TRIPLE BOTTOM LINE ASSESSMENT OF SINGLE-USE DISPOSABLE PLASTIC CUTLERY

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REFERENCE
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abbreviations

AMRF  Algalita Marine Research Foundation
CDC   Center of Disease Control
DALY  Disability Adjusted Life Year
EOL   End Of Life
FSC   Forest Stewardship Council
GPPS  General Purpose Polystrene
HDPE  High Density Polyethylene
LCA   Life Cycle Analysis
LDPE  Low Density Polyethylene
MSW   Municipal Solid Waste
PPC   Plastic Pollution Coalition
PET   Polyethylene terephthalate
PLA   Polylactic Acid
PP    Polyproplene
PS    Polystyrene

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Plastics surrounds us and poses a significant environmental, health and social impact. From an environmental standpoint, there has been significant waste generated globally by plastics. Currently the global plastic market size is estimated at 380 kilo tons in 2016 and is estimated to grow at a compound annual growth rate of 4.2 percent over a forecasted growth (Grand View Research, "Plastic Market Analyses By Product"). The key driver for this industry is the demand from the food packaging industry. The food packaging industry in the United States is the key applicator for the plastic market and is expected to drive global demand. California has been ranked 13 as the Greenest states in United States and have been a pioneer for many sustainable practices (Kierman, "Greenest States"). However, the existing solid waste infrastructure does not promote the recovery of plastic cutlery waste generated thus leading towards plastic pollution in water bodies. One factor affecting the solid waste infrastructure is the material cutlery products are made of. This paper primarily analyzes polystyrene plastic cutlery and compares it with available bioplastic and natural (wood) based material in the market. This investigation will form the basis of the recommendations aimed to provide implementable steps for non-profit organizations and businesses to take with respect to their cutlery products, to reduce the dependence on plastic cutlery and promote the use of sustainable options.

The analysis consists of an environmental and economic assessment, and also study of health implication caused by using plastic utensils. The environmental assessment is performed using life cycle analysis for each of the cutlery types. The goal of this study is to help small to medium scale restaurant chain to determine cutlery consumption habits and impacts to make informed decisions when purchasing disposable cutlery. The standard to be applied on LCA is based on ISO 14044:2006 standards*. The functional unit for this analysis is per utensil, assuming single use. The results, data and methodology used in this analysis are incorporated into the Quantis Suite 2.0 software tool, using database Ecolnvent 2.2(Quantis Intl).

The economic assessment is performed by identifying the commercial viability of the products. Understanding the monetary costs of these products will help in taking decision of materials used in the reusable cutlery industry. The health implications highlight the environmental risks and toxicity scale for humans associated with plastic cutlery. It is important to understand the health issues associated with using disposable plastic products to make an informed discussion.

In conclusion, this research will recommend how businesses can adopt interventions in their practices to adopt bio degradable cutlery in a way that can help balance their business and the environment. Another aspect of my recommendation focus on how an organization can approach businesses (restaurants) to help them implement suitable steps for a sustainable change.

Part I: Introduction
SECTION 1.1: ABSTRACT

SECTION 1.2: CLIENT INTRODUCTION

SECTION 1.3: CALIFORNIA AB341 GOAL + CHALLENGES WITH RECYCLING

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SECTION 1.1: ABSTRACT

We live in a society where the consumption of food and drink out-of-home is increasing because of changing work and recreational habits (Razza et al, 2024). As seen in Figure 1.0, 93% of millennials spend at least once in three months eating out (Morgan Stanley Research) and spend 44% of their food dollars ($2,921 annually) on eating out (US Department of Agriculture Food Expenditure Report). This suggests there is an increasing demand for providing convenient disposable utensils. Plastic cutlery such as forks, spoons and knives have become the convenient choice for many commercial uses to accommodate this demand. In the commercial food serving industries such as fast food restaurants and local small scale restaurants, disposable tableware is distributed to the restaurant guests in place of traditional durable tableware to simplify management tasks and avoid washing up (Razza et al, 2024). This practice has resulted in the negative consequence of both increasing the quantity and changing the quality of waste produced by each restaurant (Fieschi et al, 2024). Together with food waste, the following wastes are produced: plastic cutlery, plastic or laminated paper dishes, plastic or laminated paper cups and plastic bottles.

Out of 299 million of all plastic created each year on a global level, only 6 percent of it gets recycled, while the rest either are landfilled or lost in the ocean (Gourmelon, “Global Plastic Production Rises”). Another study estimated that 5.25 trillion plastic particles weighing a total of 268,940 tons are currently floating in the world’s ocean (Eriksen, ch.3). Though plastic bags are held culprit as one of the highest polluters, another major contributor is the disposable cutlery. Within the US market alone, the demand of food service disposable is expected to exceed 22 billion dollars by 2019. The impacts of these products can be seen in the decomposition rates and impacts on the ecosystems worldwide, but more so in coastal and marine ecosystems. The ocean conservancy estimates the rates of decomposition of plastic utensils to be between 50-100 years (Ocean Conservancy Report). These are also dependent on the type of plastic being used and conditions present for decomposition. According to Environmental Protection Agency (EPA), plastics make up 13 percent of the municipal solid waste stream and an overall recycling rate of only 8 percent (EPA). These factors pose an eminent threat and a need for sustainable option available with regards to cutlery options.

