BIOBASED BIODEGRADABLE PRODUCTS – AN ASSESSMENT

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CHEMICAL ENGINEERING
&
MATERIALS SCIENCE

STAKEHOLDERS

www.bpiworld.org

www.astm.org (D20.96)

US COMPOSTING COUNCIL

www.compostingcouncil.org

QUESTIONS & ISSUES TO BE ADDRESSED

- Why biodegradable plastics??
- Biobased plastics biobased products??
  - Sustainable? Manage CO_2 emissions (Kyoto Protocol), good environmental footprint (potential biodegradable)
- Sustainability??
- Biobased & biodegradable??
- Environmental profile/footprint

ENVIRONMENTALLY RESPONSIBLE MANUFACTURE, USE AND DISPOSAL

RESPONSIVE TO THE ECO (LIVING)SYSTEM (ECOLOGY)

- **Recyclable**
- **Biodegradable**
- **Non-polluting**
- **Energy efficient**
- **Tailored Functionality**
- **Annually Renewable resource based (BIOBASED)**

Material designed to breakdown for ready assimilation by microorganisms – incorporate into the biological carbon cycle – Nature's carbon cycle

BIODEGRADATION/BIOASSIMILATION

NOT

DEGRADATION ALONE!!!

BIOBASED POLYMERS – WHY?
WHAT VALUE IN THE SUSTAINABILITY –
LIFE CYCLE EQUATION

SUSTAINABILITY & SUSTAINABLE DEVELOPMENT

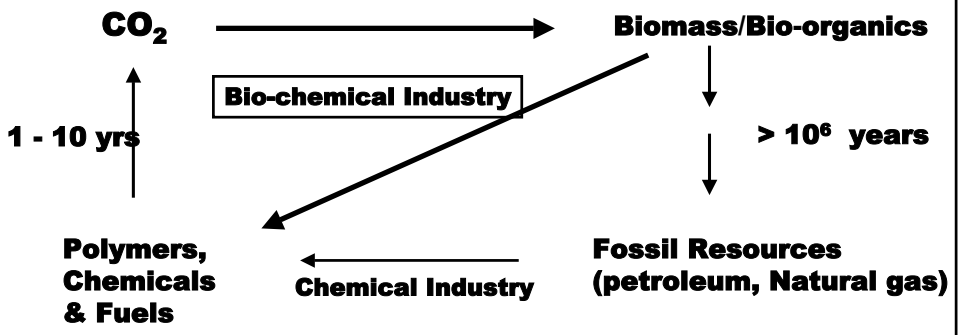
or

POLYMERIC MATERIALS (PLASTICS)
PREDOMINANTLY CARBON POLYMERS

ECOSYSTEM CARBON CYCLES

"biological carbon cycle"

GLOBAL CARBON CYCLING
THE ECO DRIVER



Renewable Carbon CO_2 , & Biomass → New Biochemical Industry Small, entrepreneurial business → Green polymers & Chemicals

ILLUSTRATION OF ECO VALULES BY USING BIOBASED PRODUCTS

Company A manufactures and sells 10 Carbon based products using petro/fossil feedstocks

Each product after use, when disposed off liberates 100 units of CO_2 (remember rates, t=1-10 years)

Total = 1000 units CO_2

QUESTION:

How does company A reduce its CO_2 emissions and improve its environmental profile? – ISO 14001

If company has a 1000 units emissions quota , how does it increase its product offering from 10 to 12 to 15 and so on?

ANSWER:

Make two products from annually renewable bio feedstock or introduce 20% biocontent into each product

Total = 800 units CO_2

IMPORTANT NOTE: Cannot claim biodegradability/compostability or environmental preferedness!!

