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Effect of adding ascorbic acid and glucose on the antioxidative properties during storage of dried carrot

Yue-Horng Yen [a], Chia-Ho Shih [a], Ching-Hui Chang [b,*]

[a] Department of Bioindustry Technology, Da-Yeh University, 112 Shan-Jiau Road, Da-Tsuen, Changhua 515, Taiwan
[b] Eco-Materials, Industrial Technology Research Institute, 8 Gongyan Road, Liujia Shiang, Tainan County, Taiwan

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Abstract

In this study, carrots were treated with ascorbic acid (0.1%) in a glucose (1.0%) solution (AA-Glu), and then freeze-dried and hot-air-dried to investigate the effects on their antioxidant content after 30 days of storage. The antioxidant components were extracted from the carrot samples using methanol. To assess antioxidative properties, tests measured the samples' reducing power, α,α-diphenyl-β-picrylhydrazyl (DPPH) radical scavenging activity, and ferrous ion chelating power. The above antioxidative properties of carrot extracts were compared with α-tocopherol and butylated hydroxyanisole (BHA). The analysis of antioxidant compounds included the total amount of ascorbic acid, total amount of phenolics, total amount of flavonoids, and carotenoids. The analysis showed that the samples immersed in AA-Glu solution prior to drying exhibited a higher antioxidative property than those not immersed.

Keywords: Carrot; Antioxidant; Antioxidative activity; Drying; Storage

1. Introduction

Current dietary guidelines recommend increasing the amount of fruits and vegetables in one's diet. These rich sources of antioxidants may prevent cancer and coronary artery diseases. Indeed, many studies have shown that a close relationship exists between the intake of vegetables and the prevention of cancer (Borek, 2005; Byers & Guerrero, 1995; Krinsky, 1989a; Marques-Vidal, Ravasco, & Camilo, 2006; Meyskens & Manetta, 1995; Sies & Krinsky, 1995; Temple & Gladwin, 2003; Zhang, Talalay, Cho, & Posner, 1992).

Carrots, in particular, are noted for their rich antioxidants, especially β-carotene (Chen, Peng, & Chen, 1996). In recent years, worldwide consumption of carrots has been steadily increasing because of their nutritional benefits (Yu, Zhou, & Parry, 2005). Carrots carry other potentially beneficial health effects, boasting anti-carcinogenic, anti-aging, antioxidant, and immune-boosting properties, as well as the pro-vitamin A activity of some carotenoids, all of which add to their importance in the diet (Rodriguez-Amaya, 1993).

Carrots contain not only nutritional antioxidants such as vitamins A, C, and E, but also a great quantity of non-nutritional antioxidants, such as β-carotene, carotenoids, flavoniods, flavones, phenolics compounds, etc. (Alasalvar, Grigor, Zhang, Quantick, & Shahidi, 2001; Bao & Chang, 1994; Havsteen, 1983; Hudson & Lewis, 1983; Takahama, 1985). As consumers move toward functional foods with specific health effects, scientists and food manufacturers have also taken an interest in the potential of the antioxidant constituents of carrots to maintain health (Loliger, 1991).

After harvesting and processing however, carrots have generally been considered to have lower nutritional value than when they are fresh. This is mainly due to the loss of nutritional compounds such as vitamins and carotenoids. Meanwhile, bitterness and an oxidized flavor may

* Corresponding author. Tel.: +886 6 6939334; fax: +886 6 6939282.
E-mail address: chinghui@itri.org.tw (C.-H. Chang).

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develop in carrots during processing and storage (Burg & Fraile, 1995; Galindo et al., 2004; Galindo et al., 2005; Lathrop & Leung, 1980; Murcia, Lopez-Ayerra, Martinez-Tome, Vera, & Garcia-Carmona, 2000; Rao, Lee, Katz, & Cooley, 1981). Mayer-Miebach and Spie (2003) investigated the influence of cold storage and blanching on the carotenoid content of carrots, and found that within 8 weeks of cold storage at 1 °C and 97% humidity, the raw carrots lost about 30% of their initial total carotenoid content (Mayer-Miebach & Spie, 2003). To reduce this loss in quality, many processing methods have been used, such as 0 °C storage with a relative humidity of 93–98% (Salunkhe & Desai, 1984). Moreover, Alasalvar, Al-Farsi, Quantick, Shahidi, and Wiktorowicz (2005) found that nitrogen treatment could be used to maintain the quality and nutritional properties of carrots in storage (Alasalvar et al., 2005). Furthermore, Li and Barth (1998) studied an edible coating that improved carotene retention in lightly-processed carrots during post-harvest storage, finding that the carotene retention was 15% greater in treated carrots than untreated over a 28-day period.

