презентаційних матеріалів, які дозволяють наочно продемонструвати аудиторії основні результати та хід роботи над проектом.

Останній етап – рефлексія, припускає, що студенти, які працюють над проектом, повинні провести аналіз власної діяльності (самоаналіз) над проектом з метою виявлення допущенних помилок, їх причин і пошуку шляхів подальшого удосконалення дослідницької культури. Отже, окрім прийнятої в традиційній системі навчання логічної схеми добавляється схема синтезу, що реалізується у різних формах: від простого виконання репродуктивних, частково пошукових завдань викладача до самостійного виконання дослідницького проекту.

Отже, метод проектів надає можливість на основі практичного життєвого досвіду, молоді в професійному пошуку, розв'язанні соціальних, освітніх психологічних і культурних проблем. Застосування методу проектів у навчальному процесі покращує ефективність засвоєння та усвідомлення знать суб’єкта навчання, сприяє формуванню вмінь працювати з інформацією, аналізувати, систематизувати, узагальнювати, встановлювати асоціації з раніше вивченим, робити висновки, висувати ідеї, знаходити варіанти розв’язання проблеми, передбачати можливі наслідки рішень, обґрунтовувати власну думку, знаходити компроміс, прогнозувати результати своєї діяльності. Творча співпраця викладача і студентів під час проектної діяльності забезпечує творчу самореалізацію як викладача, так і студентів, задовольняє їх потреби в самовдосконаленні та саморозвитку; сприяє досягненню високих творчих результатів у процесі навчання.

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ALTERNATIVES TO CONVENTIONAL PLASTICS, THEIR

RECYCLING AND DISPOSAL

У статті йдеться про потенційний вплив пакувальних матеріалів, здатних до біорозкладання, та їх утилізація, особливо шляхом компостування.

Ключові слова: *здатний до біорозкладання, компостування, біополімери, упаковка, довкілля, поводження з відходами.*

This article discusses the potential impacts of biodegradable packaging materials and their waste management, particularly via composting.

Keywords: *biodegradable, compostable, biopolymers, packaging, environment, waste management.*

Biodegradable polymers constitute a loosely defined family of polymers that are designed to degrade through the action of living organisms. They offer a possible alternative to traditional non-biodegradable polymers when recycling is not practical or not economical [1]. Recently, significant progress has been made in the development of biodegradable plastics, largely from renewable natural resources, to produce biodegradable materials with similar functionality to that of oil-based polymers. The expansion in these bio-based materials has several potential benefits for greenhouse gas balances and other environmental impacts over whole life cycles and in the use of renewable, rather than finite resources [2].

Over 67 million tons of packaging waste is generated annually in the EU, comprising about one-third of all municipal solid waste (MSW). A large number of different types of polymers, each of which may contain different processing additives such as fillers, colorants and plasticizers, are used for packaging applications. These composition complexities together with contamination during use often render recycling uneconomic compared with disposal in landfill [2]. Biodegradable plastics with functionalities and process abilities comparable to traditional petrochemical – based plastic have been developed for packaging applications [3]. Typically, these are made from renewable raw materials such as starch or cellulose. Thermoplastic starch-based polymers and aliphatic polyesters are the two classes of biodegradable materials with the greatest near-term potential [1].

Biodegradable polymers (BDPs) refer to polymeric materials that are capable of undergoing decomposition into carbon dioxide, methane, water, inorganic compounds, or biomass in which the predominant mechanism is the enzymatic action of microorganisms. Initial steps may involve abiotic (thermal, photo) and biotic processes to degrade the polymer, under suitable conditions, to a low-molecular weight species. However, the resultant breakdown fragments must be completely used by the micro-organisms; otherwise there is the potential for environmental and health consequences.

Depending on their origins, BDPs may be classified as being either bio-based or petrochemical-based. The former are mostly biodegradable by nature and produced from natural origins such as polysaccharides, proteins and lipids. Natural rubber as well as certain polyesters either produced by micro-organism/plant or synthesized from bio-derived monomers fall into this category. Petrochemical-based BDPs such as aliphatic polyesters, aromatic copolyesters are produced by synthesis from monomers derived from petrochemical refining [4]. This classification differentiates between renewable (bio-based) and non-renewable (petrochemical-based) resources. Biodegradable plastics, therefore, often comprise polymer blends that contain partly biogenic (renewable) carbon derived from biomass and partly petrochemical carbon. Current production capacity for biodegradable plastics worldwide is around 350, 000 tones, representing less than 0.2 per cent of petrochemical-based plastic. The environmental performance benefits are insufficient on their own to enable bioplastic polymers to be more widely used as alternatives to conventional plastics. They also need to be cost-effective, fit for purpose and, ideally, provide unique benefits in use. The costs of bioplastic polymers are generally still much higher than that of their traditional plastic counterparts.

