



OXO-BIODEGRADATION PROJECT REPORT

April 2019

Project: 1903001

TEST RESULTS

TESTING GUIDELINES

- ASTM D6954-04 Standard Guide for Exposing and Testing Plastics that Degrade in the Environment
- 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.

WILLOW RIDGE PLASTICS, INC. received 4 sets of samples from **Unicorn Bag** to determine the degradation 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 (page 2 and 4). Without the presence of carbonyl groups, a plastic product that has degraded will not be able to biodegrade.

All 4 samples did fully degrade during accelerated UV testing. Each sample had fully degraded beyond physical property testing by the 93hr examination. Graph 1 and 2 both give visual of the test samples physical properties as they trend downward in structural performance. The results prove that WRP additive has made these plastic samples degradable.

Brittleness and loss of physical properties does not mean it is ready for biodegradation to occur. Chemical measurements of the carbonyl index indicate the level of chemical change that has occurred in the samples. Sufficient levels of carbonyl groups were observed in all samples around the ~200hrs examination.

New 1% PDQ-M samples will have an outdoor shelf life of approximately ~4-6 months of usable shelf life.

New 2% PDQ-M samples will have an outdoor shelf life of approximately ~4-6 months of usable shelf life.

Old 1% PDQ-M samples will have an outdoor shelf life of approximately ~4-6 months of usable shelf life.

Old 2% PDQ-M samples will have an outdoor shelf life of approximately ~4-6 months of usable shelf life.

Report Author:

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Project Number: 1903001



ACCELERATED UV TESTING RESULTS

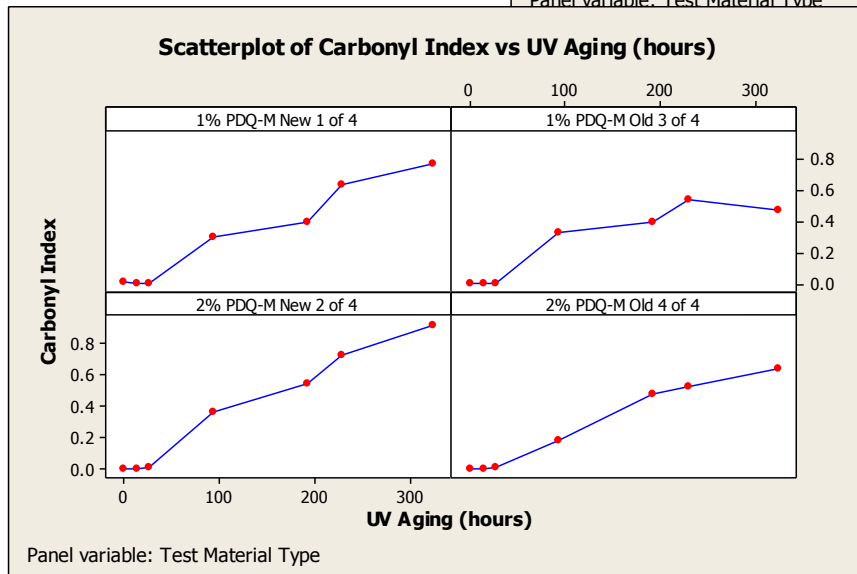
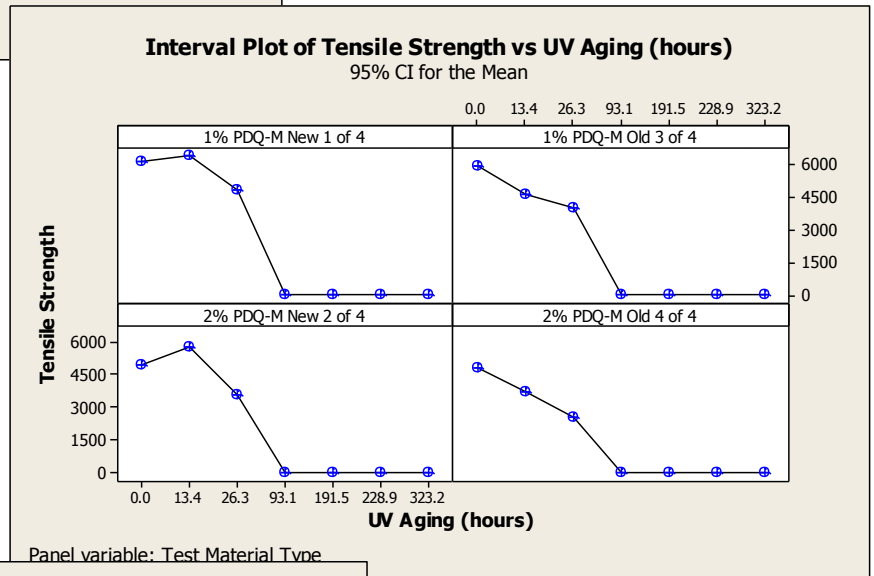
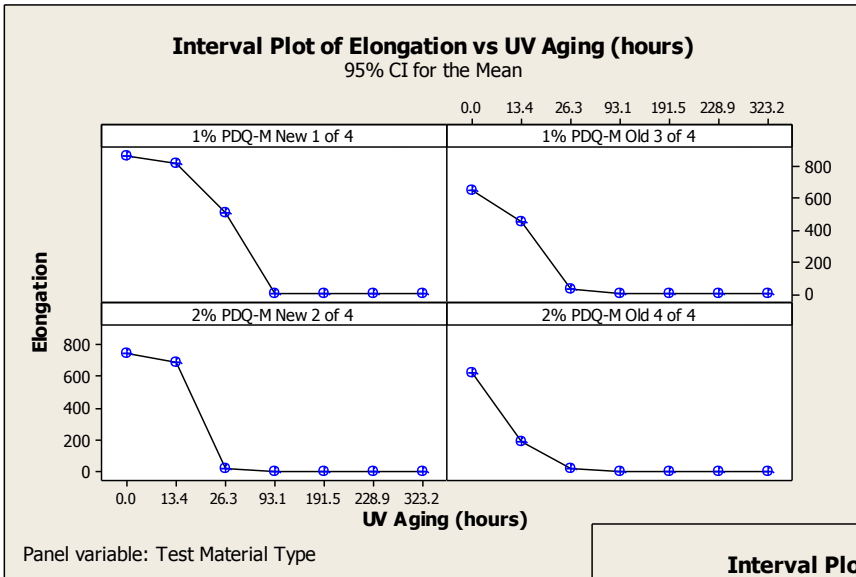
Aged (Hours)	Break Strain Elongation (%)			
	1% PDQ-M New 1 of 4	2% PDQ-M New 2 of 4	1% PDQ-M Old 3 of 4	2% PDQ-M Old 4 of 4
0	8.67E+02	7.49E+02	6.48E+02	6.25E+02
13.4	8.18E+02	6.95E+02	4.51E+02	1.93E+02
26.3	5.11E+02	2.30E+01	2.86E+01	2.19E+01
93.1	0.00E+00	0.00E+00	0.00E+00	0.00E+00
191.5	0.00E+00	0.00E+00	0.00E+00	0.00E+00
228.9	0.00E+00	0.00E+00	0.00E+00	0.00E+00
323.2	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Aged (Hours)	Tensile Strength lbs/in			
	1% PDQ-M New 1 of 4	2% PDQ-M New 2 of 4	1% PDQ-M Old 3 of 4	2% PDQ-M Old 4 of 4
0	6.12E+03	5.00E+03	5.91E+03	4.87E+03
13.4	6.34E+03	5.82E+03	4.59E+03	3.74E+03
26.3	4.80E+03	3.60E+03	3.99E+03	2.61E+03
93.1	0.00E+00	0.00E+00	0.00E+00	0.00E+00
191.5	0.00E+00	0.00E+00	0.00E+00	0.00E+00
228.9	0.00E+00	0.00E+00	0.00E+00	0.00E+00
323.2	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Aged (Hours)	Carbonyl Density			
	1% PDQ-M New 1 of 4	2% PDQ-M New 2 of 4	1% PDQ-M Old 3 of 4	2% PDQ-M Old 4 of 4
0	1.38E-02	6.04E-03	6.04E-03	3.86E-03
13.4	6.21E-03	5.39E-03	4.55E-03	7.06E-03
26.3	6.88E-03	1.56E-02	5.88E-03	1.21E-02
93.1	2.98E-01	3.64E-01	3.35E-01	1.90E-01
191.5	4.01E-01	5.46E-01	3.97E-01	4.84E-01
228.9	6.41E-01	7.37E-01	5.46E-01	5.29E-01
323.2	7.67E-01	9.24E-01	4.71E-01	6.47E-01