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Millennials</th>
<th>Gen X</th>
<th>Baby Boomers</th>
</tr>
</thead>
<tbody>
<tr>
<td>QSR</td>
<td>93%</td>
<td>96%</td>
<td>95%</td>
<td>90%</td>
</tr>
<tr>
<td>CDR</td>
<td>71%</td>
<td>80%</td>
<td>74%</td>
<td>64%</td>
</tr>
<tr>
<td>FCR</td>
<td>56%</td>
<td>69%</td>
<td>62%</td>
<td>43%</td>
</tr>
</tbody>
</table>

QSR = Quick Service Restaurant  
CDR = Casual Dining Restaurant  
FCR = Fine Casual Restaurant

Figure 1.0: Data of different generations consumer habits
Founded in 2009, Plastic Pollution Coalition (PPC) consist of more than 500 organizations comprising of business, scientific advisors and leaders as a platform to amplify a common message through strategic planning and communication. The organization seeks to increase awareness of the plastic pollution among public and to find sustainable solutions.

The mission of this organization as quoted in the official website is to empower people and organizations to take action to stop plastic pollution and to live plastic free.

The focus of this organization is single use plastic disposable subjects which lead to environment, wildlife, health and marine pollution. The organization has provided resources to the public in many different categories such as reducing plastic consumption, policy regulations such as zero waste initiatives and plastic free towns, impacting production with respect to plastic production and addressing health issues through their ReThink plastic campaign.

The organization has recently initiated a ‘The Last Straw’ campaign to eliminate the use of single use plastic straws at its source and promote the use of alternate materials such as metal straws. Similarly, this project aims to provide PPC a report for their future projects with the topic of material sustainability.
The California Department of Resources Recycling and Recovery August 2015 Report describes objectives and goals which includes plastic packaging products and plastics contributing to almost 10.4 percent of the overall waste disposal stream. Even though this may seem like a small percent of the entire waste stream, the effects of this material have caused the solid waste management agency to consider taking steps to help achieve their 75 percent goal by 2020. With regards to recycling, California has been exporting majority of their recyclable waste to developing countries like China, as their demand for low cost raw materials has increased (CalRecycle). In 2013, about 18.6 million tons of recyclables were exported from the California ports with a value of $7.4 billion. More than half of recycled materials exported through California ports were mixed paper/cardboard and paperboard, 42 percent were metals, 6 percent were plastics, and less than 1 percent was glass.

Recyclables accounted for one-fourth of all California seaborne exports by weight. Although these materials can easily be exported, the largest recycling-related job gains for California would be in processing and manufacturing for recoverable paper, plastics, and inert materials. However, California’s capacity is not sufficient to process or manufacture fiber- and resin-based products. CalRecycle databases currently list fewer than 50 recycled plastic manufacturers that produce new products and just over 100 processors that sort and consolidate materials or produce plastic pellets, granulated plastic, or plastic flake. Plastic utensils which is categorized as a durable plastic items contribute to about 2.2 % of the 10.4 percent of overall waste generated (CalRecycle).
Plastics are one of the most commonly used materials and present in nearly every part of modern life in all parts of the civilized world (Andrady, 2003). They are human-made materials manufactured from polymers, or long chains of repeating molecules. (qtd. in Parajuli). They are derived from oil, natural gas and some from plants such as sugarcane and corn. About 4 percent of the world’s petroleum is used to make plastic, another 4 percent is used to power plastic manufacturing processes (Gourmelon). Today global plastic industry generates revenue of about 600 billion dollars annually. Particularly within the food industry, global plastic demand is predicted to increase its demand by 20%. Figure 1.3 shows the forecast of plastic demand till 2025. This is very important to understand the demand of plastic products and the need for sustainable alternatives to reduce this demand.

Plastics have been used in many sectors and industries such as transportation, construction, healthcare, food products, telecommunications and consumer goods (Figure 1.2). Per capita plastic consumption has reached 100 kilograms (kg) in Western Europe and North America (Gourmelon). It is estimated that close to 40 billion individual plastic utensils are produced every year and most of them end up in landfills, beaches or oceans (“Ending Take out waste”).

In the United States, only 9 percent of plastic in general was recycled, and 13 percent gets discarded in the municipal solid waste stream (Gourmelon).
Plastic utensils are mostly made up of two types of plastics: polystyrene and polypropylene. Plastics are made by monomers and are produced from a process called polymerization. Monomers, single sequence molecules, such as ethylene and propylene are produced from natural gas and oil. Natural gas and oil, both fossil fuels, are hydrocarbons, or a series of molecules composed of carbon and hydrogen that are linked together in a repeating chain (Weisman). The natural gas and oil are heated to the point where the constituent hydrocarbons are converted into the reactive monomers (Romanowski, “Spork”). The monomers then become polymers (or multiple monomer molecules linked together) and are then cooled into blocks of the respective plastic, depending on the additives put into the liquefied substance when the monomer conversion process takes place. Since the bulk polymer is typically colorless, colorants are added to make spoons more appealing. These may be soluble dyes or comminuted pigments. To produce a white color, an inorganic material such as titanium dioxide may be used. The manufacturing process has a huge impact in the case of Prolon plastic spoon as shown in graph 2.2.3. This process is important step in understanding the impact of plastic disposable cutlery will continue to have on the environment.

Several new innovations have been achieved in polymer production for plastics. PLA (polylactide) is a polymer made from renewable resources such as cornstarch and is a common polymer in what companies assert as biodegradable (EPA). Figure 1.5 describes the material life cycle process.
On a legislative level, recently India has banned the use of all types of disposable plastic products to reduce plastic pollution (Gray). The country is responsible for 60 percent of global plastic pollution. The methodology of the ban took place in stages where they targeted large scale groceries and supermarkets to not give plastic bags along with the purchase unless the customer paid extra. This method proved positive to reduce the usage of plastic bags and made the public carry their own bags. Using the approach towards plastic bags, the country has now taken steps to target all the different types of disposable plastics including cutlery. The success of this implementation is yet to be analyzed but taking a step towards it proves to be a success.

