10th International Food Operations & Processing Simulation Workshop, 001
21st International Multidisciplinary Modeling & Simulation Multiconference

2724-0355 © 2024 The Authors.
doi: 10.46354/i3m.2024.foodops.001

Packaging and technologies for food products: a state-of-the art survey

Eleonora Bottani[1,*], Martina Nicoletti[1] and Giuseppe Vignali[1]

[1]University of Parma, Department of Engineering for Industrial Systems and Technologies - DEIST, viale delle Scienze 181/A, 43124 Parma, Italy

[*]Corresponding author. Email address: eleonora.bottani@unipr.it

Abstract

This paper proposes an in-depth analysis of the packaging materials and technologies used for commercial food and beverage products, and as such, it builds upon a previous publication by Bottani et al. (2011). The original study evaluated a sample of 175 food and beverage products, for which, through an in-field investigation of Italian retailers, the relevant characteristics of the packaging and product were retrieved. In this study, a larger sample of products is analyzed, consisting of 212 food products, and the product/packaging characteristics are updated in case changes occurred in the packaging material or processing technologies of foods. Moreover, compared to the previous research, end-of-life considerations of the packaging material are added. Statistical analyses are then made on the sample of products, to determine possible relationships between the product characteristics, the processing technology, the packaging type and the end-of-life. By delving into the relationships between product attributes and packaging technologies, results of this research contribute valuable insights to the food packaging industry, offering an up-to-date perspective, as well as suggestions for food manufacturers to identify the most suitable packaging technology for new food products.

Keywords: Food packaging; packaging material; packaging technology; end-of-life; survey; statistical analysis.

1. Introduction

In the food and beverage industry, packing plays a multiplicity of roles, ranging from technical aspects (protection and preservation of the product), commercial functions (e.g., brand communication), aesthetic purposes, safety needs (traceability), up to environmental and logistic (handling, transport and storage) functions (Coles and Kirwan, 2011; Marsh et al., 2007; Norton et al., 2022; Otto et al., 2021). Appropriate packaging design and technology for sure are of strategic importance for food and beverage companies, and key to competitive advantage (Coles & Kirwan, 2011). As food and beverages are typically sold at low prices on the market, producers are continuously trying to decrease costs in the supply chain; however, the pressure to reduce costs must be balanced against the technical requirements of packaging for ensuring food safety and product integrity, meeting the challenge to be environmentally responsible, and at the same time, ensuring efficient logistics processes (Coles et al., 2003).

From the technical and logistics perspectives, a properly designed packaging for food or beverage products has an undoubtful role in determining the shelf life of the product. Similarly, the right selection of materials and technologies for some kinds of products allows maintaining their quality and freshness during distribution and storage (Martinez et al., 1998). Generally, the package barriers to oxygen and moisture determine shelf life of the food product (Reinas, Oliveira, Pereira, Mahajan, & Poças, 2016).

Moreover, selecting the appropriate packaging significantly affects the cost of handling and transportation of product, as well as its effectiveness in delivering valuable commercial information to the consumer (Polonsky et al., 2002). To ensure product preservation, packaging material and type should be characterized by proper technical and mechanical properties; at the same time, they should simplify logistics processes, such as handling, transportation, storage and usage of the product (Marsh & Bugusu, 2007).

The global packaging market was estimated at 4,300 billion packaging units in 2015, with approx. 73% used for food and beverage products (Ketelsen, 2020). At European level, 1,130 billion packages were used for food and drinks in 2018 (Fuhr et al., 2019), with relevant environmental concerns. Common food packaging materials include plastic, glass, metal, paper, and cardboard (Coles & Kirwan, 2011). In 2015, plastic packaging, both rigid and flexible, was the packaging material with the largest market share, reaching approx. 47% (ALL4PACK, 2016). At present, the flexible packaging is expected to have the highest growth, estimated in +4.5% annual growth rate between 2023 and 2030, primarily because of the increasing consumption of processed food and beverages, but also because of the rising demand for convenient packaging solutions (ALL4PACK, 2023). This is why in recent years, the focus of academia, industry and institutions has shifted towards approaches for reducing food packaging waste (Norton et al., 2002; Otto et al., 2021). Recommended strategies include first of all reducing the need for packaging, then reusing packaging, using recyclable materials or compostable packaging, or recycling (Oloyede et al., 2021). Obviously, the various requirements of packaging could be somehow conflicting with the sustainability of the solution, resulting in not all food packaging also meeting the environmental needs (Norton et al., 2022).

