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Energy recovery from pyrolysis using non-recycled plastic

R. Skvorčinskienė*, I. Kiminaitė*, L. Vorotinskienė*, A. Jančauskas*

*Laboratory of Combustion processes, Lithuanian Energy Institute, Kaunas, LT-44403, Lithuania
(E-mail: Raminta.Skvorcinskiene@lei.lt)

Introduction

Today, our society faces a twofold problem: the depletion of resources and the accumulation of waste. Plastics amounts a large part of the waste stream, which is currently not utilized or managed correctly, especially in the context of the circular economy. According to the hierarchy for the management of plastics and other waste places the prevention, reduction or reuse ahead of recycling, but sees the energy recovery as the least desirable option but ahead of landfilling. Plastic Waste is also a major source of water pollution that causes serious environmental problems. This kind of waste is a source of harmful micro-plastic fibers when left on land, in water bodies, or in the litter. In today's perspective, most of the waste plastic is landfilled or incinerated, but this does not address the challenge of energy sustainability. Today's market dictates that conventional plastics should be replaced by bioplastics, but there is a lack of research on using bioplastics, making it still debatable whether bioplastics are more sustainable than conventional plastics (Figure 1). Since bioplastics are divided into three groups, as shown in Figure 2, each group has its own specificity and application. This research will address issues such as bioplastic thermal stability under pyrolysis environment. Moreover, there will analyze the decomposition process of substances by using thermal analysis (TG). This research aims to provide an overview of the field of bioplastic waste, discussing the challenges that may be faced in the near future, when demand will increase significantly.

