Natural Sustainable Packaging:
Connecting Circular Economy with Sustainable Development Goals

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Abstract

The unsustainable throwaway culture is putting our planet and its resources under unprecedented stress. Overconsumption has led to a drastic packaging waste issue, demanding urgent improvements within circular economy. Consequently, in an era of resource scarcity, this increasing demand requires creative alternative solutions without compromising society's sustainable development.

This work aims to find the best natural sustainable packaging materials to introduce in Portugal, which are strictly integrated in a circular economy process and connected to the sustainable development goals (SDG) introduced by the United Nations, in order to achieve a sustainable development by 2030. Based upon a literature review and case-study analysis, the theoretical knowledge regarding circular economy practices, sustainable development goals and natural sustainable packaging materials was acquired, followed by the implementation of a multiple-criteria decision analysis method to evaluate the materials chosen and semi-structured interviews with relevant companies in the packaging industry, to systematize a practical hands-on information regarding the sustainable packaging industry. Ultimately, it led to the understanding that there is not one best sustainable packaging option for each company, but rather a portfolio of products made from distinct materials that gives companies an advantage in this packaging industry in constant transformation.

Key words: Packaging, Sustainability, Circular Economy, Sustainable Development Goals

1. Introduction

The world is currently facing a global crisis due to climate change, inequalities and the still fast-growing worldwide population, putting our planet and its resources under unprecedented stress (Sachs, 2012). This stress mainly derives from the current take-make-dispose model which is blind to products' after-life, in addition to the excessive extraction of virgin materials (Ghisellini, Cialani and Ulgiati, 2016).

The urgency to attain a sustainable development has driven international attention to the means to achieve it. Accordingly, the 2030 Agenda for Sustainable Development was presented, emphasizing the recognition that "ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality, and spur economic growth – all while tackling climate change and working to preserve our oceans and forests" (Sustainable Development, 2019).

Revolutionizing the way current business is made, reduce hazardous emissions or eliminate waste is, however, a heavy task that, requires “disruptive changes and radical innovations” (Ritzén and Sandström, 2017). One particular way to attain all the 17 goals by 2030 is to implement a circular economy (CE) as it “incorporates aspects of sustainable development, such as social or economic sustainability” (Geisendorf and Pietrulla, 2018).

Moreover, by 2030, in the European Union (EU), 70% of all packaging waste must, at least, be recycled, in packaging involving industries (Packaging Europe, 2019). Accordingly, emphasis on product packaging must be provided and, therefore, this work aims to evaluate natural packaging material options to overcome this goal, by eliminating unnecessary waste and simplifying waste management while reducing resources’ usage.

In this paper, section 2 summarizes the literature review undertaken to understand current best practices and gather relevant information regarding circular economy and sustainable development goals. Succeeding, the methodology employed is explain in section 3, while in section 4, the analysis performed on the materials is presented, combined with a quantitative analysis on the princes and CO_2 emissions of the sustainable packaging. Then, chapter 5 clarifies the connections amongst sustainable packaging, circular economy and sustainable development goals. Finally, some conclusions are drawn in section 6.

2. Literature Review

2.1. Sustainable Development Goals

In 2015, during the UN Sustainable Development Summit, over 150 world leaders decided upon the 17 sustainable development goals (SDGs), which are a call for action upon crucial issues for the sustainable improvement of humanity (United Nations, 2019). These SDGs reflect the growing urgency in addressing an international sustainable development and thus, acting through the triple bottom line approach of economic development, environmental sustainability and social inclusion (Sachs, 2012).

Successfully implementing and accelerating the achievement of the SDGs will be based on how well countries are able to provide knowledge sharing platforms to increase diffusion, capacity building, specially related to technology and technical capabilities and, lastly, innovation as a way of adaptability to each country’s needs (Jha *et al.*, 2016). Therefore, on one hand it imposes a great demand on the scientific community to come up with alternatives and solutions, on the other hand, it requests the global coordination of monitoring and modeling efforts in social, economic and environmental dimensions. Consequently, it implicates close partnerships and efforts with the most varied stakeholders (Lu *et al.*, 2015).

To propose solutions regarding natural packaging alternatives, it is necessary to understand what is already being done in the industry, how it is being done and, ultimately, its impact on SDG achievement.

By analyzing the packaging process and the companies who report their efforts to attain SDGs, it became clear that the most direct and closely related SDGs to this work are goal nine “Industry, innovation and infrastructure”, goal eleven “Sustainable cities and communities”, goal twelve “Responsible production and consumption” and goal thirteen “Climate

action". Therefore, these are the goals to be further explored.

