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Effects of storage temperatures on the antioxidative activity and composition of yam

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Abstract

The effects of storage temperatures on the composition and antioxidative activities of one kind of Taiwanese yam tubers, Tainung No. 1 (TNG1) (*Dioscorea alata*), were investigated at room temperature (20 ± 8 °C), 17 ± 2 and 10 ± 1.5 °C. Measurements of the antioxidative activities included reducing power and α,α-diphenyl-β-pricryl-hydrazyl radical-scavenging activity. The crude lipid and fibre contents decreased with storage time at all three temperatures, but the reducing sugar contents increased during storage. Both the reducing power and DPPH radical-scavenging activity of TNG1 decreased after 3 and 11 weeks at room temperature and 17 °C, respectively. At 10 °C, significant decline in the reducing power was found after 14 weeks, while the DPPH radical-scavenging activity tended to increase after 7 weeks due to the microbes causing rottenness.

Keywords: Yam; Storage temperature; Antioxidative activity; Composition

1. Introduction

Yam has been classified as one of the important staples in the diets of many tropical countries because of the carbohydrate it provides. For example, yam is widely grown in west Africa (Coursey & Haynes, 1970; Waitt, 1963). Some yams are also used as medicines in oriental countries to prevent diarrhea and diabetes (Hsu, Chen, Hsu, Chen, & Chang, 1984; Yen, 1992); thus yams are considered to be helpful to human health. Yam (*Dioscorea alata*) has been suggested to have nutritional superiority when compared with other tropical root crops (Wanasundera & Ravindran, 1994). Yam is composed mainly of starch (75–84% of the dry weight) with small amounts of proteins, lipids and most vitamins and is very rich in minerals (Lasztity, Hidvegi, & Bata, 1998; Omonigho, 1988). The average crude protein content of seven yam cultivars was 7.4%, which was higher than those reported for other tropical roots, and the protein from yam also showed a better amino acid balance for human nutrition (Baquar & Oke, 1976; Bradbury, 1988; Marcus et al., 1998).

Modern researches have shown that yam extracts can reduce blood sugar (Hikino et al., 1986; Undie & Akubue, 1986) and blood lipid (Araghiniknam, Chung, Nelson-White, Eskelson, & Watson, 1996), inhibit microbe activity (Hu et al., 1999; Hu, Dong, Yao, Kobayashi, & Iwasaki, 1996; Kelmanson, Jager, & Van Staden, 2000) and show antioxidative activity (Chan, Hsu, Wang, & Su, 2004 Farombi, Britton, & Emerole, 2000;). Farombi et al. (2000) demonstrated that brown yam flour

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contained natural antioxidants and might mitigate damage and diseases caused by oxidative components. Chen, Chang, and Wang (2002) reported that *D. alata* L. Var. purpurea (M.) Pouch. (Purpurea), one kind of Taiwanese yam tuber, exerted trophic effects in the cecum by mediating luminal fermentation. Fang and Kong (2002) found that yam (*Dioscrea japonica*) could enhance serum IgG concentrations and promote splinic lymphocyte proliferation. The active components of yam include steroidal sapogenin, glycan and polyphenol oxidase. Diosgenin, extracted from *Dioscorea* species, is a natural steroidal sapogenin used as a precursor in the industrial synthesis of steroids. Araghiniknam et al. (1996) found the steroid extract from yam significantly reduced serum lipid peroxidation, lowered serum triglyceride and phospholipid levels, and increased high density lipid level in older humans. Discorin, the storage protein of yam tuber, was reported to have scavenging activity toward 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical. Dioscoran, a glycan isolated from *D. japonica*, was shown to markedly inhibit the hypoglycemic affects in normal and alloxan-induced hyperglycemic mice (Hikino et al., 1986).

The effect of storage on the composition, appearance, and physical properties of yam has been investigated (Afoakwa & Sefa-Dedeh, 2001, 2002a, 2002b; Sefa-Dedeh & Afoakwa, 2002; Treche & Agbor-Egbe, 1996). In this study, the storage effect on the composition and antioxidative activities of one kind of Taiwanese yam tubers stored at room temperature, 17 and 10 °C, were determined. We decided to work on this yam species because our previous data (Chiang, Chou, & Hsu, 2005) indicated that it had the highest antioxidative activity among five common Taiwanese yam cultivars.