ACCELERATED UV TESTING RESULTS



ACCELERATED UV FT-IR TESTING RESULTS

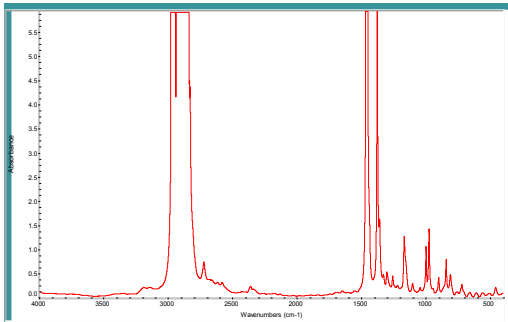


Figure 17: Medium Bag Samples Unaged

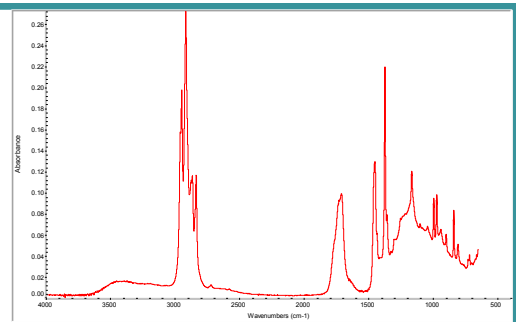


Figure 18: Medium Bag Samples Aged 379hr UV

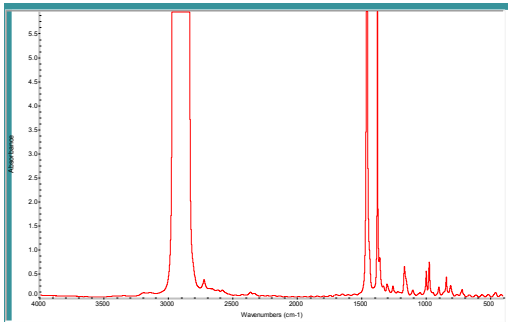


Figure 17: Medium Bag Samples Unaged

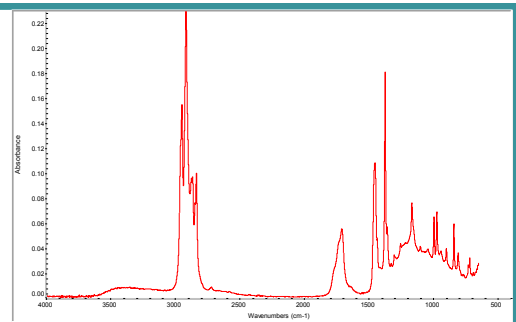


Figure 18: Medium Bag Samples Aged 379hr UV

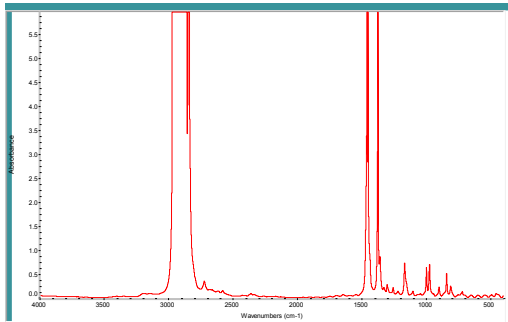


Figure 17: Medium Bag Samples Unaged

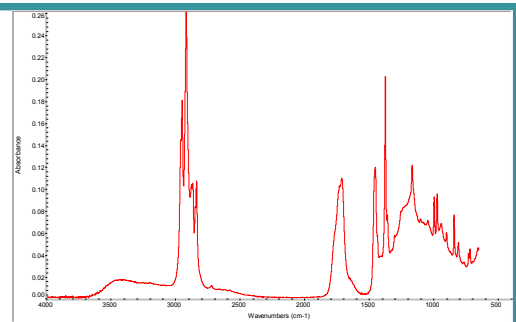


Figure 18: Medium Bag Samples Aged 379hr UV

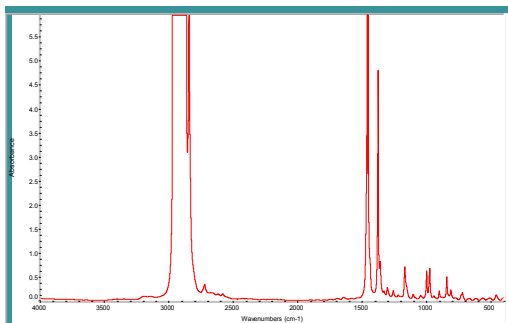


Figure 17: Medium Bag Samples Unaged

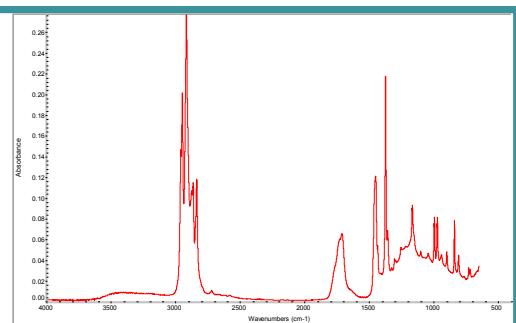


Figure 18: Medium Bag Samples Aged 379hr UV



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Willow Ridge Plastics, Inc. is a privately held, minority owned company, committed to the manufacturing and marketing of oxo-biodegradable additives. Our laboratories have been testing oxo-biodegradable plastic products since 1994. A Willow Ridge logo watermark can be found on the bottom right corner of every report. This way, you know that you contain an official WRP lab report.

To receive a more in depth lab report, contact WRP lab's or your local distributor for any assistance.

Visit our website! www.willowridgeplastics.com

WILLOW RIDGE PLASTICS: THE 2-1 COMPANY

Willow Ridge Plastics is proud to say that we are the only Oxo-biodegradable additive manufacturing facility in the world that has a state-of-the-art laboratory. With our technical professionals available for consultation, WRP is ready to give you all the resources needed to make your product environmentally friendly.

