LIFE CYCLE ANALYSIS OF BEVERAGE PACKAGING

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MASTER OF MANUFACTURING ENGINEERING
(QUALITY SYSTEM ENGINEERING)

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Faculty of Manufacturing Engineering

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A project report submitted
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DECLARATION

I hereby, declared this report entitled "Life Cycle Analysis of Beverage Packaging" is the result of my own research except as cited in references.

Signature : .....

Author's Name : AZMIZA IDAYU BINTI AZMAN

Date : 02 February 2023

DEDICATION

In the name of Allah, the Most Gracious and the Most Merciful.

A special dedication to my beloved family members especially that have been understanding and supportive. Thank you for everything.

Thank you to my honourable and supportive supervisor, Associate Prof. Ir. Ts. Dr. Shajahan Bin Maidin. I appreciate his patience and time for every meeting, advice and guidance throughout this study.

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APPROVAL

I hereby declare that I have read this dissertation/report and in my opinion this dissertation/report is sufficient in terms of scope and quality as a partial fulfillment of Master of Manufacturing Engineering (Quality System Engineering) (Hons).

Signature : .....

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Date : 20/2/23

ABSTRACT

Plastic has become a vital role in our daily life where most of the products surrounding us now are mostly made of plastic. For example television frames, shampoo bottles, tables, and others. Plastic also has become the main material for food and item packaging due to its lightweight characteristic. It will able to take up less space which means lighter loads for planes and trucks and lower emissions during transportation. However, it has been alarming concerns over the past years since the large-scale introduction of plastic after the Second World War, a total of 8.3 billion metric tons have been produced. Conventional plastic will take time to decompose approximately 450 years. Hence, it is predicted that in 2050, there will be about twelve billion tons of plastic in landfill and the environment e.g., the ocean. More plastic will be thrown away than those that people manage to clean up, even though they have tried their best. The purpose of this project is to select and compare the environmental impact of the packaging design of several consumer products using life cycle analysis software (LCA). It is software that is widely used to support sustainable development and a modeling tool to assess environmental impacts related to a product during its entire lifespan: from raw material extraction through processing, manufacturing, distribution, use, and disposal or recycling. Based on the openLCA free software, three beverage packaging were compared: plastic bottle, glass bottle and aluminium can. In order to obtain the result, the life cycle inventory (LCI) need to be identified based on case study, literature review and relevant assumptions. Then each of the beverage packaging flows, processes, product systems were also required to be identified in order able to run the openLCA software. It was found that aluminium can has less impact to the environment compared to the other two type of beverage packaging. If based on the CML eleven impact categories, plastic bottle was rank as the most impactful towards the environment, followed by glass bottle and aluminium can as the least impactful. Other than that, it may probably due to the quantity of material being used, the effect of the material during processing, and the recyclable ability.

ABSTRAK

Plastik telah menjadi peranan penting dalam kehidupan seharian kita di mana kebanyakan produk di sekeliling kita kini kebanyakannya diperbuat daripada plastik. Contohnya bingkai televisyen, botol syampu, meja dan sebagainya. Plastik juga telah menjadi bahan utama untuk pembungkusan makanan dan barangan kerana cirinya yang ringan. Ia mampu untuk mengurangkan pengambilan ruang yang sekaligus bermaksud beban yang lebih ringan untuk kapal terbang dan trak dan pelepasan yang lebih rendah semasa pengangkutan. Bagaimanapun, ia telah menjadi isu yang membimbangkan sejak beberapa tahun lalu sejak pengenalan plastik secara besar-besaran selepas Perang Dunia Kedua, sejumlah 8.3 bilion tan metrik telah dihasilkan. Oleh kerana plastik konvensional akan mengambil masa mengurai kira-kira 450 tahun. Oleh itu, diramalkan pada tahun 2050, terdapat kira-kira dua belas bilion tan plastik di tapak pelupusan sampah dan alam sekitar, contohnya, lautan. Lebih banyak plastik akan dibuang berbanding plastik yang manusia berjaya bersihkan, walaupun mereka telah mencuba yang terbaik. Tujuan projek ini adalah untuk memilih dan membandingkan kesan alam sekitar reka bentuk pembungkusan beberapa produk pengguna menggunakan perisian analisis kitaran hayat (LCA). Ia adalah perisian yang digunakan secara meluas untuk menyokong pembangunan mampan dan alat pemodelan untuk menilai kesan alam sekitar yang berkaitan dengan produk sepanjang hayatnya: daripada pengekstrakan bahan mentah melalui pemprosesan, pembuatan, pengedaran, penggunaan dan pelupusan atau kitar semula. Berdasarkan perisian bebas openLCA, tiga pembungkusan minuman telah dibandingkan: botol plastik, botol kaca dan tin aluminium. Untuk mendapatkan keputusan, inventori kitaran hayat (LCI) perlu dikenal pasti terlebih dahulu berdasarkan kajian kes, kajian literatur dan andaian yang berkaitan. Kemudian setiap aliran pembungkusan minuman, proses, sistem produk juga perlu dikenal pasti agar dapat menjalankan perisian openLCA. Keputusan mendapati bahawa aluminium mempunyai kesan yang kurang berbanding dengan dua jenis pembungkusan minuman

