The Problem with Plastics and Possible Solutions

Literature Review

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Abstract

This literary review will be an in-depth analysis of multiple articles which go over the issues with plastics and some possible alternatives. Plastics are used for a variety of applications, but their negative effect on the environment and human health is becoming a more prevalent issue. Starch-based bioplastics are a more widely used alternative to plastic and show potential to be able to be used by many different industries. Many of the journal articles being looked at in this review go over the possibility of combining multiple different types of starches to create a stronger bioplastic. Through these experiments, it may be concluded that making a bioplastic base from cross-linking multiple starches together would create stronger bioplastic. Other articles reviewed in the pages that follow go over plastics' role in the cosmetic industry. Due to the high amount of product output, billions of tons of plastics are used annually for the packaging of cosmetic products. Finding bioplastic alternatives for these packaging products will be able to prevent packaging from polluting the Earth.

Keywords: eco-friendly, bioplastic, starch-based bioplastic, microplastics

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Plastic is a material that can flow in a way that allows it to be molded into various shapes and used in a variety of manners. It is light in weight yet resistant and strong which makes it the first choice for many industries when looking for a good material to use for packaging. While plastics are useful, they cause a variety of environmental problems due to the harmful chemicals they release while they decompose (Windsor et al., 2019). With millions of tons of plastic used annually, these environmental problems are becoming a huge issue. Though plastics can be recycled, less than 9% are, with most ending up in landfills (NewsRx Health & Science Editor, 2021). Since plastics are non-biodegradable, they remain in the environment for a long time after they are discarded. With the amount of plastic the world uses, this becomes an increasingly prevalent issue as they are contaminating many different environments. These piles of plastic that are slowly degrading can cause risks to human and animal health (Plastic Health Coalition, 2018). Plastics also cause major environmental problems including, but not limited to, introducing microplastics into the air and polluting the groundwater. Plastic in general causes a lot of pollution within the oceans and other waterways (Shafqat et al., 2020). This becomes even more of an issue since, during the hundreds of years plastic takes to decompose, it creates microplastics. Microplastics are little bits of plastics that create similar environmental issues to plastic (NewsRx Health & Science Editor, 2021).

Plastics are still so widely used for a variety of reasons, mainly surrounding their cost and available applications. Not only this, but consumers also often prefer to buy products with plastic packaging because it is what they are used to in both the way it looks, feels, and works (Jonsson et al., 2021). Not only this plastic tends to look and seem clean and aesthetically pleasing which causes many

brands, especially in the cosmetic industry, to use it, which then causes more people to buy things with plastic packaging (Nguyen et al., 2018).

Section I: The Basics of Bioplastics

Bioplastics are an eco-friendly alternative to plastic, usually made from either natural materials or biomass (Sagnelli et al., 2017). They are designed to be able to function in the same way as plastic without all its harmful effects.

To create eco-friendly packaging, it is important to keep in mind the Sustainable Packaging Alliance's definition of sustainable packaging which asks if it is effective, efficient, cyclic, and clean. Effective addresses how it works and if it does what it is designed to do. Efficient addresses how well it does this. Cyclic and clean address the materials used. Cyclic addresses the cycle that the materials go through and clean addresses the safety of the materials for both humans, animals, and the environment (Herbes et al., 2020). By keeping the Sustainable Packaging Alliance's definition in mind, a better understanding of what is important when creating bioplastic is gained.

