The GROWS Project

(Green Recycling of Organic Waste from Supermarkets)

Part 3: The use of biodegradable food packaging and factors affecting its compostability

Final Report

BIFFAWARD Project Number B/1150 A, B & C
ENTRUST Project Number 710247.003

Report produced by

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1 EXECUTIVE SUMMARY

The objective of the GROWS (Green Recycling of Organic Waste from Supermarkets) project was:

"*To establish a cost effective, sustainable and environmentally sound waste management solution for biodegradable waste from supermarkets*".

Funding for the GROWS project was secured by the Progressive Farming Trust Ltd through Biffaward, a multi-million pound environment fund which uses landfill tax credits donated by Biffa Waste Services. Third party funding was provided by Waitrose, Sainsbury's and Sheepdrove Organic Farm. Project management and implementation was undertaken by the Organic Resource Agency Ltd.

The first part of the GROWS project involved setting up a system for source-separating supermarket fruit, vegetable and cut-flower waste in-store, developing a collection round to service the participating stores and composting the waste once it had been delivered to the GROWS composting site at Sheepdrove Organic Farm in Berkshire. During this collection and composting phase an intensive year-long audit of the waste was carried out to assess the quantity and quality of fruit and vegetable waste that could be collected. A complimentary programme of monitoring was also undertaken to assess three different composting systems to see how each system coped with the GROWS waste stream. Results from this part of the project were published in a separate document[1].

The field trials phase of the GROWS project followed on from the composting phase, beginning in autumn 2001, and running through the growing season of 2001-2002 until harvest at the end of August 2002. Results from this part of the project were published in a separate document.[2]

Part 3 was delayed consequent on the uncertainty surrounding the introduction of the Animal By Products Regulations (ABPR), as it was not clear whether or not cooked former foodstuffs from retail outlets could continue to be disposed of to landfill or would have to be processed by composting, anaerobic digestion and /or rendering. When DEFRA announced in June 2005 that disposal of cooked former foodstuffs could continue to go to landfill, much of the pressure on retailers to find alternative disposal routed for food was removed. Part 3 was subsequently refocused onto the potential for biodegradable packaging to assist in the composting of food waste from supermarkets.

The Part 3 project set out to answer four questions:

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1 Pickering, J. and Bulson, H. (2002). GROWS Project (Green Recycling of Organic Waste from Supermarkets) Part 1: Collection and Composting Phase. 153pp. The Progressive Farming Trust Ltd, Hamstead Marshall, Near Newbury.

2 Pickering, J. and Bulson, H. (2003). GROWS Project (Green Recycling of Organic Waste from Supermarkets) Part 2: Agricultural Field Trials Phase using GROWS Compost. 32pp. The Progressive Farming Trust Ltd, Hamstead Marshall, Near Newbury.

Are biodegradable polymers available which can be composted in home compost bins?

Yes, provided that they are produced directly from starch. Polymers produced from lactic acid will only compost at the higher temperatures encountered in commercial composting operations. Identification of a polymer as being compostable is a prerequisite that it will be composted, either in a home compost bin or through a commercial composting system via a separate collection routine. Otherwise it is likely to be sent to landfill. Several national labelling schemes exist, using differing logos; in Europe the logos are supported by the European standard EN 13432. Oxo-degradable materials (fossil based polymers with added metal ions) are not supported by this standard, and are not proven to decompose under home composting conditions.

Are there biodegrable polymers available which are suitable for food packaging?

Yes, there are at least seven companies world wide producing biodegradable polymers, and nine UK converters producing packaging products rated for food applications. There is an industry association, IBAW (International Biodegradable Polymers Association & Working Groups), which promotes the use of biodegradable polymers in food packaging.

Is it possible to obtain GMO free biodegradable packing material?

Yes, at least one manufacturer sources his raw material as being GMO free, and promotes his product as such, although his principal market appears to be compostable waste collection bags.

Is it possible to source raw material for biodegradable polymers from sources in the UK?

In theory yes, but the practicality of tracing the source of the raw materials from an international polymer producer back to the UK crop market, (if such a source exists) is not apparent. Further work will be necessary to establish such a link.

Recommendations following from this study depend critically on the extent to which biodegradable packaging, before introduction to a food waste stream, can be identified for what it is, and diverted to a suitable recovery route that will not immediately result in landfill. Landfill as a disposal option for biodegradable packaging is a poor environmental outcome.

Agencies whose support is essential if food retailers are to successfully introduce biodegradable packaging include DEFRA, WRAP, LARAC and the Composting Association. The use of the Life Cycle Analysis process will help to determine the benefits available for the producer, the retailer, the consumer and the environment.

Useful further activity could include:

- investigating the feasibility of using UK produced starch as a raw material
- trials to determine the feasibility of home composting if biodegradable materials
- a survey amongst local authorities regarding their attitude to the collection and disposal of biodegradable materials

2 BACKGROUND

The GROWS project commenced in May 2000 and has comprehensively evaluated the source separation, collection, and composting of fruit, vegetable and cut flower waste from supermarkets. This formed the basis for the Part 1 GROWS report published in July 2002. Organic crop production field trials were also carried out to ascertain the agronomic and economic value of compost produced from the GR0WS waste stream. The findings from this investigation form the Part 2 GROWS report published in February 2003.

Part 3 of the project was defined as an investigation into waste collection and disposal options for supermarkets in light of current and proposed legislation including the Animal By Products Regulations 2003 (ABPR), the draft EU Biowaste Directive, and the draft EU Soils Strategy. However, uncertainty over the implementation of the ABPR legislation with respect to waste from food retailers and food factories, led to the project being put on hold in December 2003 whilst ORA waited for DEFRA to publish a confirmed list of which former foodstuffs would be classified as Animal by Product category 3 materials.

Guidance on the relevant legislation (EC1774/2002) was published in May 2004 but exactly which waste products would be controlled by this legislation still remained unclear. In June 2005, after lobbying from various parties, DEFRA announced that the EU had decided that a large proportion of pre-treated former foodstuffs (i.e. those that had been cooked) were no longer considered to be of a significant risk in terms of animal health, and proposed that guidance be amended to indicate that these materials would no longer be categorised as category 3 animal by-products.

The implication of this was that a significant proportion of the waste which the supermarkets thought would have to be diverted away from landfill after December 31st 2005 would now still be able to be legally disposed of to landfill. Whilst there are still some products (notably raw meat and fish) which will still have to be diverted via alternative disposal routes, this means that the supermarkets no longer face a statutory requirement to divert the majority of their food waste in this way. This effectively removed the need to undertake the work proposed in Part 3 and justified the delay in implementing this phase of the work.

In the light of the above it was decided that instead it would be more useful to evaluate an important aspect of composting of food waste i.e. the use of bio-degradable packaging which could be composted along with the food which it is protecting.

Earlier trials carried out in the GROWS project established that it was possible to separately collect fruit, vegetable and cut flowers from supermarkets and to produce compost of benefit to crop production. The project demonstrated that it was possible to remove packaging from produce waste at the supermarket store and to drive down contamination levels in the material entering the composting process. However, effective removal of packaging that would not degrade in the composting process was difficult and labour intensive and required considerable management effort to ensure continued compliance. This added to the cost of dealing with the waste in store prior to collection, and also to the composting process where the contaminating packaging had to be removed to ensure that plastics were not applied to the land in the compost product.

One solution is to use biodegradable packaging that rots during composting. However even with these materials there are important issues that have to be considered. Organic farms are not allowed to use genetically modified organisms or products derived from them. Therefore for this group of farmers, including Sheepdrove Organic Farm, who are a partner in GROWS, it is important that any biodegradable packaging used is not produced from genetically modified crops.

It is inevitable that the biodegradable packaging from supermarkets will enter the domestic waste stream. Therefore the project partners also wish to evaluate the ability of the packing material to be composted in home composters, where the degradation process typically takes place at lower temperatures and over a longer period than in large scale commercial processes.

The final part of Phase 3 has therefore been amended to address these issues by including an assessment of how the use of biodegradable packaging by supermarkets can be used to assist in food waste composting, and to investigate the barriers that may be encountered in the use and success of such packaging. On the advice of the project partners, the investigation is focused on the use of British produced, non-genetically modified, starch-based biodegradable packaging and its ability to degrade both in commercial composting / anaerobic digestion systems and in home composters in a domestic system.

