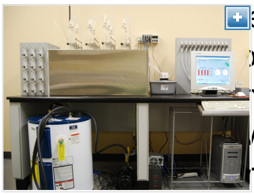
Monitoring Plastic Biodegradation With LabVIEW and NI CompactDAQ



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The Challenge:
Building a biodegradation monitoring system for plastics that meets ASTM D5338-98 (2003) standard requirements.

The Solution:
Using NI LabVIEW software and NI CompactDAQ hardware to create an automated multiunit composting system (AMUCS) to monitor the biodegradation characteristics of biodegradable plastics in compost.

Read the Full Case Study

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At the University of North Texas (UNT), researchers aim to solve complex scientific, technological, environmental, and societal problems through interdisciplinary collaborations. This project represents one such effort involving the Department of Materials Science and Engineering and the Department of Engineering Technology.

Over the past century, plastics have infiltrated all aspects of human life. From the plastic shrink wrapping that protects food from bacteria and fungus, to the Styrofoam cup that keeps coffee hot and soft drinks cold, to the life-saving medical equipment found in hospitals and doctor's offices, plastic is everywhere. However, the popularity of plastics comes at great cost. Most plastics are derived from petroleum so they are not biodegradable and continue to build up in landfills around the world.

Fortunately, biodegradable plastics have been and are continuing to be developed to replace their petroleum-based counterparts. These biodegradable plastics are derived from naturally occurring polymers, such as cellulose and corn starch, that are readily degradable in compost. However, more research needs to be conducted to develop biodegradable plastics that can withstand their intended purpose but degrade quickly once discarded by the consumer. To further this research, we wanted to build a reliable automated system that can monitor biodegradation and, in the future, even enhance it. As a result, we designed the AMUCS, which meets the ASTM D5338-98 (2003) standard requirements. The AMUCS (Figure 1) consists of three major subsystems.

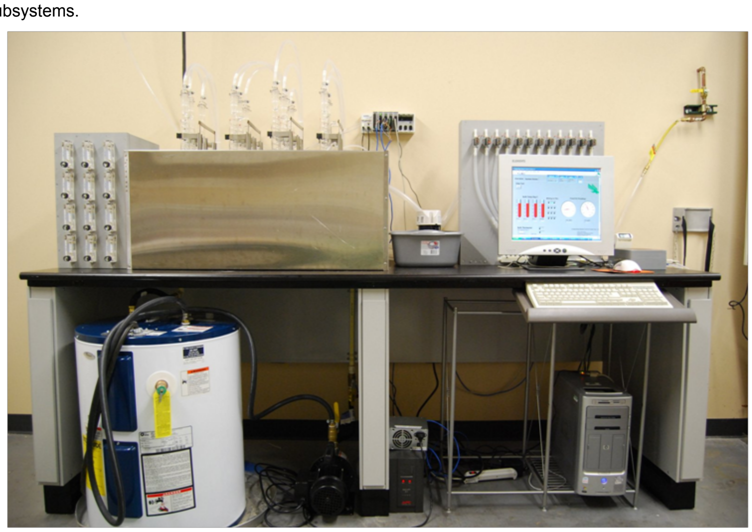

Figure 1: AMUCS for Monitoring Biodegradation

The first subsystem is a water bath, which we constructed using a residential water heater, an acrylic fish tank, and a transfer pump to hold the temperature within the thermophilic temperature range required by the standard. We validated its operation by conducting a 15-day experiment and plotting the average daily temperature over the duration of the experiment.

The second subsystem is a gas distribution system, which regulates the aeration rate of the bioreactors and measures the flow rates and CO_2 concentrations of the effluent gasses from the bioreactors. Twelve rotary flow controllers regulate the aeration rate of the bioreactors and Graham condensers to dehydrate the effluent gasses and protect the measurement equipment. We designed a gas multiplexer using 3-way solenoid valves, check valves, and a nylon manifold so we can sample each bioreactor individually. A mass flow meter and a nondispersive infrared (NDIR) CO_2 gas analyzer measure the flow rates and CO_2 concentrations of the effluent gasses from the bioreactors to calculate the carbon metabolized from the compost medium. We validated the gas distribution system by locating and fixing any leaks and then verifying the calibrations of the mass flow meter and gas analyzer.

We constructed the third subsystem, the hardware control and data acquisition system (HCDAQS), using NI CompactDAQ (Figure 2). The HCDAQS is the central nervous system of the AMUCS. We designed it using LabVIEW to acquire and log data from the resistance temperature detectors (RTDs), acquire data from the mass flow meter and gas analyzer, cycle the solenoid valves of the gas multiplexer, regulate the water bath temperature, and display real-time data to the user via a GUI. We used two architecture techniques to create a LabVIEW program that meets the required criteria. We used a producer/consumer architecture to separate the data acquisition process from the data-logging and water bath temperature regulating processes. We then used state machines to cycle the solenoid valves and to trigger the relay used to control the transfer pump that maintains the water bath temperature.

