



World Skill Development Institute

Biodegradable Plastics and Polymers

Course Duration – 1 Year.

Biodegradable plastics made with plant based materials have been available for many years. The term biodegradable means that a substance is able to be broken down into simpler substances by the activities of living organisms, and therefore is unlikely to persist in the environment. There are many different standards used to measure biodegradability, with each country having its own. The requirements range from 90 per cent to 60 per cent decomposition of the product within 60 to 180 days of being placed in a standard composting environment. They may be composed of either bio plastics, which are plastics whose components are derived from renewable raw materials, or petroleum based plastics which contain additives. Biodegradability of plastics is dependent on the chemical structure of the material and on constitution of the final product, not just on the raw materials used for its production. Polyesters play a predominant role as biodegradable plastics due to their potentially hydrolysable ester bonds. Bio based polymers are divided into three categories based on their origin and production; polymer directly extracted from biomass, polymers produced by classical chemical synthesis using renewable biomass monomer and polymers produced by microorganisms or genetically modified bacteria. In response to public concern about the effects of plastics on the environment and in particular the damaging effects of sea litter on animals and birds, legislation is being enacted or is pending in many countries to ban non degradable packing, finishing nets etc.

This course basically deals with biodegradable plastics developments and environmental impacts, hydro biodegradable and photo biodegradable, starch synthetic aliphatic polyester blends, difference between standards for biodegradation, polybutylene succinate (pbs) and polybutylene, recent developments in the biopolymer industry, recent advances in synthesis of biopolymers by traditional methodologies, polymers, environmentally degradable synthetic biodegradable polymers as medical devices, polymers produced from classical chemical synthesis from bio based monomers, potential bio based packaging materials, conventional packaging materials, environmental impact of bio based materials: biodegradability and compostability, etc.

Environmentally acceptable degradable polymers have been defined as polymers that degrade in the environment by several mechanisms and culminate in complete biodegradation so that no residue remains in the environment. The present course gives thorough information to biodegradable plastic and polymers. This is an excellent course for scientists engineers, students and industrial researchers in the field of bio based materials.

BIODEGRADABLE PLASTICS DEVELOPMENTS AND ENVIRONMENTAL IMPACTS

Biodegradable

The ASTM defines biodegradable as

Compostable

Compostable is defined by the ASTM as

Hydro-biodegradable and Photo-biodegradable

Bio-erodable

Thermoplastic Starch Products

Degradation Mechanisms and Properties

Starch Synthetic Aliphatic Polyester Blends

Degradation Mechanisms and Properties

Starch and PBS/PBSA Polyester Blends

Degradation Mechanisms and Properties

Starch-PVOH Blends

Degradation Mechanisms and Properties

PHA (Naturally Produced) Polyesters

Degradation Mechanisms and Properties

PHBH (Naturally Produced) Polyesters

Degradation Mechanisms and Properties

PLA (Renewable Resource) Polyesters

Degradation Mechanisms and Properties

PCL (Synthetic Aliphatic) Polyesters

Degradation Mechanisms and Properties

PBS (Synthetic Aliphatic) Polyesters

Degradation Mechanisms and Properties

AAC Copolyesters

Degradation Mechanisms and Properties

Modified PET

Degradation Mechanisms and Properties

Water Soluble Polymers

Polyvinyl Alcohol (PVOH)

Degradation Mechanisms and Properties

Ethylene Vinyl Alcohol (EVOH)

Photo-biodegradable Plastics

Degradation Mechanisms and Properties

Controlled Degradation Additive Masterbatches

Degradation Mechanisms and Properties

Coated Paper

Agricultural Mulch Film

Shopping Bags

Food Waste Film and Bags

Consumer Packaging Materials

Landfill Cover Film

Other Applications

Biodegradation Standards and Tests

American Society for Testing and Materials

ASTM D5338-93 (Composting)

ASTMD5209-91 (Aerobic, Sewer Sludge)

ASTM D5210-92 (Anaerobic, Sewage Sludge)

ASTM D5511-94 (High-solids Anaerobic Digestion)