Success stories of Products:

**World Centric Compostable Cutlery**

One line of sustainable cutlery is produced by World Centric, a company based in California which develops compostable containers and utensils and is a famous supplier of their products worldwide. Their product line is based on plant starch which is grown, processed and manufactured in China and shipped to America. Founded in 2004, the company had received many certification under the Biodegradable Products Institute (BPI), USDA BioPreffered Program and Forest Stewardship Council (FSC). World Centric is one of the cutlery types this paper analyzes.

**Bakeys Edible Cutlery**

Bakey’s edible cutlery, an Indian company made a switch from plastic cutlery to develop a completely 100% compostable and natural cutlery line made from food grain. The innovative disposable edible cutlery uses a combination of sorghum, rice and wheat flour. The company has orders of 25 million spoons and other cutlery products from within India and outside. The price of the cutlery line is said to be cheaper than disposable plastic cutlery and is currently trying to reduce the production price and make it more affordable. Within India, Bakeys cutlery has replaced plastic cutlery in Coffee Stores like Café Coffee Day which operates on a similar scale as Starbucks. The company aims to establish Bakeys as a food chain, competing with the fast-food
Part II: Environmental Factors + Impact of Single Use Disposal Cutlery
This section demonstrates environmental impact of plastic cutlery compared to bio plastic and natural (wood) based spoons as shown in Table 2.2. This study is important to understand the environmental impact and risk each type of cutlery pose on the environment. The results from this analysis is done by comparing the products in the following phases:

- Manufacturing
- Transportation
- End of Life

Data collected for the life cycle assessment have been collected as described in Table 2.1: Quality and Realibility Score Sheet.

<table>
<thead>
<tr>
<th>Data Quality</th>
<th>Realiability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-High Quality</td>
<td>Specific Validated or calculated data</td>
</tr>
<tr>
<td>2-Acceptable Quality</td>
<td>Validated or calculated data from other</td>
</tr>
<tr>
<td>3-Low Quality</td>
<td>Qualified estimate</td>
</tr>
<tr>
<td>4-Very Low Quality</td>
<td>Rough Estimate</td>
</tr>
</tbody>
</table>

Table 2.1: Quality and Realibility Score Sheet
Source: (qtd. in Brownlee et al,13)
Manufacturers of different type of cutlery were selected based on the company’s success rate. Another criterion for selecting the company was done by speaking with restaurant owners regarding their suppliers. Based on the information gathered and research, the following manufacturing companies was selected:

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>PROLON MANUFACTURING</th>
<th>WORLD CENTRIC</th>
<th>ASPENWARE</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEADQUARTERS</td>
<td>Colorado, USA</td>
<td>California, USA</td>
<td>Canada</td>
</tr>
<tr>
<td>BASE</td>
<td>Port Gibson, MI</td>
<td>China</td>
<td>Ontario, Canada</td>
</tr>
<tr>
<td>PRODUCT LINE</td>
<td>Plastic dinnerware and storage containers</td>
<td>Reusable flatware</td>
<td>Single use utensils</td>
</tr>
<tr>
<td>CATEGORY</td>
<td>Utensils</td>
<td>Utensils</td>
<td>Utensils</td>
</tr>
<tr>
<td>COMPOSITION</td>
<td>Polystyrene (PS)</td>
<td>Polylactic acide and Talc</td>
<td>Birth + Aspen and Discarded wood</td>
</tr>
<tr>
<td>CRITERIA OF SELECTION</td>
<td>BIODEGRADABILITY</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>COMPOSTABILITY</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>RECYCLING</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Table 2.2: Product Description

- Prolon LLC. has been developing dinnerware and plastic storage containers products by using thermoset and injection molded method in Port Gibson, Mississippi. The company has a distribution network of over 50 major retail and restaurant outlets and uses polystyrene and polypropylene based raw materials to manufacture cutlery.

- World Centric based in California provides zero waste solutions to reduce environmental impact. Their product line is based on plant starch which is grown, processed and manufactured in China and shipped to America. Their product line is said to be 100 percent compostable and biodegradable.

- Aspenware based in Ontario, Canada manufactures cutlery using wood. Most of the logs used are from trees previously cut down by timber industries while trying to reach valuable species such a spruce, pine and fir. The product can decompose in less than 50 days under a commercial composter, and less than 90 days under at-home compost conditions (Aspenware).
SECTION 2.2: GOAL, SCOPE AND SYSTEM BOUNDARY

GOAL

The main goal is to evaluate the manufacturing, transportation and end of life consequences of three different types of food utensils in food serving businesses.

This study in intended to compare the life span and environmental impact of the selected products. This study will be used for educational purposes only and is carried out following the life cycle methodology in agreement with the following standards:

• ISO 141040:2006 Environmental management- Life cycle assessment- Principles and framework.
• ISO 14041:2006 Environmental management- Life cycle assessment-Requirements and guidelines.

SCOPE

To demonstrate the impact of disposable spoons on the environment, first we should define the functional unit to analyze the impact of the product. A functional unit is a measure of the function of the system relating to the input and the output flows and used to compare impacts across similar products(Brownlee et all,9). The function of both these products, plastic based and bio plastic based facilitate the user to consume food, the functional unit is per use, considering after use the product is discarded and not reused.

