INFOSHEET

MARCH 2017 | # 5

Using magnetic materials to harvest microalgal biomass

The harvesting efficiency of Chlorella vulgaris biomass was investigated using naked iron oxide (Fe_3O_4) and yttrium iron oxide ($Y_3Fe_5O_{12}$) nanoparticles as flocculants biomass. The optimal dosages and pH values for the magnetic harvesting of microalgal biomass were measured. The separation efficiency of microalgal biomass from magnetic nanoparticles with the help of pH control was also evaluated.

AIM OF THE STUDY

This study aimed to develop an efficient magnetic harvesting method to harvest Chlorella vulgaris biomass using bare Fe_3O_4 and $Y_3Fe_5O_{12}$ magnetic nanoparticles as flocculants. The optimal dosages and pH values for the magnetic harvesting of algal biomass were investigated. In addition, this study also aimed to evaluate the deattachment efficiency for the separation of microalgal biomass from magnetic nanoparticles with the help of pH control.

MATERIAL AND METHODS IN SHORT

Microalgae biomass production. Microalgae Chlorella vulgaris was cultivated in Bristol medium, where conical flasks were served as photobioreactors to grow microalgae. To provide carbon source, a certain amount of bicarbonate of 2 g/L was added into the medium. The flasks were laid on a shaker with the rotating speed of around 220 rpm for culture mixing, and the cultivation was conducted in a ventilating chamber, where the temperature was maintained at around 23 ^{0}C. Flasks were continuously illuminated by cool white fluorescent lamps with the light intensity of around 75 μmol m^{-2} s^{-1}.

Biomass harvesting. Different dosages of magnetic materials were added into vials which contained 20 mL microalgal solution, and the dose level applied was 0.5, 1, 2.5, 5, 10, 25 and 50 g/L. The mixtures were rotated using magnetic stirrers at 500 rpm for 1 min, after which aggregates of magnetic materials and microalgal biomass were harvested by an external permanent u-shaped magnet. After 2 min, the supernatant was sampled for the determination of optical density (OD) at 680 nm. In addition, the pH effect of microalgal culture on harvesting efficiency was also investigated. During the harvesting process, the different pH values were adjusted within the range of between 2 and 8 using either 0.1 M HCl or 0.1 M NaOH.

The formula for the harvesting efficiency is shown in Eq. (1):

$$\text{Harvesting efficiency } H\% = 100\% \times (ODo–ODi)/ODo \qquad (1)$$

where ODo and ODi are defined as the mean OD values of the initial culture before harvesting and the supernatant after harvesting, respectively.

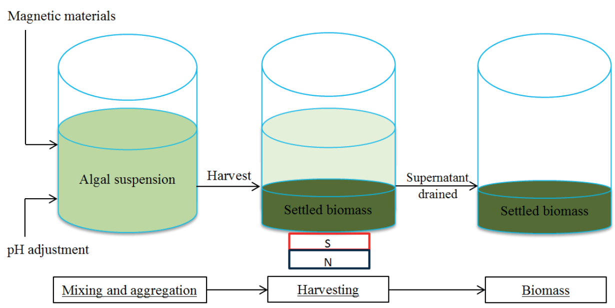

Fig. 1. Simplified harvesting process by magnetic materials

Separation of microalgal biomass from magnetic particles. After biomass harvesting the supernatant was discarded, and the flocs of microalgal cells and magnetic particles were ready for separation. The harvested microalgae slurry with pH value of 3.3 was mixed with 1–5 mL of NaOH solution (pH=13) to form the pH value of supernatant liquid within the range of between 9 and 12. Afterwards, the mixture was rotationally shaken using magnetic stirrers at 1000 rpm for 5 min, after which adsorbed lipid droplets with the detached magnetic nanoparticles were separated by employing the above-noted external magnetic field. The formula for the separation efficiency is shown in Eq. (2):

$$\text{Separation efficiency } S\% = 100\% \times ODi/ODo \qquad (2)$$

where ODo and ODi are defined as the mean OD values of the initial culture before harvesting and the supernatant after separation, respectively.

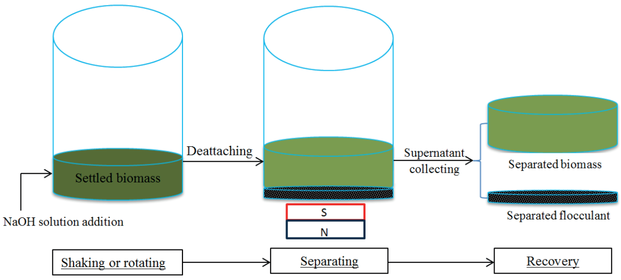

Fig. 2. Simplified process for the separation of flocs

RESULTS

Harvesting efficiency. As the dose of magnetic materials increased, the harvesting efficiency increased until it reached a peak value (Fig. 3). After that point, the increase of flocculant dosage would not lead to an obvious increase in harvesting efficiency. To achieve at least 90% harvesting efficiency, the according dosages of bare Fe_3O_4 and $Y_3Fe_5O_{12}$ were 10 and 2.5 g/L, representing the optimal amounts for microalgal harvesting. Typically, $Y_3Fe_5O_{12}$ indicated higher efficiencies in biomass harvesting under a fixed dose of flocculent, comparing to Fe_3O_4.

