Environmental Footprints and Eco-design of Products and Processes

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Editor

Environmental Footprints of Packaging

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Preface

Packaging is one of the essential elements of today's life, and it plays a major role in our daily lives. Packaging is inevitable to different communities of people: manufacturers, shopkeepers, sellers, consumers and so on. Several kinds of packaging are made out of a wide array of materials we are surrounded with every day. Packaging serves an essential function of protecting goods from damage, apart from the other secondary functions, and it is used by every industrial segment. The environmental impacts of any product produced on Earth deserve significant attention these days, and this attention is very high for packaging because of its voluminous applications. Due to this, one can imagine the quantity of production of packaging materials and the associated environmental impacts. Not only the production of packaging, but also its disposal, creates impacts to the environment. Many environmental elements—such as the biodegradation potential of packaging materials, the uncountable proportion of consumption and disposal, the short shelf-life of packaging materials, and limited landfill space, etc.—are associated with this issue.

The dissemination of information and the knowledge of quantification of environmental footprints of different packaging materials and packaging systems are of great benefit to concerned consumers as well as researchers in the scientific community, and this book is an attempt toward the same. This book deals with the environmental footprints of packaging in seven informative chapters. All seven chapters deal with various important elements associated with the environmental implications of packaging: (1) the life-cycle assessment of packaging systems; (2) the sustainable design of packaging materials; (3) organization–life cycle assessment (OLCA); methodological issues and case studies in the beverage-packaging sector; (4) the potential of fibrous and nonfibrous materials in biodegradable packaging; (5) the environmental impacts of packaging materials; (6) the bioprocessing of metals from packaging wastes; and (7) the environmental implications of reuse and recycling of packaging. I am sure that the readers of the book will receive much useful information pertaining to the environmental footprints of packaging. I take this opportunity to thank all of the authors who contributed the chapters in this book for their time and priceless efforts.

Contents

Life-Cycle Assessment of Food-Packaging Systems

Giuseppe Vignali

Abstract Food packaging plays a fundamental role in today's society because it protects food from external sources of contamination and preserves food properties during the entire assigned shelf life. Due to this fundamental role, its use is increasingly widespread including emerging or underdeveloped countries. The global amount of packaging materials manufactured and disposed of every day has led many researchers to deal with the issue of their environmental impact. Several studies have been performed starting from 1990 to the present that have been aimed at demonstrating the best type of use of and end of life for each type of food-packaging material. In recent years, some studies have also demonstrated how the extension of the food shelf life by means of improved packaging could decrease the environmental impact of an entire packaged food based mainly on the reduction of the associated food waste. Based on these premises, this chapter aims at reviewing the main articles in the field of environmental assessment of food packaging by means of a life-cycle assessment approach and showing how, during the last two decades, this issue has received increasing attention. The review was performed by analysing 172 scientific papers collected from the Scopus database using specific keywords and refining the results based on a detailed analysis of the content of each article. The results show how interest in this topic has grown consistently during the last 25 years and indicates several research lines available for further studies in this field.

Keywords Food packaging · LCA · Environmental impact · Food waste · Review · Packaging systems

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1 Introduction

In today's society, packaging has a key role in sustainability: It is no longer possible for people involved in the design, development, production, or use of packaging to ignore the environmental consequences of their work (Almeida et al. 2010). Packaging activities and materials, rather than just only the final result visible to the consumer, should be considered in each phase of a product supply chain.

The packaging sector generates approximately 2 % of the gross national product in developed countries, and approximately half of this packaging concerns the food sector (Robertson 2012). On average, in 2012, European citizens generated globally 80 million tons of packaging waste, 38 % of which was paper, 21 % plastic, 20 % glass, 15 % wood, and 6 % metals (Eurostat 2014). Overall, the packaging material life cycle generates significant environmental impacts; indeed, its production and application to food products requires the use of natural resources and energy and causes relevant emissions. Moreover, packaging wastes generate increasing disposal wastes, with the first largest fraction being municipal waste, that have exceeded the organic fraction in many countries (Edjabou et al. 2015). In developed counties, modern end-of-product life management systems can strongly reduce the environmental impacts of packaging; however, in many underdeveloped or developing countries, waste-management systems are fairly rudimentary (Denafas et al. 2014; Sealey and Smith 2014) and create significant environmental problems.

