ONLINE ISSN 2069-7430
ISSN-L 1841-4737
PRO LIGNO
www.proligno.ro
Vol. 15 N° 4 2019
pp. 306-313

UTILIZATION OF WOODEN BIOMASS CHEMICAL COMPONENTS IN BIO-PLASTICS PRODUCTION

Paschalina TERZOPOULOU
Aristotle University of Thessaloniki, Faculty of Forestry and Natural Environment
54124 Thessaloniki, Greece
E-mail: linaterzopoulou@yahoo.gr

Vasiliki KAMPERIDOU
Aristotle University of Thessaloniki, Faculty of Forestry and Natural Environment
54124 Thessaloniki, Greece
E-mail: vkamperi@for.auth.gr

Abstract:
Biodegradable polymers is an alternative option to efficient waste management solution as opposed to conventional plastics. The production of biodegradable materials from renewable sources has attracted the interest of the global community, resulting in the examination and increased use of several renewable and sustanble feedstocks. Abundant renewable sources, such as corn, soy beans, sugar cane, wood, agricultural residues, lignocellulosic residues obtained from logging or wood processing etc. could be utilized as raw materials in bioplastics production. In this study, the development of bioplastics from the past to the present is reviewed, as well as a categorization of the existent bioplastics, are implemented based on the raw materials and properties, the main advantages and disadvantages of bioplastics are analyzed. The tendency of recent years on the research field of bioplastics is recorded, while the main current European and International standards referring to the bioplastics production, application and end-of-life management are being presented.

Key words: *bioplastics; biopolymers; cellulose; lignin; PLA; tannins; wood.*

INTRODUCTION

Most plastics commercially used nowadays are petroleum based. The current global consumption of plastics is more than 200 million tons each year, which represents the largest use of crude oil. Unfortunately, plastics take more than a century to degrade and specifically, polyurethane and polyethylene are manmade polymers that microorganisms do not recognize as food, therefore, they cannot be degraded. In the case of burning, plastics release cancer causing carcinogenic chemicals that are equally harmful to people and the environment. Consequently, the world is drowning in excess of environmentally harmful plastic, made from non-renewable resources.

Biodegradable polymers can be considered an alternative to conventional plastics for the efficient waste management which is supported also by their life cycle assessment. The production of biodegradable renewable energy materials has been of interest, especially in the EU countries, resulting in increased use of renewable energy sources (Tabone et al. 2010). The proper treatment would undoubtedly minimize the environmental impacts. Plastics specifically for packaging applications are the most widely used polymers. Speaking with numbers, 34 million tons of plastic wastes are produced every year around the world and 93% of these are disposed of in landfills and oceans (Pathak et al. 2014). Part of the solution for saving fossil fuels, reducing carbon footprint and reducing waste, could be the use of bioplastics.

"Bioplastics" are being called the biodegradable plastics, whose ingredients come entirely from renewable raw materials. They can be defined as biomass plastics coming from several materials such as corn, sugar cane, seaweeds, bamboo, cotton, wood and other forest biomass species. Biodegradation in a particular environment for a plastic means that this plastic becomes a substrate for metabolism of microorganisms living in this environment, and could be totally decomposed by their action. Industrial production of bioplastics involves the participation of a biopolymer or a combination of biopolymers, plasticizer and various additives. It has been reported that the global production capacity of bioplastics will increase from 0.36 Mt in 2007 to 3.45 Mt in 2020 (Khalil et al. 2013). In 2018, the world production capacity of biodegradable bioplastics was 912,000 metric tons and the production capacity of bio-plastic / non-biodegradable bioplastics was 1.2 million metric tons.