LCA

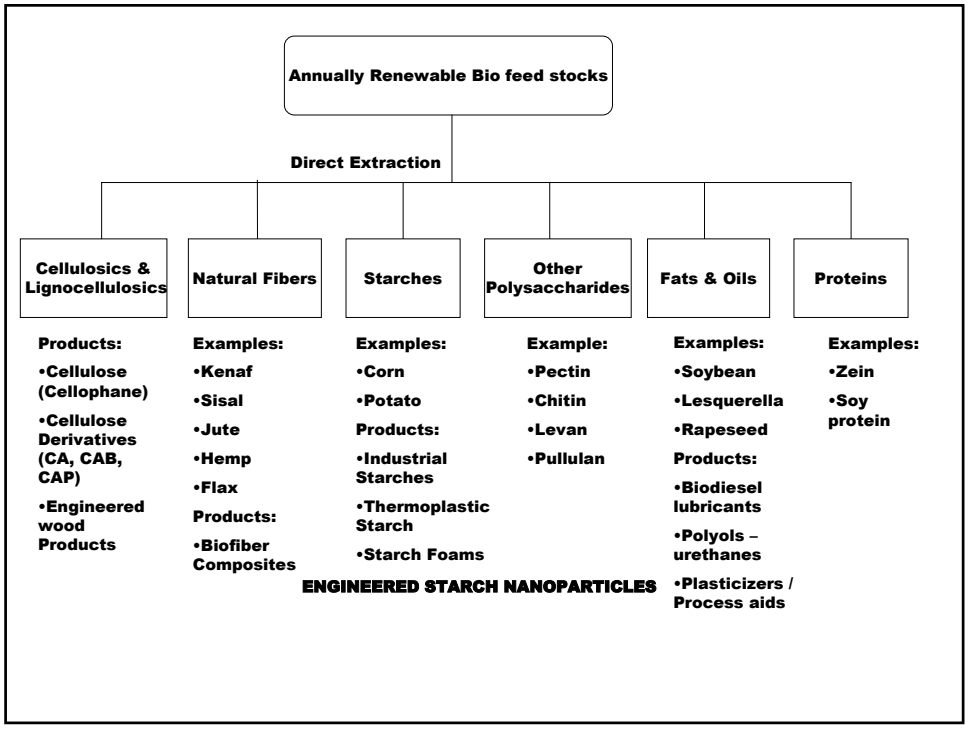
	Fossil energy requirements (cradle-to-factory gate), in GJ/t plastic		
	Process energy	Feedstock energy	Total energy
TPS	25	0	25
TPS + 15% PVOH	26	6	32
TPS + 50% POLYESTER	32	20	52
PHA grown in corn plants	90	0	90
PHA by bacterial fermentation	81/60	0	81/60
HDPE	31	49	80
PET (bottle grade)	38	39	77
PS (general purpose)	39	48	87

