OXO-BIODEGRADATION PROJECT

September 2014

Project: 1404003

TEST RESULTS

TESTING GUIDELINES

- **ASTM D6954-04 Standard Guide for Exposing and Testing Plastics that Degrade in the Environment**
- **ASTM D5510-94 (2001) Standard Practice for Heat Aging of Oxidatively Degradable Plastics.**
- **ASTM D5208-01 Standard Practice for UV Exposure.**
- **ASTM D3826-98 (2001) Standard Practice for Determining Degradation End Point.**
- **ASTM D882-09 Standard Test Method for Tensile Properties.**

We received 3 set of samples from Ecoturf Midwest Inc. to determine the degrada-tion properties of the material. The samples were cut to specimen sizes compatible with our test equipment and placed at accelerated storage conditions (ASTM D5510 and ASTM 5208).

In addition to the physical property testing, we conducted FT-IR analysis at the most relevant data points to chemically look for the presence of oxidation (carbonyl C=O groups) which are highlighted in the FTIR data. Without the presence of carbonyl groups, a plastic product that has degraded will not be able to biodegrade. Once the material becomes brittle, it is ready for incorporation into an active microbial environment. This begins the second active phase—biodegradation.

Ecoturf Midwest samples made with PDQ-M showed oxo-biodegradation results after going through Accelerated Thermal testing. All samples were allowed to go through testing for 8 weeks. The control samples showed no signs of degradation and did not lose structural integrity. The PDQ-M samples began showing signs of fracturing as early as week 2. However, the physical properties of the samples were not compromised. The 3% samples started to lose physical structure around week 4. And the 2% samples lost physical structure in week 8. In the final pull of testing, the degradation had spread to the inner parts of the sample, and testing was completed.

Thermal testing helps to determine the shelf life cycle of a plastic product. By determining what that shelf life will be, it will help to determine how long plastic products can be stored. The Eco Ecoturf Midwest stakes with 3% PDQ-M should have a shelf life around 6-12 months. 2% PDQ-M stakes should have a shelf life around 12 months. This is not to say that samples will not last longer, but worst case scenario is stakes break down between 6-12 months.

The samples also showed a change in the polymer structure through the addition of carbonyl functional groups. FT-IR graphs are displayed next to each photograph to show you molecularly what is occurring to the plastic product. The results prove that WRP additive has made these plastic samples degradable.

Report Author:

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Lab Manager

ACCELERATED THERMAL TESTING RESULTS FOR CONTROL SAMPLES

	Ecoturf Midwest Inc.		
Trial Run	Control - 1 of 3	2% PDQ-M - 2 of 3	3% PDQ-M - 3 of 3
1	0.00%	2.82%	3.83%
2	0.00%	2.13%	4.21%
3	0.00%	2.31%	3.91%
Average PDQ-M Percentage	0.00%	2.47%	4.00%

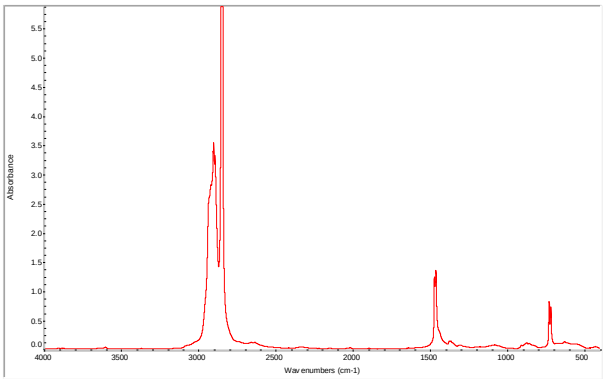
We received plastic samples from **Ecoturf Midwest Inc.** for testing and analysis. WRP addi-tives contain a trace element at a known concentration, that when tested, the ratios will remain proportional, and the ad-ditive concentration loading rate can be calculated by our lab technicians.

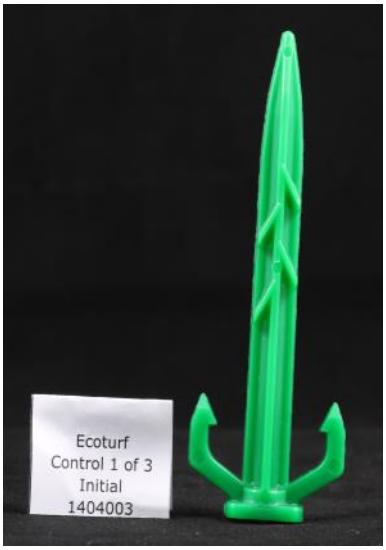
The results above indicate that PDQ-M was detected in only the two samples claiming to contain the additive and not the Control samples. The concentrations varied to a small de-gree in the samples, but the results were uniform. All con-centrations observed in testing will allow oxo-biodegradation to occur in these samples.

