

SUSTAINABLE PACKAGING DESIGN FROM A MULTIDISCIPLINARY PERSPECTIVE: A REVIEW

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Abstract. In this paper, the current research progress of sustainability related to packaging design is explored through a bibliometric analysis and literature review. The aim is to interpret sustainability in packaging design from different research perspectives and to identify the research scope and research opportunities in the field of sustainable packaging design. It was found that for a long time, more and more scholars have begun to study packaging issues to contribute to sustainable development. There are more survey-based results on packaging issues, but fewer specific design methods and measures. Under the 3R framework, sustainable packaging design methods are clearer and easier to understand. The research on Reduce is important and there are more research results in this area, while there are fewer research results on Reuse. The assessment of sustainable packaging is constantly updated, while the operability and effectiveness of the assessment methods are prerequisites for optimising sustainable packaging. Examining sustainable packaging issues from the perspective of several related disciplines provides a basis for finding the key to sustainable packaging design issues and identifying future research directions.

Keywords: Review, sustainable packaging, packaging design, visual analysis, trends and tendencies in design.

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1. Introduction

The increasing environmental damage has led to a growing awareness of the importance of sustainable development, where the problems associated with the large amount of waste generated each year have become one of the major environmental issues going into the 21st century (Grönman *et al.*, 2013; Williams *et al.*, 2020). Approximately one third of urban waste is generated by packaging used in everyday consumption (Herbes & Ramme, 2020). In the Organisation for Economic Cooperation and Development, the figures are that packaging accounts for around 20-30% of municipal waste in low- and middle-income countries and up to 50% in rich countries (Rutkowski, 2020). With such a high level of resource waste, many believe that packaging has great potential to contribute to sustainable development (Grönman *et al.*, 2013; Lindh *et al.*, 2016b; Svanes *et al.*, 2010).

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Packaging plays an important role in many complex social activities and thinking about packaging from different perspectives raises very different issues. For example, from a commercial perspective the waste generated by packaging is not a problem for products with a high environmental impact but low packaging value, such as milk. From a socio-environmental perspective, on the other hand, the waste pollution caused by the packaging of these products can be an unbearable burden on the environment. Since in industrial production most decision makers focus more on the economic efficiency of the product than on carrying out a full assessment of the product. In this case, they apply sustainable packaging methods with the goal of optimal profit and ignore what it will bring to the environment (Molina-Besch & Palsson, 2015). From another perspective, although consumers consider environmental issues to be important to them, they have limited knowledge of the packaging design and production chain. They can only choose between packaging materials and recycling issues (Lindh *et al.*, 2016a).

Lindh *et al.* (2016b) argue that the packaging legislation in Europe is relatively narrow as it deals mainly with packaging materials and focuses more on the packaging itself rather than taking a systemic view of the whole including the packaging and product. Among other studies on sustainable packaging, most focus on packaging and consumer behaviour (Jacobsen *et al.*, 2022; White *et al.*, 2019) and some look at ways to manage plastic packaging waste (Chae & An, 2018; Sarkar *et al.*, 2022), recycling technologies (Franz & Welle, 2022) and supply chain management (Silva & Palsson, 2022). These studies mainly address how to deal with the packaging and packaging waste that has been generated, but less attention has been paid to the design phase. However, the design phase is considered to have the greatest impact on the sustainability of packaging, preventing around 80% of the environmental impact (European Commission, 2018; Zhu *et al.*, 2022). This is particularly helpful for the efficient use of resources in the supply chain.

Therefore, when discussing sustainable packaging design, it is necessary to first broaden the perspective to take a more holistic view of the issues arising from packaging in order to fully realise its potential in promoting sustainable development (Verghese *et al.*, 2012; Lindh *et al.*, 2016b). In recent years, academic papers on sustainable packaging have been emerging across a wide range of disciplines. However, these substantial scientific findings are scattered across different fields, which is not conducive to gaining quick insights into the future direction of packaging design. In order to more fully illustrate the importance of sustainable packaging design, it is necessary to form a more systematic, comprehensive and objective scientometric review based on rigorous quantitative and statistical analyses.