Moving from this set of considerations, this paper provides a comprehensive analysis of different types of packaging used for commercial food and beverage products, to highlight their relationships with the characteristics of the product packaged and of the preservation treatment, but also including a view to the environmental (end-of-life) aspects of the packaging material. The analysis carried out builds upon the previous study by Bottani et al. (2011), in which a sample of 175 commercial food products was evaluated, focusing on the Italian retail channel. Relating data, in terms of the relevant characteristics of the packaging and product, were retrieved from an in-field investigation of some retail stores. In the present study, the sample of commercial products analyzed has been enlarged, through a new in-field investigation; the product and packaging characteristics were retrieved or updated, in case changes occurred to the packaging material or to the food processing technologies. Moreover, compared to the original research, end-of-life considerations were added among the characteristics of the packaging. Statistical analyses, both of descriptive nature and as cross-analyses, are then made on the resulting sample of products. Overall, the final goal of the study is to identify the key relationships between the product's characteristics, the processing technology and the packaging type, so as to provide useful guidelines for manufacturers of food packaging or food products.

The remainder of the paper is structured as follows. Section 2 details the methodology used for creating the sample of products to be analyzed, the categorization of the relating data and the statistical analyses made. Section 3 presents the findings from the survey. Finally, section 4 comments on those findings, discusses the main implications and limitations of the study, derives the key conclusions and suggests future research activities.

2. Materials and methods

2.1. Data collection

Physical site visits at some Italian retailers, located in area of Parma (Italy), were carried out in June-July 2023, to define an appropriate sample of commercial food products to be analyzed. The list of items originally evaluated in Bottani et al. (2011) was taken as the starting point for identifying representative products on which to start the data collection. Nonetheless, the original sample of products was enlarged by adding new items, reaching 212 items in total. The newly selected products belong the same categories identified in the previous study, for the sake of consistency, and were therefore classified accordingly in the following groups: beverages; milk and derivatives; bread and derivatives; fruits and vegetables; salami, meat or fish.

The products identified own different characteristics in terms of chemical, physical or organoleptic properties, and in line with these features, the packaging requirements also differ in terms of functionalities, material and technology. An appropriate checklist was set up for mapping the relevant characteristics of the product and packaging, as well as to record them in a useful way for the subsequent statistical analyses. The scheme in Table 1 was followed (Robertson et al., 2006; (Belitz et al., 2004).

Table 1. Scheme of the data collected.

Product characteristics	*Scale*
physical state	(1) liquid; (2) semi-solid; (3) solid
water activity	(1) high - between 0.9 and 1; (2) medium - between 0.6 and 0.9; (3) low - between 0 and 0.6
pH	(1) low - between 6 and

	14; (2) medium - between 4 and 6; (3) high - between 0 and 4
sensitivity to oxygen	(1) high; (2) medium; (3) low
sensitivity to light	(1) high; (2) medium; (3) low
storage temperature	(1) product is frozen; (2) product is refrigerated; (3) product is stored at ambience temperature
Packaging characteristics	*Scale*
packaging material	12 classes (paper, collagen, metal, HDPE, LDPE, PET, PP, PS, cellulose bags, tetra-brick, polystyrene foam tray, glass)
packaging technology	9 categories (aseptic, preserving fluid, modified atmosphere packaging – MAP, Pasteurization, hot filling, cold filling, sterilization, vacuum packaging, no treatment)
End-of-life considerations	*Scale*
end-of-life destination	4 categories with possible mix of end-of-life options (recycling, incineration with energy recovery, composting, reuse)

Concerning the product characteristics, various aspects (e.g., physical state or temperature) were directly derived *via* a visual inspection of the product itself. A similar procedure was follower for the packaging characteristics, most of which, again, were retrieved by directly examining the product label. This is indeed the case for the material and end-of-life considerations, which are expected to be printed on the product label in response to the legislative decree no.116/2020 (Gazzetta Ufficiale della Repubblica Italiana, 2020). Whenever some information (either about the product or packaging) was not directly available (e.g., because the product label lacked the corresponding data), the dataset was filled by consulting either specialized literature or other appropriate sources.

