INFLUENCE OF NITROGEN SPECIES AND BIOMASS RETENTION TIME ON NUTRIENT REMOVAL AND BIOMASS PRODUCTIVITY IN A MICROALGAE-BASED BIOREACTOR

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https://doi.org/10.1016/j.scitotenv.2023.168911 Code: Pxxxxmmyyyy

Abstract

This study examined the effects of nitrogen species (NH4+-N/NO3--N ratio) and biomass retention time (BRT) on nutrient uptake and biomass productivity in Chlorella sp. In batch photobioreactors (PBR), microalgae were cultivated with varied nitrogen species ratios (100% NH4+-N, 50% NH4+–N:50% NO3--N, and 100% NO3--N). It was observed that a medium containing 100% NO3—N boosted algae growth, with a maximum biomass concentration of 3188 mg/L. However, the lowest nutrient removal rates were obtained under the 100% NO3--N condition, according to the reverse logistics model. In contrast, the highest removal rates occurred for substrate containing 100% of NH4+-N species based on first-order decay models, although yield biomass was lower (2940 mg/L). The presence of the ammonia nitrogen resulted in the flocculation of the microalgae into large flocs, suggesting that ammonia nitrogen was rapidly consumed to produce flocculation-related metabolic products rather than for biomass production. Using the 100% NH4+-N medium, different BRT values (7, 5, 3, 2 days) were examined under continuous operation using a membrane photobioreactor (MPBR). At 3-day BRT, the maximum biomass productivity, nitrogen, and phosphorous removal rates were 214 ± 4, 63.1 ± 4.1, and 2.1 ± 0.6 mg/L d, respectively. The biomass yield increased as the BRT decreased, leading to an increase in pollutant removal rates. Finally, this study provides some essential information for improving the operating conditions of membrane photobioreactor system under different biomass retention times and various nitrogen sources in the feed.

Experimental set-up

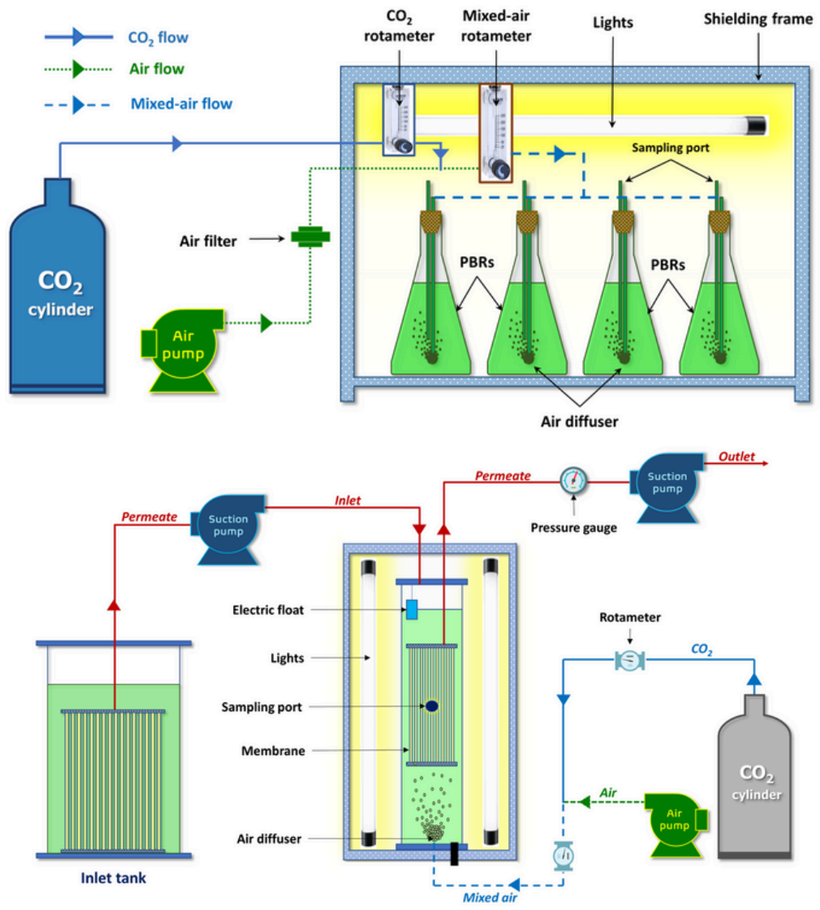


Fig. 1. Schematic diagram of (a) the batch photobioreactor(PBR); (b) the continuous membrane photobioreactor (MPBR).