2. Data and Methodology

This study uses Bibliometrix, an econometric method based on Biblioshiny, a tool specifically designed for quantitative research in scientometrics and bibliometry, which refers to the organisation and analysis of aspects of the literature using mathematics, statistics and logic (Archambaut & Gagné, 2004). It uses the principles of relational analysis to assess research themes, provides various analysis paths for the literature and maps the structure of the distribution of literature over a time horizon or domain. It was also used to visualise various metric single distribution bits by mapping knowledge ranges, providing concise results (Wang, 2018). In addition, this study uses a mixed-

methods approach to synthesise research and look at complex issues from multiple perspectives to achieve breadth and depth of understanding.

2.1. Data Collection

Research on sustainable packaging is multidisciplinary and cross-cutting, ranging from definitions of sustainable packaging to sustainable packaging design methods and evaluation criteria. Therefore, the Web of Science Core Collection database was used to search the literature, covering a large number of academic journals, book chapters, conference papers etc. covering different disciplines. To avoid bias due to daily updates of the database, articles published from 1 January 2008 to 31 December 2022 were searched for the search terms “packaging design*” “sustainable*” articles were searched. The search was conducted for 15 years because articles prior to 2008 were rare and of weak relevance.

Literature from disciplines such as materials, biology and chemistry was excluded, while literature from more relevant disciplines such as environmental science, green sustainability science, food science and ecology was retained. This decision was made because of the microscopic perspective of research on 'packaging design' in disciplines such as materials science, which are independence and completeness. Moreover, the volume of literature in the field is so large that it is easy for the subject matter to become biased. Incomplete articles and editorial material were excluded from the study, as were cases where “packaging” was not translated as “packaging” and “design” was not translated as “design”. Figure 1 documents the literature selection process.

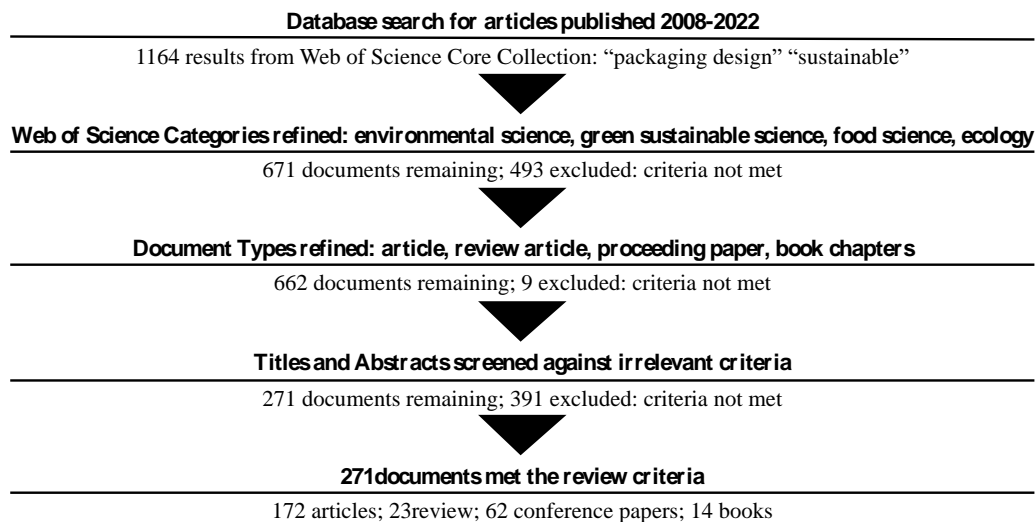


Figure 1. Data research and filtered results

2.2. Bibliometric analysis and visualization

Focusing on finding key points in the development of a field, bibliometric analysis transforms some of the labour burden of traditional content analysis into computer algorithms and interactive visualisations, thereby facilitating a comprehensive analysis of developments in the field (Chen, 2006). Helps to avoid subjectivity. This paper uses co-word analysis and collaborative network analysis to visualise the conceptual structure in lexical networks.