SYSTEM BOUNDARY

These boundaries help define the conditions under which this analysis has been performed. The following conditions has been taken into consideration:

• This study does not consider metal cutlery.
• Other types of waste generated by restaurants are not considered. (I.e. plastic or laminated paper dishes, paper cups, paper tablecloth or napkins). It is assumed that the waste does not influence the comparison of the products.
• Food scraps produced by the kitchens is not considered.
• This study does not include the impacts of packaging.
IMPACT CATEGORIES

To assess the impacts of World Centric, Aspenware and Prolon utensils during their life cycle, the following categories were used as units of measurement (Quantis Intl):

<table>
<thead>
<tr>
<th>Category</th>
<th>Unit of Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate Change</td>
<td>kilograms of carbon dioxide equivalents</td>
</tr>
<tr>
<td>Human health</td>
<td>potential disappeared fraction of species per square meter per year.</td>
</tr>
<tr>
<td>Ecosystem Quality</td>
<td>mega joules of primary energy</td>
</tr>
<tr>
<td>Resources</td>
<td>meters cubes of water</td>
</tr>
<tr>
<td>Water Withdrawal</td>
<td>meters of cubes of water</td>
</tr>
</tbody>
</table>

Source: (qtd. in Brownlee et al, 11)

Assumptions

These assumptions are taken into account to restrict any information which may alter the results. This is an important step in order to define the conditions under which the products were analysed.

- Not including primary or secondary packaging.
- Data for this study has been indirectly acquired via 3rd party methods.
- Assuming that the product is utilized by consumer to maximum of 15 minutes and discharged in the trash.
- Owner purchases the product in bulk.
- Not accounting for recycling – assuming both are incinerated at EOL
- The use of the products is only for the specified use (consumption of food).
- Assuming that forks, knives and spoons have the same weight and material.
- Considering transportation network to restaurants located in Los Angeles.

Tool-Quantis Suite 2.0

This analysis is performed using a client based life cycle assessment software developed by Quantis Intl (Brownlee et al, 11). It is designed to assist companies to determine their environmental impact and develop strategies to reduce the impacts.
The above table explains the criterion of evaluation and processing involved from the transportation of the raw material to the end of life phase of each product. The distribution network is calculated using the overall travel distance travelled by the product from the manufacturing facility till the delivery location. For each of the product the destination was a restaurant located in Los Angeles. Travel distance includes the transoceanic fleet and freight.

Payload distance is calculated using the overall distance travelled multiplied by the overall weight of the product.

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>PROLON MANUFACTURING</th>
<th>WORLD CENTRIC</th>
<th>ASPENWARE</th>
</tr>
</thead>
<tbody>
<tr>
<td>QUANTITY</td>
<td>1 Spoon</td>
<td>1 Spoon</td>
<td>1 Spoon</td>
</tr>
<tr>
<td>AMOUNT</td>
<td>1.8g</td>
<td>5.5g</td>
<td>4.5g</td>
</tr>
<tr>
<td>BATCH</td>
<td>Pack of 30</td>
<td>Pack of 24</td>
<td>Pack of 6</td>
</tr>
<tr>
<td>CORE MATERIAL</td>
<td>Polystyrene</td>
<td>Plant (Non GMO-70%), Talc (30%)</td>
<td>Wood</td>
</tr>
<tr>
<td>RAW MATERIAL</td>
<td>Oil/Natural gas Monomers, Plasticizers, Stabilizers, Protectors, Removal Compounds</td>
<td>Corn PLA, Sugarcane Bagasse, Wheat Straw</td>
<td>50%-Leftover Wood 50%-Harvested Wood</td>
</tr>
<tr>
<td>MANUAL PROCESSING</td>
<td>Oil Refining, Polymerization, Injection Moulding, Pallet production</td>
<td>Fermentation, Pallet production</td>
<td>Veneering, Drying, Pallet production</td>
</tr>
<tr>
<td>USE</td>
<td>N/A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DISTRIBUTION</td>
<td>4153.90 km</td>
<td>112543.82 km</td>
<td>165.3 km</td>
</tr>
<tr>
<td>PAYLOAD-DISTANCE[Kgkm]</td>
<td>6106.20 kgkm</td>
<td>2024.23 kgkm</td>
<td>3317.79 kgkm</td>
</tr>
</tbody>
</table>

Table 2.3: Classification of Product by categories
The following factors were assessed to determine whether they have a significant impact on the results. The factors are:

- Manufacturing and processing impacts.
- Transportation trips made using the assumption of a restaurant located in Los Angeles.
- User disposal habits and consequence of end of life impacts.

Each of the above factors will be analyzed in greater detail further in this report. To determine the environmental impact comparison of Prolon product, World Centric product and Aspenware product, two possible end of life scenario are considered:

Scenario 1: Landfill: disposal with heterogenous waste (product+ food waste) following traditional treatment routes. The European average applied: sanitary landfill using 22.9% water.

Scenario 2: Incineration: Each of the product would be disposed of in municipal incineration using 15.3% water.
OVERALL RESULTS

A graphical overview of the results can be seen in Graph 2.4.0, 2.4.1 and 2.4.2 respectively. Evidently, the most significant effects come from the manufacturing component for Prolon plastic cutlery. In the case of World Centric transportation plays a key role in determining the impact due to extraction. Aspenware gets 50% of its wood from leftover wood source that would otherwise be left to rot and the other 50% from selectively harvested wood (Fedchyshyn). For this project, it is assumed that the forestry industry did not account for the environmental impact of the unused wood and so its impact is assigned to Aspenware. Due to the scope of this project, the use and assembly phase impacts of the cutlery is not considered. For each category, this study provides environmental factor used in Ecoinvent 2.2, along with input flow quantities so that future modifications of this study are understandable. Inferences is discussed in the following pages.
Table 2.4: Data + Sources for Manufacturing

