Research Article

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Vitamin supplements enhance *Spirulina platensis* biomass and phytochemical contents

https://doi.org/10.1515/gps-2022-0028
received December 11, 2021; accepted February 20, 2022

**Abstract:** *Spirulina platensis* (SP) has a high impact on multidiscipline usage worldwide. Vitamins are considered as growth promoters due to their metabolic bio-regulating roles. This study was conducted to investigate the effect of vitamins: riboflavin (B2), thiamine (B1), and ascorbic acid (C) on SP growth and contents of pigments, phenols, and phytochemicals besides its antioxidant activities. Vitamins were added in different concentrations to Zarrouk’s medium and tested for their effects weekly for three weeks of spirulina cultivation. The results revealed that 25 mg L⁻¹ thiamine or riboflavin promoted the most significant contents of chlorophyll and carotenoids, respectively, after 14 days of cultivation. However, adding 10 mg L⁻¹ thiamine achieved the most significant increase in algal biomass yield and contents of chlorophyll, carotenoids phycocyanin, allophycocyanin, phycoerythrin, and phycobiliprotein after 21 days of cultivation. Qualitative analysis showed that both SP and SP supplemented with 10 mg L⁻¹ thiamine (SPt) for 21 days contain tannins and flavonoids but quantitative analysis approved that SPt recorded significant increase in phenolic and tannin contents. Moreover, SPt induced a significant increase of total antioxidant activity in vitro 1,1-diphenyl-2-picrylhydrazyl assay in comparison with SP. Vitamins especially thiamine added during SP culture could improve SP biomasses, pigments, and phytochemical contents and hence increased antioxidant capacity.

**Keywords:** *Spirulina platensis*, vitamins, biomass, phytochemicals, antioxidants

1 Introduction

Cyanobacteria or blue-green algae are a group of photosynthetic or nitrogen-fixing bacteria, that live in a wide variety of moist soils and water either freely or in a symbiotic relationship [1]. These classes of bacteria can synthesize a vast array of secondary metabolites including biologically active compounds that could serve as antibacterial, antiviral, antifungal, and anticancer agents [2]. *Spirulina platensis* (SP) is a multicellular filamentous cyanobacterium of helical or spiral filaments. It belongs to phylum Cyanophyta and order Oscillatoriaceae [3]. It is a ubiquitous organism that can be found in different environments such as soil, sand, marshes, brackish water, seawater, and freshwater [4]. SP is a photosynthetic autotrophic cyanobacterium that contains various pigments such as phycobilins, chlorophyll a, and carotenoids [5]. The pigment contents of SP import its therapeutic potential and increase its uses in the food and cosmetic industries [6,7].

*Spirulina* has antioxidant properties referring to its contents of essential fatty acids, phycocyanin, and phenolic compounds [8], in addition to some essential elements that have an antioxidant effect like zinc and selenium [9]. Moreover, it has a chemopreventive effect against many types of cancer as reviewed by Ramakrishnan [10].

*Spirulina*-based products are utilized by athletes as anti-fatigue and amino acid suppliers and personally used due to their anti-aging, detoxifying, and antioxidant properties. SP is also used in agriculture as biofertilizers.
and has many applications in biotechnology [12]. Due to the high applications and advantages of SP, it is important to seek factors that stimulate its growth and phytochemical constitutes. Vitamins are considered as growth promoters in plants referring to their metabolic bio-regulator roles. B vitamins are organic water-soluble molecules that play essential roles in central metabolism by acting as, or as a part of, coenzymes within the cell [13]. Vitamin C biofortification has the potential to improve plant tolerance to various stresses via its antioxidant effect, which is a prominent target to guarantee productivity in an era of global climate change. Also, it can alter plant growth, development, and responses to biotic and abiotic stresses under field conditions [14].

This study aims to investigate the effect of different types of water-soluble vitamins (riboflavin, thiamine, and ascorbic acids) in different concentrations on SP growth, pigment contents, antioxidant efficiency, phenolic contents, and phytochemical constitutes.

