Working Group
Biodegradable Packaging Recovery Project

REPORT

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PREFACE

Biodegradable plastics, thus called since they are products that can be degraded by microorganisms just like any organic material, have been on the market for several years. Raw materials used to produce these plastics come from natural products such as corn and various plants, but also from fossil materials such as oil. Their market share is becoming significant, especially in the packaging sector.

CONAI, National Packaging Consortium, institutionally concerned with recovery packaging waste, established a Working Group (hereinafter WG) for the "Biodegradable Packaging Recovery Project", with the following goals:

1) formulate a definition of "biodegradable packaging";
2) define the correct and shared pre and post-consumption management of biodegradable packaging, from their separate collection to recycling/recovery and some possible markings;
3) define suitable information to provide to the public.

Different organisations such as Consortium for biodegradable and non-biodegradable packaging waste recovery, biodegradable and conventional plastic manufacturers and users and concerned sector associations participated in the WG by signing an Agreement; all participants are scientifically coordinated on the university level.

Studies, Life Cycle Analyses (LCA), laboratory and industrial tests were conducted to verify the biodegradability and recyclability (organic, mechanical and chemical recycling) of the packaging introduced on the market for the sole purpose of finding useful information for their post-consumption management and to meet the set goals.

REPORT

This report describes the goals, results and activities performed by the WG, describing the logic followed and indicating the possible solutions for the correct management of biodegradable packaging waste in the "Conclusions".

1. WORKING GROUP (WG)

Signing the specific Program Agreement was the pre-condition for WG participation.
Group members come from different sectors that concern both conventional and biodegradable plastic materials: raw material manufacturers, packaging manufacturers and users, Associations and Consortium directly or indirectly involved in their post-consumption management:

- Coordinator: **CONAI**
- Biodegradable raw material manufacturers: **BASF*, NatureWorks, Novamont**
- Packaging users: **Barilla, COOP**
- Consortium: **CIC** (Italian Consortium of Composters), **COREPLA** (National Consortium for the Collection, Recycling and Recovery of Plastic Packaging Waste)
- Sector associations: **Assobioplastiche (Assobioplastics), Federazione Gomma-Plastica (Rubber-Plastic Federation)**
- Scientific coordination: **prof. Fausto Gironi**, Chemical Engineering Department, La Sapienza University, Rome.

***BASF** did not provide the data required for Life Cycle Analyses, contrary to that foreseen in the signed Agreement. For this reason, tests were not conducted for mechanical recycling nor were life cycle analyses furthered on BASF products.

2. WORKING GROUP GOALS

As indicated in the Agreement text signed by the participants, WG goals were:

1) formulate a definition of "biodegradable packaging" covered by the Agreement;
2) define the correct and shared pre and post-consumption management of biodegradable packaging, from their separate collection to recycling/recovery and some possible markings;
3) define suitable information to provide to the public.

3. WORKING PROCEDURE

"Working Procedure" is considered the organisational logic followed for the activities where problem solving is preparatory to solving the next problem. All this in a framework corresponding to effective social and technical needs that generated the problem.

1) First of all:

Defining what is meant by "biodegradable packaging" and verify its actual biodegradability.

The main purpose is to be able to provide the public with clear information since the wording "packaging produced with biodegradable material" is more often seen and heard, sometimes accompanied by contradictory sentences that can create confusion.

2) Next:

Verify biodegradable packaging recyclability.

Thus run laboratory tests and, where possible, industrial tests, to obtain data useful to understand the recycling potential of biodegradable packaging (organic, mechanical and chemical).

3) Then:

Consider the best ways to separate biodegradable packaging collection.

In general, biodegradable packaging waste can be collected with organic waste for organic recycling (composting); and, alone or with conventional plastics, for mechanical or chemical recycling.

For joint collection with conventional plastic packaging waste, its behaviour in the selection, recycling and recovery processes should be verified.

4) At the same time:

Study the environmental impacts (LCA) of the materials and potential post-consumption management of the biodegradable packaging made with these materials.

Life Cycle Analyses (LCAs) of retail packaging, made up of biodegradable or traditional plastic - from their production to their use until their recovery - are important to obtaining useful information on the most convenient post-consumption management from the environmental impact standpoint.

