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Full Paper

Phytoremediation of kitchen wastewater by *Spirulina platensis* (Nordstedt) Geiteler: pigment content, production variable cost and nutritional value

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Abstract: Phytoremediation of domestic wastewater by *Spirulina platensis* was carried out using kitchen wastewater. A complete randomised design (CRD) was created for the experiment which was performed on modified Zarrouk's medium (Zm), 100% kitchen wastewater (100%Kw) and 90% kitchen wastewater (90%Kw). Water quality, biomass production, pigment content and nutritional value of *Spirulina platensis* were determined from cultures harvested every 5 days for a period of 15 days. The physico-chemical properties of cultivated wastewater were: water temperature 27-28 ^{o}C, pH 8.73-9.77 and DO 0.20-7.20 mg L^{-1}. The 100%Kw and 90%Kw produced lower BOD, COD, TP, NH_3-N, ON, TKN, NO_3-N, NO_2-N, TON and TN compared to Zm with $p < 0.05$. After cultivation, the treated kitchen wastewater met the standards for safe discharge in Thailand. The highest level of β-carotene of *S. platensis* was achieved in Zm (0.29 mg g^{-1}) and 100%Kw (0.29 mg g^{-1}) while the highest levels of C-phycocyanin were obtained in 100%Kw (17.95 mg g^{-1}) and 90%Kw (16.31 mg g^{-1}). The highest production variable cost for dry weight of *S.*

platensis was in Zm (310.6 Baht kg $^{-1}$) and 90%Kw (303.6 Baht kg $^{-1}$) as compared to 100%Kw (276.6 Baht kg $^{-1}$), with $p<0.05$. The highest biomass production of *S. platensis* was achieved in Zm (0.84 g L^{-1}) and 100%Kw (0.82 g L^{-1}), with protein content of 54.44% and 35.86%, respectively. Implications for the use of *S. platensis* for phytoremediation and C-phycocyanin production using of 100%Kw and 90% Kw are discussed.

Keywords: kitchen wastewater, nutritional value, pigment content, production variable cost, *Spirulina platensis*

Introduction

Remediation of wastewater to remove unwanted nutrients using microorganisms has been widely applied throughout the world. Some of the important advantages of using microalgae such as *Spirulina platensis* include the relative safety of the microorganism, the efficient removal of the primarily nitrogen- and phosphorous-containing nutrients, its rapid growth rate, and the ability to utilise the resulting algae as a food source for fish or farm animals. Kitchen wastewater has received relatively little attention although it can make a significant contribution to the polluted stream, especially from dining facilities in large institutions such as universities. It is rich in nutrients (nitrogen, phosphorous, fats, proteins, carbohydrates, etc.) and has relatively few toxic components that need to be removed owing to its origin in the food processing environment.

The conventional nitrogen sources for *S. platensis* are ammonia nitrogen (NH_3-N) and nitrate nitrogen (NO_3-N) [1]. Interesting research work has been carried out using animal wastes, wastewater and urban effluents as low-cost nitrogen sources [2]. In batch and fed-batch cultures, large *S. platensis* biomass production was demonstrated along with elevated pigment content [3-4]. Culturing *S. platensis* for animal feed purposes using inorganic culture media is relatively expensive because of the need to provide a full complement of nutrients. Low-cost alternatives such as wastewater should be evaluated as a more cost-effective method of producing this important nutritional product. In addition, production of *S. platensis* can improve water quality, as demonstrated in a recent study in Mexico involving use of 50% swine waste in a suspended system [5]. Significant biomass levels were obtained and wastewater nutrient levels were dramatically reduced.

Another study [6] achieved 96% total nitrogen (TN) and 54% total phosphorus (TP) removal by *S. platensis* in an outdoor raceway by treating 2% diluted anaerobic effluents from pig wastewater containing almost the same amount of nitrogen and phosphorus as in the experiment carried out as described in the present study. These studies, along with the present work on kitchen wastewater, clearly demonstrate that *S. platensis* cultivation can be considered as a promising approach to nitrogen and phosphorus removal from wastewater [2,7].