yang lain. Jika berdasarkan sebelas kategori impak CML, botol plastik dinobatkan sebagai yang paling impak terhadap alam sekitar, diikuti oleh botol kaca dan tin aluminium sebagai yang paling kurang memberi kesan. Selain itu, ia mungkin disebabkan oleh kuantiti bahan yang digunakan, kesan bahan semasa pemprosesan, dan keupayaan kitar semula.

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LIST OF ABBREVIATIONS

LCA	-	Life Cycle Assessment
EPS	-	Expanded Polystyrene Foam
PET	-	Polyethylene Terephthalate
LDPE	-	Low Density Polyethylene
PS	-	Polystyrene
HDPE	-	High Density Polyethylene
PVC	-	Polyvinyl-chloride
PC	-	Polycarbonate
PP	-	Polypropylene
O2	-	Oxygen
CO2	-	Carbon Dioxide
TPS	-	Thermoplastic Starch
PLA	-	Polylactic Acid
PLA-PHB	-	Poly-(hydroxybutyrate)
PHAs	-	Polyhydroxyalkanoates
PHB	-	Poly-(3-hydroxybutyrate)
PHBV	-	Poly-(hydroxy butyl valerate)
LCI	-	Life Cycle Inventory
LCIA	-	Life Cycle Impact Assessment
EU	-	European Union

CHAPTER 1

INTRODUCTION

1.1 Project Background

Due to the increasing population in the world, food demand can see to has risen over the years. The growth of the food packaging market has actively promoted the development of the food system, while it has also generated serious environmental issues (Zhang & Sablani, 2021). Approximately 95–99% of plastic material is manufactured from non-renewable sources (synthetic plastics) by petrochemical industries (Mangaraj et al., 2019).

Plastic is used in an almost endless variety of applications due to its versatility, affordability, and durability, including clothes, equipment, building, electronics, transportation, agriculture, and packaging, with the latter contributing the most to the need for plastic (PlasticsEurope. Plastics—The Facts 2021). Some of the countries such as European Union (EU) had introduced a single-use plastic ban. This is due to the increase usage of plastic.

