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Cradle-to-Gate Life Cycle Assessment of Compostable Coffee Lids

Nikhil N. Kamble[1], Gunavant K. Kate[2]

[1]Ph.D Student, DYP Institute of Technology, Department of Civil Eng., SP Pune University, Pune, Maharashtra, India- 4110182

[2]Assistant professor, SVPMs College of Eng., Department of Civil Eng., Pune, Maharashtra, India- 411018

Abstract: ***Single-serve coffee cups are occupying a growing share in the coffee market. They come with a combination of cup and a lid which are compostable in nature. The study evaluates the environmental impacts of compostable coffee lids through their entire life cycle, from the extraction of raw materials to the production of finished lids. ISO 14040 and ISO 14044 standards, along with Eco invent database and SimaPro software was used to carry out environmental impacts of compostable coffee lids. The type of lids considered was 80mm and the functional unit was 1000 lids produced. Inventory analysis was done on site. CML baseline method and World 2000 normalization method was used to assess the environmental impacts. The results of the LCA show that compostable coffee lids have lower environmental impacts than conventional plastic lids in many categories, particularly in terms of global warming potential and fossil fuel depletion. For 80mm paper lid electricity has the highest contribution in all the environmental impact categories which is more than 90% except for ozone layer depletion viz. 67.74 %. Suggestions regarding use of renewable energy and approach to local vendors for material were suggested for reduction of impact.***

Keywords: Coffee lids, Global warming potential, Life cycle assessment, SimaPro

1. Introduction

Currently, plastic is one of the major toxic pollutants in the world. The global plastic production shows an increase from 1950 to 2015, which is 407 million tons in 2015, a nearly 200-foldofproduction compared to 1950 [1]. Most of the plastics are manufactured for packaging used, and Low-Density Polyethylene (LDPE) type of polymer film is generally used for packaging. The global production of LDPE is second dominant among the plastic production, which was 64milliontons, while the waste generation of LDPE has become the first dominant which was 57 million tons, in 2015 [5]. Unfortunately, LDPE plastics are usually non-degradable, and it will cause the accumulated waste in landfills and in natural environment. Hence various sustainable means are developed that could replace theses plastic products easily and can be more environmental friendly. To prove they are environmental friendly there emissions needs to be quantified and life cycle assessment proves to be an important approach.

Life cycle assessment (LCA) is a tool that could be used to generate information on the environmental impacts of products, systems and many other projects [4]. Since it provides a standardized platform for analyzing product processes through an input-output approach and then identifying and quantifying associated environmental impacts, life cycle assessment (LCA) has become increasingly popular in the last decade as an instrument for environmental performance evaluation in the water sector [5]. Life cycle assessment (LCA) includes Life Cycle Impact Assessment (LCIA), which proves to be an asset to better performance in LCA studies. There are many impact assessment method packs available such as CML, Eco-indicator 99, ILCD 2011, Recipe, Eco-invent, etc. The impact assessment is done by using the following categories a Acidification, climate change, resource depletion, Eco toxicity, Eutrophication, Human toxicity, Ionizing Radiation, Odor, Ozone layer depletion, Photochemical oxidation, and Particulate matter.

2. Material and Methodology

ISO 14040 and ISO 14044 were followed for this LCA. The recommendations of the latest version available of SimaPro were used as an assessment tool along with Eco-Invent date base and CML baseline. Normalization method used was World 2000.

2.1 Goal and Scope

The targeted audiences of this LCA are Coffee lids producers, who are interested in an environmental sustainability assessment of compostable coffee lid. In particular, such an assessment needs scientific evidence about the main sources of environmental impact caused by materials and the potential reduction of environmental impact allowed by replacing the conventional materials currently used for the same applications. Accordingly, this study aims to support decision makers by 1) highlighting the environmental hotspots of compostable coffee lids and 2) knowing the environmental performances single use compostable coffee lids. To reach these two objectives, it is important to consider the entire life cycle of the product and, therefore, a cradle-to-gate LCA is performed. Figure 1 shows the system boundaries generally used in carrying out life cycle assessment in a Cradle to grave system boundary.

