Review of Bioplastic Products Based on Fruit and Vegetable Waste

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Abstract

In the realm of sustainable materials, bioplastics derived from fruit and vegetable waste have emerged as eco-friendly alternatives to traditional plastics. This mini review explores the promising landscape of bioplastic products originating from agricultural by-products. Fruit and vegetable waste, abundant in nature, is being ingeniously repurposed to create biodegradable and compostable plastics, addressing the environmental concerns associated with conventional plastics. Researchers and innovators have harnessed the inherent properties of organic waste, utilizing its fibrous and polymeric components to develop bio-based polymers. These bioplastics showcase commendable mechanical and thermal properties, making them viable contenders for various applications. From packaging materials to disposable cutlery, the versatility of fruit and vegetable waste-based bioplastics is expanding. The review delves into the manufacturing processes, emphasizing the importance of sustainable practices in the production of these materials. Additionally, it sheds light on the environmental impact, decomposition rates, and potential challenges associated with the adoption of bioplastic products. As the world seeks greener alternatives, the utilization of fruit and vegetable waste in bioplastic production not only mitigates pollution but also promotes a circular economy by re-purposing agricultural leftovers. This exploration underscores the trans-formative potential of harnessing nature's surplus for a more sustainable and responsible future.

***Keywords**: Bioplastic, fruit, vegetable, biodegradable*

Introduction

In an era where environmental issues are increasingly urgent to be addressed, innovation in various fields is the key to creating environmentally friendly solutions. One trend that is starting to receive widespread attention is the development of bioplastics. Bioplastics are a promising alternative to reduce the negative impact of conventional plastics on the environment. Bioplastics refer to plastic materials that come from natural or organic sources, as opposed to conventional plastics that come from petroleum. The main idea behind the development of bioplastics is to reduce our dependence on non-renewable fossil resources and reduce their negative impact on the environment. One of the main advantages of bioplastics is their ability to decompose naturally, reducing the level of plastic pollution in the environment. Some types of bioplastics can even decompose efficiently in compost.

For plastic to be categorized as bioplastic, the raw material should be biodegradable, biocompatible, or made from renewable sources. Bioplastics are generally synthesized from biological sources such as plants, animals, microorganisms (Abdalla et al., 2023; Celletti et al., (Abdalla et al., 2023; Celletti et al., 2023; Clagnan et al., 2023; Ghobashy et al., 2023; Yang et al., 2022). Bioplastics from vegetables are usually made from raw materials such as corn starch, cassava or sugar cane (Ghasemlou et al., 2022; Manhongo et al., 2022). The production process involves extracting starch from the vegetable, which is then converted into a polymer similar to conventional plastic.

The use of fruit and vegetable waste as raw material for bioplastics is an excellent approach to reduce organic waste and utilize existing resources. Fruit and vegetable waste can consist of peels, seeds, or other parts that are usually thrown away, but can have the potential to be used in the production of bioplastics. This processing process can produce raw materials for bioplastics that have properties similar to conventional plastics. This not only helps reduce organic waste, but also creates a more sustainable alternative. An approach like this supports the concept of a circular economy where waste is transformed into valuable resources.

The concept of bioplastics from plants and fruits generally involves using natural components in fruit, such as pectin and cellulose fiber, to create a material that can replace conventional plastic. Although not all parts of the fruit can be used to make bioplastics, some parts such as the skin, seeds or fruit waste can be used as a source of raw materials (Gupta et al., 2019; Hao et al., 2020; Song et al., 2021). Using fruit in making bioplastics can be a creative and sustainable way to reduce dependence on oil-based plastics. In addition, fruit often contains natural compounds that can provide antimicrobial or antioxidant properties to the resulting bioplastic.

However, as with any new innovation, it is important to remember that bioplastics also have some problems, challenges, and questions that need to be answered. Even though it can decompose naturally, some types of bioplastics still require certain environmental conditions for the degradation process. In addition, the production itself can also involve high energy use, problems in resource sustainability and overall impact on the product life cycle. Nevertheless, technological development continues to improve the environmentally friendly properties of bioplastics.