Even a good solution has an environmental cost that the Life Cycle Analysis can estimate. This cost has to be considered in the general post-consumption management cost.

5) Lastly:

Give the public reliable information and clear instructions.

This should be based on ***objective data*** obtained from studies and tests.

4. STUDIES, TESTS AND RESULTS

a) GLOSSARY

We decided it would be helpful to provide definitions for a series or frequently used words to avoid the intentional or accidental confusion that now exists.
Various topics from the packaging sector were taken into account: packaging, collection, recovery, recycling, biodegradable materials.
It should be noted and highlighted that the definition suggested by the WG for “biodegradable packaging” is one of the WG's goals:
“The Working Group believes that packaging that can be composted as per UNI EN 13432-2002 standards (organic recycling) should be defined as biodegradable.”

b) COMPOSTING TESTS

Industrial tests, on flexible and rigid packaging made of biodegradable plastic, were conducted to evaluate disintegrability**,** due to biodegradation, during the aerobic treatment process (composting). The test was performed according to UNI EN 13432:2002 and UNI EN 14045:2003 standards.
The tests were technically conducted by the Italian Consortium of Composters (CIC).
The test lasted 12 weeks (from June 13, 2011 to September 5, 2011). Material disintegration was defined and qualitative analyses on the obtained soil improver were performed. The soil improver was obtained as a mixture between organic waste from separate collection and different percents of packaging samples, according to the following test outline:

- **CASE A**. flexible packaging: fresh product bags IV grade (PLA Ingeo);
- **CASE B**. flexible packaging: shopping bags: B1 Mater-Bi, B2 Ecovio;
- **CASE C**. rigid packaging: food trays (PLA Ingeo);
- **CASE D**. rigid packaging: food bottles (PLA Ingeo);
- **CASE E**. Catering: **E1** tableware (PLA Ingeo), **E2** cups and flatware (PLA Ingeo);
- **CASE F**. Combination of A, B, C, D, and E.

The disintegration test was conducted using the following product quantities:

- 1 - 3% test for single A, B, C, D and E materials (SING test);
- 3 - 5% test for combinations of A, B, C, D and E (MIX test);

(for example: 1% means 100 g of biodegradable material/packaging in 10 kg of organic waste)
48 tests were prepared in all with the material to be tested, plus 3 others with "control" function.

Results

Concluding remarks resulting from the disintegrability tests on biodegradable plastic flexible and rigid products are as follows:

- a level of disintegration over 90% in 12 weeks was achieved for all the tested biodegradable plastic flexible and rigid products;

- for each test analysed, the addition of a standard initial mix of 1%, 3% and 5% biodegradable products did not cause either negative effects on the compost process or on the quality of the soil improver product, which met legal regulations (Legislative decree 75/2010 – fertiliser regulation);
- all tested products thus passes the disintegrability test, both in SING tests (with 1% biodegradable plastic mix) and MIX tests (with 3 and 5% biodegradable plastic mix) and thus they are certifiable as per UNI EN 13432-2002 standards.

c) MECHANICAL RECYCLING TESTS

The tests were conducted by the Milan Polytechnics Plastic Material Test Laboratory Foundation and the Proplast laboratory.
Laboratory tests were conducted with standard methods on samples taken from both virgin materials (in granules) and from semi-finished industrial products, obtained from virgin materials or post-consumption materials.
The tests, although indicative, are normally used to provide information on the potential techniques that can be used to mechanically recycle the concerned products.
Please note that the tests conducted on PLA and Mater-Bi products were performed taking into account the post-consumption material recovery phases. In fact, tests on PLA were performed considering the potential separation of rigid packaging made with this material into a dedicated stream; while tests on Mater-Bi took into account flexible packaging made with this material but hard to separate at existent plants. In fact, this packaging waste ends up in the stream of flexible packaging waste made of conventional plastics.
The obtained results did not claim to provide information on packaging waste selection and cleaning processes or on the potential industrial applications and processes to obtain specific recycling materials/products. For these items further industrial investigations are required.

