BIOCOMPOSITES OF POLYLACTIC ACID (PLA)/CELLULOSE TO GENERATE VALUE-ADDED PRODUCTS

Roberto Cárdenas Zapata[1*]; Diana Palma Ramírez [2]; José Jorge Chanona Pérez [1]; Josué David Hernández Varela [1]
1 Instituto Politécnico Nacional - IPN, Escuela Nacional de Ciencias Biológicas (ENCB), México.
2 Instituto Politécnico Nacional - IPN, Unidad Profesional Interdisciplinarias de Ingeniería (UPIIH), México.
*rcardenasza@ipn.mx

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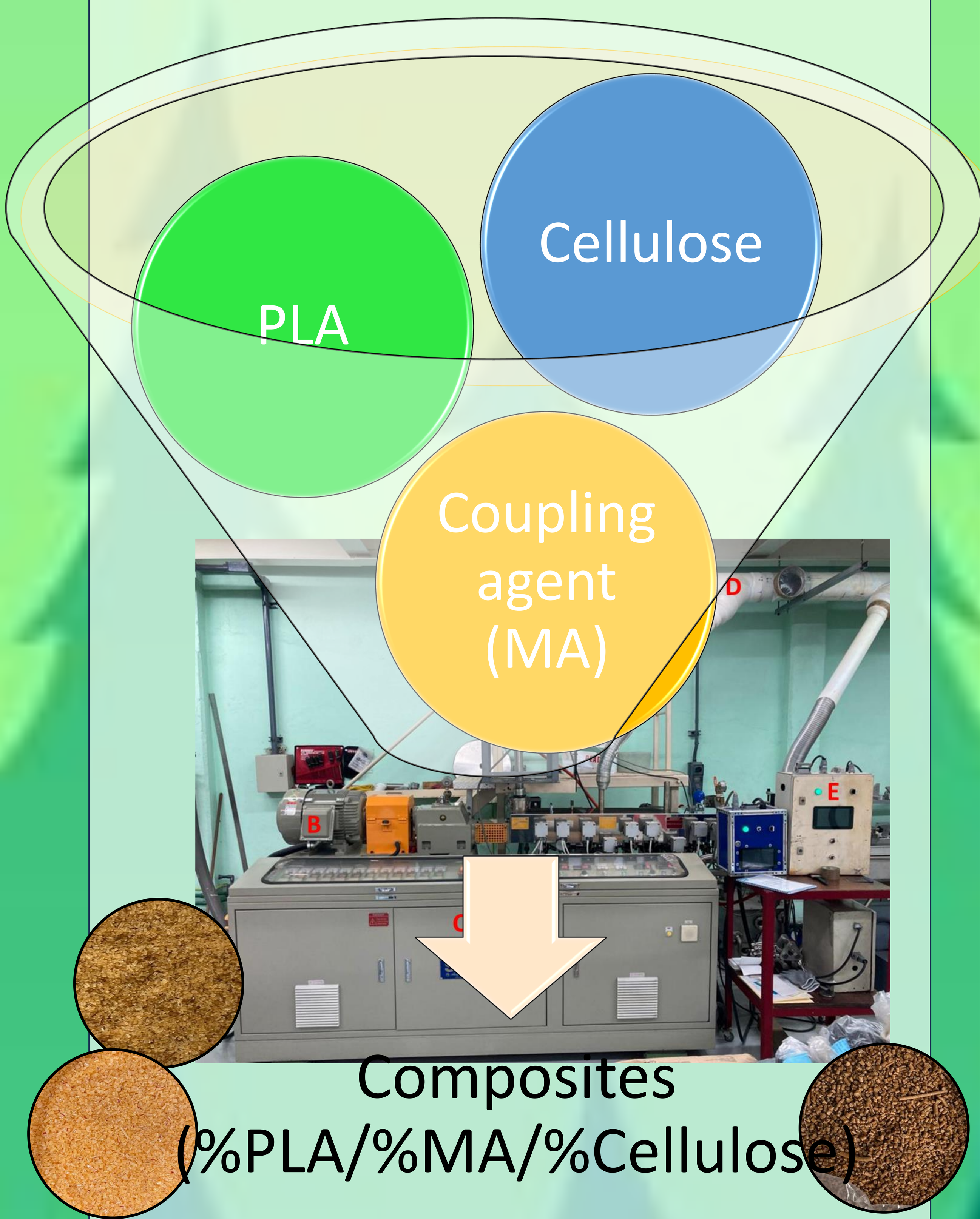
Introduction

The reduction of pollution associated to plastic industry considers three main axes, the migration fossil materials into biopolymers renewable sources, the energy efficiency and use of renewable energy, and the final disposition of the plastic product. Each one presents its problems and limitations, for example, high amounts of biopolymers to replace the conventional plastics or the lack of studies about specific energy consumption during the production process depending on the polymer. In this sense, we propose a composite of PLA and cellulose extracted from pine sawdust, the study of extraction is a previous work. Then, different formulations of PLA, cellulose and maleic anhydride were prepared via reactive extrusion in a twin screwdriver.



