MARKET AND SUSTAINABILITY OF FOOD PACKAGING: A REVIEW

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Food packaging is an essential tool in the food industry for protecting products from environmental interference that may be detrimental to the product and to the consumers' health. As a result, the global packaging market is growing and stimulates the development of new technologies to meet the industrial demand. However, with the growth of the production and use of materials from fossil sources, as well as the lack of adequate programs for post-consumer waste management, there has been a deliberate disposal of these materials into the environment, resulting in ecological impacts and health consequences. In this sense, renewable sources have gained prominence and biologically originated materials are one of the main alternatives for new applications in packaging.

KEYWORDS: PACKAGING MATERIALS; SOLID WASTES; BIOPOLYMER; BIOPLASTIC.

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1 INTRODUCTION

The need to use packaging for properly storing, transporting and commercializing products has existed since the emergence of large technological processes. Food packaging main objective is to protect products from factors such as light, oxygen and humidity, as well as mediating the communication between the consumer and the product regarding its characteristics (Realini and Marcos, 2014).

Packaging is also tasked with attracting the consumer’s attention and participating in the product’s sales strategies (Kerry *et al.*, 2006). Thus, packaging can be used as an important and decisive tool of competitive advantage in the food industry (Soares *et al.*, 2009).

Large packaging markets emerge around the world, showing their technological growth (Pellegrino, 2016). Approximations indicate that the highest growth rates for this market should be observed in developing countries, with the food and beverage segment assuming an important position in their sales share (Claire and Sarantópoulos, 2012).

With the advance of the production and use of plastic packaging, from fossil sources, as well as the difficulty of proper management of post-consumer waste, there has been a deliberate disposal of these materials in the environment, resulting in environmental impacts and consequences for human health.In this sense, concerns on environmental issues have been raised about the use of non-biodegradable and non-renewable materials applied in packaging (Khalil *et al.*, 2016). A useful technique capable of quantifying the impact of a product and its life cycle is the Life Cycle Assessment (LCA), which considers all its stages, from the extraction of raw materials to the elimination or recovery of the material (Lewis *et al.*, 2010).

A more sustainable future can be achieved through products that cause less environmental impact (Ljungberg, 2007). In this way, renewable sources have gained prominence in the replacement of packaging materials derived from fossil raw materials, and the biologically derived materials are one of the main alternatives.

Therefore, the objective of this work was to address and discuss packaging concepts and applications, as well as their position in the world market and the sustainability requirements involved throughout their production cycle, highlighting biopolymers as an alternative to materials made from fossil sources.

2 BACKGROUND AND THEORETICAL FRAMEWORK

2.1 FOOD PACKAGING

Packaging is an instrument of society’s access to consumer goods in a safe, practical and economically viable way, and should not be seen exclusively as an activity from the industry to market its products. Its technical and legal requirements make it possible to provide product protection, logistics, distribution, sales and consumption viability, while at the same time meeting the country’s social, cultural and economic standards (Associação Brasileira de Embalagem - ABRE, 2011).

Food packages can be defined as articles in contact with food, intended to contain them from their manufacture till delivery to the consumer and protect them from external agents, changes and contaminations, as well as adulterations (IAL, 2008). Overall, they are responsible for maintaining the benefits of food processing, increasing its commercial validity, and enabling it to be transported and distributed over long distances without compromising its characteristics and security (Marsh and Bugusu, 2007).

Maintaining the products’ quality and safety is a desired effect and is obtained through the functions assigned to food packages. These are traditionally defined as passive barriers, which must contain and protect the product against mechanical and environmental hazards, as well as communicate, identifying the content, and assist in the sale. Hence, it is essential that packaging must be able to control factors such as moisture, oxygen and light, and serve as a barrier against microorganisms (Fellows, 2006; Jorge, 2013).

Packaging technologies are important to protect foods against microbial, biochemical and physical effects of environmental influences. This involves delayed deterioration, increased commercial validity, and maintenance of the quality of the packaged foods (Karakaya and Duman, 2016).

In its passive characteristic, a safety criterion for food products packaged by traditional materials is related to the packaging/product migrations during their contact time. The emphasis given to the problems arising from these interactions is related to the toxic potential of migrants and the changes in the food's characteristics (IAL, 2008). Thus, the materials and constituents of traditional packaging must have characteristics close to the inert ones, with none or minimal migration to the product (Dainelli *et al.*, 2008; Abreu *et al.*, 2012; Jorge, 2013).

