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INVESTIGATING THE SUSTAINABILITY AND FEASIBILITY OF DIFFERENT DISPOSABLE CUPS: A COFFEE SHOP PERSPECTIVE

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ABSTRACT

With convenience being a sought-after factor in today's society, disposable coffee cups play a significant role in many people's daily routines. There still, however, appears to be a general confusion in many coffee shop environments regarding optimal waste treatment of disposable coffee cups to minimise their environmental impact. This study thus compares the different disposable coffee cup options that are available to South African coffee shops to determine which options (in terms of different materials) are more environmentally friendly under different conditions, whilst also satisfactorily meeting the requirements of coffee shops and customers.

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1. INTRODUCTION

The purchase of disposable coffee cups is embedded within the contemporary human lifestyle due to the convenience it offers. However, consumers rarely consider the environmental costs that are linked with disposable cups. Contrary to what many might think, the majority of disposable cups (including the majority of the "paper cups" used for hot take-away beverages) are not widely recyclable due to the polyethylene (PE) coating found inside of many of these cups. To cater for this problem, various coffee shops have started implementing biodegradable coffee cups with the aim of decreasing their environmental impact. The main differentiation of biodegradable cups is that they are lined with a bioplastic called Polylactic Acid (PLA) instead of PE [1]. Even though biodegradable cups have grown in popularity in recent years, there are still some concerns regarding their implementation. Firstly, biodegradable products are meant to be composted and not recycled [2]. It is therefore necessary to separate them from conventional plastics such as milk and soft drink bottles prior to the recycling process to prevent contamination [2]. Secondly, various manufacturers are claiming that their bioplastic products are "biodegradable", "compostable" and "environmentally friendly" when this is only the case when certain requirements are fulfilled [3]. In general, the three main requirements for biodegradable cups to decompose as intended is a temperature higher than 60 degrees Celsius, a humid environment and they must be mixed with organic material [4].

Given the complexity regarding the environmental impact of biodegradable coffee cups, guidance for coffee shops as to which cup is optimal when considering economic, social and environmental factors, remains ambiguous. The current study forms part of a growing literature, that seeks to address this gap, with a specific focus on evaluating the optimal waste management system configuration within the South African context.

1.1 PROBLEM STATEMENT

The environmental concern regarding coffee cup packaging, as well as its associated waste, has grown significantly in recent years. Biodegradable packaging has been touted as a solution to this problem due to its ability to biodegrade under certain conditions. However, it remains unclear whether biodegradable cups are better for the environment on balance, given the end-of-life (EOL) treatment of these cups in practice. There is thus a need for research that investigates the environmental impact of different disposable coffee cup alternatives. This research should consider the various disposal systems that these coffee cups end up in and make recommendations towards how these systems could be improved to reduce the possible negative effects of coffee cup disposal.

1.2 RESEARCH AIM

The aim of this project was to evaluate the different disposable coffee cup options available to South African coffee shops to derive recommendations regarding how disposable coffee cup disposal practices can be improved. These recommendations aim to reduce the environmental impact of disposable coffee cups, whilst still ensuring that the utility and affordability of disposable coffee cups use are not compromised.

1.3 PROJECT OBJECTIVES

In support of the above-mentioned aim the following research objectives were defined:

1. Define the key terms for the study and identify the different types of disposable cups that are currently on the market.
2. Identify the coffee shop owner and coffee shop customer requirements for disposable coffee cups, as well as their environmental friendliness.
3. Consider the combination of coffee shop requirements, customer requirements and environmental analyses to identify the most environmentally friendly yet feasible disposable coffee cup options and evaluate them by means of two case studies.
4. Make recommendations for the case studies evaluated and reflect on the possible implications for South African coffee shops while highlighting the possible shortcomings of the research and implications for future research.

1.4 SCOPE OF THE STUDY

This study focuses on disposable cups that are suitable for hot beverages. To simplify the study, only coffee cups and not the lids or sleeves are considered. Only existing technologies are considered and their feasibility is determined for use in South African coffee shops.

2. STRUCTURE OF THE METHODOLOGY

This section of the article covers the methodology that was followed towards achieving the objectives stated in Section 1.3. Sections 2.1, 2.2 and 2.3 discuss the first, second and third phase of the methodology, respectively. Furthermore, it is mentioned which objective is addressed.

The methodology is divided into three phases:

i. literature study phase (Section 2.1);
ii. comparative phase (Section 2.2); and
iii. case study and recommendations phase (Section 2.3).

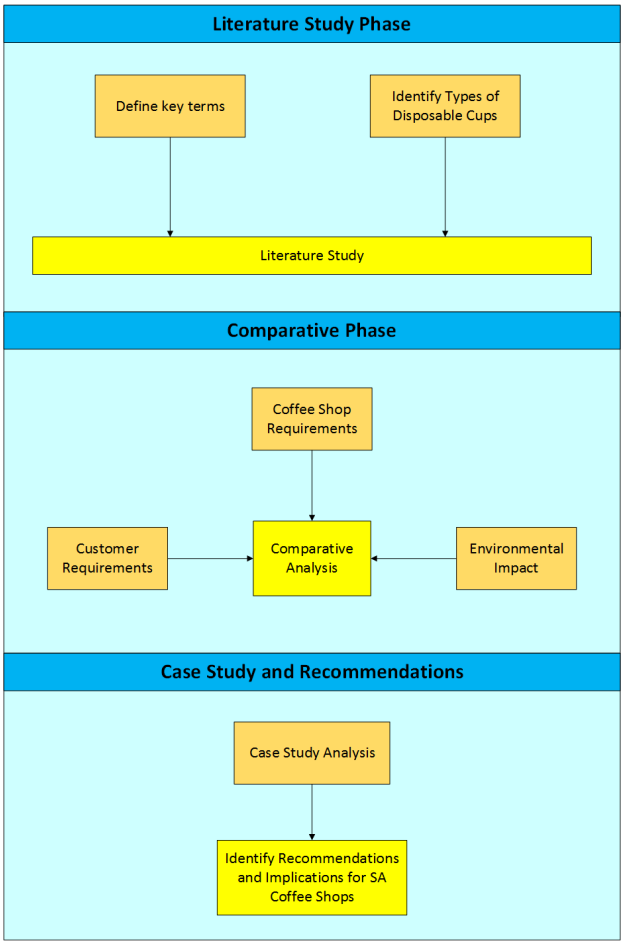


Figure 1: Structure of the Methodology.

2.1 LITERATURE STUDY PHASE

The results from the execution of the literature study phase are presented in Section 3 and addresses first objective from Section 1.3.

In Section 3.1 key terms of the study are discussed. Furthermore, the most common disposable cups are listed in Section 3.2. Thereafter, it is mentioned which disposable cups are suitable for hot beverages and therefore suitable for this study. Simplified production processes for the materials of these cups are also included.

2.2 COMPARATIVE PHASE

The results from the comparative phase are presented in Sections 4, 5 and 6 and addresses the second and third objective from Section 1.3.

This phase takes three aspects into account when comparing the disposable coffee cups that were identified in the first phase. The first aspect that the coffee cups are ranked on is how well they meet the coffee shop owner's requirements. Two coffee shop owners were interviewed to set up a list of coffee shop requirements that are listed in Section 4.1. The first coffee shop is Damascus Road that is located at the launchlab of Stellenbosch University. The second coffee shop is Deluxe coffees that is also located in Stellenbosch. The second aspect is how well the cup meets the coffee shop customer requirements. These customer requirements were identified by means of interviews with regular coffee drinkers and are discussed in Section 4.2. The final aspect against which the cups were compared is their CO_2 impact under different circumstances. This is discussed in depth in Section 5. Once all the cups were ranked according to the three aspects, their final rankings were compared. This comparison is presented in Section 6 and indicates the cup with the highest overall ranking.

