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# Effect of Drying Methods on Sensory and Physical Characteristics, Nutrient and Phytochemistry Compositions, Vitamin, and Antioxidant Activity of Grapes Seaweed *Caulerpa lentillifera* Grown in Vietnam

**Nguyen Xuan Hoan[1], Duong Hong Quan[1], Dinh Huu Dong[1], Nguyen Thi Phuong[1], Do Thi Yen[2], Dang Xuan Cuong[3], Hoang Thai Ha[1], Pham Van Thinh[4]**

[1] *Ho Chi Minh University of Food Industry, MOIT, Ho Chi Minh, Vietnam*
[2] *HaNoi University of Science and Technology, Ha Noi, Vietnam*
[3] *NhaTrang Institute of Technology Application and Research, VAST, Khanhhoa, Vietnam*
[4] *Nguyen Tat Thanh University, Ho Chi Minh, Vietnam*

**Abstract.**

The characteristics (sensory, and physical (rehydrate ratio and damage rate)), the content (nutrients (protein, lipid, soluble fiber, and pectin), phytochemistry (polyphenol, chlorophyll, and caulerpin), and vitamin (thiamin, ascorbic acid)), antioxidant activity (total antioxidant, reducing power), and microorganisms of grapes seaweed *Caulerpa lentillifera* commonly culturing at Camranh Bay, Khanh Hoa, Vietnam dried by different methods (infrared freeze-drying, hot-air drying, and sun drying) and harvested on the size (9 to 12 cm), were studied. The results showed that better sensory, less lost (nutrients content, damage rate, phytochemistry composition, vitamin, and antioxidant activity), less microorganism number in infrared freeze-dried grapes seaweeds in comparison to sun drying and hot-air drying. Sensory (18.64), nutrient content lost (protein (6.23 %), lipid (23.53 %), fiber (12.11 %), and pectin (6.06 %)), phytochemistry composition lost (polyphenol (3.57 %), chlorophyll (6.45 %), and caulerpin (7.12 %)), vitamin lost (thiamin (76.3 %), ascorbic acid (67.71 %)), damage rate (7.02 %), rehydrate ratio (94.84 %), activity (total antioxidant (24.85 mg ascorbic acid equivalent $g^{-1}$ DW), reducing power (20.17 mg $FeSO_4$ equivalent $g^{-1}$ DW)), total aerobic bacteria (2.7 x $10^2$, CFU/g), and *Coliforms* (5, CFU/g) was found in infrared freeze-drying. *E. coli*, *Samonella spp.*, *V. cholerae*, *S. aureus*, *V. parahaemolyticus*, and total yeast and mold did not occur in any dried sea grapes. Drying efficiency of grapes seaweeds decreased in order: infrared freeze-drying, hot-air drying, sun drying.

***Keywords:*** *antioxidant activity, drying, nutrient, phytochemistry, sea grapes, vitamin*

## I. INTRODUCTION

Sea grapes *(Caulerpa lentillifera)* naturally distributed in coastal areas of South-East Asian, Japan, Philippines, and the islands of the Pacific region (Avelin et al., 2009). They had been bred from Japan to Vietnam since 2003, and nowadays, cultivated in numerous coastal areas in Vietnam by different companies, for example, Nha Trang, Ninh Thuan, Kien Giang, Phu Yen, Binh Dinh, Binh Thuan. Sea grapes were popular in many countries and named "Green Caviar" because of their high nutrient value and bioactive ingredient. For example, vitamin A, ascorbic acid, unsaturated fatty acids (omega 3) (Nicholas et al., 2014, Thilahgavani and Charles, 2014), minerals (zinc, iron, cobalt, selenium, and valium), caulerpin, polyphenol, chlorophyll (Vu et al., 2017, Xiaolin et al., 2019). Bioactive components of *C. lentillifera* possessed bioactive diverse, for example, antioxidant (Nicholas et al., 2014, Ursula et al., 2005), anti-diabetic, antivirus, anticancer (Nicholas et al., 2014, Kateřina et al., 2018), neurodegenerative (Azadeh and Hermann, 2012, Kanti and Syed, 2009), anti-coagulation, blood pressure regulation, and digestion enhance (Nicholas et al., 2014, Alessandra et al., 2018). Sea grapes have a high-value economy and evaluated as "ginseng" belonging to the century XXI. Sea grapes *C. lentillifera* is useful for antidiabetic (Bhesh and Dong, 2014), antibacterial (*S. aureus* and *S. mutans*) (Faezah et al., 2015), anticoagulant (Althea et al., 2017). Sea grapes contained 95% of water content, grown according to the seasonal, and different transformation, so the storage and the processing of sea grapes are difficult. Sea grapes products in the market are mainly in a fresh product, dry-salt product, and beverages, not a dried product by different drying technology while using demand of sea grapes in many countries is increasing in near years. The study on the drying technology for maintaining nutrient quality, sensory, physical characteristics is necessary for commodity products diverse, growing develop and processing industry of sea grapes.

