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Research article

Effect of Monosodium Glutamate on the Growth and Quality of Sunflower Microgreens

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Abstract: Microgreens are increasingly recognized as functional foods due to their low-calorie content and rich profile of micronutrients and antioxidants. Sunflower microgreens, in particular, are known for their high levels of protein, vitamin C, phenols, fiber, and antioxidant activity. This study aimed to investigate the effect of monosodium glutamate (MSG) as an alternative nitrogen fertilizer on the growth and quality of sunflower microgreens. Five treatments were tested: MSG 1 (639.2 mg/L), MSG 2 (319.6 mg/L), MSG 3 (159.8 mg/L), deionized water, and Hoagland and Arnon solution, using a Randomized Complete Block Design with three replications. The results showed no significant differences among the treatments regarding fresh weight, dry weight, chlorophyll content (a and b), carotenoid, xanthophyll, nitrate, nitrite, and crude fiber content. However, sunflower microgreens treated with MSG 1 had the highest ammonium content (2.107 μmol/g fresh weight), while the Hoagland and Arnon treatment had the lowest (0.468 μmol/g fresh weight). Protein content was significantly lower in sunflower microgreens treated with MSG 1 (15.10 mg/mL) and highest in those treated with MSG 3 (21.82 mg/mL). Amino acids such as cysteine, phenylalanine, tyrosine, tryptophan, and histidine were present across all treatments. The study concluded that, while MSG did not significantly enhance growth, the quality of sunflower microgreens was better in treatments with MSG 2, MSG 3, deionized water, and Hoagland and Arnon compared to MSG 1.

Keywords: Monosodium glutamate; Microgreens; Sunflower

1. Introduction

Microgreens require light to grow and have a more extended growth-to-harvest period than sprouts, typically 7 to 28 days [1]. The edible parts of microgreens include the stems, cotyledons, and the first true leaves, usually reaching a height of 5 to 10 cm [2]. They are well-suited for urban farming and are a rich source of minerals, making them valuable for enhancing nutrient accessibility [3]. Recent studies have shown that microgreens are excellent sources of protein, fiber, and essential nutrients like ascorbic acid, vitamin E, and beta-carotene [4]. Additionally, microgreens contain higher levels of most minerals (such as Ca, Mg, Fe, Mn, Zn, Se, and Mo) and lower nitrate levels than

mature lettuces, making them an important mineral source in the human diet, particularly for meeting children's mineral requirements without the risk of harmful nitrates [5]. Sunflower microgreens, particularly, are a significant protein source, containing 24% to 30% protein and various essential amino acids. They are also rich in fiber total phenols and exhibit strong antioxidant activity while providing essential fatty acids and vitamins A, B complex, C, D, and E [6].

Monosodium glutamate (MSG) has recently been explored as an alternative fertilizer [7]. Glutamate, a key amino donor, is vital in synthesizing other amino acids [8]. It is involved in protein synthesis and various metabolic processes and functions as a signaling molecule in plants [8]. Although exogenous glutamate can support plant growth as a nitrogenous nutrient, it is less effective than ammonium nitrate or glutamine in rice seedlings [9]. Seman-Kamarulzaman and Mohamad [10] reported that MSG, commonly known as Ajinomoto, positively impacts corn plants, offering a cost-effective and environmentally friendly fertilization option. Their findings revealed that MSG increased plant height by 3.1 times, stem diameter by 2.6 times, and both the number and length of leaves by 2.5 and 2.7 times, respectively. Similarly, Singh et al. [11] used industrial MSG wastewater as a plant nutrient source. They found it promoted the germination of Chinese cabbage (*Brassica rapa* L. cv. Pekinensis) and maize (*Zea mays* L. cv. Bright Jean) in seed germination tests. Additionally, La et al. [12] investigated the effects of modified MSG wastewater on tomato growth and quality, concluding that MSG wastewater could enhance tomato yield and quality, potentially replacing a complete nutritional solution for tomato plants. Haghighi et al. [13] compared the effects of MSG wastewater and ammonium nitrate on lettuce's nitrogen metabolism and growth. Their study showed that high concentrations of MSG increased the fresh weight of both shoots and roots, as well as the protein content of lettuce, without leading to nitrate accumulation in the leaves. Therefore, this study aimed to investigate the effect of MSG as an alternative nitrogen fertilizer on the growth and quality of sunflower microgreens.