2 Materials and methods

2.1 SP

SP blue-green alga was obtained from microbiology lab, Department of Microbial Biotechnology, Genetic Engineering and Biotechnology Research Institute (GEBRI), University of Sadat City. Zarrouk’s medium was used for the cultivations and growth of SP. SP cultured on Zarrouk’s medium (control) and Zarrouk’s medium supplemented with different types and concentrations of vitamins; riboflavin (B2), thiamine (B1), and ascorbic acid (C); each at concentrations of 5, 10, and 25 mgL⁻¹. Three replicates were prepared for each supplement concentration; each replicate (11) was used for a week and distributed equally into three Erlenmeyer flasks (each one is considered as a sample). Media were sterilized in the autoclave under moist temperature at 121°C for 20 min. The vitamins were sterilized using Millipore filtration. The culture was incubated at 25 ± 2°C, with continuous illumination using cool white fluorescent tubes (2,500 Lux) and twice daily shaking for 21 days.

2.2 Estimation of SP growth and pigments content

After cultivation, SP was collected periodically (every week for three weeks), and growth was determined by measuring SP biomass turbidity using a Spectrophotometer at OD 660 nm [15].

Around 5 mL of homogenized cyanobacterial suspension was centrifuged at 4,000 rpm for 10 min to determine chlorophyll and carotenoid contents according to Parson and Strickland [16] and Jensen [17], respectively. Phycobilin investigations were performed according to Bennett and Bogorad [18].

2.3 Estimation of phytochemical constituents in SP and SP supplemented with 10 mg·L⁻¹ thiamine (SPt)

2.3.1 Preparation of methanolic algal extract

After 21 days of inoculation, SP (control) and SPt samples were dried at 60°C and ground using mortar to be in powder form. The extracts were prepared following the method of Przygodzka et al. [19]. Around 250 mL of 80% methanol was added to 10 g of the samples. The mixture was allowed to stir for 2 h at room temperature. Then filtration was done using a Whatman filter paper and the residue was collected to repeat the methanol extraction process. Extractions were carried out in triplicates. The filtered solution was then centrifuged and evaporated to dryness using a rotary evaporator, and the sediment was reconstituted to the desired volume (10 mL methanol).

2.3.2 Qualitative analysis of phytochemical constituents

2.3.2.1 Test for tannins

Here, 1 mL of ferric chloride (5% FeCl₃) was added to 1 mL of each extract (SP and SPt). The formation of dark blue or greenish-black color indicates the presence of tannins [20].

2.3.2.2 Test for saponins

In this test, 2 mL of distilled water was added to 1 mL of each extract and shaken in a graduated cylinder for 15 min lengthwise. The formation of a 1 cm layer of foam indicates the presence of saponins [20].

2.3.2.3 Test for terpenoids

Around 5 mL of extracts of SP and SPt samples were mixed with 2 mL of chloroform (CHCl₃) in a test tube.
Three milliliters mL of concentrated H₂SO₄ is carefully added to the mixture to form a layer. An interface with a reddish-brown coloration is formed if the terpenoids constituent is present [21].

### 2.3.2.4 Test for flavonoids

One milliliter mL of 2 N sodium hydroxide was added to 2 mL of algal (SP and SPt) extracts. The formation of yellow color indicates the presence of flavonoids [20].

### 2.3.2.5 Determination of total phenolic content (TPC)

The TPC was determined by a method described by Siddhuraju and Becker [22] using a spectrophotometer (UV-200-RSLW scientific). One milliliter of 10% Folin-Ciocalteu reagent was mixed with 20 μL of SP and SPt extracts and incubated for 5 min before adding 700 μL of 10% Na₂CO₃. The solutions were further incubated for 2 h before reading the absorbance at 765 nm. Gallic acid in the range of 20–200 mg·L⁻¹ was used to construct a calibration curve. The results were expressed as microgram gallic acid equivalent per gram algae [23]. Results were calculated according to Eq. 1:

\[
TPC (\text{mg·g}^{-1}) = C \times (V/g)
\]

where \( C \) – concentration of the gallic acid equivalent from a standard curve (mg·mL⁻¹), \( V \) – the volume of the extract used (mL), \( g \) – the weight of extract (g).

