



Integrating consumer behaviour into the environmental assessment of circular packaging: a scoping review

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Abstract

Purpose The impact of applying circular strategies to products is often measured through life cycle assessment (LCA). While LCA estimates and compares the impacts of circular products, its ability to integrate consumer behaviour is currently limited. The integration of consumer behavioural insights is especially relevant in the packaging sector, where consumer actions at the end-of-life are crucial for the success of circular strategies. This study explores integrating behavioural insights from consumer behaviour sciences (including psychology, sociology and socio-technical approaches) into LCA for a better assessment and design of circular packaging.

Methods Through a scoping review, scientific literature was mapped to (1) investigate the current integration of consumer behaviour aspects within packaging LCAs and (2) explore the behavioural determinants influencing the recycling and reusing of circular packaging. By building on the insights from these reviews, this study provides recommendations on how to integrate behavioural insights with LCA to assess the impact of circular packaging systems.

Results and discussion The results indicate that LCA studies for packaging are generally based on assumptions on consumer behaviour, reducing their utility for circular decision-making. The main methods currently used to integrate behaviour variability are scenario and sensitivity analysis, with some studies using consumer profiles and behaviour research to support LCA modelling. Socio-technical approaches, e.g. agent-based modelling or system dynamics, have not been applied yet to integrate a behavioural perspective into the LCA of circular packaging, while this may be a promising avenue. The behaviour science literature covered several predictors found to be important to understand packaging reuse and recycling behaviour. Our review shows that attitudinal and value dimensions have consistently been found to influence both packaging reuse and recycling behaviour, while the latter is also strongly driven by control factors. While LCA modellers can obtain behavioural insights from the behavioural literature, the step of transforming these insights into quantifiable behaviour patterns still needs to be taken. Such endeavours can help to translate individual behaviour predictors into behavioural patterns regarding packaging reuse and recycling.

Conclusions Consumer behaviour is currently not widely considered in the LCA of circular packaging. Insights from consumer behaviour sciences can contribute to LCA studies in two main ways: defining consumer profiles and modelling socio-technical parameters. Consumer profiles could be drawn from the psychological behaviour literature, while socio-technical approaches can provide models of system behaviour where the interaction of different system actors and items is quantitatively modelled and coupled with LCA models.

Keywords Life cycle assessment · Circular economy · Reuse · Recycle · Consumer profiles · Behaviour pattern

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1 Introduction

The circular economy (CE) concept builds on the well-known and established concepts of waste management, ecoefficiency and resource value retention (Reike et al. 2018). It provides a renovated view of how our society should produce and consume goods and services. Through this renewed lens, products and services reduce resource

use and waste generation as much as possible by following different strategies labelled as circular or R-strategies (e.g. reduce, reuse or recycle). Society and policymakers see the shift from the current linear economy to a CE as essential to achieving a sustainable, resource-efficient, low carbon and competitive economy (European Commission 2015). This transition is particularly crucial for the packaging sector, due to the high material intensity and waste volumes that it generates. The packaging sector consumes around 40% and 53% of European plastic and paper production, respectively, and produces about 40% of municipal solid waste (CEPI 2017; PlasticsEurope 2017). Hence, accelerating the transition towards a circular economy in the packaging sector will likely have a high impact on waste production.

According to circular and waste management principles (Kirchherr et al. 2017), the main circular strategies that could apply to packaging are (1) *refuse*, avoid using packaging at all; (2) *rethink*, modify the packaging concept for a more sustainable option, e.g. detergent bottles could be re-designed into small paper sachets of powder detergent; (3) *reduce*, decrease material and energy intensity of the packaging through, e.g. smart packaging design; (4) *reuse*, to extend the lifetime of the packaging by providing several use cycles; and (5) *recycle* the packaging materials through advanced technologies able to sort packaging items more efficiently and recover higher quality materials. From here on, we refer to packaging that follows any of these R-strategies as *circular packaging*. When pursuing circularity, the packaging sector has mostly focused on designing recyclable packaging and introducing biomass-based materials (Chakori et al. 2021), which could be considered recycle and rethink strategies. The fourth strategy, *reuse*, has also seen a recent uptake from producers and users (Megale Coelho et al. 2020a). Reusable packaging maintains the functionality of the material and product, replacing single-use packaging and thus reducing material use and waste. Most of these circular strategies are designed to reduce resource use. However, there is usually a mismatch between the expected benefits and the real environmental consequences once the products are introduced into the market. This is often the case because of the uncertainty about the consumer's behaviour; even when consumers buy recyclable or reusable packaging, they do not always separate their waste for recycling and often fail to reuse their reusable packaging. Currently, only 14% of all global plastic packaging waste is collected for recycling (EMF 2016). Therefore, ensuring that technological solutions prompt the desired consumer behaviour responses is crucial for successful circular packaging.

The impacts or benefits generated by different circular strategies are often measured and validated through sustainability assessment frameworks, such as life cycle assessment (LCA). LCA has been widely used to support the eco-design of products and is the primary tool

currently used to assess the effects of circular strategies in product systems (Corona et al. 2019). While LCA studies can estimate and compare the impacts of different products and services, their ability to integrate the influence of consumer behaviour on the environmental impact is mostly unexplored. LCA studies are generally based on the assumption that consumers have access to the right disposal option for their product (e.g. recycling), choose this option at the end of life (EoL) of their products, and do not deviate from expected behaviours. These unrealistic assumptions limit the value of the LCA method and result in guiding decision-making towards a sustainable CE, especially in circular packaging, where the influence of consumer behaviour on the success of the circular strategy is high.

By integrating consumer behaviour insights into current sustainability analysis frameworks, we can advance our understanding of the environmental benefits and impacts of circular strategies. As indicated by Polizzi di Sorrentino et al. (2016), bringing behavioural sciences into LCA has the potential to not only better predict the environmental impacts of a product but also assess the potential for behaviour change and methods for changing behaviour. However, this integration has been scarcely implemented (Polizzi di Sorrentino et al. 2016). In 2017, the Joint Research Centre (part of the European Commission) published a Technical Report on integrating behavioural sciences into LCA to estimate consumer footprints (Nita et al. 2017). They identified several steps within the LCA method where behavioural science knowledge could be integrated, including the functional unit, system boundaries, scenario analysis and result communication. However, despite an extensive knowledge base about behaviour and behaviour change in general, knowledge of consumer behaviour regarding the purchase, usage, sorting and disposal of specific types of packaging is limited (Molina-Besch et al. 2019) and scarcely integrated into environmental impact studies (Martinho et al. 2015; Williams et al. 2018). In addition, efforts so far have focused on the product use stage, while the EoL stage has usually been overlooked due to insufficient understanding of the consumer EoL behaviour. Yet, EoL behaviour is the key to successful circular strategies for packaging, such as reuse and recycling. Hence, through a scoping review, this study aims to (1) map the extent to which consumer behaviour is considered within the LCA of packaging products, (2) explore the behavioural determinants of refuse, reuse and recycling of packaging, and (3) derive recommendations for integrating consumer behaviour insights in the LCA of packaging. This article is the first to provide an overview of the interaction between behaviour and packaging impacts literature considering two perspectives: the impact of consumer behaviour on the environment and the factors inducing pro-environmental consumer behaviour.

The rest of the article is organised as follows: Sect. 2 describes the methodology followed for the scoping review. The review results are described in Sect. 3, starting with the influence that consumer behaviour has on the environmental impacts of circular packaging according to the LCA case-study literature in Sect. 3.1, followed by insights from the behavioural sciences literature on predictors of circular packaging behaviour in Sect. 3.2 and providing a classification of approaches used (or suggested) to integrate behaviour variability into LCA assessments in Sect. 3.3. The discussion dives deeper into the findings obtained and sums up to what extent consumer behavioural sciences (including psychology, sociology and socio-technical approaches) are, or can be, integrated into the LCA of circular packaging.