2.3 CASE STUDY AND RECOMMENDATIONS

The results of this third phase of the methodology are presented in Sections 7, 8 and 9 and addresses the fourth and final objection from Section 1.3.

In Section 7 two case studies are performed to identify whether stakeholders are aware of the implications of implementing compostable coffee cups. The first case study involves a student cafeteria and is discussed in Section 7.2. Thereafter, a further case study involving a Western Cape municipality is presented in Section 7.3. In Section 8 the results presented in Section 1 to 7 are evaluated. Thereafter, further recommendations and practical considerations are presented in Sections 8.2 and 8.3, respectively. In Section 9 a summary of the report is provided and the most significant limitations, that were dealt with during the course of this study, are discussed.

3. LITERATURE STUDY

This section defines terms, relevant to the study. Furthermore, the different disposable cup options, as well as which ones are focused on in this research, are discussed in Section 3.2.

3.1 IMPORTANT DEFINITIONS

To gain a better understanding of this article, it is useful to define relevant terms such as “sustainability”, as well as distinguishing between terms such as “recyclability”, “degradability”, “biodegradability”, “compostability” and “digestion”. The definitions are discussed in more detail in the following sections.

3.1.1 DEFINING SUSTAINABILITY AND THE TRIPLE BOTTOM LINE

According to [5] the overall goal of sustainable development is the “long-term stability of the economy and environment; this is only achievable through the integration and acknowledgment of economic, environmental, and social concerns throughout the decision making process”. Moreover, in many businesses “sustainability” is considered as an important goal, however, quantifying the degree to which a company is sustainable is often complex. John Elkington therefore set up a framework in the 1990s to measure the sustainability of companies [6]. His framework, called the “Triple Bottom Line”, combines three dimensions of performance: environmental, financial and social [6]. The “Triple Bottom Line” differed from traditional performance measures as it incorporated social and environmental means of measurement.

3.1.2 BIODEGRADABILITY, COMPOSTABILITY AND DIGESTION

Further terms that are beneficial to define include “biodegradability”, “compostability” and “digestion”. The meanings of the terms “biodegradability” and “compostability” are often confused. There are two significant differences between the two terms. The first differentiation is that compostable materials break down into humus and supply the soil with nutrients, whereas biodegradable materials are generally broken down into more basic molecules that integrate with the environment as basic organic building blocks [7]. The second difference between biodegradability and compostability is that biodegradable materials are generally able to disintegrate under the conditions prevalent in landfills. Compostable materials, on the other hand, generally require specific composting conditions in order to decompose to the desired level and through the desired pathways [8]. These conditions generally include an elevated temperature, high humidity and a mixture with other organic materials [4]. Compostable cups, for example, require a temperature of above 60 degrees Celsius before they decompose along the desired pathways and within a generally acceptable timeframe [4]. A further term that is beneficial

to define is "digestion. Similarly to composting, digestion is a biological waste treatment. The major difference between the two is that during digestion organisms can feed off the organic waste itself without additional oxygen, whereas during composting organic matter is naturally oxidised by organisms [9].

3.2 DISPOSABLE CUP TYPES

Towards addressing the first objective in Section 1.3, it is necessary to review the types of disposable coffee cups that are currently on the market.

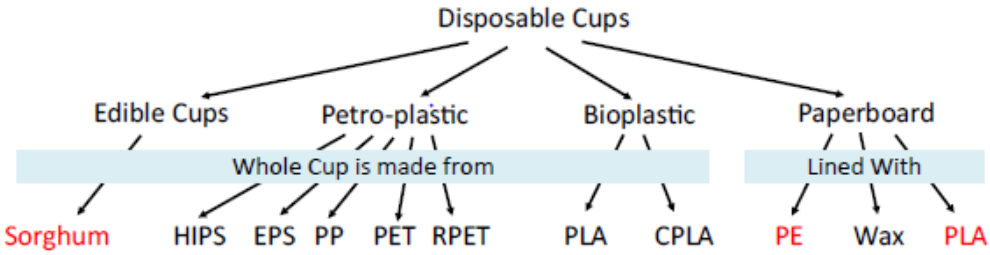


Figure 2: Types of Disposable Cups adapted from [4].

As can be seen in Figure 2, disposable cups can be categorised into four different material types: edible cups, petro-plastic, bioplastic and paperboard [4]. Figure 2 also shows the materials that the disposable cups consist of or are lined with. For example, Petro-plastic cups are either made from HIPS (high impact polystyrene), EPS (expanded polystyrene), PP (poly propylene), PET (poly ethylene terephthalate) or RPET (recycled PET). As mentioned in Section 1.4, this article focuses on cups that are suitable for hot beverages. The cups that are suitable for hot beverages are therefore edible cups and paperboard cups lined with PLA or LDPE as indicated in red in Figure 2. Even though EPS Petro-plastic cups can also be used for hot beverages, they are considered to pose a considerable health risk and are therefore excluded from further consideration in this article [10]. In Sections 3.2.1, 3.2.2 and 3.2.3 a brief overview is given of PE-coated, PLA-coated and edible cups, respectively.

3.2.1 PAPERBOARD CUPS LINED WITH PE

The manufacturing of heat-resistant paper cups involves a thin line of polyethylene (PE) on the inside to ensure that they are waterproof [11]. Moreover, a simplified diagram of the production of PE can be seen in Figure 3. The process starts with the coupling of a natural gas, namely methane or ethane, with an oxygen source. This process is referred to as Oxidative Coupling of Methane (OCM). The outputs of this process are ethylene and other associated products. These are then put under a pressure of between 10 and 80 bar and a temperature of between 250 and 300 degrees Celsius to create polyethylene. Polyethylene is then used to coat the paperboard cups, which increases the recycling process complexity of these cups and generally renders them infeasible to recycle [12].

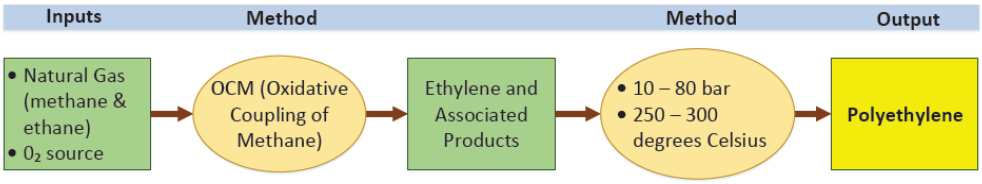


Figure 3: Manufacturing of Polyethylene collated from [13].

3.2.2 PAPERBOARD CUPS LINED WITH PLA

One of the most common compostable coffee cups is made from paperboard that is lined with PLA. A simplified manufacturing process of PLA can be seen in Figure 4. The key factor that differentiates PLA from thermoplastics, such as PE, is that it is manufactured from renewable resources such as corn starch or sugar cane [14]. These renewable resources are then fermented to produce lactic acid. The lactic acid is polymerised to achieve lactide and then condensed to finally achieve PLA. PLA-coated disposable cups can be composted,

however, similarly to the PE-coated cups are infeasible to recycle. The reason for this is that the PLA must be separated from the paperboard before the two materials can be recycled separately. This process is generally too expensive to make it economically feasible to recycle the coffee cup.