### 2.3.2.6 Determination of tannins using vanillin-HCl assay

Samples (0.2 g) of SP and SPt were extracted with 10 mL of methanol for 24 h at 30°C. One milliliter of the resulting extract was reacted with 5 mL of vanillin reagent (50:50 mixtures of 1% vanillin/8% HCl in methanol) for 20 min at 30°C, and absorbance was read at 500 nm.

For blanks, 4% HCl in methanol instead of vanillin reagent was added to the extract, and absorbance was also read at 500 nm. Blank values were subtracted from experimental values to give adjusted data. Tannic acid standard curve from 0.0 to 1.0 mg·mL⁻¹ was used in calculating tannin levels [24].

### 2.3.2.7 In vitro determination of total antioxidant capacity (1,1-diphenyl-1,2-picrylhydrazyl, DPPH, assay)

The free radical scavenging activity by antioxidants present in the extract was estimated by DPPH assay. The reaction mixture contained 100 μL of tested extracts of SP and SPt and 1 mL of methanolic solution of 0.1 mM DPPH radical. The mixture was then vigorously shaken and incubated at 37°C for 30 min. The absorbance was measured at 517 nm using ascorbic acid (100–500 μg·mL⁻¹) as a positive control.

Lower absorbance of the reaction mixture indicated higher free radical scavenging activity which was calculated according to Molyneux [25] using Eq. 2:

\[
\text{DPPH scavenging effect(%) } = 100 \times \frac{(A_0 - A_i)}{(A_0)}
\]

where \( A_0 \) is the absorbance of the control reaction, \( A_i \) is the absorbance of the sample reaction at 517 nm.

### 2.4 Statistical analysis

Values are presented as mean ± standard error of mean (SEM). Statistical analyses were performed by one-way analysis of variance followed by Duncan’s multiple range test using Statistical Package for Social Sciences Version 16 released in 2007. Statistical significances between different means were considered at \( p < 0.05 \).

### 3 Results

#### 3.1 Effect of riboflavin, thiamine, and ascorbic acid on the growth rate of SP after 7, 14, and 21 days of cultivation

The effects of different concentrations of vitamins (riboflavin, thiamine, and ascorbic acid) added to 11 of Zarrouk’s medium on SP growth were determined by measuring the biomass optical density (OD) after 7, 14, and 21 days of cultivation. As presented in Table 1, it was found that after seven days of SP inoculation, thiamine (25 mg·L⁻¹) and ascorbic acid (10 and 25 mg·L⁻¹) induced the best algal growth as the OD recorded significant elevations compared to those supplemented with other vitamins but recorded insignificant changes with control SP. Meanwhile, with the continuous culture of SP for 14 days, 25 mg·L⁻¹ thiamine and 10 mg·L⁻¹, ascorbic acid showed significant elevations...
of growth. Thiamine at 10 and 5 mg·L⁻¹ achieved a significant increase in growth after 21 days of cultivation compared to the control and other vitamins supplemented groups at p < 0.05. Finally, 10 mg·L⁻¹ thiamine supplement for 21 days induced the best growth for SP over all times of detection and other vitamin types and concentrations.

### 3.2 Effect of different concentrations of riboflavin, thiamine, and ascorbic acid on pigments contents of SP after 7, 14, and 21 days of cultivation