Categorization of plastics according to the raw materials

Biodegradable plastics can be divided into three groups based on their origin: (a) polymers that can be formed from a bacterial biofilm or microbial fermentation; (b) plant-derived polymers; and (c) chemically synthesized polymers (Ishigaki 2004). Biodegradable polymers derived from renewable sources such as plants or micro-organisms are ecologically sustainable because they do not accumulate in the environment

for long periods of time and are degraded or mineralized by micro-organisms. However, these polymers are characterized by some physicochemical properties that limit their use (Kiatsimkul et al. 2008).

Biodegradable plastics synthesized through chemical modification can be divided into two groups: (a) those derived from the degradation of chemical structures by the direct action of enzymes such as amylase and cellulase; and (b) those degraded by action of one or several physicochemical processes, for example, hydrolysis, photolysis or pyrolysis (Kiatsimkul et al. 2008). Unlike most synthetic petroleum derived polymers, biodegradable polymers, when discharged into the environment, may initially be cleaved from the polymer chain by non-enzymatic processes such as photolysis and chemical hydrolysis and then degraded by enzymes produced from algae, bacteria or fungi (Ojeda et al. 2009). These biodegradable polymers can be converted into carbon dioxide, methane, water, biomass, humus and other substances (Gross and Kalra 2002).

Cellulose is considered to be used as a raw material for the production of bioplastics. Cellulose is the main ingredient of all plant materials and can be found in high quantities in wood and cotton. Specifically, the composition of wood is 50% cellulose, 15-30% hemicelluloses, 15-35% lignin and 5-30% ash. To improve the quality of bioplastics, cellulose is acetylated to be cellulose acetate. Cellulose acetate is usually made from wood pulp by reaction with acetic acid and acetic anhydride in the presence of sulfuric acid to form cellulose triacetate. Cellulose acetate is characterized by a high transition temperature and cannot be melt processed as a raw material due to its thermal properties. For this reason, plasticizers are usually added to cellulose acetate. These substances allow melting of polymers without thermal degradation and reduce stiffness (Tanaka et al. 2017).

Previous researches on biodegradable plastics based on cellulose acetate has revealed that, these plastics produced could be decomposed into soil or water within only a few years. However, the material can also be recycled or burned without residues. Studies have also been carried out examining the most crucial properties of cellulose acetate, including mechanical strength, impact strength, transparency, construction flexibility, casting capacity and dielectric power (Fischer et al. 2008). This produced plastic is generated in the form of a fluid and is therefore, easily configurable and does not require a large amount of energy, unlike the conventional plastic, which is usually stored in the form of granules and requires a large amount of energy to be molded, infused or extruded.

Evolution of bio-plastics from the past till nowadays

Biopolymers and bioplastics are not something new. In 1500 BC several civilizations in America (Olmec, Maya, Aztecs) use natural latex and rubber to make balls, containers and make their clothes waterproof. In 1862 Alexander Parkes (UK) creates Parkesine, the first artificial cellulose plastic. Parkesine was one of the forms of bioplastic. In 1897, German chemists invented Galalith, a biodegradable plastic made from casein (milk). Its commercial utilization was limited for a variety of reasons, such as that it could not easily be formulated and milk was rare and the development of petroleum-based plastics was reinforced during the First World War. Galalith is still used today to make buttons. In 1926 Maurice Lemoigne (FR) developed polyhydroxybutyrate (PHB) from the Bacillus megaterium bacterium. These were the first bioplastics of bacteria (Lemoigne 1976). In 1907 Leo Baekeland (BE) invented the Bakelite that corresponded to a "National Historical Chemical Milestone" due to its great importance, as it was a synthetic plastic that was revolutionary for the electrical properties of non-electrical conductivity and heat resistance in electrical insulators, radio and telephone enclosures and other products such as cooking utensils, jewelery, toys and firearms. In 1912 Brandenberger (CH) invented Cellophane, a transparent sheet of wood, cotton or hemp. The cellophane is a trademark and generic term. The trademark is currently owned by Futamura Chemical UK. In 1930, Henry Ford (US) used bioplastics from soybean seeds for some automotive parts. Ford stopped using soy plastics after the Second World War due to the abundance of cheap oil supply (Lougee 1936). In the 1950s and 60s, WR Grace (USA) assessed whether bioplastics polyhydroxyalkanoates (PHA) and polyhydroxybutyrate (PHB) can be produced from microbes and bacteria on a commercial scale. They applied to many patents but lost interest due to cheap oil (Laxmana et al. 2013). In 1973, oil and energy crisis arose due to the embargo on Arab oil producing countries in support of Palestine. The rise in oil prices and dependence on oil in the 1970s became the driving force for the development of bioplastics (Laxmana et al. 2013). In 1975 a group of Japanese scientists discovered the principle of biodegradable plastics. They discovered a bacterium (Flavobacterium) that breaks the nylon (Parth et al. 2011). In 1979, the Iranian Revolution raises oil prices, causing huge debts and deficits in Western democracies, which would lead to overproduction and oversupply of oil in the 1980s making it less urgent to find alternatives to petroleum-based plastics. In 1983, Imperial Chemical Industries (UK) and a local venture capital firm (Marlborough Teeside Management) created the first bioplastic company, Marlborough Biopolymers. Their bioplastics were made from bacteria and were named “Biopol”. Biopol produced by bacteria can be processed into strips, filaments, chips, panels and powders (Kržan 2018). In 1990, Novamont (IT) was established. Novamont is considered to be a leader of the Bioplastics industry. It is

