Waste to Wealth: Bioconversion of Agro-Wastes for the Production of Industrially Valuable Enzyme Tannase

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Abstract

Agro-industrial fruit processing generates large quantities of peel wastes that pose serious environmental challenges. However, these residues are rich in tannins and other bioactive phytochemicals, making them suitable substrates for microbial enzyme production. The present study explores a waste-to-wealth approach through the bioconversion of selected fruit peel agro-wastes for the production of the industrially important enzyme tannase (tannin acyl hydrolase, EC 3.1.1.20). Aqueous extracts of fruit peels including pomegranate, grape, banana, papaya, watermelon, muskmelon, orange, and sapota were subjected to qualitative phytochemical screening to identify tannins and related constituents. The results revealed the presence of alkaloids, glycosides, carbohydrates, tannins, saponins, and flavonoids in varying combinations, confirming the suitability of these wastes as tannase-inducing substrates. Fungal isolates obtained from fruit peel waste dumping sites were screened for tannase activity using tannic acid agar medium, and efficient tannase-producing strains were identified based on clear zone formation. Among the substrates evaluated, grape peel supported the highest tannase production, followed by pomegranate peel, which may be attributed to their higher tannin and polyphenolic content. The findings of this study demonstrate that fruit peel agro-wastes can be effectively utilized as low-cost substrates for microbial tannase production, offering an eco-friendly and economically viable strategy for waste management and industrial enzyme production.

Keywords: Tannase, Phytochemicals, Fruit peels

Introduction

Agro-industrial processing of fruits generates enormous quantities of organic waste, particularly fruit peels, which are often discarded without proper treatment, leading to environmental pollution. These wastes, however, are rich in valuable phytochemicals such as tannins, flavonoids, glycosides, and phenolic compounds, making them promising low-cost substrates for microbial bioconversion processes. Tannins are naturally occurring polyphenolic compounds widely distributed in plant tissues including fruit peels, seeds, bark, and leaves (Haslam, 1996). They play an essential role in plant defense and possess considerable industrial significance. Tannase (tannin acyl hydrolase, EC 3.1.1.20) is an inducible enzyme that catalyzes the hydrolysis of hydrolysable tannins into gallic acid and glucose (Aguilar et al., 2007). Gallic acid has extensive applications in the pharmaceutical, food, cosmetic, leather, and chemical industries. Conventional chemical methods for tannase and gallic acid production are often expensive and environmentally hazardous. In contrast, microbial production of tannase using agro-wastes offers an eco-friendly, economical, and sustainable alternative (Belmares et al., 2004). Fruit peels such as pomegranate, grape, watermelon, muskmelon, banana, orange, papaya, and sapota are abundantly available and known to contain appreciable amounts of tannins and other bioactive compounds.

Although tannase production using individual substrates like grape and pomegranate peels has been reported, comparative studies linking phytochemical composition of diverse fruit peels with their efficiency as tannase-inducing substrates remain limited. Therefore, the present study focuses on the valorization of fruit peel wastes through phytochemical screening, isolation of tannase-producing fungi, and evaluation of selected agro-wastes for tannase production, highlighting a sustainable waste-to-wealth bioconversion approach.

Materials and Methods

Collection and Preparation of Fruit Peel Substrates

Fresh fruit peels of pomegranate (*Punica granatum*), grape (*Vitis vinifera*), banana (*Musa paradisiaca*), papaya (*Carica papaya*), watermelon (*Citrullus lanatus*), muskmelon (*Cucumis melo*), orange (*Citrus sinensis*), and sapota (*Manilkara zapota*) were collected from local fruit markets. The collected peels were thoroughly washed under running tap water to remove adhering dirt and impurities, followed by rinsing with distilled water. The cleaned peels were shade-dried at room temperature until constant weight was achieved, powdered using a mechanical grinder, and sieved to obtain uniform particle size. The powdered samples were stored in airtight containers at room temperature until further use as substrates for phytochemical screening and tannase production studies.

