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Analysis of nutritional and antioxidant components of ice plant grown in An Giang, Vietnam

Nguyen Duy Tan[1,3], Vang Thi Tuyet Loan[2,3], Tran Van Khai[2,3] & Vo Thi Xuan Tuyen[2,3*]

[1]Food Technology Department, Faculty of Agriculture and Natural Resources, An Giang University, Long Xuyen City, An Giang Province 880000, Vietnam

[2]Crop Science Department, Faculty of Agriculture and Natural Resources, An Giang University, Long Xuyen City, An Giang Province 880000, Vietnam

[3]Vietnam National University-Ho Chi Minh City (VNU-HCM), Ho Chi Minh City 700000, Vietnam

*Email: vtxtuyen@agu.edu.vn

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Abstract

The ice plants are a new crop that has recently received attention in Vietnam because they have outstanding characteristics such as being able to grow in drought conditions, saline soil and prolonged cold weather and plants with economic potential for climate change adaptation. Currently, this vegetable plant is being in trial cultivation and is expected to be widely commercialized in the Vietnamese market soon. Therefore, the study analyzed macro and micronutrients, amino acids components, bioactive compounds and the antioxidant ability of ice plant vegetables grown in an experimental area of An Giang University. Analytical results showed that ice plant has nutritional components such as moisture 96.9 ± 0.85%, protein 0.74 ± 0.01%, carbohydrate 0.83 ± 0.03%, ash 1.43 ± 0.06%, solute fiber 0.11 ± 0.01%, insoluble fiber 0.22 ± 0.02% (fresh weight-FW), except lipid that was not detected. It was also found to contain 14 amino acids such as alanine, leucine, lysine, aspartic acid, valine, glutamic acid, glycine, isoleucine, arginine and phenylalanine ranged from 15.32 to 42.43 mg/100g FW; serine, histidine, proline and methionine ranged from 1.83 to 7.17 mg/100g FW); and 8 minerals such as potassium and sodium ranged from 3518 to 3713 mg/kg FW; magnesium, phosphorus and calcium ranged from 84.4 to 142.0 mg/kg FW; iron, zinc and manganese ranged from 0.85 to 3.27 mg/kg FW. In addition, the ice plant possessed a lot of bioactive compounds such as polyphenol 187.72 mgGAE/100g FW, flavonoid 22.08 mgQE/100g FW, tannin 50.28 mgTAE/100g FW, saponin 88.44 mgSE/100g FW, alkaloid 195.00 mgCE/100g FW, carotenoids 0.57 mg/g FW and total chlorophyll 7.18 mg/g FW. The antioxidant ability of the crude ethanol extract was 78.50% (DPPH) and 66.11 mM $FeSO_4$/100g FW (FRAP). The ice plant can be considered a super plant that has the potential to become a food source supplying essential nutrition components for humans.

Keywords

acid amine; antioxidant activities; bioactive compounds; macro and micronutrients; *Mesembryanthemum crystallinum* (ice plant).

Introduction

Vegetables are known as the edible parts of plants including leaves, roots, fruits, or seeds. It is considered a valuable food source for people and provides essential vitamins, minerals, fiber and antioxidants. Vegetables in the daily diet are closely related to overall health, improving digestive health and vision and decreasing the cause of certain illnesses such as cancer, heart illness, stroke, diabetes, anemia, stomach ulcers, rheumatoid arthritis and other chronic diseases (1).

The ice plant (*Mesembryanthemum crystallinum* L.) is native to South and East Africa, belonging to the group of halophytes. The plant can survive in conditions such as drought, salinity and prolonged cold. The appropriate temperature for growth ranges from 12°C to 30°C (2). In favorable conditions, plants photosynthesize in the C_3 pathway, but when affected by stress such as poor nutrition, drought and salinity, plants will strongly take the CAM photosynthetic pathway (3). According to Ksouri et al (4), the leaves of the ice plant can be used as food for humans, the seeds contain many secondary metabolites and are considered a plant with potential economic value in the future to adapt to climate change. The leaves are rich in minerals (Ca, Mg, K, P), organic acids and vitamins and contain many bioactive compounds (alkaloids, polyphenols, carotenoids, flavonoids, saponins, tannins), especially the active ingredient D-pinitol has the same function as insulin to help support and stabilize blood sugar (5). Because of its high salt tolerance, from a little-noticed plant species, the ice plant has gradually become an economically valuable crop in many countries and has great potential to become a valuable crop in agricultural production. The ice plant is used as a leafy vegetable or raw material for the production of pharmaceuticals. The leaves contain many nutrients and bioactive compounds, especially high antioxidant activity (6).

