

Valorization of Banana Leaves (*Musa* spp. var. Cavendish): Bioactive Characterization and Optimization of Herbal Tea Formulation

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Abstract

Banana leaf is an abundant, commonly discarded as an agricultural by-product during the banana harvesting process. In particular, approximately 700 million tons of banana leaves were wasted from harvesting 145 million tons of banana [1, 2]. Thank to their non-toxic nature and distinct aroma, banana leaves are often used to cover various traditional cakes throughout Asia, including Vietnam, Malaysia, and Indonesia. Moreover, they also have used in folk medicine for wound treatment and blood clotting [3]. However, a comprehensive study of chemical composition in banana leaf, its biological potential and its potential in food and pharmaceutical industry is still lacking, especially for the triploid variant *Musa* spp. var. Cavendish, which is abundant in the Southeast Asia region. Here, we showed that banana leaves are rich in fatty acids (46.40%), terpenes and derivatives (22.99%), along with other bioactive constituents. The most abundant compounds found in banana leaf were palmitic acid (22.80%) and α -linolenic acid (19.75%), followed by terpenes such as neophytadiene (6.90%), phytol (5.18%) and 3,7,11,15-tetramethyl-2-hexadecen-1-ol – (5.48%). Oven drying at 50 °C was identified as the appropriate condition for preserving these bioactive compounds. Extract of leaf dried at 50 °C showed the highest antioxidant activity (DPPH EC₅₀: 33.69–54.40 µg/mL; reducing power EC₅₀: 76.04–97.75 µg/mL, beta-carotene bleaching IC₅₀: 295.33 ± 7.35 µg/mL). Banana leaf also exhibited a strong NO-production inhibition by LPS activated macrophages (IC₅₀: 43.79–68.09 µg/mL), pointing to the biological potential of banana leaf on the inflammatory pathway of macrophages. This could be the result of the high content of potent anti-inflammatory agents such as linolenic acid [4], neophytadiene [5] and phytol [6] in banana leaves. Additionally, extracts of banana leaf also showed a potent antifungal capacity against *Candida albicans* (MIC: 256 µg/mL) and a modest antibacterial capacity. Those properties indicated that banana leaves are suitable for tea production. Using D-optimal-mixture-design, the optimal formulation (53% banana leaf, 30% peel, 16% corm, 1% sweet grass) was chosen for maximizing achieved total phenolic content, DPPH-inhibition and customers' acceptance. With this optimal formulation, total phenolic content in tea water was 5.89 mgGAE/ml, comparable to that of 30 % ethanolic extracts of green tea (4.68 ± 0.08 mg GAE/mL) and mate (5.16 ± 0.02 mg GAE/mL) [7]. The DPPH-inhibition and customer acceptance were determined as 68.26%, and 3.47 (slightly like), respectively. These experimental values are fell within a 95 % average confidence interval of the predicted values, which indicates a good agreement between the experiment and the predicted values using the established models. Additionally, the product met WHO-recommended limits for heavy metals and microbial contamination [8], assuring product safety. These findings indicate that *Musa acuminata* AAA by-products possess great potential as alternative sources of antioxidants for tea production. By promoting sustainable utilization of agricultural residues and reducing waste, this work aligns with the United Nations Sustainable Development Goals by advancing responsible utilization of agricultural residues and resource-efficient processing (SDG 12), encouraging moderate, climate-conscious post-harvest methods that reduce waste (SDG 13), and promoting sustainable management of land-based biomass and biodiversity conservation (SDG 15).

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