After 7 days of spirulina inoculation on Zarrouk’s medium supplemented with different concentrations of various vitamins, the evaluated pigment contents showed that ascorbic acid (10 mg·L⁻¹) significantly raised the chlorophyll content but thiamine (25 mg·L⁻¹) significantly elevated all other pigments content (carotenoids phycocyanin, allophycocyanin, phycocerythrin, and phycobiliprotein) as presented in Table 2. After 14 days of incubation, the values were changed as presented in Table 3, thiamine (25 mg·L⁻¹) significantly enhanced more chlorophyll and allophycocyanin contents; riboflavin (25 mg·L⁻¹) significantly enhanced more carotenoids content; thiamine at 10 mg·L⁻¹ caused significant elevations in phycocyanin, phycocerythrin, and phycobiliprotein contents: phycocerythrin was significantly increased at adding ascorbic acid (25 mg·L⁻¹). Meanwhile, after 21 days of spirulina cultivation, the results cleared that 10 mg thiamine supplement significantly raised all pigment contents of SP compared to other concentrations and vitamin types at p < 0.05, as shown in Table 4. Numerically 10 mg·L⁻¹ thiamine supplement for 21 days of cultivation was elevated all pigment contents in comparison to the control of SP.

### Table 1: Mean values of OD for SP growth supplemented with different concentrations of riboflavin, thiamine, and ascorbic acid for 7, 14, and 21 days of culture

|               | OD after 7 days | OD after 14 days | OD after 21 days |
|---------------|-----------------|------------------|------------------|
| Control       | 1.19 ± 0.06a    | 1.32 ± 0.06b     | 1.34 ± 0.02c     |
| 5 mg          | 0.37 ± 0.03d    | 0.79 ± 0.01et    | 0.51 ± 0.01f     |
| Riboflavin    | 10 mg 0.4 ± 0.03e | 0.68 ± 0.03f     | 0.31 ± 0.01g     |
|               | 25 mg 0.99 ± 0.06b | 0.92 ± 0.03d     | 0.91 ± 0.04e     |
| Thiamine      | 5 mg 0.69 ± 0.02c | 0.89 ± 0.01de    | 1.56 ± 0.05ab    |
|               | 10 mg 0.96 ± 0.05b | 1.08 ± 0.03c     | 1.62 ± 0.06a     |
|               | 25 mg 1.32 ± 0.14a | 1.52 ± 0.06a     | 0.93 ± 0.02d     |
| Ascorbic acid | 5 mg 0.89 ± 0.04b | 1.13 ± 0.01c     | 1.44 ± 0.09bc    |
|               | 10 mg 1.21 ± 0.02a | 1.45 ± 0.06a     | 1.39 ± 0.08c     |
|               | 25 mg 1.12 ± 0.02a | 0.53 ± 0.01f     | 0.5 ± 0.01f      |

Data are presented as mean ± SEM (n = 3). Values having different superscript letters within the same columns are significantly different (p < 0.05).

### Table 2: Mean values of chlorophyll, carotenoids, and phycobilins concentrations (mg·mL⁻¹) in SP supplemented with various concentrations of riboflavin, thiamine, and ascorbic acid for 7 days of culture

|                | Chl-a (mg·mL⁻¹) | Cart (mg·mL⁻¹) | PC (mg·mL⁻¹) | APC (mg·mL⁻¹) | PE (mg·mL⁻¹) | Phycobiliprotein (mg·mL⁻¹) |
|---------------|-----------------|----------------|--------------|---------------|--------------|---------------------------|
| Control       | 8.41 ± 0.07g    | 2.82 ± 0.01h   | 4.81 ± 0.09i | 8.49 ± 0.04d  | 3.44 ± 0.05f  | 0.168 ± 0.001f            |
| Riboflavin    | 5 mg 3.46 ± 0.05j | 0.92 ± 0.02j   | 6.74 ± 0.12h | 11.73 ± 0.13cd | 4.64 ± 0.05a  | 0.231 ± 0.001b           |
|               | 10 mg 3.83 ± 0.06h | 0.94 ± 0.03j   | 6.97 ± 0.05h | 11.45 ± 0.05cd | 4.58 ± 0.06a  | 0.229 ± 0.001c           |
|               | 25 mg 3.5 ± 0.09f | 3.42 ± 0.02d   | 9.13 ± 0.09g | 15.33 ± 0.07bc | 4.69 ± 0.04a  | 0.293 ± 0.001c           |
| Thiamine      | 5 mg 9.83 ± 0.04a | 3.02 ± 0.01e   | 9.92 ± 0.15f | 13.34 ± 0.14bc | 5.57 ± 0.04f  | 0.288 ± 0.001f           |
|               | 10 mg 10.75 ± 0.07d | 3.76 ± 0.01f   | 12.43 ± 0.07d | 15.14 ± 0.09cd | 5.76 ± 0.04b  | 0.333 ± 0.002c           |
|               | 25 mg 16.77 ± 0.07b | 6.74 ± 0.02a   | 29.9 ± 0.07a | 24.26 ± 0.12a | 6.41 ± 0.03e  | 0.606 ± 0.011c           |
| Ascorbic acid | 5 mg 13.04 ± 0.06c | 4.99 ± 0.01c   | 13.97 ± 0.08c | 14.27 ± 0.06bc | 5.04 ± 0.07d  | 0.333 ± 0.001d           |
|               | 10 mg 17.42 ± 0.02a | 6.28 ± 0.01b   | 17.03 ± 0.11b | 16.68 ± 0.11b | 5.63 ± 0.06bc | 0.393 ± 0.00b            |
|               | 25 mg 8.68 ± 0.07f | 3.22 ± 0.01f   | 11.65 ± 0.09g | 12.43 ± 0.1bc  | 4.55 ± 0.02e  | 0.286 ± 0.001f           |