To measure the "green" characteristics of a product or a system, it is essential to assess its environmental impacts and resources utilization using quantitative and objective methodologies that consider its entire life cycle. In this regard, life-cycle assessment (LCA), as regulated by the ISO 14040 (2006) International Series of Standards, is a useful methodology to assess the environmental impact of a product throughout its lifetime. This methodology allows quantifying the level of greenhouse gas emissions, the amount of energy consumed, and the level of hazardous substances emitted throughout a product's life cycle. It also allows, by means of a selection of specific mid- or end-point indicators, identifying the most relevant impact among those evaluated (e.g., ozone depletion, CO_2 emissions, etc.) as well as identifying the processes that generate the greatest environmental impact; the final purpose is to propose guidelines for the improvement of the current situation.

In recent years, various LCA studies related to packaging have been performed with many of them focusing on the food sector. In this field, the impact of packaging-materials production, packaging application, and packaging use and disposal have been thoroughly analysed among several food supply chains. During the latter period, evaluation of the advantages resulting from decreased food losses as a consequence of improved food packaging use has emerged (Williams and Wikström 2011; Grönman et al. 2013; Wikström et al. 2014). Depending on the type of food, the relative impact of the packaging may change reaching, e.g., a high percentage for beverages or vegetables foods (Roy et al. 2009; Manfredi and

Vignali 2014). Aware of these issues, some researchers attempted to define frameworks or guidelines to develop sustainable packaging focusing not only on the impact of the packaging materials but also on the preservation of its performance and the impact of packaging technologies (Sonneveld 2000; Grönman et al. 2013; Toniolo et al. 2013; Wever and Vogtländer 2013; Manfredi and Vignali 2015).

Based on this chapter aims to underscore the importance of the environmental impact of food-packaging systems by means of an in-depth analysis of the existing literature on this issue. A review of available data about the environmental impact of food-packaging systems was performed by dividing the reviewed works among the most frequent topics addressed in the literature. The results show how attention paid to food-packaging systems by evaluating their environmental impact has increased in the last 25 years, thus reaching a wide level of diffusion.

The remainder of the chapter proposes a description of the LCA principles applied in the context of packaging systems, describes the adopted review methodology, and presents the main results of the review as well as discussion. Finally, a section on conclusions and future research recaps the main chapter findings and, based on them, proposes new research in the field of the environmental assessment of food-packaging systems.

2 LCA of Packaging Systems

LCA is a technique to assess and quantify the environmental impacts associated with a product, process, or activity. The entire life cycle of a product, from raw-material extraction to disposal, is considered.

This method is composed of the following steps:

1. Goal and scope definition
2. Inventory analysis
3. Impact assessment
4. Interpretation and conclusion

As far as the issue of this article is concerned, the following subparagraphs are aimed at describing a generic framework as well as some particularities about applying an LCA to packaging systems.

2.1 Goal and Scope Definition

The first activities that should be performed in an LCA are (1) identifying the functional unit (i.e., the object of LCA analysis); (2) defining the study motivation (i.e., the targeted evaluation); and (3) determining the final recipients of the results (i.e., who makes use of the analysis).

2.1.1 Functional Unit

All of the problem data must be referred (for normalization) to a functional unit, e.g., in the field of food-packaging systems, a functional unit could be 1 kg of packaged food product or 1 kg of packaging materials. The choice of this reference unit is fundamental in determining how the materials flows inside the system boundaries.

