OXO-BIODEGRADATION PROJECT REPORT

Ocotober 2012

Project: 1203001

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.**

WILLOW RIDGE PLASTICS, INC. received 1 set of samples from Winrigo (Calfarme Singapore Pte Ltd.), 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. 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.

The Oxo-Bio samples did degrade after 24 weeks of thermal exposure. Inked areas deteriorated much quicker over non-inked sections. Graph 1 and 2 both give visual of the test samples physical properties as they trend downward in structural performance. The Oxo-Bio samples also showed a change in the polymer structure through the addition of carbonyl functional groups (Graph 3) trending upward. The results prove that WRP additive has made these plastic samples degradable and will eventually break them down far enough to start oxo-biodegradation.

Under accelerated UV-exposure, Oxo-Bio samples showed extremely fast degradation results. After only 324 hours of UV exposure, samples had degraded beyond the point of physical property testing. If a sample is left for a long exposure time to UV light, it eventually it will become amenable to subsequent microbial biodegradation when properly disposed of. The best example of showing the difference that WRP additive has made in the plastic samples can be seen in Figure 6. Samples with Oxo-Bio had a huge growth in carbonyl groups and without these carbonyl groups, oxo-biodegradation will not occur.

PRO-OXIDANT PURITY ANALYSIS & EXPECTED OXO-BIODEGRADATION

Given enough time, products made with Willow Ridge Additive will fully oxo-biodegrade. Using Pro-Oxidant Purity Analysis, Oxo-Bio levels were found to contain 1%. It is recommended that the amount of additive remain the same at 1% Oxo-Bio.   It can also be confirmed these plastic samples contained WRP additive and did not contain any regulated heavy metals.

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 polymer 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.

THERMAL DEGRADATION TESTING RESULTS OF OXO-BIO

Aged (Weeks)	Break Strain Elongation (%) Oxo-Bio	Tensile Strength lb/in Oxo-Bio	Carbonyl Density Oxo-Bio
0	3.65E+04	7.66E+05	2.47E-03
1	4.20E+04	7.51E+05	2.34E-03
2	1.83E+04	6.72E+05	3.26E-03
4	8.02E+03	5.53E+05	4.36E-03
8	8.64E+03	5.30E+05	6.22E-03
16	0.00E+00	0.00E+00	3.20E-02
24	0.00E+00	0.00E+00	5.84E-01

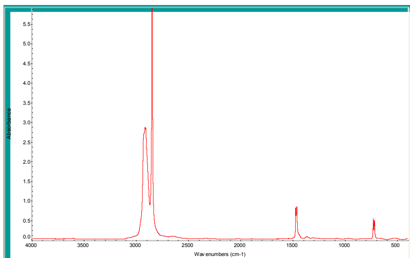
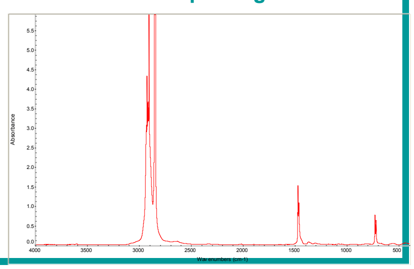


