Bioplastics: Does biodegradability have any ecological advantage per se?

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ABSTRACT
We analysed the environmental (dis)advantage of bioplastics with regard to their biodegradability in several studies. Data for composting and anaerobic digestion of bioplastics were derived from standardized composting and digestion studies. For the interpretation of the environmental impacts the ecological scarcity method was used for decision support and as a validation compared to the ILCD single score method. Biodegradability does not have an advantage per se from an environmental perspective. Composting of bioplastics leads to its disappearance in the best case. But there is no added value such as fertilisation or soil improvement (organic matter, humus) that normally occurs by composting organic waste. The same applies to digestate of bioplastics. Anaerobic digestion produces methane that can substitute natural gas. Whereas only about 60 % of the energy content can be "harvested" with anaerobic digestion, thermal exploitation in an incineration plant has higher yields. Biodegradability has no environmental advantage per se if compared to other end of life treatment options.

Keywords: bioplastics, composting, anaerobic digestion, thermal utilization, soil improvement

1. Introduction

The market of biodegradable bioplastics is growing each year. And the property biodegradable – among others such as renewable – is used for the promotion of their ecological benefits. Nowadays, many day-to-day consumer goods such as take-a-way packaging is made of biodegradable bioplastics. But how does the optimal end of life treatment look like – except for recycling which was not part of this study? Shall we compost biodegradable plastics, or put them to an anaerobic digestion plant, or is thermal utilization in an incineration plant also a advisable option? On behalf of the Amt für Umwelt und Energie, Basel (AUE) and the Amt für Abfall, Wasser, Energie und Luft, Zürich (AWEL) a study was done answering these questions.

2. Methods (or Goal and Scope)

Goal and Scope

The goal of this study was to analyse the end of life treatment options anaerobic digestion, thermal utilization or composting of biodegradable bioplastics by means of life cycle assessment. As functional unit 1 kg of biodegradable bioplastic was chosen. Only processes of the waste streams were included. The production and the use phase of the bioplastics were excluded because they are outside the system boundary and not necessary to answer the questions of the study. The different end of life treatments deliver different products: methane and digestate for anaerobic digestion, electricity and heat for thermal utilization and some sort of compost for composting. In order to make the end of life treatments comparable, credits were given for the different products assuming that they replace similar products on the market (e.g. electricity from a thermal utilization plant replaces otherwise produced electricity etc.).

Inventory data

Data for composting were derived from Pladerer et al. (2008). Data for anaerobic digestion of bioplastics are based on a preliminary study about the degradability of bioplastics in anaerobic digestion plants. In this preliminary study the actual degradability rates and methane yields were measured under standardized digestion settings (Baier, 2012).

Data for energy recovery in incineration plants were taken from the Rytec report (2013) on energy efficiency of Swiss incinerations plants.

The data and methodology of Dinkel et al. (2011) described in Zschokke et al. (2012) was used to derive credits for organic matter.

Impact assessment methods

Different environmental impacts were analysed. But in order to guarantee sound and effective decision support aggregated single-score results were used (Kägi et al., 2016). Therefore, the ecological scarcity method (Frischknecht & Büsser Knöpfel, 2013) was used for the interpretation of the environmental impacts. This method was also used as a validation compared to the ILCD single score method (European Commission-Joint Research Centre, 2011), using the weighting scheme suggested by Huppes et al. (2011).

3. Results

Figure 1 shows the overall results of three end of life treatments of the three bioplastics polylactic acid (PLA), starch blend and cellulose acetate. It is obvious that incineration is always among the best end of life treatment options, whereas composting seems always to perform worst.

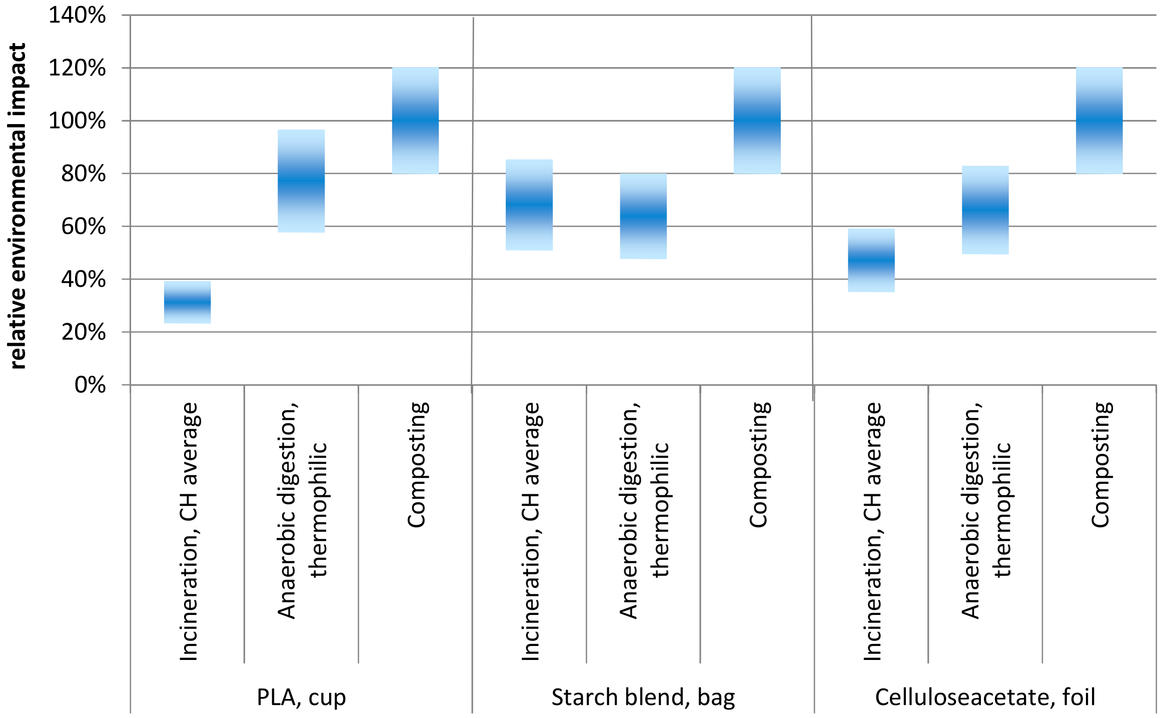

Figure 1: Relative environmental impact of different end of life treatments of bioplastics (PLA, starch blend, cellulose acetate) using the ecological scarcity method 2013 and the basket of benefits concept.