2. Materials and methods

2.1. Chemicals and materials

α,α-Diphenyl-β-pricryl-hydrazyl (DPPH), gallic acid, and α-tocopherol (α-Toc) were purchased from Sigma Chemicals Co. (St. Louis, MO, USA). Tainung No. 1 (TNG1) yam (*D. alata*), within one week after harvest, was purchased from a farmer in Mingjian Shiang, Nantou county, Taiwan. The yam was stored at three temperatures until sampling; they were: room temperature (20 ± 8 °C), 17 ± 2 and 10 ± 1.5 °C.

2.2. Weight loss and germination/rottenness

The weights and appearances of 12 randomly selected yams stored at each temperature were recorded during storage. Data for the appearance observations were reported as the percentage of the number of rotten or germinal yams out of twelve.

2.3. Composition determination

The analysis of the protein, lipid, moisture, ash, and fibre contents of TNG1 was performed according to standard AOAC methods (AOAC, 1984). The method for determining the reducing sugar content was based on Hariprakash and Nambisan (1996). The crude mucus content was measured according to the method reported by Tsai and Tai (1984). Sliced yam tubers were homogenized and extracted with 3 volumes of 0.1% $NaHSO_3$ solution and then centrifuged at 10,000*g* (0 °C) for 30 min. The extracts were precipitated with 3 volumes of acetone. After centrifugation at 2500*g* for 10 min, the precipitate was dissolved in water, dialyzed against distilled water and then centrifuged at 10,000*g* (0 °C) for 30 min. The supernatant was precipitated with 3 volumes of acetone and centrifuged at 2500*g* for 10 min. The final precipitate was dried in vacuum and weighed.

2.4. Measurement of DPPH radical-scavenging activity

Yam DPPH radical-scavenging activity was measured according to the method of Yamaguchi, Takamura, Matoba, and Terao (1998). The samples were blended with 50% ethanol, and then its aliquot of the mixture (100 μl, 200 mg sample/ml of 50% ethanol) was further mixed with 100 mM Tris–HCl buffer (400 μl, pH 7.4) and then added to 1 ml of 500 μM DPPH in ethanol (final concentration of 250 μM). The mixture was shaken vigorously and left in the dark at room temperature for 20 min. The absorbance of the resulting solution was measured spectrophometrically at 517 nm. α-Toc (0.04–1.25 mg/ml) was used as the standard for the calibration curve, and the DPPH radical-scavenging activities were expressed as μmole α-Toc equivalents per gramme of tested dry samples.

2.5. Measurement of reducing power

The reducing power of the yam extracts was determined according to the method of Yen and Chen (1995). The extract (0.16–10.0 mg/ml) was mixed with an equal volume of 0.2 M phosphate buffer (pH 6.6) and 1% potassium ferricyanide, and then incubated at 50 °C for 20 min. An equal volume of 1% trichloroacetic acid was added to the mixture to stop the reaction, and then the mixture was centrifuged at 2500*g* for 10 min. The supernatant was mixed with distilled water and 0.1% $FeCl_3$ at a ratio 1:1:2, and then the absorbance were measured at 700 nm. The reducing powers of the tested samples increased with the absorbance values. Gallic acid was used as the standard for the calibration curve, and the reducing powers were expressed as mg gallic acid equivalents per gramme of tested dry sample.

2.6. Statistical analysis

One-way analysis of variance (one-way ANOVA) was conducted using a package (SAS Institute Inc., Cary, NC). Duncan's multiple range test was used to determine the significant difference between different treatments.