2 Methods

The scoping review was conducted by a multidisciplinary team composed of researchers with expertise in industrial ecology and behavioural sciences. The review methodology was based on the framework followed by Pham et al. (2014) and included the following five key phases: (1) research question definition, (2) identifying relevant studies, (3) selection of studies, (4) charting the data and (5) summarising, reporting and discussing the results. According to the goal of this study, the method of scoping review was selected as it allows mapping topics that have not been extensively reviewed before and have a complex or heterogeneous nature (Pham et al. 2014). The main goal of scoping reviews is to summarise and disseminate research findings while identifying lines for future research. It differs from a systematic literature review in that the latter aims at summing up all the available research on a specific question and providing a critical view of included studies, whereas the former focuses on giving an overview of a large and diverse body of literature (Pham et al. 2014).

The scoping review was guided by a general question, “How can we integrate insights and methods from social and behavioural sciences into the LCA of circular packaging items?” subdivided into three sub-research questions: (Q1) To what extent is consumer behaviour currently integrated into the LCA of packaging?, (Q2) What are the behavioural determinants of refuse, reduce, reuse or recycling of packaging? and (Q3) What are the most promising methods to integrate knowledge on consumer behaviour in the LCA research on circular packaging? Relevant studies were identified through a literature search conducted in January 2022 on the search engines Web of Science Core Collection and Scopus. The search was focused on scientific articles, conference reports and book chapters in English, with keywords related to packaging, life cycle assessment or consumer behaviour, in either the title, abstract or keywords.

The selection of studies was carried out by reviewing the abstracts of each document and selecting the articles that were related to environmental impacts, consumer behaviour, packaging and circular strategies. The details regarding search strings, number of results and selection criteria are described in (Fig. 1). A snowball technique (both forward and backward) was also used in which citations within selected articles were included if relevant for the integration of consumer research into LCA. In addition, articles published from January 2022 to May 2023 and found through publication alerts were included when relevant. The contents of these articles were used to answer question 3.

2.1 Selection of articles and review of contents

The identified and selected articles were classified into three main groups: (1) LCA studies analysing the environmental impacts of packaging while considering consumer behaviour variability, (2) quantitative consumer behaviour studies and (3) studies or reviews focused on modelling pro-environment consumer behaviour in the context of environmental impact assessment. The identification and selection process resulted in 24 LCA studies assessing the environmental impacts of packaging while considering the influence of consumer behaviour (group 1), 69 articles studying consumer behaviour towards packaging products (group 2) and 23 articles exploring the topic of modelling behaviour in the context of LCA.

The content of the articles in group 1 was analysed through an attribute matrix, used to systematically document the methods and findings of the case studies, and contribute to answer questions 1 and 3, namely: how the variability in consumer behaviour affected the environmental impacts of packaging (described in results Sect. 3.1) and how behavioural aspects were integrated into the LCA (described in Sect. 3.3). The matrix was used to collect information regarding the object of analysis, the goal of the study, the method for consumer behaviour integration, the life cycle where consumer behaviour is explored, and the main findings related to packaging’s environmental performance. Table 1 summarises the attribute matrix, including the most critical parameters.

The review of articles in group 1 helped identify the main behavioural aspects affecting the environmental impact of circular packaging strategies. These aspects guided the review of articles in group 2, which were coded into the circular behaviour analysed (refuse, reduce, reuse, recycle), the predictor investigated, the type of object or packaging under study (e.g. plastic bottles, or general household waste) and the location of the study. The identified predictors of circular packaging behaviours were then inductively coded to explore patterns in the types of predictors identified in behavioural literature (i.e. environmental

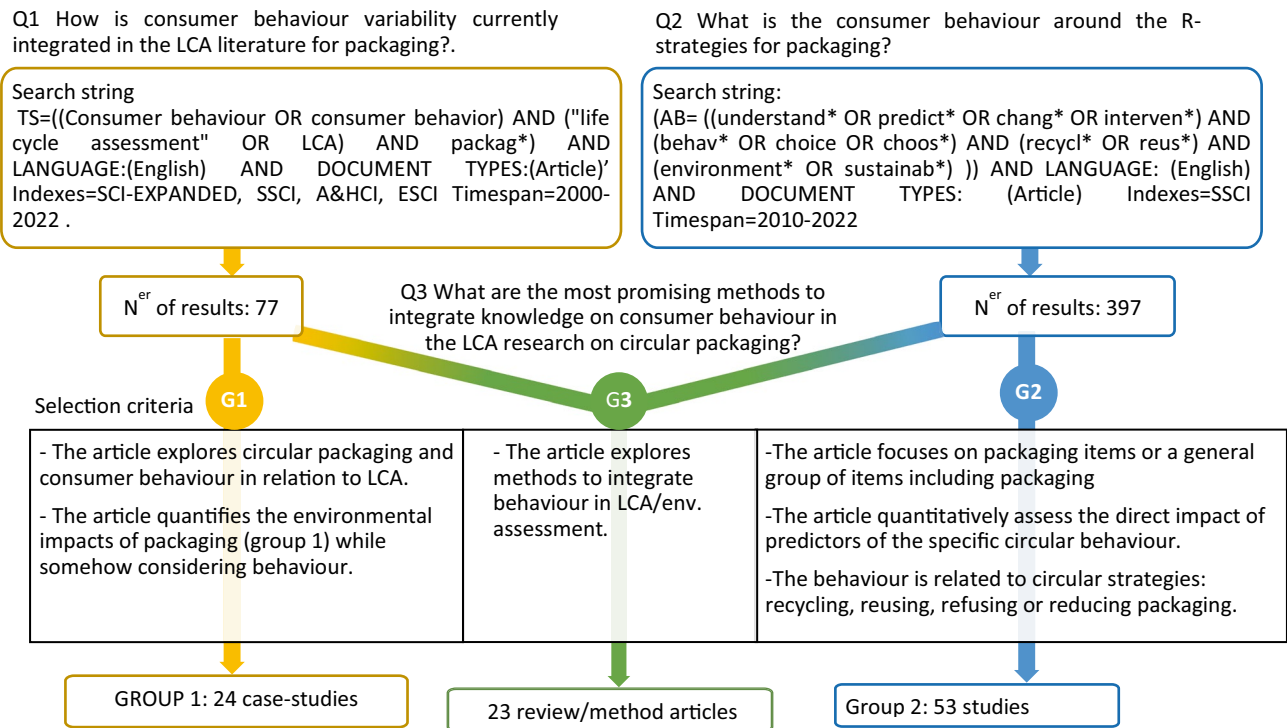


Fig. 1 Search strings, results, and selection criteria for the literature search

orientations, knowledge, demographics, social influences and individual traits).

In addition, several articles were found that do not provide LCA case studies or behaviour analyses but explored the integration of consumer behaviour sciences into the environmental assessment of packaging items. These articles were classified into a third group (answering Q3), and their findings were integrated into Sect. 3.3.

The results obtained from these three article groups were combined to provide recommendations on how to consider the findings and methods from consumer behaviour sciences in the LCA of packaging items.

3 Results

The results of the review are organised into three sections. The first Sect. 3.1 describes the influence of consumer behaviour on the life cycle environmental impacts of circular packaging as found in the LCA studies within group 1. Section 3.2 describes the main determinants for consumer behaviour around circular packaging as found in the articles of group 2. Finally, Sect. 3.3 combines the findings from the articles in groups 1, 2 and 3 to provide an overview of methods that are currently or can potentially be used to integrate consumer behaviour variability into LCA studies of circular packaging.