2.1.2 System Boundaries

LCA analysis requires identifying the processes and activities comprising the system under examination. For each operation, the input and output should also be identified. The definition of system boundaries implicitly describes what is included and what is excluded from the analysis. Regarding the LCA of a packaged food product, the system boundaries usually include the cultivation, manufacturing and processing of the food product, as well as the packaging and distribution phases, to understand the relevant environmental impacts of the different phases. If the reference unit is related to a specific quantity of packaging materials, the system boundaries could be defined not considering food production and processing and sometimes not considering the distribution phase but only considering the packaging materials supply chain. Usually the equipment-manufacturing phase is not included in the system boundaries due to the limited impact caused by the long life time of packaging equipment. Figure 1 presents an example of system boundaries considering all possible approaches adopted in an LCA of food-packaging systems

2.2 Life-Cycle Inventory (LCI) Data Analysis

LCI analysis involves creating an inventory of flows from and to nature considering the previously selected system boundaries. Inventory flows include inputs of water, energy, and raw materials and releases to air, land, and water. The inputs and outputs are collected for all activities within the system boundaries. Packaging systems must be accurately evaluated and shown in the analysis, thus allowing comparison between different materials or processes.

There can be two types of LCI data:

- Primary data, i.e., plant-specific data
- Secondary data, i.e., average data contained in databases

The use of primary data is fundamental to assess the impact of a specific packaging system, and for this reason the use of secondary data is limited to only some minor impact or to impacts that do not vary from case to case.

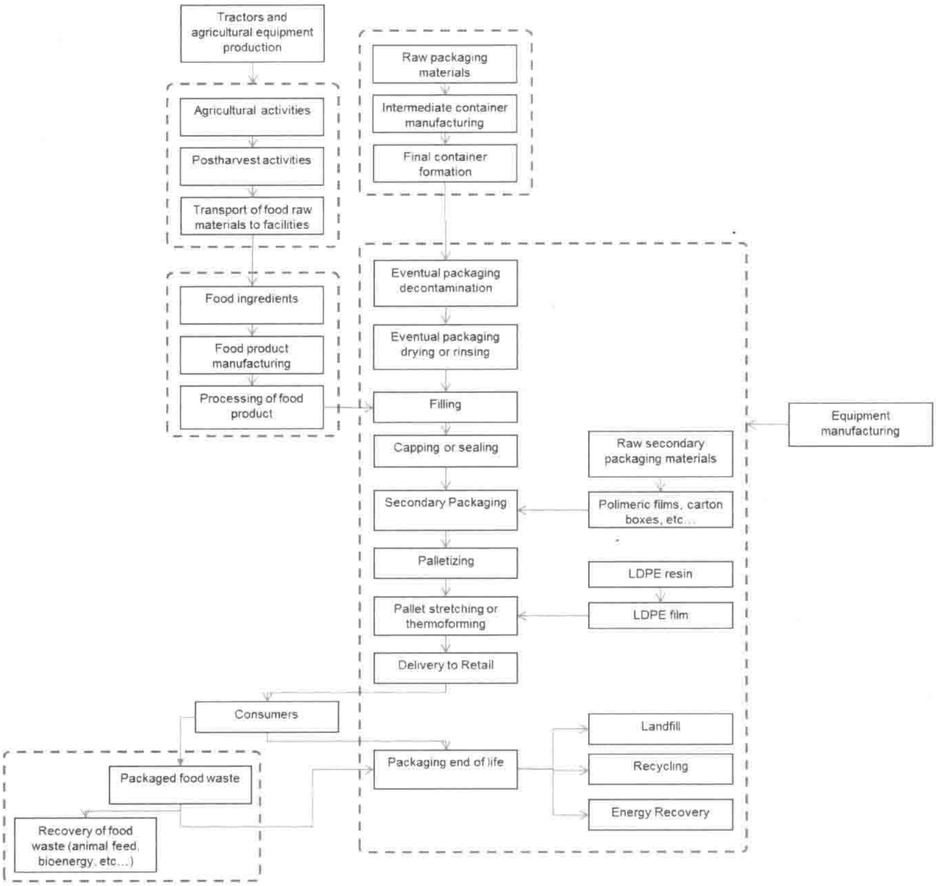

Fig. 1 Possible systems boundaries regarding LCA of food-packaging systems

2.3 Life-Cycle Impact Assessment (LCIA)

LCIA is aimed at evaluating the significance of potential environmental impacts based on the LCI flow results. A classic LCIA consists of the following mandatory elements:

2.3.1 Selection of Impact Categories and Characterization Models

Some relevant impact categories internationally accepted for the evaluation of the environmental impact of food-packaging systems include the following:

- global warming potential (GWP)
- natural resource depletion
- stratospheric ozone depletion

- acidification
- photochemical ozone creation
- eutrophication
- human toxicity
- aquatic toxicity

In an LCA for food-packaging systems, various characterization models can be used to calculate the results of impact assessment.

Regarding methods to assess impacts, some of the most used methods for assessing food-packaging systems include the following:

- CML 2001 (Guinée et al. 2001)
- ReCiPe 2008 (Goedkoop et al. 2009)
- ILCD 2011 (European Commission's Joint Research Centre 2010)
- Impact 2002+ (Jolliet et al. 2003)

Classification stage is another mandatory element: In this phase, the inventory parameters are sorted and assigned to specific impact categories. Usually this phase is performed by specific commercial software frequently used for LCA of food-packaging system (e.g., SimaPro or GaBi).

Impact measurement is where LCI flows are characterized into common equivalence units, which are then summed to provide an overall impact category.

2.4 Interpretation of Results

This step consists of presenting the results of LCA analysis with the aim to:

1. identify the most relevant impact (e.g., ozone depletion, CO_2 emissions, etc.);
2. identify processes that generate the greatest environmental impact (e.g., manufacturing of packaging materials, food-packaging operations, packaging transport);
3. Propose guidelines for improvement.

3 Methodological Approach to Literature Review

The methodology adopted to identify the studies analysed in this book is systematic literature review (Transfield et al. 2003). A systematic literature review is commonly adopted to identify key scientific contributions to a field or question, and it is grounded on a rigorous, replicable, scientific, and transparent process (Cook et al. 1997).

A systematic review requires two subsequent steps (Alderson et al. 2004). First, the inclusion criteria for the selection of the studies to review should to be identified. In our case, we decided to include in the review only studies that met the following criteria:

- We selected only papers concerning LCA of packaging systems that were applied exclusively in the food sector. Therefore, articles describing the environmental assessment of packaging not applied directly to food (e.g., secondary and transport packaging) were not retained;
- We selected only papers that were published in peer-reviewed international journals. Other publication forms (e.g., books, conference proceedings, newspapers articles, unpublished works, doctoral dissertations, etc.) were not considered in order to maintain a high scientific level and also to have access to the full articles;
- We selected only papers that were written in English.

No specific criteria were defined for the publication time span.

The second step of a systematic review is the strategy of locating and selecting the studies. In our review, we performed a computerized search of the Scopus database (www.scopus.com) by entering different pairs of keywords and taking into account the different terminology used by authors when referring to the environmental assessment of food packaging. In particular, two searches were performed (1) by coupling "food" with "packaging" with either "environmental assessment" or "life-cycle assessment" as keywords (search 1); and (2) by searching for these keywords in title, abstract, or article keywords in the Scopus database (search 2). These queries lead, respectively, to 250 and 115 studies published up to June 2015 including, e.g., books, conference proceedings, newspapers articles, unpublished works, doctoral dissertations, etc. According to the above-mentioned criteria, 184 articles of the 250 obtained from search 1 and 94 articles of the 115 obtained from search 2 were considered, gathered, and checked to avoid duplication. As a result, 95 articles were removed from the original set of 315. The remaining 220 articles were examined directly by checking the article title and the abstract to ensure that they complied with the inclusion criteria; 48 articles were removed after that check (e.g., they did not deal with as main aim of the environmental assessment of food packaging but also considered the themes of packaged food, new environmentally friendly food packaging, and food waste). This left a total of 172 studies that matched all the inclusion criteria, and thus they constitute the object of our analysis.

