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Plastics - Recommendation for terminology and characterisation of biopolymers and bioplastics

Plastiques - Recommandations pour la terminologie et la caractérisation des biopolymères et bioplastiques

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Foreword

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Introduction

The main reason of the recent interest in bioplastics is due to the origin (i.e. use of biobased raw materials) or to the biodegradability of the final products, needed for instance for organic recovery. The use of biobased raw materials could be beneficial with reference to two current problems: fossil resources depletion and climate change. Today, regarding the latter issue, we have to manage the carbon in order to avoid its accumulation in atmosphere. Efficient use of all available resources and responsible utilization of renewable carbon is a way to participate to this reduction. Plastics are important materials which contribute significantly to environmental protection: thanks to their tailor-made properties (e.g. light weight, excellent insulation ability, tunable properties for optimum food protection, etc.) they reduce energy use by 26 % and reduce greenhouse gas emissions by 56 % across variety of applications compared to alternatives[1)].

The global manufacture of plastics in all applications only uses a small part of the entire consumed mineral oil: in Europe, it makes up only about 4 %[2)]. The major fraction (> 80 %) of the residual fossil material is used for energy production, predominantly for transportation and heating purposes. Besides crude oil, natural gas and coal, biomass is an additional raw material source for plastics.

The currently available biomass is consumed in different segments: food and feed production, power and heat generation, biofuel production and industrial applications (e.g. production of paper, fine chemicals). Due to the limited capacity of ecosystems, the utilization efficiency of renewable resources and availability issues have to be addressed across the whole bio-economy landscape. The eco-efficiency in this competitive use (e.g. energetic use vs. manufacture of goods) should always be in focus.

According to various scientists[3)], it would appear appropriate to use agricultural raw materials predominantly in a cascade of uses, instead of burning them directly in furnaces or engines. That would mean, for example, first producing a bioplastic from biomass: around 2 t to 10 t of bioplastic can be produced per hectare of agriculture land. The bioplastic thereby stores CO_2 in the form of vegetable carbon and removes it from atmosphere. It would be desirable to trap this CO_2 in the plastic for as long as possible. Finally, after maximum utilization including recycling when achievable and appropriate, the polymer can then be used either as energy source or as soil improver – to return the bound carbon to the natural cycle in the form of CO_2.

In order to ensure responsible and environmentally conscious use of natural (fossil and renewable) resources, a clear and unambiguous terminology is of particular importance.

1) GUA – Gesellschaft für umfassende Analysen, "The Contribution of Plastic Products to Resource Efficiency," Vienna, 2005.

2) Plastics*Europe*, WG Market Research & Statistics, 2005.

3) Bioplastics - Renewable raw Materials and Climate Protection" (Kunststoffe International Journal October 2007, p; 109-115).

1 Scope

This Technical Teport gives recommendations for bioplastics and biopolymers related terminology. These recommendations are based on a discussion of commonly used terms in this field.

This Technical Report also briefly describes the current test methods state of the art in relation to the characterization of bioplastics and products made thereof.

2 Commonly used terms

2.1 "Bio"polymers: polymers based on renewable raw materials

2.1.1 General

In this context, the "bio-"prefix is used as an abbreviation of "derived from biomass" or "obtained from renewable raw materials".

The term biopolymer then identifies polymers which derive from organic matter constituting living organisms and their residues[4]. Biomass is considered as a renewable resource. A renewable resource is replenished by natural processes at a rate comparable to its exploitation rate. The carbon content of such polymers is derived from the so-called short carbon cycle (expected time frame: 1 year to 10 years; see Figure 1). Most industrial polymers and plastics are presently produced starting from fossil resources which are non-renewable as they cannot be replenished at a rate comparable to the exploitation rate (long carbon cycle, expected time frame to convert biomass to petroleum, gas and coal: $>10^6$ years).