This study explored the effects of ascorbic acid and glucose on the antioxidative properties of dried carrots. Freeze-dried (FD) and hot-air-dried (AD) processed carrots were used. Antioxidant activity was assessed by its reducing power, DPPH radical scavenging activity, and ferrous ion chelating power. In addition, the total amounts of phenolics, flavonoids, ascorbic acid, and β-carotene were measured.

2. Materials and methods

2.1. Chemicals

All chemicals used were of analytical grade. Sodium nitrite, (+)-catechin, aluminum chloride, sodium carbonate, sodium hydroxide, methanol, hexane, acetone, ascorbic acid, gallic acid, β-carotene, 2,6-dichlorophenolindophenol (DIP), 2,2-diphenyl-1-picrylhydrazyl (DPPH), butylated hydroxyanisole (BHA), α-tocopherol (Toc) and Folin-Ciocalteu reagent were obtained from Sigma (USA). Ferric chloride, metaphosphoric acid, trichloroacetic acid, and potassium ferricyanide was purchased from Katayama (Japan).

2.2. Samples preparation

Ten kilograms of regular red carrot (*Daucus carota L.*), purchased from the local supermarket were used. All the carrots were cleaned, cut into cubes of 10 mm × 10 mm × 4 mm, and blanched by steam for 1 min at 103 °C before processing. About 5 kg carrots were immersed in 5 l of ascorbic acid (0.1%, w/v) with glucose (1.0%, w/v) solution (AA-Glu), and then dried by freeze-drying (FD) and hot-air-drying (AD). The other carrots were not immersed before being dried by FD and AD. All of the products of FD and AD were separated into two parts, one part of them was stored for 30 days at 35 °C, the other part was tested after drying. All of the samples were extracted with methanol and analyzed for the antioxidant components and antioxidative activity. The FD treatment was operated at −50 °C, 5 Pa, for 24 h in a freeze dryer (FD-1000, Eyela, Japan). The AD process was conducted in a hot-air-oven (DK63, Yamato, Japan) at 80 °C for 1 h and then moved to 60 °C for 8 h. After FD or AD treatments, the products were then ground to powder, packed and stored at −40 °C until use.

2.3. Ascorbic acid

Ascorbic acid content was quantitatively determined according to the modified 2,6-dichlorophenolindophenol (DIP) method described by Klein and Perry (Klein & Perry, 1982). Each carrot sample (0.5 g) was extracted by 50 ml, 1% metaphosphoric acid (v/v) for 1 h. The extract was centrifuged at 3000*g* in a centrifuge (CR22E, Hitachi, Japan) at room temperature (25 °C) for 15 min. One millilitre supernatant was added to 9 ml of 0.05 mM DIP and mixed for 15 s, then the absorbance was measured at 515 nm versus the blank by an UV–vis spectrophotometer (Unikon 930, Kontron, Italy). The standard curve was obtained within the range of 0.0–500.0 μg ascorbic acid per ml.

2.4. Total phenolic content

The amounts of total phenolics were analyzed by spectrophotometrically using the modified Folin-Ciocalteu colorimetric method (Eberhardt, Lee, & Liu, 2000; Singleton, Orthofer, & Lamuela-Raventos, 1999). Each sample (0.5 g) was extracted with 50 ml methanol for 1 h. Each methanolic extract (ME) was diluted to 1:5 (v/v) with DI water. Diluted extract (125 ml) was mixed with 0.5 ml of DI water in a test tube followed by addition of 125 μl of Folin-Ciocalteu reagent (FCR) and allowed to stand for 6 min. Then, 1.25 ml of 7% sodium carbonate solution was added and the final volume was made up to 3 ml with DI water. Each sample was allowed to stand for 90 min at room temperature (25 °C) and the absorbance was measured at 760 nm using an UV–vis spectrophotometer. The linear reading of the standard curve was from 0 to 600 μg of gallic acid per ml.