Data are presented as mean ± SEM (n = 3). Chl-a (chlorophyll), Cart (carotenoids), PC (phycocyanin), APC (allophycocyanin), PE (phycocerythrin). Values having different superscript letters within the same column are significantly different (p < 0.05).
Table 3: Mean values of chlorophyll, carotenoids, and phycobilins concentrations (mg·mL⁻¹) in SP supplemented with various concentrations of riboflavin, thiamine, and ascorbic acid for 14 days of culture

|                  | Chl-a (mg·mL⁻¹) | Cart (mg·mL⁻¹) | PC (mg·mL⁻¹) | APC (mg·mL⁻¹) | PE (mg·mL⁻¹) | Phycobiliprotein (mg·mL⁻¹) |
|------------------|-----------------|----------------|-------------|---------------|-------------|--------------------------|
| Control          | 9.52 ± 0.08a    | 3.2 ± 0.01f    | 7.21 ± 0.08i| 10.28 ± 0.04e| 4.01 ± 0.05f| 0.215 ± 0.00i            |
| Riboflavin       |                 |                |             |               |             |                          |
| 5 mg             | 7.09 ± 0.09h    | 3.71 ± 0.01f   | 10.63 ± 0.02k| 13.07 ± 0.03a| 5.18 ± 0.07f| 0.289 ± 0.00f            |
| 10 mg            | 9.22 ± 0.06f    | 3.06 ± 0.01h   | 12.88 ± 0.07l| 11.62 ± 0.06f| 4.14 ± 0.04f| 0.286 ± 0.00e            |
| 25 mg            | 2.66 ± 0.04j    | 13.03 ± 0.02a  | 9.13 ± 0.09b | 14.94 ± 0.11i| 4.2 ± 0.04d | 0.283 ± 0.001h           |
| Thiamine         |                 |                |             |               |             |                          |
| 5 mg             | 9.47 ± 0.09d    | 4.27 ± 0.01l   | 15.4 ± 0.13d| 16.15 ± 0.09s| 5.53 ± 0.02b| 0.374 ± 0.00d            |
| 10 mg            | 9.96 ± 0.09e    | 3.72 ± 0.02g   | 24.59 ± 0.12a| 18.5 ± 0.09b | 5.88 ± 0.06a| 0.486 ± 0.001a           |
| 25 mg            | 24.15 ± 0.06a   | 2.51 ± 0.01i   | 17.5 ± 0.03c | 19.69 ± 0.1a | 4.92 ± 0.04d| 0.421 ± 0.001c           |
| Ascorbic acid    |                 |                |             |               |             |                          |
| 5 mg             | 12.33 ± 0.08c   | 5.33 ± 0.02d   | 23.19 ± 0.09b| 18.38 ± 0.07b| 5.46 ± 0.03b| 0.47 ± 0.001b            |
| 10 mg            | 12.75 ± 0.06b   | 5.04 ± 0.03c   | 13.72 ± 0.1c | 15.21 ± 0.05d| 5.11 ± 0.07b| 0.34 ± 0.001b            |
| 25 mg            | 7.53 ± 0.05e    | 9.09 ± 0.02b   | 9.38 ± 0.07h | 15.77 ± 0.11d| 5.98 ± 0.06a| 0.311 ± 0.001f           |