The results show that the concentration of PDQ-M in the Turf Spike samples is around 2.47% and 4.00%. The con-centration level was higher in both samples than the claimed amount and it is recommended that the concentration be decreased back to the original amount (around 2.00% and 3.00%) However, for testing purposes, these samples should still yield workable results.

Once samples have degraded, and due to the presence of carbonyl groups, they will enter into the biodegradation phase once disposed of. Microorganisms commonly found in landfills and/or composts will feed off of the oxidized poly-mer chain to further reduce the material into CO_2, water, and biomass (humus). The CO_2 is commonly used as fuel for further microbial growth.

ACCELERATED THERMAL TESTING RESULTS FOR CONTROL SAMPLES





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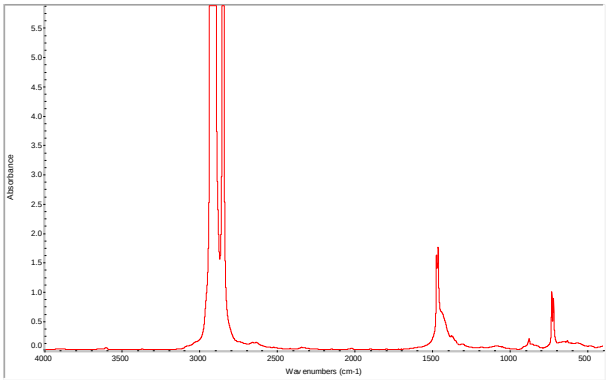
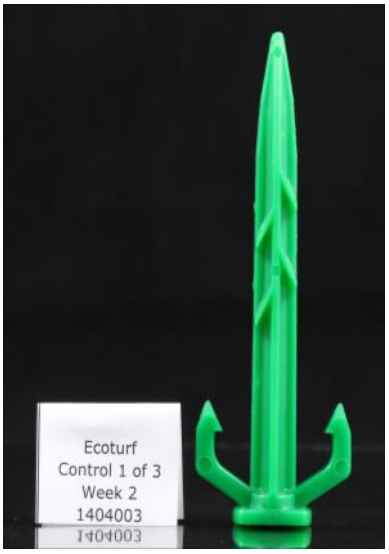
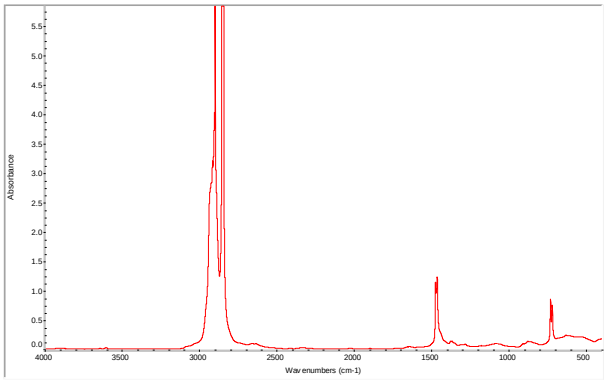
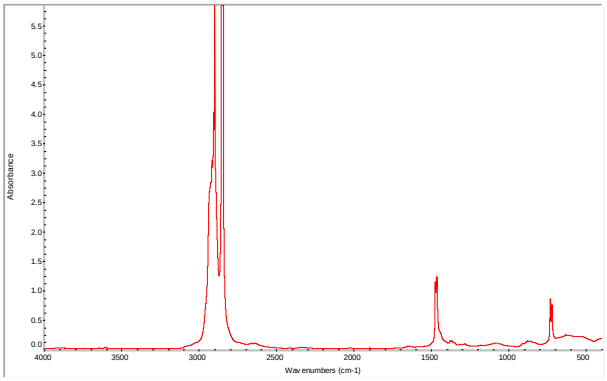
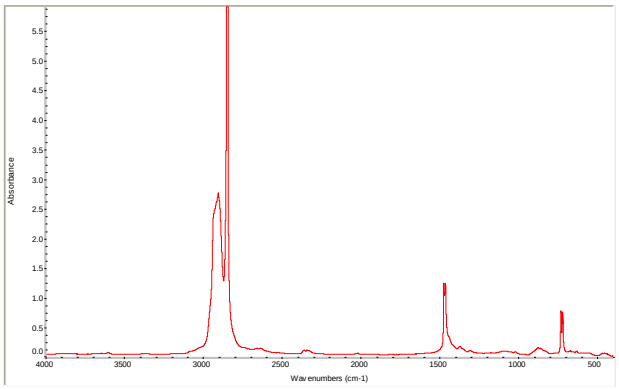