2.5. Total flavonoid content

Total flavonoid content of the carrot extracts was determined using a modified colorimetric method described previously (Dewanto, Wu, Adom, & Liu, 2002; Zhishen, Mengcheng, & Jianming, 1999). MEs or (+)-catechin standard solutions (250 μl) were mixed respectively with 1.25 ml DI water and 75 μl of 5% $NaNO_2$ solution, then mixed for 6 min. After that, 150 μl of 10% $AlCl_3$solution was added and mixed for 5 min. The further 0.5 ml of 1 M NaOH was added and the total volume was made

up to 2.5 ml with DI water. Sample absorbance was read at 510 nm against a prepared blank using UV–vis spectrophotometry.

2.6. β-Carotene content

The β-carotene was determined according to Prakash, Jha, and Datta (2004). Dried carrot sample (2 g) was placed in a 250 ml flask and 40 ml of acetone was added. A stirrer was used to aid extraction of the carotene and the process was continued until the residue became colorless. The acetone extract was filtered and petroleum ether (100 ml) was added along with a squeeze of sodium sulphate (to absorb any moisture) were placed in a separating funnel and shaken for 1 min. Two distinct layers were formed of which the yellow upper layer was collected and the lower layer was drained off to another separating funnel. The lower layer solution was again extracted with petroleum ether (100 ml) and the upper yellow layer was collected. Combined the petroleum ether extracts in a volumetric flask and the volume was made up to 250 ml. An aliquot of this solution was placed in a cell of a spectrophotometer and the absorbance at 452 nm was measured for determination of the β-carotene content of the carrot sample. The curve was obtained within the range of 0–5 μg β-carotene per ml.

2.7. Reducing power

A method developed by Oyaizu (1988) was employed for the determination of reducing power. Different weighted dried samples (100–1000 mg) were mixed with 50 ml methanol to prepare samples with the weight to volume ratios of 2, 4, 8, 12, 16, and 20 mg/ml. The MEs were then filtered in vacuum, and tested for antioxidant activities. Ten millilitres of MEs of carrot samples along with methanolic solutions of α-tocopherol and BHA were mixed with 2.5 ml phosphate buffer (0.2 M, pH 6.6) and 2.5 ml of 1% potassium ferricyanide. The mixture was reacted in a 50 °C water-bath for 20 min, then rapidly cooled (0 °C, 5 min), and mixed with 2.5 ml, 10% trichloroacetic acid for 5 min, then centrifuged at 3000*g* for 10 min. Five millitres of the supernatant mixing with 5 ml of DI water and 1 ml of 0.1% ferric chloride was left to stand for 10 min. The absorbance was then detected at 700 nm and used as the reducing power indicator.

2.8. DPPH radical scavenging activity

A method according to Shimada, Fujikawa, Yahara, and Nakamura (1992) was used to detect the DPPH radical scavenging activity. Five milliliters of the test solutions, including MEs of carrot samples, α-tocopherol, and BHA solutions, were mixed with 1 ml of freshly prepared 1 mM DPPH methanolic solution, respectively, and left to stand for 30 min prior to being spectrophotometrically detected at 517 nm. The percentage of DPPH scavenging activity is expressed by [1 − (test sample absorbance/blank sample absorbance)] × 100 (%).

2.9. Ferrous ion chelating power

The method proposed by Decker and Welch (1990) was adopted. Five milliliters of the test solutions, including MEs of carrot samples, α-tocopherol, and BHA, were mixed with 0.1 ml of 2 mM $FeCl_2$ and 0.2 ml of 5 mM ferrozine solutions and allowed to react for 10 min. The absorbance at 562 nm of the resulting solutions was measured and recorded. The percentage of ferrous ion chelating ability is expressed by [1 − (test sample absorbance/blank sample absorbance)] × 100 (%).

2.10. Statistical analysis

All the analyses of antioxidative components values were expressed as mean ± SD mg per grams of carrot for three replications basis on dry matter (DM). The possible correlation between the antioxidant activities and analyses of antioxidative components of the extracts was analyzed by analysis of variance (ANOVA) using Statview. Differences at $P < 0.05$ were considered significant.

