

Valorization of degradation products stemming enzymatic and model-compost degradation of pre-treated PLA by advanced oxidation processes to bacterial nanocellulose

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Fossil-based polymers are still widely used due to their versatility, light weight, durability, and low production cost, leading to their uncontrolled disposal in the environment. Currently, these polymers represent the most common pollutants, accounting for 54% of all human generated waste material [1,2].

It is well acknowledged that microplastics are a major environmental problem and that the use of plastics, both petro- and bio- based, should be reduced. Nevertheless, it is also a necessity to reduce the amount of the already spread plastics. These cannot be easily degraded in the nature and accumulate in the food supply chain with major danger for animals and human life. It has been shown in the literature that advanced oxidation processes (AOPs) modify the surface of polylactic acid materials in a way that bacteria more efficiently dock on their surface and degrade them. In the present work we investigated the influence of different AOPs (ultrasounds, ultraviolet irradiation, and their combination) on the degradability of PLA films treated for different times between 1 and 6 hours.

PLA used in this study was received from Nature works, Ingeo (4043D). The crystallinity of the pellet was 35.2 %, the melting point 152.3°C, and MFR, 6 g/10 min. Prior to processing the PLA pellets were dried for 50°C for 5 h. Polymer pellets were pressed into films (ca. 1 mm thickness) using a Servitech Polystat 200 T compression press at 180°C. PLA samples pretreated with ultraviolet waves (UV) for 6 h, ultrasonic waves (US) with a frequency of 20 kHz and 860 kHz, as well as the combinations of UV and US treatments, were cut into pieces (1 cm x 2 cm), weighted, rinsed with 70% (v/v) ethanol and air dried. All samples were prepared in duplicates, including non-treated control PLA sample. Details on the sample preparation as well as on the pre-treatment methods can be found in our previous publications [3,4].

The pre-treated samples have been degraded using a home model compost as well as a cocktail of commercial enzymes at mesophilic temperatures (37°C and 42°C, respectively).

Biodegradation in model compost

Biodegradation of control and pretreated PLA samples was performed in model compost according to the previously described protocol [5,6]. Experiment was set up in glass Petri dishes (120 mm diameter, 30 mm height), in 150 g of compost per Petri dish. Samples were placed inside the compost at a depth of 1 cm. Petri dishes were incubated at 37 °C for 10 and 24 weeks, and the humidity of the compost was maintained around 50% by weight. At the end of experiment samples were rinsed with 70% (v/v) ethanol, air dried and weighted. Degradation degree has been measured and degradation products have been identified.

Enzymatic biodegradation

Enzymatic hydrolysis of PLA samples was performed using enzyme mix of alcalase 2.4 L FG (Novozymes, batch PLN05554), savinase (Novozymes, GHSFS-1-02-1) and 3 lipases (Serowar PL; Sigma, cat.no. 54327 and Sigma, cat.no. 52001). Enzyme mix contained 5 mg/mL of alcalase and savinase, and 1.5 mg/mL of each of lipases in 20 mM Tris- HCl buffer (pH 8.5) and was stored at -20 °C.

Excellent degradation of PLA films has been achieved with enzyme cocktail containing commercial alkaline proteases and lipases of up to 90% weight loss.

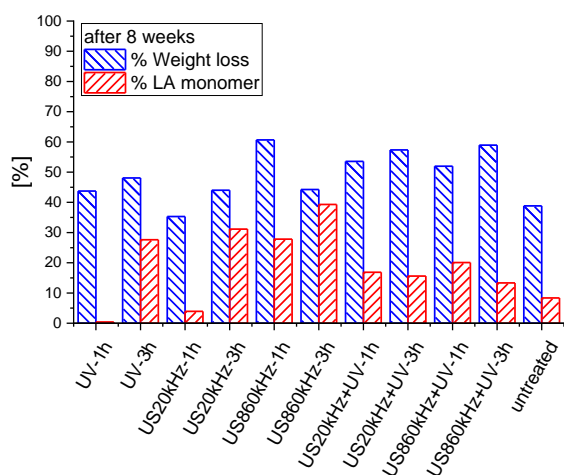


Figure 1: Weight loss in [%] of selected PLA samples after 8 weeks of enzymatic degradation and corresponding lactic acid (LA) monomer in [%] of weight loss.

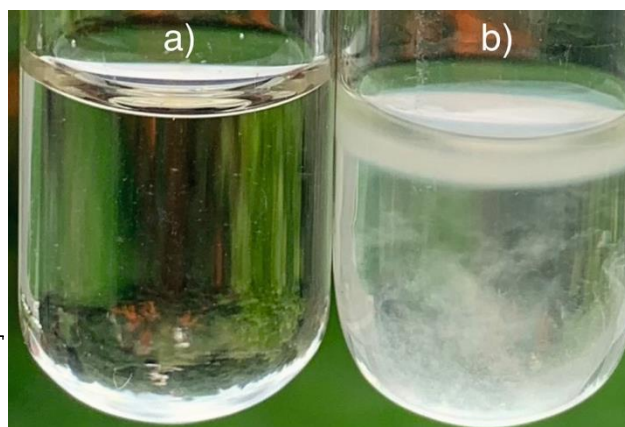


Figure XX. Bacterial nanocellulose production from PLA hydrolysates after three days of incubation: a) control and b) hydrolysate obtained after enzymatic degradation.

For the first time, we report valorization of PLA into bacterial nanocellulose after enzymatic hydrolysis of the samples. The enzymatic degradation degree using enzyme cocktail has been measured and degradation products have been identified. Depending on the pre-treatment method between 1.8 and 4.3 g/L nanocellulose have been produced.

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