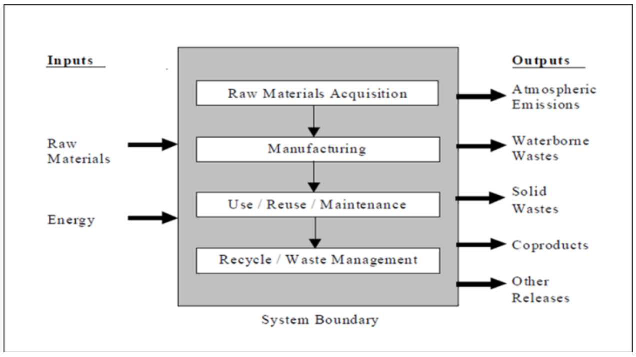

Figure 1: System boundaries in LCA

The goal of study is to carry out life cycle assessment for compostable coffee lids for environmental potential impact parameter assessment. Figure 2 shows the production process and system boundaries considered to carry out assessment for compostable coffee lids.

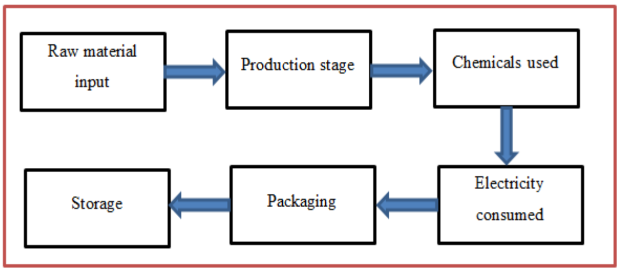

Figure 2: System boundaries

2.1.1 Scope of Study

The scope of the study describes the most important methodological choices, assumptions, and limitations. An LCA is an iterative process, one may start with a set of choices and requirements that may be adapted later when more information becomes available.

2.1.2 Functional unit:

An attribution approach has been taken in this study and the functional unit is 1000 lids produced. The weight of 1000 lids having a dia. of 80mm is 3.7 kg.

2.2 Life cycle inventory

In this section, the life cycle inventory is detailed. Figure 3 describes the processes of the compostable coffee lids production.

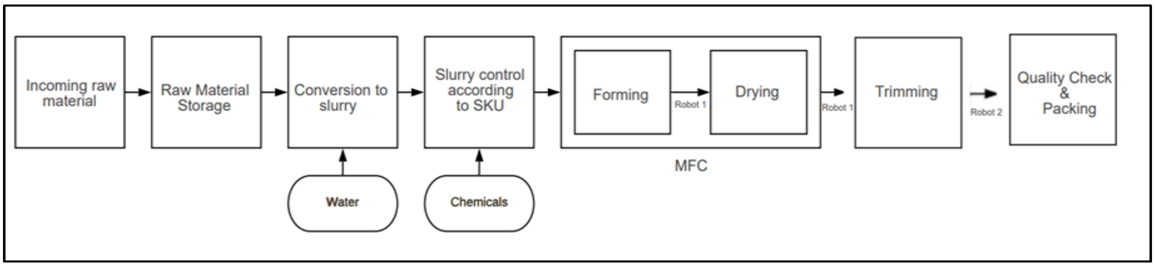

Fig -3: Production process for compostable coffee lids

The process starts with raw materials which includes Bagasse wheat rice straw in it. They were available in a dry state and are fibrous in nature. These raw materials are sent to the pulp mill where the pulp mill produces thick sheets of softwood and hardwood. Once the raw material is procured in the factors the process of stock preparation starts. The stock production process is divided into 5 parts.