3. Results and discussion

3.1. Quantitative analysis of antioxidative components

Carrots were either immersed in the solution before drying, or not immersed. The samples were labeled I or NI. The carrots were then processed using FD or AD. The dried carrots were analyzed before storage (NS) and after storage (S).

The amount of ascorbic acid (AA) in various carrots is shown in Table 1. In this investigation, the AA content of air-dried samples was significantly lower than that of freeze-dried samples. The results illustrated that low-temperature processing (FD) had only a small effect on the AA content. High-temperature treatment (AD), however, led to a significant decrease in AA. The heating process might speed up AA oxidation, and, accordingly, result in a loss of ascorbic acid in carrots. Furthermore, the AA content of carrot samples decreased when carrots were stored at 35 °C for 30 days. However, both I-FD-NS and I-FD-S showed more effective AA retention in carrots than the other samples. NI-FD-NS had 26% more AA than NI-FD-S. I-FD-S resulted in an AA level drop 5% greater than I-FD-NS. The content of AA in NI-AD-S decreased 1% more than NI-AD-NS, but in I-AD-S the content dropped by 6% more than in I-AD-NS. The AA contents of both NI-AD-NS and NI-AD-S showed no significant difference, and the amount of AA retained was the lowest of all the samples. This investigation clearly demonstrates that carrots immersed in an AA-Glu solution before drying retain more ascorbic acid. The result may indicate that the immersing solution acts like an edible coating, preventing

Table 1
Antioxidant composition (mg/g DM) in carrot with various treatment (means ± standard error, $n = 3$)

Sample	Ascorbic acid	Total phenolics	Total flavonoids	β-Carotene	TAC[A]
NI-FD-NS	8.62 ± 0.14^{cB}	3.72 ± 0.13^{a}	3.02 ± 0.11^{b}	0.24 ± 0.01^{b}	15.54
NI-FD-S	6.53 ± 0.27^{e}	3.34 ± 0.15^{bc}	2.84 ± 0.06^{b}	0.11 ± 0.01^{e}	12.71
I-FD-NS	10.41 ± 0.18^{a}	3.71 ± 0.17^{a}	2.93 ± 0.12^{b}	0.28 ± 0.02^{a}	17.28
I-FD-S	9.95 ± 0.12^{b}	3.71 ± 0.18^{a}	2.81 ± 0.08^{b}	0.21 ± 0.01^{cd}	16.61
NI-AD-NS	7.53 ± 0.14^{d}	3.05 ± 0.15^{c}	2.23 ± 0.08^{c}	0.20 ± 0.01^{d}	12.90
NI-AD-S	7.42 ± 0.20^{d}	2.52 ± 0.07^{d}	1.85 ± 0.10^{d}	0.22 ± 0.01^{bcd}	11.92
I-AD-NS	8.84 ± 0.52^{c}	3.53 ± 0.11^{ab}	3.34 ± 0.09^{a}	0.25 ± 0.02^{ab}	15.85
I-AD-S	8.33 ± 0.41^{c}	3.51 ± 0.11^{ab}	2.92 ± 0.08^{b}	0.23 ± 0.01^{bc}	14.93

Abbreviate with different treatments of sample:
NI or I: carrot was not immersed or immersed with ascorbic acid (0.1%, w/v) and glucose (1.0%, w/v) solution, respectively.
NS or S: sample not storage (or storage) at 35 °C, 30 days, respectively.
FD: freeze-dried.
AD: hot-air-dried.
[A] Total antioxidant content: the sum of the amount of ascorbic acid, total phenolic, total flavonoids and β-carotene.
[B] Values bearing different superscripts in a column are significantly different ($P < 0.05$).

chemical deterioration (oxidation) that turns ascorbic acid into dehydroascorbic acid (Gregory, 1996).

The total phenolics (TP) content of the various carrot samples is shown in Table 1. Hot-air-dried (AD) carrots contained a lower TP content than FD processed ones in this investigation, a result confirmed by previous research (Asami, Hong, Barrett, & Mitchell, 2003). After 30 days, the NI-FD-S and NI-AD-S samples showed significant TP reductions: 11% and 17% less than NI-FD-NS and NI-AD-NS, respectively. However the carrots immersed in AA-Glu solution showed no change in the TP content after 30 days, (I-FD-S compared to I-FD-NS, and I-AD-S compared to I-AD-NS). These results revealed that carrots immersed in the solution were able to retain phenolics during storage at 35 °C for 30 days.