Currently, this vegetable plant is being in trial cultivation and is expected to be widely commercialized in the Vietnamese market soon. Through reference to many published documents, it has been shown that ice plants have different nutritional compositions when being grown in different environmental conditions (weather, climate, soil and care). Therefore, this study was conducted to analyze the macro and micronutrients, amino acids component as well as bioactive compounds and antioxidant ability of ice plants. The purpose is to provide more data on the nutritional compositions of ice plants grown in An Giang, Vietnam and to serve as a reference for researchers and consumers on this plant.

Materials and Methods

Preparation of material and chemical

Ice plants were collected from the experimental practice area in An Giang University (latitude: 10°37'16.77" N, longitude: 105°43'20.98" E), with a growth time of 75 days after cultivation (**Fig. 1**). The vegetable sample was taken to the laboratory ready for proximate composition analysis. The ice plant sample was prepared according to different methods to determine chemical components, bioactive compounds and antioxidant activities.

Most chemicals were used for analysis of bioactive compounds, chemical components in ice plants have origin from Sigma and Merck.

Analysis of chemical compositions

Proximate components of ice plant were analyzed by standard methods of AOAC and TCVN. The content of fat was analyzed by the acid hydrolysis method using Soxhlet extractor; the content of protein was analyzed by the Kjeldahl method; total ash was determined according to the gravimetric method; mineral components using an inductively coupled plasma optical emission spectroscopy (ICP-OES); and the content of fiber was analyzed by the enzymatic gravimetric method (7). Carbohydrate was determined according to the general volumetric method (8). The content of moisture was determined using a hot air oven (9). Amino acid components were determined according to the HPLC method (10).

Analysis of bioactive compounds and antioxidant activities

Sample preparation: fresh whole plant was ground and extracted with rate of ethanol: water (60: 40, v/v) for 60 minutes at a material: solvent ratio (1: 20, w/v). The extract was filtered with Whatman No.1 filter paper and then evaluated for its antioxidant capacity and bioactive compounds.

The bioactive compounds were analyzed including the content of polyphenol (mg GAE/100g FW- fresh ice plant weight) was analyzed by Folin-Ciocalteu reagent method (11). The content of flavonoid (mg QE/100 g FW) was determined by the aluminum chloride colorimetric method (12). The content of tannin (mg TAE/100 g FW) was analyzed by the Folin-Denis method (13). The content of saponin (mg SE/100g FW) was analyzed by colorimetric method (14). The content of alkaloid (mg CE/100g FW) was analyzed by colorimetric method (15). The content of chlorophyll and carotenoids was analyzed by colorimetric method (16).

The antioxidant capacity of the ice plant was determined the evaluation of free radical (DPPH) scavenging activity and ferric reduction antioxidant power (FRAP). FRAP measurement (mM $FeSO_4$/100g FW) was conducted following the method described by Adedapo et al. (17). DPPH measurement (%) was determined following the method described by Tola et al. (18), DPPH (%) = [(A - B)/A] x 100, where, A is the absorbance of control sample, B is the absorbance of extract sample.

Statistical analysis

The data were analyzed with 3 replicates. The results are presented as mean values with plus/minus standard deviations.

Fig. 1. The ice plant (*Mesembryanthemum crystallinum*).

Results and Discussion

Nutritional compositions in the ice plant

The components of food that people use a lot such as lipids, glucid and protein which are called macronutrients. They supply energy and maintain the systems and structures of the human body. Energy-producing nutrients are often present a lot in foods of animal origin but very little in plants, except for legumes. The quality of food is determined by nutritional components such as protein, glucid, lipid, fiber, moisture and ash (19). The chemical composition of the ice plant sample collected in the experimental practice area of An Giang University (AGU) is shown in Table 1.