3. Outline of review

When exploring a hot topic in a research subject, grasping the keywords in the literature is an important way to summarise and refine the core content of articles, which can help scholars to efficiently search and target relevant literature in their subject areas (Shokri, 2021). By the Biblioshiny program, the high frequency keyword word cloud map is shown in Figure 2. Current research on sustainable packaging design focuses on “design”, “life-cycle assessment”, “frameworks”, “perception”, “green”, “waste”, “impact” etc. The keyword analysis emphasises that sustainable packaging should be viewed in terms of the life cycle and that themes such as the framework of sustainable packaging design and consumer perceptions are major concerns. This reflects the fact that packaging development is influenced by many different needs and surrounding environments (Sastre *et al.*, 2022; Rundh, 2013). Figure 3 shows more specifically that the research themes fall into two main categories, the first of which is based on “intentions”, “perceptions”, “information”, “attitudes”, etc., arising from consumer research. In this category, it can be concluded that “consumer attitudes towards sustainable development”, “green perceptions and information” are closely related to “consumption and purchasing behaviour”. The second category of themes relates to packaging sustainability in the context of the “industrial chain” and “circular economy”. Specifically, “Efficiency”, “Frameworks, Models and Systems”, “Products and Logistics”, “Supply Chain Management”, “Carbon Footprints and Energy Systems” and “Logistics Based on Life Cycle Assessment” are sub-themes of the second category. Overall, sustainable packaging is inextricably linked to the disciplines of economics, logistics, environmental engineering, production management and social humanities. Therefore, this review explores the current state of sustainable packaging design research which can be divided into three parts (a) sustainable packaging design from a consumer research perspective; (b) sustainable packaging design from a supply chain perspective; (c) assessment of sustainable packaging design.



Figure 2. WordCloud

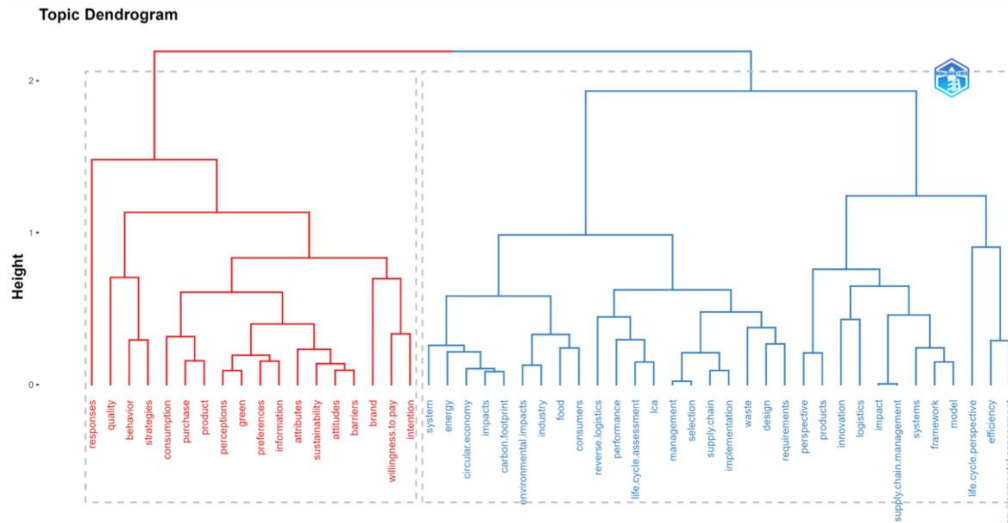


Figure 3. Topic dendrogram

4. Literature review

4.1. Sustainable packaging design from a consumer perspective

A large number of studies on consumer intentions, claims and satisfaction have emerged, examining the link between sustainability and packaging from a variety of disciplines including management, psychology, logistics management and environmental engineering (Molina-Besch & Palsson, 2015; Ishimura, 2022). Borusiak et al. (2021) used the theory of planned behaviour as the main theoretical framework to quantitatively investigate the link between consumers' willingness to purchase a product and its packaging which confirmed the indirect impact of environmental concern on both intention and behaviour concerning bottled water consumption (BWC): environmental concern is positively related to attitudes towards reducing BWC, subjective norms regarding reduction in BWC, perceived behavioural control over BWC and perceived moral obligation to protect natural resources, all of which, in turn, are positively related to intention to reduce BWC. Similar to this study, Cavaliere et al. (2020) investigated the determinants of consumers' decision to avoid purchasing single-use plastic eating utensils and plastic water bottles while grocery shopping. The results of the Structural Equation Model reveal that environmental and health-related concerns associated with plastics are key drivers of plastic avoidance.