Food packaging technology is constantly evolving in response to the growing challenges of modern society (Kerry, 2014). The needs and demands of consumers for fresh, tasty, convenient products, with their natural characteristics preserved and a long-term shelf-life, have been responsible for driving innovations in the food and beverage packaging industry (Kruijf *et al.*, 2002; Emamifar, 2011; Dobrucka and Cierpiszewski, 2014). In addition, packaging functions have also progressed to include aspects of product marketing, material reduction, safety, tampering, and environmental problems (Han *et al.*, 2014).

As a result, in the face of the competitive market, packages have become strategic for business competitiveness in terms of packaging, distribution and sales efficiency and essential for optimizing the use of food and inputs demanded by society as well as reducing global waste, in the face of population growth (Pellegrino, 2016).

2.2 THE PACKAGING MARKET

Packaging is considered to reflect the culture and habits of a society and its stage of economic, social and environmental development. At the same time, it is considered as the thermometer of an economy, helping to gauge the volume of the activity of the productive sector. Worldwide, it moves more than US$ 500 billion, between 1% and 2.5% of each country's GDP. Currently in Brazil, it moves around R$ 47 billion and generates more than 200 thousand direct and formal jobs (Pellegrino, 2016).

In the developed economies, there are several social and market trends that have impacted packaging sector, such as the increase of smaller families and the consequent demand for smaller packaging formats, as well as the increasing requirement of convenience and consumer friendliness (Campos, 2013).

Overall volume of packaging units was 3.576 trillion in 2015 and by 2018 this number is expected to reach 4.029 trillion units. The largest volumes are composed of flexible packaging, with 36% of the units, paper and cardboard (24%) and rigid plastics (20%). The largest end markets are food (40%), soft drinks (26%) and tobacco (12%) (Clearthought, 2016).

Food makes up a class of products typically consumed at least 3 times a day, consequently, its packaging is responsible, in volume, for almost two-thirds of the total packaging waste produced. In addition, food packages accounts for about 50%, in weight, of the total commercialized packaging (Marsh and Bugusu, 2007).

According to the Brazilian Association of Food Industries, in 2012, the food and beverage industries were responsible for producing about 9% of Brazil's Gross Domestic Product (GDP) and, in addition of creating an increasing number of jobs, they generated a balance higher than that created by the rest of the economy (CNI, 2012). According to Jorge (2013), this is because changes in dietary habits due to lifestyle have led to an increase in the processed foods supply. Associated with this evolution, the requirements of the distribution systems have also favored the appearance of new packaging.

The growth of the global packaging market is driven by a number of general trends such as increasing urbanization and rapid development in emerging economies including China, India, Brazil and some Eastern European countries. The improvement of living conditions and the increase in personal income in developing regions stimulate consumption expansion in their markets, resulting in packaging industries growth (Sarantópoulos and Rego, 2012; Campos, 2013). Thus, the economic development of Brazil, as well as the retraction of consumption and production of non-durable goods, are said to be responsible for packaging production growth (ABRE, 2015).

The global packaging market has reached $ 812 billion in 2014, an increase of 2.8% over 2013, according to Smithers Pira, who expects to see an annual growth of 3.5% by 2020 and sales of $ 997 billion dollars (Smithers Pira, 2015, Clearthought, 2016).

The gross value of packaging production in Brazilian industry in 2014 increased by approximately 6.17% compared to 2013. The largest share in this value is represented by plastics with 39.07%, followed by the sectors of cellulose, metallic, glass and wood packaging. The estimate for 2016 is that Brazil's participation in the world market for packaging production will increase from 3.7% to 4.0%, rising to the 5th largest packaging market in the world ranking (Sarantópoulos and Rego, 2012; ABRE, 2015).

Packaging plays a key role in the food industry due to its multiple functions. Its importance, besides containing the product, concerns the preservation and maintenance of quality and safety. The largest share of world sales of packaging is attributed to the divisions of Food, with 51% of the total market value, and Beverages with 18% (Rexam, 2011, Jorge, 2013).

The packaging segment is perceived as promising by experts from the plastic industry. The characteristics of plastic are highlighted as being a more versatile raw material than other materials, making it possible to obtain formats with attractive and functional designs that are highly sought after by industry clients (Santana, 2015).

One of the main reasons, from the many that justify the greater use of plastic in the manufacture of food packaging, is its low cost in relation to other materials, especially in the logistic phase. In addition, plastic packages provide the necessary protection for food, allow its visualization by the consumer and enable elaborate prints (Santomauro, 2015). In the beverage sector, due to their barrier properties and gas impermeability characteristics, plastic bottles do not allow the gas' escape prior to consumption, making them suitable for carbonated soft drinks (ABIPLAST, 2014).