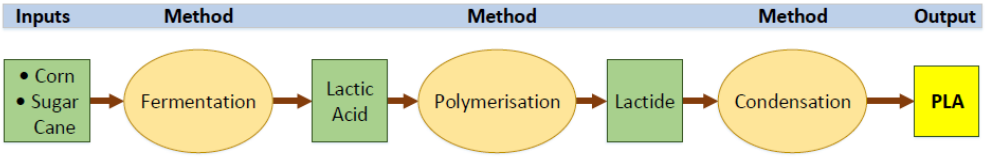


Figure 4: Production of PLA adapted from [15].

3.2.3 THE EDIBLE CUP

The third disposable cup that was investigated is the edible coffee cup. An application of this idea can be seen at an Indian edible cutlery manufacturer called "Bakeys". All their products consist of Sorghum as the primary ingredient [16]. Kentucky Fried Chicken (KFC) implemented their own edible disposable coffee cup in 2015 in the United Kingdom. However, this cup was not made from Sorghum, but rather a biscuit that is wrapped in sugar paper and lined with white chocolate [17]. This cup was discontinued in the same year that it was introduced. This was due to the fact that there is a trade-off between the cup's sturdiness and its taste. In order to make the cups durable and able to withstand hot liquids, they would be extremely hard and therefore not have the best taste. Another downside of these cups was that coffee shop customers did not always want to eat cookies while buying coffee. If the cup therefore remained uneaten it would most likely be thrown away and considered food waste. Even though the implementation of KFC's edible cups was unsuccessful, edible cups made from Sorghum are still compared with PE and PLA cups in this study as they could potentially still be successful if implemented using a different business model or design.

4. IDENTIFYING COFFEE SHOP AND CUSTOMER REQUIREMENTS

This section focuses on determining the various requirements, that stakeholders have, regarding the properties of disposable coffee cups. Two perspectives were considered: the coffee shop owner perspective is covered in Section 4.1 and the coffee shop customer perspective is covered in Section 4.2. Finally, the two perspectives were combined in Section 4.3. The interview questions can be found in Appendix A.

4.1 REQUIREMENTS AND PRIORITIES OF WESTERN CAPE COFFEE SHOPS FOR COFFEE CUPS

To identify the coffee cup requirements from a coffee shop perspective, two coffee shop owners who operate coffee shops in the Western Cape in South Africa were interviewed. Both shops have a large focus on coffee and currently sell coffee in take-away cups. Their first requirement was that the cup must be of low cost. Economically it would therefore only make sense for the company to purchase a cup that is price competitive. Their second requirement involved the strength of the cup. It was deemed to be of importance that the cup is sturdy as it deals with hot liquids that could lead to burn wounds. Thirdly, the outer appearance of the cup was also of importance. Fourth, the coffee shops mentioned that they would prefer using environmentally friendly cups over a non-environmentally friendly cups. Lastly, the coffee shop owners both agreed that the cup must have good insulation properties. If the cup has poor insulation, additional sleeves must be purchased at an additional cost, which might or might not be beneficial for the company depending on whether they use sleeves for marketing purposes.

4.2 REQUIREMENTS AND PRIORITIES OF CUSTOMERS FOR COFFEE CUPS

Three regular coffee drinkers identified at a South African university cafeteria were interviewed and asked what their disposable coffee cup requirements are. These coffee drinkers were selected as they on average buy at least one cup of take-away coffee per day from a local coffee shop. Of all their requirements, there were four that were common amongst all of the coffee drinkers. The first requirement is that the coffee cup must have good insulation properties. A further requirement, that all three coffee drinkers expressed, was that the coffee cup must be able to be sealed at the top. Further customer requirements included good grip and environmentally friendliness.

4.3 COMBINING COFFEE SHOP AND CUSTOMER REQUIREMENTS

It is evident that many of the coffee cup requirements are common amongst coffee shops and customers. To get an overall perspective of what is expected from disposable coffee, the coffee shop and customer requirements were combined and the final list can be seen in Figure 5.

Low cost
High strength
Good aesthetics
Good insulation properties
Must be able to be sealed
Good grip
Environmental friendliness

Figure 5: Combined Disposable Coffee Cup Requirements

5. EVALUATING THE CUP OPTIONS IN TERMS OF THEIR EINVIRONMENTAL IMPACT

This section aims to compare the environmental impacts of the three viable hot cup types that were identified in Section 3.2. To evaluate the environmental impact of cups under different usage scenarios, different EOL scenarios are investigated. The various EOL scenarios for PE-coated, PLA-coated and edible cups are shown in Figure 6.

Section 5.1 discusses the CO_2 equivalents of landfilling PE-coated and PLA-coated cups. Seeing as different assumptions about decomposition affect the CO_2 equivalents, three situations were investigated. The first assumes maximum decomposition, the second assumes 50 percent decomposition and the third assumes zero decomposition in the landfill. Section 5.2 focuses on the digestion and industrial composting of PLA-coated cups. Seeing as PE-coated cups cannot be digested or composted, only PLA-coated cups are investigated in this section. Moreover, Section 5.3 compares the different EOL options of PLA cups to determine which scenario has the lowest CO_2 equivalent footprint. In Section 5.4 the EOL scenario of edible cups is discussed. Thereafter, in Section 5.5 the degradation times of landfilling, composting and digestion are compared.