Beyond that, a qualitative study investigating consumers' expectations and opinions of sustainable packaging was conducted by Oloyede & Lignous (2021) which indicated price and quality were the main driving forces for consumers' purchase intent. While consumers were impressed by the sustainable packaging, they were not willing to pay more for a sustainable packaging. Reijonen et al. (2021) also proved costs and facilitating conditions play the significant role in supporting households to recycle more packaging.

As a result, a large number of studies have shown that consumers' daily consumption choices make an important contribution to environmental impacts. Most researchers consider that consumers' environmental and health perceptions determine their choice of sustainable packaging. Others consider that price, quality and convenience are the key factors in consumers' choices.

4.2. Sustainable Packaging Design from a Supply Chain Perspective

In the context of the circular economy, a large number of scholars have researched the issue of sustainable packaging recycling, with Rutkowski (2020), Gronman et al. (2020) and Molina-Besch and Palsson (2015) investigating and developing a number of different recycling systems, respectively, with the aim of improving the efficiency of the supply chain, including stacking, mixed intermodal containers and parcel services. Emblem and Emblem (2021) conclude from extensive research that the physical design of packaging influences how it is handled in production, transport, storage, use and disposal and is an important component of sustainable packaging design. Specifically, Zhang et al. (2020) conducted experiments on the sealing performance of cigarettes and Wever (2011) did a quantitative study on the volume ratio of packs. Their experiments are again specific and do not apply to all product packages. Molina-Besch and Palsson (2015) and Nguyen et al. (2020) have optimised the size distribution of packs This is to adapt to users' consumption habits without causing them to discard unnecessary product 'leftovers'. At the same time, Williams et al. (2012) show that “too big packaging” is one of the reasons for household food waste. Unlike Molina-Besch and Palsson (2015), who optimise distribution for primary packaging only, Olsmats and Dominic (2003) argue that distribution decisions should take into account the impact on secondary and tertiary packaging to ensure high transport fill rates.

In addition, Zhou et al. (2020) carried out a simulation of a catering scenario and showed that sharing tableware could reduce waste generation by up to 92%, reduce environmental emissions and reduce water consumption by more than two thirds. This mechanism offers a potential solution to the food packaging waste dilemma and a new strategy for promoting sustainable and zero-waste lifestyles. Schmidt et al. (2019) studied the environmental impact of packaging and the food supply chain through the Life cycle assessment (LCA) which is a quantitative environmental assessment method that can help compare different packaging options in the later stages of packaging development, found significant differences in greenhouse gas emissions per food package depending on package size, packaging material and brand.

All of the above research suggests that designing sustainable packaging involves taking decision-making information from all parts of the supply chain because the actors in the supply chain have differing packaging needs, rather than just considering individual parts (Molina-Besch, 2019). A key message that came up several times in the research was the 3R policy, Reduce, Recycle and Reuse (Lindh *et al.*, 2016b; Rutkowski, 2020; Oloyede & Lignou, 2021), which was considered as an excellent example of practical problem solving in the supply chain, it is also a key point to design sustainable packaging. The policy has long been widely applied in European countries, according to Wang et al. (2020), countries implementing the 3R policy reduced packaging waste by 3 percent and corrugated cardboard waste by 12.4 percent. Table 1 summarises the various sustainable packaging approaches in the supply chain, using the 3R policy as a framework.