The Building Blocks of Bioplastics:

At the base of most bioplastics are polysaccharides which are a type of carbohydrate made up of monosaccharide chains joined by glycosidic bonds. Polysaccharides are both biodegradable and stable while also being easy to renew. They can be formed into bioplastics that can be used in a variety of situations such as in the food, pharmaceutical, and medical industries (Shafqat et al., 2020). The most common types of polysaccharides are starches, glycogen, and cellulose. Starches are what is often seen within the human diet within foods such as grains and seeds. They are a mix of amylose and amylopectin which are two types of polymers. Glycogen is most often seen in animals that store their carbohydrates as glycogen and can be found in the liver and skeletal muscles. Glycogen is similar to amylopectin within its structure. Cellulose is found in plants which causes it to be the most copious of the carbohydrates. In paper manufacturing, cellulose is often used ("Polysaccharides," n.d.). The reason

that these polysaccharides are good in bioplastics is because they replace the synthetic polymers seen in traditional plastics with natural ones that can biodegrade (Utility of Starch-Based Plastics 2018).

The Issues with Bioplastics:

Some issues with biodegradable plastics come with what must happen when they are thrown away. Bioplastics can take months to break down and can contaminate plastic that could have been recycled. Not only this, but some current bioplastics still form microplastics when they degrade. An experiment was done at the Department of Energy's Lawrence Berkeley National Laboratory and UC Berkeley (2021) that worked to fix these problems by designing a compostable bioplastic that is enzyme-activated. Enzymes are proteins that help things to break down in nature. By embedding small amounts of these enzymes into PLA and PCL plastics, they can degrade in a matter of weeks, sometimes days. When they do degrade, they don't produce microplastics but instead are broken down into their building blocks which allow them to be reconstructed into a new bioplastic product. This product ended up being relatively cost-effective as well, only adding a few cents to the overall production costs (NewsRx Health & Science, 2021).

Bioplastics in the Cosmetic Industry:

One issue when it comes to making bioplastics for the cosmetic industry is the fact that they must be able to preserve the product that it is packaging and hold up to the conditions that these products must go through. Some of these conditions include transportation and storage as well as being strong enough to hold the product without breaking. The bioplastics must be able to create a barrier against oxygen, water, and UV lights to protect the packaging all while preventing outside substances from getting into the products. Not only that but the bioplastic must not seep into the product (Cinelli et al., 2019).

Section II: Possible Solutions

Cross-Linking Bioplastics:

As bioplastics are becoming a more common alternative to plastics, there are many common materials used. One main material used is starch, which can replace petroleum-based polymers in synthetic plastics with natural ones. Due to the increased degradation rate, the cross-linked bioplastics can degrade faster than regular plastics (Matusow, 2021). While the idea of using starch-based plastics is becoming a more widely tested possibility for bioplastics, some issues have been arising from a general lack of stability. One experiment by Sagnelli et al. (2017) tried to solve this problem by cross-linking the starches with other materials. They decided to cross-link them with lipids complexed to amylose at a specific temperature which allowed the starches to become stronger, meaning they could be used in similar ways to plastic. The expected result was that the lipids strengthen the barley starch when used to make bioplastics. The authors ran a mechanical analysis to test this, looking mainly at their stress and strain levels. This data can be seen in figure 1. For all the graphs in figure 1, the y-axis represents the levels of stress, and the x-axis represents the percent of strain at break. It is important to recognize here that the scales for the graphs are different for each of the parts. The error bars in all six graphs represent the standard deviation. Part A of the figure is the data from the control starches and part B shows the data from the AO starches. The rest of the parts show comparisons between the data from parts A and B. Part C compares the data when they have no glycerol, part D compares the data when it is are crosslinked with CA, part E compares the data when they are cross-linked with CA, and include glycerol, and part F compares the data when it is are not cross-linked by does have glycerol. This data allows us to see that cross-linking the starches increases the strain at break for both the control and the AO starches. The samples that only have glycerol did have a higher elasticity, but their strength was lower. When both cross-linking and glycogen were used together, it had high elasticity, but low strength compared to the control starch meaning that it is not a viable solution. It was found however

that cross-linking alone does affect both the flexibility and cohesion of the bioplastic. These tests were quite successful which shows that the new bioplastic created from cross-linking could compare to the current plastic on the market. The experiment shows a huge potential for starch-based bioplastics to become more widely used. Cross-linking was also found to allow for better flexibility which is necessary for the bioplastic to be able to be formed into various shapes, meaning that it can be used for many different applications (Sagnelli et al., 2017).