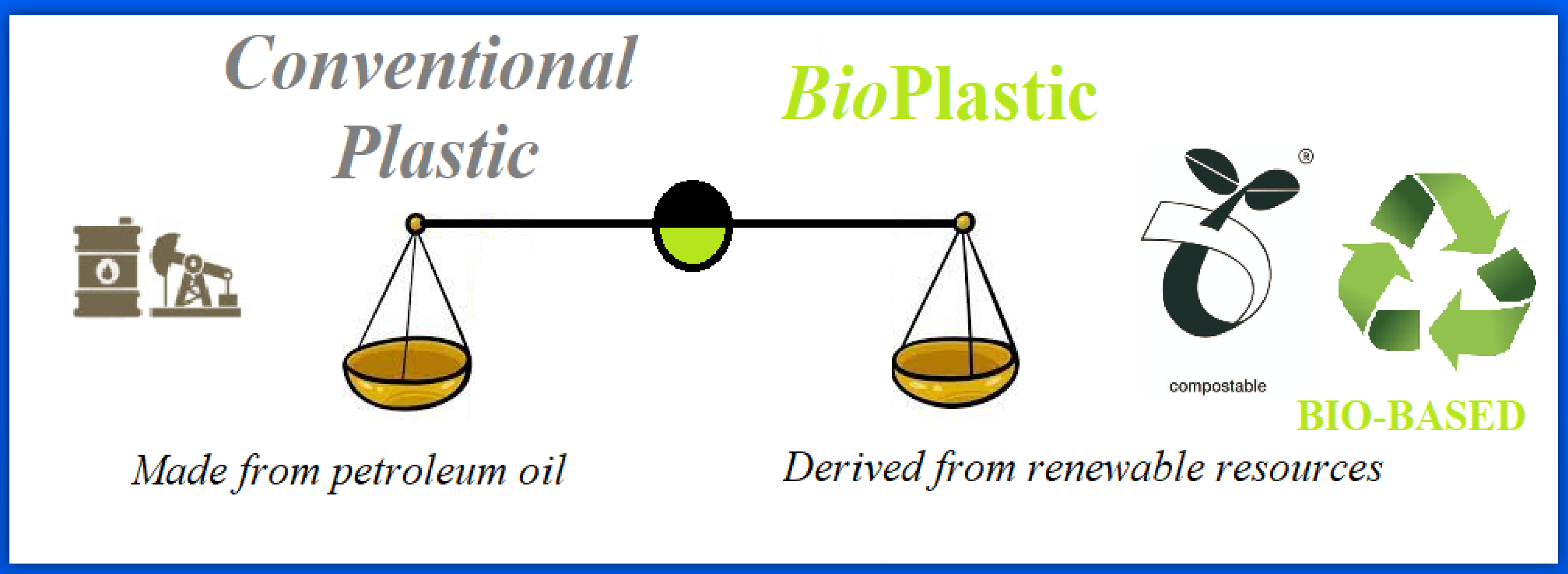

Figure 1: Comparison of plastics: which is more sustainable

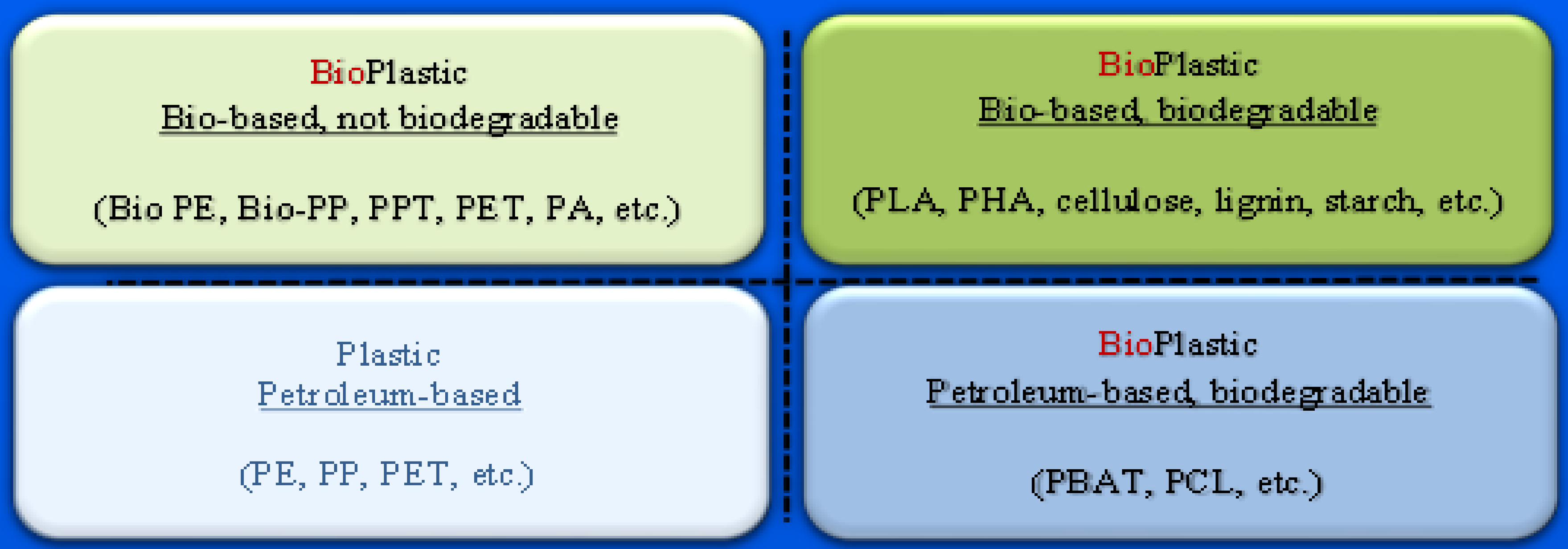

Figure 2: Types of bioplastics

Results & Discussion

The analysis will be carried out on 10 different samples (Table 1) that are used in the beauty, hygiene and packaging fields. Of these samples, three samples meet the definition of bioplastic and are bio-based and biodegradable, and three samples are bio-based but not biodegradable. One sample chosen is a petroleum-based bioplastic, which is supplemented with some materials needed for degradation. The remaining three samples are made of petroleum-based plastics, but there are several choices for recycled and not.