2. Materials and Methods

2.1 Plant materials and growth conditions

This study selected sunflower (*Helianthus annuus L.*) as the plant material. Empty trays measuring 60×25×5 cm were prepared, filled with coconut coir, and moistened with distilled water. 100 grams of sunflower seeds were soaked in water at 50°C for 12 hours. After soaking, the seeds were evenly spread over the coconut coir in each tray, covered with an additional layer of coconut coir, and then topped with an empty tray. The trays were watered daily with distilled water for two days. After this initial period, the microgreens in each tray were treated with different concentrations of monosodium glutamate and exposed to red LED light for 48 hours. Finally, the microgreens were harvested and stored in Ziploc bags at 4°C.

2.2 Experimental design

Five treatments with varying concentrations of monosodium glutamate (99.0% purity, Ajinomoto, Thailand) were applied, and the experiment was conducted using a Randomized Complete Block Design with three replications. Both positive and negative controls were included in the experiment: a half-strength Hoagland and Arnon nutrient solution served as the positive control, while deionized (DI) water was used as the negative control (Table 1).

Table 1. The composition of nutrient concentrations in treatments involving three levels of monosodium glutamate (MSG), Hoagland and Arnon solution, and deionized (DI) water.

No	Treatment	N	$C_5H_8NNaO_4$	NO_3	NH_4	Na	K	P	Mg	Ca	S
		mg/L									
1	MSG 1	52.94	639.20	-	-	30.102	-	16	24	86	31
2	MSG 2	26.47	319.60	-	-	73.552	-	16	24	86	31
3	MSG 3	13.24	159.80	-	-	95.724	-	16	24	86	31
4	DI water	-	-	-	-		-	-	-	-	-
5	Hoagland and Arnon	26.47	-	100	5		117	16	24	86	31

2.3 Fresh weight and dry weight

The microgreens were gently blotted with soft tissue paper to measure fresh weight to remove surface moisture and then weighed immediately. The microgreens were dried in an oven at 65°C for three days for dry weight measurement, cooled in a dry Ziplock bag, and then weighed.

2.4 Determination of chlorophyll a, chlorophyll b, carotenoid, and xanthophyll

Chlorophyll a, chlorophyll b, carotenoids, and xanthophylls were determined using a colorimetric method with ethanol as the solvent [14]. A sample weighing 1 ± 0.001 g was finely ground, and 5 mL of ethanol was added. The mixture was then filtered using filter paper No. 1, and 250 µL of the supernatant was pipetted into a 96-well plate. Absorbance measurements (A) were taken at wavelengths ranging from 350 to 700 nm, and the concentrations were calculated using equations 1-4.

$$\text{chlorophyll a}\left(\text{mg/g}\right) = \frac{13.7A_{665} - 5.76A_{649}}{\text{mass} \times 200} \quad (1)$$

$$\text{chlorophyll b}\left(\text{mg/g}\right) = \frac{25.8A_{649} - 7.6A_{665}}{\text{mass} \times 200} \quad (2)$$

$$\text{carotenoids}\left(\text{mg/g}\right) = \frac{4.7A_{440} - 0.263c_{\text{chla+chlb}}}{\text{mass} \times 200} \quad (3)$$

$$\text{xanthophyll}\left(\text{mg/g}\right) = \frac{11.51A_{480} - 20.61A_{495}}{\text{mass} \times 200} \quad (4)$$

2.5 Determination of nitrite

Nitrite content was determined using the Griess reaction, following the method of Hachiya and Okamoto [15]. A standard curve was prepared by creating a nitrite dilution series with sodium nitrite (10, 20, 30, 40, and 50 µM) in deionized water. Microgreens (2 g) were extracted with 5 mL of deionized water, and the supernatant was centrifuged at 20,100 x g at 4°C for 10 minutes. Then, 260 µL of the supernatant was transferred to a microplate, followed by the addition of 65 µL of 1% (w/v) sulfanilamide in 1 mol/L HCl and 65 µL of 0.02% (w/v) N-1-naphthylenediamine dihydrochloride in 910 µL of deionized water. The mixture was incubated at room temperature for 15 minutes. Absorbance was measured at 540 nm using a spectrophotometer, and the apparent nitrite concentration (mM) in the supernatant was calculated using the standard curve. The nitrate content of the sample (µmol/g fresh weight) was then determined using Equation 5.