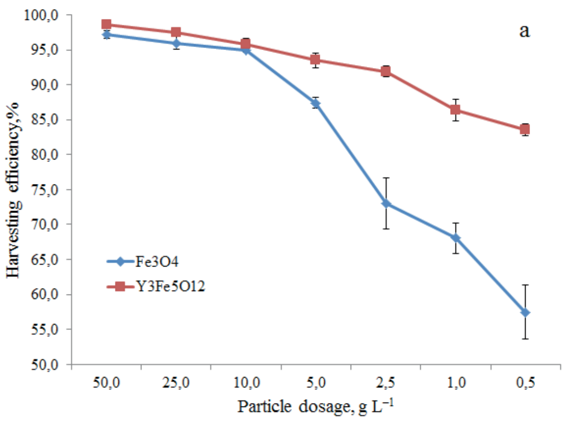

Fig. 3. Particle dosage effects on the harvesting efficiency

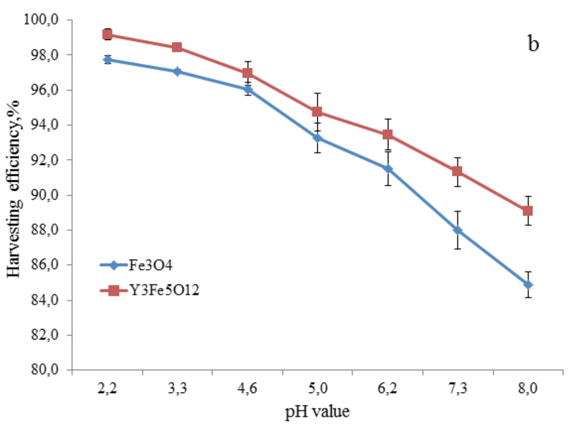

Fig. 4. pH value effects on the harvesting efficiency

The harvesting efficiency of Fe_3O_4 and $Y_3Fe_5O_{12}$ nanoparticles increased as the pH value decreased under the dosage of 10 g/L (Fig. 4). When the pH value of the culture reached 2.2, high harvesting efficiency of more than 98% was achieved for both flocculants. To achieve at least 90% harvesting efficiency, the appropriate pH values for Fe_3O_4 and $Y_3Fe_5O_{12}$ were 6.2 and 7.3, respectively. It can also be found that $Y_3Fe_5O_{12}$ indicated higher efficiencies in biomass harvesting under a fixed pH value, comparing to Fe_3O_4.

De-attachment effects. As the pH value of the mixture increased, the separation efficiency increased (Fig. 5). Under the fixed pH value, Fe_3O_4 showed higher de-attachment efficiency than $Y_3Fe_5O_{12}$. In general, the de-attachment effect for both nanoparticles was not ideal, especially for $Y_3Fe_5O_{12}$ nanoparticles which indicated the separation efficiency range of between 16.5% and 25.2%. When the floc pH value reached 12.3, 62.9% of Fe_3O_4 nanoparticles could be de-attached from the aggregates.

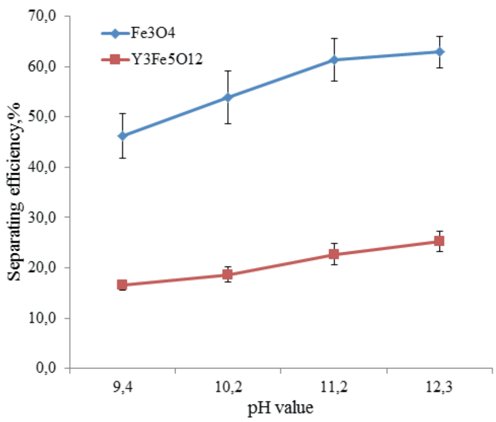

Fig. 5. The flocs de-attachment efficiency

CONCLUSION

Naked Fe_3O_4 and $Y_3Fe_5O_{12}$ can be used to efficiently harvest microalgal biomass, and the optimal dosage for more than 90% of harvesting efficiency was 10 and 2.5 g/L, respectively, while the appropriate pH values in culture for Fe_3O_4 and $Y_3Fe_5O_{12}$ were 6.2 and 7.3, respectively. However, separation of harvested biomass from magnetic materials is difficult, and further research is needed.

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