4 Review Results

The first article dealing with the themes of environmental assessment of food packaging was authored by the FDA association in 1990 (Hoffman and Nowell 1990). After this first publication, which was aimed at introducing the theme of sustainability of food packaging, two other works by Kooijman (1993, 1994) dealt with the theme of the environmental assessment of food packaging. Starting from these three works onward, the increasing number of articles published shows the increasing interest in this issue with the passage of time. As reported in Table 1 and Fig. 2, the number of articles published per year has consistently increased over time.

On the basis of this preliminary analysis, we analysed the sources of the reviewed articles. The 172 articles retrieved were all published on scientific journals, in particular, *International Journal of Life Cycle Assessment* (27 articles), *Journal of Cleaner Production* (22 articles), *Packaging Technology and Science* (9 articles), and *Resources, Conservation and Recycling* (7 articles) emerged as being the journals that published most of the articles included in the review. It is also interesting to note that several studies related to the environmental assessment of food packaging were published in international journals, which fall among the waste-management disciplines of the Scopus classification (e.g., *Waste Management, Waste Management and Research*). Overall, 11 of the 172 articles included in the review were published in these two journals. This is in line with the recognized importance of food packaging in the field of waste management as previously described.

As far as the specific issues are concerned, four main topics could be identified among the reviewed articles:

Topic 1. General aspect about the environmental impact of food-packaging use and disposal (e.g., municipal waste, recycling activity, or other use)
Topic 2. Environmental assessment of packaged food including the contribution of packaging

Table 1 Number of articles on environmental assessment of food packaging or related issues per year

Year	No. of articles	Year	No. of articles	Year	No. of articles	Year	No. of articles
1990	1	1997	0	2004	5	2011	18
1991	0	1998	2	2005	2	2012	17
1992	0	1999	1	2006	4	2013	34
1993	1	2000	2	2007	6	2014	28
1994	1	2001	2	2008	13	2015	12
1995	1	2002	2	2009	7		
1996	0	2003	3	2010	10		

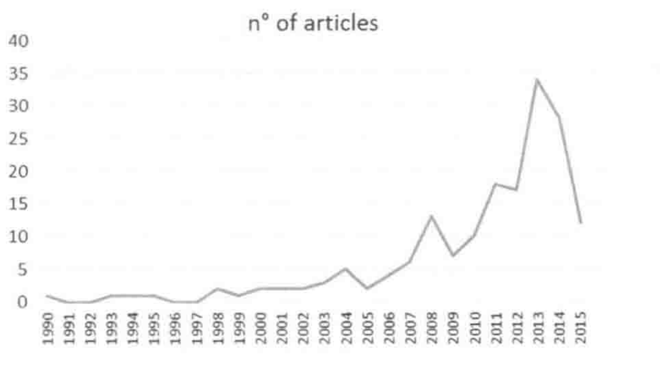

Fig. 2 Trend of numbers of articles on the environmental assessment of food packaging or related issues per year

Topic 3. Comparison of the environmental impact of several packaging systems and materials suitable for a specific food
Topic 4. New treatments or materials able to reduce the environmental impact of packaging (e.g., using biomaterials or enhanced materials and technology able to decrease food waste).

The 172 reviewed articles are classified in Table 2 based on this characterization.