Table 1. Methods for sustainable packaging based on 3R (reduce, recycle, reuse)

Type	References	Methods	Descriptions
Reduce	Wang, G., 2020	Teuristic algorithm Taguchi method	to obtain optimal packaging schemes and improve the upgrade of packaging process company to find the best optimization parameters
	Nguyen, V., 2020	Plan-Do-Check-Act (PDCA) cycle	to improve quality and efficiency of heavily fragile product packaging and decrease cost to profit for companies
	Zhou, Y., 2020	One paper substitution and two sharing tableware scenarios	to explore the packaging waste and life-cycle environmental impacts of the takeaway industry in China
	Garcia-Arca, J., 2020	A systematic and dynamic method	to connect design decisions about the dimensions of that box with their impact on overall efficiency and sustainability of the supply chain
	Guillard, V., 2018	Decision Support System (DSS)	to provide unique and specific guidance to food and packaging SMEs in terms of technical assistance for the selection among eco-innovative packaging alternatives
	Schmidt Rivera, X. C., 2018	Decision-support framework	to guide the design and development of new food packaging solutions within the new plastics economy
Recycle	Keller, J., 2022	Cyclos HTP method	to determine recyclability and conduct reference calculation
	Ishimura, Y., 2022	An instrumental variable (IV) approach	to investigate the impact of the Containers and Packaging Recycling Law (CPRL), to encourage municipalities to domestically recycle plastic waste in Japan
	Reijonen, H., 2021	The theory of planned behaviour (TPB)	to identify and examine household plastic sorting and recycling factors in Finland's new recycling scheme
	Rutkowski, J. E., 2020	European P-EPR	to reduce overall recycling costs and expand recovered re- sources, providing income to a jobless population
Reuse	Singh, J., 2017	A proposed business model	to reduce the consumption of plastic shopping bags and to collect and recycle discarded bags more effectively
	/ Zhang, S., 2022	Energy-saving packaging design on artificial intelligence	to realizes the combination of market and green environmental protection design, and improves product utilization and production efficiency
	/ Fresán, U., 2019	Life cycle assessment (LCA)	to perform an assess- ment of the greenhouse gas (GHG) emissions of the materials used for the packaging of foods, and to determine whether the size of the products, the main material used, and the commercial brand have any effect on this

4.3. Assessment of sustainable packaging design

Due to the complexity of sustainability factors in packaging, packaging assessment becomes difficult to carry out using a single standardised methodology (Table 2). Assessment methods are different for different products. For example, fast-moving consumer goods are often single-use products. Packaging design limitations, inadequate collection systems and inefficient recycling processes prevent the achievement of high recycling rates. Murank et al. (2021) identified a framework that includes five reuse models and evaluated these models to determine their ability to deliver environmental value compared to traditional disposable and single-use Fast Moving Consumer Goods (FMCG). They found that the five reuse models can operate independently or a multi-modal approach and different sequencing of them can be used to improve the efficiency of FMCG consumption. At the same time, the provision of the infrastructure required to enable reuse and recycling was considered as key to sustainable deployment of the reuse models. Heiges et al. (2022) learnt about the methods currently available for assessing the generation and disposal of food packaging waste in school food service and proposed a practical standardised tool for assessing the generation and disposal of food packaging waste in school food service. The creation of a standardised methodology will become increasingly important given the changing trends in food packaging, the need to conduct more research to assess food packaging waste in school foodservice in the United States and the need to minimise hazards to the environment and human health.

In addition, many of the available whole package assessment tools have been refined and developed based on the life cycle analysis approach. For example, due to time-consuming and complex to apply, Molina-Besch et al. (2020) proposed a simplified

environmental assessment tool for food packaging that allows for a holistic assessment of the product and packaging combination. Packaging systems are assessed against packaging criteria that are organised into four dimensions representing the life cycle steps of production, transport, domestic use and end-of-life of packaging materials. Meet the practitioner's need for a simple and quick eco-design approach without the need for comprehensive data input. Packaging systems are assessed by packaging standards that are categorised into four areas, representing the life cycle steps of production, transport, domestic use and end-of-life of packaging materials, with simple and quick eco-design methods without comprehensive data input. Zhu et al. (2022) similarly suggested that LCA studies tend to simplify the steps and boundaries in order to manage the study within a reasonable timeframe. He suggests a quantitative cross-sectional comparison of two types of packaging for the same product and he proposes packaging development in food environmental assessment, with standardised scenario analysis as one of the many viable tools for the development of a transparent assessment. Guo et al. (2022) proposed the evaluation model between recyclability and environmental performance (EMRE) based on LCA, which is developed that reduces environmental impact by controlling the number of times a box is recycled. In the case of recyclables, a model is developed that allows for a more efficient use of the recyclables and a more efficient use of the recyclables. At the design stage of recyclable express containers, the recyclable capacity should be rationally designed through EMRE so as to minimise the environmental burden. At the design stage of recyclable containers, EMRE helps to rationalise the design of the recyclable capacity so as to minimise the environmental burden.