2.2. Analysis

Statistical package for the social science (SPSS), release 29 for Windows (www.ibm.com) was used to process the data collected. An initial set of statistical analyses was made for providing an overview of the sample of products under examination and of the relating characteristics. Contingency tables were then used to correlate the product and packaging characteristics, as well as to the end-of-life destinations, so as to identify possible relationships between these aspects. A comparison of the results obtained with the outcomes of the previous study was also made, where appropriate, to identify trends in the aspect evaluated. Figure 1 depicts the scheme of the analyses made.

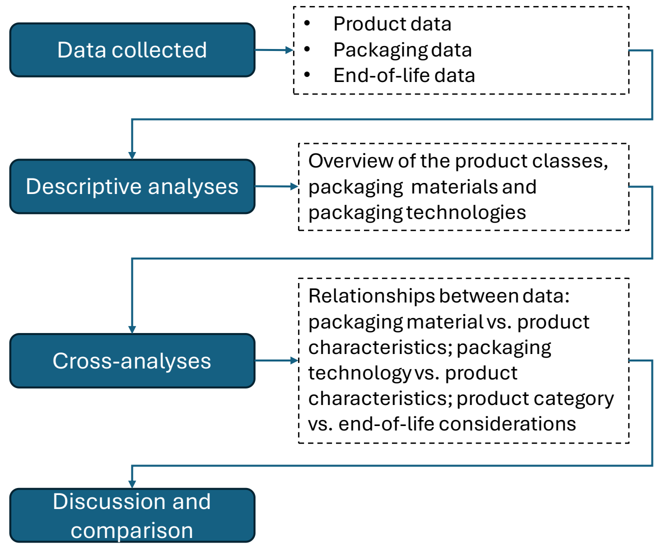

Figure 1. scheme of the methodological approach.

3. Results

3.1. Sample description

The 212 products of the sample belong to the following categories: milk and derivatives (29 products, 13.7% of the sample); beverages (35 products, 16.5%); bread, pasta and bakery (59 products, 27.8%); fruit and vegetables (59 products, 27.8%); salami, eggs, meat and fish (30 products, 14.2%). Most of these products are solid (136 items, 64.2%), while semisolids and liquid products accounted for 12.3% (26 items) and 23.6% (50 items) of the sample, respectively. Compared to the previous study, whose sample was smaller in size, newly introduced products mainly belong to the category of liquid foods, whose size grew from 18.9% to 23.6%, at the expenses of the remaining two groups of products.

As far as the packaging materials (Table 2 and Figure 2), PP is by far (27.8%) the most used material for the food products considered, followed by glass (16.5%); this result confirms the outcomes of the original study. Great increase was found in the usage of paper, which rose from a value of 6.3% observed in Bottani et al. (2011) to the current quota of 14.2%, thus ranking, at present, among the most used materials. Metal (13.2%) also confirms its wider usage for food packaging.

For 9 products, the packaging technology could not be determined for sure, and therefore, these products were excluded from the corresponding analyses. Table 3 shows the share of the packaging technologies across the sample of products. From the table it is evident that the most popular packaging technologies are MAP (23.6%), usage of preserving liquids (9.9%) and aseptic packaging (7.4%). Moreover, 42.4% of the analyzed products (86 items) have no treatment type; most of these products belong to the category of bread and derivatives (36 items, 41.9% of the sample), followed by beverages (20 items, 23.3%); on the contrary, a very small quota of items belonging to the salami, meat or fish category is not subject to treatments (5 items, 5.8%).

