

POST-CONSUMER GLASS PACKAGING IN THE SELECTIVE COLLECTION SYSTEM: A CASE STUDY OF THE CITY OF LONDRINA

EMBALAGENS DE VIDRO PÓS-CONSUMO NO SISTEMA DE COLETA SELETIVA: O CASO DA CIDADE DE LONDRINA

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ABSTRACT

Purpose: This article presents the results of an in-depth and contextualized study on the problems in the commercialization of glass containers sent to the selective collection system of the city of Londrina-PR, Brazil.

Design: The methodological strategy was the triangulation of sources of evidence desiring to understand the situational characteristics, as well as the operational and environmental challenges faced by the local actors involved, especially the cooperatives. Quantitative and qualitative study case using primary and secondary data collection from multistakeholders.

Findings: The data collected here allow us to conclude that vitreous materials have demonstrated difficult commercialization processes and are among those materials that are economically less interesting for cooperatives, intensifying the high social fragility of cooperates.

Practical implications: The search for solutions to environmental and economic problems caused by the high generation of municipal solid waste in Brazil still have strong deficiencies in methodologies and technologies.

Social implications: How the reverse logistics of vitreous packaging is operationalized has increased public financing with this type of material, since the sales price obtained by waste pickers does not corroborate the economic support of cooperative enterprises.

Originality/value: This study allows to advance in the explanation and description of the way of structuring the reverse chain of vitreous packaging, especially in medium-sized municipalities in the inland.

Keywords: post-consumption; packaging; glass; recycling; selective collection

RESUMO

Finalidade: Este artigo apresenta os resultados de um estudo aprofundado e contextualizado sobre os problemas na comercialização de embalagens de vidro enviadas para o sistema de coleta seletiva da cidade de Londrina-PR, Brasil.

Metodologia: Utilizou-se como estratégia metodológica a triangulação de fontes de evidências almejando uma compreensão detalhada das características situacionais, bem como dos desafios operacionais e ambientais enfrentados pelos atores locais envolvidos, em especial, as cooperativas. O estudo de caso de âmbito quantitativo e qualitativo abarcou dados primários e secundários advindos de *multistakeholders*.

Constatações: Os dados permitem concluir que materiais vítreos possuem dificuldade para serem comercializados e estão entre aqueles economicamente menos interessantes para as cooperativas, intensificando a elevada fragilidade social dos cooperados.

Implicações Práticas: No Brasil, a busca por soluções aos problemas ambientais e econômicos causados pela geração elevada de resíduos sólidos urbanos ainda apresentam fortes deficiências quanto às metodologias e tecnologias.

Implicações Sociais: A forma como está operacionalizada a logística reversa das embalagens vítreas tem elevado o financiamento público com este tipo de material uma vez que o preço de venda obtido pelos catadores não corrobora com a sustentação econômica dos empreendimentos cooperativos.

Originalidade/valor: Este estudo permite avançar na explicação e descrição sobre o formato de estruturação da cadeia reversa de embalagens vítreas, em especial em municípios de médio porte do interior do país.

Palavras-Chave: embalagens pós-consumo; vidro; reciclagem; coleta seletiva

1 INTRODUCTION

The development of science and technology, together with a linear economic system, the contemporary way of life, and the increase of the global population, has resulted in a vast production of municipal solid waste (Landim, 2019). The large mass of materials discarded daily becomes a pressing challenge to public management, which has dealt with materials of difficult degradation. The current characteristics of urban life rule out the possibility of zero waste and motivate the organization of a complex and necessary structure for the management of the discarded object (Gonçalves-Dias, 2015; Santos *et al*, 2016).

The recycling of materials has been understood as an essential way because it avoids negative externalities specific to the current production model by reusing the materials in new production cycles. At the same time, some authors criticize it for softening discussions on disposal and further debate on measures for waste prevention and reduction of consumption in modern society (Layrargues, 2002; Gonçalves-Dias, Ghani, & Cipriano, 2015).

Selective collection, an important element of the structure of reuse of materials, has grown substantially in the largest urban centers in the country since the enactment of the National Solid Waste Policy - NSWP (Brasil, 2010). The same law also provided for the reverse logistics system and the incentive to create and develop cooperatives or other forms of association of waste pickers.

The legality of the reintroduction of recyclable materials in new production chains increased the number of cooperatives in the country and, from the sectoral agreement made in 2015 for the implementation of reverse packaging logistics (Ministry of the Environmental [MMA], (2015), boosted the organization of an economic sector with relevant social and environmental roles. However, some materials with high recyclability potential have difficulty being reinserted by cooperatives in new production cycles due to the obstacle of finding buyers and/or their low value in the recycled market. This can condemn the material to be mixed with organic waste and, consequently, convert it into rejected waste (unusable waste).



Hollow glass packaging of various shapes and colors corresponded to 7.7% of the physical production of packaging in Brazil (Brazilian Packaging Association [ABRE], 2019). They are used daily in homes, bars, snack bars, restaurants, and in the packaging of non-food products (pharmaceuticals and cosmetics), taking the form of bottles, pots, and jars that are used to package beverages, processed foods, medicines, perfumes, cosmetics, cleaning products, among others.

Hollow glass packaging spread throughout the city and exceed half of Brazil's glass production (Compromisso Empresarial para Reciclagem [CEMPRE], 2018). Classified as Class IIB by the Brazilian standard ABNT/NBR 10004/2004, glass is commonly utilized due to its property of keeping untouched the flavor, purity, and quality of the product stored, besides being more difficult to deform and resistant to high temperatures.

The reuse of post-consumer vitreous packaging by industries in a returnable model is declining in Brazil, but the possibility of recycling continues to be widely disseminated by the glass sector (Brazilian Glass Association [ABIVIDRO], 2019) since the time for degradation in the environment is undetermined. The insertion of glass in new production cycles, from selective collection to reverse logistics, reduces pressure on landfills and the emission of greenhouse gases while increasing the efficiency of the use of natural raw materials present in its composition, without the loss of quality or properties during the remelting process (United States Agency for International Development [USAID], 2016; ABIVIDRO, 2019).