Table 1. Operating conditions of PBR and MPBR

Parameters		Values		
Batch experiment (PBR)				
NH_4^+–N/NO_3^-–N ratios (Each condition had a TN of 200 mg/L)	100:0	NH_4Cl (mg/L)	764.3	200 mg N/L
		$NaNO_3$ (mg/L)	0	
	50:50	NH_4Cl (mg/L)	382.5	200 mg N/L
		$NaNO_3$ (mg/L)	607.2	
	0:100	NH_4Cl (mg/L)	0	200 mg N/L
		$NaNO_3$ (mg/L)	1214.3	
Continuous experiment (MPBR)				
HRT (d)			2	
BRT (d)	7	5	3	2
Flux (L/m² h)			4.0 ± 0.2	
Filtration (on/off-mins)			8/2	
Fixed parameters for the two experiments				
N/P	15:1			
pH	7.0–8.5			
Initial biomass (mg/L)	50			
Temperature (°C)	25–32			
Light:Dark cycle (h)	24:0			
Light intensity (lux)	3300			
CO_2 (%)	2.5			

Effects of NH4+-N/NO3--N ratio on biomass growth and nutrient removal of Chlorella sp. in PBR systems

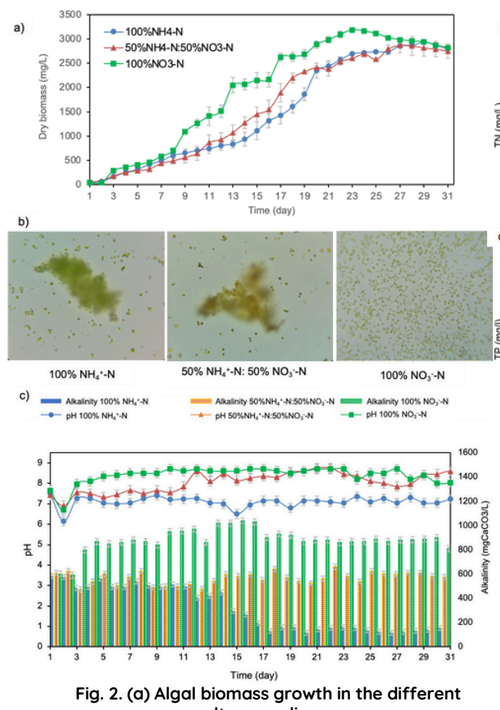


Fig. 2. (a) Algal biomass growth in the different culture mediums;
(b) Microscopic view (40X) of algae in the different culture mediums;
(c) Profiles concentration of pH and alkalinity

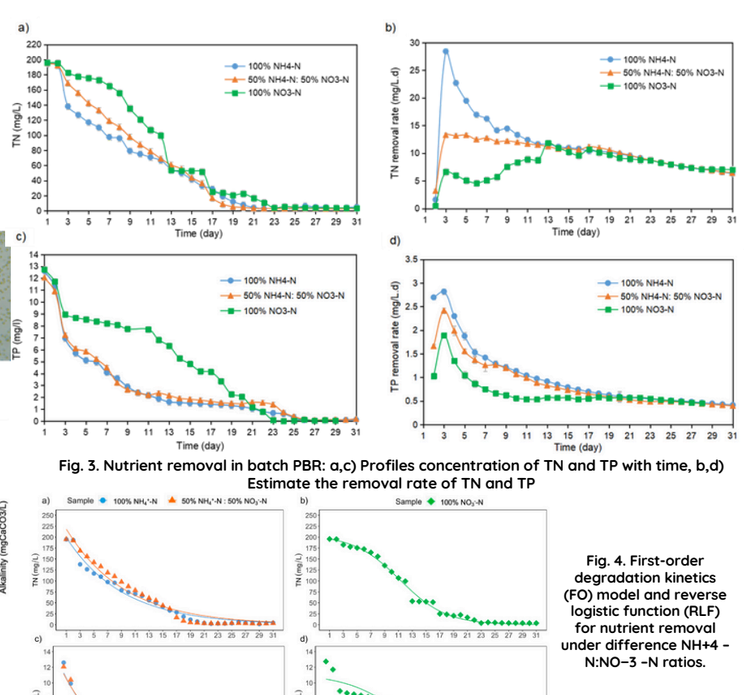
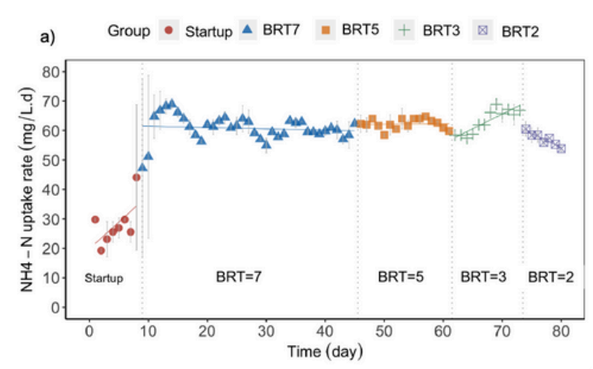