Outcomes relating to the packaging technology appear in line with the previous study, which returned 45.7% of products with no treatment; the quota of MAP was similar too (22.3%). On the contrary, both the usage of preserving fluids and aseptic packaging have increased their percentage share.

Table 2. Share of the packaging materials.

Packaging material	Total %	Salami, eggs, meat and fish [%]	Beverages [%]	Fruit and vegetables [%]	Bread, pasta and bakery [%]	Milk and derivatives [%]
Polypropylene (PP)	27.8	20.3	1.7	22.0	39.0	16.9
HDPE	4.2	11.1	11.1	11.1	44.4	22.2
LDPE	1.9	0.0	0.0	100.0	0.0	0.0
PET	9.9	4.8	76.2	0.0	0.0	19.0
Polystyrene (PS)	0.5	0.0	0.0	0.0	0.0	100.0
Polystyrene foam tray	2.4	100.0	0.0	0.0	0.0	0.0
Collagen	0.5	100.0	0.0	0.0	0.0	0.0
Paper	14.2	6.7	6.7	6.7	70.0	10.0
Tetra-brick	5.7	0.0	58.3	0.0	0.0	41.7

Table 3. Share of the packaging technologies.

Packaging technology	Number of products	Percentage
aseptic	15	7.4
preserving fluid	20	9.9
modified atmosphere packaging (MAP)	48	23.6
Pasteurization	8	3.9
hot filling	8	3.9
cold filling	1	0.5
no treatment	86	42.4
vacuum packaging	9	4.4
sterilization	8	3.9

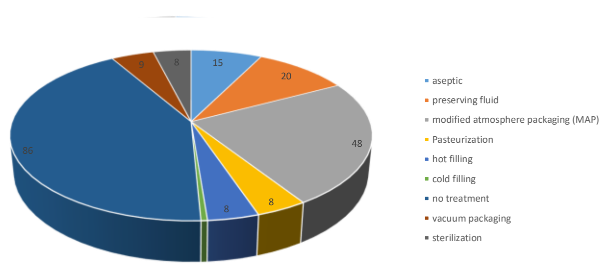

Figure 3. Share of the packaging technologies.

3.2. Cross-analyses

Several cross-analyses between the packaging characteristics and the product features were made. The various analyses relate the packaging material (Tables 4) and technologies (Tables 5) with different properties of the products examined. Outcomes show that paper, metal and PP are particularly adopted for solid food packaging, with 86.7%, 75% and 81.4% of the product, respectively. In the previous study, more than 80% of solid products were found to be packaged in glass; a different situation emerges instead in this updated analysis, with a split between liquid (37.1%) and solid foods (48.6%).

Glass-packaged products are characterized by very similar characteristics, which can be summarized in: high water activity, with 31 out of 35 glass-packaged products showing water activity between 0.9 and 1, low pH; high sensitivity to oxygen; medium sensitivity to light. As opposed to other packaging materials, glass can be subject to various treatments, such as sterilization, pasteurization, hot filling, preservation with liquid, aseptic packaging, or no treatments.

PET is mainly used for liquid products (18 out of 21), which is an expected result considering the wide use of this material for beverage bottling. These products are mainly characterized by ambient temperature or refrigerated storage, medium to high light sensitivity, high oxygen sensitivity, and high water activity, while pH does not seem to significantly influence the usage of PET for packaging. Products packaged with PET are also subject to aseptic filling (25%) or are packaged without treatment (35%).

Similarly, most of the products packaged with tetra-brick (10 out of 12) are liquids, characterized by high water activity and high sensitivity to oxygen and light. Moreover, these products, being generally beverages, are mainly stored at room temperature and packaged under aseptic conditions or even without undergoing any treatment. PP is instead mainly used for packaging solid products (81.4%), with medium or high pH, medium sensitivity to light, medium or high sensitivity to oxygen; the technology most frequently used for such products is MAP. Water activity does not seem to substantially affect the choice of PP for packaging, as the products examined show a balanced share between high, medium and low water activity.