The reason can be better understood in analysing figure 2 which shows the environmental impacts and benefits of different end of life treatments of bioplastics such as cellulose acetate and biomass (example of palm leave; presented here to better understand credits for organic matter).

Inspecting the environmental impacts due to emissions only (figure 2, example of cellulose acetate), incineration shows the highest impact due to air emissions followed by anaerobic digestion and composting. For biomass (figure 2, palm leave) the results look differently: Anaerobic digestions and composting show higher impacts than incineration mainly due to the heavy metal emission to soil (digestate and compost). As there are no such heavy metals in bioplastics, the corresponding emissions do not exist at all.

Looking at credits only with the example of cellulose acetate, incineration shows the highest credits due to sold electricity and heat (replacing marginal electricity and heat), followed by anaerobic digestion with credits for sold biogas (replacing natural gas in a co-generation plant). The biogas credits are lower because – among other reasons – only a certain fraction of the embedded energy is transferred to methane (the remaining carbon is transferred to CO_2 or is not converted at all and remains in the organic residues). No credits are given for organic matter (humus) and for fertilisers. This stays in contrast to biomass, for which quite high credits are given. This is due to the fact that the considered bioplastics do not contain any substantial nutrients such as nitrogen, phosphorus, or potassium. They are also lacking any structural molecules that could lead to humus build-up or complex top soil structures. Humus is only formed if some sort of lignin or complexing agents are included, which is the case for biomass but not for bioplastics (Dinkel & Kägi, 2013; Zschokke et al., 2012). This implies that the carbon in bioplastic digestate or compost is weakly bound and will therefore be metabolised to CO_2 sooner or later.

Over all, the credits are higher than the impacts, therefore leading to negative total results as only the end of life step was considered. In general, the anaerobic digestion and composting show equal or worse results than the incineration path for bioplastics.

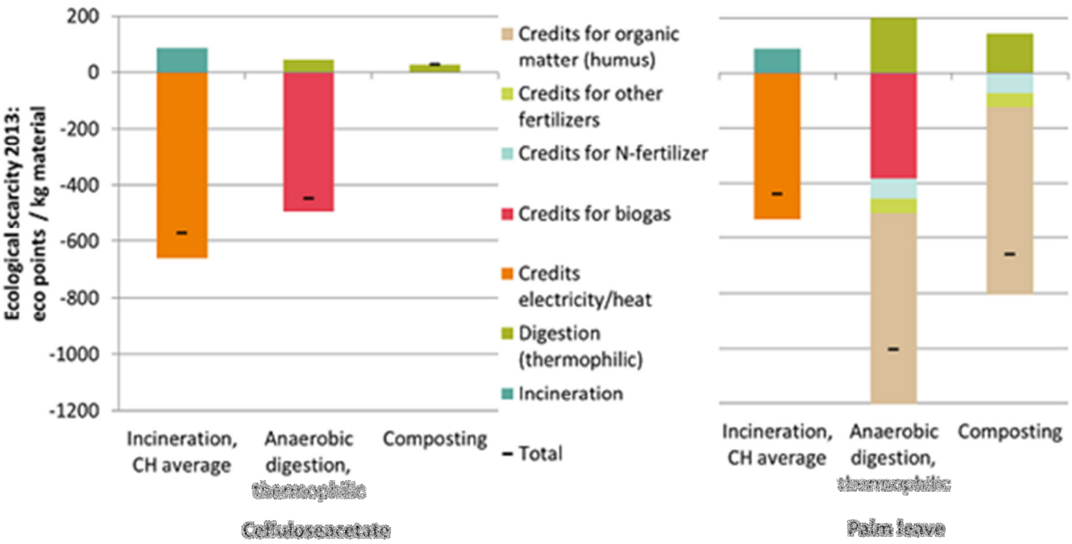

Figure 2: Environmental benefit of different end of life treatments of bioplastics (cellulose acetate) and biomass (palm leave) as an example for credits for organic matter using the ecological scarcity 2013 method and the avoided burden concept.

4. Discussion

Biodegradability does not have an advantage per se from an environmental perspective. Composting of bioplastics leads to its disappearance in the best case. But there is no added value such as fertilisation or soil improvement (organic matter, humus) which normally occurs by composting organic waste. The same is true for digestate of bioplastics. Anaerobic digestion leads to methane that can substitute natural gas. But whereas only about 60 % of the energy content can be “harvested” with anaerobic digestion, thermal exploitation in an incineration can mineralise almost all of the organic matter and shows always similar or even better results than anaerobic digestion.

5. Conclusions

Biodegradability has no environmental advantage per se if compared to other end of life treatment options. Biodegradability of bioplastics does not reduce the environmental footprint. On the contrary, the biodegradation of bioplastics often leads to higher environmental footprints compared to incinerating them. Our results are of course only valid for countries in which incineration is combined with energy recovery. In other countries where landfilling is normally employed and incineration plants are missing, the biodegradability of bioplastics may have advantages.

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