The reverse chain of vitreous packaging generated at home and its interfaces with municipal selective waste collection systems has been the subject of a small number of studies in Brazil so that there are gaps in the theoretical-empirical understanding of the activity (Lemos, 2012; Morais *et al*, 2018; Santiago, 2011; Soares, 2018; Torres & Gonçalves-Dias, 2018; Dourado, 2020). Thus, this article aims to present the results of exploratory-descriptive research, including data from multiple stakeholders on the problems existing in the commercialization of glass packaging forwarded to the selective waste collection system of the municipality of Londrina, State of Paraná, Brazil.

Londrina is located in the north of the State of Paraná and the fourth-largest municipality in the southern region of Brazil, with more than 560,000 inhabitants (Brazilian Institute of Geography and Statistics [IBGE], 2018). It is a pioneer in the selective collection of recyclable household waste. Door-to-door segregated household garbage collection was instituted in the city 14 years before the enactment of the National Solid Waste Policy and is currently carried out in 100% of the urban area, including districts, patrimonies, and rural villages (Municipal Urbanization Transit Company [CMTU], 2018). Besides being among the 40 largest cities in the country, Londrina has a scale in the selective collection of materials with potential for recyclability and privileged location, located less than 600 km from 6 large manufacturing units of vitreous packaging.

The present study is justified because, based on the need to understand the implementation of the National Solid Waste Policy (Brazilian Law n. 12305/2010) from the theoretical approach of circular economy and reverse logistics after consumption, it allows to advance in the explanation and description of the way of structuring the reverse chain of vitreous packaging, especially in medium-sized municipalities in the inland.

For this, this work is structured as follows: first, it presents a brief review of the literature on circular economy and its interaction with the recycling activity, as well as the structuring of the production chain and post-consumption of vitreous packaging; describes the methodology used; presents the results found from the analysis of the multiple data sources; and, finally, discourses the conclusions and implications concerning the reality found.



2 LITERATURE REVIEW

This reference is divided into two sections: the first one addresses the concept of circular economy and its interrelation with the recycling of materials; the second presents the structuring of the production and reverse chain of vitreous packaging in Brazil.

2.1 The Circular Economy and its Interaction with Post-Consumer Recycling

A sustainability policy presupposes the transformation in the structure and defining patterns of production and consumption that need to be replaced with processes of reduction, reuse, remanufacturing, and recycling, as well as strategies for extending the product's life cycle (Morsetto, 2020). Rethinking the use of material and energy led to the concept of a circular economy. The Ellen MacArthur Foundation defines the circular economy as “restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times” (Ellen MacArthur Foundation [EMF], 2015). This definition is more used in circular economic studies (Kirchherr, Reike, & Hekkert, 2017).

The circular economy, therefore, is contrary to the current model of linear production based on the exploration, production, and post-consumption disposal of packaging and materials, which results in the release of waste in the natural environment. Its premises are aligned with the preservation of natural capital and the improvement of its effectiveness to reduce the risks of shortages of finite resource stocks. (EMF, 2015)

A central feature of its design is the substitution of the concept of “end of lifespan” by “product life cycle”, in which materials remain repeatedly within production systems. Thus, as highlighted by De Jesus *et al* (2018), the circular economy implies a model of systemic innovation involving dynamic and holistic combinations in services, as well as new configurations and organizational arrangements.

In this sense, the reverse flow – biological and technical (McDonough & Braungart, 2002) – of open and closed types (Haupt, Vadenbo, & Hellweg, 2017) are different resource recovery strategies for new production cycles. From this perspective, the selective waste collection activity for recycling has an important economic function of reintroducing discarded materials into production chains (Geyer *et al*, 2016). Haupt, Vadenbo, and Hellweg (2017, p. 615) even claim that: “Recycling rates (RRs), an indicator for the circulating behavior of materials, are often used as a measure for the degree of circularity of an economy”.

However, it is important to note that the recycling of materials involves other important dimensions that go beyond the selective waste collection system. It is essential to have a market for each of the materials submitted to the waste sorting facilities (Velis & Vrancken, 2015). It is not enough to design products and packaging with materials that have the potential for recyclability and possibility of returning to new production cycles, after the end of their lifespan, if there is no interest of business agents in the reuse of these materials in new chains.

2.2 The Production and Post-Consumption Chain of Vitreous Packaging

In 2018, the packaging industry based in Brazil accounted for 1.3% of the country's GDP (IBGE, 2019). The macroeconomic study of the Brazilian packaging industry conducted by Euromonitor for the Brazilian Packaging Association shows that the revenue of the sector in 2018 was R\$ 87.9 billion, of which R\$ 13.3 billion of these refers to the vitreous packaging segment, with a growth trend until 2024. (Brazilian Packaging Association [ABRE], 2018).

The vitreous packaging sector, according to the National Solid Waste Policy (NSWP nº



12305/2010, art. 33), is obliged to structure and implement reverse logistics systems independent of the public urban cleaning service, upon return of their products after being used by the consumer, ensuring recovery from an environmental point of view and recapturing the economic value of the material. The sectoral agreement for reverse packaging logistics, as provided for in the legislation, which aims to implement, structure, and operationalize the system, was signed in 2015 by 22 associations and trade unions, representing more than 3,780 corporations in the industry and commerce business sector. But, as highlighted by the Packaging Coalition (2019), an organization formed by the companies that signed the agreement, “this number of companies does not represent the industrial park installed in the Brazilian market, especially because the glass and steel sectors did not sign the agreement.”

Therefore, 10 years after the enactment of the NSWP and the establishment of Federal Decree no. 7404/2010 that regulated it, ABIVIDRO, the association that gathers the glass industries of the country, has not yet signed a sectoral agreement for the collection of waste generated and reuse in new production cycles. This indicates, as already pointed out by Demajorovick and Massote (2017), that the sector agreement signed tends to benefit only packaging with more structured chains, such as aluminum, PET, and cardboard.

In Brazil, hollow glass is widely used for storage of processed products from various production chains because it is inert, impervious to gases, moisture, odors, and microorganisms, and allow modeling in various formats and colors (Gava, Silva, & Frias, 2008; Soares, 2018). Besides, it is disseminated by the industry as a material that can be reprocessed infinitely without losing its properties. This constitutes a great environmental advantage, not only by the economy of virgin mineral raw materials (sand, sodium carbonate, and limestone) but also by the lower generation of waste (Lemos, 2012; Götze, 2016; ABIVIDRO, 2018).