<table>
<thead>
<tr>
<th>Brand</th>
<th>Climate Change (KG CO₂ eq)</th>
<th>Human Health (DALY)</th>
<th>Ecosystem Quality (PDF.m².yr)</th>
<th>Resources (MJ primary)</th>
<th>Water Withdrawal (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prolon</td>
<td>0.0397</td>
<td>4.35E-08</td>
<td>0.01449</td>
<td>0.6595</td>
<td>0.00029</td>
</tr>
<tr>
<td>World Centric</td>
<td>0.00488</td>
<td>5.83E-09</td>
<td>0.00616</td>
<td>0.06493</td>
<td>3.01E-05</td>
</tr>
<tr>
<td>Aspenware</td>
<td>0.02095</td>
<td>2.13E-09</td>
<td>0.00300</td>
<td>0.38111</td>
<td>0.00063</td>
</tr>
</tbody>
</table>

Table 2.5: Impact per Functional Unit for Manufacturing
DISCUSSION:

The overall comparison shown in graph 2.4.6 from this analysis shows that Agra-based products have the highest impact on ecosystem quality. This is justified due to the agricultural input required to produce corn and talc for the manufacturing of World Centric PLA based spoons. However, looking closely into the individual product results as shown in graph 2.4.3, 2.2.4 and 2.4.5, Prolon raw materials have the highest impact in all the categories measured. Prolon spoons use the technology of injection moulding to manufacture their PS based spoons. Injection moulding uses a ram or screw-type plunger to force molten plastic material into a mould cavity; this solidifies into a shape that has conformed to the contour of the mould (Malloy, 1994). It is most commonly used to process both thermoplastic and thermosetting polymers, with the volume used of the former being considerably higher (Malloy, 1994). This process requires high quantity of water to produce the spoon and to clean the polymers during its production stage. The raw material which is oil or natural gas has a significant impact on ecosystem quality as compared to World Centric spoon or Aspenware Spoons.

From graph 2.4.4: World Centric Manufacturing Impact Analysis, the processing and manufacturing stage specifically to polyactic acid shows significant impact on climate and resources. The processing of World Centric raw materials has the lowest impact on Ecosystem Quality hence proving the sustainability of the product.

From graph 2.4.5: Aspenware Manufacturing Impact, the area of discussion is limited due to the base of operations for Aspenware’s manufacturing is in British Columbia. The results show a high impact on resources, water withdrawal and human health because the material input is assumed to be largely wood based, due to negligible quantities of other material inputs.

Table 2.4 provide the data assumptions and sources for manufacturing for each product and Table 2.5 provide the impact per functional unit for each material.
## TRANSPORTATION

<table>
<thead>
<tr>
<th><strong>Brand</strong></th>
<th><strong>Climate Change (KG CO₂ eq)</strong></th>
<th><strong>Human health (DALY)</strong></th>
<th><strong>Ecosystem Quality (PDF.m².yr)</strong></th>
<th><strong>Resources (MJ primary)</strong></th>
<th><strong>Water Withdrawal (m³)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Prolon</td>
<td>0.0397</td>
<td>4.36E-08</td>
<td>0.01449</td>
<td>0.6595</td>
<td>0.00029</td>
</tr>
<tr>
<td>World Centric</td>
<td>0.00488</td>
<td>5.83E-09</td>
<td>0.00616</td>
<td>0.06493</td>
<td>3.01E-05</td>
</tr>
<tr>
<td>Aspenware</td>
<td>0.0105</td>
<td>1.28E-08</td>
<td>0.00455</td>
<td>0.17148</td>
<td>7.65E-05</td>
</tr>
</tbody>
</table>

### Table 2.6: Data + Sources for Transportation

<table>
<thead>
<tr>
<th><strong>FLOW</strong></th>
<th><strong>DATA</strong></th>
<th><strong>UNIT</strong></th>
<th><strong>ENVIRONMENT FACTOR (EF)</strong></th>
<th><strong>QUALITY</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mississippi-Los Angeles</td>
<td>203.54</td>
<td>kgkm</td>
<td>2.2-Transport,lorry 20-28t, fleet average-CH(Ecoinvent 2.2:1942)</td>
<td>2-Acc</td>
</tr>
<tr>
<td><strong>WORLD CENTRIC</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal Transport-China (Road)</td>
<td>6.627</td>
<td>kgkm</td>
<td>2.2-Transport,lorry 3.5-20t, fleet average-CH(Ecoinvent 2.2:1940)</td>
<td>2-Acc</td>
</tr>
<tr>
<td>China-California (Water)</td>
<td>72.88</td>
<td>kgkm</td>
<td>2.2-Transport,transoceanic freight ship-OCE (Ecoinvent 2.2:1968)</td>
<td>2-Acc</td>
</tr>
<tr>
<td>California-Los Angeles (Road)</td>
<td>4.833</td>
<td>kgkm</td>
<td>2.2-Transport,lorry 3.5-20t, fleet average-CH(Ecoinvent 2.2:1940)</td>
<td>2-Acc</td>
</tr>
<tr>
<td><strong>ASPENWARE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal Transport-Canada(Road)</td>
<td>79.39</td>
<td>kgkm</td>
<td>2.2-Transport,lorry 3.5-20t, fleet average-CH(Ecoinvent 2.2:1940)</td>
<td>2-Acc</td>
</tr>
<tr>
<td>Canada-California(Water)</td>
<td>76.1</td>
<td>kgkm</td>
<td>2.2-Transport,transoceanic freight ship-OCE (Ecoinvent 2.2:1968)</td>
<td>2-Acc</td>
</tr>
<tr>
<td>California-Los Angeles(Road)</td>
<td>31.2</td>
<td>kgkm</td>
<td>2.2-Transport,lorry 3.5-20t, fleet average-CH(Ecoinvent 2.2:1940)</td>
<td>2-Acc</td>
</tr>
</tbody>
</table>