3 INTRODUCTION

For a packaging material to be both biodegradable and acceptable to a food producer or retailer, it needs to exhibit a series of properties, which are investigated in this report:

- Manufactured from a renewable resource
- Freely available in the market place
- Approved for food use
- Biodegradable
- Compostable
- Identifiable
- Accredited
- Free of Genetically Modified material
- Incorporating British raw materials

True biodegradable polymers do not contain polyethylene or other fossil fuel based polymers and are engineered to completely biodegrade in a microbial environment. Such polymers, which are usually starch or polysaccharide based, include:

- aliphatic polyesters
- polylactic acid (PLA)
- polyhydroxyalkanoates (PHA)
- polyester amides
- starch copolymers

The sustainability of the raw material is always a consideration to bear in mind. Suitable sources of starch include:

- rice
- sugar cane
- wheat
- sweet potatoes
- corn
- maize

The polymer can be made from a locally available crop, helping and raising rural economic growth. The production of dextrose and lactic acid from biomass is already a well established and major industry.

Polymers for which degradation is initiated via a non biodegradable mechanism use a polyethylene or similar fossil derived polymer base and incorporate a small amount of a bio based material or a metallic ion complex mixed into the polymer melt. Degradation initially begins when the product is exposed to light (photodegradable), heat (thermodegradable), or water (hydrodegradable), and the products of decomposition, **which is a disintegration process and not biodegradation**, will inevitably still contain the non-degradable additives.

This report is concerned primarily with biodegradable polymers.

The majority of the information presented has been taken from freely available sources, referenced as footnotes or web site addresses.

4 WHAT MATERIALS ARE AVAILABLE?

4.1 Naturally occurring materials

4.1.1 Cellulose

Cellulose is a widely occurring carbohydrate, being naturally synthesised as the structural component of most living plants. It is commercially available as an alkali soluble component of wood, or in its pure form as cotton. Early synthetic polymer materials produced from pure cellulose include celluloid (cellulose nitrate), cellulose acetate, and cellophane (crystallised cellulose), the latter still being widely used today for food packaging. Cellophane is water soluble, and will disintegrate within 14 days in wet environments, becoming fully biodegraded after 8 weeks. Commercial cellophane is usually coated with less degradable materials, (nitrocellulose wax or PVC), the latter will disintegrate, rather than degrade in a composting process.

4.1.2 Starch

Starch, like cellulose, is built from the basic glucose monomer and is readily available as the major component of cereal and ground crops. It is easily plasticised with water, and can then be moulded or formed or turned into film. Its limitation is that it is water soluble, and has no wet strength. The major use for starch in plastic formulations is as a thermoplastic blend with poly vinyl alcohol (PVA), in which case it is completely biodegradable. It can also be blended with polythene, in which case it will assist in the disintegration of the product after disposal, but not in its biodegradability. Extruded starch/acetate blends are widely used as agricultural land blankets, where they degrade in contact with soil. They can also be used as foamed products in totally degradable loose fill packaging materials. These foams can also be formed into shaped articles such as cups and trays.

4.1.3 **Lactic Acid**

Lactic Acid is a naturally occurring material, a component of milk, and a product of muscular activity. As a commercial raw material it is readily produced by the synthetic bacterial fermentation of glucose, whether in the form of sugar or starch. Lactic acid is readily polymerisable into Poly Lactic Acid (PLA), a thermoplastic material that can be formed and extruded into film, and importantly, is water insoluble. It is widely used as biodegradable food packaging, in agricultural applications as a soil warming cover, as bin liners and disposal sacks, and as single use fast food accessories (knives & forks). It is also approved for use in many medical applications, including temporary inserts and micro encapsulated drug delivery systems.

4.1.4 **Polyesters**

Synthetic polymeric polyesters are produced by the fermentation of varying proportions of glucose and propionic acid, the products are known as polyhydroxyalkanoates (PHA) polyhydroxybutyrates (PHB) and polyhydroxybutyratevalerates (PHBV). These polymers have excellent water resistance, moulding and film properties, and when blended can have processing and product properties which approach those of polyethylene and polypropylene. These synthetic polyesters are biodegradable in most composting environments, degrading to carbon dioxide and methane over a period of a few months in a cool compost environment. The rate of degradation is shape and bulk dependent. When used as bio-plastics in medical applications, they will degrade to products naturally found in the body.

4.2 Commercially available materials – polymer producers

The following companies[3] are currently producing synthetic polymeric materials from renewable sources, such as starch, cellulose and other polysaccharides, fibres, proteins and plant oils:

[3] Company contact details are contained in Appendix A

- Novamont (Mater Bi®, starch) Terni, Italy
- Plantic Technologies Ltd (Plantic™, starch) – Melbourne, Australia
- Rodenburg (Solanyl®, starch) – Oosterhout, Holland
- Natureworks LLC (formerly Cargill Dow: Natureworks® PLA, polylactic acid) - Nebraska, USA
- Innovia Films (formerly UCB: Natureflex®, cellulose) Bridgwater, UK
- Procter & Gamble (Nodax® PHA, polyhydroxy alkanoates)
- Treofan – (Biophan films, PLA) Raunheim Germany

Toyota in Japan has constructed a pilot plant to produce 1,000tpa of PLA.

Hycail, in the Netherlands is to start up a 50,000tpa PLA plant.

Tianan in China is said to be operating a PLA plant.

4.3 Commercially available materials to the UK packaging producers

Huhtamaki – A global producer of packaging with a range of compostable foodservice packaging using Natureworks PLA (cups, plates, containers, cutlery) under the trade name Bioware®
http://www.huhtamaki.com/

NNZ – UK and worldwide producer of sustainable packaging under the trade name Ökopack®, manufactured from renewable raw materials such as starch from maize, grain or potatoes. Ökopack packaging is CEN 13432 certified.
http://www.nnz.com

Innovia Films Ltd – Producers of packaging films. The base film is manufactured as NatureFlex from biodegradable cellulose derived from wood pulp which is harvested from managed plantations. The external

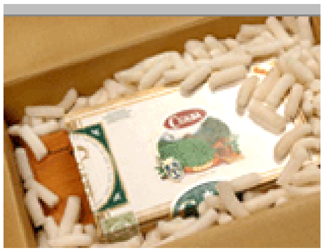
sealant layers are also biodegradable. The finished film is certified as compostable to EN 13432:2000.
http://www.innoviafilms.com

Polargruppen – Producers of the Biobag. The BioBag is made of the material Mater-Bi, the main component of which is cornstarch. The BioBag is 100% biodegradable and compostable and biodegrades after 10 to 45 days, depending on the composting method used. The BioBag has earned the "OK COMPOST" certificate, which is based on the European Standard EN 13432, the strictest standard for compostable bio-bags. Mater-Bi is also certified by "DIN CERTCO," which is a German certification company. In addition, the Norwegian National Agricultural Inspection Service has approved the BioBag as packaging for food waste within the food disposal industry which is then recycled as animal feed. The BioBag can also be used by the food production industry, since the BioBag is UK certified in accordance with the packaging convention for food products.
http://www.polargruppen.com/biobag.htm

Ecosac Ltd - Compostable bag manufacturer, Ecosac Ltd, has become the first company to gain certification for its products through the compostable packaging certification scheme run by The Composting Association and German certification body, Din Certco. The polymer is maize derived PLA, from Mater Bi, from Novamont, Italy.
http://www.edie.net/webforms/ecosac/index.htm

Biopac Ltd – Offering a wide range of films, bags, trays and disposable items, certified to EN13432. Some of the products are produced from biodegradable polymers, for example films, whilst some are produced from plant fibre (food trays) The example shown here is packaged for Sainsburys in a fibre based tray.

http://www.biopac.co.uk/



Greenlight Products – Producers of bio-based loose fill packaging
http://www.greenlightproducts.co.uk/

Potatopak Ltd – Producers of bio-based moulded and formed trays for food packaging applications, principally from waste potato starch.
http://www.potatopak.org/home.html

Nvyro - Producers of moulded trays made from starch derived from Cassava, a tropical root crop from Thailand, which is also the source of Tapioca
http://www.nvyro.com/products.htm

4.4 Oxo-degradable materials

Biodegradable materials should not be confused with the oxo-degradable materials also available on the market. These plastics are often marketed as 'degradable polyethylene' but offer no benefits over conventional polythene bags, being unsuitable for composting or anaerobic digestion as they do not comply with the European norm for biodegradable and compostable packaging (EN 13432:2000). As with conventional polythene bags, these non-renewable materials may be incinerated but are far more likely to end up in landfill. The effects of oxo-degradable plastic carrier bags may in fact be even more harmful to the environment than the conventional bags, as the metal-based additives (e.g. cobalt) will be liberated during degradation, adding toxic, persistent and bio accumulative substances to the environment.

Visible fragments consequent on the disintegration of oxo-degradable packaging will be present in composted material at the end of industrial scale composting. The presence of this waste residue in composted material would restrict its use in applications to land. It can take over 2 years for oxo-degradable packaging to fully degrade.

There are clearly differences of opinion between the two groups of manufacturers offering a supply of degradable plastic. Those of bio origin are relying on conformance with an EN standard to achieve consumer awareness and performance verification. Those relying on additive technology claim compostability but do not appear to claim conformance with EN 13432.

