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Synergistic Reinforcement of Starch Matrices: Investigating the Combined Effect of Natural Fiber (Banana Peel) and Antioxidant (Polyphenol) on Bioplastic Performance

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Abstract

The demand for sustainable materials has driven the use of agricultural residues to develop starch-based bioplastics as alternatives to conventional plastics. This study investigates the combined effect of polyphenol (PP) and banana peel (BP) on starch-based bioplastic properties. Four starch-based formulations were developed: P2B30 (2% PP, 30% BP), P2B60 (2% PP, 60% BP), P4B30 (4% PP, 30% BP), and P4B60 (4% PP, 60% BP), and characterized. Moisture content was highest for P4B60 (36.41±0.16%) and lowest for P2B30 (28.30±0.12%), whereas P2B60 and P4B30 showed intermediate values with significant difference (p<0.05). Thickness was highest for P4B60 (0.97±0.01 mm) and lowest for P2B30 (0.76±0.01 mm), whereas P2B60 (0.85±0.01 mm) and P4B30 (0.91±0.01 mm) were intermediate (p<0.05). Density was 1.12±0.02 (P2B30), 1.15±0.02 (P2B60), 1.17±0.02 (P4B30), and 1.19±0.02 g/cm³ (P4B60) with no significant difference between formulations (p>0.05). Tensile strength was highest for P4B30 (9.30±0.14 MPa) and lowest for P2B60 (5.32±0.13 MPa), whereas P2B30 (7.28±0.11 MPa) and P4B60 (8.45±0.12 MPa) (p<0.05). Elongation was highest for P2B60 (15.55±0.08%) and lowest for P4B30 (6.63±0.09%), whereas P2B30 (12.42±0.10%) and P4B60 (9.18±0.09%) (p<0.05). Total phenolic content (TPC) was highest for P4B60 (1.19 mg GAE/g) and lowest for P2B30 (0.94 mg GAE/g), whereas P2B60 (1.05 mg GAE/g) and P4B30 (1.12 mg GAE/g) (p<0.05). Antioxidant activity (AA) was highest for P4B60 (85.95±0.68%) and lowest for P2B30 (40.79±0.26%), whereas P2B60 (62.34±0.45%) and P4B30 (74.18±0.52%) (p<0.05). Biodegradability was highest for P4B60 (49.2%) and lowest for P2B30 (36.01%), whereas P2B60 (42.15%) and P4B30 (45.83%) (p<0.05). Results demonstrate synergy between natural fibres and antioxidants, supporting renewable bio-components as sustainable plastic alternatives.

Keywords: *Antioxidant activity, Banana peel, Polyphenol, Starch Bioplastics, Sustainable material*