probably the only bioplastics company that managed to keep its head above water, commercially and economically. In 1992, Chris Somerville of the Michigan State University reported to the scientific journal Science that bioplastics (PHB) could be produced from a plant called *Arabidopsis thaliana*. In 1996, Monsanto acquired Biopol from Zeneca and started using bioplastics instead of microbes and bacteria. In 1997, Cargill and Dow created the joint venture Cargill and Dow Chemicals to produce bioplastics from corn. The consortium is starting to produce polylactic acid (PLA) in 2001. The company emerged in BrandWorks in 2005 and is the largest PLA producer. In 2001, Metabolix Inc. bought Monsanto's Biopol assets. The researcher at the University of Lincoln (United Kingdom), Nick Tucker, was the first to use the elephant binocular for the production of bioplastics. In 2010, Rémy Lucas (FR) founded Algopack, the first bioplastics company to use seaweed as biomass. Seaweeds need no fertilizers, pesticides, herbicides or soil. Seaweed bioplastics are biodegradable within 12 weeks on soil and 5 hours in water. In 2018, Arctic Biomaterials (FI) managed to boost PLA with biodegradable glass fibers. Their technology will enable PLA upgrading at the same time, Neste (FI) is launching the biopolypropylene industrial production (Bio-PP) for the IKEA household furniture company. Polypropylene (PP) is the second most used polyethylene (PE) plastic with total sales of $ 145 billion. Neste could replace the fossil-PP with bio-PP and become a major player. Also Project Effective launched to replace nylon with bio-nylon also creating the first prototype car made of bioplastics and fruit packaging. PLA has a share of 42.5% of the bioplastics market, while starch and cellulose have a share of 22.2% and 8.5%, respectively. The interest at that time was solely on end-of-life considerations, to reduce waste going to landfill and control litter and marine pollution, although the emphasis is now changing back to renewable sourcing. The currently used bio-polymers are not necessarily biobased or fully biodegradable and many of them, particularly some aliphatic polyesters, are petrochemical-based.

Advantages and drawbacks of bioplastics

Bioplastics are characterized by much lower carbon footprint, they are made of renewable resources, such as corn, sugar cane, soybeans, seaweeds, wood and other plant sources as opposed to common plastics, which are made from petroleum, they present energy efficiency, since during their production less energy is used, compared to the conventional plastics. Additionally, they seem to be eco-friendly, produce fewer greenhouse gases and no toxins. Specific bioplastics are selected for particular applications, depending on the requirements for: mechanical, thermal, optical and tactile properties; chemical, oil, fat and grease resistance; barrier properties towards oxygen, carbon dioxide, water vapor and organoleptics, adhesion and printability, sterilizability, and cost. There is a considerable ability to tailor-make packaging to fit specific property combinations and optimize protection of the packaged contents, while reducing costs by minimizing materials use and maximizing processing speeds.