Fig. 3. Nutrient removal in batch PBR: a,c) Profiles concentration of TN and TP with time, b,d) Estimate the removal rate of TN and TP

Fig. 4. First-order degradation kinetics (FO) model and reverse logistic function (RLF) for nutrient removal under difference NH+4 –N:NO−3 –N ratios.

Effects of biomass retention time on biomass growth and nutrient removal of Chlorella sp. in MPBR systems



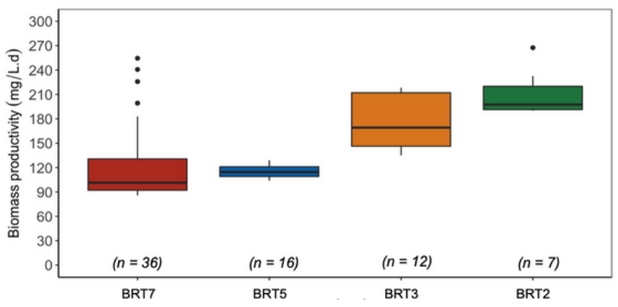


Fig. 4. Biomass production of Chlorella vulgaris at different biomass retention times (BRT7: 7 days, BRT5: 5 days, BRT3: 3 days, and BRT2: 2 days)

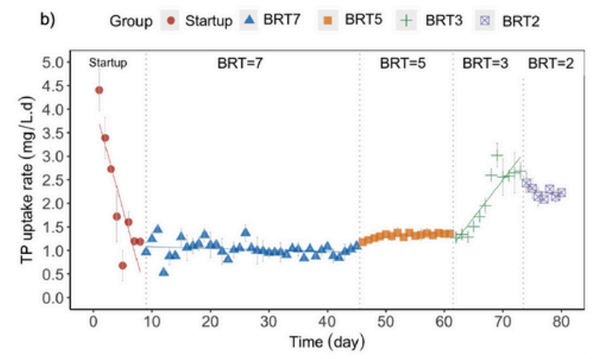


Fig. 5. Nutrient removal of the membrane photobioreactor at different biomass retention times

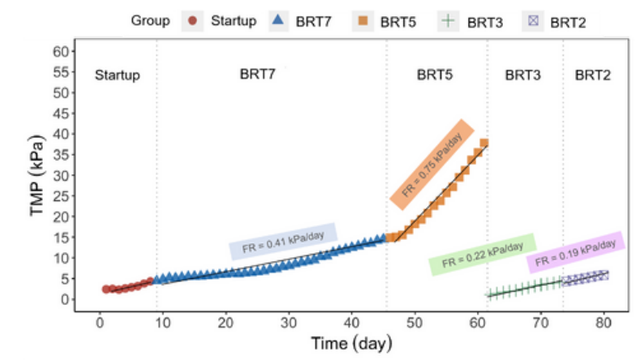


Fig. 7. Profiles of transmembrane pressure (TMP) and fouling rate (FR) of the membrane photobioreactor over different biomass retention times

Conclusions

- In the batch test, changing NH4+-N/NO3--N ratios influenced nutrient uptake and biomass growth in PBR.
- Nitrogen supplies in the form of NH4+-Nare preferred by Chlorella sp., however, the growth rate is greater with 100% NO3--N condition.
- In continuous mode, low biomass retention time led to higher algae production and higher nutrient uptake rate in MPBR.
- Given results suggest that the highest biomass production and nutrients removal in the MPBR were obtained at the 3-day BRT, HRT of 2 days, the average flux of 4.0 L/m2.h, and continuous illumination of 24 h/24 h.
- The relatively low fouling rate was obtained at the 3-day BRT (0.22 kPa/d) and the 2-day BRT (0.19 kPa/d) which positively correlated with the biomass concentration.
- The results of this study could provide basic information for improving the operating conditions and configuration of the algal process in wastewater treatment.

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