Table 1. The content of nutrient compositions in ice plant

No.	Compounds	Results (Mean ± SD, n = 3) (g/100g FW)
1	Protein (%)	0.74 ± 0.01
2	Lipid (%)	Not detected (MDL=0.02)
3	Carbohydrate (%)	0.83 ± 0.03
4	Ash (%)	1.43 ± 0.06
5	Solute fiber (%)	0.11 ± 0.01
6	Insoluble fiber (%)	0.22 ± 0.02
7	Moisture (%)	96.9 ± 0.85

The content of moisture in the AGU ice plant was very high (96.9 ± 0.85%) and higher than the moisture of ice plants cultivated in China (94.90%) and Thailand (95.45%) (20). It shows that ice plants will reduce quickly post-harvest quality and so it should be preserved carefully in transportation and delivery. The high moisture content can create good conditions for the degradation activity of enzymes and microbial. When we eat raw vegetables that contain a lot of water, that thing helps the body to digest them easily (21). The high moisture content however has a negative correlation on the dry matter content. The moisture content in the ice plant will be decided by damp of the air environment, temperature and harvesting time. Besides, the content of protein, carbohydrate, ash and dietary fiber in AGU ice plant was 0.74 ± 0.01%, 0.83 ± 0.03%, 1.43 ± 0.06%, 0.11 ± 0.01% of solute fiber and 0.22 ± 0.02% insoluble fiber (% FW), respectively. Lipid content was not detected in the method detection limit (MDL = 0.02). These components in ice plants grown in AGU were found to be lower than in ice plants grown in China (presented 0.18% of fat, 1.13% of protein, 1.68% of carbohydrate, 2.11% of ash) but it had some components higher than in ice plants grown in Thailand presented 0.37% of protein and 0.00% of fiber and equal 0.00% of fat, lower than at content of ash and carbohydrate presented 1.63% and 2.55%. The chemical components of different parts of the ice plant were different, for instance, the moisture content in cotyledon was 97.67%, the stem was 90.60% and the shoot was 95.89%; the crude protein content in cotyledon was 0.51%, the stem was 0.78% and the shoot was 1.09%; the crude lipid content in cotyledon was 0.07%, the stem was 0.03% and the shoot was 0.13%; the crude ash content in cotyledon was 0.87%, the stem was 1.99% and the shoot was 1.65%; the carbohydrate content in cotyledon was 0.87%, the stem was 6.60% and the shoot was 1.35%; the dietary fiber content in Cotyledon was 1.44%, the stem was 3.84% and leaf was 2.35% (22).

If it was calculated on dry matter, the nutritional components in ice plants grown in AGU such as crude protein, carbohydrate, ash and fiber were 23.87%, 26.77%, 46.13% and 10.65% respectively. These components were equal to or higher than comparison to some vegetables excepted lipid content such as *A. trifoliatus* contained crude protein of 5.01%, total fat of 0.95%, total carbohydrate of 16.47%, dietary fiber of 8.54% and ash of 2.95% (23) and the chemical components of some leafy vegetables possessed crude proteins (13.12 - 22.26%), carbohydrates (26.19 - 59.99%), crude lipids (1.17 - 4.90%), crude fibers (12.11 - 33.00%), ash (7.25 - 26.79%) (24). The nutritional components were found in vegetables (bitter gourd, pointed gourd, plantain, sweet gourd) as the protein content varies from 1.08 to 2.75%, fat from 0.12 to 0.45%, carbohydrate from 3.361 to 16.15% and ash from 0.36 to 0.48% (25). The edible plants had protein ranging from 7.84 to 13.99%, lipids ranged from 1.10 to 2.19%, carbohydrates ranged from 9.08 to 19.84%, ash ranged from 8.34 to 23.26%, fiber ranged from 6.54 to 16.89% (26).

Protein, carbohydrates and lipids are components that participate in body structure and energy production, while food fiber supports the digestive system, the minerals of food expressed by ash content and participate in enzyme structure and bone and joint formation. These components will have different content in various plants. This difference can be affected by species, living environment and growing time of the plant.