3.1 Influence of consumer behaviour on the life cycle environmental impacts of circular packaging

Although there are many LCA studies focusing on packaging (e.g. a search on Web of Science with the words “Life cycle assessment” and “packaging” gives more than 590 results), only 24 studies were found that explicitly explored the influence of consumer behaviour in the environmental profile of packaging. Most of these studies are related to food systems: eight studies focus on the impacts of food packaging (or container) items, five studies evaluate the impacts of food products (including packaging) and six studies focus on the impacts of food waste and their relation with packaging design (see Table 1 for a list of these studies). Only five studies focused on other types of product packaging, namely two studies exploring the impacts of packaging related to online shopping, one study on ink cartridges, one study on packaging-free supermarket products and another study on aerosol spray cans. Many of the reviewed studies explored consumer behaviour towards the packaged product rather than the packaging itself, although the behaviour was often related to, or affected by, the shape, size, material or information contained in the packaging.

Most of the LCA literature on primary packaging is focused on food products (e.g. 83% of the reviewed studies were related to food products). This is probably related to the high share of food packaging within the packaging sector and

Table 1 Simplified attribute matrix for the review of LCA studies

Study	Object of analysis			Method for consumer behaviour integration in LCA				Life cycle aspect where behaviour is explored			
	Food items	Food waste	Food packaging	Sensi. analysis	Profile scenarios	Consumer research	Other*	Packaging choice	Transp. mode and freq.	Prod. use & food waste	Packaging EoL
1 (Azapagic et al. 2016)	x			x						x	
2 (Boesen et al. 2019)			x				x				x
3 (Brommer et al. 2011)	x			x						x	
4 (Burek et al. 2018)			x	x				x		x	x
5 (Büsser and Jungbluth 2009)			x	x	x			x		x	x
6 (Espinoza-Orias and Azapagic 2018)	x			x				x		x	x
7 (Gruber et al. 2016)		x			x			x		x	
8 (Hischier 2018)				x			x		x		
9 (Kunamaneni et al., 2019)				x			x				x
10 (Kounina et al. 2012)			x	x						x	
11 (Krystofik et al. 2014)				x		x			x		x
12 (Manfredi et al. 2015)			x				x			x	
13 (Stankiewicz et al. 2019)		x		x				x		x	
14 (Sturtewagen et al. 2016)	x					x			x	x	
15 (Svanes et al. 2019)				x				x		x	
16 (Van Loon et al. 2015)				x		x			x		
17 (Vázquez-Rowe et al. 2013)				x					x		x

Table 1 (continued)

Study	Object of analysis			Method for consumer behaviour integration in LCA					Life cycle aspect where behaviour is explored				
	Food items	Food waste	Food packaging	Food packaging	Other packaging	Sensi. analysis	Profile scenarios	Consumer research	Other*	Packaging choice	Transp. mode and freq.	Prod. use & food waste	Packaging EoL
18 (Wikström et al. 2014)	x		x						x	x		x	x
19 (Wohner et al. 2019)		x				x						x	
20 (Yokokawa et al. 2019)		x				x						x	x
21 (Yokokawa et al. 2018)		x				x				x		x	x
22 (Scharpenberg et al. 2021)				x				x				x	x
23 (Zhang et al. 2019)			x					x				x	
24 (Woods and Bakshi 2014)			x					x				x	x

*In these studies behaviour was explored but not numerically integrated with LCA, except for one study that used Discrete Event Simulation

the critical link between packaging and food waste. Packaging fulfils the essential function of preserving food from field to fork in a safe environment while avoiding spillages or losses (Wikström et al. 2014). Therefore, many studies exploring consumer behaviour in environmental assessments of packaging focus on how the packaging design affects the volume of food wasted by consumers. Impacts from producing and disposing of the packaging item can be labelled as “direct impacts”, while the impacts from food waste related to the packaging design are labelled as “indirect impacts” (Molina-Besch et al. 2019). Results from the LCAs of food products indicate that the direct impacts of packaging have a low contribution to the total life cycle impacts of the packaged food product. Nevertheless, this depends on the type of product (INCPEN 2009); the share of direct impacts from packaging in solid food products can typically be 10% of the total impact of the product, while for beverage or liquid food products can be as high as 50%, e.g. soft drinks (Boesen et al. 2019) or canned or jarred tomato (Del Borghi et al. 2014).

This review identified several moments in the life cycle of packaging where consumers’ decision-making influences the environmental impacts of packaging. These decisions are related to packaging materials and size, transportation mode and frequency, product use and food waste and packaging EoL or disposal (including recycling and reuse). Most of the studies explored the influence of consumer behaviour on several life cycle stages, especially on product use and food waste (78%). The EoL stage of the packaging was explored in 43% of the studies, while 40% explored packaging choice (e.g. materials/size) and 26% looked at transportation mode or frequency. None of the reviewed studies explored the effects of littering, which Caspers and colleagues (2023) recently highlighted as an important behaviour to be included in the LCA of packaging.

The following sections focus on the main behavioural aspects affecting the impacts of the purchase and use (related to refuse and reduce strategies) and EoL of packaging (reuse and recycle) since these are the critical behaviours for circular packaging strategies. A summary of the most relevant behavioural aspects, as identified during the review of the studies, is included in Table 2. These aspects were linked to significant variability in the environmental impact of the packaging under study.

3.1.1 Packaging refuse and reduce

The reduce or refuse strategies can be induced by designing sustainable packaging attributes or by changing purchasing practices. Packaging attributes can be considered design parameters of the packaging item that enable or restrict the actions of consumers (Wikström et al. 2014). By designing circular attributes, consumers can be encouraged to act in the most environmentally preferred way. For instance, food

Table 2 Main behavioural aspects affecting the environmental impact of circular packaging strategies

<i>Strategies</i>	<i>Behaviour relevant for LCAs of circular packaging</i>
<i>Refuse and reduce</i>	- How consumers reduce product, material or food waste due to specific packaging or product attributes
<i>Reuse</i>	- Packaging/container cleaner behaviour - Return behaviour - Transportation mode and frequency (to and from the store)
<i>Recycle</i>	- Sorting behaviour depending on situational factors and packaging attributes

packaging can be designed to easily close hermetically after opening, inducing a reduction in food waste, or soap can be re-designed into a concentrated form, e.g. solid bars packaged in cardboard boxes, reducing transportation weight, packaging materials and life cycle impact (Koehler and Wildbolz 2009).

Several of the reviewed studies explored the environmental impacts resulting from different packaging materials, types and volumes, providing trade-offs between different material types and sizes and their relationship with life extension and food waste (Yokokawa et al. 2018). In particular, twelve of the reviewed studies explored the influence of packaging design on consumers' food waste behaviour. At least five of these studies conclude that increasing the material intensity for packaging improves the protection functionality of the packaging and, as a consequence, reduces the environmental impacts of food products because of the avoided food waste (Svanes et al. 2019; Yokokawa et al. 2018). For instance, Manfredi et al. (2015) estimate higher environmental savings from adding an antimicrobial coating to milk packaging due to the associated extended shelf life and reduced milk waste. Since the impacts of producing food are higher than the impacts of producing the packaging, food waste has a relatively higher environmental impact than packaging materials. Such insights lead to a preference for the reuse and recycle strategies for packaging over the higher-level refuse and reduce strategies. This argument has often been used to advocate for the use of packaging in items that could, in principle, use no packaging at all. The plastic wrap around cucumbers is a well-known case. A recent study concluded that plastic wraps contribute to only 1% of the cucumber impacts while avoiding 5% of cucumber losses in the supply chain, hence compensating for the wrap impacts (Shrivastava et al. 2021). However, it is unclear if an optimised supply chain for unwrapped cucumbers would still result in a 5% loss of produce. In addition, two studies pointed out that the trade-offs between packaging materials and food waste can differ, e.g. a study on cabbage packaging indicated that an increase of packaging material per product leads to a higher total impact on global warming (Yokokawa et al. 2019), and the other study emphasised that packaging designed to reduce food waste does not necessarily lead to an increase of the packaging impacts in isolation (Wikstrom et al. 2014).