The improvement to effluents (lower N, P) from a pig manure biogas digester by *S. platensis* was described in 1999 [8-9]. The *S. platensis* biomass produced during the experiment could be used

later as a dietary protein supplement in aquatic farming. All experimental ponds were continuously aerated. Water and algal samples were collected every 3 days over a culture period of 30 days. Over 98.99% of the NH_3-N was removed in all treatments and dilutions of different effluents, thus meeting the pollution control standards in Thailand. The COD was reduced by 97.13% in the 30% effluent dilution. The COD concentration after 30 days was also lower than the effluent standard of Thailand [26]. The highest biomass production (0.32 g L^{-1} as dry-weight) was achieved in the 50% effluent, where the chlorophyll-a content was between 38.6 and 69.2 μg L^{-1}[9]. However, the COD actually increased for this mixture.

Many studies have been carried out to examine microorganisms as a source of protein for human consumption and animal feed. Among these is the microalga *S. platensis*, one of the phytoplankton in the division Cyanophyta [10]. This organism has a protein content that ranges from 60 to 72% (dry weight) and contains 18% C-phycocyanin, 1.7% β-carotene, 1.6% chlorophyll-a, and 26-30% gamma linoleic acid (as percentage of total fatty acids) [11]. *S. platensis* has a low nucleic acid concentration and the amino acid content is similar to that recommended for human or animal consumption by the international Food and Agriculture Organization (FAO) [12]. C–phycocyanin is one of the major biliproteins of *S. platensis*, a blue green alga, with antioxidant and radical scavenging properties. It is also known to exhibit anti-inflammatory and anti-cancer properties.

The main objective of this study is to investigate the efficiency of *S. platensis* in improving the water quality of the effluent from kitchen wastewater and to determine the production variable cost of the resulting alga, as well as its content of β-carotene, C-phycocyanin and other nutritional components.

Materials and Methods

Kitchen wastewater preparation

One hundred litres of wastewater from the day's food and dish washing at the cafeteria kitchen in the Department of Biology, Chiang Mai University, were collected every Friday. This wastewater was placed in 100-L cement tanks and allowed to ferment for 3 weeks for microorganisms to break down the solid organic wastes. The liquid portion in each tank was then filtered through an 80-micron plankton net filter. The filtrate was taken for determination of temperature, pH, dissolved oxygen (DO) and BOD by azide modification, COD by closed reflux, NH_3-N by direct nesslerisation, NO_3-N by phenoldisulphonic acid, NO_2-N by diazotisation, TN by the macro Kjeldahl method, and TP by persulfate digestion/stannous chloride [13-14]. This filtrate, or "100%" solution (100%Kw), was diluted to 90% with tap water to make an additional starting solution (90%Kw). Greater dilutions were found to produce significantly lower growth rates, so only 100% and 90% solutions were used in this study [15].

S. platensis stock culture preparation

Stock Zm: *S. platensis* was cultured in modified Zarrouk's medium (Zm) in a 5-litre bottle and allowed to grow for 2 weeks until the optical density at 560 nm reached 1 (OD_{560nm}=1).

Modified Zarrouk's medium (Zm) [8]: this medium is composed of 2 g L^{-1} of $NaHCO_3$ (Qingdao Co., LTD, China), 1 g L^{-1} of NaCl (Purity Salt Industry, Co., LTD, Thailand), 1 g L^{-1} of $MgSO_4$ (UTIDS Enterprise Co., LTD, Thailand), 0.5 g L^{-1} of $NaNO_3$ (Qingdao) and 1 g L^{-1} of N:P:K (16:16:16, YARA International ASA Co., Ltd, Norway), adjusted to pH 10 $\pm$ 0.5 using NaOH.

Stock Kw: *S. platensis* from stock Zm was cultured in fermented 100%Kw in 50 L glass tanks and allowed to grow for 2 weeks until the optical density (OD) at 560 nm reached 1 ($OD_{560\ nm\ =\ 1}$). This stock Kw would then be used as "*S. platensis* inoculum" for the experiments in 100-L cement ponds.