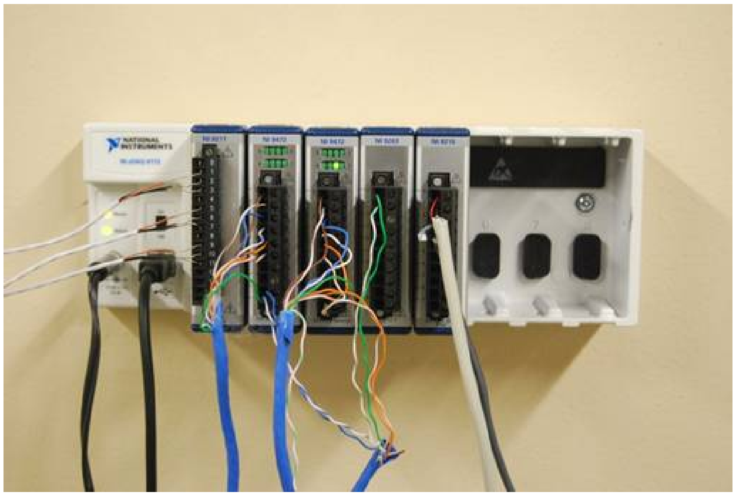

Figure 2: Data Acquisition Hardware—Heart of the AMUCS

We validated each subsystem individually. After integrating the subsystems, we validated the complete operation of the system by performing a 15-day characterization experiment. At the conclusion of the experiment, we found that the system created and maintained the environment for biodegradation. We verified this by making visual observations with the naked eye and an environmental scanning electron microscope (ESEM). We also quantified the effect of the composting conditions on the thermal properties and stabilities of the specimens using differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA).

We showed that the AMUCS could measure the metabolization of carbon from the compost medium, and that the metabolization rates of the three bioreactors with compost were consistent. The characterization experiment also revealed that several of the reactors had leaks that affected the CO_2 concentration measurements. We identified and corrected these leaks before conducting the next experiment.

After validating the operation of the entire system, we performed a 45-day experiment that conformed to the ASTM D5338-98 (2003) standard. We achieved this by using microcrystalline cellulose powder as a positive control to validate the results of the experiment. We also compared the biodegradation behavior of a biodegradable polymer P(3HB-co-3HV), with no nanofiller, and the same polymer with synthetic clay nanofiller.

Once the experiment ended, we determined that the average mineralization of the cellulose was 72.05 percent, which validates the experimental results according to the ASTM standard. Also, we found that clay nanofiller had a significant effect on the biodegradation behavior of P(3HB-co-3HV). At the conclusion of the test, the P(3hb-co-3hv) specimens with five percent clay nanofiller metabolized just over eight percent more carbon weight than the neat samples.

The automated composting system that we constructed will enhance research opportunities at UNT College of Engineering by opening four areas of internal research and create numerous external research opportunities for local and regional plastics manufacturers. First, we can study the effect of the biodegradation process on the crystalline structure on a variety of different biodegradable plastics. This research will help develop bioplastics for more applications that are currently dominated by petroleum-based plastics. Second, we can look into potentially using the automated composting system to develop and test new biodegradable plastics that withstand use but degrade rapidly after being discarded. Third, we can use the automated composting system to focus on developing techniques to increase the biodegradation rate at which biodegradable plastics convert to biomass. Fourth, the university will have opportunities to market the system to local plastics manufacturers to perform biodegradation tests on their products. Marketing the system for industry use would increase funding to maintain and improve the system and would open even more areas of research.

Finally, the automated composting system helps UNT begin developing an approved biodegradation laboratory. This laboratory will study not only the biodegradation rate of plastics, but the complete lifecycle of biodegradable plastics and their effect on the environment after they have completely degraded into biomass as mandated by the ASTM 6400 – 99 standard . Once a biodegradable plastics laboratory is established, it will be the 15th approved facility in the world, the 3rd within the United States, and the only one in the southern United States.

