Article

A Comparative Study of the Growth and Nutrient Removal Effects of Five Green Microalgae in Simulated Domestic Sewage

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Abstract: Microalgae have shown great potential in wastewater treatment. This study evaluates the growth and nutrient removal characteristics of five different microalgae strains, namely *Chlorella vulgaris*, *Tetradismus obliquus*, *Parachlorella kessleri*, *Hydrodictyon* sp., and *Scenedesmus quadricauda*, in simulated domestic wastewater. The five microalgae could adapt to wastewater, but the growth potential and nitrogen removal capacity were species dependent. The nutrient removal effect of the microalgae used in this experiment was about 50% in the first two days. *Parachlorella kessleri*, selected from the five strains of green algae, shows good potential in removing nutrients from simulated domestic wastewater. For the simulated domestic sewage treated with *Parachlorella kessleri*, the chemical oxygen demand was almost completely reduced, and ammonium-N (NH₄-N) and total nitrogen (TN) removal exceeded 70% at the end of the 10-day treatment. Total phosphorus (TP) removal was slightly worse, more than 65%. *Parachlorella kessleri* showed the best growth in sewage with the highest biomass reaching 366.67 mg L⁻¹ and the highest specific growth rate reaching 0.538 d⁻¹. This study can provide a reference for selecting suitable microalgae species to treat actual domestic sewage.

Keywords: green algae; growth characteristics; nutrient removal; simulated domestic sewage

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1. Introduction

Rapid urbanization brings a significant amount of wastewater emission and generates more environmental risks [1–3]. Domestic sewage is one of the main sources of water pollution, as it can easily cause the eutrophication of water bodies [4], and has aroused great public concern in recent years [2,5]. Domestic sewage is rich in organic matter and nutrients, and it is derived from various scattered sources [6]. The discharge of domestic sewage generated by human activities in urban and rural areas can directly or indirectly result in the serious pollution of surface water and groundwater [7,8].

Conventional physical- and chemical-based methods for sewage, such as oxidation ditch, SBR, A/O, A²/O, ion exchange, and coagulation precipitation, require a combination of multiple reaction components and large energy inputs to realize nitrification and denitrification [9,10]. These processes generally entail high investment, complex operations and operational costs, and they can easily lead to secondary pollution [10,11]. Considering the capacity to remove high concentrations of nutrients, in particular, nitrogen and phosphorus [5,12–14], microalgae have been utilized to explore an economically sustainable and environmentally friendly approach to effectively treat wastewater from different sources [15,16].

The algae-based approach has been widely used in wastewater treatment [17]. Sufficient quantities of various nutrients in domestic sewage, such as N, P, and carbonaceous substances, are used to support the growth of algae and thus lower the concentrations of these compounds in water [18–20]. The primary advantage of integrating microalgae is their fast growth and strong adaptability in wastewater [21]. Both inorganic and organic nitrogen present in ammonia, nitrite, and nitrates can be utilized by microalgae in wastewater [2,22,23]. All microalgae have potential to remove or transform heavy metals and other contaminants from wastewater [19,24–26]. Secondly, large amounts of biomass are simultaneously produced as an alternative to the production of third generation biofuels [14,27–29], and as value-added ingredients [2,30,31]. Furthermore, microalgae also represent a promising method for CO₂ fixation and O₂ generation by photosynthesis to achieve carbon emission reductions [32–34]. *Chlorella vulgaris*, *Tetradismus obliquus*, *Parachlorella kessleri*, *Hydrodictyon* sp., and *Scenedesmus quadricauda* have shown good application effects in pig wastewater [35–37], fishery wastewater [38,39], brewery wastewater [40], and as a secondary effluent of sewage plants [41,42]. Therefore, studies should be carried out to determine the effectiveness of a broad variety of algae species, which is of great value to microalgae usage for the treatment of wastewater from different sources.

The aim of this study is to analyze and discuss current trends in the use of microalgae biotechnology for the bioremediation of artificial domestic sewage. Specifically, the objectives are to evaluate the growth and consumption of COD, nitrogen, and phosphorus from simulated domestic wastewater by five commonly used green algal species: *C. vulgaris*, *T. obliquus*, *P. kessleri*, *Hydrodictyon* sp., and *S. quadricauda*. Microalgae species with the highest efficiency in nutrient removal and good growth are identified. The results of this study will aid the future use of microalgae-based biological methods for domestic wastewater treatment.

