



Food Polymeric Packaging Life Cycle Assessment (LCA)

Jalal Sadeghizadeh-Yazdi; PhD^{1,2}

¹ Department of Food Sciences and Technology, School of Public Health, Shahid Sadoughi University of Medical Sciences, Yazd, Iran.

² Nutrition and Food Security Research Center, School of Public Health, Shahid Sadoughi University of Medical Sciences, Yazd, Iran.

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Corresponding author:

j.sadeghizadeh@ssu.ac.ir

Department of Food Sciences and Technology, School of Public Health, Shahid Sadoughi University of Medical Sciences, Yazd, Iran.

Postal code: 1981619573

Tel: +98-9133584580

Food packaging is used to maintain the safety and quality of food during distribution and storage and to protect them from adverse internal and external conditions, such as water vapor, spoilage due to microorganisms, moisture, light, and dust. In this regard, lots of research studies have been done to increase shelf life, safety, and quality to create suitable physicochemical conditions for food (Othman *et al.*, 2014). The use of polymers in the preparation of food packaging materials has increased greatly due to advantages, such as strength, oxygen/moisture barrier power and flexibility compared to traditional materials. Polymers commonly used for food packaging include polyethylene, polypropylene, polyvinyl chloride, polyethylene terephthalate, and polystyrene. But the environmental problems of these materials have encouraged us to use biopolymers in industry. Biopolymers are polymeric materials that are naturally degraded by the metabolism of organisms. Biopolymers can be divided into natural biopolymers, synthetic

biodegradable polymers and microbial polyesters. Starch as a biodegradable polymer in combination with other materials is used to reduce the inherent weaknesses of this natural polymer, leading to its further development in various industries, especially the packaging industry (Sadeghizadeh-Yazdi *et al.*, 2019). Also, the use of nanoparticles in food packaging has chemical and thermal stability, recyclability, mechanical resistance, biodegradation, heat resistance, antimicrobial activity, and the ability to perceive and signal biochemical changes (Bajpai *et al.*, 2018, Bathla *et al.*, 2015, Sharma *et al.*, 2017).

Environmental impacts of food packaging

The total value of global food waste production is estimated at \$ 1 trillion, which, if economic and social costs are taken into account, would increase to \$ 2.6 trillion (Food and Agriculture Organization, 2014). Greenhouse gas (GHG) emissions related to food waste production chains account for 6.8% of global GHG emissions. Therefore, the issue of food waste becomes

important by increasing pressures for the implementation of the rotational economy in the European Union (European commission, 2015, Scialabba, 2015). As the world's population grows, waste production also increases rapidly, which can have a devastating effect on humans, wildlife, and the environment. When food packaging is destroyed, some toxic gases are released into the air or polluted by irresponsible discharge into the environment. Non-biodegradable packaging materials contaminate the soil, since they remain in and around it for a long time, destroying soil nutrients. Packaging waste or dumping waste and dumping raw or untreated waste can threaten marine life and eventually kill marine life. It is estimated that 8 million tons of plastic leak across the ocean each year, causing a unique environmental crisis (Guillard *et al.*, 2018).

Stages of life cycle assessment

Life cycle assessment (LCA) is a useful method for conducting a thorough analysis of the environmental impacts of food packaging systems. This method mainly focuses on minimizing the amount of packaging material. According to ISO 14040 and ISO 14044 standards, LCA is done in four stages:

1- *Determining the purpose and scope of application:* The purpose and scope of LCA should be clearly defined and should be consistent with the intended application of the study. Due to the repetitive nature of LCA, the scope of application may be adjusted during the study.

2- *List analysis:* The life cycle list (LCI) is a collection of data and outputs, including data collection and calculations to quantify the product life cycle inputs and outputs. In fact, the list is the heart of the LCA method. Accurate data collection is done in this step of LCA, but the lack or absence of data can be the biggest challenge in this phase of the LCA.