Osawa (1994) noted a number of phenolic compounds with strong antioxidant properties that have been identified in plant extracts. The antioxidant properties of phenolic compounds is due mainly to their redox properties, which can play an important role in absorbing and neutralizing free radicals, quenching singlet and triplet oxygen, or decomposing peroxides. Rice-Evans, Miller, Bolwell, Bramley, and Pridham (1995) postulated that phenolic compounds also have metal chelating potential. In addition, Veloglu, Mazza, Gao, and Oomah (1998) described the antioxidative and free radical scavenging properties of polyphenolic compounds in several plant extracts. They also suggested that polyphenolic compounds can reduce the risk of cardiovascular diseases in humans.

The total amount of flavonoids (TF) in various treated carrot samples is shown in Table 1. From this investigation, the carrots immersed in AA-Glu solution, retained more flavonoids after 30 days, than untreated carrots. NI-FD-NS and NI-AD-NS contained 3.0 and 2.2 mg/g DM, respectively. After 30 days, the amount of TF was 2.8 and 1.8 mg/g DM in NI-FD-S and NI-AD-S, respectively. The immersed carrot samples before storage, I-FD-NS and I-AD-NS, had TF contents of 2.9 and 3.3 mg/g DM, respectively. After storage for 30 days, the retention TFs was 97% in I-FD-S and 88% in I-AD-S. The results demonstrate that the immersion treatment could lead to better retention of flavonoids.

Le Gall et al. (2003) mentioned several flavonoid compounds such as naringenin, chalcone, rutin (quercetin-3-*O*-rutinoside), etc. and described how the chemical structure (a C6-C3-C6 configuration consisting of two aromatic rings joined by a three-carbon link) of these flavonoids could act as good hydrogen and electron donors and therefore exhibit considerable antioxidative ability.

Table 1 also shows the alteration in the content of β-carotene during storage at 35 °C for 30 days. As in our tests with ascorbic acid, TP and TF, the amount of β-carotene retained was higher when samples were immersed in the AA-Glu solution. Pesek and Warthesen (1988) found that amount of β-carotene decreased as storage temperature and time increased. In our study, the amount of β-carotene dropped from 0.24 mg/g DM in NI-FD-S to 0.11 mg/g DM in NI-FD-NS, a 54% reduction (Table 1). However, the β-carotene content in I-FD-NS went from 0.28 to 0.21 mg/g DM after 30 days (I-FD-S), a 29% decrease. The amount of β-carotene in NI-AD-S (0.22 mg/g DM) showed a 27% decrease from NI-AD-NS (0.30 mg/g DM). In the treated samples, I-AD-S had β-carotene content of 0.23 mg/g DM, dropped down from 0.25 mg/g DM in I-AD-NS, a change in content of only 8%. The untreated samples were clearly more unstable than those treated with the AA-Glu solution, resulting in more degradation of β-carotene.

Chen et al. (1996) noted that the carotenoids in carrots contain a highly unsaturated molecule, so pigments are subject to isomerization, which causes color loss and oxidation, lowering the nutritional value of the carrot when stored. Moreover, Pesek and Warthesen (1988) pointed out that many reactions such as photoisomerization and photodegradation can occur simultaneously and competitively when carotenoids are exposed to light, with the degree these reactions depending upon the intensity and temperature of the light and on the presence of a catalyst.

Carrots treated by immersion in AA-Glu solution can be protected from light and heat.

The beneficial effects of β-carotene to human health have been well documented. For instance, β-carotene has been found to reduce the risk of cancer (Borek, 2005; Brandt & Goldbohm, 2006; Krinsky, 1989b), to increase immune response (Prabhala, Garewal, Meyskens, & Watson, 1990) and to protect against liver damage (Zamora, Hidalgo, & Tappel, 1991). Thus, improving the stability of carotenoids during storage is an important objective to make the final product more nutritious and marketable.