Methodology

- BIODEGRADABILTY

Biodegradability study according to the ISO 14855-2. Determination of the ultimate aerobic biodegradability of plastic materials under controlled composting conditions—Method by analysis of evolved carbon dioxide.

Figure 1. Biodegradation system for CO_2 evolution. (Top) System. (Bottom) Biological reactors

- ENERGY EFFICIENCY

Energy consumption was monitored using a triphasic energy meter (Fluke® 434 B multi-phases) that allows real-time monitoring of voltage, energy demand and other relevant variables. The total specific energy consumption (SEC) includes the consumption of the motor, the heating barrel, the cooling system and the control panel.

$$SEC = \frac{Required\ energy\ (kWh)}{Feed\ (Kg)}$$

- MECHANICAL ANALYSIS

After extrusion, the blends were dried for 24 h at 40 ◦C before injection molding into tensile specimens. Specimens were Type I dog-bones according to ASTMD-638. To determine the optimal formulation of composites for processing a biodegradable plate, a response surface methodology (RSM) was used, incorporating data on both mechanical and rheological properties. The response variables selected for this study included Shore D hardness, tensile strength, Young's modulus, strain percentage, and melt flow index (MFI).

Results

Biodegradability

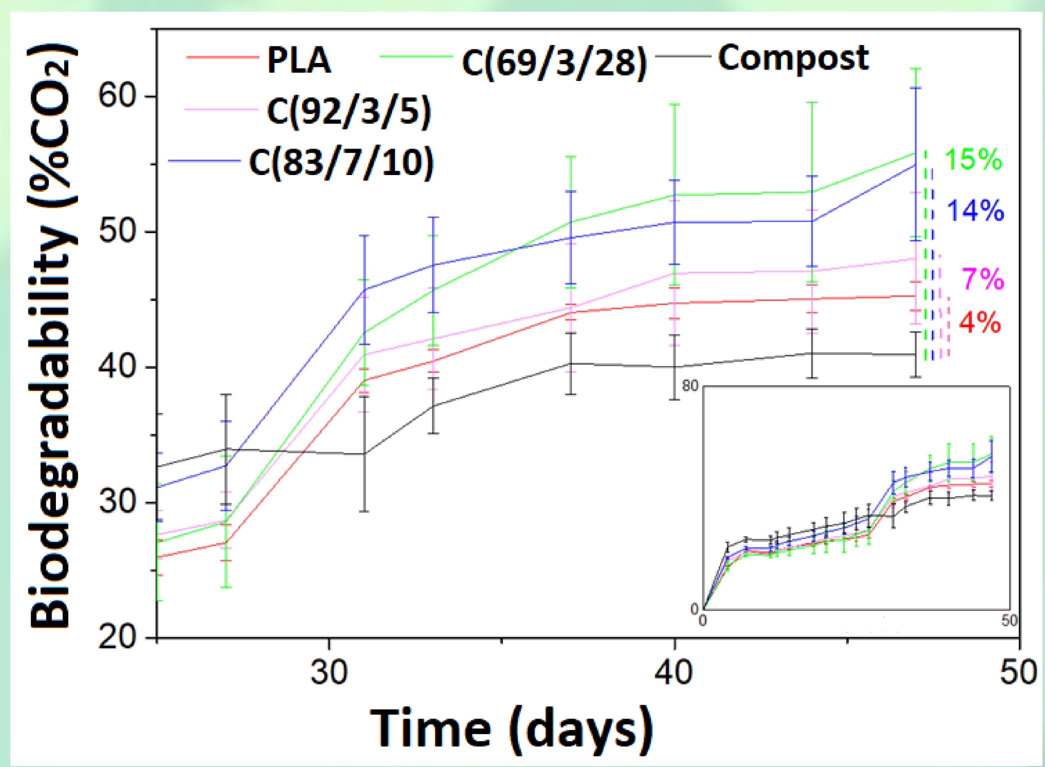


Figure 2. Biodegradability of PLA and selected-PLA/PLA-g-MA/cellulose composites.

