Life cycle assessment of production of Polyhydroxyalkanoates using agro-industrial waste as a carbon source

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Polyhydroxyalkanoates, or PHAs, are polyesters of microbial origin with high molecular weight that are synthesized by bacteria. In contrast to traditional plastics, these biopolymers are eco-friendly because they can decompose completely into non-toxic substances, such as carbon dioxide and water. PHAs present a very broad spectrum of features and potential applications, ranging from agricultural to medical. Issues of economy of scale remain a key barrier to their wider adoption owing to the high cost of production associated with the use of refined carbohydrates as a carbon source. In order to address such issues, agro-industrial waste, which is carbon-rich and frequently underused, provides an inexpensive feedstock alternative for PHA synthesis. Businesses cut down on production expenses while at the same time alleviating problems of waste disposal. With additional evolutionary engineering the amount of PHA produced can also be increased by using improved microbial strains. Further biomolecules generated from PHA can also be utilized in various ways in addition to their useful properties such as biodegradable polymer. The development of such PHA valorization techniques contributes to the increase of their circular economy perspective making them a more preferable material from both environmental and economic point of view. The demand to progressively turn towards polymers based on renewable resources stems mostly from their supposed benefit regarding ecological performance over fossil fuels. This issue generally focuses on the idea that products derived from renewable materials possess an inherent ecological advantage compared to those generated from other sources, particularly fossil fuels.

This assertion, however, has to be supported by investigating the ecological effects of manufacturing a good from the raw material generation to the delivery of the end product along the complete life cycle. Only comprehensive, measurable information about the ecological performance of products can come from extensive life cycle assessments (LCA), so addressing the topic of any superiority of bio-polymers about their environmental implications. The main aim of this study is the evaluation of non-renewable energy use, greenhouse gas emissions, eutrophication potential for the PHA production. These results have been compared with the existing studies.

Materials and methods:

The study presents a “cradle to gate” assessment using the ISO Standards 14040:2006 and 14044:2006. These standards states four phases of performing an LCA study: goal and scope definition, inventory analysis, impact assessment and interpretation. In the goal and scope definition, the goal should clarify the major application of the study, the reason for the study, the target factors, whether the result will be used in comparative allegations which are publically released. The scope reveals about the qualitative and quantitative information such as what is included in the study, how it is performed especially the functional unit, product system, system boundaries. The inventory analysis deals with the process modelling, and collection of all necessary data accounted for material,

energy, any other resources which are consumed or produced within the boundaries of the process set in the previous phase. In the impact assessment phase, all the results from inventory phase are converted into impacts on environment ecosystem, humans or resources with the aim to assess their importance. This work studies for the production of 1kg of PHA, which is considered equivalent to 1kg of fossil based polymers. The system boundaries includes the production of agricultural crops, their transportation to the industry, raw material extraction, fermentation and recovery of PHA. Emissions that take place during construction of production facilities, machinery and maintenance are excluded. The feedstock used here is from the agro-industrial waste which are very prominent source for the production of PHA and finally compared it with the corresponding impacts of the fossil based polymers.

Conclusion:

There is an ample evidence that the fossil based polymer production and management practices are not sustainable and caused irreversible damages to the environment. The major issues of concern is their degradation and this has driven an attention towards the bioplastics using renewable resources. The result presented in this study shows that the emissions associated with PHA production mainly depends on the raw material and the methodologies used. This results in estimations of emissions are significantly lower than that of the fossil based polymers. Thus, it is illustrated that PHA production is advantageous compared to its petrochemical counterpart. Further the use of alternative raw materials such as waste from food industry, wood industry may offer several advantages when combined with the development of integrated bio refineries.