2. Materials and Methods

2.1. Microalgae Species and Pre-Culture Conditions

C. vulgaris (FACHB-8), *T. obliquus* (FACHB-416), *P. kessleri* (FACHB-729), *Hydrodictyon* sp. (FACHB-735), and *S. quadricauda* (FACHB-1297) were obtained from the Culture Collection of Algae, Institute of Hydrobiology, Chinese Academy of Sciences (FACHB-collection, Wuhan, China). Before the experiment, the algae were pre-cultivated with a BG11 medium in flasks under a 12 h:12 h light/dark cycle under an incident light intensity of 2000 lux. The temperature of the culture room was maintained at 25 °C.

2.2. Synthetic Wastewater

Synthetic wastewater was used to formulate simulated domestic wastewater. The composition and concentration of trace elements in the synthetic wastewater were consistent with those in Blue-Green Medium (BG11). The composition of the synthetic wastewater was as follows (mg L⁻¹): glucose 400, NH₄SO₄ 189, NaNO₃ 243, KH₂PO₄ 43.90, NaHCO₃ 100, NaCl 64, MgSO₄·7H₂O 185, FeSO₄·7H₂O 9.10, CaCl₂ 25, H₃BO₃ 2.86, CuSO₄·5H₂O 0.08, and CoCl₂·6H₂O 0.05. The water quality indexes of synthetic domestic sewage were measured according to the Chinese state standard testing methods (Administration, 2010). The initial pH of synthetic wastewater was approximately 7.5. Before the experiment, the synthetic wastewater was sterilized by ultraviolet light on a single-person, single-sided horizontal purification workbench (SW-CJ-1G, Suzhou, China) for 30 min.

2.3. Microalgal Batch Cultivation and Experimental Set-Up

All five microalgae growing in the BG11 medium were collected via centrifugation at 6000 rpm for 5 min when they were in the logarithmic growth phase. Pellets were washed with deionized water and centrifuged a second time at 6000 rpm for 5 min. Pellets were then suspended in a small volume of wastewater and subsequently inoculated to 250 mL flasks containing 200 mL of wastewater.

2.4. Analytical Methods

2.4.1. Determination of Microalgal Growth

For microalgal growth determination, biomass production was measured as the dry algal cell weight (DW) concentration, according to the Chinese state standard monitoring method (Monitoring Method of Water and Wastewater, 2002) [43]. The algae liquid was shaken manually; 10 mL of the algae liquid was taken each time; and the cells were collected by filtration with a 0.45 µm cellulose acetate membrane to determine the microalgal biomass. Then, the blank cellulose acetate membrane and the cellulose acetate membrane with algae cells were dried at 105 °C for 24 h, and the dry weights were respectively weighed.

The microalgal concentration (mg L^{-1}) was calculated according to the following Formula (1):

$$\text{Microalgal concentration} = (\text{DW}_{t_i} - \text{DW}_{t_0}) / V \quad (1)$$

where DW_{t_i} and DW_{t_0} refer to the dry weight of filters with microalgal cells and dry weight of blank filters, respectively. V is the volume of microalgal culture.

The specific growth rate (μ) of microalgae was calculated according to the following Equation (2):

$$\mu = (\ln \text{DW}_{t_2} - \ln \text{DW}_{t_1}) / (t_2 - t_1) \quad (2)$$

where DW_{t_2} and DW_{t_1} refer to the dry weight of microalgal biomass per unit volume (mg L^{-1}) at time t_2 and t_1 , respectively.

2.4.2. Determination of Water Quality

For each experiment, 10 mL of the algae mixture was centrifuged at 6000 rpm for 5 min, and the supernatant was filtered through a 0.45 µm cellulose acetate membrane. Approximately 8 mL of the filtered supernatant was collected. The filtered supernatant was then used to determine COD, $\text{NH}_4\text{-N}$, TN, and TP. COD, $\text{NH}_4\text{-N}$, TN, and TP were analyzed by the dichromate method, salicylic acid spectrophotometry, alkaline potassium persulfate digestion UV spectrophotometric method, and ammonium molybdate spectrophotometric method, respectively (Monitoring Method of Water and Wastewater, 2002) [43]. The pH of wastewater was measured using a portable multiparameter analyzer FE-28 (Shanghai Mettler Toledo Instruments Co., Ltd., Shanghai, China).