Experimental design

A complete randomised design (CRD) was carried out using 3 treatments, each performed in triplicate. Initial physico-chemical properties were measured on the media before inoculation. *S. platensis* was obtained by first filtering 30 L of the stock solution (stock Kw) to give the "raw *S. platensis*." The control tanks consisted of the raw *S. platensis* added to 100 L of Zm. The treated tanks were 90% (90%Kw) and 100% (100%Kw) wastewater inoculated with raw *S. platensis*. The initial optical density of each tank was 0.30. All experimental tanks were cultured for 15 days with continuous aeration. Samples were collected every 5 days from each tank and analysed for their physico-chemical properties viz. temperature, pH, DO, BOD, COD, TP, NH_3-N, organic nitrogen, total Kjeldahl nitrogen (TKN), NO_3-N, NO_2-N, total oxidised nitrogen (TON) and TN. Algal biomass concentration was also determined by filtration using a 120- μm plankton net. Samples of *S. platensis* were analysed for production variable cost, nutritional content (protein, fat, ash, fiber, moisture), β-carotene and C-phycocyanin [16-18].

β-Carotene and C-phycocyanin analysis

The β-carotene concentration (mg g^{-1}, dry weight) in *S. platenisis* was determined by HPLC (Mightysil RP-18 GP, 5 µm, 150 x 4.6 mm ID column, Kanto Reagent Co., Ltd, Japan). The algal sample (0.75 g, dry weight) was homogenised in a homogeniser with hexane as extracting solvent, then filtered and the filtrate collected and evaporated to dryness. The residue was dissolved in methanol : chloroform (4:1) before injection. The mobile phase flow rate and the measured wavelength were 1 mL min^{-1} and 456 nm respectively. Authentic β-carotene (Sigma, USA) was run through the same procedure as described above [16]. The C-phycocyanin concentration (mg g^{-1}, dry weight) in *S. platenisis* was determined by HPLC (Agilent Technologies, USA) using a reverse phase ZORBAX Eclipse XDB-C-18 (5 µm, 150 x 4.6 mm) column. Approximately 1g (dry weight) of *S. platensis* was suspended in 10 ml of phosphate buffer solution (PBS), pH 7.2, and maintained in the dark at 4 ^{0}C for 16 h. The crude extract was then centrifuged at 10,000 rpm for 15 min at 4 ^{0}C to separate cell debris. The volume was adjusted to 10 ml with PBS. Then other components in the supernatant were

precipitated by addition of solid ammonium sulfate (25% w/v final composition). The resulting C-phycocyanin-containing solution was evaporated to dryness. The solid residue was dissolved in 10 mL of a methanol:water mixture (1:1) prior to analysis by HPLC. The mobile phase was methanol:water (1:1), the flow rate was 0.50 mL/min, and the detector wavelength was 214 nm. Authentic C-Phycocyanin (Sigma Aldrich, USA) was run through the same procedure as described for the *S. platensis* samples [17].

Production variable cost and nutritional value

The production variable cost was calculated from the cost of *S. platensis* culture plus the variable costs, viz. nutrient cost, stock *S. platensis* cost, labour cost, and electricity and water cost [19]. Samples of *S. platensis* were analysed for their nutritional content (protein, fat, ash, fiber and moisture) [18].

Statistical analysis

Data were presented as mean values ± standard deviation. Comparison of mean values was made by one-way analysis of variance (ANOVA), followed by Duncan's multiple range test (DMRT) at a significance level of $p<0.05$ (SPSS Inc., Chicaco, USA, Ver.15).

Results and Discussion

Water quality

The water quality values for the kitchen wastewater filtrate are summarised in Table 1 and the progress of their changes is illustrated in Figure 1. After completing the 15-day experimental period, it was found that the physical and chemical properties of the water changed significantly (Table 1). All media showed an increase in pH during the period, consistent with the usual behaviour of blue green algal cultures. In the commercial growth of *S. platensis* the media employed have high pH (9.5-12) and high salinity and they are particularly selective for this organism, an important factor in preventing contamination of the reactor by bacteria, algae and protozoa [20]. A large increase in dissolved oxygen (DO) occurred for both preparations of kitchen waste media as a result of aeration. The optimum level of DO for algal cultures in water is normally more than 5 mg L^{-1} [21], thus the final solutions under aeration had adequate levels (6.12-7.20 mg L^{-1}). The initial level in the Zm medium was high since it was prepared using tap water containing considerable DO, and 90%Kw contained 10% tap water, resulting in a slightly elevated DO level compared to 100%Kw.