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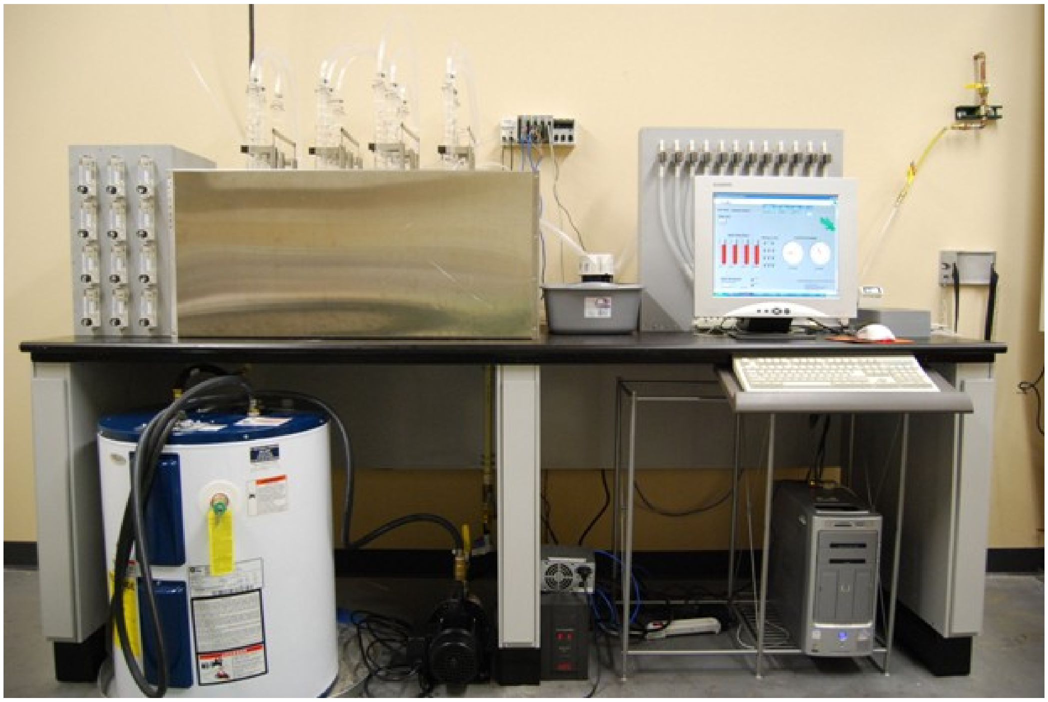

Figure 1: Automated Multiunit Composting System (AMUCS) for Monitoring Biodegradation

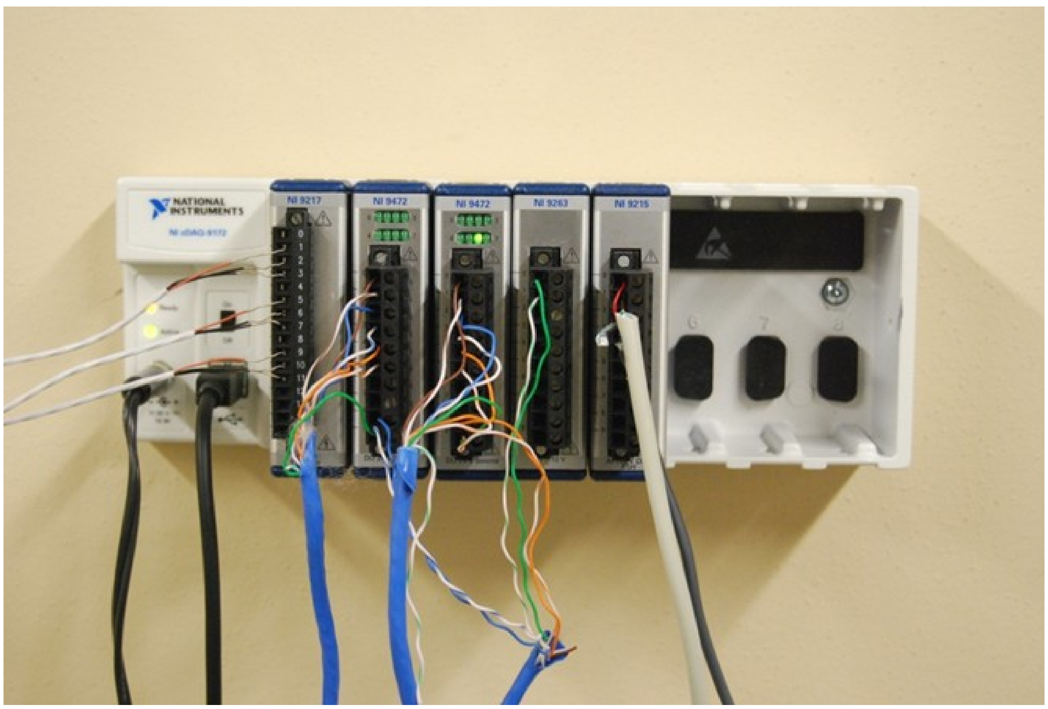

Figure 2: Data Acquisition Hardware—Heart of the AMUCS

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