PLA

Analyses performed at the Milan Polytechnics Plastic Material Test Laboratory Foundation coordinated by Dr. Canali.
Materials analysed:

- **Material 1:** NatureWorks virgin granule (PLA 2003D): both injection moulded and extruded in sheets at the Bandera Group;
- **Material 2:** Re-ground from ILIP trays: both injection moulded and extruded in sheets at the Bandera Group;
- **Material 3:** Re-ground from ILIP trays and hot washed with soda solution.

The analysis concerned variations in:

- average molecular weight and rheological properties;
- thermal and mechanical properties;
- visual aspects.

Tests performed on PLA mechanical recyclability provided positive results from the technical standpoint.

Additional test

An industrial PET spinning test with PLA additives in increasing quantities was also conducted (0.25 % - 0.5 % - 1.0 % - 2.0 %).
In short, excluding the PET drying phase, the variations observed from the process and product standpoints were not significant and it can be reasonably concluded that a concentration of about 1% - 2% of PLA in recycled PET can be managed in a common short-spinning plant.

Mater-Bi

Analyses conducted at the Milan Polytechnics Plastic Materials Test Laboratory Foundation and Proplast laboratories in Tortona (by COREPLA) aimed to gather information on the characterisation of Mater-Bi biodegradable polymer added to fraction of plastic film.

A. Milan Polytechnics Plastic Materials Test Laboratory Foundation Analyses

Materials analysed:

- Mater-Bi and PE virgin granules;
- Mixture of PE and 2.5% Mater-Bi;
- Mixture of PE and 5% Mater-Bi;
- Mixture of PE and 10% Mater-Bi;
- Mixture of PE and 20% Mater-Bi;
- Three samples of recycled PE Mix granules, with Mater-Bi content varying from 0% to 10%, from industrial production at CIER (Teramo).

The analysis concerned the changes in mechanical and chemical-physical properties.

Tests revealed that it is possible to reprocess/recycle mixture of up to 10% concentrations of Mater-Bi shoppers with conventional plastic shoppers. At higher concentrations (tested up to 20%) problems could arise that must be investigated.

B. Analyses at Proplast

Materials analysed:

- domestic packaging film (mainly LDPE) from separated urban waste collection with the addition of 5% and 10% Mater-Bi shoppers;

The analysis concerned the characterization of the obtained mixtures and the accelerated natural weathering process (Xenotest), after which the mechanical characterisation tests were repeated.

The results are in line with that discovered at the Milan Polytechnics Plastic Materials Test Laboratory Foundation, confirming the 10% threshold and possible problems at higher concentrations.

d) LIFE CYCLE ANALYSIS

LCAs were conducted both with a Mid-point method, supported by ISO standards, and End-point type method.
The first, used with the EPD method (Environmental Product Declaration), calculates the value of some environmental impact categories and expresses the material results providing the value assumed by each single impact category.
The second method is the so-called Ecoindicator 99, End-point type that evaluates a higher number of environmental impact categories that are grouped, after standardisation, in three macro categories. Assigning a weight to the three macro categories leads to, for each product, a single environmental impact index that makes quantitative comparisons possible between two or more products.
The environmental impacts of the pairs of polymers most commonly used in the production of a certain product were compared: the table I lists some of the comparisons, considering both granule production and product production and end of life.
As possible ends of life, the LCAs considered landfilling, incineration, composting, closed cycle (e.g. bottle to bottle) and open cycle (bottle to fibre) mechanical recycling, chemical recycling and mixed scenarios in which the product was sent to different final destinations

TABLE I Main final comparisons between Mater-Bi and PLA products

Mater-Bi		
Comparison		Functional Unit
MB 2010 end of life (comparison between Incineration, Composting/Peat, Composting/Fertilizer, Landfilling and Mechanical Recycling)		1000 Mater-Bi Shoppers (15 kg)
Mechanical MB shopper recycling	Mechanical PE shopper recycling	1000 Mater-Bi Shoppers (15 kg) 1000 PE Shoppers (12 kg)
MB shopper incineration	PE shopper incineration	1000 Mater-Bi Shoppers (15 kg) 1000 PE Shoppers (12 kg)
MB shopper composting	PE shopper incineration	1000 Mater-Bi Shoppers (15 kg) 1000 PE Shoppers (12 kg)

