Recovery of resources from wastewater to synthesise nutrient-loaded slow-release hydrogel: Release characteristic and mechanism

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Water resources that have been utilized by humans become complex wastewater, which contains a significant amount of recyclable nutrients that are not fully utilized (Li, 2015). In addition, the excessive and rapid release of chemical fertilizers contributes to low utilization rates and serious environmental concerns (Geng, 2015; González, 2015). To address these problems, hydrogel materials with excellent adsorption, loading and modification capabilities can be employed to recover nutrients from wastewater and produce nutrient-loaded slow-release carriers(Tian, 2019). However, to improve the efficiency of nutrient utilization and minimize loss, it is necessary to establish a release model that allows for the prediction of controlled release of nutrients and clarifies the mechanism of nutrient binding and release from the hydrogel. In this work, we prepared a biodegradable chitosan/polyvinyl alcohol/montmorillonite hydrogel through a cyclic freeze-thaw process and utilized the response surface model to construct a model for nutrient release. Additionally, we used DFT calculations to probe the interaction sites between nutrient elements and hydrogel as well as the change of electrostatic potential before and after loading to illustrate the release mechanism.

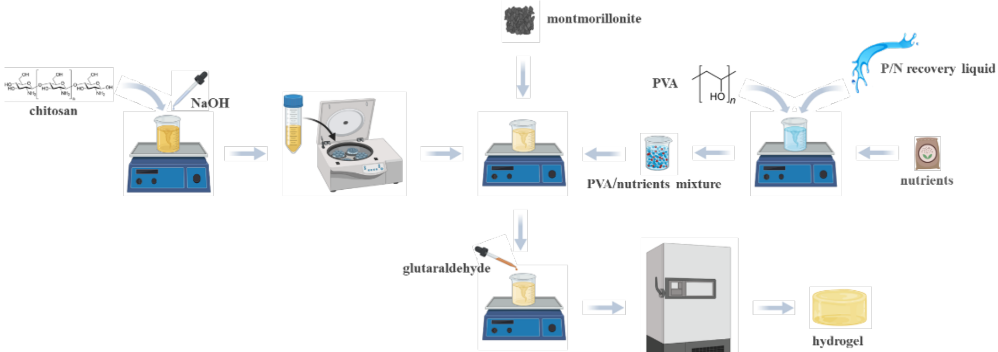

Figure 1. Schematic diagram of recovery nutrients from wastewater to prepare nutrient-loaded slow-release hydrogel.

Table 1.The material composition of different kinds of hydrogel.

Groups	Chitosan (%wt)	polyvinyl alcohol (%wt)	Montmorillonite (%wt)	Glutaraldehyde (μmol)
HGA	1.5	2.5	1.0	40
HGB	1.5	2.0	1.5	40
HGC	2.0	2.0	1.0	40
HGD	2.5	2.0	0.5	40
HGE	2.5	1.5	1.0	40
HGF	2.5	1.0	1.5	40

Based on the characteristics of recycled water and the nutrients required for vegetable growth, an artificial wastewater was prepared (Table 1). Chitosan and polyvinyl alcohol with varying mass ratios of montmorillonite were then added to the solution to construct hydrogels with different formulations and glutaraldehyde was used as the crosslinker.

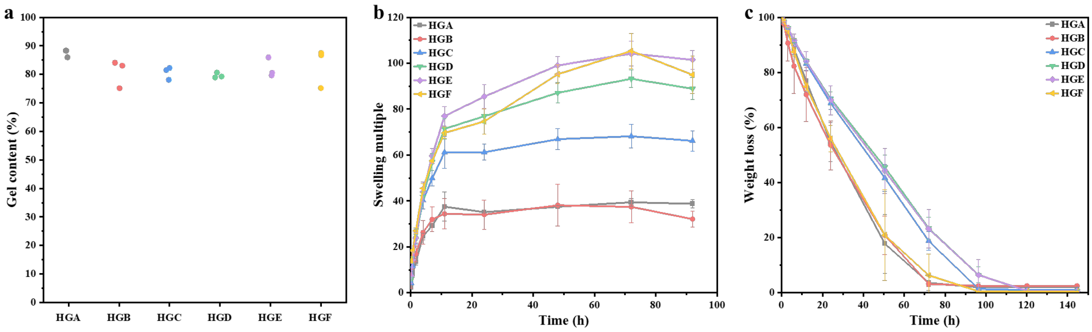

Figure 2. The gel content of synthesized hydrogel(a); Swelling capacity(b) and the water holding ability (c) of different kinds of hydrogel.

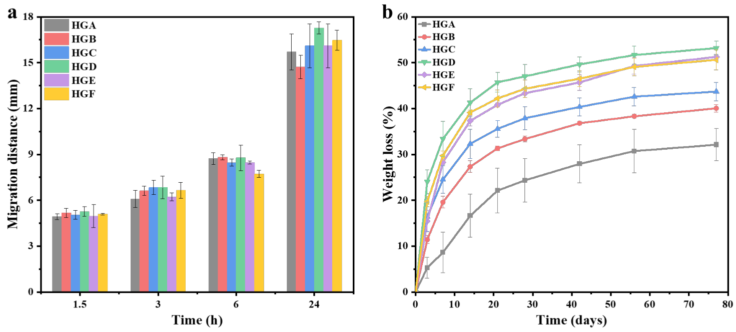

Figure 3. The nutrient migration performance (a) and biodegradation of different kinds of hydrogel (b).

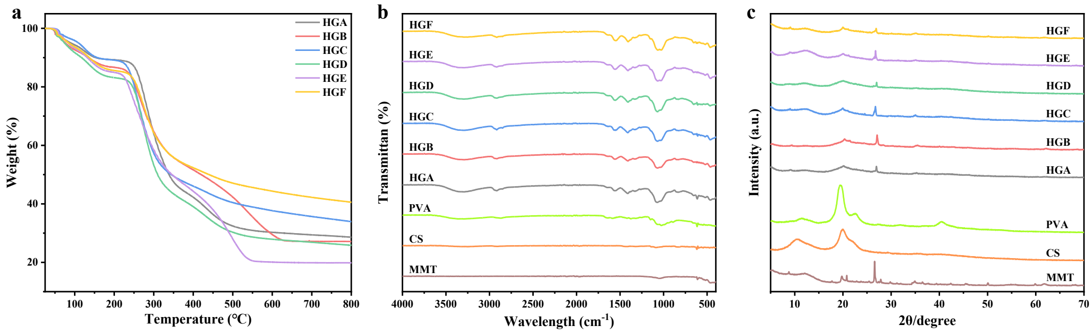

Figure 4. (a) Thermogravimetric analysis of different kinds ofhydrogel; (b) Fourier transform infrared spectra of chitosan, polyvinyl alcohol,montmorillonite and different kinds of hydrogel; (c) X-ray diffraction spectra of chitosan, polyvinyl alcohol, montmorillonite and different kinds of hydrogel.

Based on Figure 2, it can be observed that the hydrogels prepared had similar gel contents, which accounted for about 80% of the solid content. As the chitosan content increased, the water absorption capacity of the hydrogels gradually increased to over 100 times. Additionally, as the chitosan content increased, the quality loss of the hydrogels caused by biodegradation also increased gradually (Figure 3). By the 11th week, the degradation had exceeded 50%. The FTIR and XRD analyses confirmed that each raw material was successfully cross-linked and that the nutrients were effectively loaded onto the hydrogels (Figure 4).

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