For 100%Kw and 90%Kw, the BOD decreased by 72.74 % and 71.08 % respectively. The chemical composition of Zm resulted in a low BOD initially since it contained no significant amount of biodegradable organic compounds such as protein, carbohydrate or fat. The present study showed a slightly larger decrease in BOD using kitchen wastewater than the 70% decrease during the cultivation of *S. platensis* in the 40% dormitory effluent from Maejo University [22]. With 100%Kw and

90%Kw the COD value decreased dramatically (72.6% and 73%), but somewhat less than in the cultivation of *S. platensis* in wastewater from the production of sago starch as reported by Canizares [5], where COD decreased by 98.00 %, and in the cultivation of *S. platensis* in 30% effluents from pig manure biogas digester reported by Promya and Traichiyaporn [9], where COD decreased by about 97% using different waste sources.

Improvement in water quality is often assessed by the ability of a process to reduce nutrient matter, especially nitrogen and phosphorous. Cultivating algae in water with high nutrient matter can dramatically reduce nitrogen and phosphorous levels and, at the same time, produce a useful product, such as algae for animal feed. Kitchen wastewater generally has a high level of nutrients and large quantities are produced every day at commercial and residential sites, so it is especially noteworthy that the experiment described in this work showed dramatic improvement in water quality, sufficient to meet the standard for discharge, and produced significant amounts of useful algal material.

Total phosphorous levels in all three media (Zm, 100%Kw and 90%Kw) were initially high (3.83-4.35 mg L^{-1}) and decreased by nearly the same percentages (50, 50.4 and 50.4 %, respectively). These are similar to those in other studies where 54-55% reductions were achieved [6, 23-25]. Ammonia nitrogen (NH_3-N) was not added to Zm, so the measured levels were near the detection limit. However, there were significant levels of NH_3-N initially in the kitchen wastewater (7.03 and 5.75 mg L^{-1} for 100%Kw and 90%Kw, respectively). Algae prefer to use NH_3-N than NO_3-N, and the optimum concentration range of nitrogen for algal growth is 1.3 - 6.5 mg L^{-1} [14]. After 15 days of cultivation, the NH_3-N levels dropped dramatically by 98.0 and 97.8 % for 100% Kw and 90% Kw respectively, to those within the allowable discharge limit for NH_3-N (<1.1 mg L^{-1}) [26]. Total Kjeldahl nitrogen (TKN) is the sum of organic nitrogen and ammonia nitrogen [27]. Since Zm contained neither ammonia nor organic nitrogen, the initial and final levels were very low (0.07 and 0.05 mg L^{-1}, respectively). Kitchen wastewater contained a significant amount of both organic and ammonia nitrogen, so the initial TKN was high (22.56 and 20.3 mg L^{-1} for 100%Kw and 90%Kw, respectively). Culturing *S. platensis* in kitchen wastewater resulted in 97% decrease in TKN for both 100%Kw and 90%Kw, and the resulting water was improved to within the discharge limit of <100 mg L^{-1} [26]. Since organic nitrogen is derived from TKN by subtracting with NH_3-N, similar decrease (near 97%) was observed.

NO_3-N was the sole source of nitrogen for Zm, so the initial level was very high (30.73 mg L^{-1}). Cultivation of *S. platensis* reduced this by 94.2%. The lower starting levels in 100%Kw and 90%Kw (3.8 and 3.47 mg L^{-1}) were also dramatically reduced by 99.2% for each medium. Again, all media after cultivation were within the discharge limit for NO_3-N (<0.5 mg L^{-1}) [26]. NO_2-N in all media was very low (0.003 – 0.008 mg L^{-1}) as anticipated, since neither Zm nor the kitchen wastewater had an identifiable source of this nutrient. Total oxidised nitrogen is the sum of NO_3-N and NO_2-N, so this quantity is dominated by the effect of NO_3-N (<0.5 mg L^{-1}) [26]. Total nitrogen is the sum of TKN and total oxidised nitrogen and the resulting values are summarised in Table 1. A reduction of 94-97% was achieved in all media after 15 days of cultivation of *S. platensis*.

Table 1. The statistical summary (mean ± SD) of water quality and percentage removal in wastewater culture of *S. platensis* after15-days (Boldface numbers indicate the largest changes.)

