussions

5.1. Deterioration analysis

Improvements in understanding the stages of deterioration allow retailers to classify F&V into the perfect, intermediate, imperfect, and disposable categories.

The analyses of these findings – considering the technological advances – suggest that deterioration within supermarkets could be identified using cameras mounted on ceilings or shelves, as well as by odour sensors (IoT). Accordingly, sensors (or other similar devices) should be developed/adapted to capture the image/odour of each type of F&V and its variation throughout the day. Such technological advances contribute to the establishment of support systems that guide and monitor practices' transformations into sustainable, suitable, and low pollution (Khan et al., 2020; Song et al., 2019).

The information gathered should be stored in a database (thus generating a Big Data). AI and ML could then use this information to predict F&V's remaining time before a transformation to the next deterioration stage. This study contributes to the field by indicating how these new technologies could enhance environmental sustainability (Arunraj and Ahrens, 2015; Dubey et al., 2016; Jagtap and Rahimifard, 2019; Manita et al., 2020) or support decision-making (Fosso Wamba et al., 2015; Jagtap and Rahimifard, 2019; Manita et al., 2020). Since F&V degradation is a common problem for all retailers, supermarket managers could develop joint actions with their competitors. These actions could begin with a series of presentations to large supermarkets in which the issue is identified and explained, and start-ups could be informed of the problem in order for them to develop the appropriate technology. We would therefore suggest that future studies on large-scale group decision-making in uncertain environments could also focus on the suppliers of technology (Tirkolaee et al., 2020), as well as how to promote sustainable value innovation in the supply chain (Shakeel et al., 2020).

5.2. Prices

Understanding the stages of deterioration opens space for supermarkets' price policies to be reviewed, especially since some customers are willing to buy items that are not at the perfect stage (Coderoni and Perito, 2020; de Hooge et al., 2017; McCarthy et al., 2020). Attractive pricing creates options for furthering corporate sustainability (Tollin and Christensen, 2019), enhancing an organisations' bottom line, and can positively affect consumer (and societal) well-being (Hofenk et al., 2019; Painter-Morland et al., 2017; Schaltegger and Hörisch, 2017). The different price options between F&V items will encourage customers to choose intermediate items voluntarily. This finding contributes to the literature by indicating that differentiated pricing for F&V at the perfect and intermediate stages successfully focuses on consumers' positive traits, thereby encouraging their sustainable consumption and effective purchasing choices (McCarthy et al., 2020; Song and Kim, 2018; Luchs and Kumar, 2017; Panzone et al., 2016; Ross and Milne, 2020).

The findings also indicate that waste mitigation could be improved through dynamic, deterioration-based pricing based. Alternatives to such management include dynamic pricing based on item traceability (Zhu, 2017) and analysis at the point of sale (Aschemann-Witzel et al., 2020).

A further contribution of this study is that it highlights the need for developing a tool with which to determine the best moment to reduce the price of intermediate items (related to the deterioration stage) and the percentage of this price reduction. This tool should access the aforementioned database of F&V's images/odours and the remaining time until transformation. This information should complement the historical data about the promotions already realised during a day, as well as their impact on sales and waste reduction. AI and ML should analyse all of this information to improve the definition of prices that simultaneously reduce waste disposal and protect against financial or environmental losses.

This study also contributes by suggesting which new technologies should be adopted to support enhanced decision-making (Fosso Wamba et al., 2015; Jagtap and Rahimifard, 2019; Manita et al., 2020), particularly related to prices and revenues (Shakeel et al., 2020). Moreover, it contributes by indicating a new challenge for those systems designed to reduce pollution (Song et al., 2019).

In Brazil, millions of people live on small monthly incomes. For these people, each cent saved can be used to buy more food. People with lower incomes can also be found in developed countries. Therefore, this study contributes by indicating how traditional markets can help mitigate a social issue: the lower purchasing power of consumers (Khalid and Seuring, 2019; Mahto et al., 2020).