3.2. Antioxidant activity

3.2.1. Reducing power

This research analyzed the reducing power of the carrots' MEs along with α-tocopherol and butylated hydroxyanisole (BHA). The results are shown in Fig. 1. In general, as the concentrations increased, so did the reducing powers of the MEs. At concentrations of up to 4 mg/ml, the reducing powers in all the carrot samples were higher than those in α-tocopherol (Toc) and in BHA. This means that carrots have higher natural reducing powers compared to Toc or BHA. The MEs of both I-FD-NS and I-AD-NS carrots showed excellent reducing powers (Fig. 1). However, the reducing powers decreased after 30 days of storage. Furthermore, the MEs of both NI-FD-S and NI-AD-S showed the lowest reducing powers of the samples (Fig. 1). The results indicate that AA-Glu treatment allows higher retention of antioxidant activity. Toc and BHA are commonly used as antioxidant additives in foods. However, they showed the lowest reducing powers when concentrations were less than or equal to 4 mg/ml. The reducing power of MEs in various treated products might be due to their hydrogen-donating ability as described by Shimada et al. (1992). Accordingly, the MEs from I-FD-NS and I-AD-NS carrots might contain the highest amount of reductone, which could react with free radicals to stabilize and terminate free radical chain reactions. The untreated samples, NI-FD-NS and NI-AD-NS, showed a decrease in antioxidant substances. Yen, Duh, and Tsai (1993) and Siddhuraju, Mohan, and Becker (2002) reported that the reducing power could be attributed mainly to the bioactive compounds associated with antioxidant activity. These bioactive compounds present in carrots' MEs, including ascorbic acid, total phenols, flavonoids, lycopene, and other hydrophilic or hydrophobic antioxidants, are good electron donors and could terminate the free radical chain reactions by converting free radicals to more stable products.

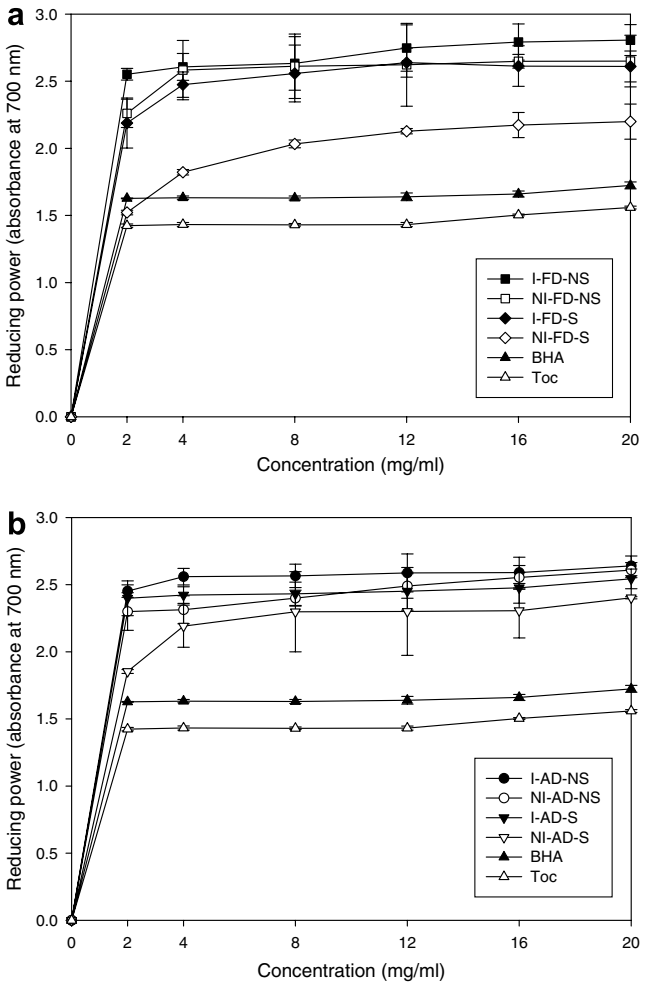

Fig. 1. Reducing power of the extracts from freeze-dried and hot-air-dried carrot which were treated with or without immersed ascorbic acid (0.1%) and glucose (1.0%), and the samples were tested after storage or not, in comparison with α-tocopherol and BHA. (a) Freeze-dried; (b) hot-air-dried.