Recent Condition and Potential of Fruit and Vegetable Waste

Fruit and vegetable waste has great potential and presents its own challenges depending on the management system. Based on data reported by Indonesia's National Development Planning Agency, food waste (mostly vegetables and fruit) over the last two years reached 184 kilograms per capita annually. From the existing data, Indonesia is ranked fourth in the ranking of the highest number of food losses in the world after China, India and Nigeria (Bappenas, 2021).

Several steps have been taken to manage waste, especially from vegetables and fruit. Some of the management steps that have been taken are diversifying vegetable and fruit products, processing vegetable and fruit waste into compost and biogas, or increasing the value of waste that still has active/nutrient substances by extracting these substances. Apart from that, several researchers are also trying to process vegetable and fruit waste as raw material for making bioplastic as a solution to obtain environmentally friendly plastic that is easily degraded (Gupta et al., 2019).

Diversification of fruit and vegetable products is a strategic step in increasing added value in the agricultural industry. Producers can develop various derivative products from fruit and vegetables that not only meet consumer needs, but also create diverse business opportunities. For example, apart from selling fresh fruit, manufacturers can expand to processed products such as juices, sauces or healthy snack packages. Fruit and vegetable processing can also involve innovation in the processing of organic foods or functional products that can improve health. By diversifying products, vegetables and fruit-based food can last longer and be consumed more widely, thereby reducing the amount of waste (Asif et al., 2016; Richa et al., 2023).

Processing vegetable and fruit waste into fertilizer is a good step to recycle organic waste and minimize its negative impact on the environment. Processing vegetable and fruit waste into fertilizer is a sustainable solution that supports organic waste management efforts. This process begins with selecting vegetable and fruit waste that is still fresh and free from dangerous contaminants. After that, the waste is broken down into small pieces to facilitate the decomposition process. By adding composting ingredients and maintaining a balanced carbon-nitrogen ratio, compost can be produced efficiently. The process of mixing and maintaining proper humidity supports the growth of decomposing microorganisms, producing organic fertilizer that is rich in nutrients.

Fertilizer produced from well-managed vegetable and fruit waste not only provides agronomic benefits by increasing soil fertility, but also helps reduce the amount of organic waste that pollutes the environment. By observing the principles of recycling and waste management, this process becomes an important part of a sustainable approach to food production and consumption. By processing vegetable and fruit waste into fertilizer, we can minimize the negative impact of organic waste while creating valuable resources for agriculture and the environment.

Apart from becoming compost, vegetable and fruit waste still has the potential to extract the compounds contained in it for many applications, such as processing it into dyes, anti-oxidant agents, anti-bacterial agents, insecticides, fungicides, or even pharmaceutical products. Previous research reported that the skin waste from dragon fruit can be used as a red dye, vegetables as a green dye, the skin and seeds of avocado as a pink dye. In addition, several important compounds can also be obtained from this waste, most importantly pectin which can be extracted from citrus peel (Abral et al., 2018; Richa et al., 2023; Visakh et al., 2022).

Several previous researchers have also reported the results of their research on the use of vegetable and fruit waste into bioplastic. Vegetable waste such as carrots, cucumber, parsley, radicchio and cauliflower as well as jicama, orange and banana peel waste are known to have the potential to be processed into bioplastics. Apart from having properties like commercial plastic, this bioplastic has the advantage of being eel which can be degraded more easily and has various active substances such as anti-bacterial (Kharb & Saharan, 2023; Lang et al., 2022; Santos et al., 2023).

Bioplastic Production from Fruit and Vegetable Waste: Research Development and Mechanism

Bioplastics from fruit and vegetable waste is one of the promising innovations in waste management and development of environmentally friendly materials. Several studies have been carried out to explore the potential of this organic waste as a basic material for bioplastics. Bioplastics produced from fruit and vegetable waste can have varying properties depending on their composition and production process. Various important properties of bioplastics include strength, ductility and degradability.

