

Functionalizing pure *Luffa cylindrica* with quaternary ammonium salts and examining the biosorption of industrial dyes.

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An eco-friendly aqueous method has been devised for altering the surface of *Luffa cylindrica* (LC) by employing a quaternary ammonium salt, hexadecyltrimethylammonium bromide, at various weights (0.1 g, 0.5 g, 1 g, 1.5 g). This initiative is driven by the aim to enhance the competitiveness of *Luffa cylindrica* in the removal of dyes from industrial wastewater, a task currently dominated by activated carbon. The functionalization of *Luffa cylindrica* with amines amplifies its adsorption capacity towards anionic dyes such as methyl orange (MO) and indigo carmine (IC) dyes, presenting new avenues in industrial pollution mitigation. The modified *Luffa cylindrica* structure underwent meticulous examination through comprehensive physicochemical characterization, encompassing Boehm titration, determination of the point of zero charge (pHpzc), Infrared (IR) spectroscopy, scanning electron microscopy (SEM), differential scanning calorimetry (DSC), and thermogravimetric analysis (TGA). These analyses revealed a substantial enhancement in the adsorption efficiency of binary dyes. The adsorption of indigo carmine (IC) onto *Luffa cylindrica*, whether in its pure form or modified, at a concentration of 150 mg/L, increased from 10.256 mg/g to 20 mg/g, respectively. Similarly, for methyl orange (MO), the adsorbed quantity surged from 9.564 to 17.556 mg/g. Furthermore, mathematical kinetic modeling was employed, indicating that the Brouers-Sotolongo model outperformed the pseudo-first and second-order models in describing the adsorption process.

Keywords: Adsorption; *Luffa cylindrica*; Luffa modified; Methyl Orange; Indigo Carmine.

Table 1. The zero charge points of raw **Luffa cylindrica** and Luffa cylindrica modified with amines.

Adsorbents	pHpzc
<i>Luffa cylindrica</i> pure	7.79
Luffa modified with 0.1g of salts.	5.96
Luffa modified with 0.5g of salts.	5.87
Luffa modified with 1g of salts.	5.74
Luffa modified with 1.5g of salts.	5.37

These findings indicate that the pHpzc of this material, modified at various levels, is relatively acidic. Hence, the presence of quaternary ammonium salts appears to affect the point of zero charge. However, it's worth noting that the introduction of amines amplifies the acidity of the biomass surface.