3.2.2. DPPH radical scavenging activity

Antioxidant activity in natural compounds has been shown to be related to the termination of free radical reactions (Shimada et al., 1992). Except for NI-FD-S, the MEs of various treated carrots, along with α-tocopherol and BHA all showed excellent scavenging effects on DPPH radicals, in the range of 80–98% at 20 mg/ml (Fig. 2). BHA, I-FD-NS and I-AD-NS had the highest levels of DPPH radical scavenging activity. NI-FD-S and NI-AD-S contained the lowest DPPH radical scavenging activities of our samples. This result again showed that carrots not immersed in AA-Glu solution had higher antioxidant degradation after 30 days storage than immersed carrots.

Furthermore, in comparison research by Wong and Yen (1997), the DPPH radical scavenging activity in 2 mg/ml MEs of I-FD-S and I-AD-S were higher than those at the same concentrations in mungbean and soybean sprouts, and equal to those of radish sprouts. Lin (1999) reported that the DPPH radicals scavenging effects of 2 mg/ml MEs in commercial mushrooms were 43–70%. In comparison, carrots treated with AA-Glu solution, dried and stored for 30 days, had higher DPPH radical scavenging activity than commercial mushrooms.

As shown in Table 1, a higher TAC yielded higher DPPH radical scavenging activity. This is probably due to the combined effects of the ascorbic acid, total phenols, total flavonoids, and βcarotene, as well as their high hydrogen atom

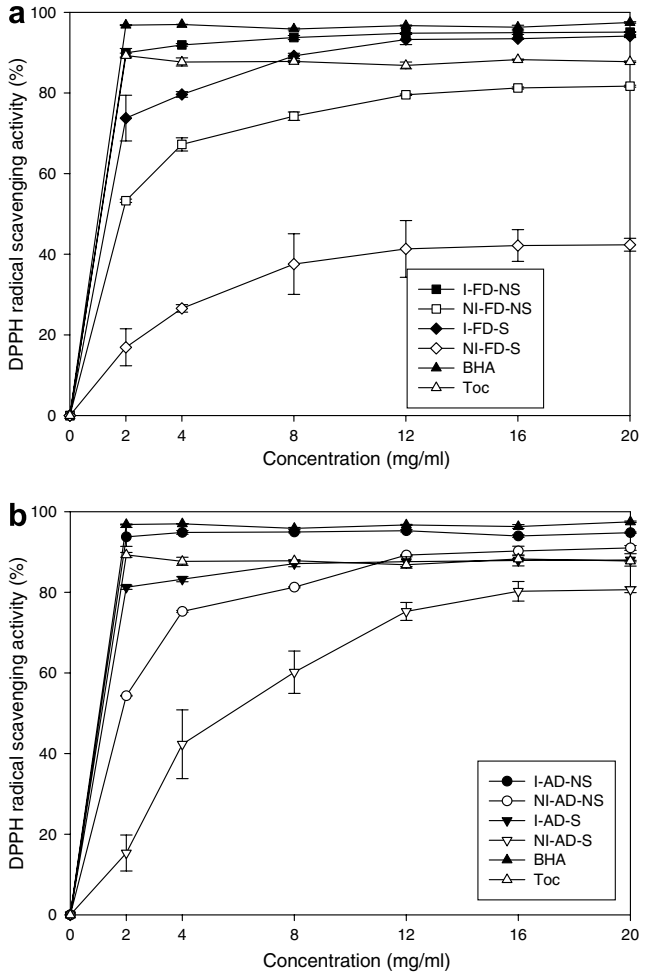

Fig. 2. DPPH free radical scavenging activity of the extracts from freeze-dried and hot-air-dried carrot which were treated with or without immersed ascorbic acid (0.1%) and glucose (0.1%), and the samples were tested after storage or not, in comparison with α-tocopherol and BHA. (a) Freeze-dried; (b) hot-air-dried.