The food-waste LCA literature suggests that LCA studies addressing the environmental impacts of food packaging should take food waste into account, e.g. through the use of a functional unit that quantifies the amount of food eaten instead of the amount of food contained, thus accounting for the losses of food (Wikström et al. 2014). In this respect, Yokokawa et al. (2018) developed an assessment framework to explore the environmental impact trade-offs between packaging, food waste and consumer behaviour scenarios that can be helpful for food-related packaging items.

3.1.2 Packaging reuse

A recent review of 33 LCA studies on reusable packaging indicated that reusable packaging can have lower environmental impacts than single-use packaging. However, this is not always the case and depends on several parameters, including packaging material, transportation distance, cleaning mode and frequency and the packaging return rate by users (Megale Coelho et al. 2020b). The latter depends on the reuse behaviour of consumers and is usually one of the most critical parameters defining the environmental and economic viability of reusable packaging. The LCA literature typically addresses consumers' uncertainty regarding packaging reuse behaviour by performing break-even point analyses, i.e. by estimating how often reusable packaging should be reused to perform better than single-use items. This is the case, for instance, in a study on reusable cups for festivals that estimated their break-even point in 10 uses (Garrido et al. 2007), or a study on bottles for carbonated drinks that indicated break-even points of 3 uses for reusable glass bottles compared to aluminium cans and single-use PET bottles (Amienyo et al. 2013). Such an approach can tell us how reusable packaging should be used to perform better than the alternative but tells us little about how reusable packaging would actually perform in real life (e.g. the percentage of users that would at least reach the environmental break-even point).

LCA studies could be better informed by the behavioural sciences literature regarding the number of times that consumers reuse a packaging item and the key parameters that stimulate consumers to return the packaging. In this review, we found three studies exploring reusable packaging that consider consumer behaviour variability beyond break-even points, namely studies on packaging-free

supermarkets (Scharpenberg et al. 2021), refillable ink cartridges (Krystofik et al. 2014) and reusable cups (Woods and Bakshi 2014). These studies explored the consumer's influence regarding their purchase transportation mode and frequency, return rate and packaging cleaning behaviour, confirming the findings of previous literature regarding the relevance of these parameters. For instance, Scharpenberg et al. (2021) performed a comparative LCA on six typical products sold in packaging-free supermarkets. In these supermarkets, customers either bring their own refillable packaging containers or return the producer's containers. The authors conducted a survey to better understand the cleaning and returning behaviour of the consumer and used it to model the baseline scenario. They found that two product packages performed worse than the single-use alternatives partly due to the extra effort for cleaning and the low return rate. However, they concluded that there is currently little data about consumer behaviour, and further research is needed regarding cleaning habits, means of transport for grocery shopping and the types of containers used.

3.1.3 Packaging recycle

Few studies within the reviewed LCA studies focus on consumers' sorting behaviour (i.e. waste separation for recycling). Ten studies explored the variability of impacts at the EoL of packaging through a scenario analysis (e.g. recycle or reuse, such as in Krystofik et al. (2014) or sensitivity analysis (e.g. 100% recycling vs 100% incineration, such as in Wikstrom et al. (2014)), but only three of them linked these scenarios with real or specific consumer practices. In particular, one study looked at different disposal scenarios if the packaging was designed for at-home or on-the-go consumption (Burek et al. 2018), and two studies modelled three disposal patterns (no separation for recycling, occasional and regular separation) for food packaging (Yokokawa et al. 2019, 2018). Some authors recognise a lack of behavioural data, which leads to general, sometimes unrealistic, assumptions regarding the disposal, e.g. 100% recycling rate for aluminium packaging and 0% for plastic packaging. Most of the reviewed LCA studies model the waste treatment of packaging items by considering average waste treatment rates (derived from national statistics) for the materials involved in the packaging. In most studies, the waste treatment of the packaging items involves some degree of recycling, leading to a reduction of impacts because of the generation of secondary materials. For instance, the results from an LCA on milk packaging indicate that a 100% recycling rate could reduce the climate change impacts of plastic pouch packaging by up to 16% (Burek et al. 2018), and a study on sandwiches indicated that different packaging waste management scenarios can lead to a variation between 2.5 and 9.5% in the climate change impacts of sandwiches (Espinoza-Orias and Azapagic 2018).

Because packaging design, consumer interaction and available infrastructure influence the way consumers sort the packaging waste, it seems unwise to base EoL modelling of packaging solely on average recycling rates of materials (Molina-Besch et al. 2019). Still, most studies assume that plastic packaging will be recycled, independently of its design or consumer interaction. Only one study explored different sorting behaviours depending on the product consumption (on-the-go or at home) (Burek et al. 2018), and only two studies determined the recyclability of the packaging item by considering local sorting infrastructure (Wohner et al. 2019; Brommer et al. 2011) but did not consider variability in disposal behaviour. LCA practitioners could learn from the behavioural sciences literature what the different recycling behaviours are depending on different packaging systems characteristics.

3.2 Behavioural determinants in relation to circular packaging strategies

Although just a few LCA studies have taken the step of combining behavioural studies with LCA studies, there is a growing interest in recycling and reusing the behaviour of consumers in behavioural sciences. The articles from the behavioural sciences literature investigated consumer behaviour predominantly through correlational studies (e.g. Gkargkavouzi Halkos and Matsiori, 2019; Mtutu and Thondhlana 2016), while only a few experiments were reported (e.g. Ding et al. 2021; Ofstad et al. 2017). Many of these studies measured individual predictors such as values (e.g. environmental orientation) and norms (e.g. personal or social norms) and how such individual differences predict behaviour. The two most frequently used theories to explain pro-environmental behaviour were the theory of planned behaviour (Ajzen 1991) and the value-belief-norm theory (Stern et al. 1999). Only 10% of the studies reported one specific object of analysis, such as bottles, reusable cups or plastic bags. In most studies, the object of analysis was either unspecified (e.g. "waste") or a range of packaging items (e.g. household packaging) or materials (e.g. paper) that were treated as one homogeneous group. Topics that were recurrently investigated by authors included household recycling (e.g. Fan et al. 2019) and waste prevention behaviour (e.g. Bortoleto et al. 2012), including waste prevention behaviours within a university (e.g. Geiger et al. 2020) or adolescent populations (e.g. Balunde et al. 2020a).

A large majority of the papers reported on recycling behaviours, while other R-strategies (refuse, reduce, reuse as described in the introduction) were less frequently investigated. In particular, all the studies investigated recycling behaviour, 21% of studies investigated reuse behaviour and only 10% investigated reduce or reuse behaviours usually in combination with recycling or reuse behaviour. We, therefore, focused our review on the circular strategies regarding

Table 3 Number of articles that reported a significant influence of the respective predictor categories on recycle and reuse behaviour in the reviewed literature

Predictor category	Recycle	Reuse
Demographics and personality, <i>e.g. age, gender, income, personality</i>	14 (26%)	7 (64%)
Social influences, <i>e.g. social norms, social influence, reputational concerns</i>	15 (28%)	4 (36%)
Attitudes and values, <i>e.g. attitudes, values, environmental orientation, environmental identity</i>	29 (55%)	8 (73%)
Control, <i>e.g. perceived behavioural control, habits, situational factors</i>	33 (62%)	3 (27%)
Knowledge, <i>e.g. awareness, knowledge</i>	5 (9%)	2 (18%)
Total	53	11

recycling and reuse. Articles that assessed the impact of an intervention on behaviour or that presented qualitative studies were not included in this analysis, meaning only articles that quantitatively assessed the direct impact of individual differences on the specific circular behaviour were considered. We classified the significant predictors of the behaviours into six predictor categories of recycling and reuse behaviour, namely control, demographics, individual traits, environmental orientations, social influence and knowledge. These categories serve to organise the predictors of the behaviour. The frequency in which we found these to predict behaviour in the reviewed literature is displayed in Table 3. We discuss the specific predictors for recycling and reuse in the following subsections.