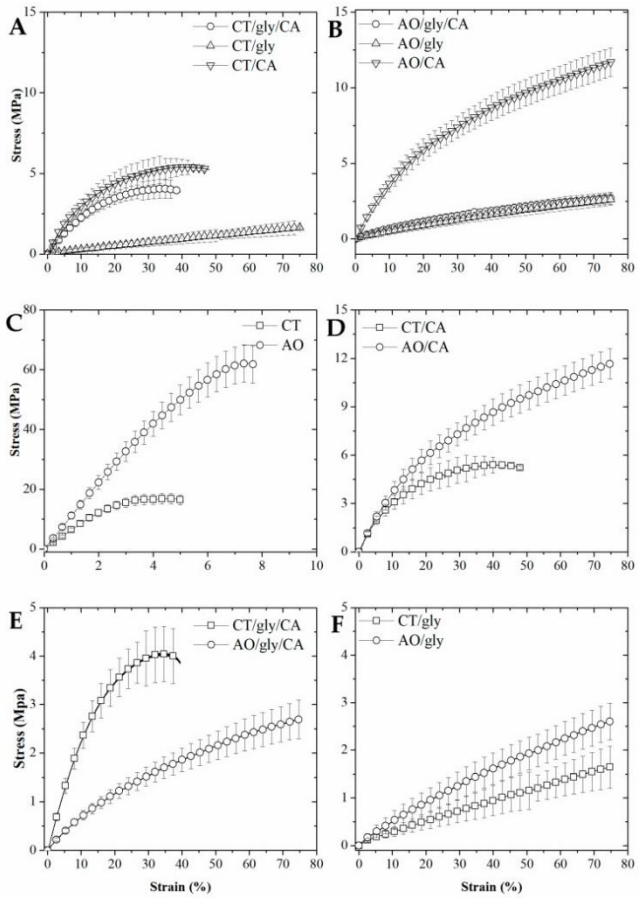

Figure 1: Stress and Strain. shows the stress and strain of the (A) cornstarch; (B) AO starch; (C) pure starch; (D) starches cross-linked with CA; (E) starches cross-linked with glycerol; (F) stretches with glycerol (Sagnelli et al., 2017).

Another common way to use multiple starches in bioplastics is to mix already existing biodegradable plastic with another starch to make it stronger. In one experiment by Rossi et al. (2020), the scientists mixed straw with bioplastics which created a bioplastic with higher elasticity. After various

tests, the authors were able to find that by adding straw into already existing bioplastics, they were able to reduce the environmental impacts by making it easier to compost, improving the performance, and increasing the cost-effectiveness (Rossi et al., 2020).

Biodegradable Plastic Packaging:

One new promising environmentally friendly product by Yang et al. (2021) is a biodegradable packaging bag that can be left to decompose after its job is done. For context, pesticide packaging in agricultural fields is currently non-degradable, meaning that it is left to sit in whatever environment it is used in once it is done. This presents a variety of environmental and animal health problems as the plastic sits for many years and then begins to produce microplastics. This new type of biodegradable packaging bag is made up of two layers, the inner one being a polyethylene glycol film and the outer one being made of degradable paper. These layers are combined with degradable glue and then covered with a moisture-proof layer. Since this packaging is used so often, it must be biodegradable, and this new prototype offers a non-toxic alternative to the regular plastic packaging bag that will be harmless to human and animal health and the environment. Not only this but can be produced on a large scale (Yang et al., 2021). This is an important discovery as it brings another possible real-world use of bioplastic and shows that it is possible for bioplastic to be produced at a large scale.

