Feasibility of Developing Biodegradable Cups from Tea Factory Waste Coated with Pectin Extracted from Citrus Peel Waste

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The excessive use of synthetic plastic packaging materials continues to pose serious environmental and health risks due to their non-biodegradable nature and potential migration of toxic substances into food. Therefore, this study investigated the feasibility of producing eco-friendly biodegradable cups from tea factory waste reinforced with pectin extracted from citrus peel waste. The research was categorized into two phases: (1) formulation and evaluation of three base layer ratios using tea waste and citrus peel semi-solid residue (1:1, 1:2, and 2:1) combined with 1% cellulose, 2 mL glycerol, and 98 mL water per 100 g paste; and (2) development of coatings using cellulose and extracted pectin in two ratios (5.3:0.7 and 5:1) with 0.2 mL glycerol and 99.8 mL water. A total of six treatments (three bases × two coatings) were subjected to structural and mechanical evaluations, including Fourier Transform Infrared (FTIR) spectroscopy and Thermogravimetric Analysis (TGA) for functional group analysis and thermal behavior, respectively. Physical properties such as thickness (1.75 – 2.52 mm), tensile strength (3.89 – 8.53 MPa), burst strength (320 – 456 g/cm²), weight load resistance (2 – 6 kg), and water leakage time (up to 180 min) were assessed. The results of the above properties were analyzed using one-way analysis of variance with significant differences between means determined at a $p<0.05$ level. FTIR spectroscopy provides insights into the functional groups present in both the coating and base layers, indicating a complex chemical structure in each layer. The TGA assesses the weight loss of the base layer and coating layer as temperature incre ases. Results of the TGA study show that weight loss starts above 150˚C, indicating better thermal stability for both layers. Biodegradability, color change, and pH stability of the above cups were analyzed after food contact. The most promising formulation was the 1:1 base coated with cellulose and pectin in a 5:1 ratio, which showed excellent strength, water resistance, thermal stability, biodegradability, and food safety compatibility (pH variation < 0.2; color stability score > 4). This study demonstrates the potential of reusing agro-industrial waste such as tea waste and citrus peel for developing sustainable packaging solutions, supporting circular economy goals. The findings highlight a viable path for large-scale application in eco-friendly packaging industries, replacing petroleum-based polymers with renewable, biodegradable alternatives.

Keywords: Biodegradable cup, Citrus peel, Pectin, Sustainable packaging, Tea Factory waste