Table 2. Assessment methods for sustainable packaging

References	Assessment Methods	Aims
Zhu et al. 2022	planning, execution and reporting Preferred reporting Items for	to guide material selection, design facilitate recycling, design assessment tools, design education and policy making
Heiges et al. 2022	Systematic Reviews and Meta-Analyses	
Guo et al., 2022	multiple indicators	to establish evaluation model between the recyclable ability and environment performance (EMRE) based on life cycle assessment.
Muranko et al., 2021	Five reuse model framework	to evaluate their potential to deliver environmental value
Molina-Besch K et al., 2020	An Environmental Evaluation tool for Food Packaging	To support the food industry in their efforts toward developing product and packaging combinations that reduce the total environmental impact in food supply chains
Tu et al., 2015	The Kawakita Jiro (KJ) method and the meta-research method	to expand corporate social responsibility, production cannot be exempted from environmental protection, the manufacturing of clean products can generate pollution, the external production cost should be internalized, the redesign to improve the product production process and packaging, reducing resource waste

5. Discussion

According to the bibliometric analysis, the common topics on sustainable packaging include three major categories, survey research from the consumer perspective, design and measures research from the industrial chain perspective and sustainability assessment research. There are more studies on the necessity and elements of sustainable packaging design according to the survey research, which are developed from the industrial chain and the whole life cycle perspective, while there are fewer

studies on specific measures and design methods for sustainability. Some studies show that consumers' daily consumption choices play an important role in environmental impact. Consumers' environmental and health perceptions determine their choice of sustainable packaging. Other studies identified price, product quality and convenience as key factors influencing consumer choices.

The research articles within the 3R framework are providing practical ideas on some of the issues posed by packaging in sustainable development. In this framework, "Reduce" is considered a very important concept in sustainable development, with technology and manufacturing optimisation on the one hand and design considerations on the other, which still is a topic worthy of in-depth study. The calculation of recycling costs and recyclability and case studies on recycling mechanisms are included in "recycle" research. "Reuse" is the final stage of the life cycle to solve the packaging problem and there are not many studies on this kind of sustainable packaging design.

With the emergence of new products, technologies, methods and models and the constant presence of social change, the assessment of sustainable packaging should be constantly updated to keep pace with developments and the practicability and validity of the assessment methods is a prerequisite for optimization of sustainable packaging.

6. Future research directions

There are already more research results on consumer behaviour, perceptions and attitudes. Some well-targeted research on the factors of specific groups on sustainable packaging design can be launched in order to be taken into account in the design process, such as take-away packaging, express packaging. In terms of environmental sustainability, attempts to optimise packaging design by streamlining structures, rationalising design and reducing materials to reduce environmental impacts remain hot topics. One of the routes to sustainability is reuse, which is overlooked but a good strategy that can prolong the value of a resource by slowing down the flow of materials. New reuse models are emerging for the FMCG industry, requiring consumers to interact with durable primary packaging and products. However, the components and workings of this reuse model are not fully understood. Operational and efficient standardised studies are necessary for sustainability assessment and different product categories need to be specifically discussed.

7. Limitation and conclusion

This paper uses a bibliometric approach to explain the development and trends in this research, identifying, collecting, analysing and summarising sustainable packaging design methods and evaluation approaches. Although these methods and evaluation approaches have different audiences and objectives, they inform the promotion of sustainable development in packaging-related fields. In the process of sorting and summarising research-based articles, it was found that there is a preponderance of research studies on sustainable packaging and a dearth of targeted concrete measures and pilot studies. This suggests that there are still many research opportunities in this area.

The sample of this review is large and covers a wide range of content and there are many specific findings that have not been analysed. In the future, the sustainability of packaging for different categories of products should be explored and the relationship

between different sustainable models can also be compared horizontally. Provide more practical basis for sustainable packaging design.

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