Metal appears to be frequently used for solid products (75%), packaged through the use of the preserving liquid; to a small extent, in addition to the previous analysis, it also emerges as a material used for packaging liquid foods (21.4%), mainly beverages, that, in general, do not require specific technological treatments during packaging. Outcomes also show that this material (particularly aluminum) is exploited for products characterized by high water activity, high oxygen sensitivity, medium light sensitivity, and low pH, although the latter characteristic is less appreciable within the sample examined.

Finally, paper is mainly used for solid products (26 out of 30 products examined), characterized by low water activity, medium or high pH, medium sensitivity to oxygen and light. Such products usually do not undergo specific treatments during packaging (25 out of 30 products do not undergo any treatment).

As far as the environmental considerations, the product category was related to the end-of-life destination(s) of the packaging material. Results, shown in Table 6, highlight that recycling of the packaging material is possible for all product categories in the sample. Obviously, various end-of-life destinations are possible for the same packaging materials; indeed, incineration is a frequent option for the packaging material used for bread, pasta and bakery, or for that of milk and derivatives. Similarly, reuse is a suitable option for approx. 81% of the packaging materials used for beverages. Composting is instead possible for a good quota of packaging materials for bread, pasta and bakery.

Table 4. Cross-analysis of the packaging material vs. product characteristics.

Packaging material	**Physical state**			**Aw**			**pH**		
	Liquid	**Semi-solid**	**Solid**	**1-0.9**	**0.9-0.6**	**0.6-0**	**14-6**	**6-4**	**4-0**
Polypropylene (PP)	1	10	48	25	21	13	18	37	4
HDPE	2	1	6	2	3	4	1	7	1
LDPE	0	0	4	0	0	4	0	4	0
PET	18	2	1	21	0	0	6	5	10
Polystyrene (PS)	0	1	0	1	0	0	0	1	0
Polystyrene foam tray	0	0	5	5	0	0	3	2	0
Collagen	0	0	1	0	1	0	0	1	0
Paper	0	4	26	5	9	16	18	10	2
Tetra-brick	10	2	0	12	0	0	7	0	5
Cellulose bags	0	0	7	6	0	1	3	2	2
Glass	13	5	17	31	1	3	10	7	18
Metal	6	1	21	22	1	5	5	8	15

(continued)

Packaging material	**Sensitivity to oxygen**			**Sensitivity to light**			**Storage temperature**		
	high	**medium**	**low**	**high**	**medium**	**low**	**frozen**	**refrigerated**	**ambient**
Polypropylene (PP)	31	25	3	15	35	9	4	20	35
HDPE	4	5	0	7	2	0	1	3	5
LDPE	0	4	0	0	4	0	4	0	0
PET	18	2	1	11	10	0	0	4	17
Polystyrene (PS)	1	0	0	1	0	0	0	1	0
Polystyrene foam tray	4	1	0	5	0	0	0	5	0
Collagen	1	0	0	1	0	0	0	1	0
Paper	7	19	4	2	20	8	4	3	23
Tetra-brick	12	0	0	10	2	0	0	0	12
Cellulose bags	3	4	0	0	7	0	0	6	1
Glass	31	2	2	11	22	2	0	1	34
Metal	26	2	0	5	22	1	0	1	27

Table 5. Cross-analysis of the packaging technology vs. product characteristics.

Packaging technology	**Physical state**			**Aw**			**pH**		
	Liquid	**Semi-solid**	**Solid**	**1-0.9**	**0.9-0.6**	**0.6-0**	**14-6**	**6-4**	**4-0**
aseptic	13	2	0	15	0	0	5	0	10
preserving fluid	0	0	20	20	0	0	6	4	10
modified atmosphere packaging (MAP)	4	5	39	28	8	12	10	34	4
Pasteurization	5	1	2	8	0	0	3	3	2
hot filling	2	6	0	8	0	0	0	5	3

cold filling	1	0	0	1	0	0	0	0	1
no treatment	21	9	56	37	19	30	44	30	12
vacuum packaging	0	0	9	1	6	2	1	8	0
sterilization	0	0	8	8	0	0	0	0	8