With this, the plastic packaging market is in full expansion. Among its major users are the markets for biscuits, soft drinks, coffee and snacks, for flexible packaging, and the markets for soft drinks, mineral water and edible oils for rigid packaging (Sarantópoulos and Rego, 2012).

In 2010, the global production of plastics reached 265 million tonnes, confirming the long-term trend of plastics' production growth of almost 5% a year in the last 20 years until 2011 (Plastics Europe, 2011; Rexam, 2011). Already in 2013, with continuous growth for more than 50 years, global production rose to 299 million tonnes, an increase of 3.9% over 2012 (Plastics Europe, 2015).

According to Santomauro (2015), due to the additional appeals of handling and practicality, if the current pace of expansion of these synthetic materials' application in food packaging is maintained, it is possible to predict that food packaging will become synonymous with packages made of multi-layered plastic.

Nevertheless, the increasing global production of non-biodegradable plastics and the lack of adequate post-consumer management programs result in an inappropriate disposal in the environment. As a result, they cause environmental impacts, due to their high degradation resistance, and may even affect human health (Brito *et al.*, 2011; Oliveira, 2012).

2.3 PACKAGING SUSTAINABILITY

The generation of municipal solid waste (MSW) increases with population expansion and economic development, thus presenting several challenges. With the advances in the production and use of packages, these make up a significant part of MSW, which has caused increased environmental concerns (Davis and Song, 2006).

Consisting of materials such as glass, metal, plastic and paper, waste packages require careful planning, funding, collection and transportation (Marsh and Bugusu, 2007). Inappropriate management and deliberate disposal of these materials in the environment, especially those of fossil origin, result in environmental impacts and health problems. In this sense, there is an increasing urgency in defining environmentally friendly materials and creating advanced technology to develop sustainable packaging (Khalil *et al.*, 2016).

Correspondingly, the decrease in the availability of fossil raw materials for packaging and the scarcity of energy resources over the years requires the search for alternatives to materials and production methods with a view to sustainability (Ljungberg, 2007). Thus, packaging technology should balance food protection with other issues such as energy and materials costs, increased social and environmental awareness and the strict regulations on pollutants and municipal solid waste disposal (Marsh and Bugusu, 2007).

Several organizations establish definitions for sustainable packaging and stipulate indicators and metrics to measure the sustainability of packaging (Grönman *et al.*, 2012). In a simplified way, one can define a sustainable product as one that causes the least possible impact on the environment throughout its life cycle (Ljungberg, 2007). Hence, packaging must be designed, produced and commercialized in a way that allows its reuse or recovery as energy or material, minimizing the environmental impact in case it is discarded (Grönman *et al.*, 2012).

The principles of sustainable packaging, according to Khalil *et al.* (2016) are four: functionality of packaging materials, to which materials must support sustainable development while effectively protecting the products' quality; recovery of materials to minimize packaging waste generation, which is seen as a challenge; materials used for packages must be reused continuously with minimal material degradation; the materials used in packaging must be clean and safe and not present any danger to human health or to the ecosystem.

USA's Sustainable Packaging Coalition (SPC) characterizes sustainable packaging with the following criteria: it is beneficial, safe and healthy for individuals and communities throughout its life cycle; it meets market requirements for performance and cost; it is originated, manufactured, transported and recycled using renewable energy; it optimizes the use of renewable or recycled raw materials; it is manufactured using clean technologies and better practices; it is made of favorable materials throughout the life cycle; it is physically designed to optimize materials and energy; it is effectively recovered and used in biological and/or industrial closed loop cycles (Green Blue, 2011).

In order to standardize criteria, the International Organization for Standardization (ISO) works on the implementation of international parameters for packaging, which guard source reduction, reuse, recycling, energy recovery, chemical recovery, composting and biodegradation (Roos, 2010a).

In this sense, reducing the impact of packaging on the environment does not necessarily correspond to total sustainability. A complete analysis should aim to minimize the impacts of the production chain as a whole.

To optimize the product-packaging system, it is necessary to understand its chain and identify its main impacts, which can be done using the qualitative or quantitative concepts of the life cycle. "Life Cycle Thinking" represents the basic qualitative concept of assessing the entire life cycle of the production system. Its application in the development of more sustainable products provides opportunities for improvements related to the environmental performance of the product, from the extraction of natural resources, through processing, reduction of emissions, packaging optimization and transportation, consumption, till the final disposal. Conversely, the purpose of the LCA is to quantitatively assess the main environmental impacts of a product's system. It is a technique for evaluating the environmental performance of a given product, based on its function and including the identification and quantification of the energy and raw materials used at each stage of its production cycle (Karaski *et al.*, 2016).