Some of the main disantvantages of these materials are the following. Bioplastics usually cost twice as much as conventional plastic. However, by increasing the production of bioplastics in the industrial sector or improving the techonology and methods used the cost is expected to decline in the near future. Recycling problems can be caused, since the bioplastic material can contaminate the recycling process if it is not separated from conventional plastics.

The possibility of raw materials reduction resulting from the bioplastics production could raise concerns. Bioplastics produced from renewable sources can reduce the stock of raw materials. This may, of course, be overturned if we use forest residues biomass as raw material (either from logging residues where we also prevent the risk of forest fires, rainfall in urban areas or residues of the wood processing and wood products manufacturing etc.) or other sorts of feedstocks of high availabiity, such as the seaweeds.

Often, a misunderstanding in the used terms appears. The description of bioplastic as compostable can cause confusion. All bioplastics are not biodegradable at home, such as organic food waste, but usually require an industrial composting treatment not available in every composting site. Also, bioplastics and related terms are abusively used by various manufacturers to make their products more attractive on the market. Finally, there is a lack of legislation. Production of bioplastics is predicted to increase, but many countries have not set any law or legislation on the production, use or management of bioplastics wastes.

Research on the utilization of wood chemical components in biopolymers production

Lignin and lignin derivatives biopolymers have a number of commercial applications and can therefore be widely used in various sectors such as industrial applications, such as pulp, plastics, agriculture and other industrial areas. Lignin and lignin blends-based biopolymers, including protein-lignin blends and starch-lignin mixtures, have also shown promising application in the abovementioned sectors. The extraction, production and operation of lignin biopolymer present a brief insight into the development of various everyday products. Ligninsulphonates, lignin, lignincellulose, lignophenol, sodium lignin sulphonate-based polymers and organic solutions have created new incentives for researchers to develop well-designed biomaterials, biodegradable membranes, composites, and potential industrial applications.

Thermoplastic compounds based on renewable energy sources and biodegradable materials offer environmentally friendly alternatives to petroleum-based plastics. For the production of bioplastics, lignin is mixed with natural elements such as cellulose, hemp, bamboo, cotton and other additives that result in a material that can be processed at high temperatures. The mechanical properties of bioplastics such as mechanical strength, hardness, dimensional stability, etc. can be varied, enabling them to adapt to broad applications such as jewelry, musical instruments, furniture, car interiors, car accessories, garden supplies, food packaging, etc. Globally, the bioplastics industry is expected to increase significantly in the coming years.

The lignin has a plurality of effective and economic welding properties which may be improved by addition of phenol and aldehyde as well as by modification of lignin. It can be used as a rubber reinforcement, polyolefin, rubber package, used in composites but also in the unsaturated polyester and vinyl ester as a glue and as a co-monomer. Kraft lignin products are used in high-end applications such as foam fire extinguishers as they stabilize foam and print inks for high speed rotary presses, and as a rubber reinforcing pigment. After modification, lignin can be used as emulsifying agents, emulsion stabilizers, pesticide dispersants and dyes, complexing agents in micronutrient formulations, photocultivators and extenders for phenolic adhesives. Lignosulfonates are used in asphalting roads to reduce the environmental concerns caused by particulate matter dust of the conventional tar, and it is very important that they stabilize the surface of the pavement.