Data are presented as mean ± SEM (n = 3). Chl-a (chlorophyll), Cart (carotenoids), PC (phycoerythrin), APC (allophycocyanin), PE (phycoerythrin). Values having different superscript letters within the same column are significantly different (p < 0.05).

3.3 Qualitative analysis of phytochemical constituents of SP and SPt

Table 5 revealed that both methanolic extract of SP and SPt (10 mg·L⁻¹) recorded positive results for the presence of tannins and flavonoids but negative results for the presence of saponins and terpenoids.

3.4 Quantitative analysis of phytochemicals (total phenolic compounds and tannins) contents in SP and SPt

Total phenolic compound and tannin contents recorded significant elevation (p < 0.05) in SPt than those present in SP (Figures 1 and 2).

3.5 In vitro antioxidant activity of SP and SPt

Antioxidant activity of the methanolic extract of SP and SPt was determined based on DPPH free radical-scavenging activity (%). Results cleared that the antioxidant activity of SPt significantly increased in comparison with the antioxidant activity of SP at p < 0.05 (Figure 3).

4 Discussion

Vitamins are organic compounds that are required in small amounts. The organisms cannot synthesize these compounds in large quantities to provide the organisms with normal needs of vitamins [26]. Vitamins in plants...
can play as bio-regulators and as dietary supplements. They have a role in plant growth through the regulation of primary and secondary metabolism [27,28]. Riboflavin is involved in the release of energy in the electron transport chain, citric acid cycle, as well as the catabolism of fatty acids (beta-oxidation) [29]. Several studies discussed the role and effect of vitamins like riboflavin, ascorbic acid, and thiamine on growth, yield, rate of photosynthesis, as well as contents of nutrients, pigments, and others in many plants such as Vicia faba [30], Thymus vulgaris [31], Matricaria recutita [32], Calendula officinalis [33], Gladiolus grandiflorus [34], Lu pinus [35], and Ocimum basilicum [36].

After 21 days of cultivation, the results revealed that within different concentrations (5, 10, and 25 mg·L⁻¹) of various vitamins (riboflavin, ascorbic acid, and thiamine) thiamine 10 mg·L⁻¹ recorded the highest biomass and most significant contents of chlorophyll, carotenoids, phycocyanin, phycocerythrin, allophycocyanin, and phycobiliprotein. All used levels of thiamine increased the vegetative growth, carotenoid, and chlorophyll b contents of coriander. It was proved that thiamine is easily absorbed by the plant roots from the soil and distributed to other plant parts [36]. The uptake of thiamine is beneficial for plant growth [37] because thiamine (B1) acts as a coenzyme for many central metabolic enzymes of plants and also influences nutrient uptake, especially phosphorus and nitrogen, thereby having a positive effect on the growth of plants [37].

Also, it was revealed that thiamine plays as a functional coenzyme of thiamine pyrophosphate and plays an integral role in the regulation of carbon metabolism in plants [38]. The addition of thiamine on bean seeds could stimulate growth by the enhancement of the biosynthesis of photosynthetic pigments and photosynthetic rate and stability of dark respiration [30]. Thiamine plays a central role in the release of energy from carbohydrates. It is involved in ribonucleic acid and deoxyribonucleic acid production, as well as nerve function in mammals. The active form of thiamine coenzyme is called thiamine

### Table 5: Qualitative analysis of phytochemical constituents of SP and SPT for 21 days of culture

| Compounds   | Methanolic extract samples |
|-------------|---------------------------|
|             | SP | SPT |
| Tannins     | +  | +  |
| Saponins    | –  | –  |
| Terpenoids  | –  | –  |
| Flavonoids  | +  | +  |

(−) Bioactive substance is not detected in the sample. (+) Bioactive substance is detected in the sample.