### Table 2.7: Impact per Functional Unit for Transportation

Graph 2.4.7: Prolon (Plastic): Transportation Impact Analysis

Graph 2.4.8: World Centric (Bioplastic) Transportation Impact Analysis

Graph 2.4.9: Aspenware (Wood): Transportation Impact Analysis

Part II: Environmental Factors + Impact of single use disposable cutlery | Page 16
Aspenware has many distributors across North America (Brownlee et al., 2017). For the simplicity of this research, it is assumed that 50% of the product will be distributed in the United States of America while the other 50% is distributed in Canada. For the scope of this project, only the distribution process from Canada to United States is considered. Since the impact of the cutlery travelled within Canada is neglected, the assumptions result in a high impact of truck travel of the cutlery within California in all the categories.

World Centric has their manufacturing facility located in China thus resulting in high volume of transoceanic travel by sea and vehicles such as trucks to transport their line of cutlery. From the graph 2.4.8, the results show the impact due to transportation is high in all categories as their majority of production is based in China. If World Centric does implement manufacturing within United States, the results may alter significantly.

Table 2.6 provides the data and assumption and sources for transportation for each of the product, and Table 2.7 provides the impact per functional unit for transportation.

DISCUSSION:

The overall result from this analysis shows that transportation is a major contributor to overall environmental impact for each type of cutlery. This is largely due to the distance travelled by air, transoceanic freight and truck as shown in Graph 2.4.10. Vehicles are assumed to be carrying their maximum capacity in either mass or volume at all times, dependence on which is maximized first. Impact are based on vehicles of European construction, due to the original locale of the database inputs. The full life cycle of the vehicles is considered rather than the operation cycle. The distance travelled by the products is inclusive of delivery to any restaurant based in Los Angeles.

From graph 2.4.7, the transportation network of Prolon spoons show a high impact on all categories. This is considering that the manufacturing facility is located within United States and export to restaurants or distributors using only trucks.
Table 2.8: Data + Sources for End of Life (Scenario I+ Scenario II)

<table>
<thead>
<tr>
<th>Brand</th>
<th>Climate Change (KG CO₂ eq)</th>
<th>Human health (DALY)</th>
<th>Ecosystem Quality (PDF.m².yr)</th>
<th>Resources (MJ primary)</th>
<th>Water Withdrawal (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prolon (Scenario I)</td>
<td>0.0390.00101</td>
<td>4.315E-11</td>
<td>1.384E-05</td>
<td>0.0007</td>
<td>8.198E-07</td>
</tr>
<tr>
<td>Prolon (Scenario II)</td>
<td>0.0042</td>
<td>6.321E-10</td>
<td>2.154E-05</td>
<td>0.0012</td>
<td>6.044E-06</td>
</tr>
<tr>
<td>World Centric (Scenario I)</td>
<td>0.0027</td>
<td>1.647E-09</td>
<td>0.0011</td>
<td>0.0023</td>
<td>1.804E-05</td>
</tr>
<tr>
<td>World Centric (Scenario II)</td>
<td>0.003</td>
<td>1.318E-10</td>
<td>4.23E-05</td>
<td>0.0022</td>
<td>2.505E-06</td>
</tr>
<tr>
<td>Aspenware (Scenario I)</td>
<td>1.0111</td>
<td>1.346E-09</td>
<td>3.745E-05</td>
<td>0.0022</td>
<td>6.816E-06</td>
</tr>
<tr>
<td>Aspenware (Scenario II)</td>
<td>0.0027</td>
<td>1.174E-10</td>
<td>3.768E-05</td>
<td>0.0019</td>
<td>2.231E-06</td>
</tr>
</tbody>
</table>

Table 2.9: Impact per Functional Unit for End of Life (Scenario I+ Scenario II)

<table>
<thead>
<tr>
<th>Brand</th>
<th>Climate Change (KG CO₂ eq)</th>
<th>Human health (DALY)</th>
<th>Ecosystem Quality (PDF.m².yr)</th>
<th>Resources (MJ primary)</th>
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</thead>
<tbody>
<tr>
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<td>0.0390.00101</td>
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<td>1.384E-05</td>
<td>0.0007</td>
<td>8.198E-07</td>
</tr>
<tr>
<td>Prolon (Scenario II)</td>
<td>0.0042</td>
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<td>2.154E-05</td>
<td>0.0012</td>
<td>6.044E-06</td>
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<tr>
<td>World Centric (Scenario I)</td>
<td>0.0027</td>
<td>1.647E-09</td>
<td>0.0011</td>
<td>0.0023</td>
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<td>0.0022</td>
<td>2.505E-06</td>
</tr>
<tr>
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<td>3.745E-05</td>
<td>0.0022</td>
<td>6.816E-06</td>
</tr>
<tr>
<td>Aspenware (Scenario II)</td>
<td>0.0027</td>
<td>1.174E-10</td>
<td>3.768E-05</td>
<td>0.0019</td>
<td>2.231E-06</td>
</tr>
</tbody>
</table>
To determine the end of life factors for each of the cutlery product, two different scenarios was compared:

Scenario I: Landfill: disposal with heterogenous waste (product+ food waste) following traditional treatment routes. The European average applied: sanitary landfill using 22.9% water.
Scenario 2: Incineration: Each of the product would be disposed of in municipal incineration using 15.3% water.