5.3. Sales management

Sales management requires an able understanding of customers' acceptance of intermediate items. We found managers to be generally unaware of how customers with higher purchasing power perceive the simultaneous offer of perfect and intermediate items. This knowledge gap leads managers to only offer F&V at the perfect stage. This study suggests that a more comprehensive understanding of these customers' opinions could improve the balance between food supply and demand (de Hooge et al., 2018; Willersinn et al., 2017), as well as boost the sales of intermediate F&V.

A higher level of understanding could also guide F&V sales through mobile applications (Di Talia et al., 2019). It would also be necessary to improve social media campaigns (Choudhary et al., 2019; Närvänen et al., 2018) and acquire a solid understanding of the most appropriate digital resources (Ciulli et al., 2019). All of these findings further contribute by indicating the future focus of the actions designed to improve sustainable resource management (Khan et al., 2020; Song et al., 2019), including sustainable business model innovation (Shakeel et al., 2020). Supermarket managers interested in increasing F&V sales could also focus on social media and digital resources since such strategies have already been shown to improve sales in other scenarios.

5.4. Operational management

The lack of qualified professionals contributes to the increase in waste within supply chains (Mithun Ali et al., 2019). This study has identified that the F&V sector has a small number of professionals and a high rate of staff turnover. These factors combine to increase the waste of F&V. Through identifying these factors, and their combination, this study contributes by indicating the factors that limit the adoption of best practices (Capasso et al., 2019; Lebersorger and Schneider, 2014).

The mitigation of temperature problems inside supermarkets could be conducted automatically through an intelligent, IoT-based, refrigeration system (Nasir et al., 2018). Therefore, in order to instal an effective system of this type, it would be necessary to broaden the understanding of the requirements for F&V conservation (Eriksson et al., 2016). This study contributes by suggesting that monitoring and temperature adjustment could be conducted through the IoT (Song et al., 2019), thereby building a better connection between technology and staff (Jagtap and Rahimifard, 2019; Mithun Ali et al., 2019; Takano and Kajikawa, 2019).

Real-time analysis could mitigate problems related to the exposure of a large amount and variety of F&V (Filimonau and Gherbin, 2017; Teller et al., 2018), while indicators and deterioration stages can be considered to improve storage, handling, or product display (Bag et al., 2020; Centobelli et al., 2020; Santos et al., 2020). To manage exposure, retailers could use cameras and sensors to quantify the quantity of F&V exposed and the sales throughout the course of a working day. Such information could be stored in a database. AI could then be used to determine the optimal replenishment moment. Once again, Big Data and the use of AI and ML can help solve the challenges identified (Iqbal et al., 2020; Song et al., 2017).

This study also contributes to the literature by suggesting that ML can improve the management of this exposure (Gružauskas et al., 2019; Nilashi et al., 2019; Zhang et al., 2019). This improvement should focus on the optimal times and quantities to be exposed throughout the day, the amount wasted, and the impact on sales of intermediate items. Such challenges seem not to have been solved until now (Song et al., 2019). The experimental analysis of these reactions could also employ augmented reality. An example of this can be found within the literature (Rese et al., 2017).

5.5. Purchasing management

Supermarkets buy F&V in large quantities in order to take advantage of the generous discounts offered by farmers' distributors. Excessively large purchases often generate waste later in the chain (Filimonau and Gherbin, 2017; Santos et al., 2020; Teller et al., 2018). Another contribution of this study is that it emphasises the need to develop a collaborative solution that presents farmers with a realistic forecast of the quantities to be planted, thus championing innovation (Kopyto et al., 2020; Song et al., 2019; Wiener et al., 2020) and risk avoidance (Mithun Ali et al., 2019; Shoukohyar and Seddigh, 2020; Wang et al., 2020), while also cautioning against the unnecessary use of scarce natural resources (Deng and Gibson, 2019; Tashman, 2020; Zhan et al., 2019). This tool could be based on supermarkets' sales forecasts (Arunraj and Ahrens, 2015) and perishability information (Soysal et al., 2015). Such a tool should be based on cooperation and information sharing (Gupta et al., 2019).

