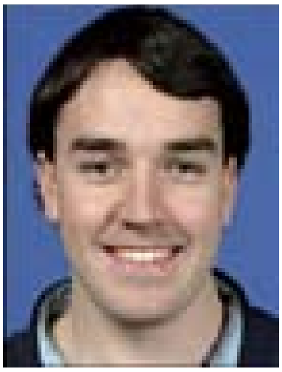
Environmentally-friendly biodegradable packaging products



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The rise of industrialisation and widespread use of petrochemicals brought with it many useful products [1]. One of these products was plastic, a highly polymerised hydrocarbon mainly used for its physical strength and effective microbial barrier properties [2, 3]. While oil is a productive and inexpensive way to produce chemicals, stocks are beginning to be depleted. Therefore, alternative ways to produce such products must be pursued. However, sustainability is becoming a necessary part of environmental management [1] and important steps are now being made towards reduced use of non-biodegradable materials. Where old packaging was once made from polystyrene foam and CFC-containing materials [4], a shift back towards paper and starch based products is occurring [5-8]. In the case where packaging materials are susceptible to moisture and other microbial attack, it is necessary to develop novel materials with increased barrier properties for use in such items as meat packaging [9].

Swinburne is moving forward in this area of research and the Environment and Biotechnology Centre has developed a number of protocols based on ISO Standards to help bring sustainability closer to reality. Biodegradable and thermally degradable products and environmental toxicity monitoring of degraded products are the current focus of this research. The underlying principles rely on conservation of microbial populations of soil compost, where starch and polyhydroxyalkanoate based products undergo bioremediation [10], leading to the production of significant amounts of CO_2. As raw materials are generally extracted from plants, which convert CO_2 to energy during growth, the resultant evolution of CO_2 during bioremediation makes starch based materials carbon neutral, which is the key to sustainable use of such products.

Testing protocols

The ISO Standard 14855 is set up using the apparatus shown in Figure 1. It has been designed for multiple testing of biodegradable products, using 20μm cellulose powder as the positive control, as specified in the standard. Each reactor contains 600g dry weight of fresh compost material and an allocated sample mass (usually 20-40g) dependent on the total carbon content of each material being tested. All samples are assayed in triplicate against a blank containing only soil compost to determine the baseline CO_2 normally evolved from soil. When a flow is applied to the system, the rate at which CO_2 is expelled from each reactor is proportional to the biodegradability of the product. Materials that do not release 90% of their available carbon after the specified 6 month trial period are not defined as biodegradable by this standard.

A related test to the ISO Standard 14855 is ISO Standard 13432 where a larger sample mass is tested in 1.5m^2 bins (Figure 2). The test is set up under controlled conditions where temperature, humidity, moisture and pH are closely monitored and uses a defined uniform blend of fresh compostable materials such as pea straw, tan bark, mushroom compost and horse manure. One bin is kept as the control while other bins may contain three to six porous sample bags composed of the material under investigation which are positioned in the centre of this blend. The sample bags contain the same defined blend, as well as a defined amount of sample based on the carbon content of the material. The standard stipulates that during the first week the temperature should be approximately 55°C and, for 4 consecutive weeks after, the temperature must idle around 45°C. The test progresses over a 3 month period. If a material passes the stringent guidelines of these two standards, then it may be certified as biodegradable.

Microbiological and other parameters

Some mechanisms used in the production of bio- and thermally degradable materials involve heavy metals. These metals act as pro-oxidants and firmly underpin the ability of the material to be acted upon biologically or thermally to yield smaller chemical derivatives [11, 12]. Given that the effects of heavy metal toxicity on microbes have been studied in detail [13], it is therefore necessary to test the effect of degraded materials on soil microbes using environmental trials.

One of these tests, Microtox®, utilises the luminescent marine bacterium, *Vibrio fischeri.* Originally cultured from aquatic animals [14], the degree of light emitted during the test gives an indication of material toxicity [15]. Material samples are most often prepared via thermal degradation, and then smaller constituents are extracted in water at different temperatures. Freeze dried or freshly cultured bacteria are then put in tubes containing different concentrations of the extract. The toxicity of the extract is effectively proportional to the resultant decrease in luminescent signal, and hence the death of the microbe.

Although the Microtox protocol demonstrates toxicity against *V. fischeri,* it is also necessary to know the specific effect on soil microbes, especially those which are import to plant health. The nitrogen-fixing bacteria, *Rhizobium* and *Azotobacter,* are of great importance in soil microbiology [16]. Current culture based methods are underway to establish an effective test protocol for determining the toxicity of materials on these and other soil microbes, including sensitivity to thermally degraded, biodegradable plastic powders. Recent laboratory trials show that solutions of cobalt (one of the heavy metal pro-oxidants) have a pronounced effect on microbial growth.