Preparation of Peel Extracts

Five grams (5 g) of dried and powdered fruit peel samples were soaked in 50 mL of distilled water for 1 hour. The mixture was boiled in a water bath for 10–15 minutes, cooled, and filtered using Whatman filter paper. The filtrate was used for qualitative phytochemical analysis.

Qualitative Phytochemical Analysis

The aqueous extracts were subjected to standard qualitative tests to detect phytoconstituents such as alkaloids, glycosides, carbohydrates, tannins, saponins, flavonoids, proteins, amino acids, and steroids, with special emphasis on tannins due to their role in tannase induction.

Screening of Tannase-Producing Fungi

Fungal isolates were obtained from soil samples collected from fruit peel waste dumping sites, emphasizing naturally adapted tannin-degrading microorganisms. The isolates were screened on tannic acid agar medium, and tannase production was confirmed by the formation of clear zones around fungal colonies.

Results

Phytochemical Screening

Qualitative phytochemical screening of selected fruit peel extracts revealed the presence of alkaloids, glycosides, carbohydrates, tannins, saponins, and flavonoids in varying combinations, confirming their biochemical richness. Proteins, amino acids, and steroids were largely absent.Watermelon and muskmelon peels exhibited alkaloids, glycosides, and carbohydrates, consistent with earlier reports. Papaya peel contained alkaloids, saponins, glycosides, carbohydrates, and flavonoids. Grape peel showed a strong presence of tannins and carbohydrates, while banana, orange, sapota, and pomegranate peels exhibited significant tannin and polyphenolic content, supporting their suitability as tannase substrates.

Screening of Tannase-Producing Fungi

Among the fungal isolates obtained from fruit peel waste dumping site soils, only three strains *Trichoderma viride*, *Aspergillus flavus* and *Aspergillus niger* exhibited notable tannase activity on tannic acid agar medium. Tannase production was confirmed by the formation of clear hydrolytic zones around the colonies. *Trichoderma viride* showed the highest tannic acid hydrolysis with a clear zone of 50 mm (colony diameter 61 mm), followed by *Aspergillus flavus* (38 mm/46 mm), *Aspergillus niger* (39 mm/42 mm). Several fungal isolates demonstrated tannase activity, as evidenced by clear zones on tannic acid agar. The efficient isolates indicated strong tannin-degrading capability and were selected for enzyme production studies. Screening of Tannase-Producing Fungi Similar observations have been reported for tannase-producing. *Aspergillus* and *Trichoderma* species (Batra & Saxena, 2005; Hamada et al., 2013).

Effect of Agro-Waste Substrates on Tannase Production

Among the evaluated agro-waste substrates, grape peel supported the highest tannase production, followed by pomegranate peel and other fruit peels. The superior enzyme yield observed with grape peel is attributed to its high tannin and polyphenolic content, reinforcing the importance of substrate composition in microbial enzyme induction. Tannase activity increased progressively up to the 9th day of incubation and declined thereafter. These results are consistent with earlier studies reporting enhanced tannase production using tannin-rich agro-wastes (Reddy & Rathod, 2012; Malgireddy & Nimma, 2015).

Conclusion

The present investigation clearly demonstrates the effective bioconversion of fruit peel agro-wastes into the industrially important enzyme tannase, thereby reinforcing the concept of a sustainable waste-to-wealth approach. The phytochemical richness, particularly the high tannin content of selected fruit peels, establishes these agro-residues as efficient, low-cost substrates for microbial tannase induction. The successful screening of potent tannase-producing fungal strains further highlights the biotechnological potential of fruit peel wastes for enzyme production. Utilization of such agro-industrial residues not only minimizes environmental pollution associated with waste disposal but also contributes to value addition and resource recovery, aligning with the principles of sustainable biotechnology and the circular bioeconomy.

Although the present study confirms the feasibility of fruit peels as promising substrates, detailed studies on tannase production, process optimization, fermentation parameters, and scale-up strategies are warranted. Future investigations focusing on optimization of substrate concentration, incubation conditions, nutrient supplementation, and purification of tannase will be essential to enhance enzyme yield and industrial applicability. Such studies will facilitate the development of economically viable and environmentally sustainable processes for large-scale tannase production.

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