3.2.1 Packaging reuse

Relatively few studies have investigated predictors of packaging reuse (i.e. 11 studies out of 53 studies reviewed). Several researchers found that demographics such as age, gender, education and income influence packaging reuse behaviour (e.g. Ong et al. 2019; Rivers et al. 2017; Zambrano-Monserrate and Alejandra Ruano 2020). In addition, research has shown that social and personal norms also play an important role (e.g. Balunde et al. 2020a, b; Loschelder et al. 2019). For example, Zukauskienė et al. (2021) found that parents and adolescents influence each other's pro-environmental intentions and behaviours related to both packaging reuse and recycling.

Attitudes and values are the largest categories of predictors of packaging reuse. Perhaps unsurprisingly, attitudes related to environmental orientation are frequently investigated and found to predict packaging reuse behaviour. The research found that biospheric values, environmental self-identity (Balunde et al. 2020a) and environmental concern (Klug and Niemand 2021) positively influence reuse behaviour. For instance, Klug and Niemand (2021) investigated behaviours related to the zero-waste approach and identified environmental orientation as a predictor. Other attitudes identified as predictors also relate to environmental sustainability; future orientation (Ong et al. 2019), voluntary simplicity and low materialism (Klug and Niemand 2021) were identified

as predictors of packaging reuse and relate to reduced or conscious consumption. The influence of control was rarely mentioned in relation to reuse behaviour; though habitual behaviour, past behaviour and situational factors were identified as predictors (Balunde et al. 2020b; Novoradovskaya et al. 2020; Ong et al. 2019). Only some studies noted the influence of knowledge and awareness on packaging reuse (Janmaimool 2017; Ong et al. 2019).

3.2.2 Packaging recycle

There is quite an extensive body of literature investigating the predictors of packaging recycling. Several studies have linked demographic factors to package recycling behaviour. Individuals of older age have consistently been found to engage in more package recycling (e.g. Afroz et al. 2010; Mtutu and Thondhlana 2016). For example, a study that aimed to map the factors related to recycling plastic packaging in a new waste management scheme in Finland found that older participants engaged in more recycling behaviour (Reijonen et al. 2021). Other demographic factors found to be associated with this behaviour include income, education, gender and cultural factors (e.g. Izagirre-Olaizola et al. 2015; Zambrano-Monserrate and Alejandra Ruano 2020).

Multiple studies have investigated the influence of the social environment on packaging recycling behaviour. Within the category of the social environment, the literature has predominantly looked at the influence of social norms on behaviour (Kirakozian 2016; Ofstad et al. 2017; Sorkun 2018). Social norms constitute the social pressures that individual experiences from others to engage in recycling, e.g. by perceiving recycling as a common behaviour in one's social environment. For example, a study that applied the norm activation model to understand recycling behaviour among two ethnic groups in Malaysia found that social norms were the strongest predictor in the model for recycling behaviour (Ghazali et al. 2019). Other social influence factors that have been related to packaging recycling behaviour include personal norms, reputational concern and empathy (e.g. Alpizar and Gsottbauer 2015; Bortoletto et al. 2012; Ding et al. 2021).

A range of attitudinal and value dimensions has been found to explain differences in packaging recycling behaviour. Most of the literature investigating such individual characteristics has found that attitudes and values are strongly associated with packaging recycling (Balunde et al. 2020a; Novoradovskaya et al. 2020). For example, a study among university students in Spain found that positive environmental attitudes predicted recycling behaviour (Vicente and Reis (2008)). Another attitudinal factor that has consistently been found to be positively related to package recycling behaviour is environmental concern (e.g. Afroz et al. 2010; Kirakozian 2016; Reijonen et al. 2021). For example, in a study on Hispanic immigrants and non-Hispanic Whites in the US, environmental concern was found to predict recycling behaviour among both groups (Liu and Segev 2017). Other attitudinal and value dimensions that have been linked to package recycling include green mindfulness, ecological worldview, environmental identity, environmental motivations and connectedness to nature (e.g. Dharmesti et al. 2020; Gkargkavouzi et al. 2019) and other individual characteristics such as future orientedness, frugality and health conscientiousness (e.g. Klug and Niemand 2021; Ong et al. 2019).

The largest category of predictors pertains to dimensions of control. This category primarily includes research that has demonstrated that situational factors influence package recycling behaviour (Mintz et al. 2019; Oliphant et al. 2020; Ong et al. 2019). For example, Martinho et al. (2015) found that accessibility to recycling systems (e.g. distance to a drop-off site) may be a potential factor explaining the success of a recycling programme. Other factors that relate to control that have been found to predict recycling behaviour include perceived behavioural control, self-efficacy, self-regulation, internal attribution, past behaviour and habits (e.g. Balunde et al. 2020a, b; Oztekin et al. 2017; Whitmarsh et al. 2018).

Perhaps surprisingly, few studies provide evidence that demonstrates that knowledge influences recycling behaviour. Current literature covers knowledge and awareness of package recycling or environmental problems more generally (Ong et al. 2019; Segev 2015; Sorkun 2018). For example, in an application of an extended version of the value belief norm theory, environmental knowledge was found to be an important predictor of recycling behaviour among Spanish students (Izagirre-Olaizola et al. 2015).

3.3 Integration of behavioural aspects in the LCAs of packaging

The combined literature review on LCA studies and behavioural studies resulted in the identification of different approaches to integrating consumer behaviour variability in LCA. We classified these approaches into four groups (see Fig. 2): scenario or sensitivity analyses, profile scenarios,

consumer research and socio-technical approaches. As indicated in Table 1, the scenario or sensitivity analysis was conducted in 15 studies, profile scenarios in 3 studies and consumer research (mostly surveys) in 7 studies. The socio-technical approaches were only used by 1 study but have been proposed by several methods and review articles.

3.3.1 Scenario or sensitivity analyses

The primary method currently used in the literature to explore the influence of consumer behaviour in LCA studies of packaging is the scenario or sensitivity analysis. Scenario analyses are performed by comparing the baseline scenario with different scenarios that include variations of the most relevant parameters, e.g. studies focusing on exploring the impacts of reusable packaging typically perform scenario analyses regarding reuse, re-fill or recycling options at the EoL of the packaging, e.g. see (Krystofik et al. 2014; Kunamaneni et al. 2019). The reviewed studies performed sensitivity analyses on parameters such as how food was prepared (e.g. the amount of water boiled to prepare tea, Azapagic et al. 2016), the transportation mode (e.g. walking or by car, Krystofik et al. 2014) or the effect of different waste treatment alternatives (e.g. composting or energy recovery, Espinoza-Orias and Azapagic 2018).

Many parameters used to model the scenario and sensitivity analyses were based on simplified assumptions or aggregated, secondary data sources taken from studies unrelated to the investigated product. These types of assumptions (e.g. 100% recycling or 100% incineration for EoL options) limit the accuracy of the results since they are not linked to real or expected consumer behaviours (Polizzi di Sorrentino et al. 2016). However, some scenario studies reduced results uncertainty by combining multiple behaviour patterns related to different consumer choices along the life cycle. For instance, Vázquez-Rowel et al. (2013) explored 24 different scenarios with different sets of purchase, storage and cooking options for the consumer, and Yokokawa et al. (2018) explored 13 different behaviour patterns related to product storage, consumption, preparation and disposal. Although these consumer choices were not based on evidence from consumer behaviour studies, they were able to provide a more comprehensive picture of the influence of behaviour variability.

More sophisticated ways of creating scenarios are described within the socio-technical approaches in Sect. 3.3.4.