$$\text{True nitrite concentration } (\mu\text{M}) \times \frac{\text{Extracted volume (mL)}}{\text{Fresh weight (g)}} \quad (5)$$

2.6 Determination of nitrate

Nitrate content was determined using salicylic acid and a colorimetric method described by Hachiya and Okamoto [15]. A standard curve was generated by preparing a nitrate dilution series with potassium nitrate (2, 4, 6, and 8 µM) in deionized water. Microgreens (2 g) were extracted with 5 mL of deionized water, and the supernatant was centrifuged at 20,100 x g at 4°C for 10 minutes. For each sample, 40 µL of 0.05% (w/v) salicylic acid in sulfuric acid (freshly prepared daily and protected from light) was added to a 1.5 mL microtube, followed by the addition of the supernatant, and the mixture was thoroughly vortexed. After incubating at room temperature for 20 minutes, 1 mL of 8% (w/v) NaOH in deionized water was gently added, and the mixture was vortexed until clear. Absorbance was measured at 410 nm using a spectrophotometer. The apparent nitrate concentration (mM) in the supernatant was calculated using the standard curve, and the nitrate content of the sample (mmol/g fresh weight) was determined using equation 6.

$$\text{True nitrate concentration (mM)} \times \frac{\text{Extracted volume (mL)}}{\text{Fresh weight (g)}} \quad (6)$$

2.7 Determination of ammonium

Ammonium content was determined using the ammonia-salicylate method [15]. A standard curve was created with an ammonium dilution series prepared from ammonium sulfate (50, 100, 150, and 200 µM

ammonium) in 0.1 M potassium chloride. The salicylate/nitroprusside solution was made by dissolving 150 g of sodium salicylate and 0.30 g of sodium nitroprusside in water, then diluting to 1 L. The hypochlorite solution was prepared daily by diluting 6 mL of 5.25% sodium hypochlorite to 100 mL with water. Microgreens (2 g) were extracted with 5 mL of 0.1 M potassium chloride, and the supernatant was centrifuged at 20,100 x g at 4°C for 10 minutes. Next, 40 µL of the supernatant was pipetted into a 96-well plate, followed by adding 80 µL of the salicylate/nitroprusside solution and 80 µL of the hypochlorite solution. The mixture was thoroughly mixed by pipetting up and down, and the plate was incubated at room temperature for 45 minutes. Absorbance was then measured at 650 nm using a spectrophotometer. The apparent ammonium concentration (mM) in the supernatant was calculated using the standard curve, and the ammonium content of the sample (µmol/g fresh weight) was determined using equation 7.

$$\text{True ammonium concentration (mM)} \times \frac{\text{Extracted volume (mL)}}{\text{Fresh weight (g)}} \quad (7)$$

2.8 Determination of fiber content

The fiber content was determined and modified using the method of the Association of Official Analytical Chemists [16], along with the method described by Umar et al. [17]. Initially, 2 g of the sample was weighed onto filter paper, which was then placed in a thimble and into a Soxhlet extractor filled with 200 mL of petroleum ether. The mixture was heated for 2 hours. After extraction, the sample was dried at 105°C for 12 hours, transferred to a crucible, and connected to a fiber analyzer. Then, 150 mL of 1.25% sulfuric acid was added, and the mixture was heated for 40 minutes to digest the sample. The acid residue was rinsed with distilled water, boiled, and filtered through the fiber analyzer. Next, 150 mL of 1.25% sodium hydroxide was added to the crucible, and the process was repeated as with the sulfuric acid. The sample was then rinsed with approximately 20–30 mL of 95% alcohol. The crucible was baked again at 105°C for 12 hours, cooled in a desiccator, and weighed. Finally, the crucible was baked at 550°C for 2 hours, cooled in a desiccator, and weighed again. The total fiber content was calculated using Equation 8.