Chemistry Parameter	Zm			100% Kw			90%Kw			Standard Limits	References
	Zm before culture	Final culture after 15 days	% Removal	Filtrate before culture	Final culture after 15 days	% Removal	Filtrate before culture	Final culture after 15 days	% Removal		
Air tem .(^oC)	30	29	-	30	29	-	30	29	-	-	
Water tem. (^oC)	28.1	27.9	-	28.2	27.93	-	28.1	27.97	-	< 40 ^oC	26
pH	8.73	9.7	-	9.3	9.71		9.54	9.77	-	5.5 - 9	26
DO (mg L^{-1})	3.73 ± 0.15^a	7.20 ± 0.10^a	-	0.2 ± 0.05^b	6.12 ± 0.12^b	-	0.3 ± 0.05^b	7 ± 0.26^a	-	> 5 (mg L^{-1})	28
BOD (mg L^{-1})	9.99 ± 0.5^a	6.11± 0.10^c	38.8 ± 2.1^b	18.71 ± 0.61^a	5.15±0.11^a	72.74 ± 0.1^a	16.84± 0.55^b	4.87 ± 0.10^b	71.08 ± 0.1^a	< 20 (mg L^{-1})	26
COD (mg L^{-1})	13.21±1.00^c	7.20 ± .25^{ab}	45.1 ± 3.8^b	28.07 ± 0.64^a	7.69 ± 0.35^a	72.6 ± 1.2^a	25.26 ± 0.58^b	6.93 ± 0.32^b	73 ± 1^a	< 120 (mg L^{-1})	26
TP (mg L^{-1})	4.35 ± 0.39^a	2.17± 0.06^a	50 ± 6 ^{ns}	4.25 ± 0.13^{ab}	2.11± 0.14^a	50.4 ± 1.8^{ns}	3.83 ± 0.12^b	1.9 ± 0.13^b	50.4 ± 1.9^{ns}	< 0.4 (mg L^{-1})	26
NH_3-N (mg L^{-1})	0.03 ± 0.01^c	0.01± 0.006^b	67 ± 18^b	7.03 ± 0.06^a	0.14 ± 0.006^a	98.0 ± 0.1^a	5.75 ± 0.14^b	0.13 ± 0.005^a	97.8 ± 0.1^a	< 1.1 (mg L^{-1})	26
Org. N (mg L^{-1})	0.04 ± 0.00^c	0.02± 0.004^c	0	15.53± 0.50^a	0.54 ± 0.014^a	96.52±0.02^a	14.55 ± 0.36^b	0.48 ± 0.015^b	96.7 ± 0.02^a	< 10 (mg L^{-1})	29
TKN (mg L^{-1})	0.07± 0.01^c	0.05± 0.01^b	70 ± 16^b	22.56± 0.56^a	0.68±0.02^a	97.0 ± 0.2^a	20.3 ± 0.50^b	0.61 ± 0.02^a	97 ± 0.2^a	< 100 (mg L^{-1})	26
NO_3-N (mg L^{-1})	30.73±1.00^a	1.78± 0.07^a	94.2 ± 0.2^b	3.8 ± 0.9^b	0.03±0.01^b	99.2 ± 0.3^a	3.47 ± 0.69^b	0.027 ± 0.01^b	99.2 ± 0.2^a	< 0.5 (mg L^{-1})	26
NO_2-N (mg L^{-1})	0.003±0.001^b	0.001± 0.001^b	67 ± 33^{ns}	0.009±0.001^a	0.003±0.001^b	65 ± 15^{ns}	0.008±0 .001^a	0.002±0.001^b	73 ± 15^{ns}	-	-
TON (mg L^{-1})	30.73± 1.00^a	1.78± 0.07^a	94.18±0.07^b	3.809±0.901^b	0.033±0.011^b	99.15±0.09^a	3.478± 0.691^b	0.029±0.011^b	99.19±0.16^a	< 0.5 (mg L^{-1})	26
TN (mg L^{-1})	30.8 ± 1.01^a	1.83± 0.08^a	94.03±0.10^b	26.37±1.46^b	0.713±0.031^{ab}	97.30±0.04^a	23.778±1.191^c	0.639±0.031^b	97.31±0.01^a	< 4 (mg L^{-1})	26

Note: The means ± SD in the same row with different superscripts are significantly different ($p < 0.05$).