The mineral compositions in ice plant

Minerals are included in the micronutrient group due to their essential role in the body, requiring only small amounts for optimal functioning. They are categorized into macro and micro minerals. Macro minerals consist of potassium, sodium, calcium, magnesium, phosphorus, etc. Meanwhile, microminerals include iron, zinc, copper, selenium, etc. (27).

Minerals are an essential composition of the diet. They have a lot of different functions, such as materials to create bone structure, affecting the function of muscle and nerves and regulating the body's water balance, components of hormones and enzymes as well as other bioactive compounds. Additionally, some minerals also play a crucial role in activity of the immune system can affect sensitivity to infections and have effects on the development of chronic illness (28).

The analysis result of the AGU ice plant is expressed in Table 2. It showed that ice plants had high content of minerals such as potassium (3518 ± 2.68 mg/kg), sodium (3712 ± 3.22 mg/kg), magnesium (142 ± 1.06 mg/kg), phosphorus (133 ± 1.52 mg/kg), calcium (84.4 ± 0.56 mg/kg), manganese (3.27 ± 0.28 mg/kg), iron (2.38 ± 0.11 mg/kg), zinc (0.85 ± 0.01 mg/kg). However, it was not detected of copper and selenium at the method detection limit (MDL = 0.02). According to reported results showed that content of macro and micro minerals in different parts of the ice plant was different such as Cotyledon was Na 3084.67 mg/kg, K 1047.33 mg/kg, Mg 108.33 mg/kg, Ca 275.00 mg/kg, Fe 1.87 mg/kg, Cu 0.14 mg/kg, Zn 2.10 mg/kg and Mn 1.17 mg/kg; Stem was Na 2864.33 mg/kg, K 2086.00 mg/kg, Mg 174.00 mg/kg, Ca 1971.33 mg/kg, Fe 3.60 mg/kg, Cu 0.25 mg/kg, Zn 7.53 mg/kg, Mn 6.57 mg/kg; Leaf was Na 2998.33 mg/kg, K 1592.33 mg/kg, Mg 441.00 mg/kg, Ca 988.00 mg/kg, Fe 5.23 mg/kg, Cu 1.66 mg/kg, Zn 6.27 mg/kg, Mn 1.17 mg/kg. These results showed that the AGU ice plant had a higher content of potassium and sodium, but a lower content of magnesium, calcium, iron and zinc and the same the content of manganese as compared to the research result of Kang & Joo.

Table 2. The content of mineral compositions in ice plant

No.	Mineral components	Results (Mean ± SD, n = 3) (mg/kg FW)
1	Potassium (K)	3518 ± 2.68
2	Sodium (Na)	3712 ± 3.22
3	Magnesium (Mg)	142 ± 1.06
4	Phosphorus (P)	133 ± 1.52
5	Calcium (Ca)	84.4 ± 0.56
6	Manganese (Mn)	3.27 ± 0.28
7	Iron (Fe)	2.38 ± 0.11
8	Zinc (Zn)	0.85 ± 0.01
9	Copper (Cu)	Not detected (MDL=0.02)
10	Selenium (Se)	Not detected (MDL=0.02)

Moreover, reported research showed that the content of macro and micro minerals in spinach samples had Na, K, Ca, Mg and P arranged from 57 to 7393 mg/kg; and Fe, Cu, Zn, Se arranged from 0.001 to 120.1 mg/kg. The mineral content in lettuce samples including Na, K, Ca, Mg and P arranged from 48 to 4135 mg/kg; and Fe, Cu, Zn and Se arranged from 0.002 to 17.1 mg/kg. The mineral content in parsley samples including Na, K, Ca, Mg and P arranged from 210 to 4837 mg/kg; and Fe, Cu, Zn and Se arranged from 0.001 to 51.7 mg/kg (29). Different types of vegetables have different nutritional values. Vegetables are low in fat but contain good amounts of vitamins and minerals.