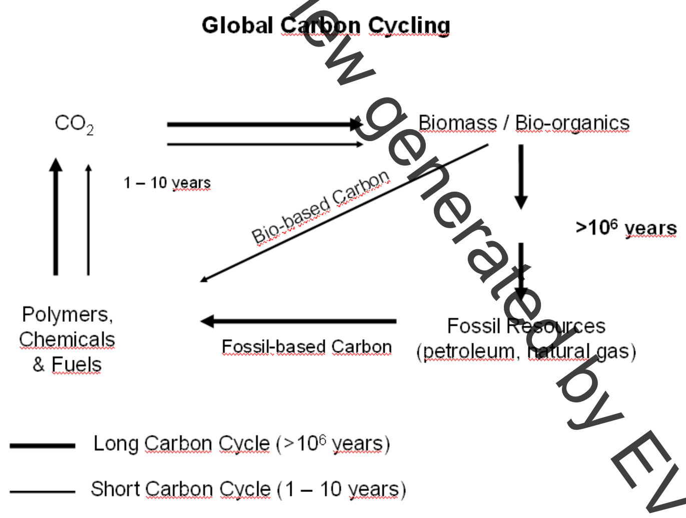

Figure 1 —Global Carbon Cycling[5]

4) EC DECISION (2007/589/EC) of 18 July 2007: 'biomass' means non-fossilised and biodegradable organic material originating from plants, animals and micro-organisms.

5) Narayan, Ramani, Biobased and Biodegradable Materials, Rationale, Drivers & Technology exemplars, ACS (An American Chemical Society Publication) Symposium Ser., 939, Ch. 18, pg 282, (2006).

The same polymer can often be made from both biomass and fossil resources. Polymers made from biomass may be biodegradable (see 2.2.2.) or can exhibit a long lifetime.

Polymers derived from biomass can be natural (2.1.2) or synthetic (2.1.3). Some bioplastics may be a combination of both natural and synthetic polymers, in which context the term biocomposite has already been used.

2.1.2 Natural polymers from biomass

In biochemistry, biopolymers are polymers synthesized by living organisms (animals, plants, algae, micro-organisms). The most abundant biopolymers in nature are polysaccharides. Cellulose and starch are polymers of glucose and are extremely abundant in the biosphere. Proteins and bacterial polyhydroxyalkanoates are also polymers.

All these polymers are natural, i.e. they are synthesized by living organisms, essentially in the form in which they are finally used. Direct industrial exploitation is possible after extraction and purification, i.e. by physical processes. Other industrial exploitation is also possible, e.g. in case the natural polymer is undergoing a chemical process of functionalization.

2.1.3 Synthetic polymers derived from biomass

The term biopolymer is also applied to define polymers whose monomers derive from renewable resources, rather than from fossil resources, even though the conversion to polymer involves chemical transformation. In principle, many polymers can be synthesised from renewable feedstock. Amongst them, poly(lactic acid) is a good example of this class. Corn starch is hydrolyzed to make dextrose, which is used as the fermentation feedstock and bio-converted into lactic acid. This biomass-derived product is processed chemically to produce poly(lactic acid). In this case the polymer is renewable because the original feedstock comes from agriculture, but non-natural, i.e. it is not extracted from a plant or a bacterium, but synthesized in a chemical plant. In a similar way it is possible to produce ethylene from bioethanol produced by fermentation, and to use the monomer as a bio-derived feedstock to make ethylene based polymers. The polymer is again renewable but non-natural. Polyamide 11, made from castor-oil, is another example.

NOTE Other sources than agriculture are possible (e.g. organic waste, forest, sea).

2.2 “Bio”polymers: polymers exhibiting a “bio” - functionality

2.2.1 Polymers for biomedical applications

In this context the “bio-” prefix is used to indicate biocompatibility with living cells and tissues.

Biocompatible means that the polymer does not harm the body or its metabolism in any way while fulfilling the expected function (e.g. artificial hip or knee). In substitutive medicine the term biopolymer is used as a synonym for biocompatible or bioabsorbable polymer. This refers primarily to the ability of a scaffold for tissue-engineering devices to perform as a substrate that supports the appropriate cellular activity, without eliciting immune responses. Furthermore, the scaffold is expected to be bioabsorbed after healing.

2.2.2 Biodegradable polymers

In this context, the “bio-“ prefix is used as a abbreviation of biodegradable polymers.

The term biopolymer is used for designating those polymers which are used in biodegradable products. In this case, the focus is on the biodegradability and on the possibility of organic recovery of waste.

Criteria designating plastics or packaging suitable for organic recovery (i.e. anaerobic digestion and industrial composting) are specified by standards such as EN 13432, EN 14995, ASTM D 6400, and ISO 17088. Products complying with the strict requirements of these standards are suitable for organic recovery under industrial composting conditions.