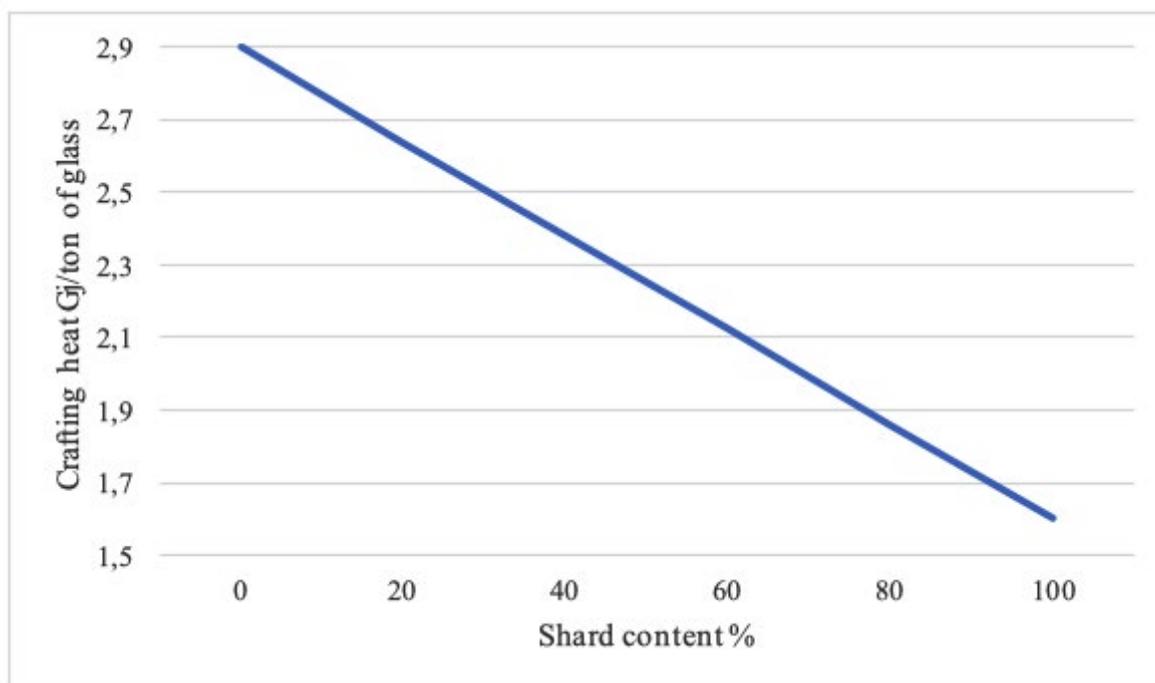
The gains for the industry of using recycled glass shards in the composition of new packaging are in reducing the temperature of the oven, which translates to lower gas emissions from burning fuels and greater longevity of the ovens. But the main benefit is in reducing the energy cost for material production, as described by Akerman (2014, p. 27).

The energy needed to prepare a glass with the same characteristics as the originating raw materials is much lower from the shard. While it takes 2.889 GJ/t for the production of glass from raw materials, only 1.616 GJ/t is required when the input is the shard.

The use of 10% of glass shard in the mixture of materials for the industrial process generates a reduction of 4% of the energy required (0.14 GJ) for fusion in industrial furnaces, a reduction of 9.5% in water consumption, and 24.5 kg of CO₂ per ton of hollow glass produced (Rosa, Cosenza, & Barroso, 2007; CEMPRE, 2018; Akerman, 2014).



Graph 1 – Energy required for the production of 1 ton of glass depending on the shard content employed



Source: Akerman (2014, p. 27).

The gains for public agencies and society are evidenced by the decrease in the volume of waste, for which the municipalities are responsible and must provide the collection, transshipment, and final disposal. As highlighted by Lemos (2012), the interest of the federal and state governments consists of the saving of energy, foreign exchange, water resources, and an increase in the quality of the environment, especially concerning the maintenance of natural reserves and the reduction of air and water pollution.

Theoretically, all glass can be recycled. However, there are some important technical elements to be considered. For example, the fact that colored glass shards cannot be used in colorless glass, with the risk of damaging the color, but the reverse is possible (Götze, 2016). The biggest problem that restricts the use of glass packaging as secondary raw material in the production process is the presence of contaminants. Morais *et al*, 2018, point out that: “The insertion of these contaminants in melting ovens generates defective products, such as some solid inclusions in the final product (porcelain or stones), in addition to reducing the lifespan of melting ovens” (p. 3). Thus, contaminants are important risks for the production of flat glass, leading manufacturers to employ only the shard generated in their production lines, due to safety. On the other hand, “packaging glasses suffer less from the presence of possible inclusions, because the products are smaller, rarely exceeding 1 kg, and are never tempered” (Akerman, 2014, p. 55).

The glass industry is a relatively little-known sector of the Brazilian economy, about productive and economic aspects (Rosa, Cosenza, & Barroso, 2007). The productive activities are quite diversified and can be segmented into three types: flat glass (tempered, laminated, reflective or metalized, double-shielded); hollow glass (for home use and packaging); and technical or special glass (fiberglass, video monitors, lighting, ophthalmic blocks, among others). The basic glass industry in Brazil, responsible for the fusion of glass, has a focus on the domestic market and is characterized by the high productive and commercial concentration, consisting of about 23 manufacturing units of 12 business groups (Akerman, 2014).

Considering only the industries that manufacture hollow glass, presented in Table 1, this market can be classified as an oligopoly in production and an oligopsony in the consumption of glass shards for recycling (Calderoni, 2003; Lemos, 2012; Rosa, Cosenza, & Barroso, 2007). There are only seven business groups that own the entire national production of packaging (for food, medicines, cosmetics, and household utilities), two of which are of foreign capital and amount 69% of the market.