For this project and life cycle assessment, only the results pertaining to disposal of product (spoon) was considered. The mass for each of the product was considered as the whole weight until the end of the usage. For the sake of simplicity, each meal is assumed to be only one utensil, and the utensil is disposed thereafter. Given the scope of this project, the disposal of the bio plastic cutlery and wooden cutlery through commercial composting is not considered.

Although the end of life component is very small compared to manufacturing and transportation, it plays a significant factor to consider when making a purchasing decision.

Based on the above scenarios, the results of each of the product was analyzed. For the plastic spoon as shown in graph 2.4.11, it was found that Scenario I have high impact on resources and Ecosystem quality, whereas Scenario II has high impact on Ecosystem Quality and Resources. This information can help us understand that if the plastic spoons which end up on landfill it will continue to deplete the land and discard toxic gases which will pollute the environment and the neighborhood. For World Centric and Aspenware cutlery, the impact of landfill or incineration as shown in Graph 2.4.12 and Graph 2.4.13 respectively is almost equal whether it is incinerated or landfilled.

Graph 2.4.14 and graph 2.4.15 provide an overview comparison in Scenario I and Scenario II respectively for all categories compared. The result show plastic as the highest impact in all categories in both scenarios.

Table 2.8 provides the data and assumptions and sources for End of Life of the product, and Table 2.9 provides the impact per functional unit for End of Life.
Part II: Economic Analysis
To understand the dynamic of the impacts in global market of plastic cutlery, economic analysis is important. This part of the paper discusses the commercial viability of the product, analyzes the factors influencing current restaurant industry with respect to purchasing cutlery and highlighting some of the issues faced by restaurants when it comes to sustainable flatware options.

SECTION 3.1: FACTORS INFLUENCING RESTAURANTS INDUSTRY

SECTION 3.2: PRICE COMPARISON OF SELECTED PRODUCTS
SECTION 3.1: FACTORS INFLUENCING THE NEED FOR SUSTAINABLE CUTLERY OPTIONS

The factors influencing the need for sustainable cutlery options in the restaurant industry are:

- The ever-growing market of restaurants industry.
- The number of people eating out.
- The cutlery market projections.

1) The growing Market of Restaurant Industry:

The National Restaurant Association projects that the restaurant industry sales will reach $798.7 billion by 2017. With the emergence of different types of eating choices, restaurants are categorized as: Quick-Service Restaurant (QSR), Casual-Dining Establishments (CDE) and Fast Casual Restaurants (FCR). For the scope of this project, only research and recommendations relating to quick service restaurants is provided. The quick service and fast casual restaurants are expected to raise a total of $233.7 billion by 2017 (National Restaurant). To complement this projection, the plastic packaging industry produces almost 18 billion spoons every year.

In California, there is about 27,120 quick service food restaurants. According to data shown in Green Restaurant Association, only 75 restaurants in California are certified green. This provides a huge market and projects the opportunity for sustainable options to be made available.

2) The number of people eating outside.

Another factor which influence the need for sustainable options to be made available is the growing population who choose to eat outside of home. According to Morgan Stanley report on millennials dining habits, millennials are the highest number of the population which spend at least one meal outside in a day (Figure 1.0, shown in Section 1.1). This increase of people choosing to eat out has put a demand for disposable options to be made available.

3) The cutlery industry projections:

The global plastic industry generates a revenue of about 650 billion dollars annually (Grand View Research). With respect to plastic disposable products, the revenue is projected to increase 3.9 percent per year to 21.9 billion by 2019 (Freedonia group). The main driver for this increase is the continuous demand from the quick service restaurant segment, which accounts for almost 80 percent of the total disposables. Comparing this projection to current bio plastic industry proves to be a huge gap. The report from Biodegradable plastic market by type indicates bioplastics industry is currently at a steady raise to a 3.4-billion-dollar industry by 2020 thus forming the basis that PLA spoons can be made available for restaurants in order to compete with the plastic industry.
To understand deeper of the issues regarding the economics of cutlery product, the prices of the selected products was analysed. The prices have been provided from the manufactures. From the above information, we can understand that bulk purchase of the products is the most feasible option compared to purchasing the product as single units. From an economical point of view, Aspenware and World Centric cutlery prove to be a cheaper compared to Prolon plastic cutlery thereby making it a much more feasible choice for reusable cutlery solution. Understanding that the cost is the main driving force behind the many choices that business in the food service industry make, we can assume that the sustainable options listed above prove to be much more economically practical option from an investment point of view.

<table>
<thead>
<tr>
<th>Item Description [Single Unit]</th>
<th>Price (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prolon Manufacturing LLC Spoon set</td>
<td>$4.99</td>
</tr>
<tr>
<td>World Centric Spoon set</td>
<td>$2.89</td>
</tr>
<tr>
<td>Aspenware Spoon set</td>
<td>$2.55</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Item Description [Bulk Purchase]</th>
<th>Price (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prolon Manufacturing LLC set (1000 pc.)</td>
<td>$2.99</td>
</tr>
<tr>
<td>World Centric spoon set(24 pc.)</td>
<td>$2.58</td>
</tr>
<tr>
<td>Aspenware spoon set (1000 pc.)</td>
<td>$1.78</td>
</tr>
</tbody>
</table>
Part IV: Health Implication of Plastics
Most advances of human society over the past century have been facilitated using plastics (Plastics Europe, 3). However, the widespread use of plastics facilitates continuous contact of these materials with the human body and with it daily exposure to ingredients in plastics. Biomonitoring studies have demonstrated the presence of steady-state concentration of plastics’ components in the human body, thereby reflecting the ongoing balance of constant exposure, metabolism and excretion of these compounds (North and Halden, “Plastics and Environmental Health”). This situation implies that in today’s plastics-enabled society there are no control groups to be found to analyze the effects on human health from low-level, environmental exposures to plastic constituents.