Previous studies showed there are different drying techniques for fisheries, for example, infrared freeze, sun energy, hot-air, ultrasonic, microwave, freeze-drying, and infrared. The ultrasonic and microwave drying technique was not popular in the industry because of its economic and difference in operation. Many studies also showed the superiority of infrared freeze-drying, sun drying, and hot-air drying, for example, quality stabilization, replication of drying pattern, and production cost.

Thus, the study focused on the effect of different drying methods (infrared freeze-drying, sun drying, and hot-air drying) on sensory, nutrient compositions (protein, lipid, soluble fiber, and pectin), phytochemistry composition (polyphenol, chlorophyll, and caulerpin), vitamin (B1, C), damage rate, rehydrate ratio, activity (total antioxidant, and reducing power), and microorganism of dried sea grapes.

## II. MATERIALS AND METHODS

### 2.1 Material

Sea grapes (*Caulerpa lentillifera* J. Agardh, 1873) got the size of 9 to 12 cm was supplied by Dai Phat Bplus company, Cam Ranh Bay, Khanh Hoa. Sea grapes was intact, not crushed, bright colour, glossy, viscous outside transparent, iridescent bluish colour, good elasticity, and natural fishy smell. They were transferred into the laboratory under 10 $^{o}$C and cleaned using 1 % of seawater for 5 minutes. Sea grapes were then kept in 20 % of sorbitol for 30 minutes after impurities movement. Sea grapes were continuously blanched for 10 seconds at 85 $^{o}$C and drained for 30 minutes for drying study.

**Figure 1. Sea grapes *Caulerpa lentillifera***

### 2.2 Drying investigation

#### *2.2.1 Infrared freeze-drying*

Prepared sea grapes put into the infrared freeze-drying oven that operated at 44 ± 0.1 $^{o}$C with the air velocity of 2.6 m/s until the moisture content of 14 ± 2 %. The distance between sea grapes and the infrared lamp was 19 ± 0.2 cm. The layer thickness of dried sea grapes was 1.8 ± 0.2 cm. The control of the air velocity and the temperature in the oven were by using machine Testo 405 – V1 (German) and dixell XR60C temperature relay, respectively. The distance and the layer thickness measurement were by using the ruler (Figure 2).

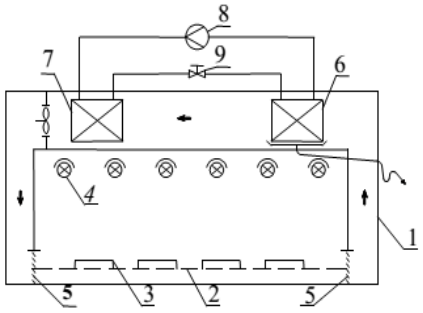



**Figure 2. Oven structure of infrared freeze-drying**

Where in: 1. Oven shell; 2. Net rack of material; 3. Drying materials; 4. Infrared radiation lamp; 5. Wind distribution department; 6. Cooler (Indoor unit); 7. Condenser (outdoor unit); 8. Refrigeration compressor; 9. Throttle valve

#### *2.2.2 Hot-air drying*

Prepared sea grapes put into a hot-air drying oven that operated at 60 ± 0.1 $^{o}$C with forced air convection fans until the moisture content of 14 ± 2%.

#### *2.2.3 Solar energy drying*

The sea grapes were sun-dried on the bamboo net until the moisture content of 14 ± 2%.