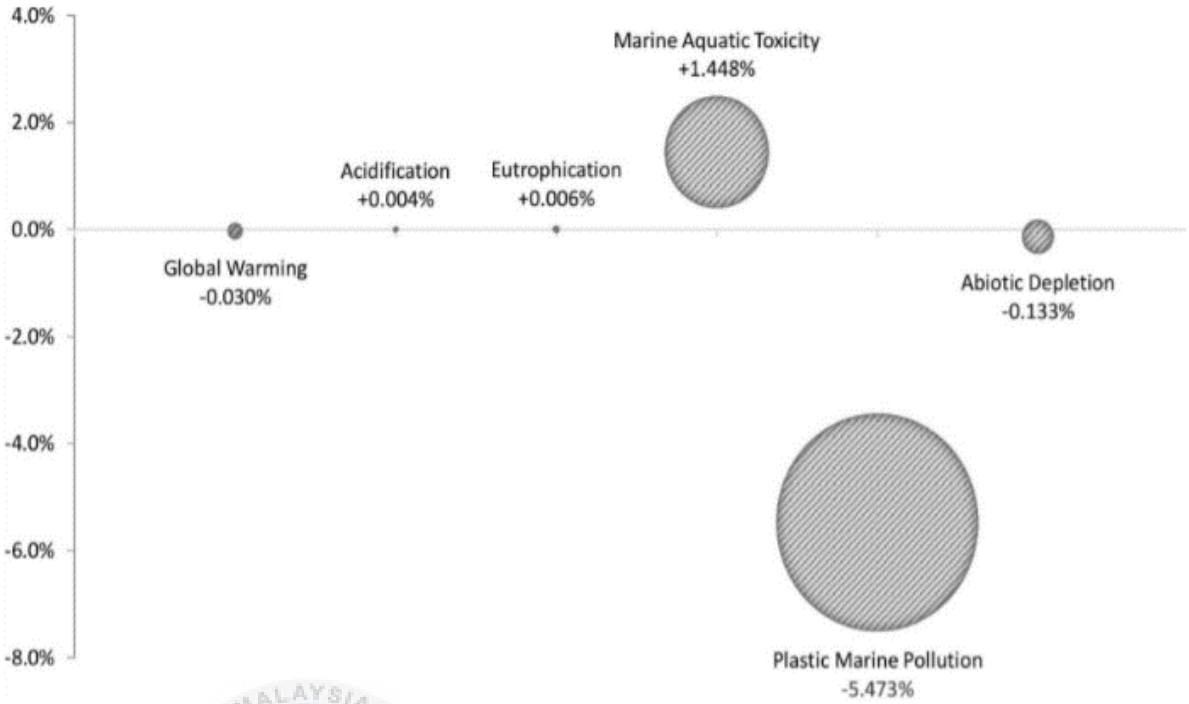

Figure 1.1: Impacts of a single-use plastics ban in the EU. Percentages show the increase or decrease of annual emissions for the six assessed impact categories concerning total emissions in the EU (Herberz et al., 2020)

A comparison of the environmental implications of the two product categories was made using EU consumption data for 2016. Based on Figure 1.1, EU-wide ban on single-use plastics will reduce plastic marine pollution by 5.5%, which translates to a worldwide reduction of 0.06 percent (Herberz et al., 2020). There is a lot of plastic pollution in the oceans, as well. Plastic pollution reached the seas at a rate of 4.8 to 12.7 million metric tonnes in 2010, according to (Herberz et al., 2020) estimates. Nearly 10.2 million metric tonnes of post-consumer plastic garbage will be collected and delivered to recycling facilities across Europe and beyond in 2020 (PlasticsEurope, Plastics—The Facts 2021).

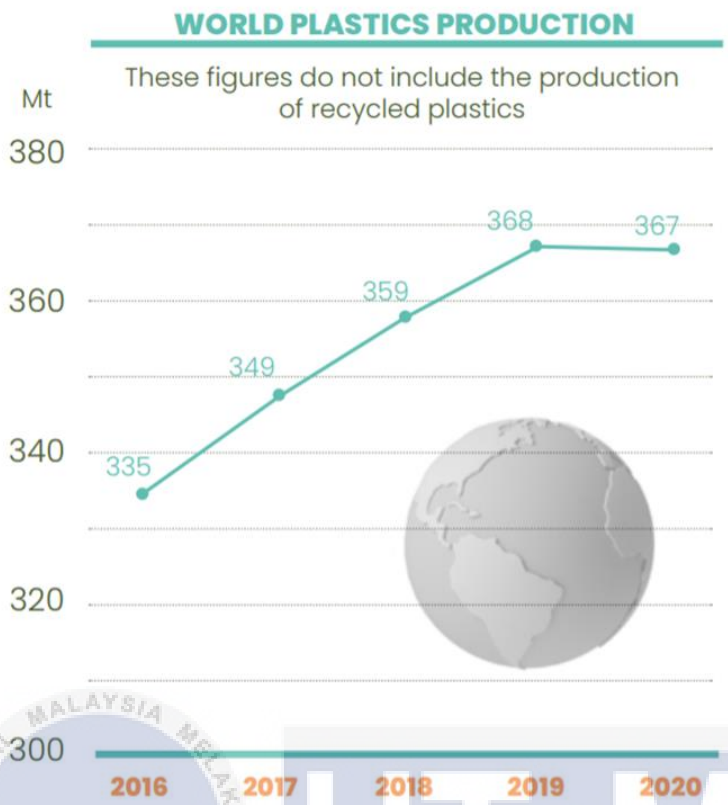

Figure 1.2: World plastics production (PlasticsEurope. Plastics—The Facts 2021)

From the Figure 1.2, it is shown the increase in plastic production from 2016 to 2019. In 2020, 367 million ton of plastic production had recorded.