$$\text{Crude fiber (\%)} = \frac{\text{W1-W2}}{\text{weight of sample}} \times 100 \quad (8)$$

2.9 Determination of amino acids and total protein

Protein content and amino acids were determined using the method outlined by Okoronkw [18]. First, the microgreens were dried and ground into a powder using a mortar and pestle. A 1.25 g sample was placed into a 50-mL beaker and added 10 mL of methanol. The mixture was then warmed on a hotplate and stirred for 15 minutes. Afterward, the solution was filtered through filter paper No. 1 into a volumetric flask, and methanol was added to bring the volume to 25 mL. The spectrophotometer was then used to analyze the sample, automatically tracking the graph's peak to identify the absorption points of specific amino acids at their respective wavelengths: cysteine (204-220 nm), phenylalanine (240-265 nm), tyrosine (274-300 nm), tryptophan (275-312 nm), and histidine (above 312 nm). The protein concentration was calculated using the equation 9.

$$\text{Concentration in mg/mL} = \left(\frac{\text{Absorbance}}{\varepsilon_{\text{percent}}}\right) \times 50 \quad (9)$$

To determine the protein contents, a percent solution extinction coefficient ($\varepsilon_{\text{percent}}$) was used. The extinction coefficients ($\varepsilon_{\text{percent}}$) typically range from 4.0 to 24.0. While the value of $\varepsilon_{\text{percent}} = 10$ is commonly applied. It can vary considerably depending on the specific protein. However, for a mixture of various proteins, the average is often estimated to be around 10.

2.10 Statistic Analysis

Means were compared using the LSD multiple range test at a significance level of $p \leq 0.05$, with the analysis performed using Microsoft Excel Office 2019.

3. Results and Discussion

3.1 Fresh weight and dry weight

In this study, we examined the effects of various concentrations of monosodium glutamate on the fresh weight of sunflower microgreens. The results revealed no significant impact on their fresh weight (Table 2). However, sunflower seedlings treated with MSG1 had the highest fresh weight (46.553 ± 6.081 g/100 seedlings), followed closely by those treated with Hoagland and Arnon solution (46.268 ± 5.462 g/100 seedlings), MSG3 (45.693 ± 5.952 g/100 seedlings), MSG2 (44.357 ± 6.869 g/100 seedlings), and DI water (44.144 ± 7.166 g/100 seedlings) (Table 2). Similarly, there were no significant differences in the dry weight of sunflower microgreens among the treatments (Table 2). The highest dry weight was observed in microgreens treated with DI water (2.665 ± 0.176 g/100 seedlings), followed by those treated with Hoagland and Arnon solution (2.569 ± 0.066 g/100 seedlings), MSG3 (2.542 ± 0.170 g/100 seedlings), MSG1 (2.529 ± 0.344 g/100 seedlings), and MSG2 (2.477 ± 0.166 g/100 seedlings). The findings showed no significant differences in fresh and dry weights among the treatments. In their study, Mursilati et al. [19] reported that monosodium glutamate did not affect plant growth. In contrast, Haghighi et al. [13] found that monosodium glutamate could increase the fresh weight of shoots and roots. Similarly, Septiyana et al. [20] observed that monosodium glutamate enhanced growth in okra, including plant height, fresh weight, and dry weight. Seman-Kamarulzaman et al. [10] also noted that a 10% w/v solution of monosodium glutamate promoted plant growth. Conversely, Hassama et al. [21] found that monosodium glutamate did not significantly affect fresh and dry weights compared to other fertilizers like mono ammonium phosphate, potassium nitrate, calcium nitrate, ammonium sulfate, ammonium nitrate, urea, and DI water in sunflower microgreens. Therefore, the effect of monosodium glutamate on fresh and dry weights appears to vary by plant species and growth stage, with no significant impact observed in sunflower microgreens.