Table 1 - Hollow glass producing industries installed in Brazil

Manufacturers	Source capital	Capacity installed (ton/day)	Packaging for Beverages and Food	Bottles	Housewares
Owens Illinois	United States	2,300	x	x	x
Verallia, belonging to the Saint Gobain Group	France	1,300	x		
Vidroporto	Brazil	300	x		
Ambev, belonging to the namesake beverage company	Brazil	350	x		
Wheaton Brasil Vidros	Brazil	460		x	x
Nadir Figueiredo	Brazil	400			x
Anchieta	Brazil	80	x		

Source: Data obtained from Akerman (2014, p. 23) and updated by the authors.

Vitreous packaging is designed to be absorbed in the technical cycles of circular economy (McDonough & Braungart, 2010) because they are inert and biologically inactive, without degrading in the natural environment. Haupt, Vadenbo, and Hellweg (2017) state that they are aligned with the closed-loop supply chain (CLSC), and Carr and Kim (2017, p. 322) emphasize that:

The true sense of CLSC of glass containers, therefore, can be completed only if the glass is collected, sorted out, and transported to glass processor suppliers, processed at a high quality, and finally sold to glass container original equipment manufacturers (OEMs). The success of the CLSC depends on multiple factors at each decision point involving end consumers, recycler service providers (including haulers and materials recovery facilities), cullet processors suppliers, and glass container OEMs.

Therefore, post-consumption vitreous material is used in new products of the same nature, in a strong integration between the direct and reverse chains (Lemos, 2012; Souza, Paula, & Souza-Pinto, 2012). This characteristic, together with the concentrated structure of the Brazilian glass sector, causes important market failures that consist of the inability to bring the economic process of recycling to an optimal social situation.

The structure of the sector corroborates the determination of the prices of the glass shard that has led to problems concerning the flow of return of materials. Currently, transport logistics is the main obstacle to recycling post-consumer vitreous packaging (Lemos, 2012; Akerman, 2014), making it an unattractive activity for waste pickers' cooperatives. In many Brazilian municipalities, this situation can cause the incorrect final destination for landfills and even the irregular destination to the banks of watercourses, wasteland, dumps, and public roads.

Cooperatives in various parts of the country have had problems finding buyers for screened packaging and when commercialized, the price of post-consumer glass is substantially less attractive than other recyclable materials (Costa, Costa, & Freitas, 2017). In many cases, the sale value of the material is not higher than the cost of freight (Morais *et al*, 2018; Santiago, 2011; Lemos, 2012). Calderoni (2003), Gonçalves-Dias (2009), Souza, Paula, Souza-Pinto (2012), Cândido, Soulé, and Neto



(2018) had already highlighted that the waste pickers have a minimum power to influence the price of the material to be paid in the market so that the recycling industries have great control over the reverse chain's price formation.

Studies conducted after the enactment of the NSWP in the state of Santa Catarina (Lemos, 2012; Bó, 2019), in the Federal District (Morais *et al*, 2018; Dourado, 2020), in the metropolis of São Paulo (Torres & Gonçalves-Dias, 2018), and the municipalities of Belo Horizonte (Santiago, 2011; Venâncio, 2020) and Uberlândia (Soares, 2018) pointed out difficulties in the process of selling and transporting the material sorted out in shard to the vitreous industries, as well as the exploitation of waste pickers by intermediaries and middlemen. Although conveyed by the industry as a recyclable material, it takes on the category of non-marketable in many studies. For example, in the Brazilian capital, Brasília, the selective collection of glass packaging was considered unfeasible by the public authorities and the population is oriented to discard the material along with conventional collection, having the Samambaia landfill as the final destination (Morais *et al*, 2018; Dourado, 2020). Torres and Gonçalves-Dias (2018, p. 7) denounce that "In this scenario, infinitely recyclable material is not recycled because it has no market".

Carr and Kim (2017), in a study that looked at the dynamic relationships between recycler service providers and processor suppliers, as well as between processor suppliers and glass manufacturers of original equipment in Ohio, United States, also identified difficulties in the shared management of reverse logistics of vitreous packaging and stated that:

In most cases, because the processor suppliers did not pay for the transportation distribution costs or for the collection of recycled glass from end customers, the costs for the recycler service provider organizations were higher than the benefits, unless they were offset by a subsidy from the local government. (p. 322)

The research concludes that public agencies will need to intervene in promoting the return of materials to the production cycle and recapturing the value of post-consumer glass packaging, implying greater commitments and benefits for all agents in the chain.

3 RESEARCH METHODOLOGY

The research is a case study with exploratory-descriptive purpose and quantitative and qualitative scopes, using the collection of primary and secondary data from various sources of evidence from multistakeholders. The study included a documentary and field research to analyze the mass and destination of post-consumer vitreous packaging sent to the household selective waste collection system of the city of Londrina. We sought a detailed understanding of the situational characteristics, as well as the operational and environmental challenges faced by the local actors involved, especially cooperatives.

The unit of analysis was the post-consumption vitreous packaging sent by the residents of the municipality to the selective waste collection system. The methodological strategy was the triangulation of sources of evidence that, as highlighted by Yin (2014), allows in-depth understanding and multiple evaluations of the same phenomenon.

The collection of primary data carried out during the first half of 2018, involved semi-structured individual interviews and unsystematic direct observation. The primary data were obtained from Cooperregião and Cooperoeste, the largest recyclable waste cooperatives in Londrina in the number of cooperative members and responsible for carrying out the door-to-door collection in over 116,700 households, equivalent to the total of 50.7% of households incorporated into the selective waste collection system of the municipality. The direct observation protocol involved pre-storage,



management for cooperative sorting, compaction of the material, as well as the final disposal of the processed material inside the shed.

For the most part, the secondary data comprises official documents and reports made available by different actors directly or indirectly linked to the system, such as representatives of the public sector, cooperatives, and associations of companies. Table 2 presents in detail the construction between the sources of evidence, actors, and information collected.

It should be emphasized that most of the documentary data were obtained directly from the database of the Municipal Urbanization Transit Company (MUTC), an indirect administration body of the municipality responsible for the management of household waste in the city of Londrina.