4.5 Environmental impact

Life Cycle Analysis (LCA) is a method for analysing manufacturing processes, products and services that requires studying systems from a global viewpoint. The only way to study production systems completely is to examine their performance, following, step by step, the route covered by the raw materials through all of the transformation and transportation processes, until they are disposed of by whatever route in the form of waste.

The role of LCA is essential in identifying the manufacturing processes that have the greatest environmental impact, and in indicating the options for improvement in order to maximise the positive effects, and reduce the negative effects on the environment to a minimum.

Only by conducting a comparative LCA on the option (biodegradable packaging) and the current practice (existing packaging) can the true effect on the environment of making the change be established. This comparison can only properly be done for a real life scenario, but a typical LCA undertaken by Novamont in which they compare the starch based Mater-Bi, Paper and Polythene is reproduced in Appendix IV. It demonstrates the lesser environmental impact of bags made from starch based polymers when compared with paper or polythene bags.

5 HOW COMPOSTABLE ARE THE AVAILABLE MATERIALS?

5.1 Suitability for home composting

Commercial composting operations operate for extended periods at temperatures that can exceed 70°C, whereas domestic compost heaps are more likely to be operating at temperatures only slightly above ambient. The mechanisms of degradation change with temperature, in particular they slow down at lower temperatures, and not all materials degrade similarly.

Starch based materials (as opposed to lactic acid based materials) will compost under cool conditions as well as under hot conditions, and are thus suitable for home composting.

Materials made from PLA, PHB and PHV are designed for composting under commercial operating conditions, taking typically 9 weeks to fully degrade, but the manufacturers do not offer any guide as to the decomposition performance in domestic composing units, as the conditions are both cool and variable. The implication is that the time scales are lengthy. Promotional literature seen from a German supplier (Natura Packaging)[4] states that "PLA trays are only for industrial composting".

The test that is used to determine degradability under EN 13432 (ISO14855) [5] is conducted at 58°C. This test would not determine the degradability of materials under typical home composting conditions, as a home composter would not be expected to achieve such a high temperatures for extended periods of time.

5.2 Suitability for commercial composting

5.2.1 Source segregated materials

Local authorities across the UK are working to introduce methods of collection and processing waste in a form in which it can be recycled or composted rather than being sent to landfill. If the biodegrable waste is to be diverted away from landfill and into a composting or anaerobic digestion facility for turning into compost it is essential that the householder puts the packing into the bin or bag which is provided by the council for the compostable waste.

To allow the householder to do this it is essential that the local authority provides clear instructions and an easy method for the separation and collection of this waste.

[4] Natura Verpackungs GMBH, Postfach 5080, 48419, Rheine

[5] ISO 14855 - Determination of the ultimate aerobic biodegradability and disintegration of plastic materials under controlled conditions -- Methods by analysis of evolved carbon dioxide

It is also essential that the polymers are labelled in a way which makes it clear which plastics are biodegradable and can be put into the bin with other compostable material. It should be noted however that even with high levels of public education and an efficient collection system it will be impossible to divert all of the biodegradable packaging into the compostable waste stream. The implication is that a proportion will inevitably end up in the plastics stream for recycling, (where it may be a contaminant) or be sent to landfill as residual waste.

5.2.2 **Case Study - TMBC**

The extent to which packaging materials can be recovered into a compostable waste stream is illustrated by the ORA's experience with Tonbridge and Malling Borough Council (TMBC).

The soft packaging content of most household waste will consist mostly of two components, cardboard and plastic. From studies conducted by ORA, and in particular a waste audit conducted for TMBC in 2005, the proportion of cardboard (which is a specified and allowable component of the TMBC separate green waste collection scheme) actually segregated is about 80%. This is demonstrated in Table 1, which tabulates the amount of cardboard arising in four separate areas within TMBC. Material recovered was separated into the composting stream by the householder, material not recovered was left in the residual waste stream.

kg/household/week			
	Recovered	Not Recovered	Total
West Malling	1.21	0.46	
Ditton	1.37	0.30	
Larkfield	1.14	0.44	
Hadlow	1.11	0.25	
Average	1.43	0.36	1.79
Percentage	**80%**	20%	

Table 1: Cardboard arisings, TMBC

These separation figures were achieved following a successful public awareness campaign by the council, aimed at maximising household awareness of the options available for recycling and composting.

It would not be unreasonable to presume that if biodegradable packaging was both readily available to the householder, and easily identifiable, that similar separation rates could ultimately be achieved.

5.2.3 **Case Study - SCDC**

In 2001, as part of a project to improve the recycling rates of compostable materials for Suffolk Coastal District Council, ORA conducted a series of trials measuring the degradability of starch based bags and of degradable polythene bags in a commercial composting environment.

In order to monitor the degradation of the biodegradable polymer utilised within the pilot areas, controlled polymer samples were buried one meter within the composting windrows. The polymer samples were contained within a non-degradable plastic mesh bag that would allow the heat, moisture and microbes access to the samples but would limit the amount of detritus sticking to the samples and protect them from puncture. Polymer weight loss was measured over a two month period on a series of samples extracted at varying composting times. The results are shown in Figure 1, which is adapted from the Suffolk report.

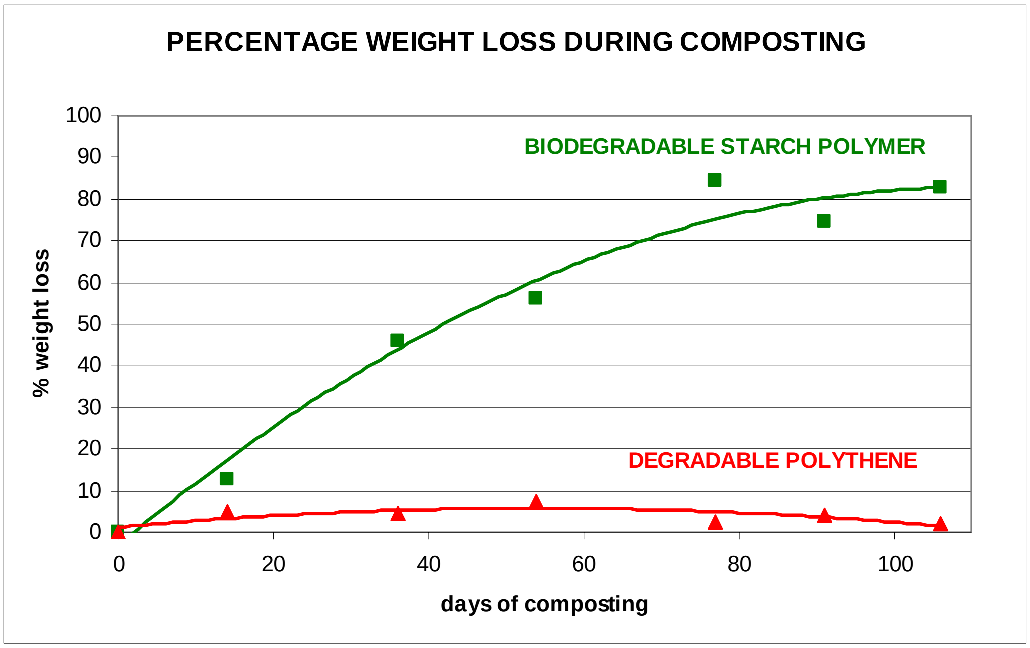
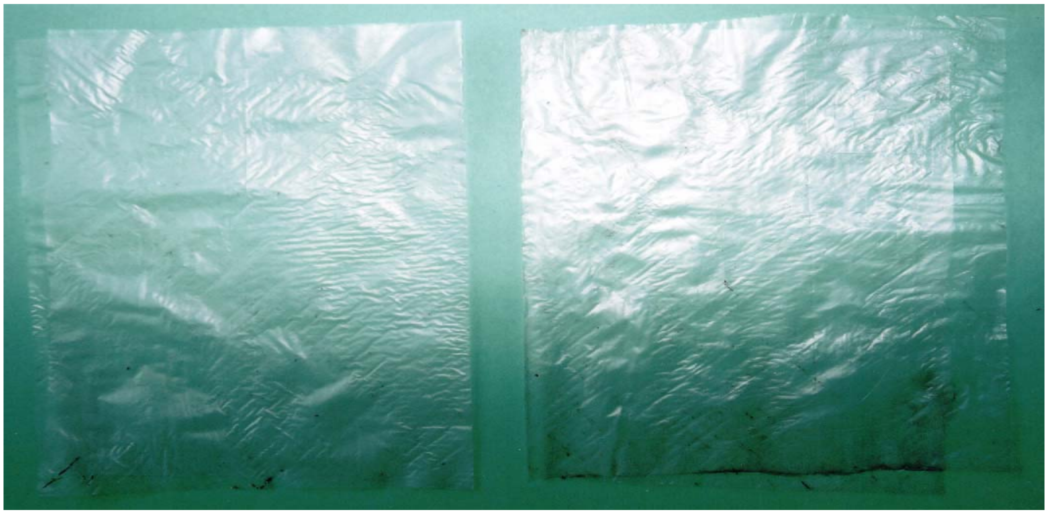