### 2.3 Physico-chemical and biological analysis

#### *2.3.1 Sensory and physical characteristics*

*2.3.1.1 Rehydration ratio determination of dried sea grapes*

Rehydration ratio determination of dry sea grapes was by the following equation:

$$W = \frac{(G_2 - G_1)}{G_1} x100\%$$

Where in: $G_1$: Dried sea grapes weighs before water maceration, (g);

$G_2$: Dried sea grapes weighs after water maceration, (g);

*2.3.1.2 Damage rate* determination *of sea grapes*

Determination of damage rate based on the percentage of grapes shedding and seaweeds breaking was by counting. 200 g of sea grapes weighs and counted the total number of grains and seaweed stalks, A (grains). Then, counting the total number of fallen grains and damage stalks, B (grains). The damage rate calculation of sea grapes was final following the formula:

$$X = \frac{B}{A} x100\%$$

*2.3.1.3 Sensory* evaluation

Sensory evaluation was according to the method of colour analysis through the soft Image J, (Natl, Inst of Health, Bethesda, Md, USA (http://rsb.info.nih.gov/ij/)) and camera canon (IXY Digital 510 IS, 12.1 megapixels, Canon Corp, Tokyo, Japan). Dried sea grapes put into the black box for preventing the interference of external light before taking pictures. The pictures were saved under the JPEG style and analysed the colour (red (R), green (G), and blue (B)).

#### *2.3.2 Quantification of nutrient content*

*2.3.2.1 Quantification of protein content*

Protein content was quantified to base on the nitrogen content with the factor 6.25 following the description of the AOAC method (920.103) (AOAC Official Method 920.103-1920)

*2.3.2.2 Quantification of lipid content*

Quantification of lipid content was according to the method AOAC using n-hexane (AOAC Official Method 2003.05). Crude fat in feeds, cereal grains and forages (hexane extraction)

*2.3.2.3 Quantification of soluble fiber content*

Fiber quantification was according to the description of the method AOAC 2011.25 (Eric et al., 2018).

*2.3.2.4 Quantification of pectin content*

Pectin content quantification followed the description of Shelukhina and Fedichkina (1994).

#### *2.3.3 Quantification of phytochemistry content*

*2.3.3.1. Quantification of polyphenol content*

Polyphenol content was according to the method of Vu et al. (2017).

*2.3.3.2. Quantification of chlorophyll content*

Chlorophyll content quantification was according to the description of Priscila et al. (2014).

*2.3.3.3 Quantification of caulerpin content*

Caulerpin content quantification was by using the method of Serena et al. (2012).

***2.3.4 Quantification of vitamin content***

*2.3.4.1 Quantification of thiamin content*

Quantification of thiamin content was according to the method AOAC 953.17 (AOAC Official Method 953.17).

*2.3.4.2 Quantification of ascorbic acid content*

Ascorbic acid content quantification was according to Nicoleta et al. (2012) with the ascorbic acid standard and the absorbance measurement at the wavelength of 700nm.

***2.3.5. Determination of antioxidant activity***

*2.3.5.1 Total antioxidant activity*

Total antioxidant activity determination was according to the method of Dang et al. (2016).

*2.3.5.2 Reducing power activity*

Reducing power activity determination was according to the description of Dang et al. (2016).

***2.3.6 Quantification of microorganisms number***

Determination of total aerobic bacteria was by using the simplate total plate count (Feldsine et al., 2003). Quantification of *Escherichia coli* and *Coliforms* was according to Method 1604 (2002). Quantification of *Salmonella* was according to Denise et al. (2003). *V. cholera* detection was according to the method ISO/TS 21872-1:2017 (ISO/TS 21872-1:2017, 2017). Quantification of *Staphylococcus aureus* was base on the method of AOAC (1995). Quantification of *V. parahaemolyticus* was according to Hara-Kudo et al. (2003). Total yeast and mold was quantified according to the AOAC method (Bird et al., 2015).

## III. RESULT & DISCUSSION

### 3.1. Sensory and physical characteristics

***3.1.1 Sensory characterization***

Sensory characterization of dried sea grapes got the highest value in the infrared freeze-drying method, compared to other methods. The colour value (R, G, and B) of dried sea grapes by infrared freeze-drying, sun drying, and hot-air drying method corresponded to (116, 127, and 103), (78, 95, and 82), and (104, 113, and 98), respectively (Figure 3, 4, and 5), described by Vu et al. (2017) . Sensory characterization of dried sea grapes was ranged in the decreasing order: infrared freeze-drying, hot-air drying, and sun-drying method. Sun-drying seaweed was darker than other methods. Infrared freeze-drying sea grapes gave lightest, compared to other methods.

