Poly(Lactic Acid) / Poly(Hydroxyalkanoate) Nonwovens as Biodegradable Agricultural Mulches

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Introduction

- ➢Plastic mulching is commonly used worldwide for the production of specialty crops : (i) Increasing soil temperature (ii) Reducing weeds; and
- ➢(iii) Providing a microclimate (water and soil conservation)
- ➢Traditional mulches, often made of polyethylene (PE),are **non-biodegradable** and **extremely difficult to remove after their usage in fields because of fragmentation**.
- ➢Furthermore, landfills seldom accept PE mulches. Therefore, the idea of biodegradable mulches(BDMs) was conceived in the1980s.
- ➢**Currently available products are frequently not biobased; their biodegradability in ambient soil consditions is not known**
- ➢Plastic mulches using nonwovens technology with PLA, a biobased polymer, as major component have been prepared by us.
- ➢**Nonwovens technology** is used to prepare material consisting of long PLA based fibers that are bonded together by chemical, mechanical, heat or solvent treatment.

Objectives

1. ***Determine the effect of soil moisture and hydrolytic enzymes on the biodegradation of nonwoven PLA and PLA-blend-PHA mulches via 30 week soil burial studies conducted in a greenhouse .***
2. ***Determine the effect of composition (%PHA in PLA-enriched feedstock), nonwovens type, and color on weathering (weatherometry)***
3. ***Determine the effect of weathering and mulch composition and nonwovens type on microbial assimilation***

Materials & Methods

➢**Nonwoven PLA Mulches:**

▪**Spunbond (SB) 100%PLA:** Contains relatively large fiber diameters (14.8±0.08µm, SEM analysis), bonded by heat, providing it a relatively high tensile strength .

▪**Meltblown (MB) 0-25% PHA, 75-100% PLA:** The fine filaments of this material are made by molten extrusion. Fiber diameter = 6.3±0.23µm.

➢**1. Soil Burial Study: Effect of Moisture and Pineapple Juice (PJ)** (Univ Tennessee)

- Low Moisture (**LM**) - 500 mL of water / 48 h
- High Moisture (**HM**) -1000 mL of water / 48 h
- **PJ** - 30mL / 48 h

➢**Procedure**

i. *Soil from organic farm mixed with compost and laid in trays.*

ii. *Mulches are buried under 2cm in the soil bed in plastic trays 20.5"x10"x 2.25".*

iii. *The buried mulches were retrieved after 10 and 30 week(wk) period and cleaned (see Fig.1).*

❖ **Experimental design:** Randomized complete bock design (RBD)

2. **Weatherometry:** Ci4000 Xenon Weather-Ometer, ASTM G155-05a; exposure Cycle: 102 min light at 63°C; 18 min light and water spray Exposure time: 21 d (504 h); irradiance: 0.35 W m^{-2} nm^{-1}; 340 nm (Mich St. Univ)

3. Testing of microbial assimilation: % conversion of C → CO2 under composting conditions (58 C): ASTM D5338 (Mich St Univ)

Mulch burial, retrieval, and cleaning

Figure 1: Photographs showing **A.)** Experimental trays with mulches buried in greenhouse aligned. The total number of trays are **4** (mulches) * 2 (replicates) * 2 (sampling times) * 4(treatments) = **64**. **B.)**Sensors are inserted inside the trays to monitor the soil temperature and humidity **C.)** The process of removing mulches from plastic trays in the greenhouse (note that soil was removed by hand and mulches were rinsed with water), and **D.)** Nylon organza fabric supported on a wire mesh were laid over the mulches for cleaning with water after removed from trays.

RESULTS Greenhouse Studies

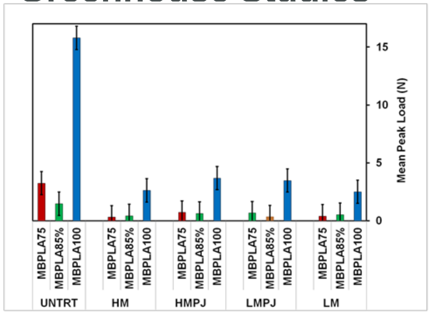

Figure 2: Change in peak load (tensile strength) of PLA mulches over 10 wk of soil burial. MB-PLA/PHA of 75%,85% and 100% showed a decrease in peak load for all the treatments. SB-PLA showed no decrease in peak load for all the treatments , 10 & 30 wk (not shown).

➢The peak load of 10 wk mulch samples decreased compared to unexposed or untreated mulches (Fig. 2). Due to high fragmentation, load could not be measured at 30 wk mulch samples is significantly high, except for Spunbond PLA. The latter showed no or little statistically significant decrease (data not shown).

➢GPC results indicated a 10-25% loss of number-averaged molecular weight (M_n) for MB-PLA(PHA (85/15 and 75/25); both 100% PLA nonwovens underwent a small, < 10% change in M_n.

➢SEM images confirmed the occurrence of fiber bond breakage in all the samples except Spunbond PLA.

➢There are other soil burial studies ongoing to determine the difference between films and nonwovens, increase of temperature of trays of soil and compost mixture, and kinetics of tensile testing as well as molecular weight.

➢FTIR: hydrolysis of ester bonds

➢See also a recent publication of our early soil burial studies: Wadsworth, LC, et al, *JEFF J*, 2012, in press

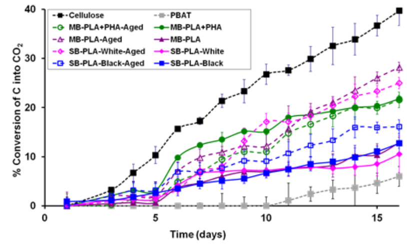

Figure 3: microbial assimilation of weatherometry-treated (21 days) and untreated PLA-based nonwovens mulches via ASTM D5388

Weatherometry and Microbial Assimilation

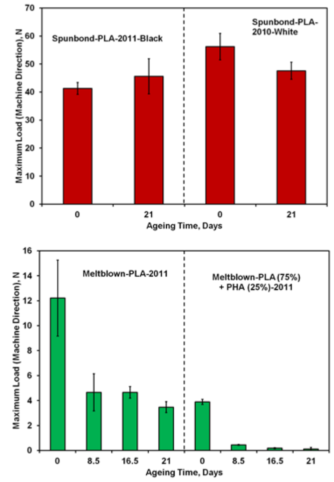

Figure 4: Effect of weatherometry treatment on tensile strength (breaking load)

➢All mulches are undergoing microbial assimilation under compost conditions (Fig 3)

➢Weathering greatly enhanced the extent of microbial assimilation between 0 and 16 weeks for most mulches

➢MB-PLA (75%) + PHA (25%) underwent the greatest extent of deterioration due to weathering:

➢97% loss of tensile strength 9Fig 4)

➢40% decrease of MW

➢SB-PLA-White and MB-PLA underwent slightly greater deterioration SB-PLA-Black (Tensile Strength, CO_2 release)

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Further Reading

➢ Hayes et al,, 2012, Biodegradable Agricultural Mulches derived from Biopolymers, ACS Symp Series (K. Khemani, C Scholz, eds), in press