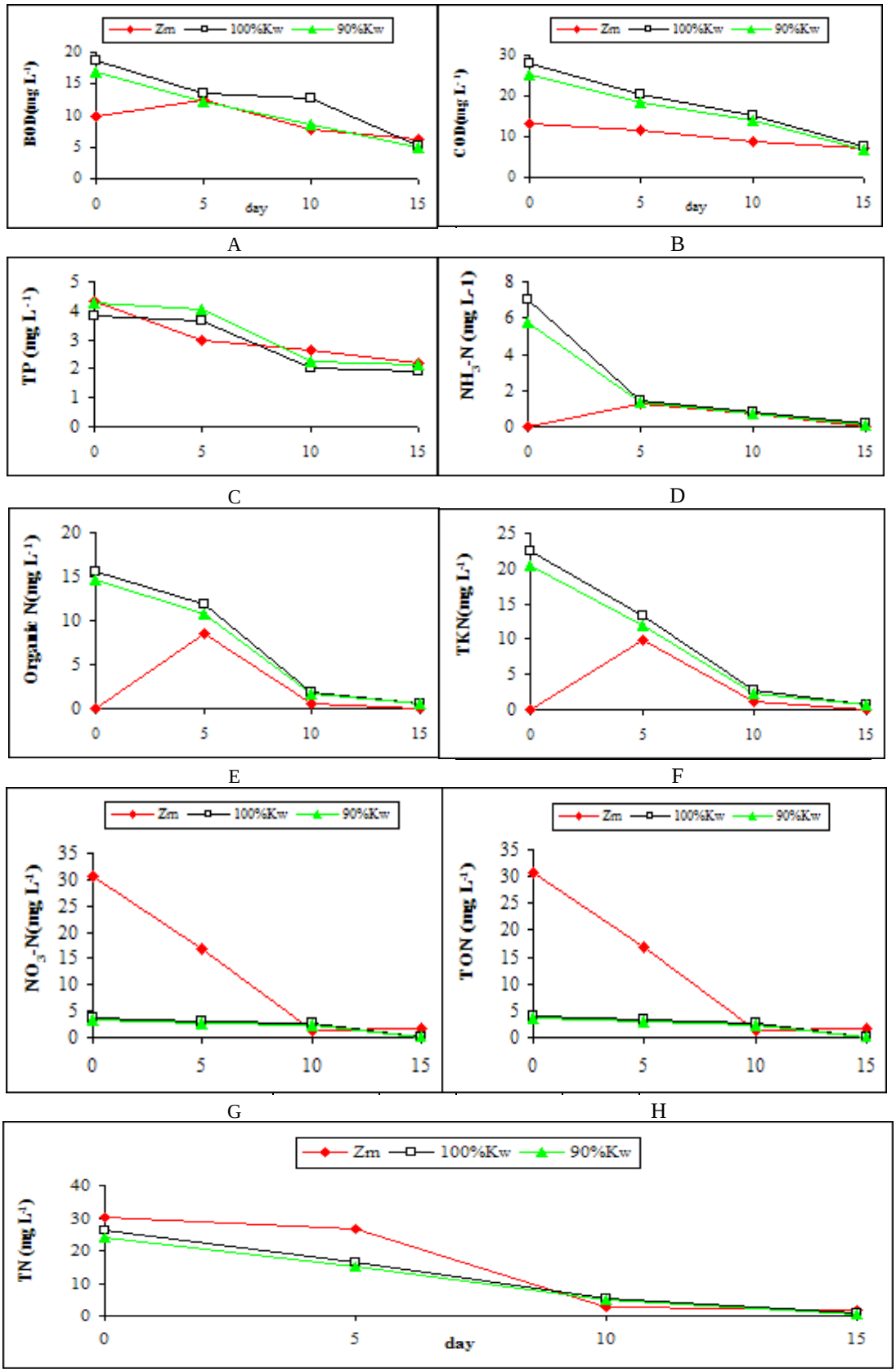

Figure 1. Changes of nutrients: A) BOD, B) COD, C) TP, D) NH_3-N, E) ON, F) TKN, G) NO_3-N, H) TON, and I) TN in the experimental wastewater