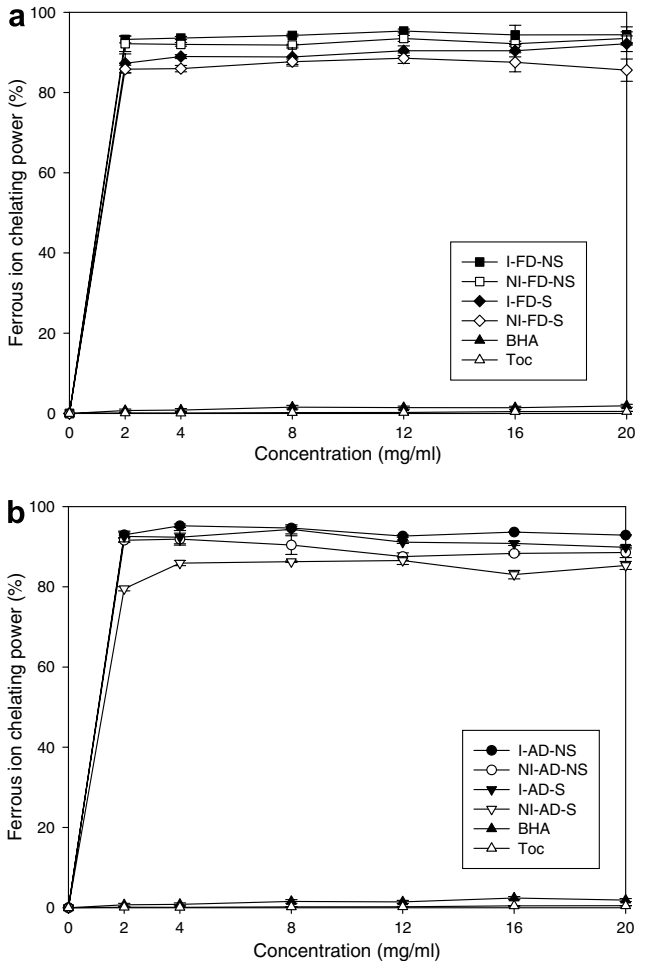

Fig. 3. Ferrous ion chelating power of the extracts from freeze-dried and hot-air-dried carrot which were treated with or without immersed ascorbic acid (0.1%) and glucose (0.1%), and the samples were tested after storage or not, in comparison with α-tocopherol and BHA. (a) Freeze-dried; (b) hot-air-dried.

donating abilities. In general, these results show that MEs from carrots are excellent free radical inhibitors or scavengers, possibly acting as primary antioxidants and reacting with free radicals, particularly peroxyradicals, which are the major propagators of autoxidation of fat, thereby terminating the chain reaction (Frankel, 1991; Gordon, 1990; Shahidi, Janitha, & Wanasundara, 1992).

3.2.3. Ferrous ion chelating power

Ferrous ion chelating powers (FICP) of MEs from various treated carrots increased corresponding to increases in MEs concentration. The FICP values were in the range of 85–95% for the MEs at concentrations up to 20 mg/ml (Fig. 3). BHA and Toc had very little FICP: MEs at 20 mg/ml of BHA and Toc were only 1.9% and 0.5%, respectively. Since ferrous ions are the most effective prooxidants in the food system, higher chelating abilities from carrots would be beneficial. As shown here, both BHA and α-tocopherol can hardly carry the FICP due to their chemical structure. The MEs of both I-FD-NS and I-AD-NS showed the highest FICP at 20 mg/ml (Fig. 3). The MEs of NI-FD-NS and NI-AD-NS showed the lowest. The FICP of I-FD-S was significantly higher than that of NI-FD-S. Similarly, the I-AD-S was greater than NI-AD-S. The result confirms that the AA-Glu treatment prevents the degradation of antioxidant components. Furthermore, the MEs of all carrot samples at concentrations of 2 mg/ml had more than 80% FICP.

In other research, the use of a soybean sprout extract with a concentration of 3 mg/ml was required to obtain the same level of FICP Wong and Yen (1997). MEs from medicinal mushrooms of Chang-Chih had FICP of 64.4–74.5% at 5 mg/ml. (Huang, 2000). Compared to these results, carrots contain a better FICP than Chang-Chih and soybean sprouts.

4. Conclusion

Carrot products contain multifunctional properties and are important sources of antioxidants. Dried carrots are

often used as additives to instant food products, and retaining the natural antioxidant contents is an important task. In this study, processed carrots were immersed in AA-Glu solution to reduce the degradation of antioxidants. Over a 30-day storage period, this method proved effective. Further research to develop new types of products could be helpful to promote the nutritional value and extend the storage life of carrots. Immersing with ascorbic acid and glucose prior to the drying process to protect the antioxidant activity is an idea that could be further developed in other food applications such as instant food products.

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