Specific Energy Consumption

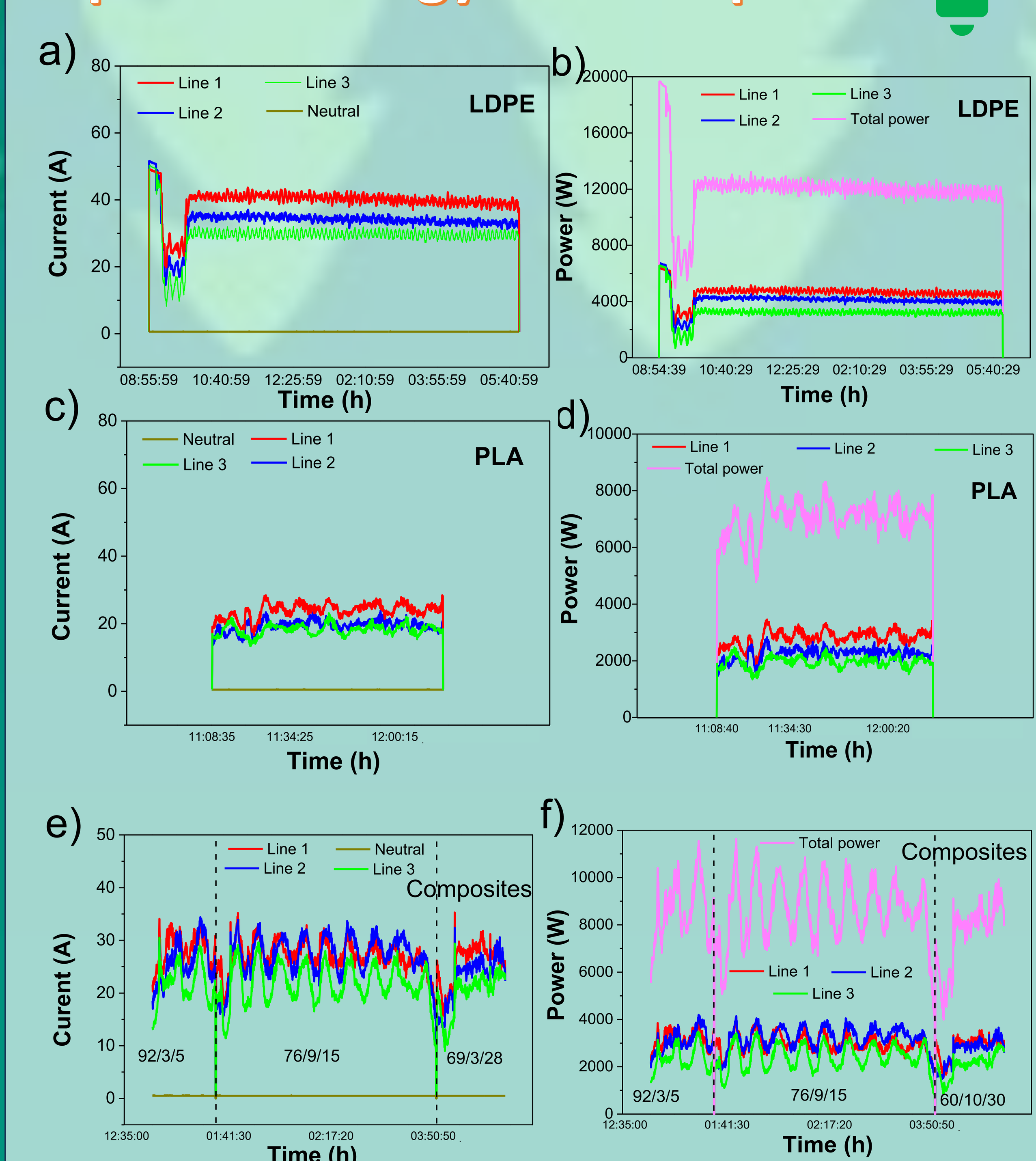


Figure 3. Energy demand during a work cycle of the twin screw extruder a, c, e) currents at each line with respect to the neutral and b, d, f) measured active power of each line for LDPE, PLA and composites.

Results

Table 1. Energy consumption analysis

Material	Power (kW)	Charge factor (%)	Feed (kg)	SEC (kWh/kg)
LDPE	11.35	92.32	105.42	1.78
PLA	7.09	57.65	5	1.11
C(92/3/5)	8.94	72.72	1.5	1.78
C(76/9/15)	8.69	70.63	6	1.68
C(60/10/30)	7.56	61.45	1.5	1.34