(continued)

Packaging technology	Sensitivity to oxygen			Sensitivity to light			Storage temperature		
	high	medium	low	high	medium	low	high	medium	low
aseptic	14	1	0	14	1	0	0	0	15
preserving fluid	20	0	0	7	13	0	0	0	20
modified atmosphere packaging (MAP)	31	17	0	18	30	0	8	21	19
Pasteurization	7	0	1	2	6	0	0	3	5
hot filling	8	0	0	0	8	0	0	0	8
cold filling	1	0	0	0	1	0	0	0	1
no treatment	38	41	7	22	48	16	4	16	66
vacuum packaging	6	3	0	5	2	2	0	5	4
sterilization	8	0	0	0	8	0	0	0	8

Table 6. Product category vs. end-of-life destination of the material.

Product category	Recycling	Incineration	Composting	Reuse
Salami, eggs, meat and fish	100.0%	80.8%	53.8%	30.8%
Beverages	100.0%	75.0%	6.8%	81.8%
Fruit and vegetables	100.0%	60.8%	43.1%	37.3%
Bread, pasta and bakery	100.0%	93.0%	77.2%	43.9%
Milk and derivatives	100.0%	92.6%	48.1%	51.9%

4. Discussion and conclusions

This paper has proposed an updated analysis of the packaging materials and technologies applied to commercial food products, building upon the previous publication by Bottani et al. (2011). A representative sample of 212 food and beverage products, whose data were collected through site visits at retail stores, was examined, which enlarges the range of products compared to the previous study. As a further improvement compared to the original paper, end-of-life considerations were added to the data collected about the sample of products, given the increasing importance of ensuring sustainability of packaging materials (Otto et al., 2021).

The outcomes of the study allow capturing some relationships between the product's characteristics, and the processing technology and type. These aspects are relevant to both packaging manufacturers and food/beverage manufacturers, as suggestions can be easily derived for the optimal design of the packaging as a function of the product characteristics.

As far as the relationships between the product category and the end-of-life destinations of the corresponding packaging material, these aspects are relevant from a practical perspective. Indeed, packaging waste constitutes around one third of the municipal waste and have continuously increased in the last years in the EU (European Economic and Social Committee, 2020). Estimates by Eurostat (2020) indicate that the amount of packaging waste generated per capita increased from 150 kg to 173 kg between 2009 and 2017. Accordingly, reuse of the packaging materials is the second-ranked strategy of managing waste, as described in the Waste Framework Directive (European Commission, 2023). Second, the characteristics of the food/beverage product obviously affect the usage of a given packaging material, which, in turn, has some possible end-of-life destinations; hence, the eating habits of the consumers, and in particular, the consumption of the different product categories, should be taken into account when commenting on the outcomes of this study. In this respect, comparing 2023 to 2022, the consumption of bakery products (cereal derivatives, breakfast products, bread and substitutes) has significantly increased (+18%), as well as the consumption of pasta (+11%) and rice (+26%) (ISMEA Mercati, 2024). The same can be stated for dairy products, for which the consumption experienced a relevant increase as well (+17.8%). An increase in packaging waste generated by those product categories is thus to be expected, i.e., according to the findings of this study, primarily, paper, tetra-brick and plastic materials (HDPE, PP and PET). These indications could guide future research activities towards the analysis of these specific packaging materials.

The findings of this study could be complemented by carrying out additional, more structured, statistical analyses, in the form of multi-variate statistics, to explore, e.g., whether the food/beverage products analyzed in this study could be grouped into homogenous clusters with similar characteristics in terms of the packaging requirements. This would allow deriving further suggestions for packaging or food/beverage manufacturers.

References

ALL4PACK, 2016. Packaging. Market and challenges in 2016. Available at: www.all4pack.com.

