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미역과 매생이의 총 페놀함량 및 항산화성

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Total Phenolic Contents and Antioxidant Activities of *Undaria pinnatifida* and *Capsosiphon fulvescens*

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Abstract

This study compared the total phenolic contents and antioxidant activities of two seaweed cultivars, *Undaria pinnatifida* (UP) and *Capsosiphon fulvescens* (CF), subjected to different drying methods. UP and CF were dried under two different conditions: vacuum drying (VD) at 20℃ and hot-air drying (HD) at 60℃. After drying, the total phenolic content, DPPH, and nitrite scavenging activities of the water extracts were determined. Total phenolic contents were 101.94 mg/100 g for UP and 171.35 mg/100 g for CF upon VD-20, and these values were significantly decreased to 67.59 mg/100 g for UP and 141.48 mg/100 g for CF upon HD-60. UP upon VD-20 and HD-60 had 46.17% and 35.20% DPPH radical scavenging activity, whereas CF upon VD-20 and HD-60 scavenged 57.73% and 35.22%, respectively. UP upon VD-20 and HD-60 had 40.36% and 40.01% nitrite scavenging activity at pH 1.2, whereas CF upon VD-20 and HD-60 scavenged 72.35% and 55.24%, respectively. Nitrite scavenging activities of UP and CF were reduced at pH 3.0.

Key words: *Undaria pinnatifida*, *Capsosiphon fulvescens*, drying method, polyphenol, antioxidant activity

I. Introduction

Seaweed has a long history as a food resource and popular food ingredient in Korea. *Undaria pinnatifida* and *Capsosiphon fulvescens* are most often served in soups, salads, and side dishes. The phenolic compounds and dietary fiber in seaweed are known to have a variety of health benefits (Abbott IA 1989).

Phenolic compounds act as electron donors and hence protect living cells and tissues from free radical-mediated oxidative stress such as aging and human degenerative diseases (Finkel T & Holbrook NJ 2000, Urquiaga I et al. 2000). As such, phenolic compounds have attracted considerable attention due to their health benefits, which has encouraged food scientists to discover and explore food sources rich in phenolic compounds. Seaweeds are known to contain considerable amounts of polyphenols as well as antioxidant capacity (Ragan MA & Glombitza KW 1986, Audibert L et al. 2010). Dietary phenolic compounds, particularly in a highly acidic environment such gastric conditions, are reported to reduce nitrite to NO (Weitzberg E & Lundberg JO 1998, Rocha BS et al. 2009). Recently, this mechanism has emerged as an alternative health benefit of dietary polyphenols (Schewe T et al. 2008). By promoting the reaction from nitrite to NO, polyphenol might actually inhibit the formation of carcinogenic nitrosamines by yielding a molecule (NO) that plays a role in vessel homeostasis and the immune system (Archer MC 1989).

In Korea, seaweeds are usually processed to dried products in order to reduce their moisture content and increase shelf life. Unfortunately, heat-labile antioxidants can be lost through the drying process. Indeed, the effect of drying conditions on the destruction of antioxidants in seaweeds has been rarely reported.

Therefore this study investigated the changes in the total phenolic contents and antioxidant activities of seaweeds subjected to different drying methods.

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II. Materials and Methods

1. Chemicals

All chemicals and solvents were purchased from Sigma Chemical Co. (St. Louis, Mo, USA), and all other reagents were of analytical grade.

2. Sample preparation

Fresh *Undaria pinnatifida* (UP from Namhae) and *Capsosiphon fulvescens* (CF from Wando) were purchased from a local market (Pusan, South Korea). UP and CF were thoroughly washed, randomly sliced, and stored at -20℃ until used. The samples were dried under a vacuum at 20℃ (VD-20) using a Vacuum Dryer (HB-501V, Hanbaek Scientific Tech., Bucheon, Korea) and with hot-air at 60℃ (HD-60) using a Heat Dryer (KED-10, Korea Medi Co., Daegu, Korea).

Each dried sample (50 g) was ground, sieved through 40 mesh, and then extracted with 500 mL of water at 80℃ for 2 h by continuous shaking at 120 rpm. The water extracts were then centrifuged at 8000 rpm for 20 min. The supernatants were clarified by filtering through Whatman No.2 filter paper.

