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Material selection for environmental responsibility: the case of soft drinks packaging in Brazil

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A B S T R A C T

The unprecedented scale of packaging waste in global soft drinks supply chains is attracting increasing attention due to its environmental, social and economic impacts. The selection of the most feasible packaging options is one of the key approaches towards reducing resources depletion and packaging disposal. From an environmental point of view, selection requires knowledge of all product life stages including the type and the amount of materials used and the manufacturing practices such as recycling and reuse. In this context, decision makers in industry are looking for assessment methods that address the problem as a whole and not only as a sum of parts for selecting the most appropriate and reliable option. This paper introduces environmental accounting based on emergy as a tool to assist materials selection. This tool can help decision makers in industry providing information on the environmental cost of each decision. Emergy has low cost compared to other methods that require extensive information databases and commercial software. To exemplify the application of the emergy as a tool for material selection, options for the production of soft drinks are compared. The results obtained for the Brazilian case make it possible to select refillable glass bottles as the best option according to the resources available in the country; establishing the best production model for the selected option and determining when and if a recycling stage should be implemented.

1. Introduction

Packaging in general has the characteristic of being immediately discarded after product consumption and must pursue environmental responsibility when designing, filling and importing. In general, environmental responsibility includes the amount of materials used, the type of material and the fabrication adopting practices such as recycling and reuse. Products such as soft drinks that satisfy a short-term need for the consumer produce a large amount of material to be reused, recycled or discarded. In this sector, the main packaging used are glass and PET (polyethylene terephthalate) bottles and aluminum cans. Glass partakes 12.3% of the Brazilian soft drinks market according to the Association of Soft Drink Industries (Abir, 2014), PET containers dominate with 79.8% while the aluminum cans are left with only 7.9% (CEMPRE, 2014). The return to glass bottles for the soft drink industry has been considered beneficial to the environment, and the main argument is that these packages are refillable, allowing reuse by dozens of times.

The choice of a more environmentally friendly package involves several aspects. The manufacture of the three packages is completely different and it would be necessary to account for the use of energy and auxiliary materials to estimate which one is least harmful to the environment. Allegedly, in the long run, the damage of the glass bottle would be lower, since they are produced only once and reused up to 40 times (Abividro, 2015) on average. Logistically it is stated that the PET bottles and aluminum cans are less detrimental because they are lighter, having a better weight/content relationship decreasing fuels consumption and CO_2 emissions during transportation (Amienyo et al., 2013). Both arguments are valid, but each one relates to only a part of the productive chain of the product.

Another crucial point at this stage is the after use destination of the packaging. All three materials are recyclable. The most recycled material in Brazil is aluminum with 91.5% (IBGE, 2010), and it is essential to mention that aluminum cans recycling in Brazil also generates jobs for more than 160 thousand people in activities that

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cover used cans collection to the scrap processing into new cans (Brazilian Aluminum Association, 2009). PET containers have a recycling rate of about 50%, while glass remains stable in recent years with 47%, according to data released by the Corporate Commitment to Recycling (CEMPRE, 2014).

Life cycle Assessment (LCA) has been widely used to examine and compare the environmental impacts of different disposal methods for food packaging, including laminated foils made from polyethylene and aluminum. Results shown that the environmental impacts from packaging material waste treatment were highest for landfill disposal, followed by incineration and recycling (Xie et al., 2016). Simon et al., 2015 analyzed six bottle collection systems for five different packaging materials. These authors observed that recycling allowed saving large amount greenhouse gas emission particularly in the case of aluminum can and glass bottles, and that even though refilling of bottles leads to decreasing greenhouse gas emission, it became less significant after a certain number of reuse.

In regard to the use of natural resources, glass is basically composed of sand, limestone, and soda ash. The PET bottle derives from petroleum, while aluminum cans are basically bauxite. All three packages are made of non-renewable resources and in that respect; it is difficult to establish the best option especially considering the short shelf-life of soft drinks packages. In particular, the overuse of non-renewable natural resources in human activities induces both resources depletion and increased production of waste, which can cause serious consequences for future generations.