ASTM Tests for Specific Disposal Environments

International Standards Research

International Standards Organisation

European Committee for Normalisation

OK Compost Certification and Logo

Compost Toxicity Tests

Plant Phytotoxicity Testing

Animal Toxicity Test

Difference Between Standards for Biodegradation

Development of Australian Standards

Composting Facilities and Soil Burial

Key Factors Defining Compostability

Physical Persistence

Chemical Persistence

Toxicity

Effect on Quality of Compost

Anaerobic Digestion

Waste Water Treatment Plants

Reprocessing Facilities

Landfills

Marine and Freshwater Environments

Litter

Key Issues

Recyclable Plastics Sorting Considerations

Reprocessing Considerations

Polyolefin Reprocessing

Polyethylene Reprocessing

Composting

Landfill Degradation

Energy Use

Greenhouse Gas Emissions

Pollution of Aquatic Environments

Increased Aquatic BOD

Water Transportable Degradation Products

Risk to Marine Species

Litter

Compost Toxicity

Recalcitrant Residues

Aromatic Compounds

Additives and Modifiers

Isocyanate Coupling Agents

Plasticisers

Fillers

Catalyst Residues

Prodegradants and Other Additives

Source of Raw Materials

Development of Australian Standards and Testing

Life-Cycle Assessment

Minimisation of Impact on Reprocessing

Determination of Appropriate Disposal Environments

Education

Identify standards and test methods for biodegradable

plastics in Australia

Abiotic disintegration

Activated Sludge

Aerobic degradation

Aliphatic-aromatic Copolyesters (AAC)

Aliphatic polyesters (e.g. PCL)

Amylose

Anaerobic degradation

ASTM

Bioassimilation

Biodegradable

Bioerodable

Biomass

Compostable

Compostable Plastics

Composting

Co polyesters

Decomposer organism

Degradability

Degradable PET

Eco toxicity

Foamed starch

Functional Group

Humus

Hydrolysis

LCA

Master batch

Mineralisation

Modified PET

Monomer

Organic Recycling

Photo-biodegradation

Photodegradable

Phytotoxicity

Plastified Starch

Polybutylene succinate (PBS) and polybutylene

succinate adipate (PBSA)

Polycaprolactone (PCL)

Polyesters

Polyhydroxyalkanoates (PHA)

Polyhydroxybutyrate (PHB)

Poly(lactic Acid) (PLA)

Poly(lactic acid aliphatic copolymer) (CPLA)

Polymer

Poly(vinyl Alcohol) (PVOH)