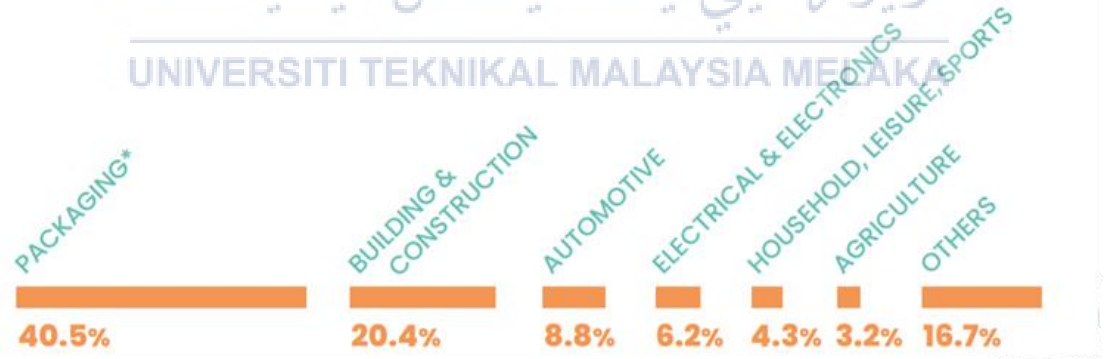

Figure 1.3: Plastic usage in sectors (PlasticsEurope. Plastics—The Facts 2021)

In terms of end-user, the packaging and construction industries dominate, Auto Industry is the third-largest end-user market as can be seen in Figure 1.3 (PlasticsEurope. Plastics—the Facts 2021). Plastics used in furniture, medical devices, machinery, and mechanical engineering, as well as technical parts, are all included under the umbrella term "others". Post-consumer plastic trash collection figures don't match demand or

consumption because of the wide variety of product lifespans (from 1 to 50 years or more) of plastics. Over 23% of the waste was transferred to landfills, and more than 40% was delivered to energy recovery operations, even though more than a third of the waste was recycled. Most products are packaged in a large amount of film and paper, which is then discarded in the landfill by the consumer, increasing the number of landfills for rubbish (Berketova & Polkovnikova, 2020). However, because this material is extremely difficult to degrade, it has the potential to pollute the environment. Many of the problems we confront and the solutions we need to develop are tied to the food and beverage (F&B) business (Bogers et al., 2020).

Packaging is a crucial aspect of the food industry. The functions are mainly to protect, containment, and also act as information details. It is to protect the food from unnecessary physical, chemical, and biological changes. Other than that, it acts as a storage during transport and distribution during the supply chain and also includes all the important information which covers ingredients, allergens, and barcodes. However, non-degradable plastic cannot undergo physical, chemical, and biological degradation which will lead to increasing plastic waste that also impacts the pollution and environment.

Aligned with this issue, there are many new ideas for packaging design improvement. One of the new developments in the subject of ecology is the use of environmentally friendly, biodegradable, and edible packaging (Berketova & Polkovnikova, 2020). Modern disposable eco-friendly dishes are manufactured by a variety of companies using eco-friendly materials such as wood, bamboo, carbonized bamboo, sugar cane, and other natural materials, all without the use of chemical preservatives (Berketova & Polkovnikova, 2020). Ecological packaging has been increasingly popular in recent years, bringing us back to the basics of using natural resources that are easily biodegradable (Saxena et al., 2018). The decomposition of biodegradable plastic produces water, carbon dioxide, inorganic compounds, and biomass. This will be good towards the environment as there is no accumulated waste.