Choosing the most feasible packaging options from an environmental point of view requires knowledge of all product life stages, in addition to considering the factors and levels of the components of the manufacturing process. In this context, decision makers in industry are looking for assessment methods that address the problem as a whole and not only as a sum of parts for selecting materials, as the need for altering the current non-sustainable product development practices turn out to be increasingly patent. As a result, techniques such as LCA attempt to quantify significant environmental variables, seeking to scientifically estimate resource consumption and environmental impact (Rebitzer et al., 2004). LCA has been used widely to quantify and evaluate the environmental impact of products (Andersson and Ohlsson, 1999), processes (Amienyo et al., 2013), and the consequences of packaging selection on the product life cycle (Munhoz et al., 2013; Meneses and Pasqualino, 2012). Authors also propose new indices for product design (Khan et al., 2004; Almeida et al., 2010a), methods combining costs, environmental impact and customer evaluation (Bovea and Vidal, 2004; Simon et al., 2015). For three olive packaging options, Simon et al. (2015) highlighted the importance of technologies for waste treatment and of national household waste collection rates of packaging design, concluding that increasing waste collection rates and recycling is crucial to improve packaging sustainability. In this LCA study, the packaging solution with the lowest environmental impact is made of plastic, in agreement with Almeida et al. (2010b) who found that, despite of the exceptional condition of aluminum recycling in Brazil, PET bottles were the best option. Both results (Simon et al., 2015; Almeida et al., 2010b) contradict the common suggestion for limiting the use of non-renewable and non-recyclable materials (Bertolucci et al., 2014).

Materials selection based on LCA has been explored for products such as asphalt wearing (Mladenovič et al., 2015), and for energy recovery to reduce the fossil fuel consumption (López-Sabirón et al., 2014). Based on LCA, Peças et al. (2013) proposed a method called "Materials Selection Engine" as a new selection procedure to overcome some of the limitations found in other methods. Cleary (2013) examined the argument that refillable packaging substitutes to single-use glass bottles for wines and spirits reduce environmental impacts. LCA results estimated using the ReCiPe impact assessment method showed that the refillable glass bottle had the lowest environmental impacts. Due to the numerous LCAs dealing with beverage packaging systems, von Falkenstein et al. (2010) published a 'meta-analysis' in an attempt to answer if it is possible to draw general conclusions about the environmental performance of beverage packaging alternatives from existing LCAs. Their result showed that there is still modest scientific agreement on the proper method for matching the environmental performance of products and process options.

Emergy synthesis is a powerful metric to introduce environmental concerns into the materials selection. Most the information needed to perform an emergy analysis is available in free databases, which makes emergy syntheses an attractive tool for small and medium enterprises (ISAER, 2016). Every step of the analysis is transparent, and discussions are supported by a scientific model based on the general systems theory model. This method avoids also the use of streamlined analysis that considers only one or two categories of impact. With a strong scientific basis, emergy provides information on the environmental loading of production processes and their sustainability. Moreover, emergy allows for accounting of additional and circulating flows that mimic natural ecosystems, and with the development of the method, several studies devoted to analyzing production processes were published (Cao and Feng, 2007; Giannetti et al., 2008).

This study introduces the use of emergy accounting for material selection checking the claim that refillable glass bottles reduce environmental impacts of the beverage value chain. Given the holistic nature of material selection for an environmentally friendlier option, this paper presents an alternative low cost method to provide a more systemic approach to be adopted in companies praxis.

2. Methods

Emergy accounting can be used to appraise the load imposed by a product to the environment. Considering that solar energy is the common basis of all energy flows within the biosphere, Howard T. Odum (1988) defined emergy as the quantity of solar energy necessary to obtain a product or energy flow in a specified process. The greater the emergy flow necessary to sustain a process, the greater the quantity of solar energy consumed and the larger the environmental cost. Emergy is associated with the memory of all the solar energy usage during a process, and is calculated in solar energy joules (sej) (Odum, 1996). The Unit Emergy Values (UEV) stand for the solar energy directly or indirectly required to obtain one unit of product or service, and the inverse of the UEV is called global productivity (GP) (Almeida et al., 2010b). This value provides information on the amount of product that can be fabricated per emergy invested (output/input; unit/sej). More competitive will be the process in which a smaller amount of emergy is needed to obtain a certain amount of product.

Indices obtained from emergy accounting make a distinction between renewable (R, such as sun, wind, water), non-renewable (N, such as minerals) and imported inputs (F, as electricity and fossil fuels) of the total emergy of the product, Y (Odum, 1996). The environmental loading ratio (ELR) was selected among the emergy indices for the estimation of environmental burden into the production process. ELR matches up the quantity of non-renewable and purchased emergy ($N + F$) to the quantity of local renewable emergy (R) (Brown and Ulgiati, 2004), providing a quantitative way for appraising the stress caused by, in this case, the packages fabrication (Eq. (1)). The higher ELR, the larger is the

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