Just as important as toxicity to soil microbes is material toxicity on plants [17]. As such, we use a wide selection of plants, including pea, barley and pumpkin, to assess the ability of plants to deal with toxic materials. Cobalt solutions lead to a distinctive decrease in plant health and germination, while bio- or thermally degraded plastics result in less deleterious effects on plant growth and overall health.

Other efforts are focused on the isolation of microbial species that can utilise high content polyethylene (PE) materials. Trials have demonstrated that fungi grow well in the presence of thermally degraded plastic containing >98% PE. Some less fastidious Gram-negative bacteria also exhibit healthy growth.

Conclusions

There is general acceptance that biodegradable polymers are desirable and that promotion of such products is in accord with consumer demands for packaging products that are environmentally friendly. However, there is a need for rigorous scientific evaluation of such products to ensure the claims of the manufacturers meet with the biological definition of biodegradable and that the products of degradation do not themselves pose additional environmental pollution issues.

Acknowledgements

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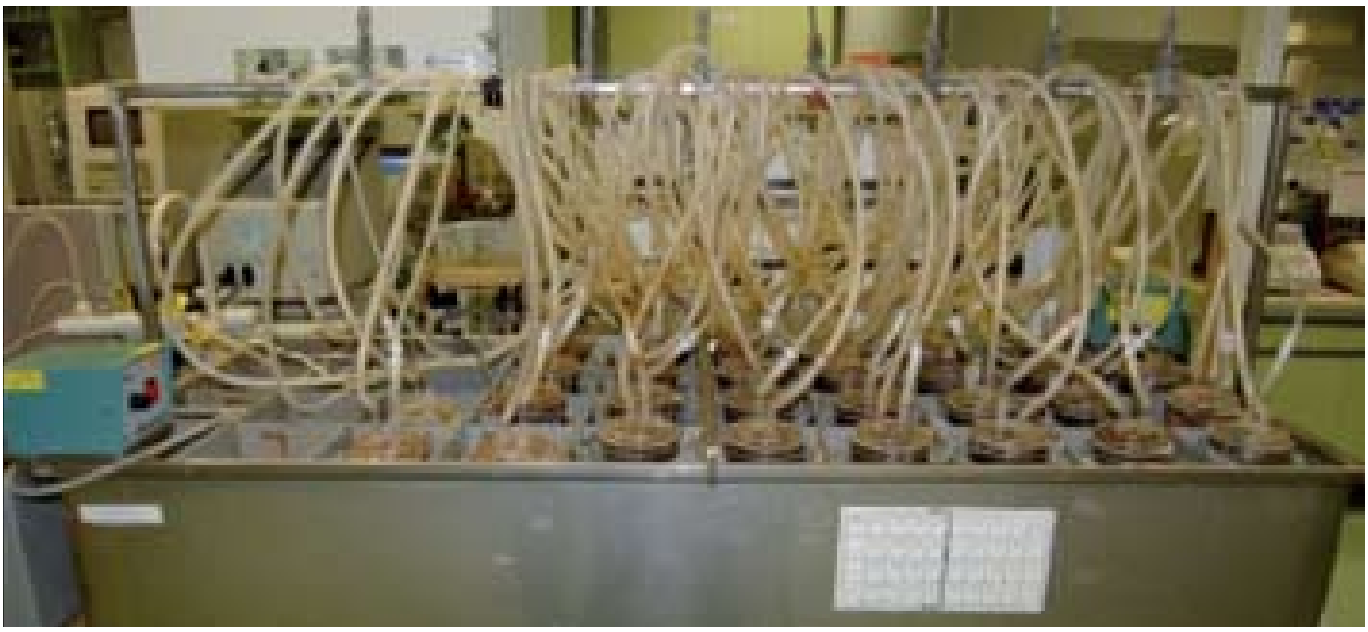

Figure 1. Apparatus used for ISO 14855. Each reactor contains one sample with an inflow and outflow. Flow rate and CO_2 are measured twice daily, where the switching of solenoids are controlled by computer software.

Figure 2. Experimental setup of ISO 13432, showing (a) fresh, uniformly blended compost, into which temperature probes are inserted. The samples (b) are placed in the centre of the bin and covered with more compost. The compost is mixed every week to increase the microbial load. *Phanerochaete chyrsosporium* (commonly called white rot fungi), a visual indicator of a good blend, may be seen growing on wood sources with the aid of extracellular lignin peroxidases (c) and (d).

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