Table 2 Classification of reviewed articles based on specific issues

Topic	Articles
1	Alvarenga et al. (2012), Angellier-Coussy et al. (2013), Armel et al. (2011), Arvanitoyannis and Bosnea (2001), Azapagic (2010), Barlow and Morgan (2013), Bevilacqua et al. (2008), Bugusu and Bryant (2006), Card et al. (2011), Coltro and Duarte (2013), Darlington et al. (2009), Detzel and Mönckert (2009), Dobon et al. (2011a), Dobon et al. (2011b), Edjabou et al. (2015), Edwards and Mercer (2012), Flegal et al. (2013), García-Arca et al. (2014),Gentil et al. (2011), Gentry and Shah (2004), Giugliano et al. (2011), Grizzetti et al. (2013), Grönman et al. (2013), Grosso et al. (2012), Heller and Keoleian (2003), Hoffmann and Nowell (1990), Hyde et al. (2003), Infante Amate and González De Molina (2013), Jayaraman et al. (2011), Jones (2002), Jungbluth et al. (2000), Kim et al. (2004), Kooijman (1993), Kooijman Jan (1994), Kroyer GTh (1995), Lathrop and Centner (1998), Lea and Worsley (2008), Lee et al. (2014), Li et al.(2013), Lorber et al. (2015), MacRae et al. (2013), Marsh and Bugusu (2007), Maxime et al. (2006), Meier and Christen (2013), Mena et al. (2014), Nichols et al. (2011), Oki and Sasaki (2000), Pimentel et al. (2008), Russell DAM (2014), Salhofer et al. (2008), Sanyé et al. (2012), Scipioni et al. (2013), Singh et al. (2014), Svanes et al. (2010), Tobler et al. (2011a), Van Passel (2013), Vandermeersch et al. (2014), Wan (2011), Wikström (2014), Williams et al. (2012), Xue and Landis (2010), Yano et al. (2014), Zampori and Dotelli (2014), Zhang and Wen (2014)
2	Amienyo et al. (2013), Andersson and Ohlsson (1999), Andersson et al. (1998), Bengtsson and Seddon (2013), Bevilacqua et al. (2007), Büsser and Jungbluth (2009), Calderón et al. (2010), Cellura et al. *(2012), Cordella et al. (2008), Davis and Sonesson (2008), Del Borghi et al. (2014), Espinoza-Orias et al. (2011), Flysjö (2011), Fusi et al. (2014), González-García et al. (2011), González-García et al. (2013a), Goyal et al. (2012), Hanssen (2007), Høgaas Eide (2002), Hospido et al. (2005), Hospido et al. (2006), Iribarren et al.·(2010), Karakaya and Özilgen (2011), Kendall et al. (2013), Keoleian et al. (2004), Kim et al. (2013), Manfredi and Vignali (2015), Manzini et al. (2014), Marletto and Sillig (2014), Mourad et al. (2008), Nilsson et al. (2010), Oglethorpe (2009), Pardo and Zufía (2012), Pattara et al. (2012), Robertson et al. (2014), Röös et al. (2011), Roy et al. (2008), Roy et al. (2012), Sanjuán et al. (2014), Sanyé-Mengual et al. (2013), Schmidt Rivera et al. (2014), Sonesson and Berlin (2003), Talve (2001), Tanner (2006), Teixeira et al. (2013), Tobler et al. (2011b), Vázquez-Rowe et al. (2012), Vázquez-Rowe et al. (2013)
3	Accorsi et al. (2014), Accorsi et al. (2015), Albrecht et al. (2013), Azadnia et al. (2015), Banar and Çokaygil (2009), Bertoluci et al. (2014), Bø et al. (2013), Davis and Sonesson (2008), De Monte et al. (2005), Foolmaun and Ramjeeawon (2012), Humbert et al. (2009), Manfredi et al. (2015), Meneses et al. (2012), Poovarodom et al. (2012), Raheem (2013), Romero-Hernández et al. (2009), Rujnić-Sokele (2011), Silvenius et al. (2014), Siracusa et al. (2014), Toniolo et al. (2013), Von Falkenstein et al. (2010), Williams and Wikström (2011)

(continued)

Table 2 (Continued)