Our findings also contribute by suggesting that the IoT can be used to identify and disseminate information in supply chains in order to improve their control, planning, and optimisation, as well as accuracy of quantities to be planted (Ciulli et al., 2019; Mithun Ali et al., 2019; Takano and Kajikawa, 2019). The use of such technologies throughout the whole chain can also help reduce scarcity in food-rich countries (Mahto et al., 2020), improve the food-energy-water-health nexus on a life cycle basis (Slorach et al., 2020), and the entrepreneurial orientation of rural women (Chatterjee et al., 2020).

This study also suggests that different technologies could be combined with the improvements to large-scale group decision-making within uncertain environments (Song et al., 2019; Tirkolaee et al., 2020). This improvement to decision-making could use Big Data about the history of the chain production, sales, and disposal of each F&V. This information should then be analysed by AI and ML in order to define the optimal alternative for the partners and the environment, thus unveiling how to enhance environmental sustainability (Dubey et al., 2016; Sivarajah et al., 2019; Song et al., 2017) or better support decision-making (Fosso Wamba et al., 2015; Jagtap and Rahimifard, 2019; Manita et al., 2020). Our findings also contribute by indicating that reducing farmers' losses may help support rural financial development and minimise rural poverty (Zameer et al., 2020), as well as to stimulate such farming organisations as cooperatives (Manda et al., 2020).

6. Conclusion

6.1. Academic contribution

It is vital to recognise food waste as a significant issue when pursuing the circular economy (Pagotto and Halog, 2016), particularly in emerging economies. Supermarkets play an important role in dealing with food waste. However, supermarkets depend on consumer attitudes towards F&V deterioration. Consequently, they must pay close attention to suppliers' accurate forecasting and sales offers in order to reduce the wastage of scarce resources, including of both food and its inherent sources (e.g. energy, water, soil use). Therefore, based on the NRDT, supermarkets can adopt marketing strategies underpinned by digital technologies to avoid such dependencies.

This article has discussed both marketing strategies – including the management of prices, sales, operations, and purchases – and digital technologies suitable for heavily reducing the food waste occurring within the retail sector.

To the best of our knowledge, this is the first article to analyse food waste from the angles of marketing strategies, the use of such digital technologies as Big Data, ML, and AI, and the combination of these factors to discuss the reduction of supermarkets' dependence on consumers and suppliers. This article sheds light on implementing actions underpinned by emerging technologies to persuade consumers to accept intermediate F&V, as well as to manage suppliers in order to balance supply and demand.

6.2. Managerial and policy-making implications

F&V waste accounts for approximately 85% of supermarkets' losses. Such waste can be reduced if supermarkets were to change their commercial policies, adopt new technological solutions, help small farmers and their distributors, and induce changes in public policies. The lessons learned regarding the options available are presented below.

- Lesson 1 – The reduction of F&V waste demands a new commercial policy in the retail sector. This policy could use knowledge of the deterioration stages to prevent intermediate items from becoming imperfect within the branch. This policy must also include differentiated pricing for perfect and intermediate items, and a better understanding of the acceptance of offering such products in stores that serve consumers with higher purchasing power. The existence of dynamic pricing based on the stage of deterioration can also boost F&V sales to customers with less purchasing power, thus contributing to heightened nutrition for these customers.
- Lesson 2 – Sensors and cameras for detecting deterioration can be combined with Big Data, AI, and ML to manage dynamic pricing, storage, and item display. The sale of items at the perfect and intermediate stages can be increased using digital solutions, provided they are accompanied by attractive prices (particularly regarding those items in the latter stage). Additionally, technologies such as robotisation, the IoT, blockchain, and temperature control can transform supply logistics and influence consumer behaviour. These digital technologies can reduce the handling of items by employees, control exposure, and, above all, facilitate interaction with the consumer. The combination of these benefits would thus allow retailers to build a closer relationship with members of their community.
- Lesson 3 – Supermarket purchasing managers could organise teams to help small farmers reduce waste in planting and harvesting. Such assistance should focus on developing more accurate sales forecasting. Greater accuracy in sales forecasting may reduce farmers' costs, thus allowing them to offer lower prices to supermarkets. This option would simultaneously improve farmers' use of natural resources and increase supermarkets' profits.