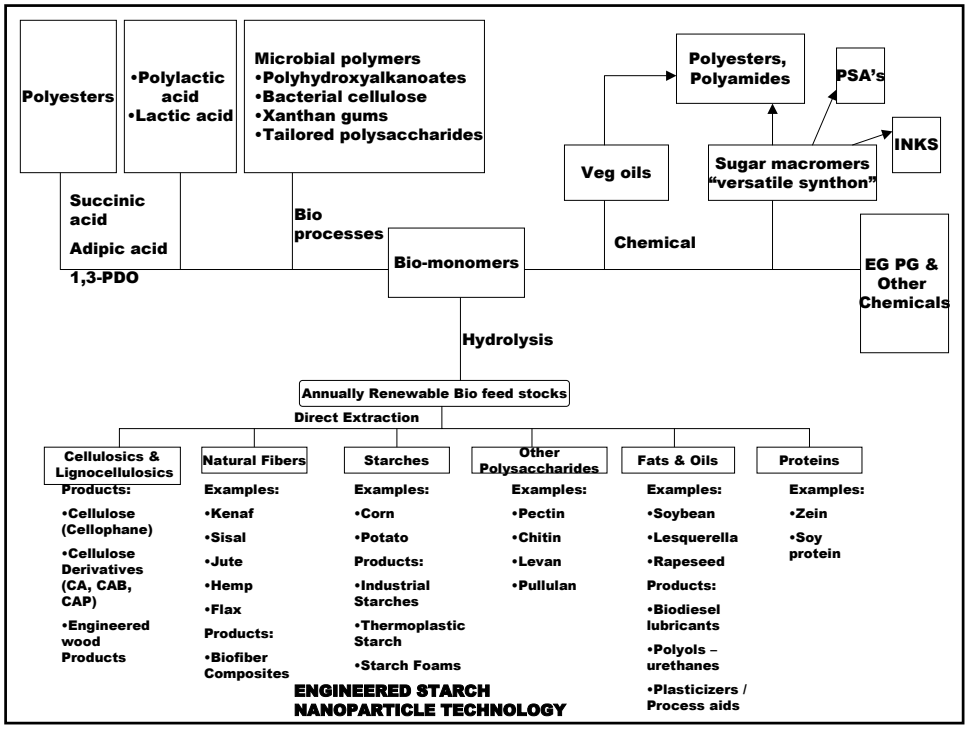
RESOURCES
AGRICULTURAL
FEEDSTOCKS

BIOBASED MATERIALS

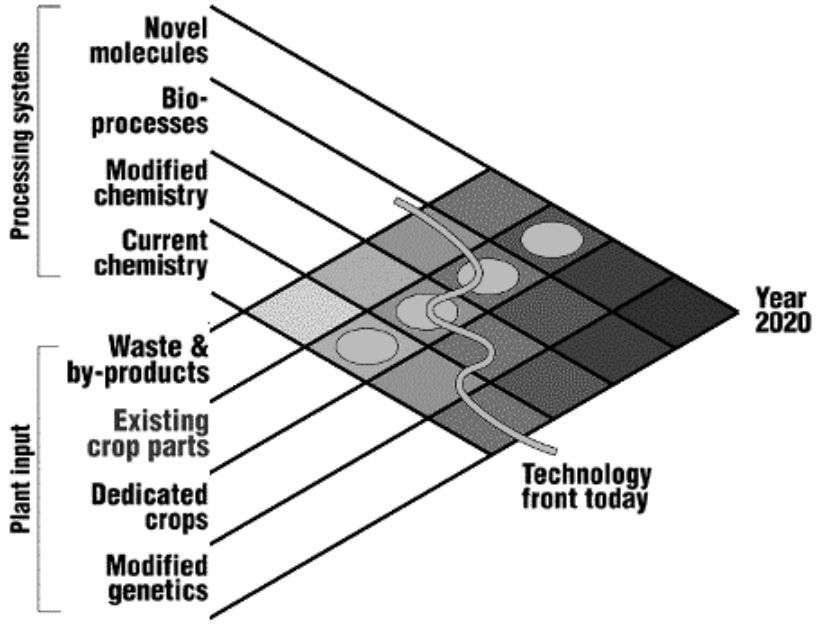
- **For sustainable development of carbon based polymer materials**
- **Control and even reduce CO_2 emissions and help meet global CO_2 emissions standards – Kyoto protocol**
- **Improved environmental (LCA) profile**

BIOBASED BIODEGRADABLE MATERIALS TECHNOLOGIES


Annually Renewable Bio feed stocks
Direct Extraction
Cellulosics & Lignocellulosics
Natural Fibers
Starches
Other Polysaccharides
Fats & Oils
Proteins
Products:
•Cellulose (Cellophane)
•Cellulose Derivatives (CA, CAB, CAP)
•Engineered wood Products
Examples:
•Kenaf
•Sisal
•Jute
•Hemp
•Flax
Products:
•Biofiber Composites
Examples:
•Corn
•Potato
Products:
•Industrial Starches
•Thermoplastic Starch
•Starch Foams
Example:
•Pectin
•Chitin
•Levan
•Pullulan
Examples:
•Soybean
•Lesquerella
•Rapeseed
Products:
•Biodiesel lubricants
•Polyols – urethanes
•Plasticizers / Process aids
Examples:
•Zein
•Soy protein
ENGINEERED STARCH NANOPARTICLES