Topic	Articles
4	Auras et al. (2004), Bhat et al. (2013), Blanco and Siracusa (2013), Bohlmann (2004), Bugnicourt et al. (2013), Chen et al. (2014), Cheng et al. (2010), Coltelli et al. (2008), Cruz-Romero and Kerry (2008), El-Hadi (2014), Gebbink et al. (2013), González-García et al. (2013b), Hermann et al. (2010), Jamshidian et al. (2010), Juodeikiene et al. (2015), Kale et al. (2007a), Kale et al. (2007b), Leceta et al. (2013a), Leceta et al. (2013b), Leceta et al. (2015), Majeed et al. (2013), Manfredi and Vignali (2014), Mitrano et al. (2015), Montanari et al. (2014), Râpă et al. (2013), Reig et al. (2014), Rossi et al. (2015), Shen and Patel (2008), Siracusa et al. (2008), Souza et al. (2013), Tawakkal et al. (2014), Varžinskas et al. (2012), Vidal et al. (2007), Williams et al. (2008), Xu et al. (2015a), Xu et al. (2015b), Zhang et al. (2014)

As can be seen by regarding the references presented in Table 2, the majority of the articles deal with the theme of general aspects of environmental impact of food-packaging use and disposal, and this theme appears as being uniform distributed along the time span of the considered review. Following the trend shown in Fig. 1, this first topic (no. 1) in the last 5 years showed a larger number of works per year than in the past. However, when comparing the number of articles with that of overall articles per year, the ratio tends to briefly decrease (Table 3).

Regarding articles addressing topic 2, they began to appear later than those on topic 1, but in the last 10 years their number has tended to become similar to those addressing topic 1 (Fig. 3 and Table 3). This could be due to the increased number of packaged food products sold worldwide as well as the attention paid to the environmental impacts of packaging materials and technologies compared with impacts associated with food production and processing.

Based on this assumption, articles addressing topic 3 appear to be a consequence of research into the assessment of a specific packaged food product in order to find all possible solutions to decreasing its environmental impact. When investigating packaging materials and technologies, many researchers have proposed comparative solutions during the past 8 years to determine the most

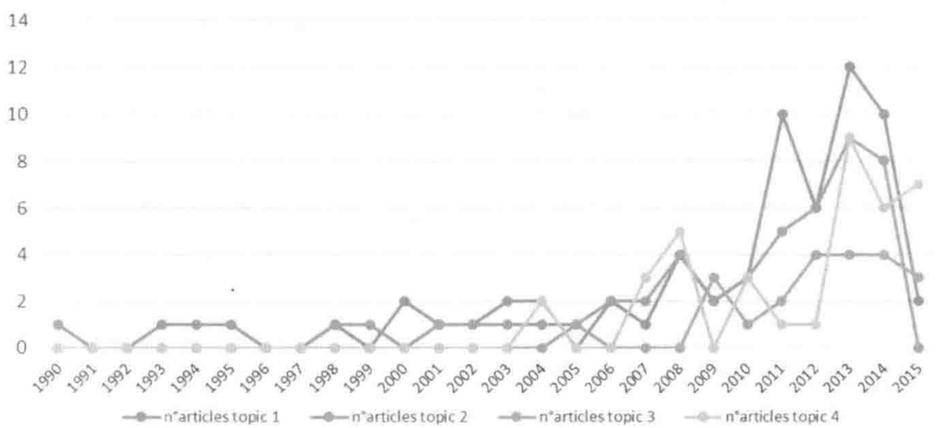

Fig. 3 Trends of articles' topics on the environmental impact of food packaging systems

Table 3 Distribution throughout 4 years of the topics of reviewed articles and the ratio between the number of articles for each topic and all reviewed articles published each year