Table 2. Effects of concentration levels of monosodium glutamate (MSG 1, MSG 2, MSG 3), DI water, and Hoagland and Arnon on fresh weight and dry weight of sunflower microgreens

Treatment	Fresh weight (g/100 seedlings)	Dry weight (g/100 seedlings)
MSG 1	46.553 ± 6.081	2.529 ± 0.344
MSG 2	44.357 ± 6.869	2.477 ± 0.166
MSG 3	45.693 ± 5.952	2.542 ± 0.170
DI water	44.144 ± 7.166	2.665 ± 0.176
Hoagland and Arnon	46.268 ± 5.462	2.569 ± 0.066

Results are means ± Standard Deviation. Means not significantly different at $p < 0.05$ according to the LSD test.

3.2 Pigments

The pigment contents of sunflower microgreens, including chlorophyll a, chlorophyll b, carotenoids, and xanthophylls, exhibited no significant differences among the treatments (Table 3). However, the highest chlorophyll content was observed in microgreens treated with DI water (0.028 ± 0.006 mg/g), followed by MSG 2 (0.027 ± 0.005 mg/g), Hoagland and Arnon (0.021 ± 0.004 mg/g), MSG 1 (0.021 ± 0.002 mg/g), and MSG 3 (0.021 ± 0.001 mg/g). Similarly, the highest chlorophyll b content was found in microgreens treated with DI water (0.039 ± 0.015 mg/g), with MSG 2 (0.036 ± 0.009 mg/g), Hoagland and Arnon (0.034 ± 0.014 mg/g), MSG 3 (0.032 ± 0.009 mg/g), and MSG 1 (0.032 ± 0.009 mg/g) following. Carotenoid content was highest in microgreens treated with MSG 2 (0.032 ± 0.002 mg/g), followed by DI water (0.031 ± 0.005 mg/g), Hoagland and Arnon (0.030 ± 0.003 mg/g), MSG 3 (0.029 ± 0.002 mg/g), and MSG 1 (0.029 ± 0.002 mg/g). The highest xanthophyll content was found in microgreens treated with DI water (0.015 ± 0.002 mg/g), followed by MSG 2 (0.015 ± 0.001 mg/g), Hoagland and Arnon (0.013 ± 0.003 mg/g), MSG 1 (0.012 ± 0.002 mg/g), and MSG 3 (0.012 ± 0.001 mg/g).

The monosodium glutamate is composed of 12.08% nitrogen [22]. Nitrogen is a crucial element in chlorophyll for pigment formation, antioxidants, nutrient absorption, shoot growth, and cell division [23]. Glutamate is an essential precursor in chlorophyll biosynthesis within the chloroplast. This process begins with glutamate and progresses to the formation of the tetrapyrrole protoporphyrin IX in the plastid stroma,

leading to the initiation of chlorophyll production [24, 25]. Hassama et al. [21] reported that sunflower microgreens treated with monosodium glutamate had significantly lower chlorophyll a and b contents than those treated with ammonium nitrate. They also found that monosodium glutamate had no significant impact on carotenoid and xanthophyll contents when compared to other fertilizers such as monoammonium phosphate, potassium nitrate, calcium nitrate, ammonium sulfate, ammonium nitrate, urea, and deionized water [21].

Table 3. Effects of concentration levels of monosodium glutamate (MSG 1, MSG 2, MSG 3), DI water, and Hoagland and Arnon on the pigment of sunflower microgreens

Treatment	Pigment (mg/g)			
	Chlorophyll a	**Chlorophyll b**	**Carotenoids**	**Xanthophyll**
MSG 1	0.021 ± 0.002	0.032 ± 0.009	0.029 ± 0.002	0.012 ± 0.002
MSG 2	0.027 ± 0.005	0.036 ± 0.009	0.032 ± 0.002	0.015 ± 0.001
MSG 3	0.021 ± 0.001	0.032 ± 0.009	0.029 ± 0.002	0.012 ± 0.001
DI water	0.028 ± 0.006	0.039 ± 0.015	0.031 ± 0.005	0.015 ± 0.002
Hoagland and Arnon	0.021 ± 0.004	0.034 ± 0.014	0.030 ± 0.003	0.013 ± 0.003

Results are means ± Standard Deviation. Means not significantly different at $p < 0.05$ according to the LSD test.