1.2 Problem Statement

The largest segment of demand growth for plastic production is predominantly single-use plastic. Managing plastic waste is one of the planet's biggest problems. It has been affecting landfills and waterways to be increasingly clogged with plastic bags, Styrofoam food packaging, and others. While there are many other more phenomena in other countries around the world that are facing almost similar issues. There were a huge amount of plastic waste being dumped into the environment due to human activities which contaminate the entire planet, from the summit of Mount Everest to the deepest oceans, which mainly come from food industries such as beverage container and food packaging. Most of the types of beverage containers that can be found in Malaysia are typically made of plastic-type compared to aluminium or glass. This may relate to a cheaper manufacturing cost in production compared to the other two which can be the main reason why it is more favourable by most beverage manufacturers in Malaysia. However, the cheaper cost will not always be the best choice in terms of environment and health.

Hence, it is time for people to start shifting from solely depending on plastic usage to other better packaging materials and better designs. From this approach, less waste and fewer harmful chemicals could be achieved simultaneously. Plastic is also the main culprit in microplastic pollution. Recently, microplastic pollution has been detected in human blood for the first time, with scientists finding tiny particles in almost 80% of the people tested (Carrington, 2022). There are many manufacturers have started to make a step toward a better sustainable packaging design and these activities should be encouraged and broadened. For example, carton eggs which are paper by-product materials are better than those which use plastic packaging in terms of their reusable and environmentally friendly.

Comparing these three main types of beverage containers in LCA, will able to help in better understanding the environmental impact of products, mitigating the environmental impact, and developing an effective environmental marketing strategy at the end of the findings.

1.3 Objectives

The objectives are as follows:

(a) To conduct literature review on the recent studies of packaging material and design.

(b) To conduct comparative analysis of three type packaging design of beverage container: aluminium, glass and plastic.

(c) To compare the environment effect of various beverage packaging via the open LCA software.

1.4 Scopes of the Project

The scopes of project are as follows:

(a) Research on the effect of the current packaging vs. a better environmentally friendly packaging based on its properties and design. In this project, it will focus more on the beverage packaging.

(b) Evaluating the environmental impact of the packaging through their life cycle compassing extraction and processing of the raw materials, manufacturing, distribution, use, recycling and final disposal.

1.5 Report Organization

The organization of this report is divided into four main chapters. There are the introduction, literature review, methodology, result and discussion section, and conclusion with recommendations. Chapter 1 covers the project background, problem statement, objectives, and scope of the project.

Chapter 2 will include literature reviews comprising previous studies or research regarding sustainable packaging. For example, the journal, article, and others related sources. While chapter 3 methodology will briefly explain the project to be conducted using the LCA software.

Chapter 4 will discuss the results which were obtained from the previous chapter where the analysis can identify the less impact of packaging design on the environment. Finally, chapter 5 will include a summary of the project which may include several future recommendations that need to be further studied.

CHAPTER 2

LITERATURE REVIEW

In this chapter, literature reviews and studies within the last twenty years that are related to the sustainable packaging study and findings will be discussed and elaborated.

2.1 Food packaging

Consumption of packaged foods could be seen to be substantially increased in recent decades. The expansion of packaged food in the current market can be due to it being conveniences, advancements, and benefits of packaging. According to Singh et al. (2017), one of the advantages of food packaging is that it provides information to consumers regarding the contents, shelf life, and storage conditions of the product. Good packaging should be able to secure the food from any external impact and ensure that the food will not get damaged during delivery and shipment. Without a proper type of packaging, the food can lose its shape and texture. High-quality packaging can able to reduce the amount of care needed to handle the products, resulting in easy shipment and storage.

2.1.1 Types of food packaging

Food packaging can be made from several types which we can easily find in our local supermarket store. There are sardines in cans, a box of fruit juice, and chicken thighs wrapped in thin plastic with Styrofoam trays. Other than single-use plastic, existing food packaging can also be categorized into three other types:

(a) Plastic packaging

Plastic can be further divided into different types which are Styrofoam, thin clear plastic, water bottles, and others. Many are not aware that Styrofoam is an expanded polystyrene foam (EPS), which is made of polystyrene. It is a type of plastic which usually being used to make clear products like food packaging or even lab equipment.