3- *Outcome assessment:* Life cycle outcome assessment is the part of LCA that aims to identify and assess the magnitude and significance of the potential environmental outcomes of a system through the product life cycle. The starting point of

the Life cycle impact assessment (LCIA) is the information obtained from the life cycle list section. Therefore, the quality of the information obtained in the list section is a key issue for this assessment. Life cycle outcome assessment seeks to make the connection between a product or process and its potential environmental outcomes.

4- *Interpretation:* This is the last part of the LCA study in which the results provide a combination of critical sources of implications and options to reduce them. ISO describes the interpretation as follows: A part of LCA in which the findings of inventory analysis or outcome assessment, or both, are evaluated in relation to the defined purpose and scope of application to reach conclusions and recommendations.

Types of LCA

Depending on the purpose and scope of the study, LCA is divided into four categories, which are "cradle to grave", "cradle to gate", "gate to gate", and "cradle to cradle" LCA. The difference between these evaluations is in the choice of the boundaries of the system adopted in them. "Cradle to grave" means that all the important steps in the life cycle of a product are included in the analysis, specifically, extraction of raw materials from the environment (soil, water, air), production of final materials and products, use, and disposal of their waste. It also includes all the transfers that occur between these steps. The difference between the "cradle to gate" approach and the "cradle to grave" approach is that the assessment of the "cradle to gate" life cycle does not include the use and disposal of waste, but LCA from raw material extraction to the production of the product at the gate of the factory inspects for market release. Similarly, the "gate-to-gate" approach refers to the evaluation of the life cycle from the input materials to the factory gate to the output product from the factory gate and does not seek to evaluate the materials from the source of extraction as well as the use of product and waste. But the "cradle to cradle" approach is a special type of "cradle to grave" category, the final part of which is the part of reuse and waste recovery instead of waste and disposal of the product, so that the waste can be

used again as raw materials. The following figure shows the first three types of LCAs in question.

LCA software

The heavy reliance of LCA on data led to the development of LCA software. Environmental processes are often very complex and interconnected, making LCA modeling difficult. In addition, LCA is highly dependent on data. Therefore, computers and sufficient software tools help the user to manage and edit this huge amount of information. LCA software also shows process chains and presents and analyzes results. LCA software can be used whenever LCA is used.

Currently, many software for LCA have been designed and presented, most of which are commercial software, the most important of which are SimaPro software, Gabi software, Umberto software, Quantis Suite software, software EarthSmart, Sustainable Minds software and Enviance System software. However, one of the best free software for LCA is OpenLCA software, which, unlike previous software, is designed and offered for free. It is not necessary to use software to perform life cycle evaluation, but it helps a lot in the calculation process and better presentation of results.

LCA limitations

LCA, despite its many benefits, has a number of limitations. For example, it considers potential consequences rather than actual consequences and this is because, in the LCA, the consequences are not specific to time and place. The actual environmental effects depend on where, when, and how to release food packages into the environment. The LCA generally considers all processes linear. As material production doubles, the consequences are assumed to be doubled, and so does the release of pollutants into the environment. Although improvements have been made to reduce this limitation, the nature of LCA is nevertheless based on linear modeling. Data availability is another limitation. Although databases have been developed in different countries, in some cases, obtaining the required data will not be easy due to some limitations. It

should be noted that assessing the risk of diseases caused by chemicals in food packaging is very difficult, but human exposure to these substances is a clear strategy in assessing the consequences of the life cycle.

Conclusion

It is essential to have complete information about nanocomposite-based packaging materials used in the food industry, especially whether these nanoparticles are in direct contact with food or can migrate into the human body. The migration of nanoparticles into the human body depends on various factors, such as size, chemical composition, structure, and solubility, since the size of nanoparticles is very small and allows them to pass through different organs and be located in the central nervous system. In case of possible migration of these particles to the body, it is necessary to study how the body metabolizes and excretes or eliminates them, as well as to identify possible adverse effects on the organs.

Although it is very difficult to assess the risk of diseases caused by chemicals in food packaging, following the regulations of the Environmental Protection Agency, LCA instructions, recycling, preparation of edible wrappers, packaging prepared from milk proteins, and biodegradable packaging materials, can minimize the negative effects of food waste on the environment and humans.

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