Table 2 – Data Collection Strategies

Data Type	Stakeholder	Source of Evidence	Type of Information Collected
Primary	Recycling cooperatives (Cooperregião and Coopereste)	Semi-structured interview with managers	Difficulties in the collection, screening, and commercialization of the material.
		Unsystematic direct observation	Management in the sheds for the sorting and compaction of the material.
Secondary	Indirect administration body of the municipality responsible for waste management - MUTC	Database	Data of monthly invoices for the sale of vitreous waste commercialized by cooperatives: mass, sales value, and registration data of buyers (2017); Monthly data on the operation of cooperatives: number of waste pickers in service, number of households served, and measurement of the mass of materials (screened by cooperative and household) (2017); Monthly subsidy for the payment of the rent of cooperative sheds (2018); The average monthly cost of the municipal selective waste collection system per household (2017); Mass in ton and financial value of door-to-door collection and transportation of household waste to landfill (2017); The monthly amount for operation and maintenance of the landfill (2017).
		Internal report on the current situation of recycling cooperatives (2018)	Weaknesses of the system: the situation of the sheds, transport vehicles, monthly income of the cooperative members, and commercialization in tons.
		The contract for the Provision of Recyclable Waste Collection and Transportation Service	Monthly transfer by household paid to cooperatives for door-to-door collection and transportation of recyclable waste to the sorting shed (2017 to 2020).
	Recycling cooperative (Cooperregião)	Database	Quantity and type of material screened per month (2017); The average value of the ton traded, by material type (2017).
	Business Commitment to Recycling - CEMPRE	Documents made available on the website	Glass technical data sheet; The average sales price of recyclable materials practiced by selective collection programs.
	Brazilian Association of Glass Industries - ABI-VIDRO	Documents made available on the website	Associates; Benefits of glass recycling; Glass recycling guide (2019).

Source: the authors



The collected data revealed the dynamics of structuring the selective collection system of the municipality. The data processing focused on making connections between apparently disordered observations, as well as on the use of descriptive statistics for in-depth analysis of the commercialization of vitreous packaging of each of the cooperatives and in the comparative analysis between them. The data obtained from the MUTC also allowed analysis of municipal economic costs generated and avoided in the management of vitreous post-consumption materials screened by cooperatives.

4 RESULTS

This section is segmented into two parts: the first one presents the main characteristics of the selective collection system adopted in Londrina, highlighting the interactions between the actors of the field; then, reports information on the marketing process of vitreous packaging sent to recycling cooperatives installed in the municipality.

4.1 Characterization of the Selective Collection System of the Municipality of Londrina

Considered the second most populous in the state of Paraná and the fourth in the Southern region of Brazil, the municipality of Londrina instituted the system of a selective household waste door-to-door collection in the central area in 1996, using servers and trucks of the city. Later, associations of waste pickers took over this activity, which was redefined in 2009 by the “Londrina Recicla” program (Municipal Decree No. 829/2009), with the structuring of cooperatives (Ethos, 2015). Selective collection in Londrina is a historically constructed environmental and social asset. The engaged operation of cooperatives has made it a reference for the selective waste collection movements in Brazil, with awards and national recognition (Fundacion Avina, 2012).

Currently, the door-to-door collection system of recyclables is carried out in 100% of the urban area, including districts, patrimonies, and rural villages, totaling 230,095 households. The municipality recognizes the selective waste collection as a continuous public service, being a pioneer in the realization of a contract for the provision of services for the collection and sorting of materials with the cooperatives. The contracting takes place through a bidding waiver.

Seven cooperatives, involving 360 cooperative members, signed a contract with the government with a term of 36 months and annual adjustments based on the National Index of Consumer Prices (NICP/IBGE). They operate in different locations in the urban territory and receive R\$ 1.47 per month per household attended from the municipality, in addition to the full transfer of the rent of the sheds for sorting and storage of materials and the transfer of the INSS payment of the cooperative members. The municipal investment in the selective collection system was R\$ 5,549,123.00 in 2018 (Municipal Urbanization Transit Company [CMTU], 2018). The data collected reveal that this value represents 14.2% of the total municipality's investment in household waste management.

The population is responsible for separating metals, glass, paper/cardboard, long-life packaging, and plastics. Once a week, the cooperative responsible for a given territory collects recyclable waste door-to-door using its trucks. When they arrive in the sheds, are poured into tracks and screened manually, placed in bags, and then compacted and baled. Vitreous materials, after being screened, are allocated in containers where they are manually crushed. Each cooperative sells processed waste and share the profit among its members. If the material does not have a buyer, even though it is potentially recyclable, it is taken to the landfill by the concessionaire of the urban cleaning service, because it is considered a recycling waste.



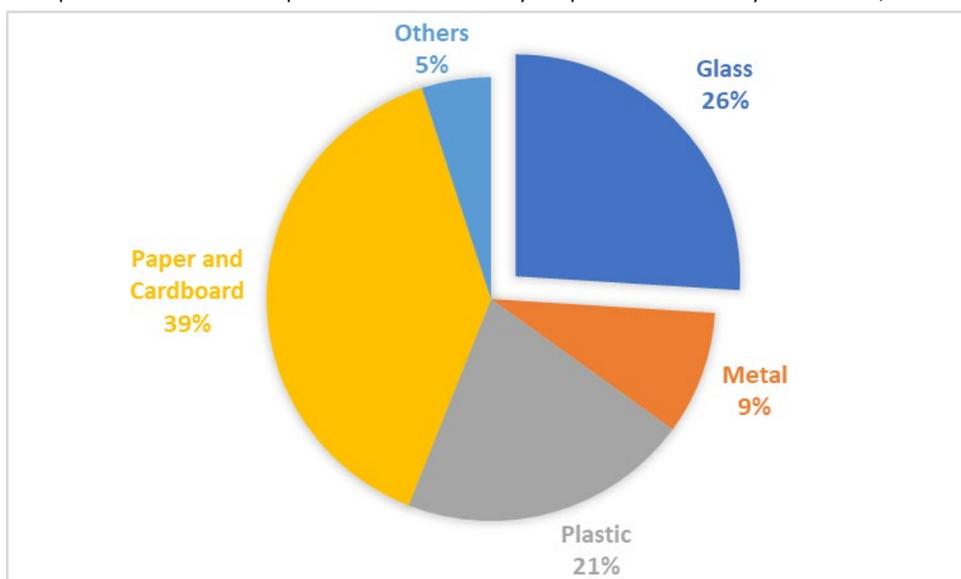
Cooperatives have important differences in the size of the operating territory, the number of cooperative members, and management models. They present different levels of social vulnerability, great asymmetries, and power inequality (CMTU, 2017; CMTU, 2018).