Reused MB shopper composting	Reused PE shopper incineration	1000 Mater-Bi Shoppers (15 kg) 1000 PE Shoppers (12 kg)
Reused MB shopper composting	Reused PE shopper landfill	1000 Mater-Bi Shoppers (15 kg) 1000 PE Shoppers (12 kg)
Reused MB shopper landfill	Reused PE shopper landfill	1000 Mater-Bi Shoppers (15 kg) 1000 PE Shoppers (12 kg)
MB tableware + organic waste composting	PS tableware + organic waste incineration	1000 Mater-Bi tableware and Mater-Bi lined plates (20.3 kg Mb and 27.9 kg paper) + organic waste 1000 PS tableware and plates (31.4 kg) + organic waste
MB tableware + organic waste composting	PS tableware + organic waste landfill	1000 Mater-Bi tableware and Mater-Bi lined plates (20.3 kg Mb and 27.9 kg paper) + organic waste 1000 PS tableware and plates (31.4 kg) + organic waste
PLA		
PLA 2010 end of life (comparison between Incineration, Composting, Landfill and open/closed loop mechanical recycling)		1000 PLA bottles weight 12.5 kg
Mechanical PLA bottle recycling	Mechanical PET bottle recycling	1000 PLA bottles weight 12.5 kg 1000 PET bottles weight 12.5 kg
PLA bottle incineration	PET bottle incineration	1000 PLA bottles weight 12.5 kg 1000 PET bottles weight 12.5 kg
PLA bottle composting	PET bottle incineration	1000 PLA bottles weight 12.5 kg 1000 PET bottles weight 12.5 kg
PLA bottle landfill	PET bottle incineration	1000 PLA bottles weight 12.5 kg 1000 PET bottles weight 12.5 kg
PLA shell composting	PS shell incineration	1000 PLA shells weight 8 kg 1000 PS shells weight 8 kg
Mechanical PLA shell recycling	Mechanical PS shell recycling	1000 PLA shells weight 8 kg 1000 PS shells weight 8 kg
PLA chemical recycling	PLA mechanical recycling	1000 PLA shells weight 8 kg
PLA chemical recycling	PET mechanical recycling	1000 PLA bottles weight 12.5 kg 1000 PET bottles weight 12.5 kg

With reference to the above tests, the main results were the following:

- considering composting, landfilling, mechanical recycling and incineration as possible ends of life, for any end of life, if two products are made with materials that have different physical/mechanical characteristics that justify a non-negligible thickness difference between one product and the other, the overall comparison, in environmental impact terms, always favours the product made with the higher performance product (lesser weight) due to the lower material use;
- analysing the biodegradable and conventional polymer product production processes, the biodegradable product has overall less impacts than the conventional one if more importance is given to the categories that take into account non renewable resource consumption. Contrarily, biodegradable materials are less favoured if significance is given to categories like water consumption, soil and chemical use;
- as for the above PLA, Mater-Bi, PET, LDPE, PS, EPS product end of life, regardless of the costs and feasibility of collection and selection processes, mechanical recycling with the production of flakes to be reused in open or closed loops has overall less impacts than the other analyses ends of life (composting, incineration, landfilling).
  For information completeness, it should be said that based on the data from university level research available on industrial production, still being tested, chemical recycling is possible for PLA which, even when using a high temperature (160-180°C) and high pressure (1.0-1.4 MPa) process, is characterised by a lesser environmental impact than mechanical recycling;
- for domestic organic waste collection or disposable tableware collection with food residue (as with fast food), biodegradable plastics are preferred since the optimal final destination of this waste is composting.

5. CONCLUSIONS

CONAI, National Packaging Consortium, institutionally concerned with recovery packaging waste, established a Working Group (hereinafter WG) for the "Biodegradable Packaging Recovery Project", with the following goals:

1) formulate a definition of "biodegradable packaging";
2) define the correct and shared pre and post-consumption management of biodegradable packaging, from their separate collection to recycling/recovery and some possible markings;
3) define suitable information to provide the public.