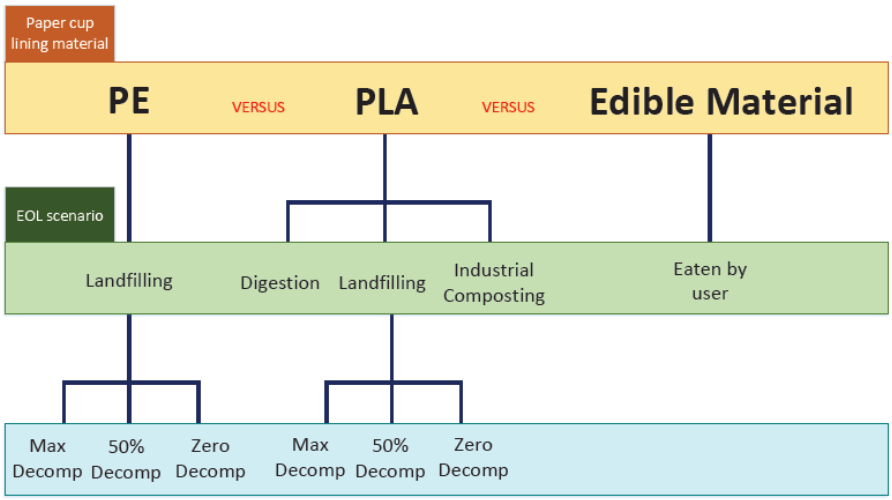


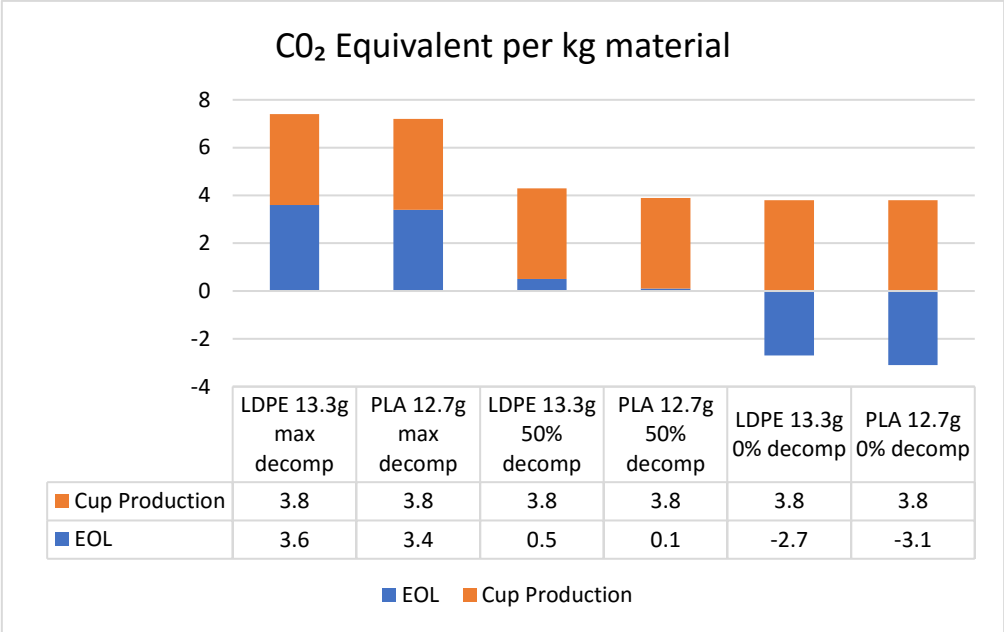
Figure 6: Paper Cup Lining Materials with their EOL Scenarios.

5.1 LANDFILLING OF DISPOSABLE COFFEE CUPS

The data used in this section regarding CO_2 impacts of landfilling cups was obtained from an existing LCA study [18]. In their LCA, 16oz "hot cups" were investigated with a functional unit of 10 000 cups. Considering that the LCA study that was worked from is based in America, various assumptions were based on American statistics. For example, in the United States, 80 percent of the municipal solid waste, that is not recycled or composted, is landfilled and 20 percent is incinerated. This assumption was therefore held throughout this analysis to ensure comparability. During this LCA three situations were considered. The first scenario assumes a maximum

decomposition at the landfill, whereas the second scenario assumes 50 percent decomposition at the landfill and the third assumes zero percent decomposition. Furthermore, even though an additional corrugated sleeve could be added to improve the user insulation experience, this optional feature was disregarded as this study specifically focuses on the disposable coffee cup itself.

Figure 7 shows the comparison between PE and PLA cups for the three landfilling EOL scenarios. It can be seen that the less the cup decomposes the less the CO_2 equivalent is. This can be explained by considering that no atmospheric gases are produced and all the biomass carbon is sequestered in the paperboard, which results in a large CO_2 sequestration credit [18]. This is also the reason why there is a sequestration credit for the EOL carbon equivalents at zero percent decomposition. For all three decomposition levels the PLA cup has a lower CO_2 equivalent than the PE cup. The differences between the CO_2 equivalents of PLA and PE are, however, not large. At maximum decomposition, for example, the CO_2 equivalent of PE-cups is only 3 percent greater than that of PLA-cups. This therefore suggests that landfilling compostable (PLA) cups is not significantly better for the environment than landfilling PE cups in terms of its CO_2 equivalent.



	LDPE 13.3g max decomp	PLA 12.7g max decomp	LDPE 13.3g 50% decomp	PLA 12.7g 50% decomp	LDPE 13.3g 0% decomp	PLA 12.7g 0% decomp
Cup Production	3.8	3.8	3.8	3.8	3.8	3.8
EOL	3.6	3.4	0.5	0.1	-2.7	-3.1

Figure 7: Landfilling of PE and PLA Disposable Coffee Cups sourced from [18].

5.2 COMPOSTING AND DIGESTION OF DISPOSABLE COFFEE CUPS

As mentioned in Section 3.1.2, there are four different biological waste treatments [19]. Seeing as no composting data for PLA-coated disposable coffee cups could be found, separate data for PLA and for paper (chemical pulp) was combined to achieve an approximation for the cup. Environmental data for chemical pulp was used as this comprises the "paper" part of the cup that is lined with PLA. Chemical pulping is a method of producing paper by chemically cooking wood chips under high pressure [20]. In Table 1 the four biological waste treatments are shown, as well as whether or not the treatment can be used to compost PLA and chemical pulp and therefore also compost coffee cups. The two waste treatments that can be used to compost both PLA and chemical pulp are highlighted in green in Table 1.

Table 1: Four Biological Waste treatments adapted from [19].

	Anaerobic Degradation (without oxygen)	Aerobic Degradation (with oxygen)
50-60°C	**Thermophilic digestion:** Suitable for PLA and chemical pulp	**Industrial composting:** Suitable for PLA and chemical pulp
≤35°C	**Mesophilic digestion:** Not suitable for PLA Suitable for chemical pulp	**Home composting:** Not suitable for PLA Suitable for chemical pulp

The data for the analysis was obtained from a LCA, in which different bio-based and biodegradable materials were compared based on their post-consumer waste treatment phase [19]. This LCA only investigated PLA and not the disposable coffee cups in particular. To estimate the CO_2 equivalent of the PLA-coated coffee cup, the individual CO_2 equivalents of chemical pulp and PLA were combined. Considering that the CO_2 equivalents of PLA and chemical pulp were found to be very similar, it was assumed that the average could be taken of the two to get an estimate of the overall cup. The individual CO_2 equivalents can be seen in Figure 8. The combined CO_2 equivalents for composting and digesting PLA-coated paper cups are shown in Figure 9. The data is expressed as CO_2 equivalents per kilogram of material.

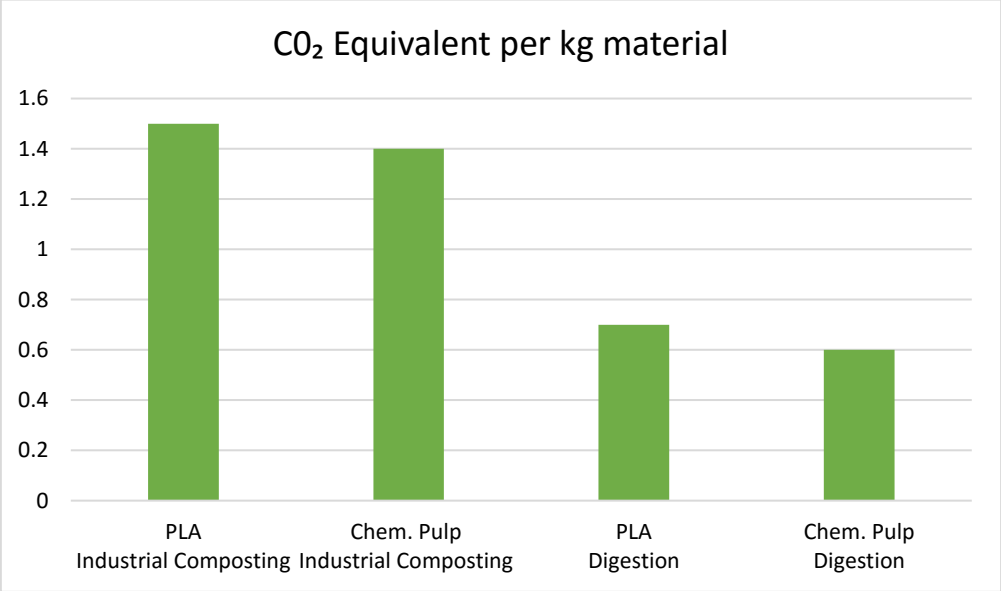


Figure 8: PLA and Chemical Pulp: Industrial Composting vs. Digestion adapted from [19].