Organic solution lignin, with low inorganic impurities such as sulfur and ash, is an important precursor to converting it to CF (carbon fiber) (Oroumei and Fox 2015). Baker and Rials (2004) reported that the tensile strength of the CFs fused from a purified lignin organic solution is as high as 0.71 GPa. Electro-spinning is a technique that allows the construction of robust, multifunctional fibrous materials. By applying an external electric field during the process, the latter fibers have a sub-meter (from 10 -2 to 1mm) diameters can be formed by continuous stretching of a viscoelastic jet. The nanofibers have a higher rate, durability and strength as compared to the micro-scale fibers (Papkov et al. 2013). The smaller diameter size affects not only the mechanical properties but the higher specific surface exhibits a favorable way to improve the poor connection between the microfiber and the matrix in the composite materials. The purified epoxy matrices are being reinforced with non-woven membranes with electrical polishing (Bergshoef and Vancso 1999). The resistance to breakage of high performance composite sheets (Lubineau and Rahaman 2012) has also increased. The blending of lignin with high molecular weight polymers such as polyethylene oxide (PEO) (Wang et al. 2013), polyvinyl alcohol (PVA) (Lai et al. 2014 etc.) is a direct approach to coordinating ability to electrospin. By using PAN as an additive in electrical spinning, the mechanical performance of CF based on lignin would theoretically improve.

The hemicelluloses, the second most abundant polysaccharide after cellulose, continue to be treated as a side flow in the biomass processing industries. In the study of Xu et al. (2018) an approach to the production of a biopolymer based on wood and spruce hemicelluloses galactoglucomannan (GGM) to partly replace the synthetic PLA as a feedstock material in applications of 3D printing. To ensure a uniform distribution of the formed binary biocompatible, a solvent blending approach was developed. The hemicelluloses and PLA mixtures with a varying proportion of up to 25% hemicelluloses were extruded into hot melt extrusion yarns. 3D prototypes were successfully printed by composite filaments by printing three-dimensional deposition modeling. When the crystallized PLA was replaced with up to 20% amorphous GGM, the composite materials could maintain mechanical strength. It is worth noting that rational biorefinery technologies are available for the procurement of large volume hemicelluloses, however, the application of hemicelluloses as bioplastics is still not thoroughly studied. A new approach has been demonstrated on the use of such a biopolymer/bioplastic with wood as a feedstock material for 3D FDM printing. On the one hand, the incorporation of wood hemicelluloses in the feedstock may reduce the production of PLA, but on the other hand, hemicelluloses with versatile active sites as vectors or molecular receptors can be used to introduce the desired functionality and characteristics. Printed matter has significant potential in many applications, but not limited to, biomedical devices where physical and chemical indications are present to meet tissue engineering requirements.

Laoutid et al. (2018) conducted a study where tannic acid (TA) was investigated as a flame retardant for PLA. Different strategies for modifying the thermal degradation pathway have been explored in order to improve the granulation effect. The first consists from the combination of TA with the organo-modified montmorillonite (oMMT) and allows to limit the thermal degradation of TA and promote the formation of an effective layer of paper. The flame deceleration behavior (FR) of the PLA-based composition has been found to be positively affected by this combination since the decrease in the peak of the heat-release rate (PHRR) is more significant than the value recorded when oMMT used tannic acid separately. The second strategy, in which tannic acid is associated with phosphorus-based compounds of biological origin, i.e. phthalate metal salt, has shown another alternative that has allowed the flame retardant TA to be boosted with 30% by weight of loading content. The third and last strategy under investigation is to chemically modify TA by

chemically transplanting phosphoric acid groups. This phosphorylated TA has been shown to exhibit the most effective flame retardant effect (FR). However, a significant decrease in the molecular weight of PLA was observed.