3. Measurement of total phenolic contents

The total phenolic contents of aqueous extracts were determined using the Folin-Ciocalteu colorimetric method with some modifications (Ragazzi E & Veronese G 1973, Sanoner P et al. 1999). Briefly, each extract (2 mL) was mixed with 2 mL of 50% Folin-Ciocalteu reagent and 2 mL of 10% Na_2CO_3. After 1 h of incubation at room temperature, the absorbance was measured at 700 nm using a Spectrophotometer (UV-1601, Shimadzu Co., Kyoto, Japan). The results were expressed as tannic acid equivalents (mg tannic acid/100 g extract), and the values were presented as the means of triplicate analyses.

4. Measurement of DPPH radical scavenging activity

The DPPH radical scavenging activity of each extract was measured according to the method of Mensor LL et al. (2001) with slight modifications. A 5 mL aliquot of 0.2 mM DPPH solution in 95% ethanol was incubated with 0.5 mL of the extract. The reaction mixture was then shaken and incubated for 10 min at room temperature. DPPH radical scavenging capacity was monitored at an absorbance of 517 nm and determined by comparison with an ethanol control. The percentage (%) of DPPH radical scavenging activity was calculated by the following equation: Radical scavenging activity (%) = $[(A_c - A_s) / A_c] \times 100$, where Ac is the absorbance without sample and As is the absorbance with sample. All extracts were analyzed in triplicate.

5. Measurement of nitrite scavenging activity

Nitrite scavenging activity was determined under different pH conditions (pH 1.2 and 3.0) by measuring absorbance (Kato H et al. 1987). A 1 mL aliquot of sample mixed with 1 mL of 1 mM $NaNO_2$ was diluted in water to 10 mL and then adjusted to pH 1.2 and 3.0 using 0.1 N HCl. The reaction mixture was incubated at 37℃ for 1 h. Then, 1 mL of the reaction mixture was mixed with 5 mL of 2% acetic acid and 0.4 mL of Griess reagent, followed by incubation at room temperature for 15 min. The absorbance was measured at 520 nm in order to measure the residual amount of nitrite. Nitrite scavenging activity (%) was calculated using the following equation: Nitrite scavenging activity (%) = $\{1 - (A_{abs} - C_{abs})/B_{abs}\}$, where A_{abs} is the absorbance at 520 nm after incubation of the 1 mM $NaNO_2$ solution sample at 60 min, B_{abs} is the absorbance at 520 nm before incubation with $NaNO_2$ solution, and C_{abs} is the absorbance at 520 nm with the test sample.

6. Statistical analysis

Statistical analyses were performed using SPSS version 12.0 for Windows (SPSS, Inc., Chicago, IL). All results are expressed as mean ± standard deviation. The differences in the results between groups were statistically verified by *t*-test.

III. Results and Discussion

1. Phenolic contents

UP and CF were dried by vacuum and hot-air drying, followed by extraction with hot water. The amounts of phenolic compounds in water extracts are shown in Table 1. Total phenol contents upon VD-20 were 101.94 mg/100 g in UP and 171.35 mg/100 g in CF, and those at HD-60 were significantly decreased to 67.59 mg/100 g in UP and 141.48 mg/100 g in CF. The results show that vacuum drying at lower temperature was better at preserving phenolic compounds than hot-air drying (Table 1).

The influence of the drying process on the stability of phenolic compounds remains slightly controversial. Ballis-

Table 1. Total phenolic contents of *Undaria pinnatifida* and *Capsosiphon fulvescens* dried using different drying methods

Drying method	*Undaria pinnatifida*	*Capsosiphon fulvescens*
VD-20[1)]	101.94±1.66[2)]	171.35±4.47
HD-60	67.59±1.57	141.48±1.73
p-value	0.000	0.003

[1)] VD-20 & HD-60 indicate vacuum drying at 20℃ and hot-air drying at 60℃, respectively.
[2)] Values are represented in mg tannic equivalent/100 g extract as mean±SD(n=3).