Nevertheless, it is relevant to explain the metrics to measure the implementation of this SDGs and to further assess the improvement attained, as "In an increasingly performance-oriented society, having the right metrics is very important. What we measure affects what we decide and do. If we use incorrect measurements, we will drive the wrong priorities" (Social Progress Imperative, 2017). Therefore, 3 tools used to measure implementation and improvement are presented: SPI, GRI and GapFrame.

As "Countries need a new measure that assesses and quantifies the things that really matter to real people" such as if they have enough to feed themselves, shelter, access to education, clean water and many more (Social Progress Imperative, 2019), the Social Progress Index was created, a tool that measures the success of each country in implementing the SDGs and, allows for comparisons and acceleration of progress.

The sustainability reporting standards, GRI's framework, is currently a global best practice on how to articulate reports on sustainability, as it is the most credible and flexible reporting tool which ensures compliance to all the requirements imposed by international organizations on sustainability. The GRI standards provide topic-specific reporting standards in economic, environmental and social modules, in addition to universal standards such as foundation, general disclosures and management approach (GRI, 2019).

GapFrame is a framework which "translates the Sustainable Development Goals into nationally relevant issues and indicators for business" (GapFrame, 2019). It builds on a "safe operating place" which considers Earth's limitations and social requirements and includes twenty-four issues (each one directly related to one or more sustainable development goals) and sixty-eight indicators. The furthest an issue is from its safe place, the higher the gap is and, therefore, the higher its priority is (Muff, Kapalka and Dyllick, 2017).

Therefore, firstly SPI is used to measure the output attained through actionable and objective measures in the social, environmental and economic areas, for a holistic understanding of the improvements and indicators' analysis. Then, GapFrame is used to provide the prioritization in the matters to address while providing strategic tools for opportunities in the long-term. Lastly, the GRI is used to track the business' performance and support the decision making, while making sure all international sustainability requirements are met.

2.2. Circular Economy

Currently, society's consumption stems a "linear take-make-dispose model" leading to scarcity of resources due to inefficient usage, hence being unsustainable (Ellen Macarthur Foundation, 2017). The depletion of non-renewable resources has caused severe ecological damages and social impacts (Ritzén and Sandström, 2017).

CE aims to "decouple growth from finite resource consumption" (Ellen Macarthur Foundation, 2017), and despite using the **four R-strategy** which refers to repair, reuse, recondition and recycle, implementing a circular economy worldwide requires a major paradigm shift and poses the foremost

challenges of resources scarcity, environmental impact of actions and being able to grow economically while changing the current paradigm (Ritzén and Sandström, 2017). Furthermore, several companies have realized the current "throwaway culture" is harming their businesses, as they are facing increased exposure to risk, higher resource prices, supply disruptions and price volatility (Ellen Macarthur Foundation, 2013).

Product packaging devises, therefore, a crucial role to achieve a fully circular economy, demanding sustainable decisions from the sourcing of raw materials to its disposal (PWC, 2012). Consequently, new alternatives are needed (PAC NEXT, 2017), as the major challenge is being able to "protect and distribute the right product to the right end-user in a safe, cost-efficient and user-friendly way", in addition to preventing waste and providing safe use, with good balance among packaging and product itself (Grönman et al., 2013).

Accordingly, consumer demand, involvement and education regarding sustainable packaging innovation is key, as "consumers should be able to see sustainable packaging as a tool to assist their purchasing decision, to encourage minimization of packaging waste and ultimately to help promote sustainable consumption (Nordin and Selke, 2010).

To understand the extension of what sustainable packaging can change within the implementation of a CE solution and its viability in the market, a characterization of the demand for such products was performed.

Currently, the global packaging market is worth around **500 billion EUR**, being food and beverages packaging the main uses for packaging production and "Consumers want packaging that helps them become more sustainable, even if it costs more – now brands must respond" (Raconteur, 2017). Moreover, a study performed by a leading developer of sustainable packaging for consumer goods, states that 3 in 4 consumers worldwide say they are willing to pay for sustainable packaging, in particular, if it increases profitability for brands while reducing their environmental impact (Raconteur, 2017).

Consequently, companies are now forced to rethink their business for sustainability, materials and processes, environmental impact and recyclability of products (Environmental Journal, 2018), since "Eco-friendly packaging is becoming a ticket to the game, rather than just being a game-changer" (Raconteur, 2019). Therefore, more and more the issue becomes how to create a cost-competitive supply chain that meets the clients' demands and is sustainable from cradle-to-cradle, as products more sustainable will provide greater competitive advantage (Environmental Journal, 2018).