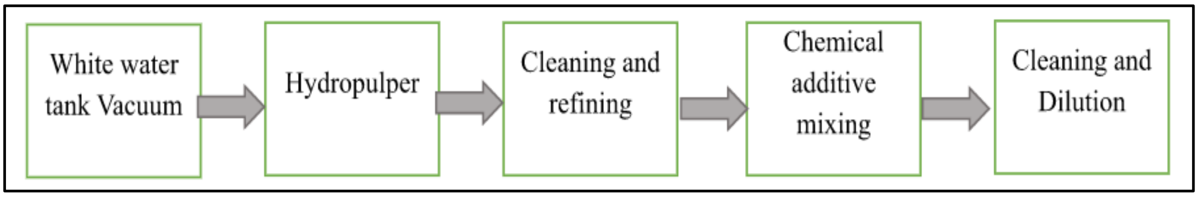

Figure 4: Stock production processes

The white-water tank vacuum provides clean water for the system and vacuum for the MFCs to operate. Bales of raw materials are loaded into a circular tank containing water called a hydra pulper. The hydra pulper has a very powerful agitator at the bottom which breaks up the bales into small pieces. The pulp mass created looks like thick porridge. It agitates pulp in water and breaks down it into wet pulp. Then cleaning and refining takes place. High-density cleaning using hydro cyclones and refining of the pulp to improve freeness is done. After this process, certain chemicals are added. As per the recipe, chemicals are added to improve strength, resistance to water and oil or grease and improvement retention of fine fibres. The process of stock preparation ends with cleaning and dilution. Centric leaner cleans the pulp further, which is then diluted with water to achieve required consistency by closed-loop feedback control.

Once the stock is ready it is pumped to the MFCs i.e. the Moulded Fiber Cell. The final output of MFC is the finished product with just a trimming left. MFC is divided into 6 steps

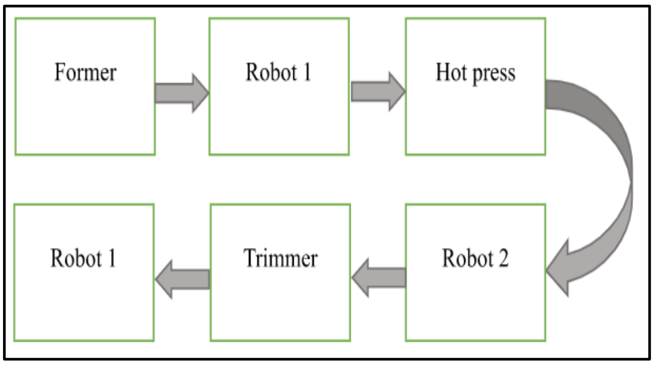

Figure 5: MFC Steps

MFC process starts with forming. The consistent pulp slurry is formed into shape over specially designed mesh moulds using a vacuum. 6 Axis robots are used for transfer of formed parts from former to one of 4 Hot Presses for drying. There are 4 no's of the hot press present in the MFC system. In the hot press, the wet parts from the former are dried with up to a 120 MT force & 200+ degree Celsius temperature. Again the 6-axis robot doubles up to transfer dried parts from the hot press to the trimmer. The dried-formed parts are trimmed at the edges to obtain smooth and perfectly shaped edges. Then the robotic assembly picks the finished product and lets it on a conveyer belt where manual picking and packaging of lids are done. Then the lids are packed into cartons and sent to storage facilities.

3. Life Cycle Inventory Analysis

Above table shows the data collected for 80mm compostable lid. The presented data is for 1000 pieces of 80 mm lid.

Table 1: Data collection for 80 mm compostable lid

Sr. No.	Section	Amount	Unit	Details
1	Pulpwood softwood	0.0017	Cum	Raw material
2	Pulpwood hardwood	0.0038	Cum	Raw material
3	Lubrication oil	0.049	Kg	For machines
4	Water	57.5	Liter	Used for slurry
5	Isobutyl acetate	0.093	kg	Used as solvent
6	Hydrogen peroxide	0.00744	kg	Chemical
7	Transportation	1395	kgkm	Mumbai port to Paithan MIDC (3.7*377km)
8	Transportation	83953	kgkm	Canada port to Mumbai port (3.7*22690km)
9	Transportation	2.47	kgkm	Local (164.44 grams*15)
10	Electricity	59.2	kWh	Consumption

Impact Assessment

To identify and evaluate the amount and significance of the potential environmental impacts arising from the LCI, the inputs and outputs are assigned to impact categories. CML-IA will be used in this study as LCIA methodology. This LCA methodology was developed by the Centre of Environmental Science (CML) of Leiden University in The Netherlands. This method is an update of the CML 2 baseline 2000 and released by CML in April 2013 (version 4.2). The CML-IA (baseline) method elaborates the problem-oriented (midpoint) approach. SimaPro software version 9.4 has been used in the study.