Polyesters
•Polylactic acid
•Lactic acid
Microbial polymers
•Polyhydroxyalkanoates
•Bacterial cellulose
•Xanthan gums
•Tailored polysaccharides
Polyesters, Polyamides
PSA's
INKS
Veg oils
Sugar macromers "versatile synthon"
Succinic acid
Adipic acid
1,3-PDO
Bio processes
Chemical
Bio-monomers
EG PG & Other Chemicals
Hydrolysis
Annually Renewable Bio feed stocks
Direct Extraction
Cellulosics & Lignocellulosics
Natural Fibers
Starches
Other Polysaccharides
Fats & Oils
Proteins
Products:
•Cellulose (Cellophane)
•Cellulose Derivatives (CA, CAB, CAP)
•Engineered wood Products
Examples:
•Kenaf
•Sisal
•Jute
•Hemp
•Flax
Products:
•Biofiber Composites
Examples:
•Corn
•Potato
Products:
•Industrial Starches
•Thermoplastic Starch
•Starch Foams
Examples:
•Pectin
•Chitin
•Levan
•Pullulan
Examples:
•Soybean
•Lesquerella
•Rapeseed
Products:
•Biodiesel lubricants
•Polyols – urethanes
•Plasticizers / Process aids
Examples:
•Zein
•Soy protein
ENGINEERED STARCH NANOPARTICLE TECHNOLOGY

MATRIX FOR BIOBASED TECHNOLOGY DEVELOPMENT



BIOBASED PRODUCT DRIVERS -- U.S. GOVERNMENT

Presidential Executive Order 13101 (Greening the Government Through Waste Prevention, Recycling, and Federal Acquisition, dated September 14, 1998)

- **U.S. Department of Agriculture (USDA) is proposing guidelines for listing commercially available biobased products for purchase by Federal agencies.**
- **Biobased product is defined as a commercial or industrial product (other than food or feed) that utilizes biological products or renewable domestic agricultural (plant, animal, and marine) or forestry materials.**
- **USDA is listing only those products which are considered by USDA to be within the U.S. Environmental Protection Agency (EPA) Environmentally Preferable Products Guidelines.**
  - **U.S. EPA has issued "Guiding Principles" for products to be listed as "Environmentally Preferable". Recycling, and the use of recycled products is on the top of the list of these principles.**
  - **Composting is Biological (Organic) Recycling**

BIOBASED PRODUCT DRIVERS – U.S. GOVERNMENT (Contd.)

The requirement for Federal agencies to consider biobased products which is environmentally preferable (U.S. EPA) is also in Office of Management and Budget (OMB)/Office of Federal Procurement Policy (OFPP) Policy Letter 92-4 and applies to all Federal agencies.

BIOBASED PRODUCTS & ENERGY SOURCES

US Public Law 106-224 (Biomass Research and Development Act of 2000")

U.S. Congress finds that conversion of biomass into biobased industrial products offers outstanding potential for benefit to the national interest through:

- **improved strategic security and balance of payments**
- **healthier rural economies**
- **improved environmental quality**
- **near-zero net greenhouse gas emissions**
- **technology export**
- **a sustainable resource supply.**

The key technical challenges to be overcome in order for biobased industrial products to be cost-competitive are:

- **developing new technology (materials, processing, and design) for the utilization of biobased materials and**
- **reducing the cost of technology for converting biomass into desired biobased industrial products**

- **many biomass feedstocks suitable for industrial processing show the clear potential for sustainable production, in some cases resulting in improved soil fertility and carbon sequestration**
- **grain processing mills are biorefineries that produce a diversity of useful food, chemical, feed, and fuel products**

Farm Security and Rural Investment Act of 2002 (P. L. 107-171), Title IX Energy, Section 9002

FARM BILL

- Federal Procurement of Biobased Products
- Value Added Market Development Grants

TOOLS AND ASSESSMENT METRICS

FOR BIOBASED SUSTAINABLE MATERIALS

- **identify and quantify biobased content of materials/products (Federal Government (USDA) procurement driver)**
- **total biobased carbon used in the creation of the product, including raw materials and biobased energy – non renewable carbon and fossil energy to be also included (and, where energy has been converted to carbon equivalent)**
- **Establish and report on the environmental profile which would include total resources consumption in form of raw materials, energy, emissions, and waste generated – LCA tools**