3.3 Contents of nitrate, nitrite, and ammonium

Nitrate and nitrite in sunflower microgreens showed no significant differences among treatments (Table 4). The highest nitrate content was observed in sunflower microgreens treated with Hoagland and Arnon (0.360 ± 0.027 mmol/g fresh weight), followed by MSG 1 (0.340 ± 0.028 mmol/g fresh weight), deionized water (0.330 ± 0.024 mmol/g fresh weight), MSG 3 (0.330 ± 0.008 mmol/g fresh weight), and MSG 2 (0.305 ± 0.029 mmol/g fresh weight). For nitrite content, the highest content was found in sunflower microgreens treated with MSG 3 (0.798 ± 0.098 μmol/g fresh weight), followed by Hoagland and Arnon (0.796 ± 0.068 μmol/g fresh weight), MSG 1 (0.788 ± 0.323 μmol/g fresh weight), MSG 2 (0.526 ± 0.079 μmol/g fresh weight), and deionized water (0.517 ± 0.016 μmol/g fresh weight). However, ammonium content in sunflower microgreens showed significant differences among the treatments (Table 4). The highest ammonium content was observed in microgreens sprayed with MSG 1 (2.107 ± 1.273 μmol/g fresh weight), followed by MSG 2 (2.104 ± 0.787 μmol/g fresh weight), deionized water (0.754 ± 0.348 μmol/g fresh weight), MSG 3 (0.669 ± 0.485 μmol/g fresh weight), and Hoagland and Arnon (0.468 ± 0.060 μmol/g fresh weight). The ammonium content in sunflower microgreens treated with MSG 1 and MSG 2 was significantly higher than in those treated with Hoagland and Arnon. Additionally, there were no significant differences in ammonium content among the treatments of MSG 1, MSG 2, deionized water, and MSG 3. Plants absorb nitrate, which is then reduced to nitrite by the enzyme nitrate reductase during assimilation. The nitrite is transported into the chloroplast, which is further reduced to ammonium by nitrite reductase. This ammonium is subsequently assimilated into glutamine by glutamine synthetase within the chloroplast [26]. This study found that the nitrate content in sunflower microgreens ranged from 0.305 to 0.360 mmol/g fresh weight, while the nitrite content ranged from 0.517 to 0.798 μmol/g fresh weight. Nitrate and nitrite are considered potentially harmful due to their association with an increased risk of esophageal, gastric, and colon cancers, as well as other tumors [27,28]. The World Health Organization recommends an upper limit for daily nitrate intake at 3.7 mg/kg and nitrite at 0.06–0.07 mg/kg [29]. Ammonium is found in various compartments within chloroplasts, mitochondria, and vacuoles [30]. The current research revealed that the ammonium content in sunflower microgreens ranged from 0.468 to 2.107 μmol/g fresh weight.

Table 4. Effects of concentration levels of monosodium glutamate (MSG 1, MSG 2, MSG 3), DI water, and Hoagland and Arnon on nitrate, nitrite, and ammonium contents of sunflower microgreens

Treatment	Nitrate content (mmol/ g fresh weight)	Nitrite content (μmol/ g fresh weight)	Ammonium content (μmol/ g fresh weight)
MSG 1	0.340 ± 0.028	0.788 ± 0.323	2.107 ± 1.273 [a]
MSG 2	0.305 ± 0.029	0.526 ± 0.079	2.104 ± 0.787 [a]
MSG 3	0.330 ± 0.008	0.798 ± 0.098	0.669 ± 0.485 [ab]

DI water	0.330 ± 0.024	0.517 ± 0.016	0.754 ± 0.348 [ab]
Hoagland and Arnon	0.360 ± 0.027	0.796 ± 0.068	0.468 ± 0.060 [b]

Results are means ± standard deviation. According to the LDS multiple range test at $p \leq 0.05$, the mean with different letters in the same column indicates a significant difference.

3.4 Crude Fiber

The crude fiber content in sunflower microgreens showed no significant differences among the treatments (Figure 1). The highest crude fiber content was observed in microgreens treated with MSG 2 (15.278%), followed by Hoagland and Arnon (13.654%), deionized water (13.418%), MSG 1 (12.821%), and MSG 3 (12.138%). Khatoon and Singh [31] reported that the crude fiber content of radish microgreens ranged from 3.00 to 3.43 g per 100 g. Furthermore, Dhaka et al. [32] found that pearl millet had the highest dietary fiber content at 6.48 g per 100 g, compared to mung bean (3.48 g/100 g), lentil (3.88 g/100 g), red radish (2.86 g/100 g), mustard (2.26 g/100 g), and red cabbage (2.60 g/100 g).