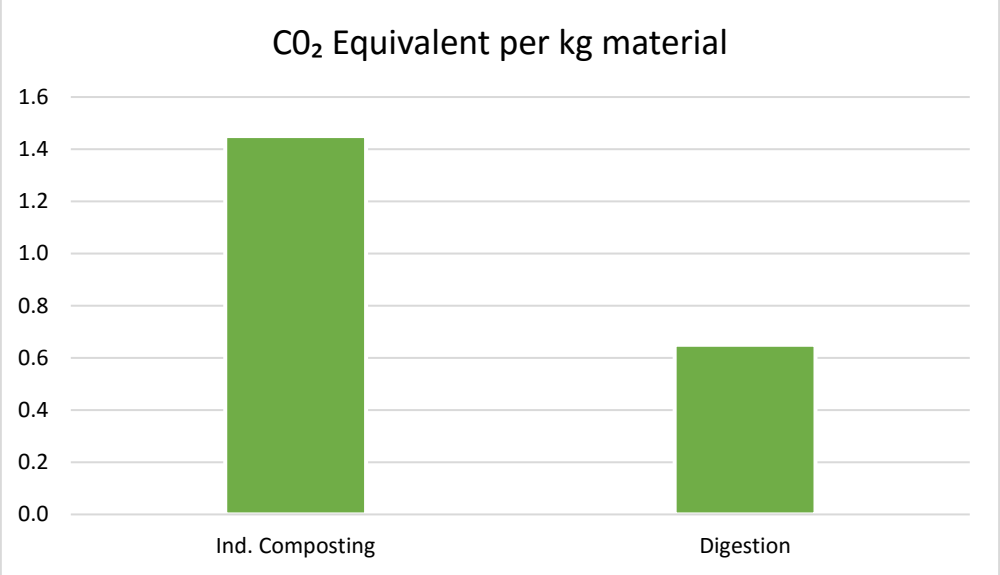


Figure 9: Combined Environmental Impact of Composting PLA Coated Cups adapted from [19].

As can be seen from Figure 9, digestion as an EOL waste treatment results in a significantly lower CO_2 equivalent value for PLA. This is due to the fact that digestion occurs below the surface, which traps the emissions and therefore prevents them from escaping. Composting, however, occurs above the surface, which results in more gases being released into the atmosphere.

5.3 COMPARISON OF ALL EOL SCENARIOS

In Section 5.1 it was established that compostable cups do not have a significantly lower carbon footprint in a landfilling EOL scenario when compared to the alternative non-compostable PE-coated cups. Furthermore, Section 5.2 showed that digesting PLA cups has a significantly lower carbon footprint than composting PLA cups. This section aims to compare the different EOL options of PLA cups in terms of their CO_2 equivalents to determine which one has the lowest CO_2 equivalent value. The LCA, that was used in Section 5.1, investigates the entire life cycle of the cup, whereas the LCA that was worked from in Section 5.2 only considers the EOL carbon footprints. It was therefore necessary to only use the EOL carbon impact from the LCA in Section 5.1 in order to make the two LCAs comparable.

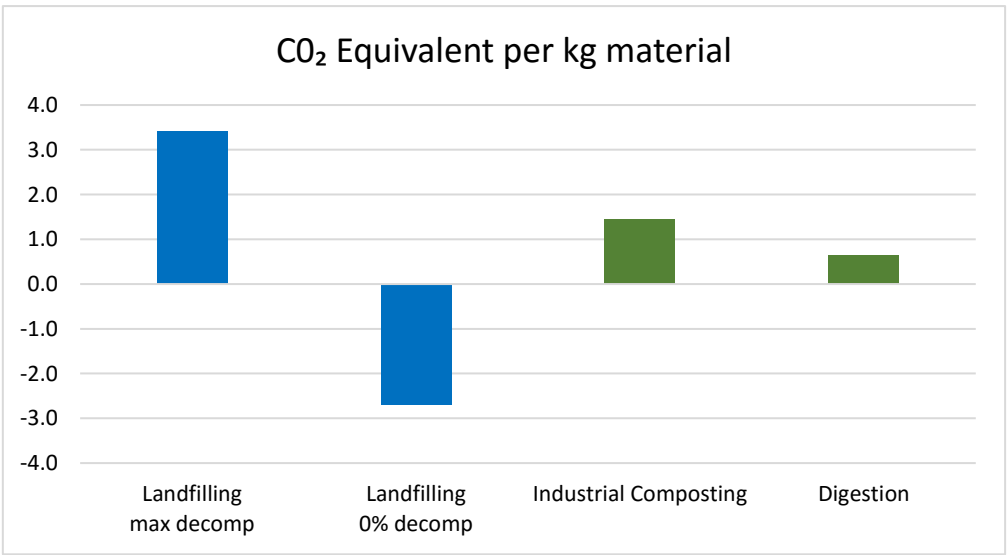


Figure 10: Waste Treatment Comparisons for PLA Cups adapted from [19].

As can be seen in Figure 10 a maximum decomposition of PLA-coated cups in a landfill have by far the highest CO_2 equivalent. A zero percent decomposition in a landfill has a negative CO_2 equivalent, because gases are not being produced and are instead sequestered within the material. Considering that this is not a sustainable waste treatment, because of the cups taking up space in landfills, the negative CO_2 equivalent does not necessarily indicate environmental friendliness. When comparing the biodegradation options for PLA-coated cups, digestion has less than half the CO_2 equivalent of industrial composting. Digestion could thus be considered to be the most sustainable waste treatment option for PLA-coated coffee cups, as it does not lead to the impact of landfilling and produces less CO_2 than the other options.

5.4 EDIBLE CUP EOL SCENARIO

As can be seen in Figure 6, it is assumed that edible cups are eaten by the user. During the course of this article it is therefore assumed that the EOL CO_2 equivalent of edible cups is zero. The CO_2 emissions of manufacturing edible cups are thus disregarded in this study.

5.5 A FURTHER ENVIRONMENTAL CONSIDERATION

A further way to compare the environmental friendliness of PLA-coated and PE-coated disposable coffee cups is by how long it takes them to degrade in a landfilling, composting or digestion EOL scenario. Table 2 been set up to show the relevant degradation times.

Table 2: Degradation Times sourced from [21] and [22].

Degradation Time		
EOL Scenario	PLA Cup	PE Cup
Landfilling Composting Digestion	50 years 3-6 months 6-8 months	50 years Not Applicable Not Applicable

Even though information regarding the time it takes for PLA cups to degrade when they are digested was not attained, it was assumed that this time is slightly longer than that of composting due to the fact that oxygen is not present to accelerate the process [19]. Even though the degradation time for digestion is slightly longer than that of composting, materials disintegrate significantly faster when they are composted or digested, as opposed to being landfilled as can be seen from Table 2. This therefore indicates that composting and digestion are significantly better EOL options for PLA than landfilling, because of the faster disintegration.