Environmental impacts of packages are largely determined by the transformation of materials and generation of energy at all stages of its life cycle. These also cover the use of the packaging and its disposal; consequently, it is important to consider all stages of its life cycle and how they can affect the environment. Different environmental criteria can be considered by evaluating improvements under a wide variety of potential impacts through LCA, such as: Reduction of mass or volume of the package; Improvement of energy efficiency in the manufacturing process of packaging or definition of new production and recycling processes; Prolongation of the life of the package and the product; Choice of raw materials of lower environmental impact, and compatible with each other in terms of recycling or with their separation facilitated (ABRE, 2006).

Faced with so many requirements to be met, complete sustainability can hardly be achieved for products and packaging, however, the attempt to achieve greater sustainability is necessary to preserve the planet. In this sense, studies, research, and information dissemination are very important for the future, especially as the market's demands in developing sustainable products has grown more and more (Ljungberg, 2007).

2.4 ENVIRONMENTAL ASPECTS IN PACKAGING PRODUCTION

The use of non-biodegradable polymer materials from fossil sources has become a problem due to the increasing number of non-appropriate discards and the long degradation time of these materials in the environment (Brito *et al.*, 2011).

The packaging development process involves several aspects that must be observed: technique, production and functionality; aesthetics; regulations, legislation and certification; market and economy; environment (ABRE, 2011). Thus, environmental concepts must reconcile with the primary functions of packaging, packing and protecting products, providing adequate distribution, conservation and consumption of these products (Marsh and Bugusu, 2007; Pellegrino, 2016).

The environmental aspects and impacts caused by the manufacture of packaging are inherent to the elaboration of raw materials and inputs, transportation, production energy, waste generation, among others. The process of integrating these aspects into the design and development of the packages is continuous and flexible, promoting creativity and maximizing innovations and opportunities for the environmental improvement of these products (ABRE, 2006).

Currently, most materials used in packaging for food, beverages, medical and pharmaceutical products, among others, are not degradable or renewable, raising concerns about environmental pollution, especially due to their inappropriate disposal and long decomposition time (Brito *et al.*, 2011; Khalil *et al.*, 2016).

Concomitant to this, with increases in fossil fuel prices and social awareness, changes in the use of polymers refer to an era of bio-sustainability in which bioplastics are reemerging as a key substrate in the packaging industry (Smither Pira, 2013). In parallel, current innovation trends and environmental regulations pressure the extremities of the packaging supply chain, requiring large investments by manufacturers (Clearthought, 2016).

As a result, the market for sustainable packaging shows a high growth, which is said to be faster than other segments of packaging industry (Roos, 2010b). The goal is to incorporate functional and innovative materials into packaging that could promote economic and environmental health. Packaging sustainability is often considered as a marketing tool to promote and distinguish a new packaging material, however, this is a much broader concept theme (Khalil *et al.*, 2016).

Consequently, demands for explore sustainable and environmentally friendly materials with superior physical, mechanical and barrier properties is increasing. In this sense, numerous studies have been carried out on the use of biologically based materials in the search for the development of sustainable packaging materials (Khalil *et al.*, 2016).

2.5 POLYMERS AND BIOPOLYMERS AS PACKAGING MATERIALS

Packaging materials can be composed of polymers, which are macromolecules with chemical units, "mers", linked by covalent factors, repeated along the chain, whose number is called the degree of polymerization of the polymer chain. Among them is plastic, a material that, although being solid in its final state, can become fluid and moldable at some stage of its processing by isolated or joint action of heat pressure (Mano and Mendes, 2004).

The term “plastic” is used to denote materials based on synthetic or natural organic polymers, with a high molecular weight, which can be molded in various ways by the aid of heat and pressure (Sarantópoulos *et al.*, 2002, Jorge, 2013). Plastic materials used in packaging are diverse in terms of chemical structure and have varying properties depending on the processing, the incorporated additives and the combination with other polymers (Jorge, 2013).

According to Hopewell *et al.* (2009), about 4% of the world’s production of oil and gas, non-renewable resources, is used in the production of plastic polymers, with 3-4% being used to supply energy in their manufacture.

As a substitute for these raw materials, renewable sources have gained prominence because they have a shorter life cycle (Brito *et al.*, 2011) and biopolymers are one of the main alternatives to these petroleum derived materials (Pinho, 2012).

Biopolymers are polymers or copolymers produced from raw materials from renewable sources, such as plants, or produced by microorganisms (ABNT NBR 15448-1, 2008). Currently, the main sources of the biomass being used in the production of bio-based plastics come from cereals (corn), sugarcane, potatoes or castor oil. Still, it is expected that other resources, such as cellulose and crop residues, will have greater importance in the future (European Bioplastics, 2015).