Pigment content

The content of *β*-carotene of *S. platensis* cultured in Zm, 100%Kw, and 90%Kw was 0.29, 0.29, and 0.26 mg g^{-1} respectively, while that of C-phycocyanin was 6.94, 18.44, and 16.31 mg g^{-1} respectively (Table 2). The present study utilised a modified Zarrouk's medium (Zm) with substantially fewer nutrients compared to the standard Zarrouk's medium, so substantially lower levels of *β*-carotene and C-phycocyanin were anticipated. (*S. platensis* cultured outdoors using standard Zarrouk's medium had 1.5 mg g^{-1} and 60.70 mg g^{-1} of *β*-carotene and C-phycocyanin, respectively [30].) Although fewer nutrients were utilised in Zm, they were sufficient to maintain the *S. platensis* culture. Also, with fewer nutrients, the production cost using Zm was lower than that using the standard Zarrouk's medium (see below). In this study, the 100%Kw and 90%Kw had a lower level of dissolved oxygen than Zm, but *β*-carotene and C-phycocyanin levels were 2.5 to 3 times higher. Other researchers [31] have also observed that the lowest dissolved oxygen (anaerobic) environment was more conducive to the accumulation of C-phycocyanin as compared to the aerobic environment.

Table 2. Statistical summary (mean ± SD) for analysis of *β*-carotene and C-phycocyanin in *S. platensis* culture in modified Zarrouk's medium (Zm), kitchen wastewater (100%Kw) and kitchen wastewater (90%Kw)

Pigment (mg g^{-1})	**Zm**	**100%Kw**	**90%Kw**
β-Carotene	0.29 ± 0.02^{a}	0.29 ± 0.02^{a}	0.26 ± 0.02^{b}
C-Phycocyanin	6.94 ± 1.69^{b}	18.44 ± 1.09^{a}	16.31 ± 1.10^{a}

Note: The means ±SD in the same row with different superscripts are significantly different ($p < 0.05$).

Production variable cost

The total production variable cost was calculated on a Baht kg^{-1} dry weight basis of *S. platensis*. The 100%Kw medium, which possessed the lowest variable cost of 276.6 Baht kg^{-1}, yielded considerable cost saving (10.9%) compared to the modified Zarrouk's medium (Zm). The 90%Kw was only slightly less expensive (2.6%) than Zm. The 100%Kw was nearly as effective as Zm in the biomass production (0.82 and 0.84 g L^{-1}, respectively); both gave a higher production than 90%Kw (0.73 g L^{-1}) (Table 3). Similar cultivation of *S. platensis* in wastewater arising from the digested pig waste yielded a biomass production of 0.77 g L^{-1} [32]. The biomass production in this study was more than that obtained from a 50% effluent from the pig manure biogas digester (0.32 g L^{-1}) [9].

Nutritional value

As can be seen from Table 3 and Figure 2, percent protein content was nearly 60% higher for the culture in Zm compared to that in either Kw medium. The protein content of *S. platensis* in 100% Kw was 35.86% (dry weight). However, the fat content of the 100% Kw culture was 60% higher than the Zm culture as expected since the kitchen wastewater contained several types of fat from the cooking process. The fibre content of both Kw cultures was more than 4 times higher than that of the Zm culture, probably because the kitchen wastewater was rich in carbon source (carbohydrate and fat/oil) compared to the sole carbon source, sodium bicarbonate, in Zm. The high ash content present in the alga grown in kitchen wastewater (up to 7 fold increase from Zm alga) is unexpected but could be due

to the presence of some unidentified inorganic components present in Kw (e.g. those added in the detergent) which could generally enhance the mineral content in algae.

Table 3. Statistical summary (mean ± SD) for analysis of production variable cost and nutritional value of *S. platensis* cultures in Zm and kitchen wastewater (100%Kw and 90%Kw)

Item	Zm	100%Kw	90%Kw
Production variable cost (baht kg $^{-1}$)	310.6 ± 7.6^{a}	276.6 ± 9.6^{b}	303.6 ± 14.7^{a}
Biomass production (dry weight, g L^{-1})	0.84 ± 0.05^{a}	0.82 ± 0.02^{a}	0.73 ± 0.02^{b}
Crude protein (%)	54.44 ± 0.63^{a}	35.86 ± 1^{c}	32.27± 0.91^{d}
Fat (%)	1.93 ± 0.16^{c}	3.13 ± 0.02^{a}	2.82 ± 0.02^{b}
Fibre (%)	2.31 ± 0.27^{e}	10.65 ± 0.79^{a}	9.58 ± 0.71^{b}
Moisture (%)	10.95 ± 0.61^{a}	7.72 ± 0.24^{b}	6.95 ± 0.21^{c}
Ash (%)	3.94 ± 0.15^{c}	27.94 ± 1.56^{a}	25.2 ± 1.4^{ab}

Note: The means ± SD in the same row with different superscripts are significantly different ($p < 0.05$).