6. COMBINING COFFEE SHOP REQUIREMENTS, CUSTOMER REQUIREMENTS AND ENVIRONMENTAL ANALYSES

The aim of this section is to determine the best overall cup from a coffee shop owner, coffee shop customer and environmental perspective. This is done by ranking the three cups (PE-coated, PLA-coated and edible cups) according to three sets of requirements. The first criterion that the cups are ranked against is how well they meet the coffee shop owner requirements that were established in Section 4.1. Thereafter, the cups are ranked according to how well they meet the coffee shop customer requirements from Section 4.2. Lastly, the cups are ranked in terms of their environmental impacts with reference to Section 5. The cups are ranked on a scale of one to five. One being a poor score and five being an excellent score. Furthermore, two cases are compared during the ranking evaluation. The first case is covered in Section 6.1 and assumes that there is no special composting system being implemented for compostable coffee cups. The coffee cups therefore either end up in the recycling or the non-recycling waste stream and not the composting waste stream. As previously established, it is generally infeasible to recycle disposable coffee cups. Therefore, even when disposable cups are channelled to the recycling waste stream, they generally still end up in landfills. The second case is considered in Section 6.2 and assumes that there is a special composting system being implemented for compostable disposable coffee cups. This leads to the PLA (compostable) coffee cups landing in the composting waste stream to be composted by means of an industrial composter or digestion. These two specific cases were chosen to emphasise the different rankings that PLA cups have under different assumptions.

6.1 OVERALL CUP RANKING: CASE 1

As mentioned previously, the first case assumes no special composting system for compostable cups and therefore an EOL scenario of landfilling. The disposable coffee cup ratings for case 1 can be seen in Table 3.

Table 3: Case 1 Cup Rankings.

Case 1: No Special Composting System			
Requirement	PE Cups	PLA (Bio) Cups	Edible Cups
Low cost	5	3	1
High strength	5	5	1
Good aesthetics	5	5	3
Good insulation	5	5	3
Must be able to be sealed	5	5	3
Good grip	5	5	3
Environmental friendliness	1	1	5
Achieved ranking	31	29	19
Total possible ranking	35	35	35

As can be seen from the rankings, the PE cups achieved the highest score. However, this is despite the fact that they are not environmentally friendly as they have a large CO_2 footprint (significantly larger than the edible cups). The PLA cups achieved a ranking of 29 out of a possible 35, putting them 2 points behind the PE cups. PLA cups received a lower rating than PE cups in the cost area, because the cups are more expensive than PE cups (approximately 28 percent according to the interviewed coffee shop owners). Similar to the PE cups, the PLA cups achieved a poor rating for their environmentally friendliness, because of the assumption that there is no special composting system for them, which causes them to end up in landfills along with nonbiodegradable (PE) cups. This is also explained in Section 5.1, which indicates that the difference between the CO_2 equivalents of PE and PLA cups is smaller than 3 percent. It can therefore be concluded that in a landfilling EOL scenario, PLA and PE cups have equally large CO_2 footprints. The edible cups achieved the lowest score of 19 out of a possible 35, because based on an interview with an employee at the Bakeys company, they are flimsy and expensive and therefore achieved a rating of 1 for both low cost and high strength. Considering that Sorghum edible cups have not yet been manufactured, the majority of coffee shop owner and customer requirements were difficult to rank. A ranking of 3 (neutral) was therefore given to the requirements of good aesthetics, good insulation, must be able to be sealed and good grip. Considering that edible cups will be eaten, they were considered to have little to no EOL environmental impact. The edible cups were thus given a rating of 5 for environmentally friendliness.

In order to account for the uncertainty related to edible cups, a sensitivity analysis can be performed. Specifically, it is possible to (in addition to the baseline case already considered) also consider the best-case scenario for the elements regarding edible cups that were uncertain. In this case the uncertain edible cup elements, namely aesthetics, insulation, sealability and grip, were given a rating of 5. For the best-case scenario, the rankings can be seen in Table 4.

Table 4: Case 1 Cup Rankings (with Sensitivity Analysis).

Case 1: No Special Composting System			
Requirement	PE Cups	PLA (Bio) Cups	Edible Cups
Low cost	5	3	1
High strength	5	5	1
Good aesthetics	5	5	5
Good insulation	5	5	5
Must be able to be sealed	5	5	5
Good grip	5	5	5
Environmental friendliness	1	1	5
Achieved ranking	31	29	27
Total possible ranking	35	35	35

Even though the uncertain elements of edible cups were given a rating of 5, edible cups still achieved the lowest ranking of the three cups as can be seen in Table 4. It can therefore be concluded that the cup rankings are not sensitive to the uncertainty related to the information regarding edible cups, as the results remained unchanged.

6.2 OVERALL CUP RANKING: CASE 2

As previously mentioned, the second case evaluates the different coffee cups under the assumption that there is a special composting system for compostable cups. The EOL scenarios for PLA (compostable) cups are therefore either industrial composting or digestion. Table 5 shows the disposable coffee cup ratings for case 2.

Table 5: Case 2 Cup Rankings.

Case 2: Special Composting System			
Requirement	PE Cups	PLA (Bio) Cups	Edible Cups
Low cost	5	3	1
High strength	5	5	1
Good aesthetics	5	5	3
Good insulation	5	5	3
Must be able to be sealed	5	5	3
Good grip	5	5	3
Environmental friendliness	1	5	5
Achieved ranking	31	33	19
Total possible ranking	35	35	35

Contrary to the first case, the cups with the overall best score in the second case are the PLA cups. The higher ranking of PLA cups was caused by them having a rating of 5 for their environmentally friendliness in the second case. This is justified in Section 5.3 that illustrates that both industrial composting and digestion of PLA cups have a significantly lower CO_2 equivalent than landfilling of PLA cups and therefore also PE cups, assuming maximum decomposition. The ratings of PE cups and edible cups remain unchanged from case 1 seeing as they are not affected by the implementation of a composting system. Similar to the first case, the uncertainty of edible cups was accounted for by means of a sensitivity analysis. The uncertain elements of edible cups (aesthetics, insulation, sealability and grip) were again given a rating of 5. This, however, did not change the overall ranking of edible cups as they still achieved the lowest ranking. It can therefore be concluded that the cup ranking for the second case is not sensitive to the uncertainty of edible cups. The ranking results can be seen in Table 6.

Table 6: Case 2 Cup Rankings (with Sensitivity Analysis).

Case 2: Special Composting System			
Requirement	PE Cups	PLA (Bio) Cups	Edible Cups
Low cost	5	3	1
High strength	5	5	1
Good aesthetics	5	5	5
Good insulation	5	5	5
Must be able to be sealed	5	5	5
Good grip	5	5	5
Environmental friendliness	1	5	5
Achieved ranking	31	33	27
Total possible ranking	35	35	35

7. INVESTIGATING SHORT LISTED OPTIONS

In Section 6 it was identified which cups are best under which conditions. This section aims to investigate whether decisions in practice correspond with the previous section's findings i.e. are coffee shops implementing the optimal strategies. To achieve this, Deluxe Cofee and Damascus Road were considered in Stellenbosch in the Western Cape and their cup choice given the current EOL scenario of the cups was evaluated. If a mismatch was found, recommendations were made as to how waste management practices could be improved. Section 7.1 considers two additional coffee shops and one university cafeteria - Blue Crane, Hazz and Chalkboard Cafeteria, respectively. It is identified how many of the five interviewed coffee shops use compostable disposable coffee cups. Thereafter, Section 7.2 presents a case study at Chalkboard Cafeteria to investigate whether or not they are following an optimal waste plan with regards to disposable coffee cups. Lastly, Section 7.3 performs a further case study at the municipality of Stellenbosch to identify what the current waste treatment of compostable cups is.