Figure 1: Polymer weight loss over time

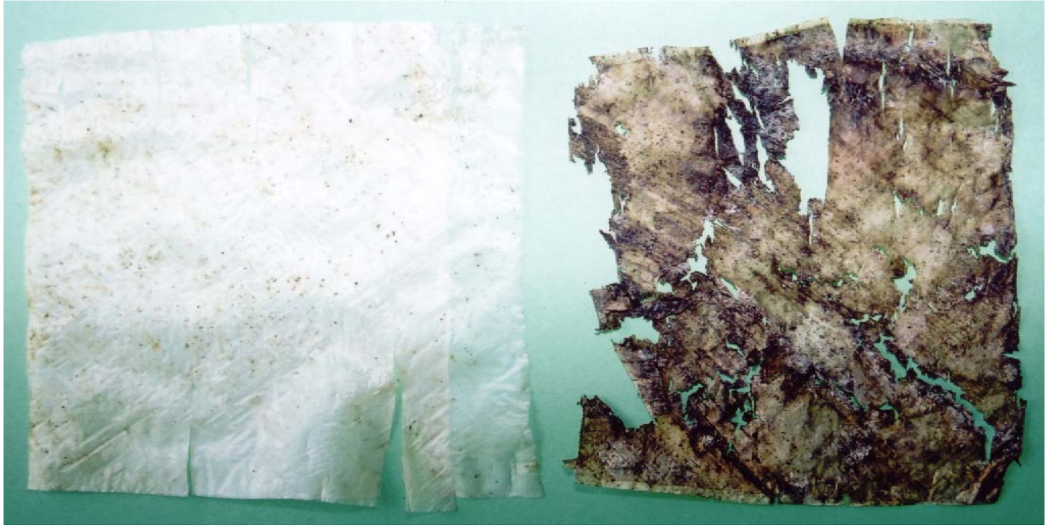
The weight loss experienced by the starch product is much greater than that experienced by the PE product. No visible degradation had occurred to the PE samples.

The visual effect of the composting process on the polymer samples can be seen in the following photographs. They show the two different polymer samples used in the mesh bag trial in SCDC pilot scheme after 14 and 35 days of exposure within the compost windrow.



14 days **35 days**

Figure 2: PE product extracted from open compost windrow



14 days **35 days**

Figure 3: Starch product extracted from open compost windrow

As Figure 3 shows there has been a considerable rate of decomposition of the starch-based product in the windrow. However, the polyethylene product in Figure 2 shows no major sign of degradation, except for slight discoloration.

These tests lend weight to the statements made by the bio based material producers in section 6.2 regarding the non-compostability of fossil based materials.

5.2.4 Case Study – Mater Bi Composting

The following chart has been extracted from the Polargruppen[6] website, and applies particularly to Mater Bi PLA material. It demonstrates the comparative compostability of cellulose and synthetic PLA by measuring the decomposition to O_2, under standard conditions. Under the conditions of the test, at 58°C, after 50 days 85% of the film grade Mater-Bi material has decomposed, compared with 88% of a pure cellulose sample, and throughout the 50 day period, the film is within 10% of the decomposition of the cellulose sample. A different form of the polymer, a moulding grade used for formed semi rigid packaging, is typically 20% less degraded that the cellulose sample, until they have decomposed equally at about 120 days.

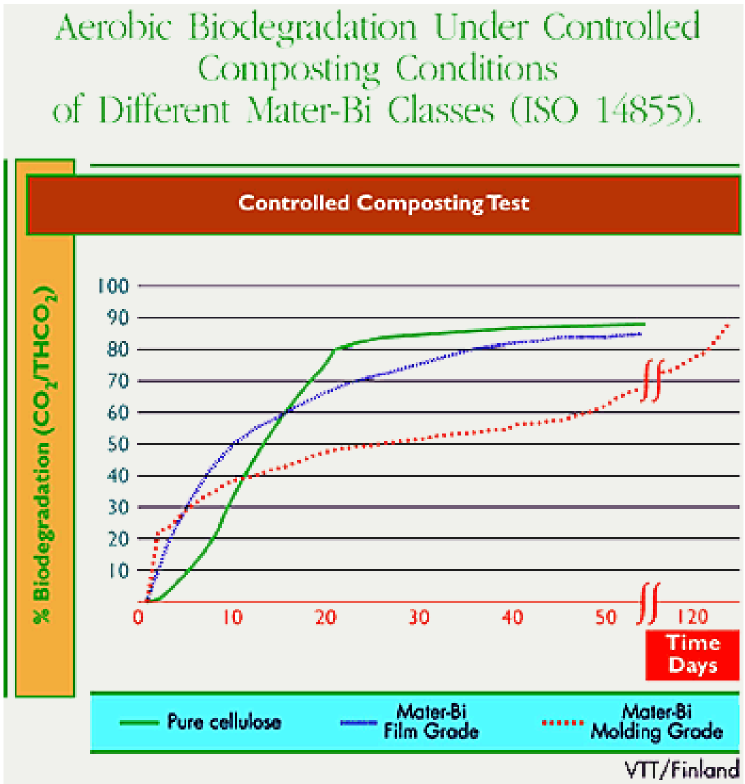


Figure 4: A comparison test between the BioBag and a paper bag with regard to compostability.

5.3 Suitability for landfill

In spite of the drive to increase recycling rates in the UK, currently only 20% of the UK's waste is recycled and the majority of waste is landfilled. Therefore it is important to consider what would happen to the biodegradable packaging which is not diverted in to a compostable waste stream.

[6] http://www.polargruppen.com/mater-bi.htm

5.3.1 The Landfill Directive (1999/31/EC)

The Directive's overall aim is "to prevent or reduce as far as possible negative effects on the environment, in particular the pollution of surface water, groundwater, soil and air, and on the global environment, including the greenhouse effect, as well as any resulting risk to human health from the landfilling of waste, during the whole life-cycle of the landfill". The Directive sets demanding targets to reduce the amount of biodegradable municipal landfilled. Financial penalties are levied against Waste Disposal Authorities who exceed their allowances for the amount of biodegradable material they send to landfill.

The introduction of biodegradable packaging that is sent directly to landfill will worsen an authority’s position over that which would have existed had the packaging been non biodegradable.

There is only any benefit to be gained at the disposal stage if the introduction of biodegradable packaging enables the recovery to composting or anaerobic digestion of a packed material which otherwise would itself have been landfilled.

The reason behind the legislative requirement to divert biodegradable waste from landfill is that such waste will decompose to a mixture of methane and carbon dioxide under the anaerobic conditions that prevail in a compacted landfill. Both methane and carbon dioxide are greenhouse gases (they contribute to the greenhouse effect whereby the earth is warmed by increasing amounts of contaminant gases in the atmosphere), but methane is some 21 times more damaging than carbon dioxide. Under controlled digestion or composting, the decomposition product is almost entirely carbon dioxide.

5.4 Treatment of waste prior to landfill

The requirement to divert biodegradable waste from landfill is forcing waste disposal authorities across the UK to develop alternatives to the landfilling of untreated municipal waste. The two alternatives which are being considered most widely are:

- Mechanical and Biological Treatment (MBT)
- Incineration

In MBT, the mechanical process could separate out some of the biodegradable polymers at which point they could be recycled, composted or anaerobically digested. The remaining biodegradable material which could not be separated would then either be composted or anaerobically digested along with the rest of the waste. The biological treatment would biodegrade these polymers and therefore this form of treatment would reduce the amount of material which is sent to landfill and the degradation would take place under conditions where the uncontrolled emissions of methane into the environment would not take place.

If the waste was incinerated and the ash disposed of in landfill then the biodegradable polymers would be burnt in the same way as the non-biodegradable polymers. In this situation the potential to produce methane is minimised but the biodegradable polymers would perform similarly to non-biodegradable polymers in environmental terms. The exception to this is polymers which contain chlorine such as poly vinyl chloride (PVC), which have the greatest potential to produce dioxins when burnt.

6 COMPLIANCE WITH PERFORMANCE STANDARDS

The Directive on Packaging and Packaging Waste (94/62/EC) defines requirements for packaging to be considered recoverable. Any packaging material investigated under this directive will independently need to pass approvals for suitability for use as a food packaging. The following discussion concerns the requirements for packaging to be considered biodegradable, it does not consider the requirements for packaging to be suitable for food use, it is assumed that in offering their products as suitable for food use, the manufacturers mentioned in this report will have ensured that their products are suitable for food use.