3.3.2 Profile scenarios

In LCA, profile scenarios are used to define sets of behaviour-related parameters that match a specific consumer profile. The modelling of profile scenarios is recommended

Fig. 2 Approaches to integrating consumer behaviour variability in the reviewed LCA studies

Scenario/sensitivity analysis	Profile scenarios	Consumer research	Socio-technical approaches
<ul style="list-style-type: none"> • Behavior patterns for purchase, usage and disposal. • Waste treatments and reuse/recycling scenarios 	<ul style="list-style-type: none"> • Different profiles of users depending on their environmental attitudes • User profiles depending on best behavior or worst behaviour 	<ul style="list-style-type: none"> • Use of average consumption patterns based on results from consumer surveys • Qualitative interviews 	<ul style="list-style-type: none"> • Sociological theories • System Dynamics • Agent Based Models or multi-agent based simulation • Discrete event simulation

by Polizzi di Sorrentino et al. (2016), who propose to use them in LCA to (1) identify realistic user profiles (e.g. gender/age-related differences, clustering of users depending on attitudes), (2) define the likelihood of various types of behaviour for each profile taking place in the case under study and (3) explore the likelihood for desired behaviours and their influence in the environmental impacts.

Three studies created user profile scenarios to model consumer behaviour variability regarding packaging (and other related practices), i.e. Gruber et al. (2016) explored three types of consumers to explore food waste: the average consumer, the environmentally conscious consumer and the careless consumer. Büsser and Jungbluth (2009) explored two types of user profiles (with their expected behaviour) for butter and coffee packaging, namely favourable behaviour and unfavourable behaviour, and Sturtewagen et al. (2016) defined two sets of sustainable practices regarding meals (high and low). The main challenge in defining profile scenarios lies in obtaining real behavioural data to define sets of behaviours. Gruber et al. (2016) used information obtained from household diaries from participants in a European project on food waste, but the other two studies did not report to base the consumer behaviours on any sort of behavioural data.

Consumer profiles could be informed by surveys, interviews, market-research reports or consumer databases, among others (see Sect. 3.3.3). We learned from the review of the consumer behaviour science literature that householders' participation in package reuse and recycling is particularly driven by attitudinal and value dimensions based on different factors. Demographic factors such as age and gender are related to the environmental awareness of consumers, with women and older people being more likely to recycle. Also, consumers with information on the recyclability of materials and who are close to a recycling point also have a greater propensity to participate in recycling. All these aspects could be used as a basis to define consumer profiles and their expected behaviour.

3.3.3 Consumer research

At least four studies used information from consumer surveys to create average behaviour patterns that can be fed into LCA models. For instance, Svanes et al. (2019) explored

the influence of packaging and food waste prevention in bread products by using data from a survey on the specific shopping, storing, processing and wasting behaviours of bread by Norwegian consumers. Similarly, Zhang et al. (2019) conducted a stated preference survey to understand and incorporate the correlation between food shelf-life extension and waste reduction into their assessment of food nano-packaging. As indicated by Polizzi di Sorrentino (2016), survey methodology can be valuable for LCA because they are able to capture and assess variables on a scale large enough to be representative of a specific population. Although using average behaviours based on evidence from consumer surveys is closer to reality than assumptions based on analyst perceptions, these averages are not giving an accurate picture of the variability of impacts due to high levels of variability in behaviours across consumers. Without insight into the variability of behaviours and consequent impacts, it is challenging to provide helpful advice on promoting sustainable behavioural change. In addition, attention should be given to the fact that surveys typically measure intentions rather than actual behaviour, and they are very sensitive to social biases (i.e. demand characteristics or socially desirable responses). Nevertheless, survey results could be gathered in a way that facilitates the construction of well-informed profiles of user behaviour and their distribution in a population. In such case, survey research could be combined with profile scenarios for better-informed decision-making. This approach has been proposed by Polizzi di Sorrentino et al. (2016) in the form of a conceptual framework.

Williams et al. (2018) conducted consumer interviews to qualitatively study how packaging functions influence the disposal and sorting behaviour of households. This approach was complemented by observational research since the households' bins were unexpectedly inspected with the purpose of double-checking against socially desirable answers. Through this method, the authors aimed at a deeper understanding of the behaviours while eliminating the degree of bias expected from self-reported surveys. They found that three main packaging functions influence consumers' decision whether to recycle or not: cleanliness, effort and environmental evaluations. For instance, sticky or smelly packaging is less recycled, as well as hard-to-clean, multi-material and hard-to-compress packaging. Environmental

judgements by consumers are usually a drive to recycle, e.g. the conclusion that recycling big packaging items will lead to bigger benefits than small packaging items. Also, some beliefs combined with process uncertainty can hinder recycling, for instance, the belief that incorrect sorting (e.g. because it is too dirty or not the right place) can spoil the recycling process may lead to the consumer disposing of the packaging item through the mixed waste. They propose to use consumer research to develop LCA scenarios that can better model the influence of consumers on the environmental performance of circular packaging.

In terms of observational research, Poortinga and Whitaker (2018) used an interrupted time series (ITS) perspective to evaluate the effectiveness of specific time-defined interventions in increasing cup reuse. They applied this approach to evaluate changes in the use of reusable cups during daily hot drink sales at different cafés, before and after implementing different measures. The results indicated that a combination of measures increased the long-term use of reusable cups by up to 43%. By quantifying the share of success in reusing cups, we can obtain a well-informed value for the reuse and return rate.

3.3.4 Socio-technical approaches

Some authors have suggested using socio-technical approaches to integrate behavioural patterns in LCA. Socio-technical approaches emphasise the interrelations between and within social and technological systems and focus on understanding the relationships between people, objects (or technologies), environment and organisations (Mumford 2000). For example, Babader et al. (2016) have proposed the use of system dynamics (SD) approaches to model and understand the social aspects and drivers of circular (or waste management) strategies, and in particular, packaging reuse. Because SD approaches focus on systems, we can explore not only consumer behaviour but also system behaviour. Although the aforementioned authors did not develop this approach with the aim of aiding LCA studies, it can prove useful to better understand and quantify the conditions and complex relationships among the different social aspects around circular practices and how they evolve over time. SD explores the structural causes of a system's behaviour (Babader et al. 2016), allowing for a better understanding of behavioural variability that can guide LCA practitioners in modelling consumer behaviour over time. This is especially relevant for LCAs with a temporal scope that goes beyond the immediate future, as is the case of circular innovations whose roll-out has only started. For instance, Babader et al. (2016) used a system dynamics approach to understand the reuse behaviour of packaging consumers, concluding that the role of the packaging manufacturing industry is especially

relevant for reusable packaging since well-designed reusable packaging will enhance the reuse behaviour of consumers. Their study shows how increased awareness of the environmental consequences of packaging reuse significantly impacts the consumer's willingness to reuse.

Additionally, the packaging design and functions have a stronger influence on reusing behaviour than on recycling behaviour. Chakori et al. (2021) developed a casual loop diagram (one of the components of SD) to represent the variables and feedback loops that influence the use of food packaging and, thus, identify the drivers of using single-use food packaging and how these can be addressed to reduce food packaging. Through this approach, the authors go beyond the packaging life cycle and impacts, concluding that the food packaging problem is actually a food system problem, derived, among others, from corporate concentration in agribusiness that leads to long and vertically integrated value chains. Eventually, the problem can only be tackled by addressing underlying societal issues, such as the economic growth paradigm and the lack of time that modern families have due to socioeconomic pressure (Chakori et al. 2021).

Similarly, although not yet combined with LCA models, a mental model approach may be worthwhile to better understand system perceptions of actors relevant to the packaging system. Mental models are internal representations of an external system, which consist of causal beliefs about the functioning of a system (Bostrom 2017). By mapping actor's perspectives of the system, new insights can be obtained about the functioning of the socio-technical system of interest. As a result, consumers' misperceptions that hinder the desired circular behaviour can be identified (van den Broek et al. 2023).