Thus, bioplastics are defined as a family of diverse materials which, in general, are partially or totally based on natural resources (European Bioplastics, 2015). They have received special attention because they are an alternative for the reduction of petroleum dependence and have the potential to reduce the environmental impacts from the packaging sector (Sarantópoulos and Rego, 2012).

The first cellulosic-based artificial thermoplastic polymer was developed in the 1860s, although it was not used for commercial production, and many inventions related to biologically based polymers were made in the 1930s and 1940s. Yet, there has been a revival of biologically based plastic polymers in the past two decades (Shen *et al.*, 2009).

According to Mensitieri *et al.* (2011), polymer materials derived from renewable resources are classified, regarding the production method or their source, in: Polymers directly extracted or removed from biomass, such as proteins and polysaccharides; Polymers produced by classical chemical synthesis from renewable biologically-based monomers such as polylactic acid (PLA); and, Polymers produced by microorganisms or genetically modified bacteria, such as polyhydroxyalkanoates and bacterial cellulose.

The fact of coming from a renewable source, however, does not necessarily result in the biopolymer being biodegradable or compostable, since this characteristic is related to the chemical structure of the materials and the type of chemical bonding. Thus, natural synthetic polymers based on carbon, such as starch, cellulose and lignin, can be biodegradable and compostable or deprived of this property due to chemical modification, such as polymerization (Siracusa *et al.*, 2008).

As regards food packaging applications, some tribulations are presented when these polymers are processed with traditional technologies and the performance of their functional and structural properties is inferior (Mensitieri *et al.*, 2011). Therefore, according to Peelman *et al.* (2013), even with their potential for the packaging industry, the evaluation and specific verification of their functional properties are essential before their application as an alternative to traditional packaging materials.

However, bio-based plastics represent an emerging, very dynamic, field with a positive development potential for the future (Shen *et al.*, 2009). According to European Bioplastics (2015), the current market for bioplastics is characterized by its high growth, around 20% to 100% per year, and its diversification. However, bioplastics currently account for only about 1% of the 300 million tons of plastics produced worldwide annually.

The global bioplastics production capacity reached 400,000 tons in 2009 and a magnitude of $ 4 billion in 2012. The forecast is for continued growth reaching 3.5 million tons in 2020 and representing an annual growth rate of 21.8%. However, for bioplastics to become predominant in the market, improvements in manufacturing processes and cost reduction are still required (Barnett, 2011; Smither Rapra, 2014).

According to Carus *et al.* (2013), current producers of bio-based polymers estimate that production capacity could reach 12 million tons by 2020. With an expected total production of 400 million tons by 2020, an increase in the biological basis percentage from 1.5% in 2011 to 3% in 2020 is assumed, indicating a faster growth of the biologically based production than the global production.

Nonetheless, the biopolymers' market is incipient in Brazil, being the low level of awareness for their use and the differences in cost and performance, when compared to conventional resins, some of the difficulties to be overcome (Brito *et al.*, 2011).

Still, due to their improved access to the raw material and a favorable policy framework, a larger share of investment for this polymer is expected for South America and Asia. Thus, between 2011 and 2020, the participation quotas of these two continents are expected to increase by 5% and 3% respectively, while European and North American quotas are expected to decrease by 6% and 2% respectively (Carus *et al.*, 2013).

The concern, however, is that the competitiveness of bioplastics will be impacted by higher prices for agricultural products or that bioplastic crops will lead to higher prices and impacts on food supplies (Barnett, 2011). This is due to the fact that biological resources are mainly used for food, biofuel production, such as bioethanol, and materials (wood and building materials). Thus, there would not be enough available biomass, sustainably produced, to cover all these ever-increasing needs of the world's population (Shen *et al.*, 2009).

Considering this, though, several studies have emerged in order to develop biomaterials from agroindustrial residues as promising materials for applications in food packaging. Thus, several segments of the market will be benefited, encompassing companies and consumers, in addition to meeting emergency needs related to the environment.

4 CONCLUSION

Food industry is responsible for a large part of the consumption of packages, which is mostly produced with fossil raw materials. The volume of packaging production and consumption has a broad spectrum in the world market, with increasing sales rates and large capital movements. In this sense, it is important to link sustainability efforts with the economic gain of the market, investing in studies on the evaluation of the environmental impacts of commercialized packages and in projects and research that result in biopolymer materials with a more sustainable character. The literary study of the factors involved in production, market and sustainability of packaging materials becomes important to guide future studies that could imply improvements in the sanitary and ecological packaging character directed to the food industries.

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