6.1 European biodegradable packaging standards

BS EN 13432:2000[7] - Packaging (Requirements for packaging to be considered recoverable through composting and biodegradation. Test scheme and evaluation criteria for final acceptance of packaging) amplifies these requirements with respect to organic recovery.

BS EN 13432:2000 is contained within a framework of standards under BS EN 13427:2000 which may be used together to support a claim that packaging is in compliance with the essential requirements for it to be placed on the market as required by the Directive.

The other three standards covered by BS EN 13427 are:

- EN 13429 - Packaging. Reuse.
- EN 13430 - Packaging. Requirements for packaging recoverable by material recycling.
- EN 13431 - Requirements for packaging recoverable through composting and biodegradation. Test scheme and evaluation criteria for the final acceptance of packaging.

(The German standard DIN V-54900 – Prufung dert kompostierbarkeit von kunstoffen, has been superceeded by EN 13432)

[7] EN 13432 and other relevant regulations are more fully discussed in Appendix B

There are other internationally accepted standards covering biodegradability, in use in Belgium, Finland, Japan and USA. Each is administered by a Certification Institute; some are supported by an Industry Association.

Country	Specifications / Norms	Certification Institute	Logo	Industry Association
European Union	EN 13432	DIN Certco		IBAW
Japan	JIS K 6950 JIS K 6951 JIS K 6953	BPS		BPS
North America	ASTM D6400-04 ASTM D6868-03	BPI		BPI
Finland	EN13432	Jatelaitosyhdystis		
Belgium	EN13432	AIB Vincotte		

Table 2: Certification systems for compostability

The droplet logo, used by Symphony Plastics, applies to an oxy-degradable fossil fuel based product engineered to decompose by a non-biological disintegration route.

6.2 IBAW - International Biodegradable Polymers Association & Working Groups

IBAW was founded in 1993 as a coalition of stakeholders in order to promote the idea of biodegradable plastics. It is a trade association representing the interests of (currently) 50 member companies operating in the field of biodegradable plastics, with headquarters in Berlin. It actively promotes the orange “seed” logo in Table 2, maintains a close liaison with DIN Certco, and aligns itself and its members with EN

13432 as a means of ensuring measurable and certifiable biodegradability of its members products.

It has recently published a position paper[8] which differentiates its members' products from those on the market that degrade by the oxo-degradable route. The following summary has been published by the Composting Association. (23-09-05)

> *"Shopping bags made from polyethylene PE, which contain metal based additives to promote the break down of the plastic into very small pieces, have a negative impact on health, plastic recycling and the environment. IBAW, the international industry organisation for bioplastics and biodegradable polymers, has published a position paper, which comments on the many questions raised by so called "degradable" PE products.*
>
> *Since their first appearance on the market in the 80s many doubts have been expressed as to whether PE Additive products that are claimed to be "oxo-degradable", "biodegradable", sometimes even "compostable", provide what they promise. The latest example of such a misleading marketing concept was the French "Neosac" launched in April. None of these products have yet met the requirements of the European Standard EN 13432, which determines whether a plastic packaging is biodegradable and compostable. While IBAW member companies test and certify their products according to this Standard, manufacturers of "degradable" PE additive products do not. For good reasons: After an initial decomposition – the product brittles into small pieces – the degradation of the remaining PE is very slow, much too slow to meet the criteria of the Standard. The resulting PE dust then could accumulate in nature, where animals and plants might incorporate it. It is well known from scientific studies that especially the marine life suffers from plastic residues.*
> *In the position paper IBAW also points at the metals used as additives, like the carcinogenic Cobalt. During the manufacture of the bags, the high concentration of the metal based additives could damage workers' health. If the bags are trashed or brought to composting the metals may be liberated with the consequence of adding (eco)toxic persistent and bio accumulative substances to the environment.*
> *IBAW criticises that these bags are advertised to solve the littering problem. In fact such a concept might promote littering and endangers organic recovery schemes which are built up to promote sustainability. Even if the bags are collected in plastic recovery schemes, the concept is hardly an innovative and favourable one: The additives will destabilise plastic recyclates of mixed origin, leading to a reduced technical and economical value of recycled plastics."*
> *http://www.compost.org.uk/dsp_news_detail.cfm?id=220*

[8] http://www.compost.org.uk/images_client/news/050606_Position_Degradable_PE.pdf

7 CONSUMER COOPERATION

7.1 The Kassel Experience

ORA are partners with a waste management consultancy in Germany IGW (Ingenieurgemeinschaft Witzenhausen GmbH) who have worked on a project to trial the introduction of biodegradable packaging to the town of Kassel in Germany.

IGW's involvement in the Kassel Project was the implementation of waste audits of both source separated waste and residual waste to determine the impact that distributing compostable packaging had on the amount of material placed in the biobin that should not be there. IGW also examined the practicality of separating compostable packaging from source separated waste which contained the compostable packaging.

Conclusions drawn by IGW regarding the operation of the trial included:

- The trial area was too large, and the density of biodegradable material in the area was too low.
- Availability of the packaging was too low
- Compatability of biodegradable materials with conventional packaging machinery was poor, particularly the filling of cups with dairy products
- Enlisting the support of the packers was vital
- Use of bags and trays for fruit and vegetable products was more successful

Extracts from a published article describing the Kassel Project and its outcome are included in Appendix III.

7.2 Labelling

To simplify the task of the householder or consumer when it comes to possible recycling of a plastic product, a system of symbols has been developed to enable identification of the material type.

The Society of the Plastics Industry, Inc. (SPI) introduced its resin identification coding system in 1988 in the USA, originally intended to identify the type of plastic used in the product. The system has developed into a means whereby the consumer can easily determine the recyclability of a package.

1	PET	**Polyethylene terephthalate** - Fizzy drink bottles and oven-ready meal trays.
2	HDPE	**High-density polyethylene** - Bottles for milk and washing-up liquids.
3	PVC	**Polyvinyl chloride** - Food trays, cling film, bottles for squash, mineral water and shampoo.
4	LDPE	**Low density polyethylene** - Carrier bags and bin liners.
5	PP	**Polypropylene** - Margarine tubs, microwaveable meal trays.
6	PS	**Polystyrene** - Yoghurt pots, foam meat or fish trays, hamburger boxes and egg cartons, vending cups, plastic cutlery, protective packaging for electronic goods and
7	OTHER	**Any other plastics** that do not fall into any of the above categories. - An example is melamine, which is often used in plastic plates and cups.

Biodegradable materials are noticeable by their absence from the table.

As mentioned in section 5.3.1, there is only any benefit to be gained at the disposal stage if the use of biodegradable packaging enables the recovery to composting of a packed material which otherwise would have been landfilled. In the absence of a suitable marker in the above series, the means available to the producer to identify packaging recyclability would seem to be the use of the orange IBAW logo, and/or the use of the words compostable or biodegradable printed onto film or embossed into moulded products. The means of identifying biodegradable loose fill is not apparent.

At the Composting Association's annual conference in December 2004 it was announced that the Composting Association would administer the UK compostable packaging logo promotion scheme according to DIN CERTCO rules using IBAW's hexagon logo. Further information is available from Melvyn Chimes at melvyn@compost.org.uk

8 HOW AVAILABLE ARE THE RAW MATERIALS?

8.1 British Sourced

The polymer producers identified in Appendix I all operate outside the UK, probably drawing their raw materials from suitable worldwide sources. The several packaging producers operating in the UK will be purchasing their materials from the manufacturers and be operating as converters. The only producer of polymers identified in the UK is Potatopak (section 4.3), who are using waste starch from the potato processing industry as their raw material. There are indications that surplus starch residues exist elsewhere in the UK at present.

8.2 GMO Free

The production routes described so far for biodegradable plastics all use a starch or glucose based material as the starting point for the production of biodegradable polymers. The extent to which the material source is Gentically Modified (GMO) free is determined by the sourcing practice of the producer, and the extent to which the producer may choose to publicise that sourcing practice. In the case of Novamont, for example, the Mater Bi polymer is promoted as GMO free.

Searches have suggested that very little, if any, GMO material is being grown in the UK at the moment, whether for consumption of for industrial processing.

The raw materials from which biodegradable polymers are made are sugars and starches, most often in pure or refined forms. The molecules that are polymerised will be these basic molecules. Genetic modification alters the DNA sequencing of plants, it does not alter the structure of starch or glucose. Additionally, the polymerisation reactions do not polymerise DNA. Consequently, biodegradable polymers should not contain genetic sequences. The question as to whether biodegradable packaging is from a GMO source is one of ethics; it is not one of material property. The Soil Association, for example, state that in order to achieve compost certification under their scheme of approval:

"<u>Soil Association standards</u>
Where biodegradable packaging is made of or derived from genetically modified organisms it would not be suitable for inclusion in material to be composted for use in organic production. The Soil Association's organic standards state that you must not use genetically modified organisms (GMOs) or their derivatives in organic farming or food processing.

