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Impact of Storage Conditions on the Stability and Bioactivity of Date Vinegar: A Comprehensive Study on Its Efficacy in Managing Metabolic Diseases

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Abstract

Date vinegar, a functional beverage derived from dates (*Phoenix dactylifera*), has garnered attention for its potential health benefits, including antidiabetic and cardiovascular effects. This study investigates the efficacy of date vinegar in managing type 2 diabetes mellitus (T2DM) and cardiovascular diseases while also examining how different storage conditions influence the stability and bioactivity of the beverage. In the first phase, a 10-week randomized controlled trial was conducted to assess the clinical effects of date vinegar on glycemic control and lipid profiles in adults with T2DM and dyslipidemia. Significant improvements were observed in HbA1c, LDL cholesterol, and fasting blood sugar levels ($p < 0.05$). Complementary computational docking and molecular dynamics simulations identified binding interactions between key bioactive compounds in date vinegar and therapeutic protein targets, such as ACE, β1AR, and DPP-IV. In the second phase, the stability of date vinegar was tested under different storage conditions. A beverage was prepared by blending date vinegar and goji berry juice, then stored at three different temperatures (room temperature, 40°C, and 50°C) for one and two months. Changes in physicochemical and phytochemical parameters were monitored, including total sugar content, antioxidant activity, and phenolic content. After two months, an electronic nose analysis was performed to evaluate sensory changes under different storage conditions. The results indicated that higher temperatures (40°C and 50°C) negatively affected the integrity of bioactive compounds, whereas storage at room temperature better preserved the beverage's quality. When stored appropriately, this integrated study demonstrates that date vinegar provides a dual-target therapeutic strategy for managing T2DM and cardiovascular diseases. The clinical findings confirm its efficacy, while the storage conditions emphasize the importance of proper storage to maintain its bioactive properties for optimal therapeutic benefits.

Key Words: *Date vinegar, Storage conditions, Bioactive compounds, Type 2 diabetes, Cardiovascular diseases, Stability, Molecular dynamics simulations, Glycemic control.*