3. Results and discussion

3.1. Weight loss and appearance changes

The effects of storage temperatures on the weight loss of Tainung No. 1 (TNG1) are shown in Fig. 1. After 16 weeks, the weight losses were 9.21%, 2.42% and 5.82% at room temperature, 17 and 10 °C, respectively. During a 16-week period, the changes of the weight losses at 17 and 10 °C were linear. For TNG1 stored at room temperature, linear weight loss was observed during a 12-week period, and then non-linear weight loss was found as storage time longer than 12 weeks. It was noted that the weight loss at 17 °C was lower than that at 10 °C because the relative humidity of the air at 17 °C (65 ± 7%) was higher than that at 10 °C (54 ± 5%). Treche and Agbor-Egbe (1996) reported that weight losses of two yam cultivars were about 31–35% at room temperature for 110 days. Wang and Liu (1992) reported that weight losses of TNG1, stored at 20 ± 8, 17 ± 1 and 14 ± 1 °C for 10 weeks, were 11.5%, 4.6% and 3.2%, respectively. As showing in Fig. 2, chill storage at 17 and 10 °C successfully delayed the germination of TNG1; however, storage at 10 °C created a significant rottenness problem after 12 weeks. Wang and Liu (1992) also reported that 17 and 14 °C storages could reduce the germination of TNG1 and prolong its shelf life, and 14 °C also caused the yam to become putrid. Since the germination for TNG1 stored at room temperature started at 12 weeks, germination might be the cause of the non-linear weight loss. The results indicated that 17 °C was a better storage temperature for yam in terms of weight loss and appearance considerations.

3.2. Effect of storage on the composition

Table 1 shows the effect of storage temperature on the composition of TNG1 stored at room temperature, 17 and 10 °C for two months. It was found that there were no significant changes in the ash, crude protein and mucus contents of TNG1 during storage. However, storage did decrease the lipid and crude fibre contents.

3.3. Effect of storage on the antioxidative activities

In the reducing power assay, the presence of reductants (antioxidants) in the samples would result in the reduction of the Fe^{3+}/ferricyanide complex to its ferrous form. Amount of Fe^{2+} complex can then be monitored by measuring the formation of Perl's prussian blue at 700 nm. The effect of storage on the reducing power of TNG1 stored at room temperature, 17 and 10 °C is shown in Fig. 3. Significant variation in the reducing power of TNG1 was found and the variation might be due to sample variation. Compared to the initial value at 0 week, significant decline of the reducing power started at 3, 11 and 14 weeks for TNG1 stored at room temperature, 17 and 10 °C, respectively. The results indicated that chill storage delayed the decrease of the reducing power. The proton-radical-scavenging action is known to be an important mechanism of antioxidation. Fig. 4 shows the effect of storage on the DPPH radical-scavenging activity of TNG1. Similar to the reducing power, significant decline of the DPPH radical-scavenging activity also started at 3, and 11 weeks for TNG1 stored at room temperature and

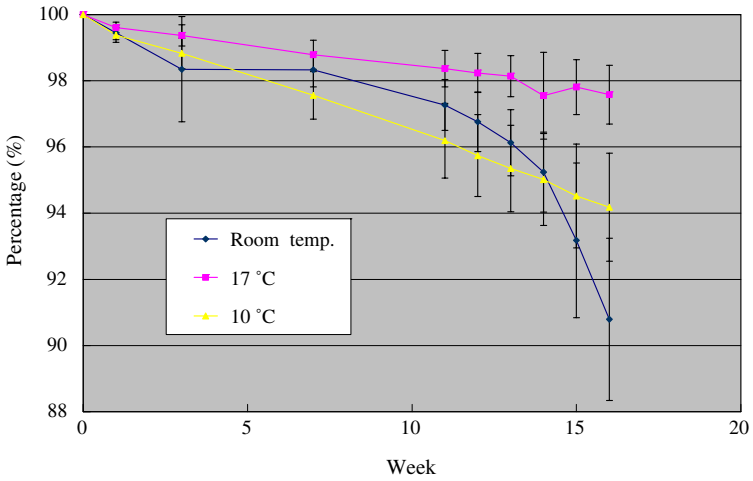

Fig. 1. Effects of storage on the weight losses of TNG1 stored at room temperature, 17 and 10 °C.