### Figure 1: Total phenolic contents of methanolic extracts of SP and SP supplemented with thiamine for 21 days of culture. Different letters mean significant change between groups (p < 0.05).

### Figure 2: Tannin content in methanolic extracts of SP and SP supplemented with thiamine for 21 days of culture. Different letters mean significant change between groups (p < 0.05).

### Figure 3: Antioxidant activity in methanolic extracts of SP and SPT for 21 days of culture based on DPPH free radical-scavenging activity (%). Different letters mean significant change between groups (p < 0.05).
Secondary metabolites of plants and algae or phytochemicals have great pharmaceutical benefits and can be used as anti-cancer, anti-viral, hepatoprotective, and neuroprotective; the concentrations of these metabolites were diminished the toxic influence of CCl4 on the liver and kidneys and showed improvement of hepatic markers, renal markers, tissue antioxidant status, and pathological pictures [46]. SP has neuroprotective potential and is used as an alternative treatment for Parkinson’s disease [47]. After 21 days of cultivation, total phytochemicals were estimated qualitatively and quantitatively. Tannins and flavonoids showed positive results for their presence in the extracts of SP and SPt and saponins and terpenoids showed negative results for their presence in the two extracts qualitatively. The total phenolic contents and tannins were significantly increased in dried biomass of SPt compared with SP. DPPH test revealed a significant increase in free radical-scavenging activity of SPt compared with SP and correlated with its phenolic and tannin contents. The antioxidant activities obtained by the DPPH assay are often expressed as percent inhibition [48].

The antioxidant compounds such as phycobilins and phycocyanins in SP exert free radical-scavenging activity by acting as acceptors for hydrogen, peroxyl, and peroxynitrite radicals. These antioxidant compounds also inhibit the activities of catalytic enzymes such as lipoygenase and cyclooxygenase or enhance the activity of enzymes such as glutathione peroxidase, catalase, and superoxide dismutase [49]. Moreover, it was clear that SP extract exhibited antioxidant properties due to its contents of various phenolic compounds [50]. Numerous studies reveal that the antioxidant contents are due to a high phenolic content from ketones, ellagic acid, vitamin C, flavonoids, and anthocyanins [51].

5 Conclusion

Due to the major advantages of SP, this research work has cleared the potential cultivation of SP by adding different types of vitamins for possibly obtaining high biomass yield, pigments, and phytochemical components. The results revealed that 10 mg·L⁻¹ thiamine (vitamin B1) was the best-tested vitamin over riboflavin (B2), and ascorbic acid (C) after 21 days of cultivations as it caused significant elevation of chlorophyll, carotenoid, phycocyanin, allophycocyanin, phycocerythrin, and phycobiliprotein. There was an elevation of phenolic contents, tannins, and antioxidant activities of SP supplemented with 10 mg·L⁻¹ thiamine over the control alga. Thiamine at 10 mg·L⁻¹ showed the best results between tested vitamins for promotion of biomasses, pigments, and phytochemical constitution of SP and hence antioxidant capacity.

Acknowledgments: The authors would like to thank all workers and staff members in microbiology lab, Department of Microbial Biotechnology, Genetic Engineering and Biotechnology Research Institute (GEBRI), University of Sadat City for their cooperation and efforts to complete this study.

Funding information: Authors state no funding involved.

Author contributions: Ragaa A. Hamouda: planning, reviewing, and editing the manuscript (supervisor); Neveen G. El-Boraey: collecting the data, methodology, resources, writing the draft, analysis; Badr E. El Bialy: editing, analysis, and reviewing the final manuscript (supervisor); Salma Saleh Alrdahe: resources and reviewing; Doaa Bahaa Eldin Darwish: resources, reviewing.

Conflict of interest: Authors state no conflict of interest.
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