However, despite consumers' influence, "The average consumer still has little awareness of the early stages of the supply chain, so positive consumer behavior cannot be relied on to absorb the cost. The initiation of greening early-door secondary supply chains will therefore likely come in the form of tax breaks and other incentives" (Raconteur, 2019). Moreover, according to Raconteur (2019), the following are the 2 major consumer barriers for purchasing of environmentally sound products:

1. Greater cost (44%)
2. Lack of environmental awareness (33%)

As end-of-life solutions alone are not enough to move us toward sustainable packaging production, the packaging systems themselves have to be redesigned, in order to use the least amount of materials and energy, maximize the recycling content and also increase the potential for reuse (Clean Metrics, 2019).

3. Methodology

The research methodology employed is a combination of several methodologies, in order to obtain more robust results. Consequently, it entails a literature review, case-study analysis, swing weighting methodology, semi-structured interviews and a quantitative analysis.

First, a comprehensive literature review on circular, economy, sustainable development goals, sustainable packaging and natural raw materials was employed to devise a knowledge foundation by facilitating theory development and uncover further investigation needs was undertaken (Webster and Watson, 2002).

It was followed by a case-study analysis, as "Case study is an ideal methodology when a holistic, in-depth investigation is needed" (Tellis, 1997). Moreover, it is used to discover details from different data sources and answer questions such as "why" or "how", as part of an exploratory research to generate theory (Yin, 2003). This was done in a 2-step approach for data collection. The first step to collect data was performing a thorough research on natural materials used for packaging, which retrieved several results. Upon information systematization, 9 distinct materials were chosen (bagasse, bamboo, banana leaves, cassava, coconut, mushroom, palm leaves, PLA and seaweed), and a more attentive research was employed on these materials, focusing on material characteristics, advantages and disadvantages, production and waste quantities and relevant data regarding the use of packaging made from these materials.

Moreover, research on companies working with such materials was the second step of data collection. Several results were retrieved which required an initial assessment. From these results, thirty-five companies were selected as they were the most relevant, meaning these companies sell sustainable packaging for Europe and other continents being, therefore, possible candidates for partnerships to introduce natural sustainable packaging in Portugal, as Europe is where some the most innovative projects related to sustainable packaging take place.

As there are many variables that come into the decision of the best packaging material such as material availability and sourcing, cost, GHG emissions, flexibility to form distinct types of materials and several more, a multi-criteria decision analysis method (MCDA) was employed to evaluate the distinct alternatives in a scientific and organized manner (Mustajoki, Hämäläinen and Salo, 2005). From the range of possible methods, swing weighting was chosen, being an easy-to-use weighting method grounded on ratio estimation (Mustajoki, Hämäläinen and Salo, 2005), and commonly used when the scale and relative importance of the criteria to evaluate are both intended to assess (Diaby and Goeree, 2013).

Subsequently, semi-structured interviews were performed, as they are based on pre-defined questions, mostly open-ended and hypothesis-directed, which will guide the interviewer (Flick, 2009). As semi-structured, flexibility is key to obtain the interviewee's perspective, providing

a foundation for interpretation of significant findings and generation of hypotheses to be further supported by quantitative studies (Flick, 2009). Moreover, semi-structured interviews allows interviewees to answer questions based on their current knowledge and theoretical presuppositions.

As the three pillars of sustainability are the environmental, social and economic dimensions, further assessment of the materials previously selected, bagasse, palm leaf and PLA, must be assessed with KPI drawn from these pillars, in order to ensure the most sustainable option is chosen.

Therefore, a price assessment comparation amongst the three materials was performed, to clarify the prices amongst materials, and products within each type of material, hence portraying the economic pillar. Moreover, the environmental pillar is represented by the CO_2 emissions assessment of the transportation routes of the company's manufacturing sites towards Portugal, where the products are intended to be delivered.

4. Materials Analysis

The systematization of information from the case-study analysis on the materials is represented in table 1.

As all the investigated materials are natural raw materials, several impactful benefits are obtained, as they are renewable, sustainable, biodegradable and not toxic, therefore, there will not be any chemicals transferred to food and the carbon footprint of manufacturing can be much lower than when using plastic.