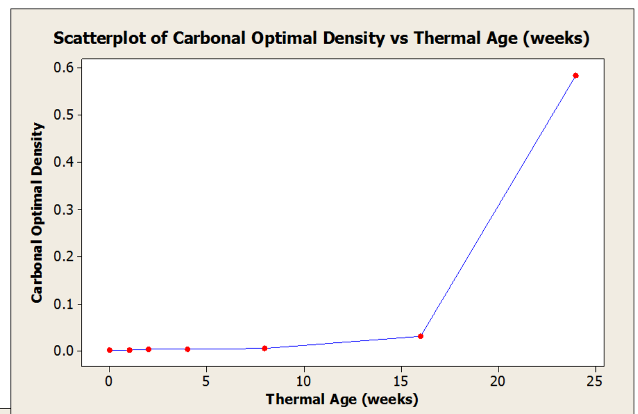
Figure 1: Oxo-Bio Samples Unaged

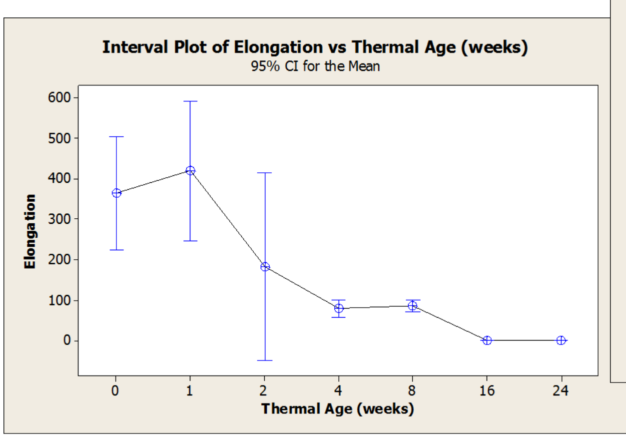
Figure 2: Oxo-Bio Samples Aged 24 Weeks

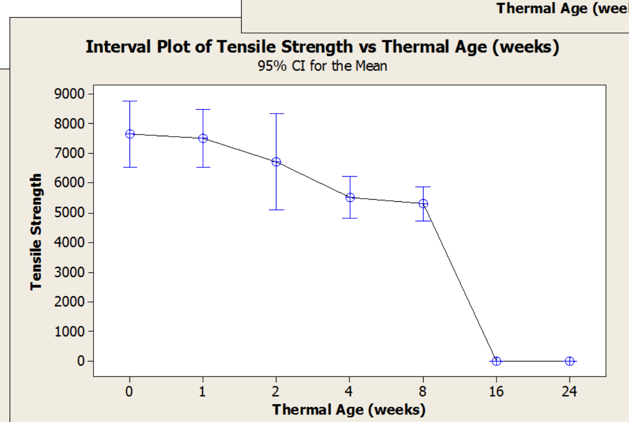


Thermal Exposure to Life-cycle Conversion Chart

Accelerated	Ambient
2 weeks	3 months
4 weeks	6 months
8 weeks	1 year
16 weeks	18 months
24 weeks	2-3 years
32 weeks	3+ years







ACCELERATED UV TESTING RESULTS OF OXO-BIO

Aged (hours)	Break Strain Elongation (%) Oxo-BIo	Tensile Strength lb/in Oxo-BIo	Carbonyl Density Oxo-BIo
0	4.80E+04	8.41E+03	2.37E-03
24	4.04E+04	6.75E+03	3.35E-03
98	2.17E+04	4.38E+03	8.15E-03
180	8.86E+03	4.12E+03	8.68E-03
251	2.02E+03	3.72E+03	1.04E-02
324	1.37E+03	3.85E+03	1.13E-02

UV Exposure to Life-cycle Conversion Chart

Accelerated	**Ambient**
200 hours	1 year

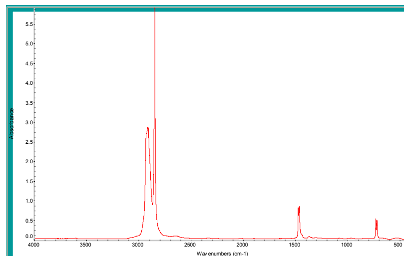
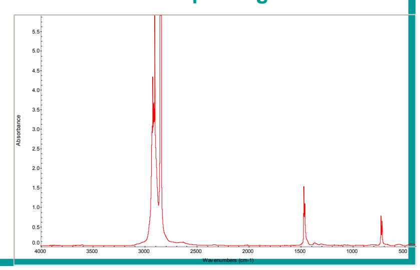
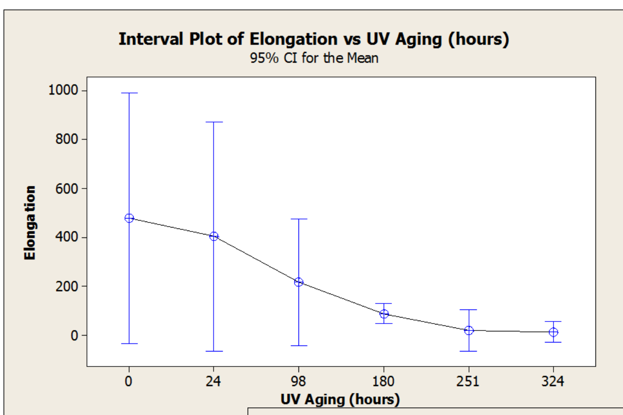
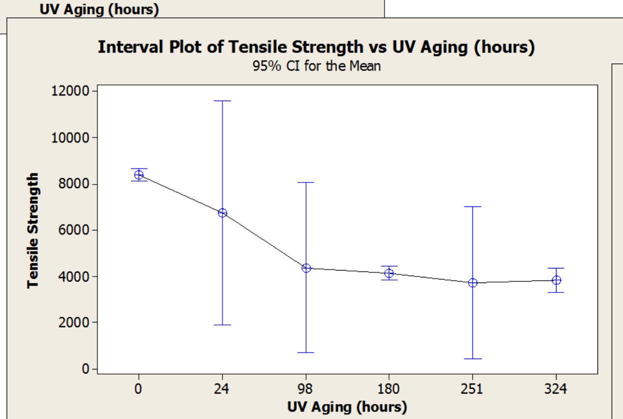