ASTM COMMITTEE D20.96

SCOPE

The promotion of knowledge and the development of standards (classification, guide, practice, test method, and specification) for biobased products.

biobased content of a product and its environmental footprint

- **standards which have a sound technical basis and which accurately describe the biobased content of products and their environmental peformance.**
- **allow industry to develop and market biobased products**
- **provide a rational and sound basis for Government procurement activities**
- **enable consumer to choose such products without confusion.**

Three types of standards that require development to assess the overall end use value of biobased products:

1. **biobased content**
2. **environmental footprint and preferability**
3. **product performance and functionality.**

(3) is already largely covered by other ASTM standards.

The focus of ASTM 20.96 will be primarily on 1) and 2), since these methods and tools (e.g.life cycle assessment, carbon tracking etc.) relate to the determination of net biobased content, energy and materials flows, and environmental performance.

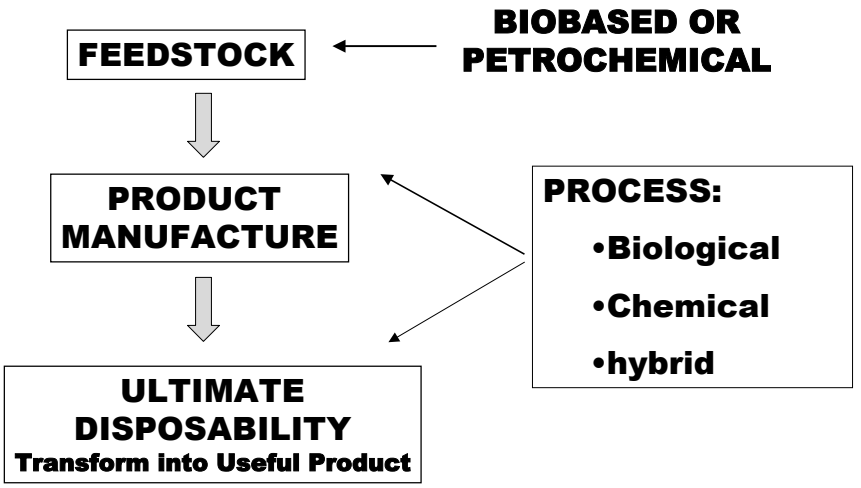
BIOBASED STANDARDS

- **Standard Guide for Determination of Biobased Content, Resources Consumption, and Environmental Profile of Materials and Products**

- Standard Test Methods to Determine the Biobased Content of Natural Range Materials via (14C/12C) Radiocarbon Analysis Using Low Level Liquid Scintillation Counting (LSC) or (14C/12C) Accelerated Mass Spectrometry (AMS) coupled with (13C/12C) Isotope Ratio Mass Spectrometer (IRMS).

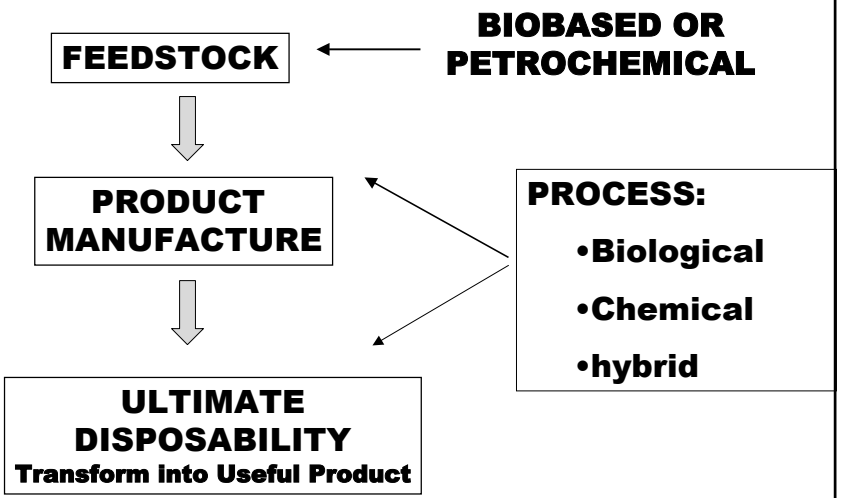
  – directly discriminate between product carbon resulting from contemporary carbon input and that formed from fossil-based input. A measurement of a product's contemporary 14C/12C content is determined relative to the modern carbon-based oxalic acid radiocarbon Standard Reference Material (SRM) 4990c, (referred to as HOxII) as it is the second in the series. It is compositionally related directly to the original oxalic acid radiocarbon standard SRM 4990b (referred to as HOxI), and is denoted in units of fM, i.e., the sample's fraction of modern carbon