In recent years, the system has been losing efficiency regarding the amount of waste per capita destined for selective collection, the number of households that have a weekly selective collection, the inclusion of waste pickers in the system formalized by the municipality, and the total mass of the recycled solid waste. Studies show that cyclical and structural factors have led to the destabilization of the system, especially due to changes in related fields, invasions, macro events, and the fragility of traditional actors (Aligleri, Borinelli, & Luzio-Dos-Santos, 2020; Borinelli, Aligleri, & Luzio-Dos-Santos, 2019). The total of waste collected and commercialized increased from 13,200 tons in 2016 to 7,300 tons in 2018, which means a decrease in the mass of waste generated by the municipality and sent to selective collection. In 2017, only 5.4% of the municipal household waste generated in the municipality went to the selective collection system and 94.6% were sent to the municipal Waste Center (landfill).

4.2 Glass Packaging in the Municipality's Selective Collection System

The total mass of glass sent to the selective collection system of the municipality in 2017 was 2,409.83 tons and 96.7% of it was screened and sent to a new cycle of transformation of the material. Only paper and cardboard packaging had greater commercialization, in mass, as shown in the graph below.

Graph 2 – Gravimetric composition of waste sold by cooperatives in the city of Londrina, Paraná



Source: the authors, from the data made available in the Diagnosis of Urban Solid Waste Management - 2017, SNIS, by the Ministry of Regional Development/National Secretariat of Sanitation.

Interviews with the managers of the cooperatives pointed out that the screened glass was commercialized in two different forms: a) a small part was sold in the form of whole packages to local companies of the family agroindustry and small artisanal producers – wine, candies, and jams – that reuse the material; b) the vast majority, mixed in various types and colors, was manually crushed into shards by the cooperative members (mixed glass) and commercialized to local middlemen or

processing industries. Glass manufacturers request the previous breakage of the glass (Torres & Gonçalves-Dias, 2018).

The commercialization of post-consumer materials by cooperatives, including vitreous packaging, reduced the volume of waste to which the City Hall would have to take responsibility for, which decreased municipal public spending on the transportation and grounding of materials in the Waste Treatment Center (WTC). In 2017, considering that the collection and transportation of vitreous packaging sold by cooperatives were carried out by conventional collection, together with rejected waste, the public cost would be increased by R\$ 302,000 to municipal public coffers. It is also necessary to consider the cost of handling inside the landfill, which would be approximately R\$ 64,500 per year for this mass of the waste. To reduce the public cost, besides the fundamental work of sorting cooperatives, it is essential to participate in the proper separation and cleaning of materials to increase the mass of packaging, with the possibility of reinsertion into the post-consumption recycling chain. It is worth remembering that some materials cannot be screened for commercialization due to their dirt (contamination of materials with soil and food or liquid scraps) or mixing level (dispersion of recyclable materials inside the raw material) that decrease their potential for placing in new markets (Varella & Lima, 2011).

The on-site analysis carried out in the cooperatives revealed that some glass packages sent by the population to the selective collection system had residues or contained liquids. This increases the foul odor of the material, hinders the transport of the material, and often makes it impossible to sort for new cycles in a circular economy.

In Londrina, in 2017 alone, more than 79.66 tons of glass destined to cooperatives were classified as rejected waste and directed to the landfill because they were considered inadequate for commercialization, which corresponded to 3.3% of the total vitreous packaging sent to the selective collection system. These materials, when they do not continue in the reverse chain, cease to generate local economic gains, as shown in Table 3. From this same picture, we can conclude that the cost of transport and management of unsorted glass in the landfill is higher than the possible economic gain generated for cooperatives. Thus, we can state that the logic of linear economics leads to economic costs that could be avoided within the municipal government.

Table 3 - Economic losses in 2017: Glass classified as rejected

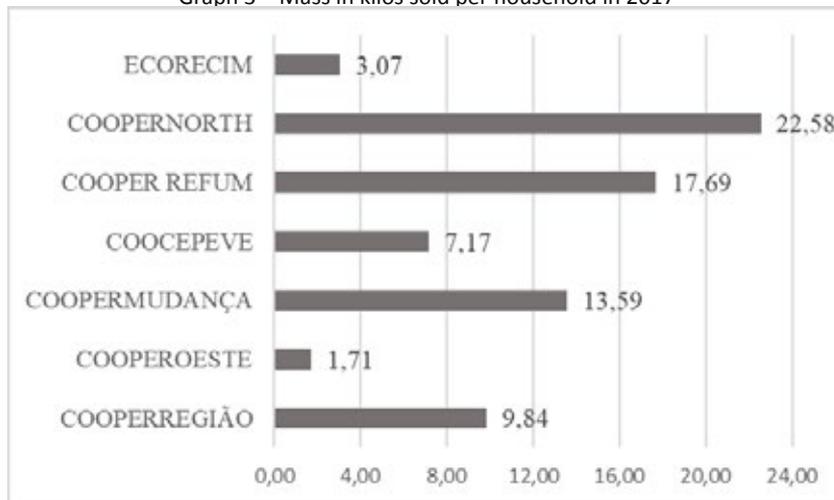
	R\$
Billing not generated for cooperatives from glass classified as rejected	R\$ 6,055.00
Cost generated for the municipality – transportation of vitreous material to the landfill	R\$ 10,348.00
Cost generated for the municipality – management of vitreous material in the landfill	R\$ 5,505.00
Total losses	R\$ 21,908.00

Source: the authors, being R\$ 76.00 per ton sold by cooperatives, R\$ 129.90 per ton transported to the landfill, and R\$ 69.10 per ton in the operation and maintenance of the landfill.

The cooperatives of Londrina operate in different regions of the city and serve a different number of households. The analysis of sales invoices issued by the seven cooperatives showed that there was a great disproportion in the mass (in kilos) recovered and commercialized per household, as shown in Graph 3. The average mass of the municipality was 10.11 kilos of glass recovered per household per year, that is, less than 1 kilo of vitreous packaging per month. This situation needs to be better investigated, but it is inferred that the family income of the citizens interferes with the type and quantity of vitreous waste generated, as well as that the low commercialization value of the material discourages screening by cooperatives.