7.1 CUP RANKING EVALUATION

As can be seen from the overall rankings of the two cases, compostable cups are only a better option if they are treated correctly and there is a correct composting method being implemented. By means of interviewing five coffee shops and restaurants within the Western Cape, it was found that all five use compostable coffee cups.

Table 7: Coffee Shop Cup Type.

Which coffee cup type do these coffee shops/restaurants use?	
Coffee Shop	Cup Type
Deluxe Coffee	Compostable
Chalkboard	Compostable
Blue Crane	Compostable
Hazz	Compostable
Damascus Road	Compostable

In order to evaluate whether or not these cups are being treated correctly two in-depth case studies are performed. The first is a coffee shop whose waste stream is handled as part of the university waste system. The second coffee shop's waste is handled as part of the local municipality's waste system. These case studies thus provide a more in-depth perspective of two parallel waste management systems.

7.2 CASE STUDY: STUDENT CAFETERIA

This case study discusses a student cafeteria. Section 7.2.1 analyses the waste treatment process that disposable coffee cups currently followed at the cafeteria. Thereafter, a suggested situation is described in Section 7.2.2 to potentially optimise the waste treatment process of disposable coffee cups at the cafeteria. To gain more information about the disposable coffee cup waste treatment at the cafeteria, an interview was held with a stakeholder involved with facilities management at the cafeteria.

7.2.1 CURRENT SITUATION

Whilst considering the cafeteria specifically, it was noticed that there is currently no special waste stream to ensure that disposable coffee cups are composted. At this stage there are either bins for all waste forms or the disposable coffee cups are thrown in the "Recyclable Bin". In both of these cases disposable coffee cups end up in the waste storage room with the aim of them being recycled. However, as previously established disposable coffee cups cannot be recycled. Thus, during waste segregation, the disposable coffee cups are separated from the recyclable waste and sent to a landfill. At this stage the compostable waste is sent to a processing facility, where it is composted, bagged and sold.

7.2.2 SUGGESTED SITUATION

In order to compost the disposable coffee cups, there either needs to be a separate dustbin for cups and compostable waste or a coffee cup icon must be added to the compostable bins. This therefore ensures that the disposable coffee cups are put in the compostable waste stream and sent to the processing facility, where it is composted. Instead of bagging and selling the generated compost, it is suggested to rather use this compost at the university gardens. This could potentially reduce the carbon footprint due to the decrease in transport and packaging.

7.3 CASE STUDY: WESTERN CAPE MUNICIPALITY

This case study involves a Western Cape municipality. In Section 7.3.1 the current waste treatment of disposable coffee cups in the municipality is described. Thereafter, in Section 7.3.2 a suggested situation to potentially optimise the waste treatment of disposable coffee cups is discussed.

7.3.1 CURRENT SITUATION

Currently the municipality implements a system to collect waste from restaurants/coffee shops three times a week. According to the manager of solid waste at the municipality, it costs the restaurant/coffee shops R560 to service a bin for a month. Coffee cups are currently put in black bags with the rest of the waste as can be seen in Figure 12. The recyclable waste is separated from the rest to go to waste processing. However, considering that PLA cups are not recyclable they are classified as "food packaging" and sent to landfills.

Figure 12: Black Bin Bags collected by the municipality.

7.3.2 SUGGESTED SITUATION

To potentially better the waste treatment of disposable coffee cups, the municipality is currently considering a new scenario. In this scenario it is recommended that restaurants/coffee shops should be given one white bag for every black bag they receive. The restaurants and coffee shops are asked to put food and compostable coffee cups into the white bags. As an incentive, the municipality will only charge a service fee of R460 per month and collect the bags five times a week. The restaurants/coffee shops will therefore also have more storage space. The aim of these white bags is to send their contents to an anaerobic digestion plant. Disposable coffee cups, along with the food waste and will therefore be anaerobically digested. The rest of the waste will be separated into recyclable and non-recyclable waste. Considering that food waste will no longer be in the same bag as recyclable waste, the chance of contaminating recyclable waste also decreases. This system can be implemented as a pilot test at a few restaurants/coffee shops throughout the municipality to test feasibility and iron out any issues.

8. CONCLUSION

This section discusses the results from the previous sections in Section 8.1 and identifies various recommendations and practical considerations in Sections 8.2 and 8.3, respectively.

8.1 EVALUATE RESULTS

Throughout the course of this study it has become evident that there is a growing awareness of the global disposable cup problem as all the interviewed coffee shops are opting for compostable disposable coffee cups. However, as can be seen by the environmental impact comparisons of PLA cups and PE cups in Section 5.3, compostable (PLA) cups only have a lower CO_2 equivalent if they are composted or digested and not landfilled. If PLA cups are landfilled along with PE cups, their CO_2 equivalent is only slightly lower than that of PE cups and their degradation time is significantly longer than that of composting or digestion. This therefore suggests that they have the same impact on the environment as PE cups in a landfilling EOL scenario. Coffee shops and consumers therefore think they are buying eco-friendly cups, but they are not aware that if these cups are not disposed of correctly, they have the same eco-impact as non-compostable cups. Moreover, disposable coffee

cups are often not consumed at the coffee shop premise. This limits the coffee shop's influence on the waste management of the disposable cups. There is therefore a need to raise awareness regarding the EOL waste management scenarios of coffee cups and their impact on environmental outcomes.

8.2 RECOMMENDATIONS

Various recommendations were developed throughout this article. The most important ones are highlighted in the following list:

1. An important recommendation is to ensure that compostable coffee cups end up in composting waste streams and are not landfilled. The suggested situations in Sections 7.2.2 and 7.3.2 are recommendations for two specific cases to ensure that compostable cups are sent to the correct waste stream. However, from a more general perspective, an improved waste management ow of disposable coffee cups can be achieved by coffee shops investigating different options and liaising with their municipalities.
2. As mentioned in Section 8.1, the consumption of disposable cups often does not take place at the coffee shop premise. This therefore limits the coffee shop's influence on the waste management of disposable coffee cups. An important recommendation is thus to raise the consumer's awareness of the correct disposal procedure for disposable coffee cups. Furthermore, the municipality and waste management company need to be aware and make the correct infrastructure available.
3. A further recommendation to help consumers understand the significance of compostable coffee cups and their disposal method is communication between the coffee shops and coffee shop customers. If coffee shops, for example, use compostable coffee cups they can have a sign that describes the benefits of using compostable coffee cups and into which bins they need to be thrown. Coffee shop customers will therefore be made aware of the importance of throwing the compostable cups into the correct bins.
4. To ensure that the compostable coffee cups are in fact compostable, coffee shops could implement various quality checks to validate this. For instance they could ensure that their supplier is trustworthy by sending sample coffee cups to an industrial composter to test whether they decompose.