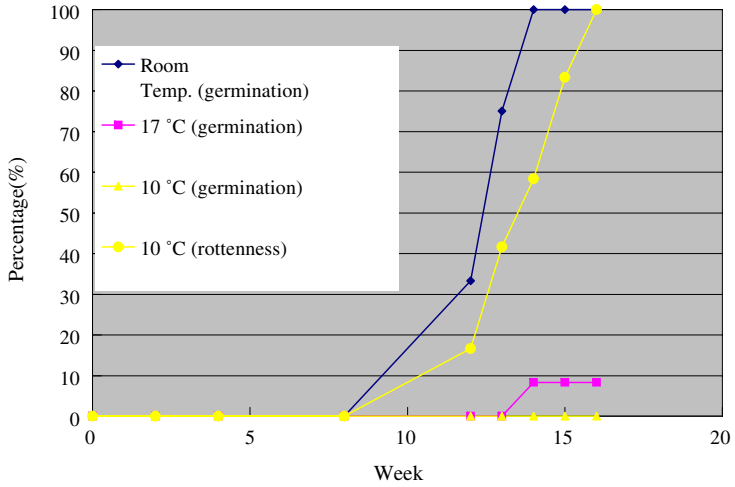

Fig. 2. Effects of storage on the germination and rottenness of TNG1 stored at room temperature, 17 and 10 °C.

Table 1
The effects of storage on the composition of yam stored at room temperature, 17 and 10 °C

Month	Temperature	Moisture (%)	Ash (%)	Protein (%)	Lipid (%)	Mucus (%)	Crude fibre (%)
0		75.5 ± 0.1^{bc}	1.12 ± 0.04^{A}	2.58 ± 0.35^{A}	0.075 ± 0.008^{a}	3.10 ± 0.15^{A}	2.52 ± 0.34^{a}
1	Room temperature	76.3 ± 0.5^{b}	1.18 ± 0.03	2.70 ± 0.11	0.061 ± 0.007^{b}	3.01 ± 0.17	1.71 ± 0.05^{b}
	17 °C	72.5 ± 0.4^{d}	1.27 ± 0.01	2.68 ± 0.03	0.078 ± 0.012^{a}	3.43 ± 0.27	1.45 ± 0.11^{c}
	10 °C	78.3 ± 0.7^{a}	1.20 ± 0.01	2.73 ± 0.02	0.058 ± 0.006^{b}	3.38 ± 0.27	1.77 ± 0.03^{b}
2	Room temperature	75.0 ± 0.8^{c}	1.04 ± 0.06	2.41 ± 0.06	0.037 ± 0.005^{c}	3.65 ± 0.24	1.32 ± 0.23^{c}
	17 °C	73.1 ± 0.3^{d}	1.10 ± 0.04	2.33 ± 0.15	0.035 ± 0.004^{c}	3.15 ± 0.71	1.28 ± 0.17^{c}
	10 °C	74.8 ± 1.2^{c}	1.03 ± 0.05	2.61 ± 0.11	0.029 ± 0.001^{c}	3.46 ± 0.25	1.30 ± 0.10^{c}

The values are means ± standard deviation.
Values in the same column followed by different superscripts are significantly different ($p < 0.05$).
[A] Values in the same column are not significantly different.

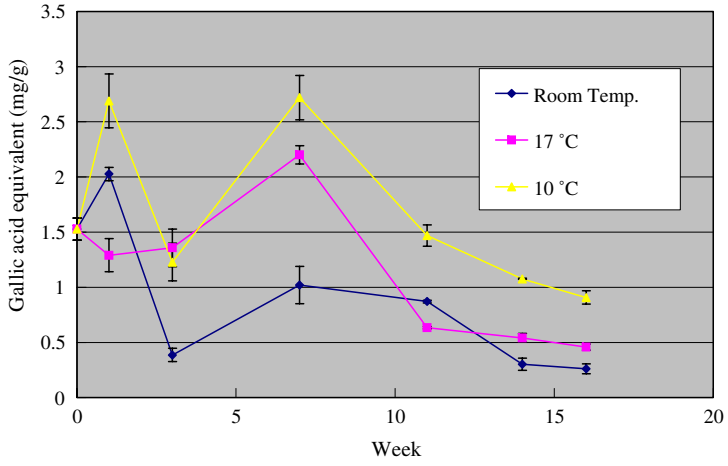

Fig. 3. Effects of storage on the reducing power of TNG1 stored at room temperature, 17 and 10 °C.