Table 1:Samples

No.	Product	Volume of recycled plastic	Type of plastic	Marking	Petroleum based plastic	Bio-based bioplastic	Biodegradable	Compostable	Recyclable	Properties	Labeling
TB1	Toothbrush bristles No. 1	0%	Bioplastic naylon-polyamide	PA	0%	100% bio-based nylon, originating	NO	NO	YES	Transparent, flexible, hard	OTHER
SCP	Sugarcane bioplastic bottle	0%	Bioplastic / polyethylene	Bio-based PE + petroleum based PE	47% PE	Sugarcane 53%	NO	NO	YES	Greyish brown, not transparent, hard,	OTHER
TB3	Toothbrush bristles No. 3	0%	Bioplastic naylon-polyamide	PA	2%	98% originating from castor oil plants	NO	NO	YES	Flexible, white	OTHER
TP	Dental floss holder (toothpick)	0%	Corn Starch / Polypropylene	PP+ corn	30% PP	70% corn starch	Partially	NO	YES	Black, slightly brittle, hard,	
CGB	Compostable garden bags	0%	Corn Starch	-	0%	100% corn starch	YES	YES	NO	Green, transparent	Biodegradable vs Compostable
FO	Biodegradable packing foam	0%	Corn Starch	-	0%	100% corn starch	YES	YES	NO	White, light, flexible, porous	Biodegradable vs Compostable
PWB	Pet waste bags	0%	Polyethylene / Reverte	HDPE+Reverte	100%+ REVERTE	0%	YES	NO	YES	Elastic, colored (blue, rosy)	2 HDPE
TB2	Toothbrush bristles No. 2	0%	NAYLON - polyamide	PA	100%	0%	NO	NO	YES	White, elastic, hard,	7 OTHER
TH1	Toothbrush handle	100%	Polyethylene terephthalate	RPET	100%	0%	NO	NO	YES	Greyish-brown, not transparent, hard	1 PET, 100%
TH2	Toothbrush handle	100%	Polyethylene terephthalate	RPET	100%	0%	NO	NO	YES	Green, not transparent, hard	1 PET, 100%

For a detailed analysis, the case for the heating rate of 3 °C/min was chosen and the obtained thermogravimetric (TG), the derivative mass loss (DTG) curves (Figure 3) during pyrolysis. In order to identify sample behavior depending on the base of material types, the obtained TG, DTG data were divided into four parts by bioplastic/plastic nature as shown in Figure 2. The firstly evaluated the thermal stability of different bioplastics upon processing at increasing temperature.