MATERIALS DESIGN PRINCIPLES FOR THE ENVIRONMENT



"LIFE CYCLE ASSESSMENT -- LCA"

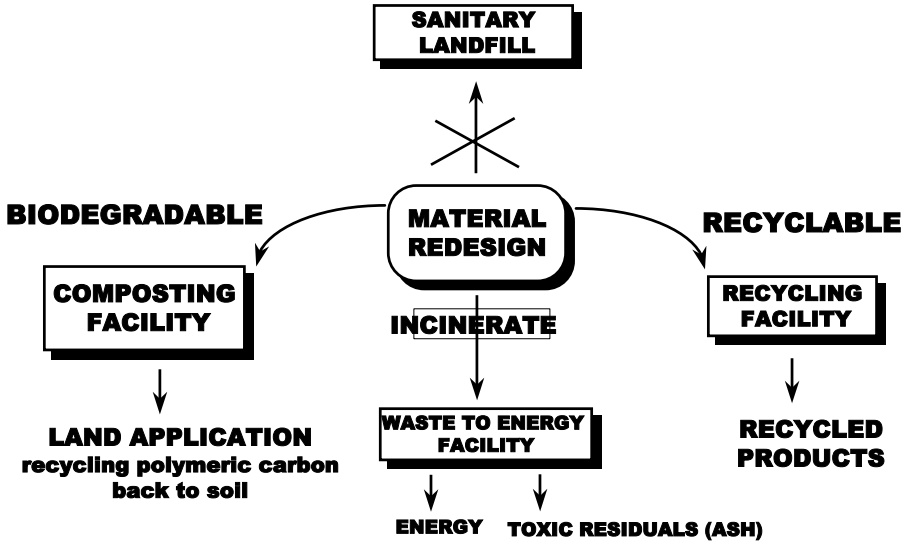
MATERIALS DESIGN PRINCIPLES FOR THE ENVIRONMENT



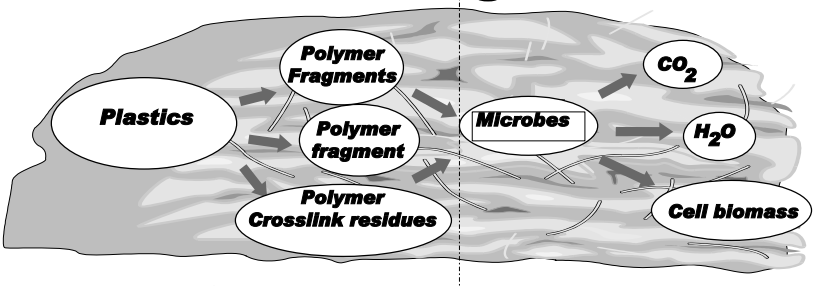
"LIFE CYCLE ASSESSMENT -- LCA"

Cradle to Grave Concept for Material Design

(Integration of Material Design with Waste Managment Infrastructure).