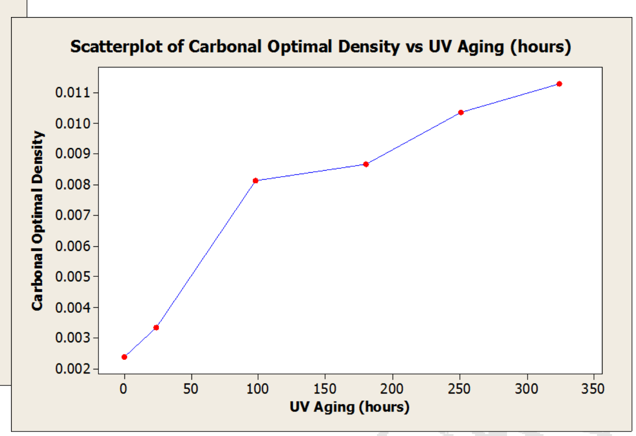
Figure 3: Oxo-Bio Samples Unaged

Figure 4: Oxo-Bio Samples Aged 324 hours









WILLOW RIDGE PLASTICS

3208 Dixie Highway
Erlanger, KY 41018
USA

Phone: 859-578-7400
Fax: 859-578-7404
E-mail: info@willowridgeplastics.com

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 accreditation. 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.

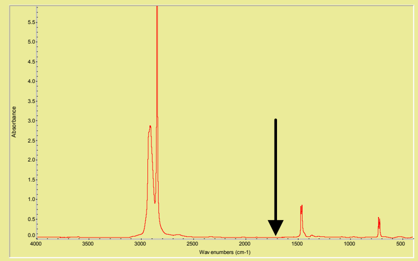
WRP Labs has extensive experience in testing Oxo-biodegradable plastics. Most of our guidelines come from ASTM standards for testing and our labs conduct all testing in-house while providing one-on-one services. We specialize in conducting Tier 1 and Tier 2 testing of ASTM D6954 and provide comprehensive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

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

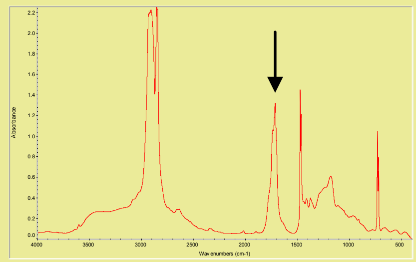
REPORT ADDENDUM

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 CO_2, water, and biomass (humas).

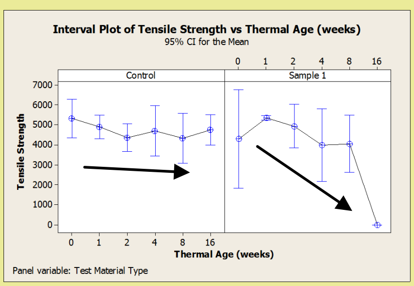
The arrows show where the C=O can be found on the graph. Notice how there is no relevant C=O peak on the Control samples even though it has been aged for 16 weeks. However, on the Samples with WRP additive, there is a very significant peak after 16 weeks of thermal aging. These same graphs are used to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



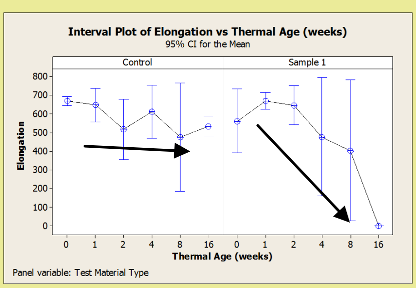
Graph 1 - Control Samples aged 16 weeks



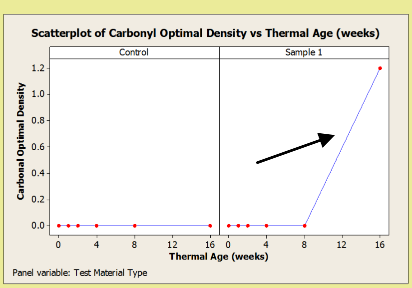
Graph 2 - Sample 1 aged 16 weeks



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 divided by 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.