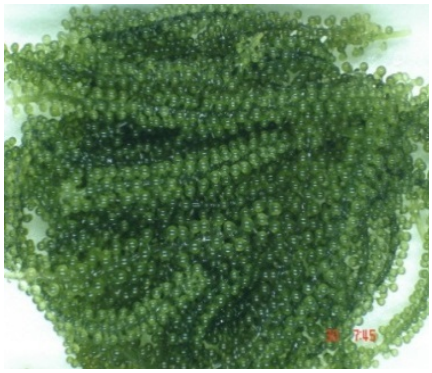
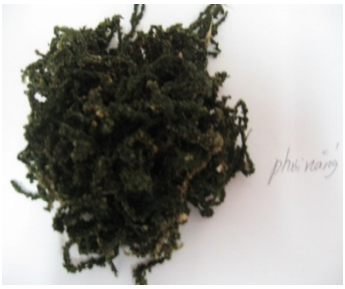


**Figure 3. Fresh sea grapes before drying**

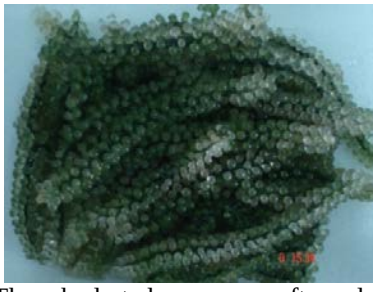


Dried sea grapes under the sun energy

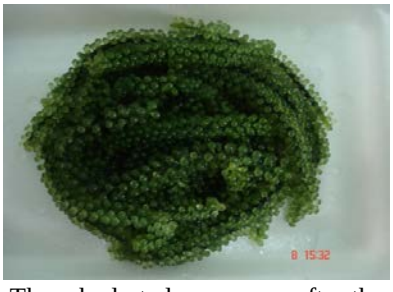
Dried sea grapes under the hot air

Dried sea grapes under the infrared freeze-drying

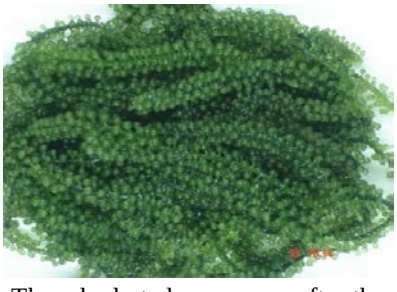
**Figure 4. Sea grapes after drying**



The rehydrated sea grapes after solar energy drying



The rehydrated sea grapes after the hot air drying



The rehydrated sea grapes after the infrared freeze-drying

**Figure 5. The rehydrated sea grapes after drying**

***3.1.2 Rehydrate ratio***

The rehydrate ratio of dried sea grapes by the infrared freeze got the highest value (94.84 %), followed dried algae by the hot air (93.23 %) and the solar energy (92.30 %). During drying, sea grapes were affected by low temperature (44 $^{o}$C) for short drying time (3.5 hours) leading to the denatured protein, similar to the notice of Hoang (2017). Basing on the rehydrate ratio of dried algae could tell that the reversible protein denaturation in cells structure of dried algae by the infrared freeze occurred that not found in another drying. The polysaccharide and protein in dried algae by the solar energy and the hot air was irreversibly denatured more than dried algae by the infrared freeze leading non-restore of hydrophilic sites in polysaccharide and protein back to the initial state, resulting in less water absorption capacity of algae cells.

***3.1.3 Rate of damage***

Damage rate of dried algae decreased in the following order: the infrared freeze, the solar energy, and the hot air. Damage ratio of dried algae got the highest and the lowest value as using the method of hot air and infrared freeze, corresponding to 18.87 % and 7.02 %, respectively. Damage ratio of dried algae by the solar energy was 62.85 % and 168.95 % of dried algae by the hot air and the infrared freeze, respectively. The infrared freeze-drying method supplied the heat on all material from outside to inside causing the inactivation of enzyme and biological metabolism in sea grapes faster than the hot air and the solar energy drying. Therefore the damage rate of dried algae by infrared freeze method was lowest, noticed by Hoang (2017).

**3.2. Nutrient content**

***3.2.1 Total protein content***

Total protein content of dried sea grapes varied from 4.89 to 6.47 (%) and got the average value of 5.68 (%) (Table 1). Protein content lost (6.23 %) was least in infrared freeze-drying method, compared to fresh sea grapes. Protein content was arranged in the decreasing order as follows: infrared freeze-drying method, hot air drying, and solar energy, different from the notice of Elsa et al. (2019) on protein content change of green algae *Ulva* that dried by the convective method. The difference in genus and species of green algae could cause the difference, and the previous study mainly focused on the protein content of *C. racemosa*, except for the study of Nguyen et al. (2011).