The amino acid compositions in ice plant

Among the three primary macronutrients, protein stands out as essential for vitality. It can be broken down and assimilated in the form of amino acids and short peptides, both of which have significant bodily effects. Amino acids serve as the foundational units for our cellular structures, forming proteins and protein complexes crucial for various physiological functions. Additionally, they contribute to the production of many vital metabolites (30). Within the array of amino acids constituting proteins, nine are deemed essential as they cannot be synthesized from other compounds and must be acquired through dietary intake. Upon ingestion by the human body, amino acids from food serve multiple purposes. Apart from their role in protein and biomolecular synthesis, they can also undergo oxidation pathways to produce energy in the form of urea and carbon dioxide. Disorders in amino acid metabolism have been associated with the advancement of numerous diseases. In addition to its involvement in cancer, amino acid metabolism has been identified as a significant contributor to the onset and progression of metabolic conditions like diabetes and obesity, along with cardiovascular, autoimmune and neurological diseases (31).

The content of amino acids in the AGU ice plant is presented in Table 3. The ice plant was a high content of amino acids such as alanine (42.43 ± 0.81 mg/100g fresh weight), leucine (37.11 ± 0.49 mg/100g), lysine (31.94 ± 0.54 mg/100g), aspartic acid (27.49 ± 0.51 mg/100g), valine (25.33 ± 0.66 mg/100g), glutamic acid (23.42 ± 0.33 mg/100g), glycine (22.03 ± 0.28 mg/100g), isoleucine (21.53 ± 0.11 mg/100g), arginine (16.57 ± 0.43 mg/100g), phenylalanine (15.32 ± 0.12 mg/100g), serine (7.17 ± 0.24 mg/100g), etc. Meanwhile, threonine and tyrosine were not detected. According to Kang & Joo, the content of amino acids in different parts (cotyledon, stem and leaf) of ice plants such as alanine ranged from 1040.36 to 1842.42 mg/100g dry matter), leucine ranged from 1268.73 to 3373.33 mg/100g, lysine

Table 3. The content of amino acid composition in ice plant

No.	Amino acid components	Results (Mean ± SD, n = 3) (mg/100g FW)
1	Alanine	42.43 ± 0.81
2	Arginine	16.57 ± 0.43
3	Aspartic acid	27.49 ± 0.51
4	Glutamic acid	23.42 ± 0.33
5	Glycine	22.03 ± 0.28
6	Histidine	5.07 ± 0.07
7	Isoleucine	21.53 ± 0.11
8	Leucine	37.11 ± 0.49
9	Lysine	31.94 ± 0.54
10	Methionine	1.83 ± 0.02
11	Phenylalanine	15.32 ± 0.12
12	Proline	2.05 ± 0.09
13	Serine	7.17 ± 0.24
14	Threonine	Not detected (MDL=0.02)
15	Tyrosine	Not detected (MDL=0.02)
16	Valine	25.33 ± 0.66

ranged from 953.48 to 2392.21 mg/100g, aspartic acid ranged from 1327.44 to 1619.19 mg/100g, valine ranged from 912.43 to 2101.76 mg/100g, glutamic acid ranged from 1257.64 to 2744.47 mg/100g, glycine ranged from 282.68 to 707.38 mg/100g, isoleucine ranged from 569.66 to 1395.43 mg/100g, arginine ranged from 1253.82 to 2371.91 mg/100g, phenylalanine ranged from 844.81 to 2237.81 mg/100g, serine ranged from 651.92 to 1685.61 mg/100g, etc.. These results have some amino acids with higher or the same content as our research results.