Anwer et al. (2015) implemented a comparison of the thermal, dynamic mechanical and morphological properties of PLA-Lignin & PLA-Tannin particulate green composites. Composites of PLA-lignin were prepared with 5, 10, 15% by weight lignin and PLA-tannin with 5, 10, 15% by weight of tannin using injection molding. The SEM morphology reveals that lignin forms droplets as dispersions within the PLA matrix unlike Tannin. The size of the lignin particles in the matrix is also 10-150 times less than that of tannin. Isothermal frequency scanning in composite data indicated that the storage rate of PLA-Tannin complex materials began to degrade by 15% filling and increasing damping concentration. PLA-Lignin composites do not exhibit such a degradation in the storage coefficient. The tensile strength of composites PLA-Lignin and PLA-Tannin decreases with an increase in filler content. Lignin has more inhibitory effect on the crystallisation of PLA than tannin. From the DSC thermograms, lignin appears to have inhibitory effect on the crystallization of PLA-Lignin composite products that are constantly increasing with the increase in lignin content. Tannin has an inhibitory effect of up to 10% by weight, after which crystallization is favored. It is believed that this may be a clear result of the interaction between the cores due to the increase in surface area and the delay in crystallization. As expected, inhibition of crystallization increased with increasing heating rate, with virtually no cold crystallisation occurring at 10°C/min and 15°C/min for PLA-Lignin complexes. The beginning of degradation of PLA-Lignin and PLA-Tannin complexes occured at slightly lower temperatures than pure PLA.

Li et al. (2013) have also established the best mechanical properties for composite materials from PET mats. They made superfine and nanoscale fibers by electrostatic spinning of sisal fiber (S) and recycled solutions of PTFE trifluoroacetic acid at room temperature, used as reinforcing agents in composite materials. The properties of the produced layers (S/PET ratios from 0.1 to 0.4) were examined by infrared spectroscopy, scanning electron microscopy (SEM), contact angle measurements (CA) thermogravimetry analysis (TGA) and dynamic mechanical analysis (DMA). DMA described not only the Tg and the storage factor of the materials, but also the interactions between the PET chains and the sisal fiber components. The liquidity of the layers was found to be dependent on the sisal / PET ratio and ranges from very hydrophobic (pure PET, advanced angle of 134° with contact angle measurements) to superhydrophilic 0°, direct water droplet absorption). This research highlighted the range of possibilities where lignocellulosic biomass can be combined with polymer matrices to improve and control their properties such as hydrophilicity and stiffness.

Lignin is expected to be the next generation precursor for bioplastics, biofuels and other applications, and because of these developments, industries such as aerospace, petrochemical, construction and automotive will witness dynamic growth. The development of bioactive lignin derivatives is expected to change the future conditions.

Karaaslana et.al (2011) conducted a study in which nano-enhanced hydrogels with unique network structure were prepared from wood-cellulose tissues coated with chemically modified wood hemicelluloses. The hemicelluloses were modified with 2-hydroxyethylmethacrylate before adsorption on the cellulose in aqueous medium. Synthesis of the hydrogels was carried out by in situ radioactive polymerization of the methacrylate groups with adsorbed coating to form a poly (2-hydroxyethylmethacrylate) (PHEMA) matrix reinforced with cellulose fibrils. Mechanical, cutting and viscoelastic properties of water swollen hydrogels were examined. The results showed that the number of effective crosslinks between the polymer chains and the average chain length between the crosslinking points was significantly different from the PHEMA hydrogels cross-linked by a conventional chemical method using a crosslinking agent. The resulting hydrogels had increased resistance, increased viscoelasticity and improved recovery behavior. Regarding mechanical properties and swelling properties, it can be assumed that these PHEMA nanopyrolysis hydrogels are capable of being used in biomedical applications such as articular cartilage replacement.