***3.2.2 Total lipid content***

Lipid content varied from 1.2 to 2.21 (%), corresponding to hot air drying and fresh algae, respectively. Lipid content of algae drying by the solar energy was 1.03, 0.73, and 0.56 times of the hot air drying, the infrared freeze-drying method, and fresh algae, respectively (Table 1). The difference in lipid content at the hot air drying and the solar energy method was insignificant ($p<0.05$). The lipid content lost of algae drying by the infrared freeze-drying method was least, compared to other drying methods. It was similar to protein content, lipid content of *Caulerpa lentillifera* only find in the notice of Nguyen et al. (2011) on *Caulerpa lentillifera* grown in Taiwan.

***3.2.3 Soluble fiber content***

Fiber content of algae drying by other methods was significant difference ($p<0.05$). Fiber content of fresh algae was 4.21 (% DW) and 1.14 %, 1.62 %, and 1.24 % of dried algae by the infrared freeze-drying method, the solar energy, and the hot air, respectively (Table 1). Similar trend of lipid content, fiber content of dried algae by the hot air was most losses in comparison to other methods. Soluble fiber content that known as an anticancer agent (Dimitrios et al., 2015), did not find in the previous notice on species *C. lentillifera*. The current study noticed in the first on the soluble fiber content of sea grapes *C. lentillifera*.

***3.2.4 Soluble pectin content***

The difference in soluble pectin content between fresh algae and dried algae by the infrared freeze-drying method, between dried algae by the solar energy and the hot air, were insignificant ($p>0.05$). The significant difference in soluble pectin content between dried algae by the infrared freeze-drying method and dried algae by the solar energy and the hot air occurred ($p<0.05$). Soluble pectin content of dried algae by the infrared freeze-drying method was 1.29 times of dried algae by the solar energy ($0.25 \pm 0.01$, %) and the hot air ($0.24 \pm 0.01$, %) (Table 1).

**3.3 Phytochemistry content**

***3.3.1 Polyphenol content***

The polyphenol content of sea grapes got the highest value of $7.02 \pm 0.15$ mg phloroglucinol equivalent $g^{-1}$ DW as drying by the infrared freeze method. The follows the hot air and the solar energy drying, corresponding to $6.45 \pm 0.23$ and $6.23 \pm 0.24$ mg phloroglucinol equivalent $g^{-1}$ DW (Table 1). The highest lost of polyphenol content was at the solar energy drying method. The polyphenol content of fresh sea grapes was 1.04, 1.13, and 1.17 times of the infrared freeze-drying, the hot air drying, and the solar energy drying, respectively. The results were similar to the notice of Pierrick et al. (2018) on freeze-drying of brown algae *Saccharina latissima*. Moreover, polyphenol content was stable more as using the infrared freeze-dry method (Shilpi et al., 2011).

***3.3.2 Chlorophyll content***

Chlorophyll content varied from $729.68 \pm 26.27$ to $745.62 \pm 23.58$ µg chlorophyll equivalent/g DW. Chlorophyll content of dried algae by the solar energy, the infrared freeze, and the hot air was decreased by 11.36 %, 1.59 %, and 9.42 %, compared to fresh sea grapes (Table 1). Chlorophyll content of algae drying by the infrared freeze method corresponded to 111.02 % and 109 % of the solar energy drying and the hot air drying, respectively. It means infrared freeze method was useful for chlorophyll content stabilization (An-Erl et al., 2001).

***3.3.3 Caulerpin content***

Caulerpin content of different dried sea grapes varied from $25.79 \pm 0.92$ to $31.17 \pm 0.65$ µg caulerpin equivalent/g DW. The infrared freeze-drying method maintained caulerpin content in sea grapes better than other drying methods (Table 1). Caulerpin content of the hot air-dried algae was 3% of the infrared freeze-dried algae. The significant difference in caulerpin content occurred for

different dried algae ($p<0.05$). Caulerpin in sea grapes possessed antivirus activity of herpes type 1 (Naoki and Alley, 1991), the maintain of caulerpin content in sea grapes contributed to the ability increase of antivirus herpes 1 in human using dried sea grapes.