Many bioplastics now have mechanical properties equivalent to that of their conventional counterparts and can be processed using technologies widely used in the polymer industry [3]. It is important to recognize that not all bio-based polymer materials are biodegradable and vice versa. Equally, it is important to recognize that attributes like biodegradability of a given polymer need to be effectively coupled with appropriate waste management in order to capture maximum environmental benefit. There are different types of biodegradable plastics, which offer different degrees of degradability and generally require specific conditions in order to do so. Degradable – to a degree. One example is polylactide (PLA), which is used to make food packaging. Compostable plastic certified to European Standard EN13432 must break down under industrial composting conditions in less than 12 weeks. Crucially, neither the terms biodegradable nor compostable imply anything about the material's ability to break down quickly in a natural environment. These plastics are generally not designed to degrade without special treatment, which means when leaked into the environment as litter they can be as harmful as typical plastics derived from fossil fuels.

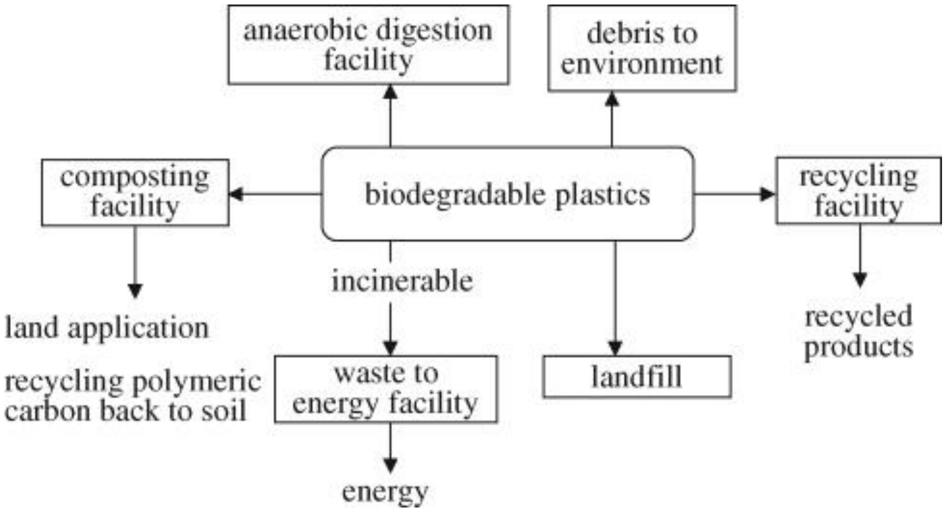
There is some evidence that producing plastics from plants has a smaller negative environmental impact than making them from crude oil. But this poses new problems through use of land that could otherwise be growing food crops. But bioplastics must also be disposed of correctly just as with conventional plastics, and the existence of compostable plastics must not become an excuse to litter. Instead, compostable plastics can be incorporated into a circular economy model, where waste is recovered and converted into useful products, or where compostable plastics and food waste and be returned to the soil as nutrients.

Biodegradable plastics that enter the municipal waste stream may result in some complications for existing plastic recycling systems. For example, the addition of starch or natural fibres to traditional polymers can complicate recycling processes. Although it is feasible to mechanically recycle some bioplastic polymers such as PLA a few times without significant reduction in properties, the lack of continuous and reliable supply of bioplastic polymer waste in large quantity presently makes recycling less economically attractive than for conventional plastics [5].

Most commodity plastics have gross calorific values (GCV) comparable to or higher than that of coal. Energy recovery by incineration is regarded as a suitable option for all bioplastic polymers and renewable (bio)resources in bioplastic polymer products are considered to contribute renewable energy when incinerated [3]. Natural cellulose fibre and starch have relatively lower GCV than coal but are similar to wood and thus still have considerable value for incineration. In addition, the production of fibre and starch materials consumes significantly less energy in the first place, and thus contributes positively to the overall energy balance in the life cycle.

Unlike conventional petrochemical-based polymers, biodegradable and compostable bioplastic polymers can be composted. This can be via aerobic waste management systems such as composting to generate carbon- and nutrient-rich compost for addition to soil. Certain BDPs are suitable for anaerobic digestors whereby biowastes can be converted to methane, which can be used to drive generators for energy production. Making or calling a product biodegradable has no inherent value if the product, after use by the customer, does not end up in a waste management system that uses the biodegradability features. Figure 1 illustrates the integration of biodegradable plastics with disposal infrastructures that use this biodegradable function of the plastic product.

Figure 1



Composting is the accelerated degradation of organic matter by a mixed microbial population in a moist, warm, aerobic environment under controlled conditions. Biodegradation of such natural materials will produce valuable compost as the major product along with water and CO_2, which does not contribute to an increase in greenhouse gases because it is already part of the carbon cycle [2].

Post-use biodegradable plastics and other biowastes unsuitable for landfill due to their potential to release methane under anaerobic conditions and their disposal by this method is inconsistent with policies like the EU Landfill Directive. Biodegradable bioplastics are most suitable for biological waste treatment through composting and, subject to further demonstration, potentially in anaerobic digestion systems. They should ideally be separated from other, non-biodegradable materials and collected with organic waste, including food waste.

By using these biological treatment methods the composts generated can be used as valuable soil improvers. The ubiquitous nature of plastics worldwide means we need to switch to making them from biological sources if we are to end our dependency on fossil fuels [1]. Bioplastic polymers have great potential to contribute to material recovery, reduction of landfill and use of renewable resources.

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