Humans are exposed to these chemicals not only during manufacturing, but also by using plastic packages, because some chemicals migrate from the plastic packaging to the foods they contain. Examples of plastics contaminating food have been reported with most plastic types, including Styrene from polystyrene, plasticizers from PVC, antioxidants from polyethylene, and Acetaldehyde from PET. (Heath effects of Plastics, 1)
The issues surrounding the toxicity nature from the single use plastics on humans are primarily due to their use in packing food stuff. (Zamin, 2) The use of polystyrene in disposable cutlery has been widely speculated to cause irritation in eyes, nose, throat and can also cause dizziness and unconsciousness. The Center of Disease Control reports have stated that workers exposed to large amounts of styrene (which is raw material used to produce polystyrene) can develop irritation of the eyes and breathing passages. With long-term and large exposures, workers using styrene have had injury to their nervous systems (Center of Disease Control Fact Sheet). Small amounts may be eaten when styrene migrates into foods from packaging made of polystyrene.

Due to the different manufacturing process, different plastics have different levels of these toxins. Figure 4.6 shows the different icons used on food grade plastics to guide consumers about the safety of the plastic constituents.
Plastics degrade very slowly in the environment. Plastic cutlery has a degradation period lasting until 1000 years because of their complex intermolecular bonds. Because of their low density they also tend to float in water. Hence plastic cutlery is found in water bodies. The plastics that enter our water-bodies like lakes and river, continue to get leached on their journey downstream to the oceans. Sometimes they may be inadvertently eaten up by fishes and sea animals. These organisms often die from the harmful physical and chemical impact of these chemicals. For those that survive, this results in the accumulation of toxins in their bodies. If they are a part of our food chain, then biomagnifications cause the accumulation and display of harmful effect on the human body. Hence what we inadvertently dump into the environment, comes back to harm us in a much more concentrated form.

Plastic cutlery collected through Municipal Solid Waste get discarded in the landfill. Landfills pose a threat to its neighboring communities directly effecting their health. As per available data from the California based, Algalita Marine Research Foundation (AMRF), plastics in the world’s oceans weigh over 100 million tons. Eighty percent of these are from watershed regions of the world. These are contributed by improperly disposed plastic waste on the streets, garbage left by the beech visitors and unused plastic pellets lost during plastic manufacture. They have noted plastics waste circulate there for the at least 12 years. Photodegradation does help break the floating debris over time, however plastics that are not light enough sink to the floor. They do not degrade that quickly and continue to trap and kill fishes (Wallace, 262).
Part V: Recommendations
To decrease the dependence on single use disposable cutlery especially in the restaurants and take out places, this section of the paper discusses few steps that can be taken from the client perspective, the business perspective and the public stand point.

1. Educate restaurants about the Green Restaurant Association Certification Program to promote sustainability.

Green Restaurant Association is a rating system which provides a transparent way to measure each restaurant’s environmental accomplishments, while providing a pathway for the next steps each restaurant can take towards increased environmental sustainability. This rating system is for manufacturers, restaurants and distributors of the food industry and certifies restaurants on seven environmental categories such as: Water Efficiency, Water Efficiency, Waste Reduction and Recycling, Sustainable Durable Goods & Building Materials, Sustainable Food, Energy, Reusables & Environmentally Preferable Disposables and Chemical and Pollution Reduction. Interested applicants can enter via their webpage all the documents for review.

The certification is provided based on total credits called GreenPoints awarded in each of the seven categories and the level of distinction is given to the restaurants.

The level of certification is as follows:
- Level 1: Certified Green Restaurant
- 2 Star Certified Green Restaurant
- 3 Star Certified Green Restaurant
- 4 Star Certified Green Restaurant
- SustainaBuild TM Certified Green Restaurant

2. Community organizations can approach restaurants and schools by giving them trial packets of sustainable cutlery and see how it affects the waste generations and finances. Review long-term vs short-term financial projections on a regular basis to evaluate the changes that can be instituted.

3. Educational workshops or programs in schools and restaurants about the use of plastic products and its harmful effects. Enabling school curriculum to include how to live plastic free workshops to encourage the youth and adults to reduce their dependency on plastics.
The key is developing the alternatives to conventional plastics and promoting them for use. Only once it is widely prevalent in the society, should we consider a ban on conventional plastics.

Since use of single use plastic have become so integrated in our way of life that the legal option to drastically cut its use is going to be a very arduous task. The debates over cost effectiveness of plastics versus the alternatives may not be that simple to begin with but a step taken in the right direction. Especially since, there is something immeasurable at take i.e. a better future for our environment in the decades to come.

FUTURE STEPS FOR BUSINESS

1. Restrict giving cutlery along with take-out food or delivery.

2. Promote the use of alternative resources of cutlery such as bamboo or wood instead of plastic.

3. Consider getting in touch with the local plastic free brands or organization which can guide you to select plastic free cutlery.

4. Get active with your community’s chamber of commerce or other business groups to encourage others to move toward zero waste, and adopt measures to reduce single-use, disposable plastics.


Associate Plastics Manufacturing Europe (APME) An Analysis of Plastics Production, Demand and Recovery in Europe. 2006


Cal Recycle, 2015- The California Department of Resources Recycling and Recovery August 2015 Report


California Department of Resources Recycling and Recovery CalRecycle.AB341 Report to the Legislature, August 2015