Where non-organic inputs are being included in composts to be used in organic production, compost producers must get a signed GMO declaration form from the suppliers of non-organic inputs to show they do not contain any GMOs or their derivatives. Depending on the risk of contamination, we may ask compost producers to provide analysis to support this. We provide GMO declaration forms for suppliers and also details of how we analyse risk" [9].

A novel alternative way of producing the polymer has been described by Monsanto[10], who claim to have created GMO plants that can "grow plastic". They have done this by inserting four genes from the polymer producing bacteria into varieties of oilseed rape and cress. This turns the plants into "biological factories" making plastic that can then be extracted from the plant. The plastic produced by the plant is not only biodegradable, it is also claimed to be suitable for widespread commercial use. It is being produced experimentally in special varieties of GMO oilseed rape and cress. One kilogram of this plastic would at best cost $3-$5 (£1.80-£2.90), compared with $1 (£0.60) per kilogram for petroleum-derived plastic. The end product at present would, however, appear to be too brittle for most applications.

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[9] e-mail response from Soil Association to an enquiry from ORA, 19-12-05

[10] http://news.bbc.co.uk/1/hi/sci/tech/459126.stm

9 BARRIERS TO THE SUCCESS OF BIODEGRADABLE PACKAGING

Once a system for the testing, certification and labelling of compostable products have been established and the compostability of such certified products have been acknowledged by operators of composting plants and others, there remains one basic question about the possible organic recovery of these products.

Is it feasible to collect such materials via the ‘biobin’ (an extra bin supplied to households for the separate collection of compostable waste) and in the skip for ‘green waste’ at household waste recycling centres?

The answer to the above question will depend on a number of issues, the extent to which householder/consumers will separate biodegradable plastics into the ‘biobin’ and the extent to which householders/consumers will distinguish between biodegradable and non-biodegradable plastics. Most of the biodegradable packaging cannot be distinguished from non-biodegradable packaging conventional plastics by their look or touch alone; a clear logo is an essential requirement in order to provide a means of differentiation. Public awareness would need to be raised and information communicated about the logo, the materials and the logic behind the new approach to consumers, local authorities and composting plant operators

The EU Landfill Directive requires the UK to reduce the volume of biodegradable municipal waste being sent to landfill. Materials derived from crops, including packaging made from starch based polymers, can make a contribution to reducing the volume of landfill waste, provided that arrangements are in place for an increase in the amount of biodegradable material actually composted or otherwise used in ways which avoid disposal to landfill or other environmental damage. **Biodegradable packaging would lose its benefit and become a disbenefit in terms of the UK’s Landfill Directive objectives if the material is sent instead to landfill.**

The effectiveness of the public information campaign that was associated with the Kassel project can be seen in the separation rates achieved by the consumer during the project, Table 3 (green dot is a means of identification of recyclable items for the purposes of compliance with recycling legislation in Germany).

Disposal route	Consumer choice (%)
Residual waste	10
Green Dot	6
Biobin	59
Home composting	25

Table 3: Consumers’ chosen disposal routes for the bioplastic packaging

Germany already makes considerable efforts to recover waste, and existing collection schemes have good recovery rates. However, it can be concluded that, based on an existing collection system (biobin), consumers were willing to differentiate biodegradable packaging and dispose of the two different types separately.

10 CONCLUSIONS

At the outset of the Part 3 of the GROWS project four questions were asked and following answers can be given by way of conclusions to the report:

Are biodegradable polymers available which can be composted in home composters?

Yes.

Biodegradable packaging materials produced directly from starch are capable of being composted at the low temperatures in the relatively slow process typically found in home composting systems. It will take longer if the packaging is thicker than if it is the form of, for example, a film.

Biodegradable packaging produced from lactic acid such as PLA, PHB and PHVB are not typically compostable in home composting systems. The biodegradation of these types of packaging requires the higher temperatures and more aggressive and faster composting process typically found in commercial scale municipal waste composting facilities.

Whether these materials are actually composted or not depends largely on whether or not the materials are identified as compostable. There are logos such as The EU DIN Certco Logo which clearly identifies packaging as being biodegradable. They key issue is how widely it is applied and whether the householder or consumer recognises it and understands that they can put the material in their home composter or in a separate collection scheme provided by the local authority.

It should be noted that some material currently available and marketed as degradable is manufactured by mixing metallic ion based additives with fossil based polymers. These materials are oxo-degradable rather than biodegradable. It is claimed that oxo-degradable polymers will not meet the requirements of EN13432 and research has found that these materials not proven to be compostable either in home or large scale composting systems. Therefore, the oxo-degradable polymer based packaging cannot carry the EU DIN Certco logo identifying it as compostable. IBAW, which promotes the use of biodegradable polymers, is active in distancing itself and its members products from oxo-degradable packing, which they claim will disintegrate rather than biodegrade, leaving small polymer particles and metallic residues after composting.

Are there biodegrable polymers available which are suitable for food packaging?

Yes.

There are at least seven companies commercially producing polymers from glucose and starch worldwide, and at least nine converters based in the UK currently manufacturing packaging products for food applications from these materials.

It is presumed that the manufacturers that are offering biodegradable packaging for food applications will already have provided evidence that their products are suitable for food applications.

The starch and glucose based manufacturers and producers in Europe have formed an industry association, IBAW, to promote the use of biodegradable polymers as packaging materials, and members promote and operate within the parameters of EN 13432. The association maintains a close liaison with the German standards authority DIN Certco, and promote the use of a definitive "seed" logo.

Is it possible to obtain GMO free biodegradable packing material?

Yes

At least one manufacturer of biodegradable packing, Novomont, produce a GMO free biodegradable material, branded as Matter-Bi and which is made into a packaging film by Polargruppen. This material is marketed for the collection of compostable food waste rather than as food packing *per se*. It would be worth investigating further whether they intend to produce products specifically for food packaging from the Mater-Bi or other GM free film.

Is it possible to source raw material for biodegradable polymers from sources in the UK?

In theory yes.

Starch is available from the UK either as a by-product from the existing food industry via crops such as potatoes and maize, which can be grown specifically for the production of starch for the production of packing. However, the manufacturers source raw material throughout the EU and third countries. Therefore, it is not possible at the moment to produce a biodegradable packaging project solely on UK produced raw materials. It would be possible to pursue this option further via UK Government programmes such as the National Industrial Symbiosis Programme and the EU ReprO programme.

Last but certainly not least it must be noted that the use of biodegradable packaging will be of no benefit if the packaging is eventually sent in an untreated form to landfill. Under this circumstance, it is likely that degradation in the low amount of air in landfill will result in the production of methane, as gas which is 21 times worse than carbon dioxide in terms of the global warming. In this case biodegradable packaging would have a worse environmental impact in terms of gaseous emissions than would be the case if non-biodegradable packaging was landfilled. It is essential therefore that the biodegradable packaging can be identified as being compostable by the householder and consumer and that they are provide with the information and means to divert it away from their rubbish and into either their home compost bin or a local authority scheme for composting or anaerobic digestion.

11 RECOMMENDATIONS

Before the widespread introduction of biodegradable packaging the food retailers should consult with national Government via DEFRA and WRAP, local authorities via LARAC and composting industry via the Composting Association. The purpose of this dialogue would be to determine the extent to which the biodegradable packaging will actually be composted or anaerobically digested. This would be a good environmental outcome as opposed to disposal via landfill without any pre treatment which would be poor environmental outcome.

As part of this process a lifecycle analysis (LCA) could be carried out to identify how the packaging lifecycle could be improved in the UK in order to reduce the environmental impact of packaging. The LCA would take account of:

- How the biodegradable polymers are likely to interact with home composting and local authority schemes for the separate collection and composting of municipal waste

- The means of producing the raw material from which the biodegradable packaging is produced

- The impact of landfilling the packaging and how the adverse effects can be mitigated by pre-treatment of the waste prior to landfilling

If it was concluded that there would be an environmental benefit from the more widespread use of biodegradable packaging then the findings of this report could be used to develop its introduction and recovery from the waste in the UK.

A study could be undertaken to determine the feasibility of using starch produced in the UK, either as a by product or a virgin material for use in biodegradable packaging in the UK.

Trials could be undertaken to determine the ability of different biodegradable material in different types of packaging to biodegrade in home composting systems.

An attitude survey could be undertaken to determine how many local authorities would allow the inclusion of biodegradable packaging in their collection schemes for compostable materials.