**3.4 Vitamin content**

***3.4.1 Thiamin content***

Thiamin content varied from 0.21 to 2.7 mg thiamin equivalent $kg^{-1}$ DW and arranged in the increase order as follows: the hot air drying, the solar energy drying, and the infrared freeze-drying. Thiamin content of algae was lost 92.22 %, 76.3 %, and 75.19 % after drying by the hot air drying, the infrared freeze-drying, and the solar energy drying, respectively (Table 1). Thiamin content lost of algae drying by the hot air drying and the infrared freeze-drying was no significant difference ($p>0.05$). The method of hot air drying caused the highest lost of thiamin content in comparison to other method. Thiamin content in the current study was lower than the notice of Dang et al. (2020).

***3.4.2 Ascorbic acid content***

Ascorbic acid content was the lowest and the highest lost for algae drying by the infrared freeze and the hot air, respectively. Ascorbic acid content of algae drying by the solar energy was 23.44 %, 72.58 %, and 160.71 % of the fresh algae, the infrared freeze-dried algae, and the hot air-dried algae, respectively (Table 1). The lowest lost of ascorbic acid content corresponded to 67.71 % of fresh algae. Sea grapes *C. centillifera* possessed ascorbic acid content lower than *Hydrocotyle sp.* (Dang et al., 2020).

**3.5. Antioxidant activity**

**3.5.1 Total antioxidant activity**

Total antioxidant activity of sea grapes depended on the effect of drying method ($p<0.05$). It was similar to the content of polyphenol, chlorophyll, and caulerpin, the total antioxidant activity (24.85 ± 0.77 mg ascorbic acid equivalent/g DW) got the highest value as using the infrared freeze-drying method, followed by solar energy (22.79 ± 0.76 mg ascorbic acid equivalent/g DW) and the hot air (21.19 ± 0.08 mg ascorbic acid equivalent/g DW) (Table 1). The difference in total antioxidant activity was significant between the infrared freeze-dried algae and dried algae by other different methods. The insignificant difference occurred for algae that dried by solar energy and the hot air. Total antioxidant activity in the current study was higher than the notice of Nguyen et al. (2011) on species *Caulerpa lentillifera* grown in Taiwan.

***3.5.2 Reducing power activity***

Reducing power activity got the highest value (20.17 ± 0.71 mg $FeSO_4$ equivalent/g DW) at the infrared freeze-dried algae, followed dried algae by solar energy and the hot air (Table 1). Dried algae by the hot air possessed reducing power activity corresponding to 91.97 % and 103.5 %, compared to the infrared freeze-dried algae and the solar energy, respectively. Reducing power activity of different dried algae was significant ($p<0.05$). Nguyen et al. (2011) noticed the infrared freeze-drying method was better the thermal drying method, and reducing power activity in the study of Nguyen et al. (2011) was lower than the current study.

***3.5.3 DPPH free radical scavenging activity***

The different drying methods affected DPPH free radical scavenging activity of dried sea grapes ($p<0.05$). DPPH free radical scavenging activity got the highest and the lowest value at the infrared freeze-dried algae (70.55 ± 2.05, %) and solar energy (63.19 ± 2.72, %), respectively (Table 1). DPPH free radical scavenging activity of dried algae by the hot air corresponded to 95.29 % of dried algae by the infrared freeze that was higher than the notice of Shilpi et al. (2011) on brown algae freeze-drying.

**Table 1. Nutrient, phytochemistry, vitamin composition, and antioxidant activities of fresh and different dried sea grapes**

