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Prunus mahaleb shell as a sustainable bioresource for carminic acid removal from aqueous solution: Experimental and theoretical studies

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ABSTRACT

This study focused on the performance of *Prunus mahaleb* shell (MS) agricultural waste, which is used as an alternative biosorbent for carminic acid (CA) removal from aqueous solution. The effects of different parameters such as pH, initial dye concentration, contact time, biosorbent dosage and temperature on the biosorption of CA dye to the MS biosorbent surface were investigated. The characterization of the biosorbent was done by FT-IR, SEM-EDX and pzc analyses. It was determined that the isotherm and kinetics of CA dye removal were consistent with the Langmuir isotherm and PSO and IPD kinetic models, respectively. The maximum adsorption capacity was calculated as 148 mg g^{-1} according to the Langmuir isotherm. According to the ΔH^0, ΔG^0 and ΔS^0 results, the biosorption was found to be endothermic and spontaneous. Based on these data, it is concluded that environmentally friendly, inexpensive, simple to use and effective MS biosorbent can be used for CA dye removal.

1. Introduction

With the increase in population and the development of industries in recent years, the primary concern worldwide has been the maintenance of adequate and good water quality [1]. Colored dyes are among the main pollutants that cause water pollution in many industries such as paint manufacturing, textile, paper, food, leather, cosmetics and plastics [2]. Many dyes are toxic and are not biodegradable. Discharge of these dyes into waste water negatively affects vital activities such as drinking, washing and bathing [3]. They can also cause dysfunction in the brain and central nervous system, liver, kidneys, reproductive system, and cancer [4]. They can affect photosynthetic activity as they reduce sunlight transmission and can be toxic to aquatic life due to metals and aromatics [5].

Carminic acid (E120) is an anionic and anthraquinone-based organic food dye obtained from the cochineal bugs [6,7]. It is widely used in textile, cosmetics, printing, food industry, medical and pharmaceutical applications [8]. According to the World Health Organization (WHO), CA is considered safe at low concentrations of 0.005 mg L^{-1}. However, it is a toxic and neurotoxic dye that can cause skin and eye diseases and cancer in higher intakes [9].

For these reasons, suitable techniques for the effective removal of dyes are investigated before the discharge of industrial wastewater. Many techniques such as coagulation, chemical oxidation, membrane separation, and electrochemical, aerobic, and anaerobic microbial degradation are applied to treat dye-containing wastewater. However, these methods are not widely used due to many disadvantages [10]. Among all these methods, adsorption is preferred more than other techniques because of its low cost, flexible and simple design, resistance to toxic substances, and high efficiency [11]. Among the factors affecting the adsorption efficiency, adsorbent-adsorbate interaction, adsorbent surface, adsorbent surface area, adsorbate/adsorbent ratio, and adsorbent particle size, temperature and pH are extremely important [12]. For this reason, in many studies, the applicability of using renewable, cheap, and abundant agricultural wastes as adsorbents has been reported compared to other adsorbent types [13–15].

Prunus mahaleb L. belongs to the *Prunoidae* subfamily of the Rosaceae family. *Prunus mahaleb* is a species that can adapt well to marginal soils, with an average tree length of 1–5 m, and sheds its leaves in winter. Mahaleb fruit, which grows abundantly in the centers of Europe and Asia and in the regions of North Africa, is consumed both fresh and in powder form. While it is used in the food industry with its bitter taste and intense aroma, it is preferred in the health and pharmaceutical industry due to the heart-protective, antidiabetic, antifungal, and cytotoxic properties of anthocyanins, coumarins, flavonols, and fatty acids. It is also among the important export products for Turkey [16,17].

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