WRP Manufacturing is continually the industry leader in product development and has recently attained ISO 9001:2008 ac-

creditation. Our commitment to quality ensures that customers will receive consistent product for every order. To create faster order processing, we've recently increased our production capacity by installing a new manufacturing line.

WRP Labs has extensive experience in testing Oxo-biodegradable plastics. Most of our guidelines come from ASTM standards for testing and our labs conduct all testing in-house while providing one-on-one services. We specialize in conducting Tier 1 and Tier 2 testing of ASTM D6954 and provide comprehensive reports for all testing upon conclusion.

Our services are usually no charge to customers who use our line of products.

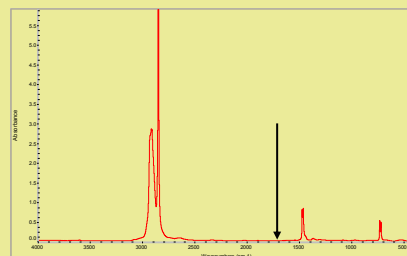




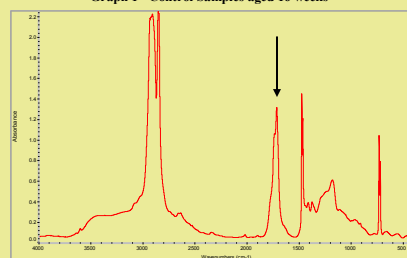
REPORT ADDENDUM

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 CO₂, water, and biomass (humas).

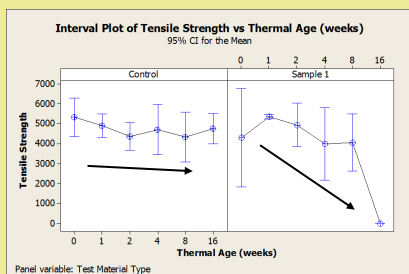
The arrows show where the C=O can be found on the graph. Notice how there is no relevant C=O peak on the Control samples even though it has been aged for 16 weeks. However, on the Samples with WRP additive, there is a very significant peak after 16 weeks of thermal aging. These same graphs are used to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



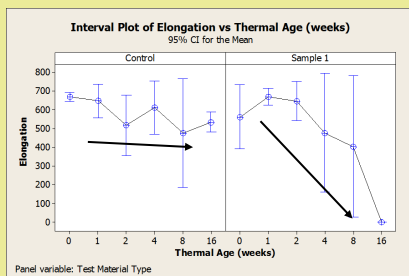
Graph 1 - Control Samples aged 16 weeks



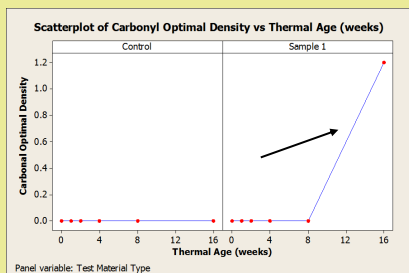
Graph 2 - Sample 1 aged 16 weeks



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.