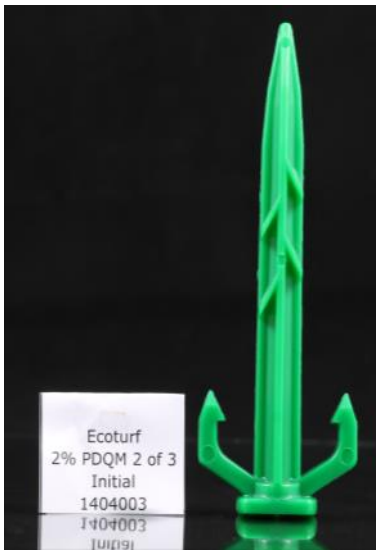


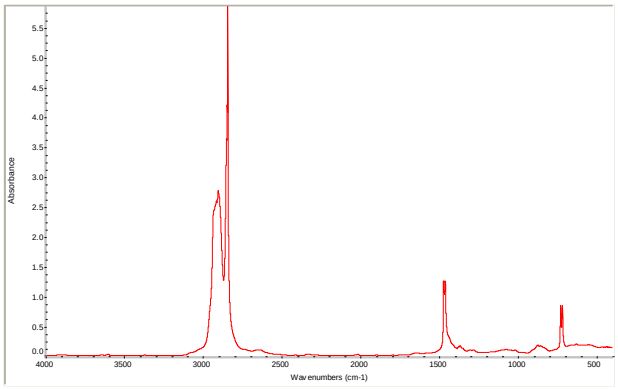


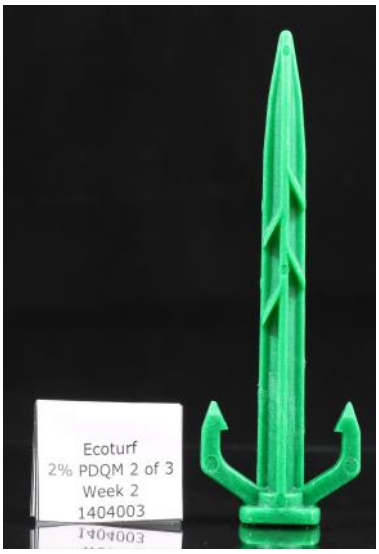


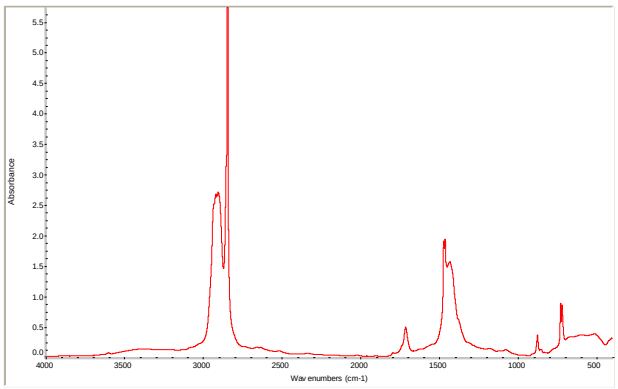
ACCELERATED THERMAL TESTING RESULTS FOR 2% PDQ-M SAMPLES

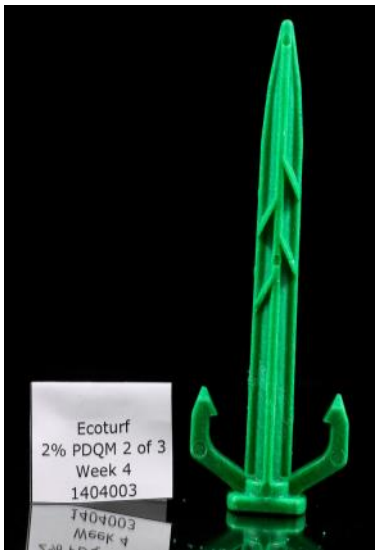


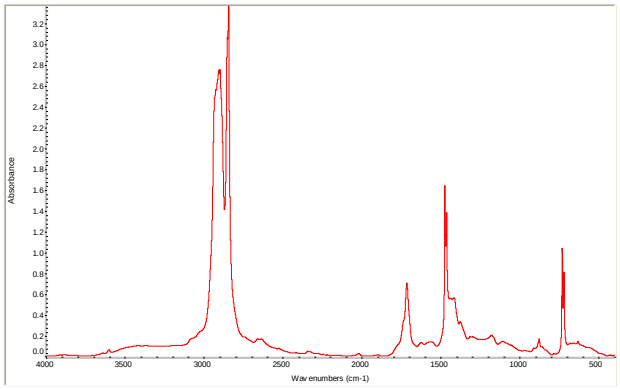


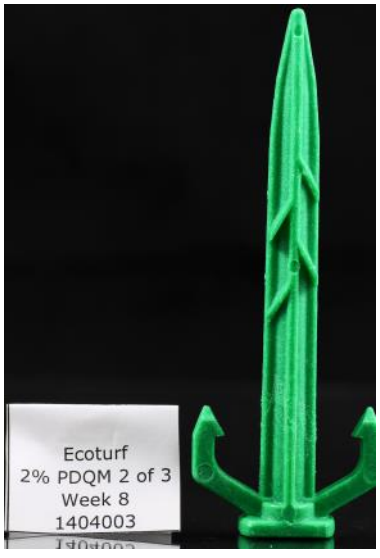




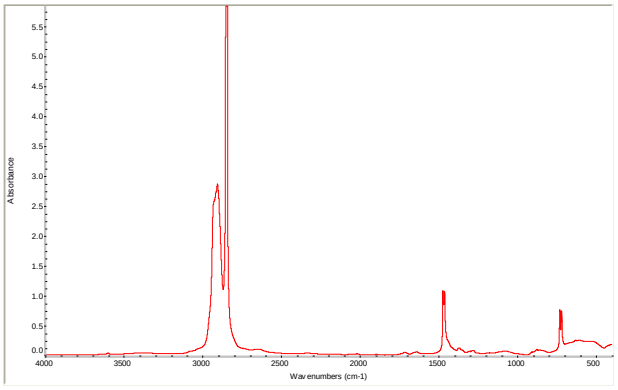


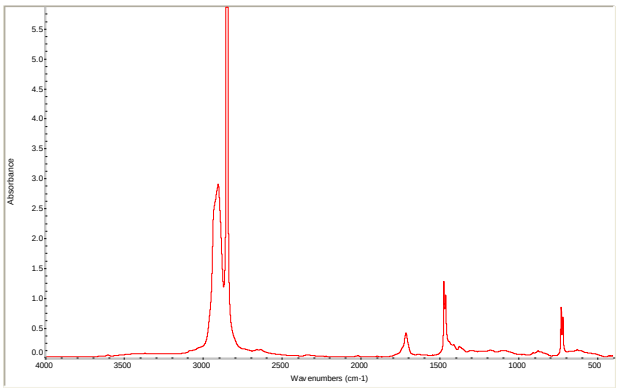


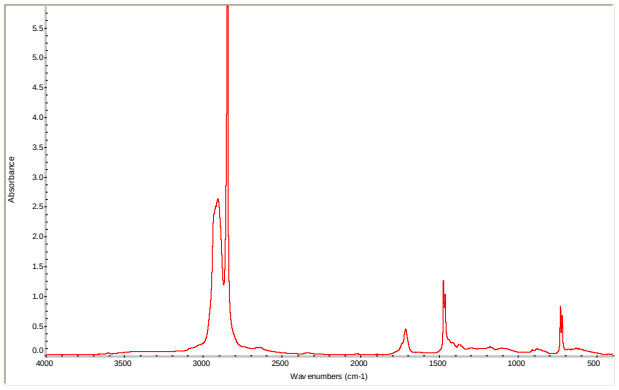


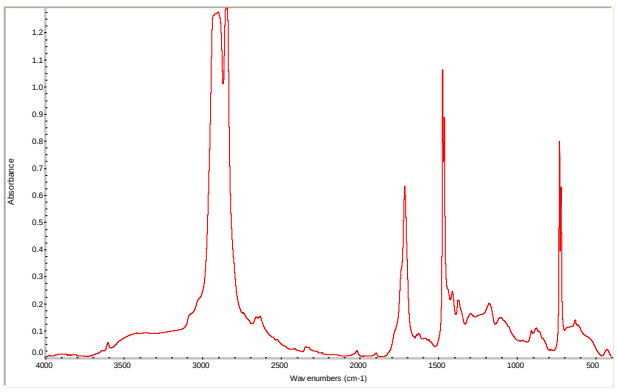


ACCELERATED THERMAL TESTING RESULTS FOR 3% PDQ-M SAMPLES



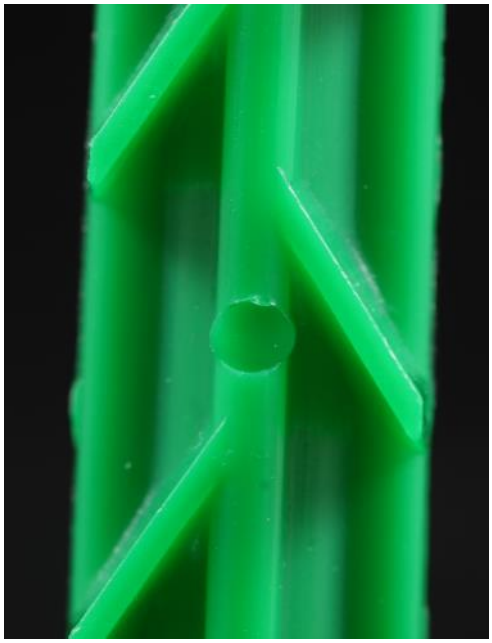




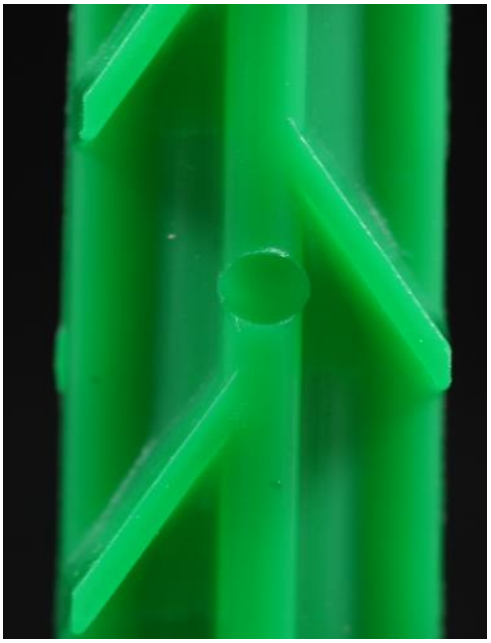


MACRO PICTURES OF SAMPLES

Control



2% PDQ-M



3% PDQ-M

Initial — Macro

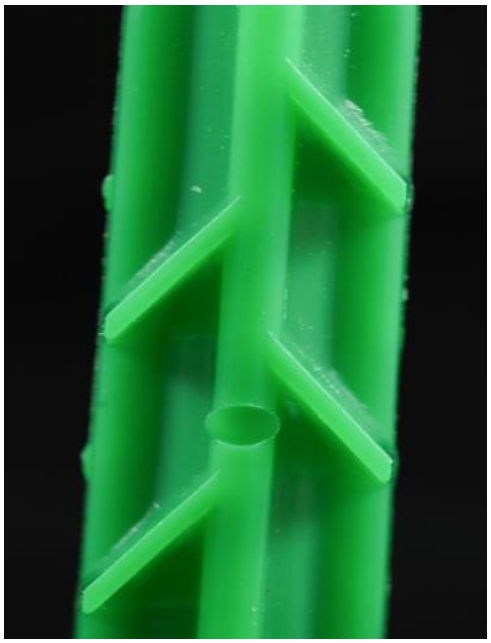
Control

2% PDQ-M

3% PDQ-M