2.4.3. Determination of Chlorophyll Fluorescence

Chlorophyll fluorescence parameters were measured according to Markou et al. [44] using a portable PAM fluorometer AquaPen-C AP-C 100 (Photon Systems Instruments, Czech Republic). The rapid information provided by the fluorescence of living chlorophyll reflects the utilization and dissipation of excitation energy by the photosystem II (PSII). For each measurement, the cuvette was filled with 3 mL of the algae culture, and the cuvette was closed with a stopper. After 15 min of dark adaptation at room temperature, the values of F_v/F_o and F_v/F_m were automatically obtained via the PAM fluorometer using the OJIP test.

The chlorophyll fluorescence parameters were as follows:

F_o : initial fluorescence (F_{50} µs, fluorescence intensity at 50 µs). Refers to the fluorescence when all reaction centers of PSII are in a fully open state, and all non-photochemical processes are at a minimum under dark adaptation.

F_m : maximal fluorescence intensity. Refers to the fluorescence when all reaction centers of PSII are in a completely closed state (that is, no photochemical reaction is carried out) and all non-photochemical processes are at a minimum in the dark adaptation state.

F_v : maximal variable fluorescence ($F_m - F_o$). Refers to the maximum variable fluorescence when all non-photochemical processes are at a minimum in the dark adaptation state.

F_v/F_o : potential activity of PSII. Although F_v/F_o is not a direct efficiency indicator, it is sensitive to changes in efficiency.

Fv/Fm: maximum quantum yield of PSII photochemistry $((F_m - F_0)/F_m, 0 < F_v/F_m < 1)$. Reflects the quantum yield when all PSII reaction centers are in an open state.

2.4.4. Statistical Analysis

Measurements were expressed as mean $\pm$ standard deviation from three independent experiments. Differences between means were determined using *t*-tests and one-way analysis of variance in SPSS25 software. A confidence level of 95% was used to assess significance; the *p*-value threshold for significance was 0.05.

3. Results and Discussion

3.1. Nutrient Removal and COD Decrease Efficiency of Five Green Microalgae Species in Artificial Domestic Sewage

In this study, the efficacy of different microalgae species for the remediation of wastewater was evaluated based on COD decrease and TP, TN, and $\text{NH}_4\text{-N}$ removal rates. Figure 1 shows the pollutant removal profiles of the five algae cultivated in artificial domestic sewage. The COD of the original wastewater was approximately 395.00 mg L^{-1} , and the original total phosphorus concentration was 11.23 mg L^{-1} . The original ammonia concentration was approximately 47.22 mg L^{-1} , and the original total nitrogen concentration was approximately 50.56 mg L^{-1} . All microalgae were capable of removing nitrogen and phosphorus from artificial domestic sewage. The pollutant concentrations in all experiments decreased rapidly within 2 d of cultivation. The nutrient concentrations decreased slightly from the 2nd to the 6th day. During the last 4 d of cultivation, the pollutant concentrations did not change significantly (Figure 1). These five microalgae species differed in their ability to remove nitrogen and phosphorus. *T. obliquus* and *P. kessleri* removed more nitrogen and phosphorus in the first 4 d compared with the other three microalgae. *T. obliquus* achieved removal rates of 69.46% and 61.33% of ammonia nitrogen and total phosphorus in the first 4 d, respectively (Table 1). *T. obliquus* and *P. kessleri* could remove 60.06% and 59.39% of total phosphorus, respectively. After 4 d of cultivation, *T. obliquus* and *P. kessleri* could reduce 73.42% and 75.95% of COD, respectively. These two microalgae could remove greater amounts of pollutants compared with the other three microalgae. After culture for 10 d until the end of the experiment, the removal rates of the different pollutants by *Chlorella vulgaris*, *P. kessleri*, *T. obliquus*, *Hydrodictyon* sp., and *S. quadricauda* in the simulated domestic wastewater were ammonia nitrogen: 72.15, 75.71, 78.76, 67.62, and 78.35%; total nitrogen: 73.46, 75.65, 74.46, 67.12, and 77.50%; and total phosphorus: 70.57, 66.79, 69.64, 73.60, and 75.33%, respectively. Except *Hydrodictyon* sp., the remaining 4 species of microalgae can reduce COD by more than 80%. (Table 1). The experimental results show that all microalgae species, except for *Hydrodictyon* sp., can effectively remove nutrients.