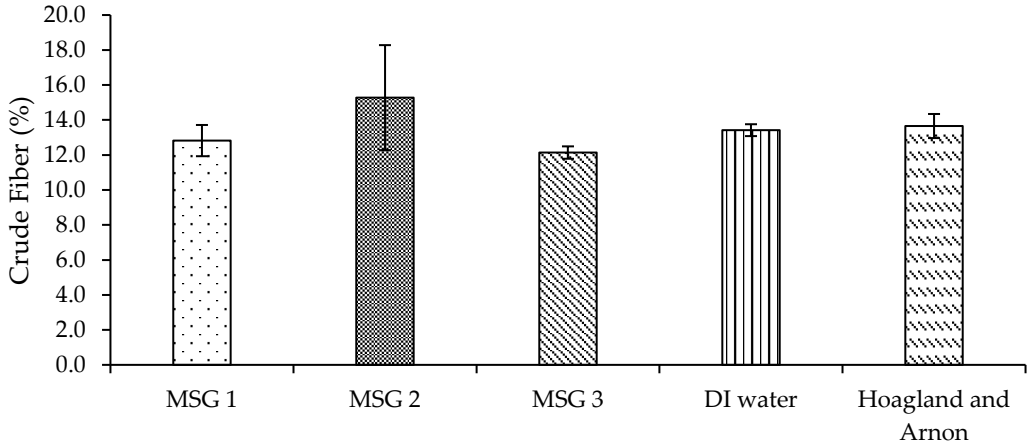

Figure 1. Effects of concentration levels of monosodium glutamate (MSG 1, MSG 2, MSG 3), DI water, and Hoagland and Arnon on crude fiber (%) in sunflower microgreens. Different letters indicate significant differences ($p < 0.05$) according to the LSD test.

3.5 Total protein contents

Total protein content in sunflower microgreens varied significantly among the treatments (Figure 2). The results for total protein content in sunflower microgreens showed that the highest content was observed in those treated with MSG 3 (21.821 mg/mL), followed by Hoagland and Arnon (21.479 mg/mL), MSG 2 (20.913 mg/mL), deionized water (20.608 mg/mL), and MSG 1 (15.096 mg/mL). However, the protein content in microgreens treated with MSG 3 was not significantly different from that of those treated with Hoagland and Arnon, MSG 2, or deionized water. However, sunflower microgreens treated with MSG 1 had the lowest protein content. Ghoora et al. [33] found fennel microgreens (4.44 g/100 g) provided highest protein content when compared to microgreens of carrot (2.42 g/100 g), fenugreek (3.33 g/100 g), french basil (2.22 g/100 g), mustard (2.78 g/100 g), onion (2.58 g/100 g), radish (1.81 g/100 g), roselle (2.55 g/100 g), spinach (2.32 g/100 g), and sunflower (3.93 g/100 g). Furthermore, Kowitcharoen et al. (2021) reported the total protein contents in microgreens, including broccoli (2.23 g/100 g), Chinese kale (2.23 g/100 g), purple radish (3.41 g/100 g), radish (2.58 g/100 g), rat-tailed radish (2.50 g/100 g), red cabbage (1.88 g/100 g), fenugreek (4.03 g/100 g), green pea (3.73 g/100 g), lentil (6.47 g/100 g), mung bean (4.55 g/100 g), black sesame (1.92 g/100 g), buckwheat (1.75 g/100 g), morning glory (1.76 g/100 g), and red roselle (4.10 g/100 g).