Mechanical analysis

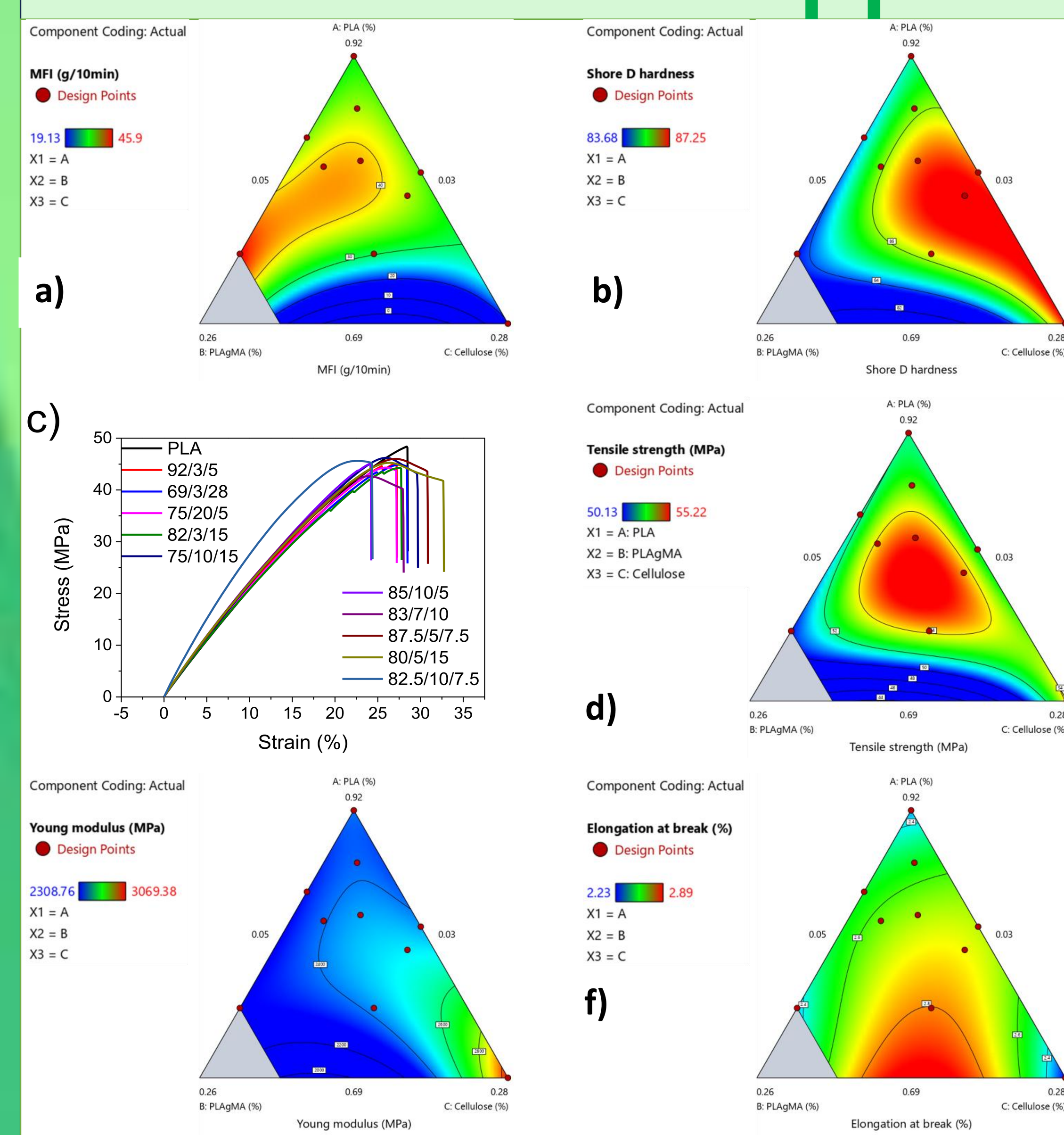


Figure 4. Contour plots of a) MFI, b) hardness, c) stress vs strain plots, d) 6, d) E and e) εb.

Table 2. Properties comparation

Material	Shore D hardness	6 (MPa)	E (MPa)
PLA	83	48	2309
Optimal formulation	87	55	2470

Conclusion

The ideal formulation was determined using the global desirability function, which optimized Shore D hardness, tensile strength, and E modulus. The resulting mixture consisted of 76 wt% PLA, 9 wt% PLA-gMA and 15 wt% cellulose. This formulation achieved a slight increase in Shore D hardness (4.5 %) and E modulus (5 %), while also resulting in a minor decrease in tensile strength (6.1 %) compared to pure PLA.

Figure 4. Ideal formulation injected.

Also, monitoring of the biodegradation indicated that a higher cellulose content enhances biodegradation capacity, as evidenced by increased CO2 production. Conversely, the SEC during the extrusion process for the composites was greater than that for PLA; however, the optimal formulation's SEC was still lower than that of LDPE at 5.6 %

Complete work