The content of amino acids in different vegetables had differences in present levels of amino acids. The leaves of the four vegetable plants including *V. amygdalina, G. Africana, G. latifolium* and *O. gratissimum* present content of amino acids such as isoleucine ranging from 3.04 to 4.71 mg/100 protein, leucine ranged from 8.64 to 9.52 mg/100g, lysine ranged from 3.96 to 5.78 mg/100g, methionine ranged from 0.76 to 1.95 mg/100g, cystine ranged from 0.43 to 1.41 mg/100g, phenylalanine ranged from 4.07 to 5.6.38 mg/100g, tyrosine ranged from 2.90 to 3.39 mg/100g, threonine ranged from 3.38 to 3.96 mg/100g, valine ranged from 4.53 to 7.70 mg/100g, histidine ranged from 1.45 to 3.25 mg/100g, alanine ranged from 4.78 to 7.60 mg/100g, arginine ranged from 5.17 to 7.71 mg/100g, asparatic acid ranged from 8.78 to 13.79 mg/100g, glutamic acid ranged from 11.86 to 14.32 mg/100g, glycine ranged from 4.94 to 10.20 mg/100g, proline ranged from 1.19 to 4.17 mg/100g and serine ranged from 4.89 to 6.22 mg/100g (32). In addition, Narzary & Basumatary reported that the six plant species in Assam, India contained aspartic and glutamic acid from 0.01 to 0.33 and 0.02 to 0.75 mg/g dry weight (DW). Serine and glycine were also found in some plant species from 0.05 to 0.27 mg/g DW and 0.02 to 0.18 mg/g DW. The above comparison results, it shows that ice plants contain most of the amino acids that the body needs in high concentrations compared to some reported leafy vegetables.

Bioactive and color compounds in ice plant

Bioactive foods and nutraceuticals demonstrate promise as supplementary options for treating a lot of illnesses and as natural dietary resources for disease prevention (33). Plant-derived bioactive compounds, such as polyphenols, flavonoids, tannins, saponins, alkaloids, carotenoids, chlorophylls, lignins, peptides and others, are widely distributed throughout nature.

These phytonutrients play multifaceted roles in plants, serving as attractants for pollinators, defense mechanisms against insects and parasites and shields against environmental stresses like ultraviolet light exposure (34). Moreover, they contribute to the sensory characteristics of plants, influencing their color, flavor and aroma. Recognized for their potential health benefits, phytonutrients are commonly incorporated into our diets through the consumption of fruits, vegetables, whole grains, nuts, legumes, aromatic herbs, tea and coffee (35).

According to Abdalla et al (36), the ice plant has many biologically active ingredients such as antioxidants and antibacterial. The ice plant is used as a medicinal plant because of the presence of secondary metabolites (alkaloids, coumarins, saponins and flavonoids). The current study also determined the composition of bioactive and color compounds in ice plants (**Fig. 2**). They were presented in AGU ice plant including polyphenol 187.72 mgGAE/100g FW, flavonoid 22.08 mgQE/100g FW, tannin 50.28 mgTAE/100g FW, saponin 88.44 mgSE/100g FW, alkaloid 195.00 mgCE/100g FW, carotenoids 0.57 mg/g FW and total chlorophyll 7.18 mg/g FW. Meanwhile, the content of total phenolic and flavonoid in ice plants (cultivated in different areas) was 5.322 mgGAE/g and 1.126 mgRE/g in Sidi Abd El Rahman; 6.999 mgGAE/g and 1.453 mgRE/g in Giza; 7.080 mgGAE/g and 1.629 mgRE/g in El-Kassasin. The content of total phenolic and flavonoids of ice plant powder were 580.70 mgGAE/100g and 212.59 mgQE/100g and these bioactive compounds of fresh pasta added ice plant paste presented in 351.88 to 439.22 mgGAE/g and presented in 231.08 to 470.25 mgQE/g, respectively.

The result of Narzary & Basumatary reported that six wild vegetables were present saponin, tannin and alkaloids with content ranging from 3.23 to 14.40, 1.02 to 8.80 and 0.31 to 3.22 mg/g dry weight, respectively. In controlled doses, saponins exhibit beneficial effects by modulating the permeability of the small intestine, thereby aiding in the absorption of specific drugs. Moreover, they function as mild steroids and contribute to the reduction of serum cholesterol levels through the secretion of bile acid (37). However, excessive intake of alkaloids can lead to gastrointestinal and neurological complications (38). The leafy vegetables (*Amaranthus hybridus, Andasonia digitata, Ceiba patendra, Hibiscus sabdariffa and Vigna unguiculata*) found in presentation of polyphenols (135.21-293.08 mg/100g), tannin (69.26-204.79 mg/100g), flavonoid (15.00-27.58 mg/100g), carotenoids (1.55-5.04 mg/100g). Chlorophyll and carotenoids are vital plant pigments crucial for life. They are utilized as a food additive and provide fruits and vegetables with their color. Both of these photosynthetic pigments serve as antioxidants, capable of combating various forms of cancer and are recommended for skin and eye health issues (39). According to Hulkko et al. (40) reported that the chlorophyll and carotenoids content in fresh biomass of *Salicornia europaea* and *Salicornia persica* were 1.25 mg/g FW and 2.21 mg/g FW; 0.43 mg/g FW and 0.44 mg/g FW. However, the carotenoid content in *Sarcocornia perennis, Thespesia populnea and Salvadora persica* were 0.56 mg/g, 0.72 mg/g and 0.84 mg/g, respectively. Differences in phenolic compound concentrations influenced by environmental factors have been observed in medicinal plant species (41).