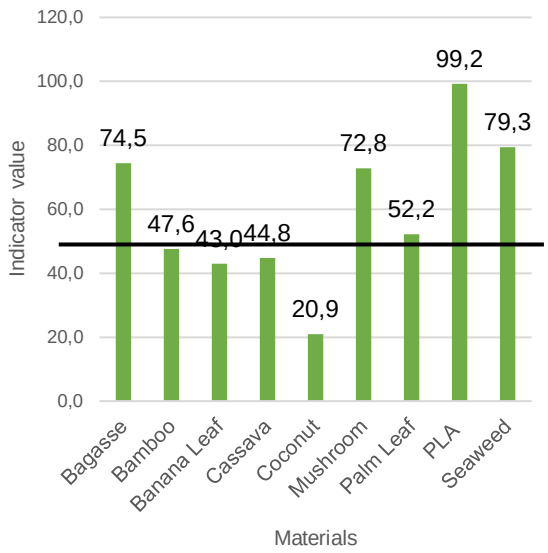
Table 1 – Advantages and disadvantages of each natural material

Material	Advantages	Disadvantages
Bagasse	• High strength and insulation	• Dependent on sugar extraction
Bamboo	• Durable, resistant and great compressive strength	• Need for treatment against insects and rotting
Banana Leaf	• Thick and flexible	• Need treatment
Cassava	• Stable crop • Grows on poor soils	• Can only be used for dry food or fast consumption
Coconut	• Tough, durable and elastic material	• Difficult to dispose of waste
Mushroom	• Infinitely available • Easily molded into any shape	• Price
Palm Leaf	• Stable and sturdy	• More adequate for ready to eat food
PLA	• Uses biological waste • Reduced CO_2 emissions	• High levels of technology required • Longer time to decompose than other materials
Seaweed	• Gelatinous properties • Good water and oil holding	• Difficult to produce high volumes

Moreover, after this systematization, the use of the swing weighting method resulted in the creation of a global indicator (GI) represented in equation (1), which was applied to every material alternative, to find which one scored best upon selected criteria and based on the decision-maker preferences, where 0.28 is the weight for the criterion "frequency of use", 0.38 is the weight of the criterion "waste generation" and 0.34 is the weight of the criterion "portfolio diversity". The results are shown in figure 2.

$$V(GI) = 0.28 * v_1 + 0.38 * v_2 + 0.34 * v_3 \qquad (1)$$

Figure 2 - Indicator values for each material alternative



Despite most materials scoring close to 50 or above in the GI, for the purpose of this work, it was decided to only further analyze the materials that scored above 50 points in the GI. Moreover, when comparing these results with the disadvantages presented in table 1, it is understandable that the materials needing specific treatment to be able to be used for packaging, or that can only be used for cold, hot or dry foods, scored less than the other materials.

What is interesting is that despite the other materials having significant disadvantages, they are outweighed the benefits. For example, using mushroom is still too expensive comparing with other materials. However, its almost limitless availability and ability to be shaped into nearly any shape changes it into a high-score material.

Then, the systematization of the collected information from the semi-structured interviews allowed to draw the following conclusions:

1. Portfolio diversification with products made from distinct materials is extremely important to reduce the company's risk due to climate change related issues and demand volatility.
2. The main barrier to enter the sustainable packaging industry is price competitiveness with plastic products and the main challenge is meeting the demand with current manufacturing capacities
3. Finding customers is not an issue at the moment, as demand for natural sustainable packaging is increasing.
4. Despite its cost and heat sensitivity, PLA is currently one of the mostly used materials.
5. Currently, seaweed packaging companies are not able to meet the demand and mostly produce small size packaging products such as sachets or straws.
6. Bagasse is a great substitute for PLA due to its close performance and cheaper prices
7. Mushroom packaging must be at least one centimeter thick, which is very beneficial for most types of packaging, but not for food packaging.
8. Palm leaf is probably the most expensive of all the materials addressed. However, it is a very good material for tableware and often used by many companies.

After careful analysis of the information retrieved from the company interviews, it was decided to cease further analysis on mushroom and seaweed, as they do not fit the range of packaging options intended to address with the goal of this work.

To continue the materials' assessment, a quantitative analysis of the unit cost of packaging products made from each type of the remaining materials (bagasse, palm leaf and PLA) was then performed, leading to the following conclusions:

1. The biggest price percentage variations occur in palm leaf products and PLA, being the former the most significant difference in actual cost variation per unit
2. From the products analyzed, bagasse was the cheaper material, followed by PLA and, lastly, palm leaf, which was the most expensive.