Years	No. of articles	No. of articles topic 1	Topic 1/all	No. of articles topic 2	Topic 2/all	No. of articles topic 3	Topic 3/all	No. of articles topic 4	Topic 4/all
1990	1	1	1		0		0		0
1991	0		–		–		–		–
1992	0		–		–		–		–
1993	1	1	1		0		0		0
1994	1	1	1		0		0		0
1995	1	1	1		0		0		0
1996	0		–		–		–		–
1997	0		–		–		–		–
1998	2	1	0.5	1	0.5		0		0
1999	1		0	1	1		0		0
2000	2	2	1		0		0		0
2001	2	1	0.5	1	0.5		0		0
2002	2	1	0.5	1	0.5		0		0
2003	3	2	0.666	1	0.333		0		0
2004	5	2	0.4	1	0.2		0	2	0.4
2005	2		0	1	0.5	1	0.5		0
2006	4	2	0.5	2	0.5		0		0
2007	6	1	0.166	2	0.333		0	3	0.5
2008	13	4	0.307	4	0.307		0	5	0.384
2009	7	2	0.285	2	0.285	3	0.428		0
2010	10	3	0.3	3	0.3	1	0.1	3	0.3
2011	18	10	0.555	5	0.277	2	0.111	1	0.055
2012	17	6	0.353	6	0.353	4	0.235	1	0.058
2013	34	12	0.353	9	0.264	4	0.117	9	0.265
2014	28	10	0.357	8	0.285	4	0.142	6	0.214
2015	12	2	0.166		0	3	0.25	7	0.583
Total	172	65	0.378	48	0.279	22	0.128	37	0.215

environmentally friendly packaging. Among the 22 articles we selected regarding this topic, most of them were aimed at comparing only packaging materials; however, especially in the last 5 years, scientific research has been aimed at both materials and technologies to understand how packaging technology could play a fundamental role in reduction of the environmental impact of packaged food.

Another interesting field of interest is oriented toward the definition of new environmental friendly packaging materials, which could fall under the categories of biomaterials and recycled packaging materials for food products. Several studies have been performed by chemical scientists to find new materials able to satisfy the market requests in terms of appearance, mechanical and gas-barrier performance, and low environmental impact. However, many studies have been performed starting from 2003 that reveal a different type of evaluation mainly due to the different system boundaries and evaluation methods adopted.

As part of the proposed classification of the four topics, it has been interesting to see the evolution (when analysing the four topics) of the consideration of the impact of food-packaging technology on the amount of food waste generated. The quantity of food waste that could be reduced by means of innovative packaging technology (e.g., modified atmosphere packaging [MA]P) or active packaging solutions (e.g., oxygen scavengers, gas emitters, or antimicrobial coatings) could be relevant. It has been demonstrated, in fact, that the avoided impact of reduced food waste is considerable greater than the impacts generated by their manufacturing and the application of the new technology.

4.1 Detailed Characteristics of the Review Studies

As far as some details of the reviewed studies are concerned, it could be interesting to evaluate (where these data are reported) the following:

1. the country has been analysed
2. the functional unit assumed
3. the system boundaries assumed

Based on the high number of the reviewed studies, the main results are summarized here as follows.

The geographic area analyzed is evident because these types of studies often concern European countries. Italy, Spain, Switzerland, France, and northern European countries (e.g., Sweden, Holland, Denmark, United Kingdom, and Germany) have more times than not been cited as the survey area. Studies in the United States are often published but less so than the sum of studies concerning European countries. In addition, analyses performed in the United States have mainly been dedicated to a general evaluation of the packaging system and less concentrated on to a specific food product or packaging than is found in Europe. In the last 2 years, China has emerged as one of the countries most interested in this kind of environmental assessment. Based on this evaluation and analysing the distribution of visualized locations for some of the surveyed studies (using, for example, the Elsevier Dashboard or the ResearchGate social network), one could expect an increasing number of works coming from Asian countries in the following years. This could be supported by the fact that, as previous investigations have shown, that the number of works on the environmental assessment of food-packaging systems has been constantly increasing in the last 5 years.

It is difficult to determine categories of functional unit because they are extremely variable from case to case. As reported before, in the case of topic 2, the functional unit often reflects a specific packaged food, for example, the analysed quantities vary from <1 kg or 1 l (often exactly 1 kg or 1 l) to >1000 kg or even