treri G et al. (2009) reported that sun-drying caused a substantial loss of phenolic compounds in pistachios. On the other hand, some have reported that sun-drying and high temperature processing actually enhanced the total polyphenol content. The total content of polyphenols was increased significantly after sun-drying, whereas a significant amount of antioxidants and carotenoids was lost (Cardona JA et al. 2009). Del Caro A et al. (2004) found that higher amounts of polyphenols were found in prunes dried at high temperature (85+75℃) and not at low temperature (60℃), which can be explained by the activity of polyphenol oxidase at relatively low temperature destroying phenol compounds in the samples. Some other studies (Dewanto V et al. 2002, Dewanto V et al. 2002, Gahler S et al. 2003) also reported that heat treatment of tomato and sweet corn resulted in significantly enhanced amounts of polyphenol compounds by liberating phenol compounds from the cell wall. In this study, however, the phenol contents of seaweeds were significantly decreased with increasing temperature.

2. DPPH radical scavenging activity

The effects of drying conditions on the DPPH radical scavenging activity (%) of water extracts of seaweeds are presented in Table 2. UP demonstrated 46.17% DPPH radical scavenging activity upon VD-20. After hot-air drying at 60℃, the DPPH radical scavenging activities were significantly reduced to 35.2%. The water extract of CF dried by vacuum at 20℃ demonstrated 57.73% DPPH radical scavenging activity. Hot-air drying at 60℃ significantly reduced DPPH radical scavenging activities to 35.22%.

DPPH radical scavenging activity seems highly related to the total phenolic content (Piga A et al. 2003, Del Caro A et al. 2004). Vacuum-dried seaweeds preserved higher amount of phenolic compounds and also exhibited higher DPPH radical scavenging activities than hot-air dried seaweeds (Table 2).

Table 2. DPPH radical scavenging activities of *Undaria pinnatifida* and *Capsosiphon fulvescens* dried using different drying methods

Drying method	*Undaria pinnatifida*	*Capsosiphon fulvescens*
VD-20[1)]	46.17±2.52[2)]	57.73±0.72
HD-60	35.20±1.11	35.22±0.99
p-value	0.008	0.000

[1)] VD-20 & HD-60 means vacuum drying at 20℃ and hot-air drying at 60℃, respectively.
[2)] Values are represented in mg tannic equivalent/100 g extract as mean±SD(n=3).

3. Nitrite scavenging activity

The effects of drying conditions on the nitrite scavenging activity of seaweeds at pH 1.2 and pH 3.0 are shown in Table 3. UP upon VD-20 showed 40.36% and 31.46% nitrite scavenging activity at pH 1.2 and pH 3.0, respectively. CP treated with VD-20 and HD-60 demonstrated 72.35% and 55.24% nitrite scavenging activities at pH 1.2, respectively, and these were significantly reduced to 35.47% and 27.43% at pH 3.0. Obviously the nitrite scavenging activities of CF were influenced by the drying conditions and pH. Nitrite scavenging activities were significantly higher in the vacuum-dried samples and under more acidic conditions. The big difference between the nitrite scavenging activities of UP and CF was possibly due to structural differences in the polyphenols, as the reduction of nitrite is dependent on phenol structure (Gago B et al. 2007) (Table 3).

In conclusion, UP and CF are good sources of polyphenols. Especially, CF with its higher polyphenol content showed higher DPPH and nitrite scavenging activities than

Table 3. Nitrite scavenging activities of *Undaria pinnatifida* and *Capsosiphon fulvescens* dried using different drying methods

Seaweeds	Drying method	Nitrite scavenging activity	
		pH 1.2	pH 3.0
Undaria pinnatifida	VD-20[1)]	40.36±0.74[2)]	31.46±1.11
	HD-60	40.01±1.39	34.16±0.48
	p-value	0.725	0.036
Capsosiphon fulvescens	VD-20	72.35±0.77	35.47±0.77
	HD-60	55.24±1.00	27.43±0.80
	p-value	0.000	0.000

[1)] VD-20 & HD-60 means vacuum drying at 20℃ and hot-air drying at 60℃, respectively.
[2)] Values are represented in mg tannic equivalent/100 g extract as mean±SD(n=3).

UP. The results of this study demonstrate that the total phenol contents and antioxidant capacities of seaweeds are dependent upon the drying conditions.

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