Kraft lignin (KL), which accounts for almost 85% of the total lignin technique, is commonly used as a fuel for energy recovery. Polyethylene glycol (PEG) is used as the most suitable grafting polymer because of its characteristic properties such as low toxicity, good biocompatibility, biodegradability and hydrophilicity. Functionalized PEG is prepared prior to adhesion of PEG to the desired molecule because the terminal hydroxyl groups are much more reactive than the polyoxyethylene chain. PEG derivatives have been shown to be valuable in a wide variety of chemical and biological applications, such as non-ionic surfactant, protein conjugates, phase transfer catalysis (PTC), aqueous biphasic separation, and pharmaceutical modification (Cole et al. 2013). The PEG was modified in one or both terminal hydroxyl groups preferably to be transplanted into lignin. Recently, several approaches have been developed to modify lignin with PEG derivatives in alkaline solution, typically PEG-mesylate (Uraki et al. 2001) and PEG-epoxide (Lou et al. 2013) to increase lignin water solubility. The modified lignin with PEG derivatives was soluble in methanol, chloroform and pyridine in addition to water. The lignin-PEG copolymer could improve the brightness and strength stabilization properties of high performance pulps, improve the cement dispersibility and strength

and enhance the enzymatic hydrolysis of cellulose and lignocelluloses. However, the PEG material was prepared by grinding PEG methyl ether (Mw 350) by reaction with methanesulfonyl chloride in methylene chloride at 0°C using triethylamine as a catalyst while PEG-epoxide was synthesized from PEG by reaction with epichlorohydrin in the presence of BF 3 and, then closed loop and dehydrochlorinated in the alkaline solution. PEG monopeptide derivatives and commercial dodecyloxy-PEG-epoxide could improve the surface activity of lignin further than that of PEX-peroxide derivatives. Activated PEG derivatives above either were prepared in organic solvents or in unusual commercial products that made the lignin modification with PEG derivatives expensive and complex.

Polyethylene (PE) is today the largest plastic commodity in volume and, until recently, it was manufactured only by petrochemicals. However, Braskem, a manufacturer of thermoplastic resin in Brazil, has developed a 200 kt/year capacity to produce PE from the polymerization of ethylene derived from ethanol by fermentation of sugar cane (Morschbacker 2007). Although PE is non-compostable, the use of carbon capture a renewable source will lead to a "zero carbon" life cycle and the post-consumer PE can be recovered by the manufacturer.

Standardization and certification of bioplastics

Some of the basic standards already used and some of the standards drafts that refer to the production and application of bioplastics are summarized hereupon.