Prodegradant

Recalcitrant Residues

Thermoplastic Polymers

Thermosetting Polymers

Thermoplastic Starch

2. RECENT DEVELOPMENTS IN THE BIOPOLYMER INDUSTRY

INTRODUCTION

FIBRE-REINFORCED COMPOSITES

STARCH BASED MATERIALS

PLANT PRODUCED POLYMERS

MICROBIALY PRODUCED POLYMERS

BIOLOGICALLY-BASED RESINS, ADHESIVES,

AND COATINGS

CONTINUING RESEARCH AND DEVELOPMENT

ON BIOPOLYMERS

CONCLUSION

3. RECENT ADVANCES IN SYNTHESIS OF BIOPOLYMERS BY TRADITIONAL METHODOLOGIES

INTRODUCTION

BIODEGRADABLE POLYMERS

POLYMER MODIFICATION

A Modification of Polysaccharides

Modification of Polypeptides

Summary

4.POLYMERS, ENVIRONMENTALLY DEGRADABLE

DEFINITIONS

OPPORTUNITIES FOR ENVIRONMENTALLY DEGRADABLE PLASTICS AND POLYMERS

TEST METHODS FOR ENVIRONMENTALLY DEGRADABLE POLYMERS

Test Methods

DEGRADATION MECHANISMS

Photo degradation

BIODEGRADATION

PRODUCTION OF ENVIRONMENTALLY DEGRADABLE POLYMERS

5.SYNTHETIC BIODEGRADABLE POLYMERS AS MEDICAL DEVICES

POLYMER CHEMISTRY

A Note on Nomenclature

PACKAGING AND STERILIZATION

PROCESSING

Factors That Accelerate Polymer Degradation

DEGRADATION

COMMERCIAL BIODEGRADABLE DEVICES

6.BIOBASED PACKAGING MATERIALS FOR THE FOOD INDUSTRY

INTRODUCTION

PROPERTIES OF BIOBASED PACKAGING

MATERIALS

Introduction

Food biobased materials - a definition

Origin and description of biobased polymers

Polymers directly extracted from bio-mass

Polysaccharides

Starch and derivatives

Cellulose and derivatives

Chitin/Chitosan

Proteins

Casein

Gluten

Soy protein

Keratin

Collagen

Whey

Zein

Polymers produced from classical chemical synthesis

from biobased monomers

Poly(lactic acid) (PLA)

Biobased monomers

Polymers produced directly by natural or genetically

modified organisms

Poly(hydroxyalkanoates) (PHAs)

Bacterial cellulose

Material properties

Gas barrier properties

Gas barriers and humidity

Water vapour transmittance

Thermal and mechanical properties

Compostability

Possible products produced of biobased materials

Blown (barrier) films

Thermoformed containers

Foamed products

Coated paper

Additional developments

Conclusions and perspectives

FOOD BIOPACKAGING

Introduction

Food packaging definitions

Primary, secondary and tertiary packaging

Edible coatings and films

Active packaging

Modified atmosphere packaging

Combination materials

Food packaging requirements

Replacing conventional food packaging materials with bio based materials - a challenge

Bio based packaging - food quality demands

State-of-the-art in bio packaging of foods

Potential food applications

Fresh meat products

Conventional packaging materials

Potential biobased materials

Ready meals

Conventional packaging materials

Potential biobased packaging materials

Dairy products

Conventional packaging materials

Potential biobased packaging materials

Beverages

Conventional packaging materials

Potential biobased packaging materials

Fruits and vegetables

Conventional packaging materials

Potential biobased materials

Snacks

Conventional packaging materials

Potential biobased packaging materials

Frozen products

Conventional packaging materials

Potential biobased packaging materials

Dry products

Conventional packaging materials

Potential biobased packaging materials

Conclusions and perspectives

SAFETY AND FOOD CONTACT LEGISLATION

Introduction

Bio based materials and legislation on food contact materials

Common EU legislation

Bio based materials

Petitioner procedures

Standardized test methods

Implications of EU legislation for food and packaging industry

Assessment of potentially undesirable Interactions

Migration of compounds from biobased packages to contained food products

Microbiological contamination of biobased food packages

Penetration of microorganisms through biobased packaging materials

Penetration of insects and rodents into biobased food packages

Collapse due to absorbed moisture from the environment and the contained food product

Conclusions and perspectives

ENVIRONMENTAL IMPACT OF BIOBA-SED MATERIALS: BIODEGRADABILITY AND COMPOSTABILITY

Biodegradability

The composting of bio based packaging

The CEN activity

The compostable packaging

Characterization

Laboratory test of biodegradability

Disintegration under composting conditions and verification of the effects on the process

Compost quality: chemical and eco-toxicological analysis

Natural materials

Biodegradability under other environmental conditions

ENVIRONMENTAL IMPACT OF BIOBA-SED MATERIALS: LIFECYCLE ANALYSIS OF
AGRICULTURE

A sustainable production of bio based products

What is LCA?