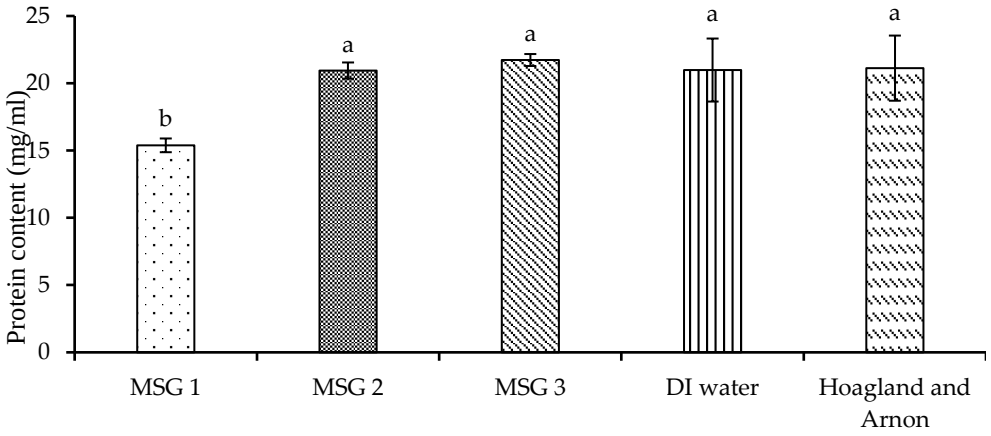

Figure 2. Effects of concentration levels of monosodium glutamate (MSG 1, MSG 2, MSG 3), DI water, and Hoagland and Arnon on sunflower microgreens protein content (mg/mL). Different letters indicate significant differences ($p < 0.05$) according to the LSD test.

3.5 Amino acid

Amino acids were analyzed in sunflower microgreens treated with MSG 1, MSG 2, MSG 3, deionized water, and Hoagland and Arnon solution. The results indicated the presence of cysteine, phenylalanine, tyrosine, tryptophan, and histidine across all treatments (Table 5). These findings are consistent with those of Wojdyło et al. [3], who also identified cysteine, phenylalanine, tyrosine, tryptophan, and histidine in five types of microgreens: kale, radish, beetroot, green peas, and amaranth.

Table 5. Comparison of amino acids identified at different wavelengths in each of the treatments in sunflower microgreens

Treatment	200 – 220 nm Cysteine	240 – 265 nm Phenylalanine	274 – 300 nm Tyrosine	280 – 312 nm Tryptophan	346 nm Histidine
MSG 1	+	+	+	+	+
MSG 2	+	+	+	+	+
MSG 3	+	+	+	+	+
DI water	+	+	+	+	+
Hoagland and Arnon	+	+	+	+	+

(+) represents the presence of the amino acids identified at the wavelength indicated. (-) represents the amino acids not present at the wavelength indicated.

4. Conclusions

This study explored the potential of using MSG as an alternative nitrogen fertilizer for cultivating sunflower microgreens. The experiment aimed to assess the effects of different concentrations of MSG on the growth and quality of sunflower microgreens. A total of five treatments were applied: three MSG concentrations (MSG 1 at 639.2 mg/L, MSG 2 at 319.6 mg/L, and MSG 3 at 159.8 mg/L), deionized water, and the standard Hoagland and Arnon solution. The study found no significant differences among the treatments regarding key growth parameters, including fresh weight, dry weight, chlorophyll content (both a and b), carotenoid content, xanthophyll content, nitrate content, nitrite content, and crude fiber content. These findings suggest that MSG, even at different concentrations, does not substantially influence the growth of sunflower microgreens when compared to Hoagland and Arnon solution or DI-water treatments. However, notable differences were observed in other quality parameters. Microgreens treated with the highest MSG concentration (MSG 1) exhibited the highest ammonium content, whereas those treated with the Hoagland and Arnon solution showed the lowest. Protein content varied significantly among treatments, highest in

microgreens treated with MSG 3 and lowest in those treated with MSG 1. Despite these variations, amino acids such as cysteine, phenylalanine, tyrosine, tryptophan, and histidine were consistently present across all treatments. The study concluded that while MSG as a nitrogen source did not significantly improve growth metrics, it influenced the quality of sunflower microgreens. Treatments with MSG 2, MSG 3, DI-water, and the Hoagland and Arnon solution resulted in better overall quality than MSG 1. This suggests that lower concentrations of MSG may have the potential as an alternative fertilizer for enhancing the nutritional value of sunflower microgreens without adversely affecting growth.

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