Antioxidant activity of ethanol extract from ice plant

Oxidation and cell damage caused by free radicals are the root cause of many diseases. Therefore, the consumption of antioxidants is important for humans. Plants are potential sources of natural antioxidants (42). There are various *in vitro* methods to determine the antioxidant ability of leaf vegetables because antioxidants reply differently to different radical and oxidant sources. A single method could not surely express all the radicals and antioxidants in complex matrixes. In general, the most important in vitro tests are based on two major mechanisms: the hydrogen atom transfer methods, which measure the ability to scavenge free radicals by hydrogen offering and the single electron transfer methods, which find the ability to transfer one electron to reduce a compound such as free radicals and metals (43). Antioxidants are important components that decrease the risk of chronic diseases by scavenging free radicals accumulated on cell tissues, thereby preventing them from oxidative damage.

The antioxidant activity of the ice plant was evaluated based on the ability of the ice plant extract to scavenge 2,2-diphenyl-1- picrlyhydrozyl free radicals (DPPH) and the ability to reduce ferric ions determined by ferric reducing antioxidant potential (FRAP) assay. The result was shown in. The present work (**Fig. 3**), showed that the DPPH and FRAP assay were 78.50% and 66.11 mM FeSO4/100g FW. The DPPH assay of raw pasta increased as it was added ice plant paste, with a range of

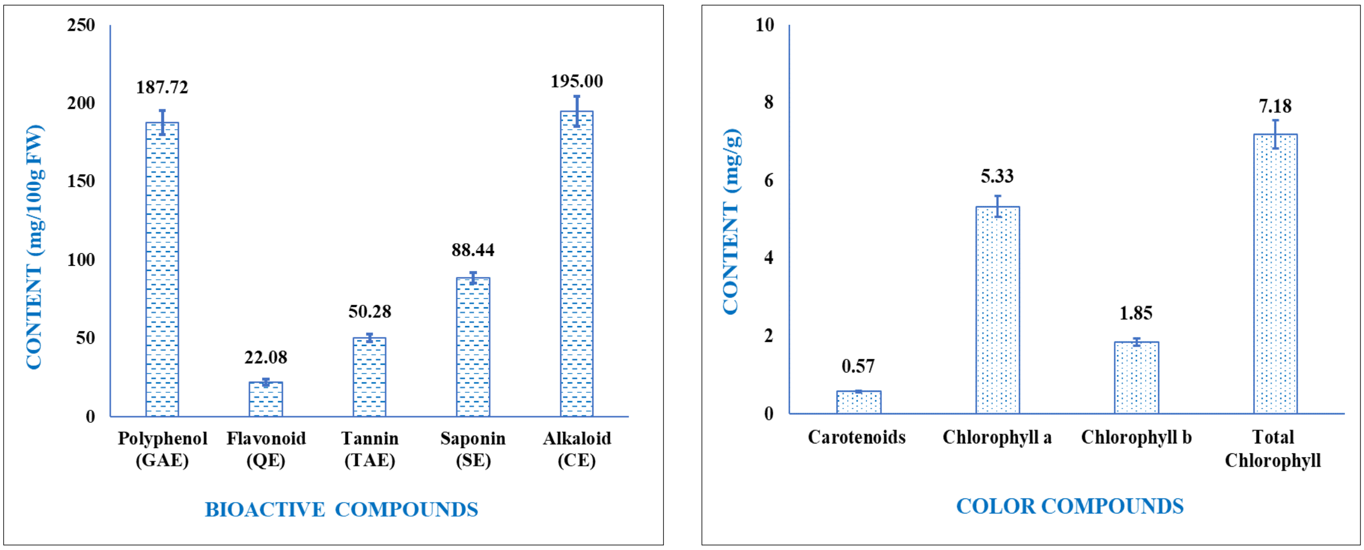

Fig. 2. The content of bioactive and color compounds in ice plant.