Socio-technical approaches can be especially useful in exploring the interaction of the different actors of the supply chain and how different behaviours could manifest. This is especially interesting for investigating consumer-related rebound effects or spill-over effects. Rebound effects can be defined as an unintended behavioural change (in overall consumption and production) induced by a change in the provision of a service, for example, a change in the energy efficiency of a household appliance (Vivanco and van der Voet 2014) or unintended effects of alternative business models (Tunn and Ackermann 2020). These effects are hard to estimate and depend on multiple variables such as the economic context, the infrastructure, regulations, consumer preferences and established practices (Nita et al. 2017). Although rebound effects have been identified as particularly relevant when assessing the environmental impacts of behavioural changes (Nita et al. 2017), none of the reviewed case studies included them in their analysis. Nevertheless, the field of rebound effects in the CE is gaining increasing attention, with recent literature aiming at identifying their

effects, causes and potential mitigation measures (Castro et al. 2022). For instance, André and Björklund (2023) created a framework to assess the impact of user behaviour (and related rebound effects) of second-hand jackets, by combining user surveys and manager's interviews with LCA.

Some sociological theories and approaches have recently been proposed to integrate rebound effects in LCA studies of circular products, such as social practice theory (PT) (Niero et al. 2021; Suski et al. 2021), actor-network theory (ANT) (Niero et al. 2021) and agent-based models (ABM) (Hicks 2022). PT implies that analyses should centre on social practices rather than individual behaviours or technology, arguing that consumption patterns are the result of practice dynamics. Niero et al. (2021) qualitatively explored the case of shower gel packaging, arguing how PT can complement LCA by providing insights into the practices around showering and, therefore, contributing to the understanding of how these practices and related consumer actions change when designing new circular packaging options. ANT would complement LCA by mapping the actors affected by a change in the packaging concept and how their interests and preferences would affect the product life cycle. ABM represent, through behavioural rules, how different actors interact among each other and affect the environment within specific complex systems. Hicks et al. (2022) argue that ABM are able to model the heterogeneity and stochasticity of human agents and provide insights on how consumers behave in different stages of the life cycle of products/services. They propose the case of single-use and reusable grocery bags as a relevant product whose fate is highly determined by the consumer, especially in the choice of packaging, the use and alternative use of the packaging and the disposal choices. They suggest a framework of implementation that starts by performing a “basic” LCA to decide if ABM is a worthwhile endeavour, and if so, identify the next steps in data collection (e.g. the need for surveys). Recent studies have also used ABM to simulate the variability of consumers' behaviours during the product use phase and integrated it with the LCA models of, for example, smart houses (Walzberg et al. 2019) and computers (Raihanian Mashhadi and Behdad 2018).

Finally, one of the reviewed studies applied a discrete-event simulation to model the probability of different consumer behaviours and the influence of behavioural changes on milk waste (Stankiewicz et al. 2019). The results from this simulation were combined with information on GHG emissions to estimate the climate change impacts of three different package delivery systems. Such an approach does not rely on behavioural models but rather uses a probabilistic approach to model behaviour variability that can be useful in the quantification step needed to integrate behaviour into LCA.

4 Discussion

4.1 Integration of consumer behaviour into LCA

Circular packaging is an emerging field, where new innovations are designed and introduced into the market with the hope of alleviating the urgent climate and resource depletion crises. When introducing new consumption patterns in a CE context, consumer behaviour is key to enabling a successful CE strategy (Shevchenko et al. 2023). However, the LCA results used to guide the development and introduction of circular packaging are usually based on a poor understanding and modelling of consumer behaviour, leading to misguided recommendations, i.e. recommendations that only apply to a small percentage of the cases, or that oversimplify the interrelations between people, packaging design and contextual factors. Consumer behaviour can greatly influence the environmental performance of packaging (Caspers et al. 2023), so a lack of insights into user behaviour hinders accurate assessment and understanding of the impacts of CE strategies (Harris et al. 2021). By leveraging the insights from the consumer behaviour literature, we can enhance the impact of CE strategies. Therefore, combining the insights and methods from social and behavioural sciences with LCA can bring deep insights into how circular packaging systems could be designed and promoted to maximise sustainable behaviour and environmental benefits.

The reviewed LCA literature on circular packaging pays little attention to consumers' intentions and behaviours. For example, as indicated in Sect. 3.1.3, most of the reviewed LCA studies model the waste treatment of packaging items by considering different scenarios for packaging disposal, e.g. recycling, landfilling or incineration. The use of scenarios (sometimes based on national statistics) instead of actual disposal behaviour is often the result of a lack of consumers' disposal behaviour data. Although these studies are useful for understanding the variability of impacts depending on different waste treatments and materials, they are not informed by real consumer behaviours and fall short to reflect the consequences of the actual sorting behaviour of consumers.

Based on the behavioural literature review, we can conclude that there is ample research on circular- or R-strategies from a consumer behaviour perspective, although it is mostly focused on recycling and reuse, with very few studies on refuse or reduce strategies. We found many quantitative studies that aimed to explain or understand pro-environmental packaging behaviours from an individual or contextual perspective. Nevertheless, the output of these studies is hard to translate into insights that are useful for LCA practitioners. On the one hand, the object of analysis is typically very general (e.g. household waste or a combination of waste-saving

behaviours), as opposed to LCA studies that focus on specific products and materials. From the consumer psychology perspective, there is not necessarily a reason to believe that the internal variables that drive, for example, the behaviour of cardboard box recycling, should differ from the variables predicting the recycling of plastic items. However, we have learned that preconceptions of material recyclability, product sustainability and situational factors may change the way people engage in sorting different waste items. This is in line with one of the main criticisms of the widely used theory of planned behaviour that focuses on conscious internal variables (e.g. attitudes and beliefs) and omits other important variables such as external factors that determine the level of control over the behaviour (Polizzi di Sorrentino et al. 2016) as well as more automatic influences on behaviour such as habits and impulses (van den Broek et al. 2019). On the other hand, these behavioural analyses are very focused on testing whether specific individual characteristics (e.g. differences in values or personal/social norms) are predictors of behaviour, while these results are difficult to integrate into LCA models that typically disregard individual motivations. As indicated by Schlüter et al. (2017), the challenges of integrating complex human behaviour in environmental modelling are enormous. Behavioural research uses different terminologies depending on the research field or theory and usually focuses on a specific aspect of the behaviour without necessarily indicating the causal mechanisms that are needed for dynamic environmental modelling.

Considering the findings from this review, it would be very helpful for the LCA field if the behavioural sciences literature could focus more on specific packaging systems, contextual situations and packaging design. In addition, in order to integrate complex human behaviour in the LCAs of circular packaging, we need an intermediate step that, drawing from the psychology literature, translates individual behaviour predictors into a behavioural pattern describing how different parts of the population would engage with circular packaging systems in different contextual situations. A few studies went in this direction and attempted to create consumer profiles based on behavioural insights. A recent study has also defined a hierarchy of consumer contributions to the circularity of products and services. From this hierarchy, the authors developed a framework to measure consumer contributions. Such a framework can be helpful in detecting relevant behaviours to investigate in the context of circular packaging (Shevchenko et al. 2023).

Nevertheless, focusing only on individual consumer behaviour may not be sufficient to develop the needed recommendations for integrating consumer behaviour into circular packaging research from a life cycle perspective. For instance, several of the reviewed case studies recommend increasing the amount of packaging material in a food product as a way to reduce food waste (see

Sect. 3.1.1). However, this conclusion is partially flawed, since other measures along the supply chain could be taken to reduce food waste while minimising packaging materials, especially related to supply chain logistics and designing consumption practices for optimised consumer behaviour. The use of socio-technical approaches, such as the ANT theory, combined with LCA could perhaps help explore the possibilities for optimised system behaviour along the supply chain. In this way, ANT would help map the supply chain actors and items affected by a change in the packaging concept (e.g. implementing reusable packaging instead of single-use packaging, or other R-strategy that reduces material consumption) and helps to understand how their interests and interactions would affect the product life cycle and the associated impacts. Such a combination was recently illustrated by Niero (2023) in the context of packaging systems.