ALL4PACK, 2023. The global flexible packaging market: a growth projection of 4.5% CAGR from 2023 to 2030. Available at: https://news.all4pack.com/the-global-flexible-packaging-market-a-growth-projection-of-4-5-cagr-from-2023-to-2030/

Belitz, H.D., Grosch, W., & Schieberle, P., (2004). Food Chemistry, 3rd ed. Springer-Verlag, Berlin (Germany)

Bottani, E., Montanari, R., Vignali, G., & Guerra, L. (2011). A Survey on Packaging Materials and Technologies for Commercial Food Products. International Journal of Food Engineering, 7(1), article no. 12

Coles, R., Kirwan, M.J., (2011). Food and Beverage Packaging Technology, 2nd edition. ISBN: 9781405189101. Blackwell Publishing Ltd, Iowa (US)

Coles, R., Mcdowell, D., Kirwan, M.J., 2003. Food Packaging Technology. ISBN: 084939788X. Blackwell Publishing Ltd, Boca Raton (US)

European Economic and Social Committee, (2020). Recycling food packaging & food waste in plastics revolution. Available at: https://www.eesc.europa.eu/sites/default/files/files/qe-03-20-534-en-n.pdf

Eurostat (2020). Packaging waste statistics. Available at: https://ec.europa.eu/eurostat

European Commission (2023). Waste Framework Directive. Available at: https://environment.ec.europa.eu/topics/waste-and-recycling/waste-framework-directive_en

Fuhr, L., Buschmann, R., Freund, J., (2019). Plastikatlas. Daten und Fakten über eine Welt voller Kunststoff. 1. Aufl. Heinreich-B€oll-Stiftung und Bund für Umwelt und Naturschuzt Deutschland (edt.) (Berlin).

Gazzetta Ufficiale della Repubblica Italiana (2020). Decreto legislativo 3 settembre 2020, n. 116 - Attuazione della direttiva (UE) 2018/851 che modifica la direttiva 2008/98/CE relativa ai rifiuti e attuazione della direttiva (UE) 2018/852 che modifica la direttiva 1994/62/CE sugli imballaggi e i rifiuti di imballaggio. Available at: https://www.gazzettaufficiale.it/eli/id/2020/09/11/20G00135/sg

ISMEA Mercati (2024). I consumi alimentari delle famiglie. Available at: https://www.ismeamercati.it/

Ketelsen, M., Janssen, M., Hamm, U., (2020). Consumers' response to environmentally-friendly food packaging – A systematic review. Journal of Cleaner Production, 254, article no. 120123

Marsh, K., & Bugusu, B. (2007). Food Packaging and its Environmental impact. Food technology, 4(7), 46-50. Available at: www.ift.org

Marsh, K.; Bugusu, B. (2007). Food packaging—Roles, materials, and environmental issues. Journal of Food Science, 72, 39–55.

Martinez, C., Mucci, A., Santa Cruz, M.J., Hough, G., & Sanchez, R., (1998). Influence of temperature, fat content and package material on the sensory shelf-life of a commercial mayonnaise. Journal of Sensory Studies, 13, 331-346

Norton, V., Waters, C., Oloyede, O.O., Lignou, S. (2022). Exploring Consumers' Understanding and Perception of Sustainable Food Packaging in the UK. Foods, 11, article no. 3424.

Oloyede, O.O.; Lignou, S., (2021). Sustainable paper-based packaging: A consumer's perspective. Foods, 10, article no. 1035.

Otto, S., Strenger, M., Maier-Nöth, A., & Schmid, M. (2021). Food packaging and sustainability—Consumer perception vs. correlated scientific facts: A review. Journal of Cleaner Production, 298, article no. 126733

Polonsky, M.J., Carlson, L., Prothero, A., & Capelins, D., (2002). A cross-cultural examination of the environmental information on packaging: implications for advertisers. Advances in International Marketing, 12, 153-174

Reinas, I., Oliveira, J., Pereira, J., Mahajan, P., & Poças, F. (2016). A quantitative approach to assess the contribution of seals to the permeability of water vapor and oxygen in thermos-sealed packages. Food Packaging and Shelf Life, 7, 34–40.

Robertson, G.L., (2006). Food Packaging: principles and practice, 2nd ed. CRC Press. Taylor & Francis, Boca Raton (US)