8.3 PRACTICAL CONSIDERATIONS

Whilst working on this study various practical concerns, that need to be considered, were identified. These are summarised in the following list:

1. A large concern that is raised by an increase in composting efforts of PLA cups within the municipality specifically, is whether there is enough space for industrial composters or digestion heaps. Seeing as the municipality is already limited for space, the added pressure of finding locations to place large composting facilities might become a problem. However, over time, this should be offset by the reduction of waste sent to landfill.
2. Another concern that was identified during this study was whether disposable coffee cups, that are sold at coffee shops, are compostable. Often disposable cup manufacturers claim that their cups are compostable, however, as mentioned in Section 3.1.2 this does not necessarily indicate that they are compostable according to the composting requirements. It is therefore of high importance that the coffee shop owners find a trustworthy compostable disposable coffee cup supplier.
3. As mentioned in Section 7.3.2, the recommended situation at the Western Cape coffee shops is to send their food waste and coffee cups to an anaerobic digestion plant. However, according to stakeholders of the municipality, the digestion plant it would be sent to is used for mesophilic digestion and not thermophilic digestion. As mentioned in Section 5.2, PLA-coated coffee cups require thermophilic digestion to disintegrate. The anaerobic digestion plant would therefore not be suited for PLA-coated coffee cups and the municipality would have to consider other options to cater for these coffee cups. This practical consideration shows that there are several points of failure that could cause compostable coffee cups to end up in landfills. It is therefore clear from the study that the necessary systems are not yet in place and many improvements still need to be made to ensure that disposable coffee cups are indeed composted. Moreover, the results from the study highlight the important of using reusable coffee cups as opposed to disposable coffee cups.
4. Considering that PLA is primarily made food sources, such as corn, corn prices might rise if there is a significant increase in PLA-coated disposable coffee cups. This could also increase world hunger, especially in third world countries. This implication might cause coffee shops to reconsider implementing PLA-coated coffee cups.

8.4 LIMITATIONS

To practically complete this project, various assumptions were required. These introduce various limitations to the research that need to be considered when interpreting the results of the study. These include:

1. There was no South African data found for the landfilling of disposable coffee cups. It was therefore necessary to use data from a different country, namely the United States of America. Even though it was assumed that South African data would not differ significantly from American data, climate and waste management system differences between the two countries may cause differences that were not accounted for.
2. This study uses a very small sample size of coffee shop owners and coffee shop customers. This was mainly due to the similar answers the two coffee shop owners and the three coffee shop customers had. However, there is still further research that can be done to build on this study.
3. There is no data for the composting of PLA-coated paperboard cups. There were, however, LCAs that had composting data for PLA and chemical pulp (paper) individually. It was therefore necessary for the student to integrate the two separate CO_2 equivalents. Considering that the data for PLA and chemical pulp did not differ significantly, the average was taken to get the overall CO_2 equivalent. However, the way these materials are combined in coffee cups may lead to unanticipated differences in emissions during degradation.

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APPENDIX A

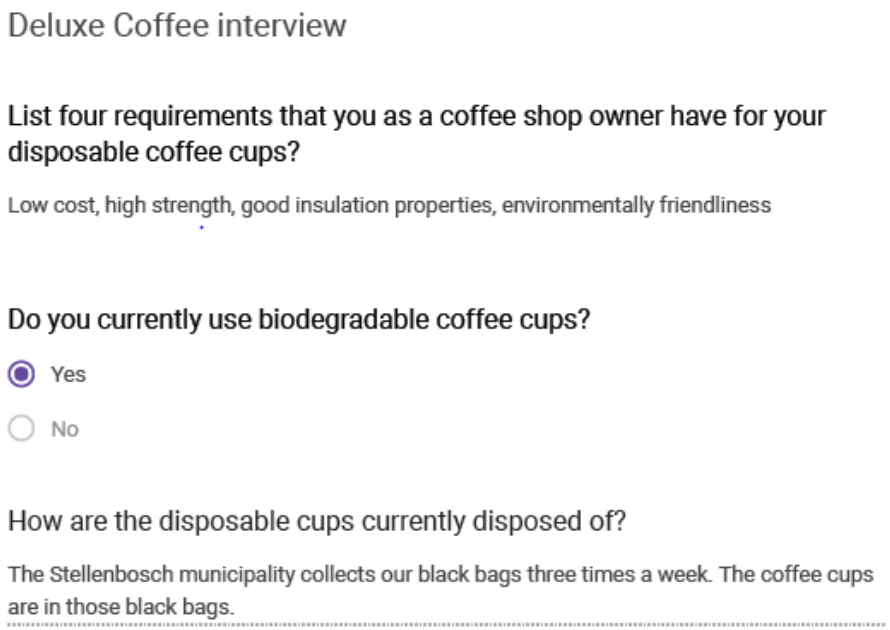
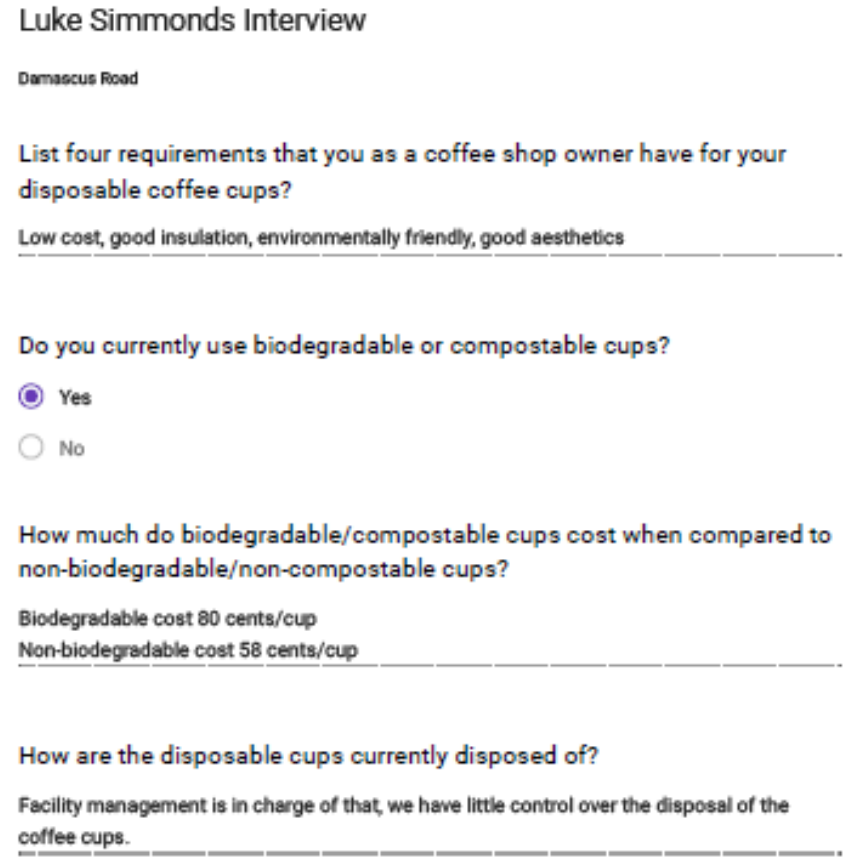


Figure A1: Interview with Deluxe Coffee



Luke Simmonds Interview

Damascus Road

List four requirements that you as a coffee shop owner have for your disposable coffee cups?

Low cost, good insulation, environmentally friendly, good aesthetics

Do you currently use biodegradable or compostable cups?

(•) Yes

( ) No

How much do biodegradable/compostable cups cost when compared to non-biodegradable/non-compostable cups?

Biodegradable cost 80 cents/cup
Non-biodegradable cost 58 cents/cup

How are the disposable cups currently disposed of?

Facility management is in charge of that, we have little control over the disposal of the coffee cups.

Figure A2: Interview with Damascus Road