APPENDIX I - Manufacturers' Contacts

NOVAMONT

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APPENDIX II - Regulatory compliance

BS EN 13432:2000

This standard specifies requirements and procedures to determine the compostability and anaerobic treatability of packaging and packaging materials by addressing four characteristics:

- **Characterisation** – identity of constituents, presence of hazardous substances (eg heavy metals), organic carbon content, solids content and volatile solids content

- **Biodegradability** – laboratory test under aerobic conditions determining CO_2 release or oxygen consumption, with levels set comparing actual degradation with theoretical maximum

- **Disintegration** – A screening test for residual particle size following controlled composting

- **Compost quality** – Assessment of ecotoxicity against national standards, with particular reference to visual quality

Materials are tested at a particular physical specification, typically (in the case of films) described by thickness, thinner materials will usually be deemed to conform.

A material is deemed biodegradable if it undergoes degradation caused by biological activity under specific environmental conditions to a specific extent within a given time.

To be designated as bio-compostable, a material has to biodegrade and disintegrate in a composting system under standard test methods.

For a material or product to be defined biodegradable according to EN13432 it has to fulfil the following criteria:

- Biodegradation: > 90% compared with cellulose (positive standard) in 180 days under conditions of controlled composting using respirometric methods (ISO14855)

- Disintegration: > 90% shall pass a 2mm sieve in 3 months (ISO FDIS 16929)

- Eco-toxicity: Toxicity tests for aquatic and terrestrial organisms (*daphnia magna*, worm test, germination test) as for reference compost.

- Absence of hazardous heavy metals detailed in a reference list

The conformity of a material or product to the EN13432 norm must be tested by accredited testing organisations; they are listed in Table 2.

Although in theory, any biodegradable packaging could be tested for conformity with EN13432, the International Biodegradable Polymers Association & Working Groups (IBAW) state that “No PE additive product has yet been shown to comply with EN 13432”.
http://www.ibaw.org/eng/downloads/050606_Position_Degradable_PE.pdf

Non EU standards

USA

ASTM D 6400-99 follows the same fundamental principles as EN 13432. First of all the proof of biodegradability in principle is necessary, followed by the testing of disintegration. To determine the biodegradability, further alternative methods and, under certain circumstances, longer time periods are accepted. Also, there are limits for the content of heavy metals, which are higher than the European standards. There is also a certifying program for this standard, in which products that fulfil this standard can be certified. In this case the certifying will be conducted by the “Biodegradable Products Institute” (BPI), New York, USA.

JAPAN

Polylactic acid (PLA), a resin derived from renewable resources such as plants, has been approved for food packaging applications by the Japanese Hygienic Olefin and Styrene Plastics Association (JHOSPA).
At the same time, PLA was officially registered by the association as a new resin. As a result, PLA is now usable in the same way as other general-purpose resins in food packaging applications.
http://www.performance-materials.net/htm/f20041001.973273.htm

Packaging and Packaging Waste

All packaging has to comply with a European Directive on Packaging and Packaging Waste (2004/12/EC, which amends a 1994 Directive 94/62/EC). The Directive has been implemented in the UK in two separate pieces of legislation: - The Producer Responsibility Obligations (Packaging Waste) Regulations 1997 - The Packaging (Essential Requirements) Regulations 2003.

The latter regulations are implemented through SI2003 No 1941[11]. The main requirement is that no person who is responsible for packing or filling products into packaging or importing packed or filled packaging into the UK may place that packaging onto the market unless that packaging fulfils the Essential Requirements and is within the Heavy Metal concentration limits. The Essential Requirements are:

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[11] dti: Packaging (Essential Requirements)Regulations, Government Guidance Notes (Revised), February 2004

- Packaging volume and weight must be the minimum amount to maintain the necessary levels of safety, hygiene and acceptance for the packed product and the consumer

- Packaging must be recoverable in accordance with specific requirements

- Noxious or hazardous substances in packaging must be minimised in emissions ash or leachate from incineration or landfill. Heavy metal limits are also set.

The regulations are enforceable by Trading Standards Officers, with maximum penalties of £5000 enforceable both individually and corporately.

The following note has been published by DEFRA[12]

> "The UK Government has taken a keen interest in the issue of biodegradable plastic and has met with representatives of the plastics industry in this regard. The Government accepts that biodegradable plastic has a place in the market; it also supports the development of biodegradable plastics from non-fossil fuel sources. The Government Industry Forum on Non-Food Uses of Crops was set up in March 2001 to provide strategic advice to Government and industry on the development of non-food uses of crops.
>
> The Producer Responsibility Obligations (Packaging Waste) Regulations, which came into force in March 1997, require certain businesses to meet targets for the recovery and recycling of packaging waste in line with the EC Directive on Packaging and Packaging Waste. This is likely to lead to an increase in the recycling of all packaging materials, as businesses will have to invest in more recycling facilities in order to meet their obligations.
>
> The Regulations require certain businesses who handle packaging (from raw materials manufacturers, converters, packers/fillers to sellers) to recover and recycle specified amount of packaging handled by their business. They also set out the national recovery and recycling obligations for the year, and the "activity obligation" relating to the activity of the producer on packaging. The Regulations work on the basis of shared producer responsibility, sharing the obligations to recover and recycle between businesses operating at different stages along the packaging chain, including those converting materials into packaging, filling packaging and selling the packaging or packaged goods to the final user or consumer."

12 http://www.defra.gov.uk/environment/waste/topics/plastics.htm

APPENDIX III – The Kassel Project

The following article describing the Kassel Project is taken from Waste Management World[13] dated 2nd March 2005.

The German Ministry of Consumer Protection, Food and Agriculture funded a study which was carried out between 2001 and 2003 in the city of Kassel, Germany, the home to 200,000 inhabitants of average social and financial background. The study provided a third-party certification for compostable plastics.

A range of about a dozen different certified products were delivered along routine distribution channels to some 80 participating retailers and sold to consumers. Based on information that had been provided, consumers were expected to sort labelled packaging into the biobin after use and to avoid disposing of conventional plastic items in this bin.

Households were provided with an information brochure together with a compostable bag for the collection of biowaste (a 'biobag'). During the campaign, several press articles featured the project and some local TV stations reported its progress. A three-metre high display of product samples was showcased for several weeks in public places such as the town hall, university cafeteria and a central bank office.

Expensive methods of communication such as TV advertisements were avoided in order to obtain a realistic picture of the feasibility of informing consumers that could be cost-effectively extended to the whole of Germany. The communication cost of approximately €2.25 per inhabitant was considerable. However, given the duration of the project (21 months) and the potential savings from economies of scale, the Kassel approach seems suitable for implementation at a national level, according to the experts involved from the waste management service company, Interseroh GmbH.

Consumer reactions.
Market research involving 600 interviews carried out in two waves during the project revealed enthusiastic reaction from consumers to the new product range. Consumers strongly supported the idea of replacing conventional plastic packaging with bioplastics. They also liked the idea of composting in order to close the material cycle. More than 80% of customers who purchased products in biopackaging were (very) satisfied with the performance of the packaging and 89% stated they would buy them again.

[13] http://www.earthscan.co.uk/news/article.asp?sp=364283336352272782492&v=5&UAN=379

TABLE 1. Results of market research: what do you think about replacing conventional plastic packaging with compostable biopackaging?

Opinion	Respondents (%)
1 (very good)	45
2	44
3	9
4	1
5	0
6 (very bad)	1

Several people even stated that they would spend more money on a product if it was packaged in bioplastics. Although this statement might be questioned in many cases, it does provide evidence that customers (especially those of high-priced products) might be willing to spend a little bit more for an environmentally friendly packaging, but this is provided the additional costs of the packaging are not shown separately but are included in the price of the product.

Especially interesting was the response when people were asked to compare compostable plastic packaging with other types of material in terms of environmental friendliness. Bioplastics were ranked as even more environmentally friendly than returnable glass packaging – a surprising result given that the latter is usually considered by far the most environmentally friendly option.

: 2. Results of market research: how environmentally friendly do you think the following packaging materials are?