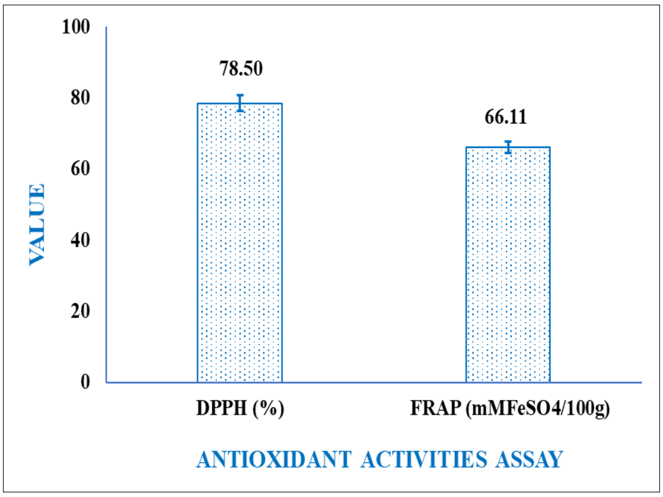

Fig. 3. The antioxidant activities of ethanol extract from fresh ice plant.

75.90-89.80% (22); antioxidant activity (DPPH) of red and green stem ice plant was ranged from 65.4 to 70.9% (44). The antioxidant activity of ethanol extract from ice plants (cultivated in different areas) was 13.35% (Sidi Abd El Rahman), 20.70% (Giza) and 21.39% (El-Kassasin) of DPPH assay (36). The antioxidant activity of ice plant powder determined following the DPPH assay was 75.86% (5). Some leafy vegetables had DPPH assay from 69.05 to 80.21% (24). Some plants had FRAP assay from 16.357 to 404.123 gFeSO4/100g extract (45). The FRAP assay of phenolic and flavonoid extracts from *Malva sylvestris* was 0.04 to 0.15 and 0.05 to 0.59 mM Fe^{2+}/mg dry extract (46).

Polyphenols serve as primary antioxidants of human food and demonstrate antioxidant ability higher than vitamins and carotenoids. Plant phenolics encompass various compounds such as phenolic acids, coumarins, flavonoids, stilbenes and tannins that have been identified in leafy vegetables (47). The concentrations of these polyphenols could explain the recorded antioxidant activity levels in the analyzed leafy vegetables. Importantly, plant extracts rich in polyphenols often display enhanced antioxidant properties, thereby contributing to their medicinal attributes (48).

Conclusion

The nutritional and phytochemical compositions of ice plants grown at the experimental area of An Giang University were found to it contain protein, carbohydrates, ash, fiber, undetectable fat (MDL = 0.02), 14 amino acids (alanine, leucine, lysine, aspartic acid, valine, glutamic acid, glycine, isoleucine, arginine, phenylalanine, serine, histidine, proline and methionine), without tyrosine and threonine and 8 minerals (potassium, sodium, magnesium, phosphorus, calcium, iron, zinc and manganese), without (copper and selenium). Besides, the ice plant also possesses many bioactive compounds such as polyphenols, tannins, flavonoids, saponins, alkaloids, chlorophylls and carotenoids. The ingredients are present in higher concentrations than in some other leafy vegetables. Therefore, the ice drop plant can be considered as a potential leafy vegetable that provides many necessary nutrients for the human body and can be considered as a super food for humans where malnutrition or hidden hunger prevails.

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Authors' contributions

NDT designed experience, wrote and edited articles. VTXT, VTTL and TVK conducted the analytical and statistical data.

Compliance with ethical standards

Conflict of interest: The authors declare that they have no competing interests.

Ethical issues: None

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