Tea Waste: A Potential Substrate for Value-added Products

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ABSTRACT

Tea is one of most consumed plant based beverage in the world. As tea is rich in minerals, polyphenols, polysaccharides and alkaloids, it has several health benefits. Because of anti-fatigue, anti-diabetic, anti-inflammatory and antioxidant properties, its demand is increasing day by day that generates huge amount of tea waste. Tea waste is dumped on land and in aquatic bodies, releases anthropogenic gas, pollute soil and water bodies. So, its proper management is necessary for the environment. This article emphasizes the management of tea waste by bioconversion techniques as these techniques are sustainable with multiple benefits. This method not only helps in reducing waste but also contributes to the production of valuable products like biochar, biofuel, biopolymer and bioactive compounds. These products can have various applications, from agricultural use to bioenergy production and even in the pharmaceuticals and cosmetic industries.

INTRODUCTION

Tea has a rich history that dates back thousands of years, originating in China before spreading to various parts of the world. Apart from its cultural significance, tea has numerous health benefits such as cardiovascular preventative, chemopreventive, anti-inflammatory, neuro-protective, anti-obesity, antidiabetic and antioxidant. Tea manufacturing has increased significantly worldwide to keep up with the

growing demand for the beverage. The emergence of novel tea products like instant tea powder and ready-to-drink beverages fortified with catechins and polyphenols reflects the dynamic nature of the tea industry. As a result, tremendous volume of tea waste is produced during the deep-processing production of tea (Debnath *et al*., 2021; Miao *et al*., 2023). Therefore, it is highly important to study on the potential utilisation of tea waste. Tea waste can be utilised for the production of industrially important products because it is rich in minerals (Ca, P, K, Mg and Mn), alkaloids, polysaccharides, polyphenols and amino acids. Bioconversion techniques such as anaerobic digestion, vermicomposting, fermentation, and silage preparation are indeed low-cost and environmental friendly techniques for the bioconversion of tea waste yielding valuable products (Negi *et al*., 2022).

Composition of tea and tea waste

Tea is a rich source of various bioactive compounds such as Methylxanthines, alkaloids, pigments, amino acids, polysaccharides, terpenoids, vitamins, minerals and polyphenols (catechins, flavonoids and proanthocyanidins) (Wang *et al*., 2016; Shang *et al*., 2021) each with its own unique properties and potential health benefits. There are different varieties of based on their chemical composition and manufacturing process, as shown in fig. 1 (Debnath *et al*., 2021). The diversity of tea ranging from green and black teas to oolong and white teas reflects the intricacies of tea culture and production techniques.

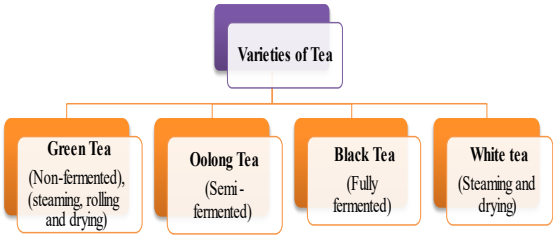

Fig. 1 Different tea varieties on the basis of manufacturing process

Tea waste mainly comprises the residue left behind after brewing tea which includes tea leaves and branches of tea plant that are generated during manufacturing process of tea products. This waste can accumulates in large quantities and presents challenges for disposal if not managed properly. Implimenting sustainable practises for utilisation of tea waste can help in minimising waste generation and creating value added products. Understanding the compostion of tea waste is essential for expoloring its potential as feedstock for generation of valuable products. Tea waste as described by Barathi *et al*., (2017), is a lignocellulosic biomas consisting of various components as shown in fig. 2.

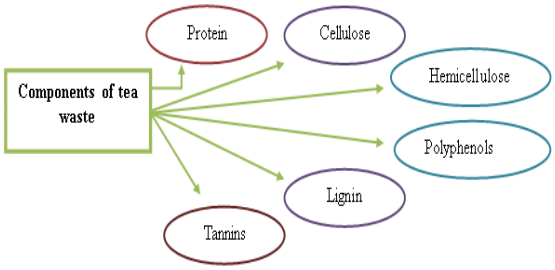

Fig. 2 Different components of tea waste

Bioconversion techniques for the tea waste

Tea waste contains significant amount of lignin that can be challenging to degrade, as well as other organic compounds that could potentially leach into water bodies if not managed properly. So, to ensure efficient utilisation and minimize environmental effect, it is important to implement well established recycling techniques. As bioconversion techniques are very inexpensive, they have been suggested as a practical approach for recycling tea waste as shown in fig. 3 and table 1.

