Junior Science Communications
Faculty of Applied Sciences, UiTM Shah Alam
https://journal.uitm.edu.my/ojs/index.php/JSC

E-ISSN 2637-0689
Vol 63 2026

Colloquium on Applied Sciences 1 2026
7-12 January 2026, Faculty of Applied Sciences, UiTM Shah Alam, Malaysia

Utilization of Waste Eggshells for pH-Dependent Removal of Methyl Red Dye from Aqueous Solution

Nur Shafiqah Natasha Johari[a], Muhammad Naziz Saat[a]*

Structured Abstract

Background: The discharge of dye-containing wastewater from textile and related industries poses serious environmental and health concerns due to the toxicity and persistence of synthetic azo dyes. Methyl red is difficult to degrade and may accumulate in aquatic environments, adversely affecting ecosystems and human health. Conventional dye removal methods, such as chemical oxidation, activated carbon adsorption, and biological treatment, are often limited by high operational costs, secondary pollution, and complex processes. Therefore, the development of low-cost and environmentally sustainable adsorbents is required. Waste eggshells, an abundant agricultural by-product mainly composed of calcium carbonate, have attracted attention as potential biosorbents; however, studies on the pH-dependent removal of methyl red using eggshell-based materials remain limited.

Methods: In this study, waste chicken eggshells were prepared and acid-treated to enhance their adsorption properties. Batch biosorption experiments were conducted to investigate the effect of pH on methyl red removal at pH 4.0 and pH 7.5. Methyl red solutions were prepared using a water–ethanol system to ensure complete solubility, while phosphate buffer solutions were used to maintain the desired pH conditions. Adsorption performance was evaluated based on decolorization percentage and rate of decolorization at selected time intervals up to 24 hours. Residual dye concentrations were measured using UV–Visible spectrophotometry at 430 nm for pH 4.0 and 530 nm for pH 7.5. Control experiments using untreated eggshells were conducted for comparison. Statistical analysis was performed using one-way ANOVA at a significance level of $p < 0.05$.

Results: Acid-treated eggshells demonstrated higher and more stable methyl red removal than untreated eggshells under both pH conditions. At pH 4.0, methyl red concentration decreased rapidly from 0.100 g/L to approximately 0.021 g/L within the first 3 hours, followed by a plateau up to 24 hours, indicating rapid adsorption and equilibrium. The highest decolorization efficiency of approximately 82% was achieved at pH 4.0 after 24 hours.

Conclusion: The findings demonstrate that acid-treated waste eggshells are an effective, low-cost, and sustainable biosorbent for the pH-dependent removal of methyl red from aqueous solutions, highlighting the potential of agricultural waste for wastewater treatment applications.

Keywords: Waste eggshells, Methyl red, Biosorption, pH-dependent adsorption, Azo dye

*Correspondence: naziz@uitm.edu.my

[a] School of Biology, Faculty of Applied Sciences, Universiti Teknologi MARA, Shah Alam, Malaysia