2 weeks — Macro

MACRO PICTURES OF SAMPLES

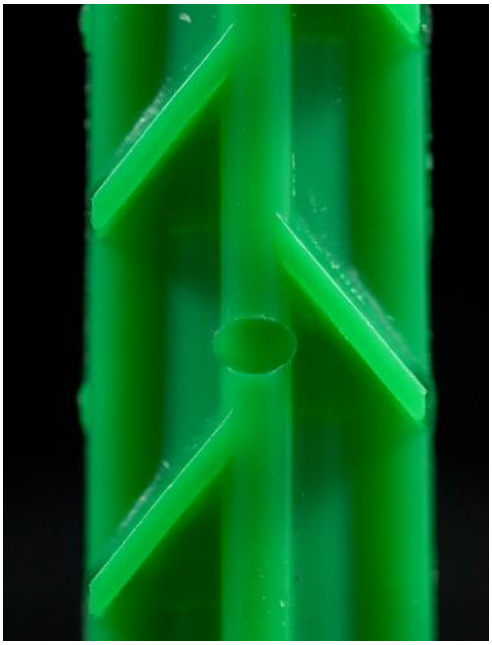


Control

2% PDQ-M

3% PDQ-M

4 weeks — Macro



Control

2% PDQ-M

3% PDQ-M

8 weeks — Macro

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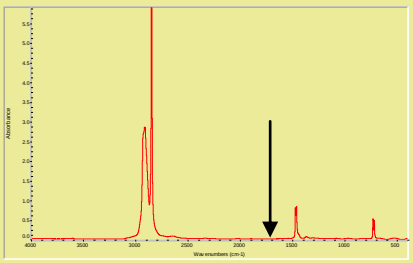
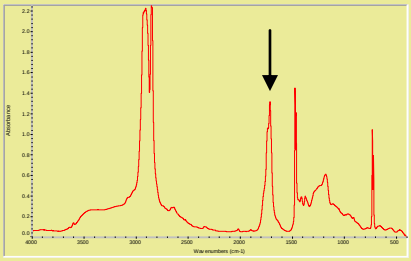
REPORT ADDENDUM

Graphs 1 and 2 are both FT-IR graphs collected by scanning plastic samples and documenting the amount of Carbon to Oxygen double bonds (C=O) that are present. The more C=O present in a plastic material, the more degradation that has occurred. Without these C=O sites, commonly found microorganisms would not be able to feed off the plastic once it's been disposed of. After microorganisms feed off of the oxidized polymer chains, all material is further reduced into non harmful CO_2, water, and biomass (humas).