Environmental impact of agriculture

Crops for bio fuels

The ECN study

Environmental impact of bio-based products

The Buwal study on starch-based plastics

The case of hemp-based materials: LCA does not
allow generic statements

Compost study on bags for the collection of organic waste

The Ecobilan study. The LCA of paper sacks

The Ifeu-IBIFA-study The LCA of loose-fill-packaging

Conclusions

THE MARKET OF BIOBASED PACKAGING

MATERIALS

Introduction

Market appeal

Market drivers

Marketing advantages

Functional advantage in the product chain

Cost advantage in the waste disposal system

Legislative demands

Consumers

The market

Today

Tomorrow

Price

Conclusions

CONCLUSION AND PERSPECTIVE

Performance of materials

Food applications

Safety and legislation on materials in contact with food

The environment

The market of biobased packaging materials

Perspective

7. PLASTICS FROM POTATO WASTE (SENATE JUNE 20, 1991)

BEGIN INSERT

PLASTICS FROM POTATO WASTE

STARCH TO GLUCOSE TO LACTIC ACID

LACTIC ACID INTO PLASTIC

POTENTIAL MARKETS

8. BIODEGRADABLE PLASTICS FROM RENEWABLE SOURCES ANALYSIS

Plastics and the environment

The move to renewable sources

Extending the recycling loop

Biopolymers, conventional plastics and
biodegradable plastics

The plastics sector

Packaging

Plastic films

Structure of the business

Recent developments

Biodegradability and compostability

Challenges ahead

9. SYNTHETIC POLYMERS FUNCTIONALIZED BY CARBOHYDRATES

Polymerizations of the vinyl sugar monomers

to obtain poly(vinylsaccharide)s

Polymerization of anhydro sugars

Anhydro sugar polymerizations

Enzymatic and Enzyme mediated Polymerizations (Chemo-enzymatic methods)

Polymer analogous reactions

10. BIODEGRADABLE POLYOLEFINS

General procedure for grafting of sugars onto poly(styrene maleic anhydride)

Determination of biodegradability of polymers using aerobic microorganisms

Weight loss data

FTIR Spectral Data

Molecular weight decrease after biodegradation by GPC

Mechanism of reaction of poly(styrene maleic anhydride) with the sugar

Scanning electron micrographs of the polymers before and after bacterial degradation

11. PROCESS FOR THE PREPARATION OF BIODEGRADABLE SYNTHETIC POLYMERS

FORMULA OF THE PRODUCT

INTRODUCTION

OBJECTIVE OF THE PRESENT INVENTION

Wherein

PREFERRED EMBODIMENTS

EXPERIMENTAL/ EXAMPLES

CLAIMS

CONCLUSION

12. FUNGAL DEGRADATION OF CARBOHYDRATE-LINKED POLYSTYRENES

Materials

Synthesis of sugar linked PS-MAH (General Procedure)

FTIR Spectra

Test microorganisms

Testing of the samples

Reaction Mechanism

Calculations (representative)

For sucrose linked to poly(styrene maleic anhydride)

13. GLUCOSE AND GLUCOSE DERIVATIVES WITH POLY(STYRENE MALEIC ANHYDRIDE)

1,2-5,6 Diisopropylidene D- glucose

Step 1: Tritylation and acetylation of D- glucose

Blank reaction of PSMAH in DMF solvent system
with 4-DMAP as the catalyst

Hydrolysis reaction of PSMAH using DMF as
the solvent and 4-DMAP as the catalyst

14. THERMAL ANALYSIS OF SUGAR- LINKED POLY(STYRENE MALEIC ANHYDRIDE)

Thermo gravimetry

FTIR characterization of the thermally treated products

15. BIOMINERALIZATION OF THE SUGAR-LINKED POLY(STYRENE MALEIC ANHYDRIDE)

Experimental set-up

Composition of minimal medium for 1 litre solution

Solutions for the titration are as follows

Preparation of the inoculum

16. BIODEGRADATION OF ACYLATED SUGAR-LINKED POLY(STYRENE MALEIC ANHYDRIDE)

Procedure for Acylation of sugar- linked poly(styrene maleic anhydride) polymers

FTIR spectroscopy of the acylated derivatives of sugar-linked poly(styrene maleic anhydride)

Thermal studies of acylated derivatives of sugar-linked poly(styrene maleic anhydride) polymers

Biodegradation by *Serratia marscecens*

Biodegradation by *Pseudomonas* sp.

Weight loss data

Materials

Test microorganisms

Testing of the samples

Weight loss data

(Sugar-linked PSMAH and their acylated products degraded by *Serratia marscecens* and *Pseudomonas* sp.)