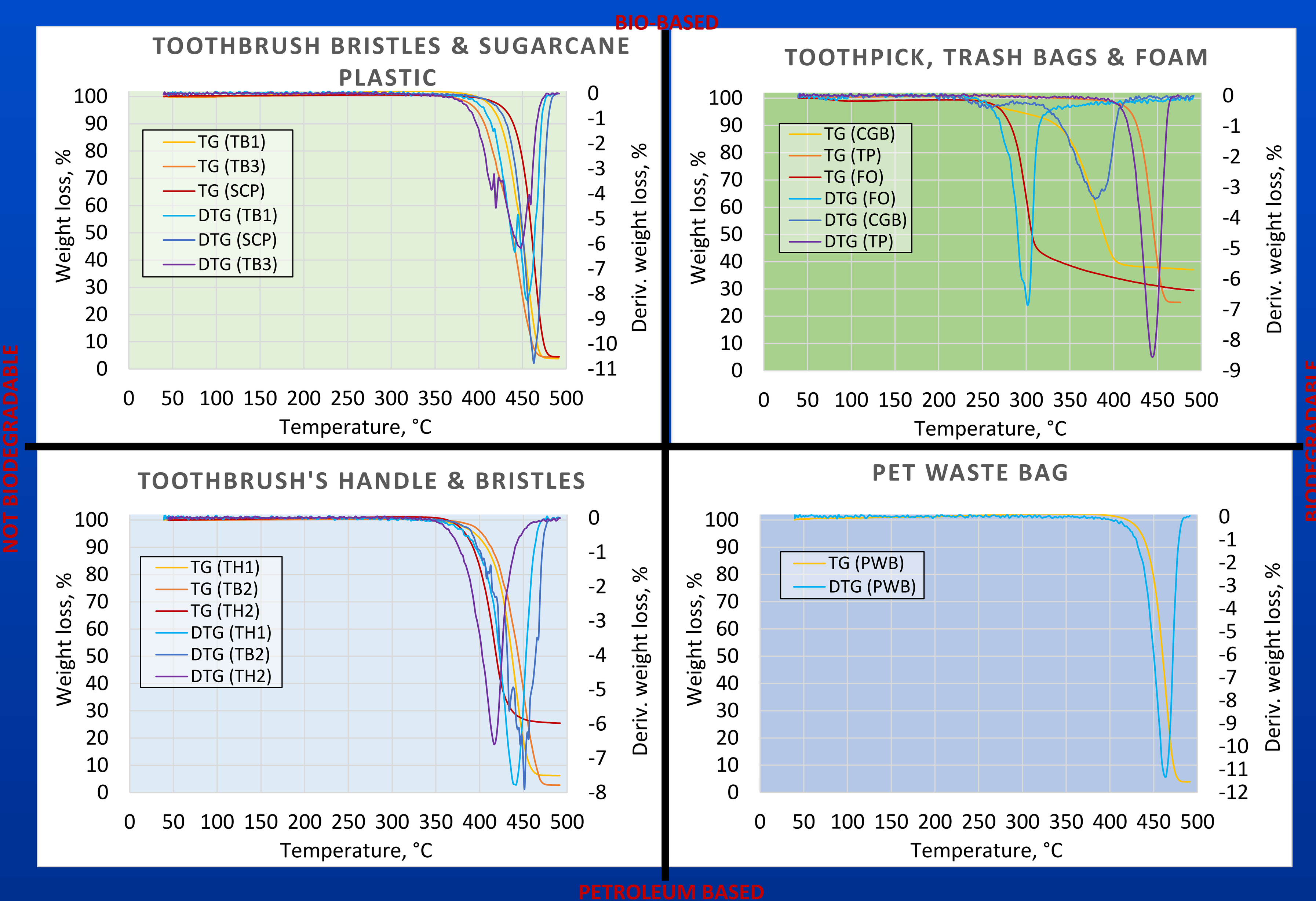

Figure 3: Temperature-dependent mass change and mass change rate at 3°C/min under nitrogen environment

The results were particularly surprising as all samples showed high thermal stability. There was established in the literature that the thermal stability of bioplastics might be in the range of 50-250 °C. However, the results showed that for a bioplastic to start to degrade it needs 270-300 °C and for another materials even 350-450 °C (Figure 3).

Based on the data obtained, it can be concluded that the bioplastic packaging available on the market is thermally stable, the properties extracted are sufficiently good and the degradation is in line with the degradation curves of petroleum-based plastics. Bio-based and not biodegradable bioplastic wastes could be considered suitable for thermochemical conversion into green energy. However, the extremely high thermal stability of biodegradable and compostable materials is a cause for concern, and degradation is likely to be longer than expected under specific conditions: humidity, air, temperature. Also, it was observed that these materials did not decompose completely to volatile substances, which can be explained by the large amount of residual mass.

Conclusions

Based on the obtained results, the following conclusions can be drawn: The literature indicates that bioplastics do not have a high thermal stability, but the results show that the thermal stability of the bioplastics tested is quite high. The degradation of the bioplastic was confirmed to start at 270-300 °C, and even at 350-450 °C for other materials. Bio-based and biodegradable bioplastics were also observed to have high thermal stability. The degradation of this group of bioplastics occurred at 400 °C, which was somewhat surprising as the degradation temperature of starch is around 300 °C. What was also surprising was the high amount of residual mass. In this case, despite the 100% composition indicated (corn starch), it can be assumed that a mass change would still be observed above 500 °C, indicating further degradation and heterogeneity of the material. The thermal stability of the other groups of bioplastics is in line with the decomposition trends of plastics-based petroleum.