Graph 3 – Mass in kilos sold per household in 2017



Source: the authors, from data in sales invoices provided by CMTU, 2017.

The average selling price of glass was R\$ 0.076 per kilo. Graph 4 shows that there was great variability in the commercialization price of the packages among the cooperatives, ranging from R\$ 0.04 to R\$ 0.18 a kilo, although all of them sell mixed-type glass broken into shards. Cooperrefum, a cooperative that obtained a sales value far above the other ones, was responsible for the price of freight that corresponded to 52.6% of the price received by the cooperative. Therefore, the real gain of screened glass obtained by Cooperrefum was R\$ 0.085 per kilo, which is close to the overall average.

Graph 4 – Sales value of the kilo of mixed glass shards (2017)



Source: the authors, from data in sales invoices provided by CMTU, 2017.

The interviews conducted with cooperative managers, as well as the unsystematic observations made in the screening sheds, showed that the screened vitreous packaging is kept for long periods in the sheds of the cooperatives to form larger sales lots, often exposed to the weather. The low price per kilo of material and the difficulty of finding potential buyers are factors that explain these long storage periods. A similar situation is reported by Lemos (2012) in the state of Santa Catarina, where “The commercialization of vitreous material has encountered difficulties in 73% of cases” (p. 81).

The invoices analyzed allowed us to conclude that a large part of the mass of glass was commercialized to local middlemen and, when sold directly to the processing industries, they are allocated in the city of Porto Ferreira, state of São Paulo, which is 490 km from Londrina (PR).

The analysis allows us to infer that the distance to be covered by the screened material to its destination for processing is one of the explanations for the low sales price in the local market and an insignificant gain for the cooperative members, as also evidenced in other Brazilian municipalities (Lemos, 2012; Torres, & Gonçalves-Dias, 2018; Santiago, 2011; Soares, 2018). For price formation purposes, it is important to express that the industry has not been considering the high degree of dangerousness in the transport and handling of this type of packaging. The manipulation of post-consumer glass for recycling makes cooperative members vulnerable to risks of work accidents in the reception and separation of glass due to the existence of shrapnel (Virgem, 2010), as well as the manual breakage of packaging to turn into shards on the container. The use of individual protection equipment has not been sufficient to avoid recurrent accidents among cooperative members.

In 2017, the cooperatives located in the city of Londrina had the job of collecting door-to-door, screening, moving the material in the shed, breaking and storing to sell for only R\$ 76.00 a ton. This value was also close to the sale price of cooperatives in the municipalities of Canoas, State of Rio Grande do Sul (R\$70.00), Guarujá, state of São Paulo (R\$80.00), Belo Horizonte, State of Minas Gerais (R\$ 70.00), and Mesquita, state of Rio de Janeiro (R\$ 80.00) in the same period, as disclosed by the Business Commitment for Recycling (CEMPRE, 2017) in its monthly newsletter. Considering the data of the different Brazilian municipalities, it can be said that glass packaging is formed by raw materials of low economic value in the national market, which decreases the added value of vitreous waste. The low remuneration of cooperatives may be related to market mechanisms, because an oligopoly situation prevails in the production of glass for packaging and the oligopsony prevails in the purchase of shards (Calderoni, 2003). That is, the industry seems to define the market price regardless of the geographical proximity of the municipality with the manufacturing units of the transformation of the material.

The low market value of vitreous waste can be easily verified when compared to other materials. For example, Table 4 shows the value per ton for other materials screened by Cooperregião, Londrina's largest recycling cooperative that alone attends 87,800 households.

Table 4 – Average price of commercialization of materials by Cooperregião

Material	Processing Type	Commercialization Value (ton)	% Gain on Glass
Glass	Mixed and ground in shard	R\$ 60.00	---
Tin scrap	Pressed and baled	R\$ 120.00	100%
White paper	Pressed and baled	R\$ 470.00	785%
Cardboard	Pressed and baled	R\$ 600.00	1,000%
Tetra Pak Packaging	Pressed and baled	R\$ 340.00	566%
Transparent pet bottle	Pressed and baled by color	R\$ 1,750.00	2,916%

Source: data provided by Cooperregião, referring to the average marketing values for the year 2017.

In Cooperregião, glass shard accounted for 25.17% of the total mass of material sold in 2017, but the financial revenue generated by it meant only 1.43% of the cooperative's revenues. The results corroborate the findings of Carr and Kim (2017, p. 322) in the state of Ohio/USA, stating that: "Therefore, most recycling between supply chain member organizations in a closed-loop supply tended to regard glass as "the least favorable item" and focus their recycling activities on other items." We deduce that the low price of post-consumer waste is part of a global strategic decision of



the industry in the sector – since glass-producing companies act as global players.

Table 5 presents a compendium of the main social, environmental, and economic problems identified in the commercialization of post-consumer vitreous packaging in the city of Londrina, from the analysis of the multiple data sources from different actors used in this study.

Table 5 – Main Problems in Reverse Logistics of Vitreous Packaging in Londrina

DIMENSIONS	PROBLEMS		
	Separation of post-use vitreous packaging performed by the population	Transfer, handling, and storage of vitreous packaging in cooperatives	Reverse logistics to drain packages screened and processed in shards by cooperatives
SOCIAL	Reduction of the participation of the population in the selective collection system of the municipality by reducing the mass of materials for cooperatives	Door-to-door collection of vitreous products mixed with other materials, which increases dangerousness in transport and management in sheds Dangerousness and unhealthy conditions in the manual breakage of vitreous packaging	The small gain of the cooperative members with the sale of materials, intensifying the high social vulnerability
ECONOMIC	Contamination of vitreous packaging that interferes with the quality of the material for recycling Possible increase in the rate of waste per household due to the high mass destined to the landfill	Vitreous packaging takes significant space inside the door-to-door collection trucks, due to its volume and density Long storage periods of packaging in cooperatives for the formation of a minimum lot of sale The low added value of color-screened vitreous packaging	Difficulty in contacting and creation of business bonds with the buyer industries High freight value due to the large distance from the buyer industries Sale of vitreous material to intermediaries - local middlemen The closed supply chain of vitreous materials The oligopoly of hollow glass industries and oligopsony in the purchase of post-consumer vitreous material Low resale value compared to other recyclables Low financial gain from screened material, which is opposed to the high costs of door-to-door collection and sorting
ENVIRONMENTAL	The improper separation that reduces landfill life	Open-air storage of packaging in warehouses at risk of spreading tropical diseases	High emission of greenhouse gases in transportation due to the large distances from cooperatives (capture points) to processing plants and glass product manufacturers. Long distances covered by road transport that increase the risk of environmental accidents in the transport of vitreous material.