Preparation of Reagent A, B, C, and D

17. BIOTECHNOLOGY: AN ENABLING TECHNOLOGY

BIOTECHNOLOGY AND CO₂ EMISSIONS

THE SOYA BEAN: AN IMPORTANT RENEWABLE RESOURCE

CHEMICALS FROM BIOLOGICAL FEEDSTOCKS

LIFE CYCLE ASSESSMENT OF PROTEASES

18. DEGRADABLE PLASTICS FOR COMPOSTING

CERTIFICATION AND STANDARDS

BIODEGRADABLE POLYMERS

DEGRADABLE PLASTICS

WHAT USERS WANT

QUESTIONS FOR THE FUTURE

19. STARCH BASED BIODEGRADABLE PLASTICS

INTRODUCTION

TECHNOLOGY COMMERCIALIZATION MODEL

APPLICATION OF TECHNOLOGY COMMERCIALIZATION MODEL

Starch-based Biodegradable Plastics – Commercialization Case Studies

CONCLUSION

20. BIODEGRADABLE PLASTICS FROM WHEAT STARCH AND POLYLACTIC ACID (PLA)

INTRODUCTION AND BACKGROUND

RESULTS FROM PREVIOUS FUNDING

RATIONAL AND SIGNIFICANCE

PROCEDURES/METHODOLOGY

OTHER RELATED WORKS

21. MAKING PACKAGING GREENER – BIODEGRADABLE PLASTICS

PLASTICS THAT BREAK DOWN

PLASTICS CAN BE PRODUCED FROM STARCH

PLASTICS CAN ALSO BE PRODUCED BY

BACTERIA

WHAT IS THE COST?

BIODEGRADABLE AND AFFORDABLE

MULCH FILM FROM BIODEGRADABLE PLASTICS

POTS YOU CAN PLANT

DIFFERENT POLYMER BLENDS FOR DIFFERENT PRODUCTS

LANDFILL SITES ARE COMPOST HEAPS

COMPOSTING THE PACKAGING WITH ITS CONTENTS

AN OLYMPIC EFFORT RECYCLING 76

PER CENT OF WASTE

22. PET MATERIALS AND APPLICATIONS

INTRODUCTION

POLYMERISATION AND MANUFACTURING PROCESSES

Manufacturing plants

STRUCTURES, MORPHOLOGY AND ORIENTATION

Structure

Morphology

Orientation

Creep

PROPERTIES

Molecular weight and intrinsic viscosity

End group

Thermal properties

RHEOLOGY AND MELT VISCOSITY

Melt viscosity

Melt flow

Moulding shrinkage

MOISTURE UPTAKE AND POLYMER DRYING

Moisture level

Polymer drying

DEGRADATION REACTIONS

Thermal and thermal oxidative degradation

Environmental degradation

REHEAT CHARACTERISTICS

GAS BARRIER PROPERTIES

AMORPHOUS POLYESTERS

Homopolymers

Low copolymers

Medium copolymers

High copolymers

CRYSTALLINE POLYMERS

POLYMER BLENDS

APPLICATIONS

TRENDS

GLOBALS

23.PET FILM AND SHEET

Extrusion

Casting

The forward draw preheat (FWDPH)

The forward draw (FWD)

The sideways draw preheat (SWDPH)

The sideways draw (SWD)

24.INJECTION AND CO-INJECTION PREFORM TECHNOLOGIES

MULTILAYER CHARACTERISTICS

APPLICATIONS

Performance-driven applications

Economics - or legislative-driven applications

Combination applications

CLOSURE VS BOTTLE PERMEATION

CONTAINER PERFORMANCE

Barrier properties

Oxygen barrier

Carbon dioxide barrier

Scavenger property

WALL STRUCTURE

PREFORM AND BOTTLE DESIGN

Permeation through finish, sidewall and base

Controlled fill

HEADSPACE OXYGEN ABSORPTION

OXYGEN DESORPTION FROM PET

BEER CONTAINERS

SMALL JUICE CONTAINERS

SMALL CSD CONTAINERS

CORE LAYER VOLUMES

RECYCLING

COMPARISON OF CO-INJECTION TECHNOLOGIES

CO-INJECTION MOLDING EQUIPMENT

25. INJECTION BLOW MOULDING

INTRODUCTION

BASIC PRINCIPLES

HISTORY

PROCESS IDENTIFICATION

COMMERCIAL PROCESSES

Rotary table machines : Jomar, Uniloy and similar

TOOLING

PROCREA

MATERIALS

APPLICATIONS

Machine and process capabilities

WSDi