To date, extensive research has been conducted on the removal of nitrogen from sewage by microalgae. Sydney et al. [45] cultured *C. vulgaris* in synthetic sewage for nitrogen removal. After 14 d of cultivation, the nitrogen removal efficiency reached 73.77%. A recent study showed that the nitrogen removal of *C. vulgaris* was greater than 98% after 25 d [46]. To enhance the removal efficiency of nitrogen and phosphorus, microalgae are often cultivated for longer periods in experiments. Obviously, the ability of microalgae to remove pollutants in sewage is reduced if the amount of sewage discharged is large. Microalgae tend to store excess phosphorus for growth and biosynthesis. Therefore, phosphorus is over-absorbed by microalgae in the early stages of growth [19,30]. The removal efficiency of ammonium and total nitrogen decreased with the growth of *P. kessleri*, which is consistent with the results of previous experiments showing that more rapid increases in biomass result in more rapid nitrogen removal and indicates that the removal of nitrogen stems from assimilation by the algae. However, during the cultivation process, the pH increased with cultivation time, which may lead to the volatilization of ammonia [47]. Simulating the imbalance of nitrogen/phosphorus in domestic wastewater may limit the removal process of assimilated nutrients. The different ratio of N/P has an important

impact on the removal effect of pollutants. According to research, the higher the ratio of N/P, the better the removal effect of nutrients. Research shows that when the ratio of N/P is 5, the removal effect of nitrogen and phosphorus is relatively good [48,49]. Stumm's empirical formula for microalgae is $C_{106}H_{263}O_{110}N_{16}P$ (the ratio of nitrogen to phosphorus is 7.2:1), which also provides a reference for the ratio of nitrogen to phosphorus in sewage; however, the average composition of microalgae cells depends on the strain and growth conditions [20]. This also confirms the excessive absorption of nitrogen and phosphorus during microalgae cultivation.

Figure 1. COD, ammonia nitrogen, total nitrogen, and total phosphorus removal of *Chlorella vulgaris*, *Tetradesmus obliquus*, *Parachlorella kessleri*, *Hydrodictyon sp.*, and *Scenedesmus quadricauda* cultivated in the simulated domestic wastewater during 10 days of cultivation time. In the figure, (a–d) correspond to changes in the removal of COD, ammonia nitrogen, total nitrogen, and total phosphorus. All values are means $\pm$ standard deviation of three independent experiments ($n = 3$).

Table 1. The percentage of COD, nitrogen, and phosphorus removal by five microalgae throughout the 10-day treatment period.

Water Quality Parameters	Cultivation Time	<i>Chlorella vulgaris</i>	<i>Parachlorella kessleri</i>	<i>Tetradesmus obliquus</i>	<i>Hydrodictyon sp.</i>	<i>Scenedesmus quadricauda</i>
COD removal (%)	2	56.962	54.430	58.228	58.228	60.759
	4	65.823	62.025	73.417	62.025	75.949
	6	83.544	75.949	78.481	67.089	83.544
	8	86.076	81.013	82.278	69.620	87.342
	10	87.342	82.278	84.810	73.418	89.873
NH_4-N Removal (%)	2	43.467	37.272	65.491	40.258	57.518
	4	65.618	52.922	69.462	43.585	61.330
	6	66.306	56.501	71.198	46.929	65.121
	8	71.177	64.040	72.067	57.412	75.699
	10	72.152	75.709	78.759	67.620	78.346
TN Removal (%)	2	52.170	55.158	46.632	47.938	52.290
	4	55.257	59.460	51.340	59.460	57.156
	6	59.044	64.049	60.993	60.756	64.929
	8	72.555	69.894	69.657	64.019	70.765
	10	73.455	75.650	74.463	67.115	77.500
TP Removal (%)	2	45.236	52.004	54.675	46.394	56.322
	4	49.377	54.363	60.062	50.757	59.394
	6	57.703	60.018	62.956	61.532	72.752
	8	70.258	63.045	64.470	64.203	73.731
	10	70.570	66.785	69.635	73.598	75.334

In the simulated domestic wastewater, *P. kessleri*, *S. quadricauda*, and *T. obliquus* had a good nitrogen removal effect in the first 4 d. *S. quadricauda* and *T. obliquus* showed strong potential activity during photosynthesis. *S. quadricauda* and *T. obliquus* had strong nitrogen removal activity compared with the three other microalgae, indicating that the nitrogen removal ability is species dependent [2]. This indicates that these two microalgae could be used for nitrogen removal when the amount of sewage discharge is large; they could also reduce the time needed to cultivate microalgae.