Table A1
Questions asked to the supermarket employees.

Code	Questions
Causes of waste	What are the causes of food spoilage in your supermarket? How do you identify these causes? Why have these causes not yet been mitigated?
Possible waste mitigators	How does your company attempt to reduce this deterioration? How could internal operations be improved in order to reduce deterioration? How could you mitigate the deterioration related to your customers' preferences?
Possibilities for adopting technologies	What would you like technology to do to mitigate waste in your operations? What would you like technology to do to mitigate waste in your F&V supply chains? What would you like technology to do to mitigate the F&V waste generated by your customers?

- Lesson 4 – Public policies designed to promote the goal of 'zero hunger' must foster the most suitable conditions for the sale of items in the intermediate and imperfect stages. Moreover, these policies need to connect retail sales forecasts with the quantities to be planted by farmers. This connection must be orchestrated by public bodies, since its cost/benefit can only be justified at the regional level. In this context, the combination of commercial policies and digital technologies can reduce food waste and preserve scarce natural resources.

6.3. Suggestions for further research and limitations

Future studies on F&V deterioration could investigate how colours and odours vary across different F&V over time, as well as the possibility of evaluating textural changes using cameras or odour sensors (thereby circumventing the current need for employees handling the product). Such studies could investigate the possibility of combining sensors, Big Data, AI, and ML in predicting changes to the deterioration stage. A third strand of studies may use cameras to identify customers' purchase options, considering the stages of deterioration.

Like any study, this study has certain limitations, which may serve as opportunities for future research. First, this is a qualitative, multiple case study with results drawn from a limited number of supermarkets and distributors. Additionally, despite the study having been conducted in the same region, one of the supermarkets investigated belongs to an internationally operating group (as opposed to the remaining five, which are regional). Other supermarkets could be investigated. Therefore, due to these limitations, the generalisation of these results should be treated with caution. Despite this, some of our findings do seem to be generalisable to other countries. This is the case with the stages of deterioration, which may be valid for all similar F&V sale trends worldwide. Beyond this, the possible strategies of managing price, sales, operations, and purchasing could also be applied internationally.

CRediT authorship contribution statement

Michele de Souza: Conceptualization, Formal analysis, Investigation, Methodology, Validation, Writing – review & editing. **Giancarlo Medeiros Pereira:** Conceptualization, Methodology, Project administration, Supervision, Validation, Writing – review & editing. **Ana Beatriz Lopes de Sousa Jabbour:** Conceptualization, Formal analysis, Validation, Writing – review & editing. **Charbel Jose Chiappetta Jabbour:** Conceptualization, Formal analysis, Validation, Writing – review & editing. **Luiz Reni Trento:** Conceptualization, Formal analysis, Investigation, Methodology, Validation, Writing – review & editing. **Miriam Borchardt:** Conceptualization, Formal analysis, Validation, Writing – review & editing. **Leandro Zvirtes:** Conceptualization, Formal

Table A2
Questions asked to the distributors

Code	Questions
Causes of waste	What are the causes of food spoilage in the supermarkets you supply? How do you identify these causes? Why have these causes not yet been mitigated by supermarket managers?
Possible waste mitigators	How could a distributor help to reduce waste? How could a distributor help to improve the supermarket's internal operations? How could a distributor help reduce waste related to the preferences of the supermarket's customers?
Possibilities for adopting technologies	What would you like technology to do to mitigate waste in your operations? What would you like technology to do to mitigate distributors' waste? What would you like technology to do to mitigate the F&V waste generated by supermarket customers?

analysis, Investigation, Methodology, Validation, Writing – review & editing.

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Appendix A

Tables A1 and A2.

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