Source: the authors



The data allow us to conclude that vitreous materials are among those economically less interesting to be commercialized by cooperatives located in the city of Londrina. We can affirm that the collection and separation of glass are activities that involve a lot of work from the waste pickers, have high vulnerability to risks of accidents, and a tiny economic gain, that intensifies the high social fragility and does not contribute to the socio-economic emancipation of the cooperative members. Also, the non-separation of material for new cycles of industrial transformation increases municipal public costs concerning the management of household waste.

The results reiterate the positioning of different researchers (Jabbour, Jabbour, Sarkis, & Govindan, 2013; Castelani, 2014; Nascimento, Sobral, Andrade, & Ometto, 2015; Gonçalves-Dias, Ghani, & Cipriato, 2015; Teodósio, Gonçalves-Dias, & Santos, 2016; Monterosso, 2016) that say the search for solutions to environmental and economic problems caused by the high generation of municipal solid waste in Brazil still have strong deficiencies in methodologies and technologies.

5 FINAL REMARKS

The value production chain, based on the premises of the circular economy, takes on the activity of recycling materials as a component of reverse logistics that enables the recovery of waste and its reuse as a raw material in new production cycles.

Thus, it can be said that cooperatives play an important role in the reverse chain of vitreous packaging, enabling multiple economic and environmental benefits for the national glass sector. However, they are the most fragile link in the chain with a low value received by the recovered material, which reflects the oligopsony structure of the sector and the reduced centrality of the compensation for waste pickers in the negotiations of the sector's reverse packaging logistics agreement signed in 2015. The unsatisfactory social result corroborates several studies that evidenced the low degree of implementation of public policy (Bauer, *et al*, 2015; Soares da Silva, Nunes da Silva, & Rezende, 2016; Demajorovic & Massote, 2017; Freitas, Besen, & Jacobi, 2017).

The study allowed us to conclude that, among the recycled materials screened by cooperatives installed in the city of Londrina, glass has the lowest market value, besides having weaknesses in various dimensions of its reverse logistics. The reality found in the city of Londrina was evidenced in recent studies conducted in other Brazilian municipalities, such as São Paulo (Torres & Gonçalves-Dias, 2018), Belo Horizonte (Santiago, 2011; Venâncio *et al*, 2020), Uberlândia (Soares, 2018), and the Federal District (Morais *et al*, 2018; Dourado, 2020), including the worsening of the difficulty of commercialization. Such reality was also evidenced by a study undertaken in the United States (Carr & Kim, 2017). Therefore, the glass packaging producing industries have to walk a long way to the construction of a sustainable production chain. Therefore, it is important to carry out new systematic studies that follow the post-consumer institutional actions developed by the glass sector and governments, in several territories, to comply with national legislation regarding the reverse logistics of their products.

How the reverse logistics of vitreous packaging is operationalized has increased public financing with this type of material, since the sales price obtained by waste pickers does not corroborate the economic support of cooperative enterprises and, in many cases, drives the destination of vitreous post-consumption materials for disposal in the condition of rejected. It is believed, as also pointed out by Dourado (2020) for the reality of the Federal District, that the post-consumer vitreous packaging is only being screened by the cooperatives of Londrina because the municipality requires its separation due to the service contract signed with them. Otherwise, due to its low market value, high effort, and processing risk, much of the glass packaging would be destined for municipal landfills.



Public agencies will need to act more forcefully to promote a value chain that genuinely includes those cooperative members in the economic gains of reverse packaging logistics. Public intervention is essential to reallocate resources in the highest interests of society.

At the municipal level, using the principle of shared responsibility, we suggest a call from the State Public Prosecutor's Office, together with executive agencies, for the industries producing vitreous packaging to enter into partnerships for the collection of packages forwarded by the citizens to the selective collection system. We also suggest to establish a system with the use of a container that is independent of other types of recyclables, also called an exclusive collection system, which has shown positive results since 2014 in the city of Florianópolis (Caetano & Luna, 2018) and other latitudes of the globe.

The glass separated from the other recyclable wastes in the source, in a single fraction collection, and specific containers, reduces the risk of accidents of the cooperative members by mixing the vitreous materials to other materials since studies indicate that the cuts with glass characterize the most common accident among household collection workers in the collection mats in recycling cooperatives and the waste pickers of garbage dumps. Such a method of separation would also increase the amount of glass recovered (about the quantity collected), which would reduce the leverage of the middlemen in the commercialization, facilitate the accountability of the industries, in addition to reducing cross-contamination, which often makes it impossible to recycle the materials (Virgem, 2010).

At the national level, it is important to foster the virtuous circle of reuse as a public policy among beverage manufacturers, to induce the production chains to reactivate the reuse of packaging from washing and sterilization, without the need to be transformed into shards. Reviewing the tax system on the use of returnable packaging can be an accelerant element of this process.

It is also urgent that the federal government sign the sector agreement with Brazilian Glass Association and use Decree No. 9177/2017 (non-signatories) to make the producing industry accountable for the environmental liabilities spread in Brazilian municipalities.

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1. Definition of research problem	√			
2. Development of hypotheses or research questions (empirical studies)	√		√	
3. Development of theoretical propositions (theoretical work)	√			
4. Theoretical foundation / Literature review	√	√		
5. Definition of methodological procedures	√	√		
6. Data collection	√	√	√	
7. Statistical analysis				
8. Analysis and interpretation of data	√		√	
9. Critical revision of the manuscript		√		
10. Manuscript writing	√			

