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Bio-based Plastics: a 'Sustainable' Alternative for the Plastic Industry?

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Abstract

Today, the pollution caused by plastics is undeniable, and the plastic industry is facing radical choices. One of these choices concerns the alternative between the increasing use of bio-based plastics or the recycling of petro-based plastics. Currently, in order to achieve the goal of a circular economy where plastics are recycled and reintegrated into the production process, the recycling of petro-based plastics is encouraged by regulations. Besides, bio-based plastics seem to offer considerable environmental advantages. However, the construction of a sustainable circular economy requires certain conditions to be met, such as the establishment of dedicated recycling chains, cost reduction, and "securing" the supply of raw materials.

Keywords: Circular economy ; Bio-based plastics ; Biodegradable plastics; Recycling; Regulation; Production; Costs

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The plastic industry is widely regarded as one of the most polluting industries in our society, highlighting the importance of transitioning towards a circular production model. This would achieve sustainable development through a cyclical system where material and energy flows are reused, reducing waste and energy consumption [1]. Environmental concerns related to the production and end-of-life of plastics have led European public authorities to implement regulations to limit this pollution [2]. In this context, exploring new paths in the petrochemical sector is encouraged, particularly through the use of bio-based plastics. These plastics represent an innovative way to produce plastics by replacing the petroleum-based raw material with naturally renewable materials [3]. Bio-based plastics are generally classified into two distinct groups: "drop-in" plastics that have a chemical structure similar to that of petroleum-based plastics (Bio-PE, Bio-PET, Bio-PP, etc.), and 100% biobased biodegradable plastics that have an innovative chemical structure and "breakthrough" technological trajectories. While bio-based plastics offer environmental benefits that seem evident, several obstacles must be overcome to exploit their potential. Firstly, unlike "drop-in" plastics, biodegradable bio-based plastics are not recyclable in the same way as petroleum-based plastics (as their chemical structure is different), which means that their end-of-life is not managed by current infrastructure [4]. Their inclusion in recycling streams can have the opposite effect: polluting them and hindering the effective recycling of other plastics [5]. Another obstacle is related to the fact that composting them can have greater environmental impacts than recycling [6]. However, in the absence of waste management infrastructure, the impact remains less harmful for biodegradable plastics compared to non-biodegradable plastics, whose degradation time can reach several hundred years. Thirdly, price is also a major obstacle to the use of bio-based plastics, whether biodegradable or "drop-in" [7]. Mass production could reduce production costs and make their exploitation economically efficient. Between 2017 and 2020, the capacity for producing bio-based plastics increased modestly from 1,38 million tons to 2,02 million tons [8]. Large-scale production of biodegradable bio-based plastics (or "breakthrough" types) would make it profitable to invest in new recycling infrastructure, while promoting economies of scale to reduce costs and ensure the valorization of the end-of-life of these plastics.

Finally, one of the main drawbacks associated with bioplastics is their potential competition with food production, as well as the risk of deforestation associated with first-generation bioplastics production. However, this point is subject to debate. Today, the land used for bioplastics production represents only 0.3% of the total agricultural land area [8]. In addition, the proportion of land used could be further reduced through the development of second and third-generation bioplastics, whose raw materials are not food-based but agricultural residues, or microorganisms such as bacteria, fungi, or micro-algae. This development should con-

tribute to minimizing pressure on agricultural land and limiting potential conflicts with food production [9].

Conclusion

There is a growing interest in transitioning to a circular economy where plastics are recycled and reintegrated into the production process. The innovation of bio-based plastics is an initiative aimed at achieving this sustainable goal by exploiting their environmental benefits, such as reducing greenhouse gas emissions and energy consumption during their production [10]. According to 2021 statistics, bio-based "drop-in" and biodegradable plastics comprised only 1,5% of the world's plastic production and 2,3% of Europe's plastic production [11].

In spite of the potential benefits of bio-based plastics, there are several obstacles to their widespread adoption [10]. Biodegradable bio-based plastics can only contribute effectively to reducing plastic pollution if they are properly disposed of, which may require specific recycling infrastructure. Drop-in plastics, on the other hand, can be recycled, but their partial dependence on oil limits their environmental potential. Additionally, their high cost may limit their use. As the success of bio-based plastics depends on several components of the value chain, there is a risk for actors to invest in a bio-based plastic that will ultimately not be adopted by other actors. Thus, the context of uncertainty regarding the market evolution of these plastics strongly hinders potential investments.

In order to meet these challenges, the implementation of incentive regulations in favor of the use of bio-based plastics could stimulate their adoption and encourage the transition to a circular industry [12]. This approach has already proven successful with recycled plastic: regulations encouraging its recycling have made it profitable and had a significant impact on the market. However, it is important to note that favoring a specific type of bio-based plastic through regulation could hinder the emergence of potentially superior new options. In the end, transitioning toward a circular industry remains a complex challenge and requires the emergence of new innovation policy methods and forms of governance [13].

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