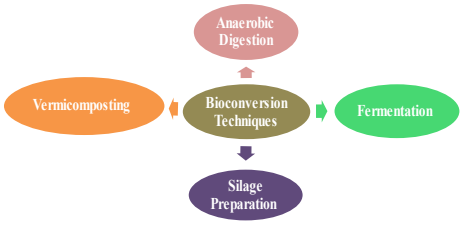

Fig. 3 Tea waste conversion techniques

Table 1: Valuable products from bioconversion of tea waste

Substrate	Conversion technique	Product	Findings	References
Spent tea waste and cow manure	Anaerobic digestion	Biogas	70% methane content	Khayum *et al*., (2018)
Tea waste, paper mill sludge and cow dung	Vermicomposting	Manure	Total organic carbon and C:N ratio reduced, Total N, P and K enhanced	Badhwar *et al*., (2020)
Green tea waste and Alfalfa hay	Fermentation	Ensilage	Decreased methane content, enhanced digestibility of crude protein and N retention	Nasehi *et al*., (2018)
Spent green tea leaves and black tea leaves	Fermentation [Cellulase and baker's yeast (*Saccharomyces cerevisiae*)]	Ethanol	Ethanol production from spent green leaves = 74.4%, ethanol production from black tea leaves = 80.7%	Mahmoud and Allam, (2020)

Different value-added products from tea waste

Tea waste's richness in polyphenolic compounds makes it and excellent candidate for generating value-added products such as compost, biofuels, biopolymers, *etc*. (Debnath *et al*., 2021, Negi *et al*., 2022).

Biochar

Tea waste can be converted into biochar through pyrolysis, a process that involves heating organic material in the absence of oxygen. Biochar is highly porous carbon rich material that serves as a soil amendment enhancing soil fertility, water retention, nutrient availability and also helps in sequestering carbon in the soil, mitigating greenhouse gas emission thus improving soil health. Tea waste's unique physico-chemical properties such as large surface area, significant pore volume (micropores, mesopore and macropores) as well as aromatic structure make it an effective adsorbent or catalyst for the remediation of polluted aquatic environments contaminated with organic and inorganic pollutants (Krasucka *et al*., 2021).

Biofuel

Tea waste can be utilised to produce biofuel such as biogas, bioethanol or biodiesel through anaerobic digestion, fermentation or other biochemical processes. High calorific value, abundance and accessibility and renewable nature of tea waste makes it a potential substrate for bioenergy production (Pua *et al*., 2020). This represents an innovative and eco-friendly approach to address the current energy crisis and advancing towards a more sustainable energy future.

Compost

Tea waste can be composted to produce organic fertilizer. Composting involves decomposition of organic materials by microorganism into nutrient-rich compost, which enhances soil fertility and structure. Tea waste have high nitrogen content, therefore, compost made from tea waste will be rich in nitrogen (Iqbal *et al*., 2007).

Biopolymer

Polyphenolic compounds extracted from tea waste can be used to produce biodegradable polymers. These polymers have applications in packaging, agriculture and biomedical industries as sustainable alternatives to conventional plastics. Natural fibers such as jute, hemp, *etc*. offer several advantages as they are inexpensive, readily available and biodegradable however they generally have lower mechanical strength and durability. In contrast, synthetic fibers such as glass, carbon, *etc*. posses high mechanical strength, stiffness and durability. However, these are non-biodegradable and may pose environmental challenges. By combining the natural and synthetic fibers in the same polymer matrix, it is possible to capitalize on the strength of each type of fibre while mitigating their respective weakness. These hybrid composites exhibit improved mechanical strength, stiffness, resistance and thermal stability, thus reduce

the environmental footprint of the material. Biopolymers such as polyhydroxyalkanoate (PHA), polyhydroxyvalerate (PHV), polyhydroxybutyrate (PHB), polylactic acid (PLA), polysaccharides and proteins can be derived with tea waste (Sirohi *et al*., 2021).

Bioactive compounds

The polyphenolic compounds extracted from tea waste have antioxidant, anti-microbial and anti-inflammatory properties, so these can be utilised in pharmaceuticals, nutraceuticals cosmetics and functional fruits (Sermyagina *et al*., 2021). Polyphenols indeed constitute a significant portion of tea's composition, with flavonoids being one of the major classes. Among flavonoids, catechins are particularly abundant in tea and these are known for their antioxidant properties. Polysaccharides found in leaves and buds of the tea plant can act as bioactive compound, contributing to the health promoting properties (antitumor, anti-fatigue, anti-obesity, antidiabetic and anti-ageing) (Xu *et al*., 2021).

CONCLUSION

Converting tea waste into value-added products is a sustainable and innovative approach that can benefit both the environment and the economy. Tea waste, such as tea leaves and left over tea grounds can be repurposed into various products such as compost, medicinal products, biofuels and many more. The bioconversion of tea waste into value-added products offers opportunities to reduce waste, generate additional revenue streams and contribute to environmental sustainability, resource efficiency and economic viability. Furthermore, polyphenols derived from tea waste can be used in formulation of nutraceuticals and natural health products promoting overall well-being.

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