Therefore, price variations in products and across material types do not depend on where companies are located nor the types of products sold, as companies with the most diverse portfolio have prices in both sides of the pricing spectrum**.**

Lastly, the quantification of the CO_2 emissions from transportation of such products from manufacturing sites from Asia to Portugal, which concluded that differences amongst routes are significative, depending on the distance from the manufacturer to the customer. However, it is almost impossible to financially compete with manufacturing in Asia, as most raw materials are found there, and labor and other expenses are less costly.

5. Connecting sustainable packaging with CE and SDG

Sustainable packaging & SDG: Natural sustainable packaging is extremely important when tackling the 2030 Sustainable Development Agenda, as sustainable development cannot take place by itself, it requires "collective commitment to shared goals" (Ecoware, 2019). Therefore, most companies in the sustainable packaging industry are already trying to tackle SDGs by seting goals on which SDGs they want to work towards achieving and impact positively, hence helpin g building a better future for everyone

For example, one company, after deciding on which SDGs to act upon, has set the goal to "Increase consumer knowledge and understanding of compostable packaging and its correct disposal", which is directly related with achieving target 12.5 of goal number 12: Responsible consumption and production. This was achieved through the implementation of 9 front-of-house initiatives for foodservice operators to educate consumers to build awareness and educate. In particular, one of the initiatives was a compost machine activation in a coffee festival. Moreover, this company uses the GRI reporting to help them track their improvement, increase transparecy and better communicate. This is a great example on how global guidelines can shape company's goals to act towards a sustainable future and take advantage of business opportunities, as sustainable packaging is an industry said to be in the development and growth phase with technology in the forefront of innovation and plenty of business opportunities to improve the current processes and materials.

Circular economy & SDG: The innovation and economic opportunities available through circular economy, used as a disruptive change, are one particular way of accelerating the achievement of the 2030 Sustainable Development Agenda (Ritzén and Sandström, 2017), due to its inclusion of social and economic sustainability as a way to reach a sustainable development.

Moreover, according to WEF (2015), the connection of circular economy with the Sustainable Development Agenda is simple: "providing a profitable opportunity to move away from resource-intensive processes, whilst maximizing the use of existing assets

and creating new revenue streams". Hence, it represents the importance of the implementation of natural sustainable packaging as a circular economy strategy leading to the achievement of SDG targets that will, on its turn, enhance circular economy, in a synergy for a sustainable development and, above all, a sustainable future.

Sustainable packaging & circular economy: The key to fully transition to a circular economy is being able to balance the consumer demand and perception with new technology and materials to provide more ecological packaging and reduce its waste (PAC NEXT, 2017).

Packaging is needed to store and transport products and protect food. However, the resource intensive consumption keeps rising, with packaging waste posing as a major threat for the environment. By introducing a circular economy, which is restorative by design, the products, and in particular packaging are forced to be redesigned in order to make processes more efficient and minimize waste, working in a synergy system to derived benefits from all interactions.

Accordingly, sustainable packaging plays a fundamental role in supporting a circular economy, as it strives for sustainable material sourcing, based on generated waste and not virgin materials, with efficient manufacturing processes reducing in less than 75% the CO_2 emissions and using 50% less energy, therefore saving valuable scarce resources. Moreover, the end-of-life of the process is harmless, as packaging is composted, returning important nutrients to the soil, rather than creating more waste.

Therefore, despite of the drawbacks, "Eco-friendly packaging is becoming a ticket to the game, rather than just being a game-changer" and the issue becomes how to create a cost-competitive supply chain that meets the clients' demands and is sustainable from cradle-to-cradle, as products more sustainable will provide greater competitive advantage

6. Conclusions

A pre-requisite to SDG targets' achievement, and ultimately, sustainable development achievement, is the implementation of a circular economy, as it provides a disruptive approach to the major issues currently affecting society, being them developmental or environmental, mainly related to resource's overconsumption. Therefore, CE is able to completely change businesses and provide simple approaches to problems by using Earth's interactions as a guideline.

However, not all major issues are going to be solved through CE, as most SDG targets are not related to it. However, to efficiently implement the transition, knowledge sharing, capacity building, technology development, sources of financing, innovation and multi-stakeholder partnerships are needed.

Therefore, companies are currently aligning their goals according to the United Nations 2030 Sustainable Development Agenda as an effort to attain a positive impact and helping building a better future for everyone, using tools such as GRI, SPI and Gapframe to help them maximize their efforts towards achivieng particular SDGs.

All in all, no option is perfect and there is not one perfect material for sustainable packaging. Many solutions work differently for different

companies, as the opportunities and needs are drawn by different factors. Therefore, all efforts must work in close collaboration, as the synergies drawn will allow the faster achievement of the ultimate goal of sustainable development.

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