| Targets | Unit | Initial sea grapes | Dried algae | | |
|---|---|---|---|---|---|
| | | | The infrared freeze | The hot air | The solar energy |
| Protein content | (%) | 6.9 ± 0.14 | 6.47 ± 0.23 | 4.89 ± 0.17 | 5.35 ± 0.18 |
| Lipid content | (%) | 2.21 ± 0.09 | 1.69 ± 0.05 | 1.2 ± 0.02 | 1.24 ± 0.04 |
| Soluble fiber content | (%) | 4.21 ± 0.16 | 3.7 ± 0.12 | 2.6 ± 0.11 | 3.4 ± 0.13 |
| Soluble pectin content | (%) | 0.33 ± 0.01 | 0.31 ± 0.01 | 0.24 ± 0.01 | 0.25 ± 0.01 |
| Thiamin content | ppm | 2.7 ± 0.07 | 0.64 ± 0.01 | 0.21 ± 0.01 | 0.67 ± 0.03 |
| Ascorbic acid content | (mg ascorbic acid equivalent/kg DW) | 19.2 ± 0.45 | 6.2 ± 0.18 | 2.8 ± 0.1 | 4.5 ± 0.19 |
| Polyphenol content | mg phloroglucinol equivalent/g DW | 7.28 ± 0.19 | 7.02 ± 0.15 | 6.45 ± 0.23 | 6.23 ± 0.24 |
| Chlorophyll content | µg chlorophyll equivalent/ g DW | 823.17 ± 28.81 | 770.09 ± 25.11 | 725.62 ± 23.58 | 695.68 ± 26.27 |
| Caulerpin content | µg caulerpin equivalent/g DW | 33.56 ± 1.24 | 31.17 ± 0.65 | 27.54 ± 1.05 | 25.79 ± 0.92 |
| Total antioxidant activity | mg ascorbic acid equivalent/g DW | 26.37 ± 1.08 | 24.85 ± 0.77 | 21.19 ± 0.08 | 22.79 ± 0.76 |
| Reducing power activity | mg $FeSO_4$ equivalent/g DW | 21.34 ± 0.62 | 20.17 ± 0.71 | 18.55 ± 0.46 | 17.92 ± 0.54 |
| DPPH free radical scavenging activity | % | 73.2 ± 1.58 | 70.55 ± 2.05 | 67.23 ± 2.76 | 63.19 ± 2.72 |

*2.6 Microorganism number of dried sea grapes*

**Table 2. Microorganism number of dried sea grapes by different methods**

| Microorganism targets | Units | Dried algae | | |
|---|---|---|---|---|
| | | The infrared freeze | The hot air | The solar energy |
| Total antioxidant activity | (Cfu/g) | $2.7x10^2$ | $3.6x10^2$ | $3.6x10^3$ |
| *E. Coli* | (Cfu/g) | - | - | - |
| *Coliforms* | (Cfu/g) | 5 | 11 | 12 |
| *Samonella* | (Cfu/g) | - | - | - |
| *V. cholerae* | (Cfu/g) | - | - | - |
| *Staphylococus aureus* | (Cfu/g) | - | - | - |
| *V. parahaemoliticus* | (Cfu/g) | - | - | - |
| Total mold and yeast | (Cfu/g) | - | 5 | 8 |

The results exhibited the number of the bacterial occurred lowest in the infrared freeze-dried seagrapes. The bacterial number in dried seagrapes decreased according to the following order: the hot air, the solar energy, and the infrared freeze. Total aerobic bacterial and coliforms appeared in dried algae by all three methods. For example, $3.6x10^2$, $3.6x10^3$, and $2.7x10^2$ CFU/g were for total aerobic bacterial, and 11, 12, and 5 CFU/g was for coliforms, corresponding to the solar energy, the hot air, and the infrared freeze, respectively (Table 2). Total mold and yeast occurred in dried algae by all dried algae, except for dried algae by the infrared freeze-drying method that limited the existence of the microorganism in dried algae better than the hot air and the solar energy drying method.

Dried seagrapes by infrared freeze-drying method possessed sensory, nutrition composition, bioactive substances (phytochemistry, and vitamin), physical characteristics, and antioxidant activities better, and microorganism less than dried algae by using the hot air and the solar energy drying method, because of their heat-transfer characterization. The infrared heat impacted everything in algae, the heat impact of the hot air and the solar energy on the algae was from outside to inside. The things led to the metabolism of the biochemistry in algae occurring more than the infrared heat.

## IV. CONCLUSIONS

Different drying methods affected the sensory characteristics, physical characteristics, nutrient compositions, polyphenol content, chlorophyll content, and antioxidant activity of grapes seaweed Caulerpa lentillifera commonly grown in Vietnam. The decrease of nutrient compositions (protein, lipid, fiber, soluble pectin), phytochemistry composition (polyphenol, chlorophyll, and caulerpin), vitamin (thiamin, and ascorbic acid) and antioxidant activity of infrared freeze-dried grapes seaweed was lowest, compared to other dried algae, also found in damage rate and microorganism number. The rehydrate ratio of infrared freeze-dried seaweed grapes was highest in comparison to sun drying and hot-air drying. All dried sea grapes did found *E. coli, Samonella spp., V. cholerae, S. aureus, V. parahaemolyticus*, and total yeast and mold. The infrared freeze-drying method was the most efficiency, followings hot-air drying and sun drying.

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