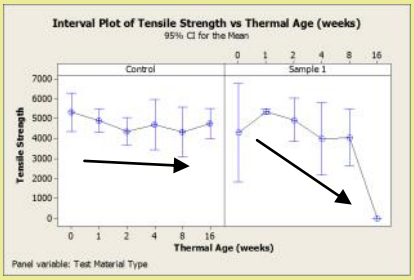
The arrows show where the C=O can be found on the graph. Notice how there is no relevant C=O peak on the Control samples even though it has been aged for 16 weeks. However, on the Samples with WRP additive, there is a very significant peak after 16 weeks of thermal aging. These same graphs are used to demonstrate how UV light affects plastic too.



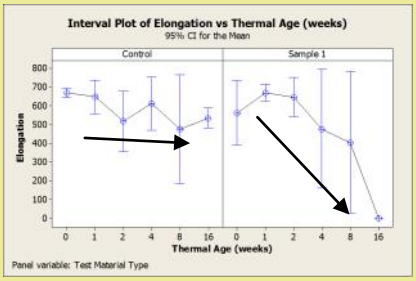
Graph 1 - Control Samples aged 16 weeks



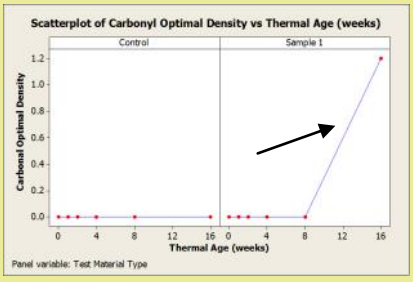
Graph 2 - Sample 1 aged 16 weeks



Graph 3 - Tensile Strength Control vs. Sample 1 aged 16 weeks



Graph 4 - Elongation Control vs. Sample 1 aged 16 weeks



Graph 5 - Carbonyl Density Control vs. Sample 1 aged 16 weeks

Three properties were evaluated in comparing the degradation performance of all sample sets. Those properties are Tensile Strength, Break Strain, and the Carbonyl Density. Tensile Strength is the total area under the tensile stress versus strain curve and is related to toughness. Break strain is the elongation percentage to the breaking point. Carbonyl density is the identified absorbance value of the carbonyl peak through FT-IR analysis after considering the material's thickness.

Notice how in each of the three graphs to the left (Graph 3, 4, and 5), the trend of the control samples are fairly consistent even after 16 weeks of accelerated thermal aging. In samples containing WRP additive, there is a definite trend of degradation. In graph 5, there is a spike in Carbonyl Density in the WRP sample, signifying a larger increase in C=O groups.

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