17 °C, respectively. It was found that the correlation coefficient between the DPPH scavenging activity and reducing power, at both room temperature and 17 °C, was 0.90; a combination of the two temperatures showed a correlation coefficient of 0.88 (Fig. 5). The results indicated a good correlation between the DPPH·-scavenging activity and reducing power. However, at 10 °C the DPPH radical-scavenging activity showed extremely different behaviour. Compared to the initial value at week 0, the DPPH radical-scavenging activity of TNG1 stored at 10 °C decreased at 3 weeks and then increased at 7, 11 and 14 weeks (Fig. 4). Since the rottenness of TNG1 stored at

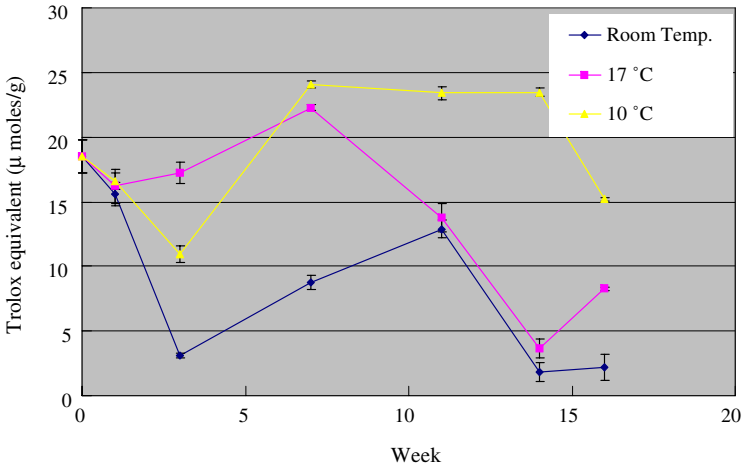

Fig. 4. Effects of storage on the DPPH radical-scavenging activity of TNG1 stored at room temperature, 17 and 10 °C.

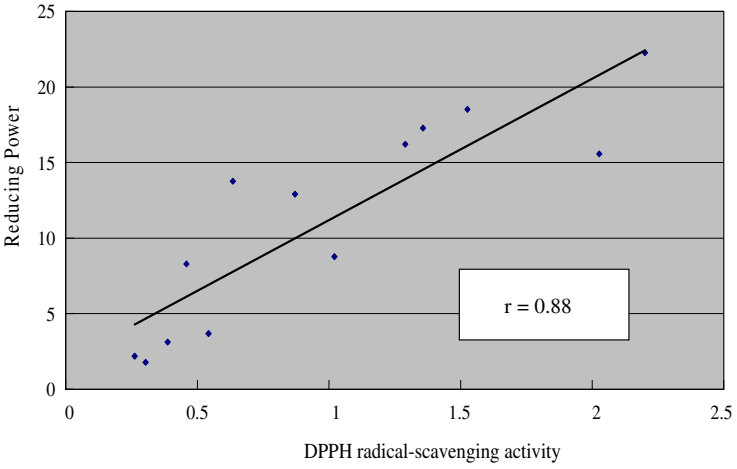

Fig. 5. Correlation between the reducing power and DPPH radical-scavenging activity of TNG1 stored at room temperature and 17 °C.

10 °C started sometime between 8 and 12 weeks, it was suggested that the increase of DPPH radical-scavenging activity at 10 °C was due to the rottenness. It was possible that the metabolites from the microbes causing the rottenness of TNG1 also contributed to DPPH radical-scavenging activity.

4. Conclusion

Significant weight loss due to germination was observed in TNG1 stored at room temperature for 12 weeks. Chill storage at 17 °C delayed and reduced the germination and no germination occurred at 10 °C during four months of storage. However, storage at 10 °C caused significant rottenness after 12 weeks of storage. Regardless of the storage temperatures, the crude lipid and fibre contents decreased with storage time, but the reducing sugar contents increased during storage. Significant declines in both the reducing power and DPPH radical-scavenging activity were found in TNG1 after 3 and 11 weeks of storage at room temperature and 17 °C, respectively. At 10 °C, no significant reduction in the reducing power was found until 14 weeks, while the DPPH radical-scavenging activity tended to increase after 7 weeks due to the microbes causing the rottenness.

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