3.2. Growth Profiles of Five Green Microalgae Species in Simulated Domestic Wastewater

Five green microalgae species, *C. vulgaris*, *T. obliquus*, *P. kessleri*, *Hydrodictyon* sp., and *S. quadricauda*, were cultivated in artificial domestic wastewater. The growth curves of the five microalgae in artificial domestic sewage are shown in Figure 2a. All five microalgae could grow wastewater without a lag phase, which indicates that all these microalgae adapted well to artificial domestic sewage. The biomass concentrations of *C. vulgaris*, *T. obliquus*, *P. kessleri*, *Hydrodictyon* sp., and *S. quadricauda* significantly increased from approximately 100 mg L⁻¹ to 413.33, 220.00, 376.67, 273.33, and 213.33 mg L⁻¹, respectively, after 3 d of cultivation (Figure 2a). After 5 d of cultivation in simulated domestic wastewater, the biomass was in equilibrium. By the end of the cultivation, the biomass concentration of these five microalgae decreased to 206.67, 76.67, 106.67, 70.00, and 16.67 mg L⁻¹, respectively (Figure 2a). In the experiment, all five species of microalgae reached the logarithmic growth phase in the first 3 d.

Figure 2. The biomass concentration (a) and pH (b) change of *Chlorella vulgaris*, *Tetradlesmus obliquus*, *Parachlorella kessleri*, *Hydrodictyon* sp., and *Scenedesmus quadricauda* in the simulated domestic wastewater. All values are means $\pm$ standard deviation of three independent experiments ($n = 3$).

The growth of microalgae requires sufficient amounts of nitrogen and phosphorus, and the addition of these elements in the absence of wastewater via fertilizer can significantly increase production costs [27]. Previous studies have shown that sewage is rich in nitrogen and phosphorus, and can thus provide an energy source for the growth of algae biomass. Consequently, microalgae can remove large amounts of nutrients, such as nitrogen and phosphorus [6]. Microalgae species vary in their degree of nitrogen and phosphorus utilization [5,6]. In this study, simulated domestic sewage was used as the nutrient source for the growth of microalgae, and the growth characteristics of five types of microalgae were studied. The maximum biomass concentration of these five microalgae cultivated in simulated domestic sewage ranged from 213.333 mg L⁻¹ to 413.333 mg L⁻¹ (Table 2). The highest biomass concentration of *C. vulgaris* in simulated domestic sewage is 413.333 mg L⁻¹. The biomass concentration of *C. vulgaris* in this study is similar to that reported in previous studies [13,50]. The microalgae biomass of *P. kessleri* grows rapidly, reaching 376.667 mg L⁻¹ in three days [51]. The biomass concentration of the remaining three microalgae exceeded 200 mg L⁻¹ on the third day [52–54]. However, the biomass concentrations of the four microalgae *T. obliquus*, *P. kessleri*, *Hydrodictyon* sp., and *S. quadricauda* were lower compared

with previous studies. These five microalgae could successfully adapt to and survive in simulated domestic sewage.

Table 2. Maximum biomass concentration and maximum specific growth rate of five microalgae cultivated in the simulated domestic sewage during 10 days of cultivation time. All values are means of three independent experiments ($n = 3$).

Microalgal Strain	Maximum Biomass Concentration (mg L ⁻¹)	Maximum Biomass Concentration Time (d)	Maximum Specific Growth Rate (μmax, d ⁻¹)
<i>Chlorella vulgaris</i>	413.333 ± 0.002 ^a	3	0.401 ^a
<i>Tetrademus obliquus</i>	220.000 ± 0.001 ^b	3	0.282 ^a
<i>Parachlorella kessleri</i>	376.667 ± 0.001 ^a	3	0.538 ^b
<i>Hydrodictyon</i> sp.	273.333 ± 0.001 ^b	3	0.353 ^a
<i>Scenedesmus quadricauda</i>	213.333 ± 0.000 ^c	3	0.439 ^a

Note: Values are means ± standard deviation, $n = 3$. Different superscript letters indicate significant differences ($p < 0.05$) in values of maximum biomass concentration or maximum specific growth rate of each microalgal species cultivated in the simulated domestic wastewater.

The specific growth rate is an important factor reflecting the growth characteristics of algae that has become indispensable for studying the growth potential of microalgae. The specific growth rate of these five types of microalgae under simulated domestic wastewater conditions was analyzed [28], which indirectly reflects the growth status of different species of microalgae in simulated domestic wastewater (Table 2). The maximum specific growth rates of the five species of microalgae ranged from 0.282 d⁻¹ to 0.577 d⁻¹ ($p < 0.05$), which was similar to or lower than values for the same algae species or genera in previous studies [50,55]. Five kinds of microalgae can adapt well to synthetic wastewater. Although the five species of microalgae were cultured and grown in the same simulated domestic wastewater, their biomass and specific growth rate varied, which reflected differences in their ability to adapt to the wastewater environment. This is consistent with the results of previous studies [49,56]. The maximum specific growth rate of *C. vulgaris* and *P. kessleri* is much higher than that of *T. obliquus* and *Hydrodictyon* sp. ($p < 0.05$), which indicates that the former two have higher growth potential in simulated domestic wastewater.