Nanoparticles:

Nanoparticles have become one possible solution for strengthening the properties of bioplastic. Nanoparticles are very small particles, under 100 nm (Murthy 2007). By adding nanoparticles to the materials, the gas barrier properties are improved which better allows it to keep everything inside the package, therefore reducing the number of contaminants. The main issue surrounding nanoparticles is that their safety levels are still under-tested and up for debate meaning that it is unlikely that we will see them in cosmetic packaging anytime soon (Cinelli et al., 2019).

Seaweed-Based Bioplastic:

Another popular material that some companies are turning to is seaweed. Seaweed is not only biodegradable and creates zero waste, but it is also lightweight and allows for a single-use packaging type that is still good for the environment. While seaweed isn't used often now, one brand called Ooho is using it in their material called "notpla" which is used to make sustainable versions of plastic bottles (Drobac et al., 2020).

Section III: Bioplastics Place in the Cosmetic Industry

Within the cosmetic industry, plastic is used quite often with around 7.9 billion units of plastic being created annually for packaging for cosmetic products (Bailly, 2020). As the knowledge of the danger of plastic grows, it is becoming evident that consumers are looking for eco-friendly alternatives to their plastic-wrapped products. Many companies are working towards solving this problem, though the cosmetic industry is still lacking. It has been found that consumers are wanting more transparency within the environmental impacts of the products they buy. Along with this, refillable products are becoming a more popular option, though they come with many problems on their own (Shafqat et al., 2020). The main issue with this is that people tend to buy products that will fit their needs and routines, not the other way around. Due to this, refillable products aren't something that will become the norm for at least a little while (Glossy, 2020). Even if it does become the norm, there will still be a need for plastic and therefore a need for bioplastic.

Appealing to Customers:

Studies have found that consumers are becoming more and more environmentally conscious, which means that the need for eco-friendly packaging on a marketing level is becoming of increased importance. The cosmetic industry is a major part of many places' economies currently so the drive for greener packaging is becoming more widely considered in many countries (Drobac et al., 2020).

One study by Nguyen et al. (2018) considered what consumers defined eco-friendly as through a series of surveys done on 36 people split up into 6 groups by age. The groups were asked questions about what they found important when buying eco-friendly packaging and what they considered to be eco-friendly. At the end of this survey, they decided that for packaging to be considered eco-friendly, it must be able to either biodegrade, be recycled, or be reused. Along with the sustainability piece, the groups also identified that the packaging should look nice, be cost-efficient, and be able to do its job (Nguyen et al., 2018). This is important to know when making bioplastic that is meant to appeal to consumers since their definition of eco-friendly will affect what products they buy and which products that brands are willing to switch over to.

Another study done on this topic involved testing people's green purchasing behavior, specifically with compostable coffee pods. From the authors' studies, they found that around 67% of people have a "favorable environmental attitude," meaning that they are willing to make certain changes to help the environment. These authors found that the main reason people were not buying the environmentally friendly options was cost, meaning that income level affects how green people can shop. This proves that cost is a very important deciding factor for many people when it comes to buying things and gives even more reason for a good bioplastic to be as cost-effective as possible. This article also touched upon a "circular economy" which is a term that describes an economy where items are reused or recycled in a way where the raw materials continue around in a circle. This is another thing to consider when making an eco-friendly packaging type because having a circular economy is very sustainable and can bring many environmental benefits (Visser & Dlamini et al. 2021).

Conclusion

This review analysis multiple articles that go over the many issues with plastic and how starch-based bioplastics can be used as possible alternatives. The harm which plastics cause to the environment and human health is becoming more of an issue as the years go on since plastic is being

created faster than it can degrade and at higher rates than it ever has before. Bioplastics are not only becoming a prevalent topic of interest for many engineers but a highly necessary one. When creating bioplastics they must appeal to consumers, as those are the people who will be the ultimate deciders in whether companies will be willing to switch to bio-based plastics or not. The implications that the current high use of plastic will have on the environment are evident and finding a possible solution will soon become necessary.

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