Basically, bioplastics have been developed from materials that are polysaccharides, such as cellulose, chitin/chitosan, starch, gum, alginate and pectin. Several types of microorganisms or enzymes can also be added during production to improve the quality and performance of bioplastics. Several studies have been carried out to utilize vegetable and fruit waste to process these polysaccharides into bioplastic and use it for various applications as can be seen in Table 1.

Table 1. Types of polysaccharides and their sources

Types of Polysaccharides	Waste Materials	Source
Pectin	Orange peel; Apple pomace	(Merino et al., 2022; Richa et al., 2023)
Alginate	Seaweed	(Selvasudha et al., 2023)
Starch	Yam; Jicama; Cassava	(Wigati et al., 2022; Zou et al., 2023)

Distribution and Application of Bioplastic from Fruit and Vegetable Waste

The distribution and application of bioplastics derived from fruit and vegetable waste plays an important role in encouraging sustainable practices in the industry, especially in the packaging department. Bioplastics sourced from fruit and vegetable waste, such as peels and residues, offer a renewable and environmentally friendly alternative to traditional petroleum-based plastics. Companies that release eco-friendly packaging materials can play an important role in distributing bioplastics to manufacturers and businesses looking to reduce their environmental footprint.

In terms of applications, bioplastics derived from fruit and vegetable waste can be used in a wide variety of packaging solutions, including food packaging, disposable tableware, bags, edible films, and more. The flexibility of bioplastics enables innovative and sustainable packaging designs. Apart from that, this bioplastic can be used in various non-packaging applications, such as medical or pharmaceutical materials (Takata & Kijima, 2023; Xu et al., 2021). As awareness of environmental issues increases, the application of bioplastics provides an opportunity to reduce dependence on traditional plastics and reduce the environmental impact of plastic waste. The widespread distribution and application of bioplastics contributes to a more sustainable and circular approach to plastic use in various industries.

Future Potential of Bioplastic from Fruit and Vegetable Waste

In its development, bioplastics based on vegetable and fruit waste have a lot of potential that can still be explored. Applications in various fields are very open for the use of bioplastics themselves. Several applications that could possibly be further explored can be seen in Table 2. Apart from reducing the amount of waste, the use of vegetable and fruit waste into bioplastics can have a positive impact on reducing sustainable environmental pressure, and drive bioeconomic cycles.

Table 2. Potential for developing bioplastic applications from vegetable and fruit waste

Aplication	**Materials**	**Potency**	**Source**
Plant fertilizer	Orange peels, banana peels, jack fruit seeds	Bioplastic can be recycled into nitrogen-rich plant fertilizer through the ammonolysis process	(Celletti et al., 2023)
Biomedical devices	Fruit peels, oil palm empty fruit bunch	Applications in tissue engineering, ink for 3D printing in the manufacture of artificial organs, and various other tools that require good biodegradability and biocompatibility	(Mohd Zairullisham et al., 2022)
Sensors	berries, vegetable, flowers, agar, and potato starch	Bioplastics are starting to develop their capabilities as biosensors as a breakthrough material that is safer and easier to obtain	(Halonen et al., 2020)
Smart packaging	Orange peels, apple peels, Citrus pulps	Edible films or coatings on food and packaging made from bioplastic can be developed as a way to preserve and maintain the nutrients of food ingredients.	(Halonen et al., 2020)

Conclusion

In conclusion, the exploration of bioplastic products derived from fruit and vegetable waste presents a promising avenue towards sustainable and eco-friendly alternatives. The mini-review has highlighted the innovative strides in utilizing agricultural by-products to create biodegradable materials that can potentially mitigate the environmental impact of traditional plastics. While advancements in this field are encouraging, it is essential to acknowledge the ongoing challenges such as scalability, cost-effectiveness, and widespread adoption. Continued research, technological innovations, and collaborative efforts among industries, researchers, and policymakers are crucial to overcoming these hurdles. In the journey towards a more sustainable future, the exploration of bioplastics from fruit and vegetable waste serves as a beacon of hope, showcasing the transformative power of environmentally conscious practices in the realm of material science. As consumers and industries alike become increasingly aware of the environmental consequences of traditional plastics, embracing and further developing these bioplastic alternatives becomes imperative for a greener and healthier planet.

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