Packaging material	Respondents who rate excellent or good (%)
Bioplastics	93
Glass (returnable)	91
Paper	82
Glass	63
Metal	16
Plastics	7

APPENDIX IV -Life Cycle Analysis

The following section is reproduced from the NOVAMONT[14] website

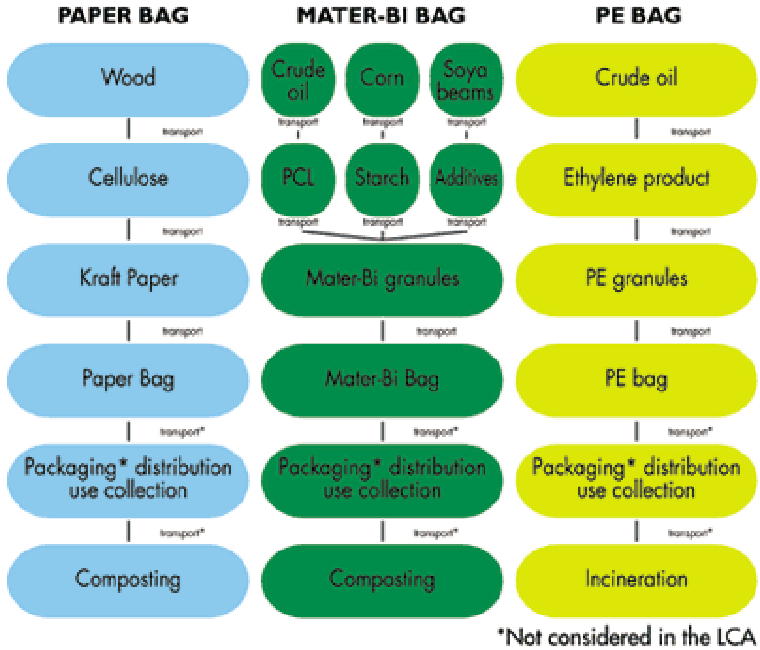
LCA of Bags In Mater-Bi™

PRODUCTS SELECTED

The environmental impact caused by the manufacture and disposal of bags in Mater-Bi™ used for the collection of organic waste was assessed using life cycle analysis, taking paper and polyethylene bags as references. The assessment covered all phases of the life cycle, from the raw materials to the manufacture, to the disposal of the product, including transportation.

[14] www.novamont.com

PHASES OF THE PRODUCTION CHAIN AND CONTENTS OF THE SYSTEM



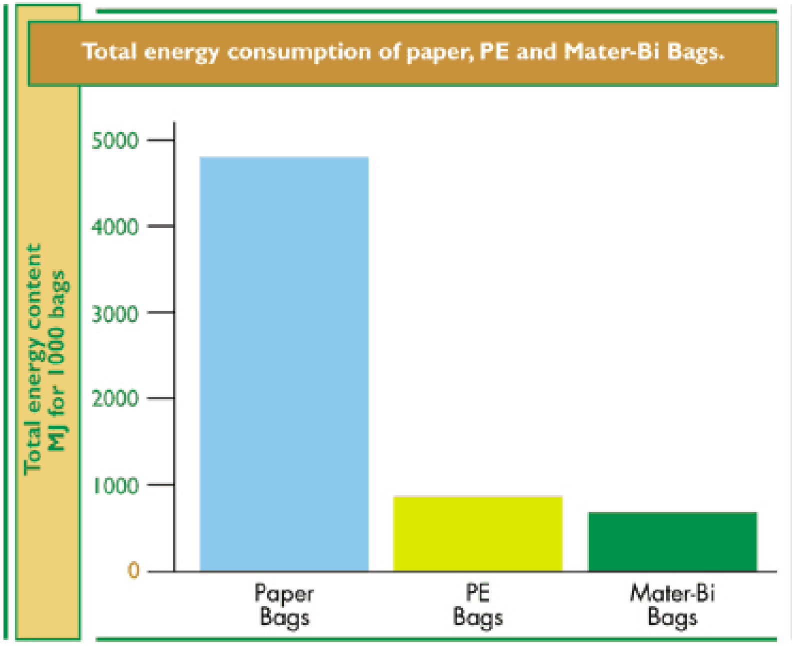
The analysis took into consideration bags used and disposed of in Switzerland. The reference products were selected on the basis of those currently on sale in the large-scale retail trade, in Switzerland.

Paper bags	Bags made of Mater-Bi™	Paper bags	Bags made of Polyethylene
Material	Z-class Mater-Bi™	Kraft paper	HDPE
Country of origin	PCL:USAmaize: FranceMater-Bi™: Italy	Paper: Sweden Bag: Switzerland	Granules:Malaysia Bag: Malaysia
Disposal	Composting	Composting	Incineration
Dimensions (mm)	(220+220)x440	(240+105)x510	(180+360)x600
Weight (g)	9.15	59.6	7.04

CALCULATION MODELS

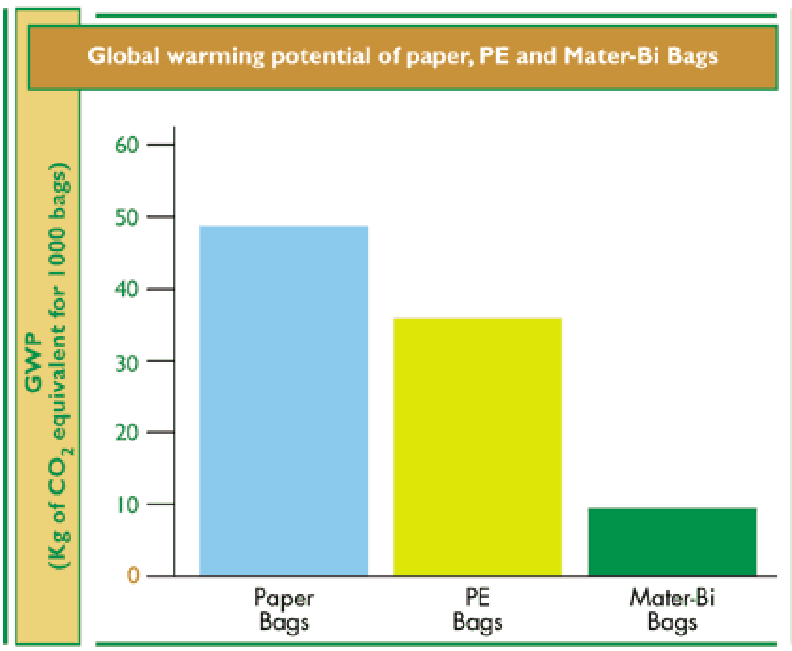
The analysis was made according to the "impact oriented" model (Heijings, 1992; BUWAL 1996), using categories of the ECO-Indicator model (Goedkoop, 1995). The calculations were made using Version 2.2 of the EMIS (Environmental Management and Information System) program. See the bottom of the page for a more detailed description of the categories considered. The analysis was carried out by an independent Swiss company, and certified in accordance with EN ISO 14040.

ENERGY CONTENT



Paper bags consume much more energy than the corresponding bags made of Mater-Bi™ and of PE, because of their greater weight.

GREENHOUSE EFFECT



Bags made of Mater-Bi™ make a significant contribution to reducing the greenhouse effect, because of their natural constituents.

OVERALL COMPARISON: MATER-BI™, PAPER AND POLYETHYLENE.

	Bag made of Mater-Bi™ compared with:		
Environmental impact category	paper bag	bag made of PE	bag made of PE, including incineration of the organic residue
Energy	+ +	0	+
Greenhouse effect	+	+	+ +
Acidification	+	0	+ +
Nutrification	+ +	0	+
Ozone formation	+ +	+	+ +
Toxicity in air	+	++	+ +
Toxicity in water	++	0	+
Salification	–	– –	+ +
Waste produced	++	– –	–

Legend:
(++) = much better
(+) = better
(0) = comparable
(-) = worse
(--) = much worse
The life cycle analysis shows that bags made of Mater-Bi™ clearly have a better environmental impact than paper bags, and are comparable with bags made of polyethylene incinerated alone after separation from the waste.

However, experience of managing the composting process shows that complete separation of the plastic bag from the organic waste is not possible, as a significant quantity of non-separable organic material remains together with the plastic. This waste must be burnt together with the plastic. If we also consider this effect, the environmental impact of bags made of Mater-Bi™ are clearly better than bags made of polyethylene.

Environmental impact categories considered in the analysis.

- Energy: consumption of energy resources (oil, natural gas, etc.), assessed from the energy content of the resources necessary (MJ)
- Greenhouse effect: temperature increase of the planet due to gas emissions (CO_2 equivalents)
- Acidification: potential damage to plants due to the emission of substances such as nitrogen and sulphur oxides (SO_2-equivalents)

- Nutrification: potential unbalancing of the water and of the soil due to the emission of substances that have a fertilising effect, such as nitrates and ammonia (PO4-equivalents)
- Ozone formation: increase in the formation of ozone (summer smog) due to the emission of substances such as organic solvents and nitrogen oxides (C2H4 equivalents)
- Toxicity in air: pollution of the atmosphere due to gas emissions
- Toxicity in water: pollution of water due to organic emissions, heavy metals, etc.
- Salification: damage to flora and fauna in water due to the emission of salts, such as chlorides (assessed as H+ ions)
- Waste produced: quantity of waste disposed of, weighed as inert substances, harmful toxic waste, radioactive waste, etc.