Table -2: Studied Life Cycle Impact Category

Name of Impact Category	Unit
Abiotic depletion	kg Sb eq.
Abiotic depletion (fossil fuels)	MJ
Global warming (GWP100a)	kg CO2 eq.
Ozone layer depletion (ODP)	kg CFC-11 eq.
Human toxicity	kg 1,4-DB eq.
Fresh water aquatic Eco toxicity.	kg 1,4-DB eq.
Marine aquatic Eco toxicity	kg 1,4-DB eq.
Terrestrial Eco toxicity	kg 1,4-DB eq.
Photochemical oxidation	kg C2H4 eq.
Acidification	kg SO2 eq.
Eutrophication	kg PO4 eq.

4. Results and Conclusions

Coffee lids play a vital role as they keep the product warm and spill-proof. These lids are designed with innovative technologies and are made from compostable paper as they are gaining importance in the market since they are sustainable and compostable. LCA of this lids can prove beneficial as a) identifies opportunities to improve the environmental aspects of products b) decision-making in industry, governmental or non-governmental organizations (e.g. strategic planning, priority setting, product or process design or redesign) c) marketing (e.g. an environmental claim, Eco labelling scheme or environmental product declaration).

Electricity has the highest contribution in all the environmental impact categories. Considering global warming potential highest impact is 98.63% and the lowest is 0% due to the transportation of lubricant and packaging products which are bought locally. As seen in figure 6 Ozone layer depletion has 97.74% of impact again due to electricity and abiotic depletion has highest impact 52.59% due to use of vehicles for transport.

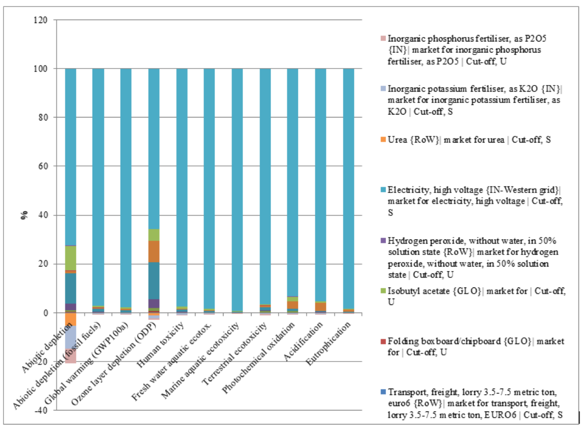

Figure 6: Impact results for 80mm coffee lids

The LCA study states the impacts associated with each individual process of the coffee lid. The impacts are evaluated under eleven different categories. From the study, it was clear that the highest contributing parameter was electricity. For 80mm paper lid considering global warming potential highest impact is 98.63% and the lowest is 0% due to the transportation of lubricant and packaging products which are bought locally. Ozone layer depletion has 97.74% of impact again due to electricity and abiotic depletion has highest impact 52.59% due to use of vehicles for transport.

These impacts can be controlled by redesigning the production process for better efficiency. Sustainable sources of energy such as installation of solar panels for electricity production or small-scale windmills can lead to reduction of consumption of electricity from the MSEB and apparently will reduce the impacts. Impacts from transport can be reduced by approaching local vendors; this can lead in reduction of transportation distances which will lead to reduction of fuel consumption. The compostable lids can be used as bio fertilizers and it can reduce the dependence on chemical fertilizers. Government can take separate initiatives for collection of such compostable lids from various locations and convert into bio fertilizers.

Acknowledgement
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