Degradable vs. Biodegradable



Degradation/Fragmentation:

Heat, moisture, sunlight and/or enzymes shorten & weaken polymer chains, resulting in fragmentation residues and cross-linking to create more intractable persistent residues

- **Biodegradation:**

  only if the fragmented residues consumed by microorganisms as a food & energy source

Key Properties for Compostable Plastics

- ASTM identified 3 criteria
  - **Mineralization**:
    Conversion to carbon dioxide, water & biomass via microbial assimilation
    - **Same rate as natural mater**
      Leaves, paper, grass & food scraps

Basis for standards in Europe, Japan & NA

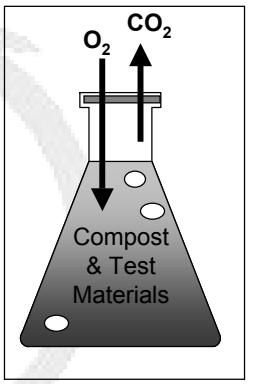
ASTM Standards

- ASTM 6400-99
  - Specification for Compostable Plastics
- Has "Pass/Fail" Specs
  - Mineralization
  - Disintegration
  - Safety
- Similar to Europe & Japan

Basis for BPI's Certification Program

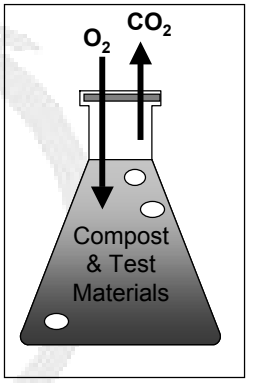
ASTM D6400-99 Details

- Mineralization: D5338
  - 60% conversion to CO_2 for homopolymers
  - 90% conversion for blends and co-polymers
  - Within 180 days



ASTM D6400-99 Details-Cont.

- Mineralization: D5338
  - 60% or 90% conversion to CO_2
  - Within 180 days
- Disintegration
  - <10% of test material on 2mm sieve
- Safety
  - No impacts on plants, using OECD Guide 208



Benefits of Certification

- Easy Identification of "Compostable Products"
  - Meet ASTM D6400-99
- Independent verification of biodegradability & compostability
- Increases credibility
  - Not based on manufacturer's claims
- Reduces confusion

A G R E E M E N T

on co-operation between

DIN CERTCO Gesellschaft für Konformitätsbewertung mbH
Burggrafenstraße 6, 10787 Berlin, Germany

and

Biodegradable Products Institute (BPI)
331 West 57th St, Suite 415, New York, NY 10019, USA

and

Biodegradable Plastics Society (BPS)
26-9 Hatchobori 2-Chome, Chuo-Ku, Tokyo 104-0032, Japan

BPI Biodegradable Products Institute
promoting biodegradable products throughout the world

USA

www.bpiworld.org

グリーンプラ
生分解性プラスチック

BPS JAPAN

kompostierbar

DIN CERTCO GERMANY

Memorandum of Understanding
Cross Certification Program
Agreement by end of year 2001

ICS – UNIDO

FACILITATOR – TRAINER FOR DEVELOPING & IN-TRANSITION COUNTRIES

BASIS FOR AGREEMENT

- DIN CERTCO, BPI and BPS have developed certification and identification programs to distinguish biodegradable and compostable materials and products that meet scientifically based specifications
- DIN CERTCO, BPI and BPS are committed to developing certification systems which rely on similar measurements of inherent biodegradability, disintegration and ecotoxicity. DIN CERTCO's standard for testing and certification is DIN V 54900-1 to –3, DIN EN 13432, and ASTM D 6400-99. BPI's standard for testing and certification is ASTM D 6400-99. BPS's standard for testing and certification is JIS K 6950, JIS K 6951, JIS K 6953 and the GreenPla Identification and Labelling System (First Edition April 1st 2000) for measuring biodegradability. Also, the BPS is currently developing tests and specifications for assessing disintegration.
- DIN CERTCO, BPI, and BPS harmonise the recognition of testing laboratories, and the acceptance of test reports in order to expand the use of biodegradable / compostable materials and products as rapidly as possible

Need for Independent Laboratories

- Valid testing & data is basis for certification
  - Knowledge of standards and regulations
- Laboratories requirements
  - Ability to run key tests