Standard	Description
AS 4736-2006	Biodegradable plastics—Biodegradable plastics suitable for composting and other microbial treatment
ASTM D5209-92	Standard Test Method for Determining the Aerobic Biodegradation of Plastic Materials
ASTM D5338-98	Standard Test Method for Determining Aerobic Biodegradation of Plastic Materials Under Controlled Composting Conditions
DIN V 54900-2	Testing of the compostability of plastics - Part 2: Testing of the complete biodegradability of plastics in laboratory tests
EN 13432: 2000	Requirements for recoverable packaging with composting criteria and biodegradation test and evaluation system for final acceptance of packaging
ISO 14851: 1999	Determination of the ultimate aerobic biodegradability of plastic materials in an aqueous medium -- Method by measuring the oxygen demand in a closed respirometer
ISO 15314: 2004	Methods for Marine Exposure ISO 16221: 2001 Water Quality Guidance for the Determination of Biodegradability in the Marine Environment
CEN / TR 15822	Plastics - Biodegradable plastics in or on soil - Recovery, disposal and related environmental issues
AFNOR NF U52-001	Biodegradable materials for use in agriculture and horticulture - Mulching products - Requirements and test methods
DIN SPEC 1206: 2010-06 DIN-Fachbericht CEN / TR 15932: 2010-06	technical report contains recommendations on the terminology of bioplastics and biopolymers. It also briefly describes the current test methods of technology in relation to the characterization of bioplastics and products made from them. CEN / TC 249 "Plastic Products", the secretariat of which is held by NBN (Belgium), is responsible for the European standard. At national level, the committee responsible for this standard is NA 054-01-07 AA Bioabbaubare Kunststoffe (biodegradable plastics) in DIN.
DIN CEN / TS 16398: 2013-01 DIN SPEC 16453: 2013-01	DIN SPEC 16453 (DIN CEN / TS 16398) establishes a standard for the reporting and communication of characteristics that cover the carbon content of biological origin and the recovery options, business transactions via a special biodiesel and bioplastics data sheet. It also provides the relevant methods for assessing and verifying the requirements and the principles and requirements for the notification of selected environmental performance requirements and the characteristics to be used - Bioplastic finished products and finished bioplastic products, including composite materials, before being disposed of to the end-user or the consumer. This technical specification does not bypass or in any way change the legally required information, requirements or labeling or any other applicable legal requirements.
DIN EN ISO 10927: 2018-10	Plastics - Determination of molecular mass and molecular mass distribution of polymeric species by laser matrix (MALDI-TOF-MS) mass spectrometry (ISO 10927: 2018). German edition EN ISO 10927: 2018
DIN EN 17228: 2018-03 – Draft	Plastics - Biometric polymers, plastics and plastic products - Terminology, features and communication. German and English edition prEN 17228: 2018
DIN ISO 20457: 2019-03 – Draft	Plastic molded parts - Tolerances and acceptance conditions (ISO 20457: 2018). Text in German and English
DIN EN 16575: 2014-10	Bio-based products - Vocabulary; German version EN 16575:2014
DIN CEN/TR 16208: 2011-07 · DIN SPEC 33928: 2011-07	DIN SPEC 33928 is the national edition of the European Technical Report CEN / TR 16208. This technical report contains a list of standards, documents and other publications on organic products. . This technical report was prepared by CEN / BT / WG 209 under Mandate M / 429 on the development of a standardization program for organic products
OENORM EN 17228: 2018-03-15 – draft	Plastics - Biometric polymers, plastics and plastics - Terminology, characteristics and communication
ISO/DIS 16620-2	Plastics - Bioactivity content - Part 2: Determination of carbon content biodegradation ISO 16620-2: 2015 defines a calculation method for determining the carbon content of biodegradation in monomeric, polymeric and plastic materials and products based on content measurement 14 C. ISO 16620-2: 2015 applies to plastic products and plastics, polymeric resins, monomers or additives, made from components based on organic or fossil materials.

CONCLUSIONS

By increasing the environmental awareness of societies, they tend to adopt a more environmentally friendly approach, and the incentives of those investing in the production of biodegradable plastic materials seem to be increasing. The numerous advantages of bio-plastics, such as being biodegradable, produced from natural renewable sources, recycled, reused, composted or burned without producing toxic by-products, etc. make them an excellent alternative to traditional fossil-based plastic products. Biopolymers reduce carbon dioxide emissions during the creation, while they degrade to organic matter after disposal. They cannot constitute a solution to all the environmental problems created by plastics, but it is a step in the right direction towards the elimination of the problem coming from plastic wastes.

It is important to establish appropriate international standards that will not be generic and that will examine each kind or group of bioplastics separately. Unfortunately, the current standards are not equated with each other and tend to be used mainly in the countries where they came from. Therefore, there is an urgent need for standardization of bioplastics, taking into account all the details, concerning the production, use and management of bioplastics waste worldwide. Additionally, the standards should take into consideration the raw materials of each bioplastic material, the energy consumption, emissions recorded during the production and use. It is necessary to ensure the high availability of each feedstock, the level of sustainability of feedstocks of the bioplastics, the risks emerging during the function of the whole value chains, to create new bioplastics materials that could be of competitive properties and could replace the fossil-based counterparts in the market. Various parameters have also to be taken into account in the production of bioplastics, including the economic viability of the bioplastics materials from which the final products are being produced, the energy consumed during the conversion of materials into bioplastics and the analysis for the assessment of its life cycle referring to the whole value chain, from the feedstock till the end-of-service life phase of the materials, taking into account the social, economical and environmental impacts,.

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