Studies, laboratory tests and semi-industrial tests were conducted with the sole purpose of obtaining data and information to support the WG's goals which mainly concern the post-consumption management of biodegradable packaging. The results are not industrial and commercial technical/economic goals for collection, selection and recycling which require other types of studies and tests.

Different organisations such as Consortium for biodegradable and non-biodegradable packaging waste recovery, biodegradable and conventional plastic manufacturers and users and concerned sector associations participated in the WG by signing an Agreement; all participants are scientifically coordinated on the university level.

That given, the main information that the research, studies and tests provided can be summarised as follows:

- for the post-consumption management of packaging made with biodegradable plastics and to avoid providing the public with unclear information, the concept of biodegradability must be associated with the degradation time of the product;
- packaging can thus only be defined as "biodegradable" if it is actually biodegradable within the maximum set time, using a reference standard such as the UNI EN 13432-2002 biodegradability and composting one;
- with reference to the tested packaging, which represents most of the current market, flexible and rigid packaging (film, shoppers, bottles, trays, etc.), cups, plates and tableware made with biodegradable plastics, alone or combined**, are biodegradable and can be composted as per UNI EN 13432-2002 standards**, at least until total 5% weight concentrations, as per the completed tests; this percentage amply covers the amount of biodegradable packaging foreseen on the market in the short and medium term;
- Life Cycle Analyses (LCAs) confirmed that for packaging made with biodegradable plastics, as with other materials**,** mechanical recycling is the solution with the lowest environmental impact;

- packaging made with biodegradable plastics now on the market can be sent to mechanical recycling with some technical precautions. Specifically:
    - flexible packaging (shoppers and film) made with biodegradable plastics, such as the tested Mater-Bi, which cannot be automatically separated in selection plants from conventional plastic flexible products, are still recyclable, up to a 10% content, with the same conventional plastic packaging (polyethylene);
    - rigid packaging, made with biodegradable plastics, such as the tested Ingeo (PLA), is mechanically recyclable. Naturally, the industrial problem of PLA selection must be addressed since, pure technical flows must be obtained for recycling. The required level of purity would be lower for any chemical recycling.

With reference to the three Working Group Goals, the following information can be provided:

1) **Definition of biodegradable packaging.**
   The Working Group believes that packaging that can be composted as per UNI EN 13432-2002 standards (organic recycling) should be defined as biodegradable.

2) **Pre and post-consumption management of biodegradable packaging, from their separate collection to recycling/recovery and some possible markings.**
   - Urban organic waste must be collected in biodegradable plastic bags, e.g. waste bags, shopping bags, fresh produce bags;
   - Even for biodegradable packaging, the concept of the ban on litter is confirmed: their degradation in air, water and land could last years;
   - packaging made with biodegradable plastics can be collected with organic waste; this is the final destination for packaging, plates, cups and various tableware made of biodegradable plastic and dirties with food residue, like those used for catering;
   - biodegradable packaging can also be collected with conventional plastic packaging, whether rigid or flexible;
   - applying a unified symbol/emblem to biodegradable packaging could be useful in the future. The symbol/emblem should be clear and well visible. The symbol/emblem would give the public the chance to easily distinguish biodegradable packaging from non-biodegradable packaging to avoid pollution in the collection phase. Furthermore, in the future, the symbol/emblem, if suitably structured, could be helpful for automatic separation in selection plants and for packaging traceability over its working life.

3) **Definition of suitable information to provide the public**.
   All the above leads to the conclusion that, for the correct management and separate collection of biodegradable packaging waste, the public should be given the following information and instructions:

- only packaging that can be composted and compliant with UNI EN 13432-2002 standards is considered biodegradable;
- biodegradable packaging should not be littered in the environment since their degradation time could last years;
- only biodegradable bags must be used for organic waste collection;
- used biodegradable packaging, cups and tableware can be collected with organic waste to be sent to organic recycling. Or, if not contaminated with organic food waste and following the local authority's instructions, they can be collected with those made of conventional plastics.

Milan, 01/10/2012

- Reports relating to studies and industrial/laboratory tests are annexed to the report in Italian