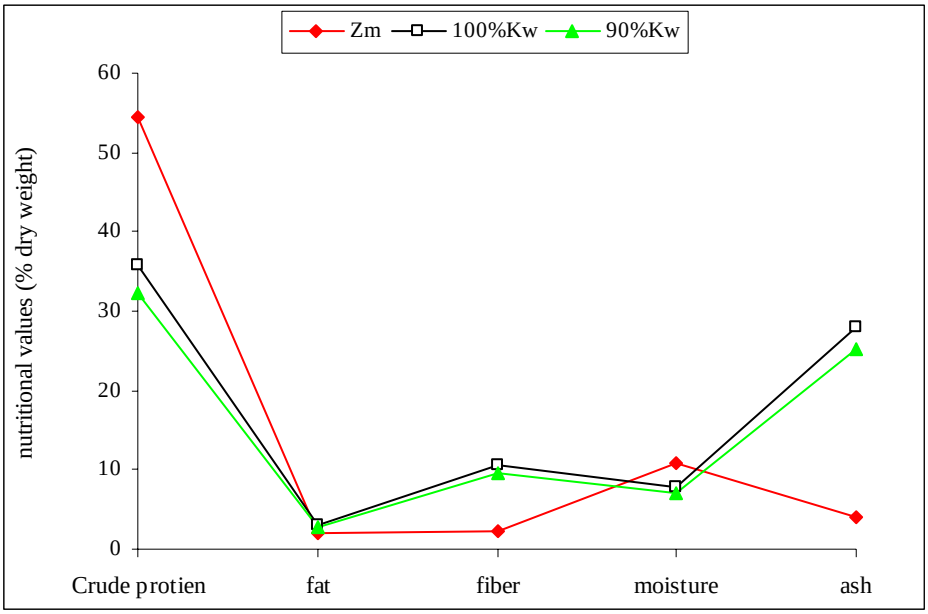

Figure 2. Comparative nutritional value of *S. platensis* cultures in Zm and kitchen wastewater (100%Kw and 90%Kw)

The biomass of *S. platensis* was evaluated as a recommended good protein source for fish, especially *Oreochromis* sp. (Tuptim tilapia). Young tilapias are easily weaned and grow fast to market size when fed the formulated diet [33]. Fast growth rates are common when fish are fed foodstuffs containing levels of 20-30% protein for fish. Future studies should concentrate on detailed nutrient

analysis of the kitchen wastewater although considerable variation is expected, depending on source and food/waste processing procedure.

Conclusions

Phytoremediation of domestic wastewater by *S. platensis* was carried out on kitchen wastewater. Water quality, biomass production, production variable cost, pigment content and nutritional value of *S. platensis* were determined in cultures harvested every 5 days for a period of 15 days. A higher % decrease of BOD, COD, TP, NH_3-N, ON, TKN, NO_3-N, NO_2-N, TON and TN was observed in the treated wastewater (100%Kw and 90%Kw) compared to that in the modified Zarrouk's medium (Zm). The highest level of β-carotene (0.29 mg g^{-1}) in *S. platensis* was achieved when cultured in Zm and 100%Kw, while the higher levels of C-phycocyanin were obtained using 100%Kw (17.95 mg g^{-1}) and 90%Kw (16.31 mg g^{-1}). The 100%Kw medium yielded considerable cost saving (10.9 %; 276.6 baht kg^{-1}) compared to the Zm (310.6 baht kg^{-1}). The higher biomass production of *S. platensis* was achieved in Zm (0.84 g L^{-1}) and 100%Kw (0.82 g L^{-1}), where the protein content was 54.44% and 35.86%, respectively. This study provides strong support for the use of *S. platensis* for phytoremediation of kitchen wastewater as well as C-phycocyanin production in this medium.

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