Changes in the pH in the process of artificial domestic sewage treatment are shown in Figure 2b. For all five microalgae species, the water was alkaline, and the pH changed little. The change in pH is mainly affected by the physiological activities of algae. The algae photosynthesize and absorb CO₂, disrupting the acid–base balance in the sewage and increasing the pH. The CO₂ produced by the respiration of algae produces H⁺, which alters the balance between CO₂, HCO₃⁻, and CO₃²⁻ in the water body and affects the pH. Algae photosynthesis consumes CO₂ at a much greater rate than the rate at which CO₂ is produced by respiration, resulting in an increase in the CO₃²⁻/HCO₃⁻ ratio and thus pH. The increase in pH during the cultivation of microalgae confirms that the culture environment in domestic sewage is alkaline. The increased pH results in the deposition of calcium and phosphorus, which also leads to a reduction in the phosphorus concentration in domestic sewage [56].

3.3. Chlorophyll Fluorescence of the Five Green Microalgae Species in Artificial Domestic Sewage

The microalgae in this study contain chloroplasts, which can convert carbon dioxide and water into organic substances, such as sugars, through chloroplast photosynthesis and light energy, and store energy. Through the fluorescence properties of chlorophyll, it reflects the growth state and activity of microalgae. The growth potential of five microalgae in artificial domestic wastewater was determined by analyzing the chlorophyll fluorescence characteristics of microalgae cells. The Fv/Fo and Fv/Fm values of all five species of microalgae increased in the first 4 days and reached relatively stable values on the fourth day (Figure 3). After the 4th day, the Fv/Fo and Fv/Fm values of microalgae have been

increasing slowly. Although there was a slight decrease thereafter, the F_v/F_o and F_v/F_m values remained relatively high. The F_v/F_m value of all microalgae cells reached approximately 0.7 (Figure 3), which is similar to values previously reported for microalgae cultured in sewage [27,57]. The F_v/F_o and F_v/F_m values of *P. kessleri* and *Hydrodictyon* sp. were relatively low, and the F_v/F_o and F_v/F_m values of *C. vulgaris*, *T. obliquus*, and *S. quadricauda* were relatively high. The F_v/F_o and F_v/F_m values of these five microalgae increased in the first 2 d; however, significant declines in the F_v/F_o and F_v/F_m values after 2 d were observed for *Chlorella vulgaris*, *P. kessleri*, and *Hydrodictyon* sp. F_v/F_o indicates the potential activity of PSII, and F_v/F_m is the maximum photochemical quantum yield under dark conditions. Therefore, *C. vulgaris* and *P. kessleri* cultivated in artificial domestic wastewater, which had higher F_v/F_o and F_v/F_m values, showed better growth and metabolic activity. As the growth of microalgae in sewage is species dependent, the selection of appropriate algae species is critically important for optimizing domestic sewage treatment [20].

Figure 3. F_v/F_o (a) and F_v/F_m (b) of *Chlorella vulgaris*, *Tetrademus obliquus*, *Parachlorella kessleri*, *Hydrodictyon* sp., and *Scenedesmus quadricauda* cultivated in the simulated domestic wastewater during 10 days of cultivation time. All values are means $\pm$ standard deviation of three independent experiments ($n = 3$).

4. Conclusions

Five commonly used green algal species (*C. vulgaris*, *P. kessleri*, *T. obliquus*, *Hydrodictyon* sp., and *S. quadricauda*) could grow in simulated domestic wastewater. *C. vulgaris* and *P. kessleri* grew better compared to *T. obliquus*, *Hydrodictyon* sp., and *S. quadricauda*. The nutrient removal effects of *P. kessleri* and *S. quadricauda* from simulated domestic wastewater were high. Within 4 to 6 d of treatment, most of the nutrient elements were removed from the simulated domestic wastewater. Therefore, *P. kessleri* was superior to the other four microalgae in terms of its growth potential and pollutant removal effect, suggesting that it could be used for the removal of nutrients from domestic sewage.

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