4.2 Understanding packaging reuse and recycle behaviour

Several predictors of circular packaging behaviours have been studied in the consumer behaviour literature. So far, most efforts have focussed on recycling, with fewer studies investigating predictors of packaging reuse and refuse. We found that the literature provides most support for attitudinal and value dimensions to be related to reuse and recycling behaviour. These predictors closely relate to the widely used technology-acceptance model (Davis 1989) which stipulates that a sequence of variables, including attitude towards using the technology and behavioural intention, precedes actual use of the technology. These predictors are useful to consider in LCA studies in order to define consumer profiles (i.e. types of consumers for profile scenarios), as described in Sect. 3.3.2.

The large body of literature investigating the predictors of recycling behaviour paints a somewhat different picture from the reuse literature. Most support has been found in the literature for dimensions of control determining the level of engagement with recycling behaviour. Specific situational factors, such as the structural context within which the behaviour takes place, are key drivers (or inhibitors) of recycling behaviour. To use this information in LCA models, we currently lack numerical functions that define the relationship between certain situational factors (e.g. distance to sorting point, diversity of recycling containers), specific packaging attributes (e.g. size, material and cleanability) and the associated sorting behaviour. An interesting avenue for future research is to provide guidelines on how to create these numerical functions. Such an approach can be facilitated by the use of PT, which can help understand consumer practices in relation to materials, skills or other non-human factors (Niero 2023).

In contrast, very little support has been found in the behavioural sciences literature for a knowledge dimension to influence this behaviour. Although a good understanding of the local recycling system is likely to contribute to uncontaminated waste streams, and therefore the quality and usability of the recycled waste, there is little evidence that more knowledgeable householders engage in higher levels of recycling. This is in line with the finding that recycling behaviour is often automatic and does not tend to involve much conscious thought but is rather habitual (Knussen et al. 2004). That is, recycling is a behaviour that originates from automatic or impulsive processes. These processes are typically fast, effortless and require little working memory involvement, whereas reflective processes are typically slow, effortful and taxing working memory capacity (Evans 2008; Strack and Deutsch 2004). Hence, considering consumers' low level of cognitive involvement in recycling behaviour, packaging should be designed in a way that facilitates automatic and effortless recycling behaviour, rather than relying on information provision. This is one of the aspects of the packaging design and functions that influence the way that consumers interact with products.

The LCA literature review pointed to some behavioural aspects relevant to circular packaging that are currently not quantitatively explored in the behavioural sciences literature. In the case of reusable packaging, the main behavioural challenge is increasing the return rate from consumers by facilitating the development of appropriate habits. One-off sustainable actions are much easier to promote in consumers than repeating actions requiring habit formation. For instance, getting a consumer to buy an attractive and practical reusable packaging is much less challenging than getting the consumer back to the store to refill the purchased packaging/container more than a couple of times (Kunamaneni et al. 2019). However, our current knowledge of how consumers can be stimulated to adopt packaging reuse habits is still limited, especially considering that pro-environmental habits were recently identified as a necessary topic in the research agenda for sustainability science (Linder et al. 2022). Reuse behaviour can be encouraged, e.g. by using deposit schemes to ensure refillable packaging is returned or by giving discounts to consumers after a certain number of refills (Kunamaneni et al. 2019). An experimental study in the UK identified several measures that can be used in universities and business sites to increase the use of reusable cups (Poortinga and Whitaker 2018). In particular, environmental messaging, provision of cup alternatives to single-use cups and a charge on disposable cups increased the use of reusable cups, while a discount on reusable cups did not. The largest effect on behavioural change was achieved with a combination of measures. Therefore, it would be interesting to know to what extent certain incentives would increase the return rate of packaging items and, therefore, model the

LCA accordingly depending on the incentives placed on the analysed product. Future behaviour research could enable reusable packaging strategies by focusing on this and on how packaging reuse and recycling habits can be encouraged.

4.3 Limitations

The findings from this scoping review are limited to the search strategy defined in Sect. 2.1. The search string used to answer Q1 was designed based on the assumption that articles that include the words “consumer” and “behaviour” in the title, abstract or keywords, will most likely pay special attention to modelling consumer behaviour and, therefore, would contain interesting insights for this review. This approach may have resulted in overlooking studies that explored behaviour, and the authors either did not mention consumer or behaviour in the abstract or used different words to describe it (e.g. “user” instead of “consumer”). This search strategy may have resulted in the exclusion of articles that explored different consumer actions through sensitivity analysis, which is a common technique in LCA to explore the variability of results due to the variability of input parameters or assumptions. Nevertheless, the articles included in the review were expected to provide a good representation of the extent to which the variability in consumer behaviour is currently investigated in LCA studies of circular packaging. Another limitation of this study relates to the timing of the literature search, which was done in January 2022. Articles published on the topic during the year 2022 were only included if notified by publications alerts received by the authors or found by forward and backward snowballing. This may have resulted in the exclusion of relevant studies published in the year prior to the publication of this review.

The findings of the review tended to suggest that socio-technical approaches may provide valuable avenues to better connect consumer behaviour's individual-level approaches with LCA's system-level approach. However, this review did not focus on socio-technical approaches, and this term was therefore not reflected in the search string and the results of the review. Scholars have begun to unpack the role of psychology in socio-technical transitions (e.g. Bögel and Upham 2018), but the application to LCA is currently under-explored. This approach may provide the needed insights into systems behaviour required to develop a framework to better integrate consumer behaviour into LCA research. Hence, more work is needed to unpack the role of socio-technical approaches for LCA.

In the same vein, the decision to review the literature through a scoping review rather than a systematic review or meta-analysis has implications for the findings of this review. Although the scoping review better suited the study's aim and the LCA literature landscape, a systematic review or meta-analysis could provide more robust conclusions

on the relative influence of the various behavioural drivers on circular packaging behaviour. Hence, future studies are needed to confirm the results reported here using alternative literature review methods.

5 Conclusions

The success of strategies for circular and sustainable packaging is highly dependent on consumer choices and behaviour. Achieving optimised consumer behaviour is only possible when we understand the factors affecting consumer behaviour and leverage this knowledge in sustainability assessments. However, the complexity of the task and its multidisciplinary nature has resulted in poor integration of the extensive knowledge from consumer behaviour sciences into environmental assessment frameworks. As a consequence, the modelling of circular behaviour is usually relying on arbitrary assumptions, or assigning generic percentages of waste treatment that lead to average waste scenarios detached from the real practices of consumers, or from the evaluated product.

While LCA modellers could learn from findings from behavioural sciences literature, the step to transforming these findings into actual behaviour patterns that can be used in LCA models is still missing. To advance the interdisciplinary field, consumer behaviour sciences (including psychology, sociology and socio-technical approaches) can contribute to industrial ecology studies in several ways, by defining consumer profiles, exploring the influence of packaging attributes on consumer behaviour and using socio-technical approaches to model system behaviour. The first two ways would require defining behaviour patterns per consumer profile/type and product/service and the share of the population that corresponds to each profile. Such consumer segmentation would facilitate the creation of profiles that can be modelled into LCA frameworks. In addition, socio-technical approaches (as defined in Sect. 3.3.4) could prove very useful in the integration and modelling of system behaviour within LCA. These approaches understand behaviour as a combination of social and cultural practices, depicting, e.g. recycling, as a combination of tasks and not only one isolated task (Thomas and Sharp 2013). Socio-technical approaches, e.g. ABM or system dynamics, can potentially provide a comprehensive picture influenced by a variety of contextual factors that can be more easily modelled by LCA practitioners. This integration can prove time-consuming but invaluable for LCA practitioners. While the authors did not find case studies using this approach for circular packaging, it has already been used for other products such as smart houses or computers. Future research will hopefully provide clear guidelines and practical examples of

how to integrate these approaches for the case of circular packaging, achieving valuable and more realistic insights for sustainable decision-making.

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Data availability Data supporting the findings of this study are available within the paper and its Supplementary Information.

Declarations

Conflict of interest The authors declare no competing interests.

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