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# Chemical composition, physical properties, and antioxidant activities of yam flours as affected by different drying methods

Chin-Lin Hsu[a], Wenlung Chen[b], Yih-Ming Weng[a], Chin-Yin Tseng[a,*]

[a]*Department of Food Science, National Chiayi University, 300 University Road, Chiayi (600), Taiwan, ROC*
[b]*Department of Applied Chemistry, National Chiayi University, 300 University Road, Chiayi (600), Taiwan, ROC*

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**Abstract**

Yams (the tubers of the *Dioscorea* spp.), consumed and regarded as medicinal food in traditional Chinese herbal medicine, are seasonal foods and easily deteriorate during storage. It is of great importance to prolong the storage of yams for supplying in the off-season and without losing nutritional functionality. Three varieties of yams, *Dioscorea alata* (cultivars of Tai-Nung no. 2 and Ta-Shan) and *D. purpurea* (cultivar of Ming-Chien), were made into flours by freeze-drying, hot air-drying, and drum-drying in this report. The proximate compositions and physical properties, as well as antioxidant activities, of yam flours were determined. While drying methods showed significant effects on the moisture contents of yam flours, they had no marked effects on other components of yam flours. Colour attributes and physical properties were all affected by drying methods to different extents. While freeze-drying usually preserved more antioxidant activity of the yam flours, yam flours made of different yam varieties showed different antioxidant mechanisms.

*Keywords:* Yam; *Dioscorea* spp.; Herbal medicine; Freeze drying; Hot air drying; Drum Drying; Antioxidant activities

## 1. Introduction

Yams, the tubers of *Dioscorea* spp., are important staple foods in many tropical countries (Akanbi, Gureje, & Adeyemi, 1996; Omonigho & Ikenebomeh, 2000). Even more interestingly, yams have also been used as health food and herbal medicinal ingredients in traditional Chinese medicine (Liu, Wang, Shyu, & Song, 1995). Recently, several beneficial properties of yams were reported in the literature. Yam extracts showed significant antioxidative activity and modified serum lipid levels in humans (Araghiniknam, Chung, Nelson-White, Eskelson, & Watson, 1996). Yam flour was reported to protect rats from chemical-induced toxicity (Farombi, Nwankow, & Emerole, 1997). The extracts of browned yam flour showed antioxidative activity in model systems (Farombi, Britton, & Emerole, 2000). Dioscorin, a purified storage protein of yam, was reported to possess scavenging properties against free radicals (Hou et al., 2001).

Usually, one piece of yam tuber is as large as several kilogrammes, which is an amount exceeding the capacity of ordinary families to consume in a relatively short period of time. Fresh yams are difficult to store and are subject to deterioration during storage (Afoakwa & Sefa-Dedeh, 2001; Otusanya & Jeger, 1996). Because yams are regarded as health foods and not staple foods in oriental countries, it is feasible to develop a stable form of yam products to fulfil the health food market. Since flours can be easily stored for long period of time and conveniently used in manufacturing formulated foods or capsules for consumption, dried yam flour is worth developing. Among different drying processes, freeze-drying can give the highest product quality but the relatively high production cost is a major drawback (Litvin, Mannheim, & Miltz, 1998; Ratti, 2001). Relatively cheaper hot air-drying is commonly used in food production but the longer drying time usually results in inferior product quality. Drum-drying involves introducing extra water into raw materials but can complete the drying process in a short period of time. It is

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* Corresponding author. Tel. +886-5-271-7618; fax: +886-5-277-5484.

*E-mail address:* cytseng@mail.ncyu.edu.tw (C.-Y. Tseng).

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interesting to investigate the effects of different drying methods (freeze-drying, hot air-drying, and drum-drying) on the quality of yam flours, and especially the beneficial antioxidant activities of yams.

There are many varieties of yams currently available in Taiwan. Three commonly consumed yams, *D. alata* (cultivars of Tai-Nung No. 2 and Ta-Shan) and *D. purpurea* (cultivar of Ming-Chien), were chosen in the present study. Thus, the objective of the present study was to explore the effects of drying methods on yam flour qualities, including proximate composition, physical properties and antioxidant activities.

## 2. Materials and methods

### 2.1. The preparation of dried yam flours

Three varieties of yams, *Dioscorea alata* (cultivars of Tai-Nung no. 2 and Ta-Shan) and *D. purpurea* (cultivar of Ming-Chien), were used in the present study. Yam tubers were provided by the Taiwan Agricultural Research Institute (Taichung, Taiwan). The yam tubers were washed and steam-blanched (98±2 °C, 14 min) immediately after delivery to the laboratory. After peeling, the yam tubers were cut into slices (2 cm thickness), steamed (98±2 °C, 7 min), and cooled to room temperature. For freeze-drying, cooked yam slices were dried with a freeze-dryer (12ES, Virtis Co., Gardiner, NY, USA), ground with a blender (DM-6, Yu-Chin Machinery Co., Changhua, Taiwan), and sieved through a 60-mesh screen to obtain yam flour. For hot air-drying, cooked and cooled yam slices were dried in an electric convection oven (60 °C, 48 h), then ground and sieved as in the preparation of freeze-dried yam flour. For drum-drying, fresh yams were washed, peeled, and blended with water (yam:water = 2:1, w/w) to obtain yam slurry. The yam slurry was dried with a drum-dryer (RDM, Lu-Hai Mechanical Works, Hsin-Chu, Taiwan) at temperatures from 95 to 100 °C. The dried yam flakes were further ground and sieved as freeze-dried yam to obtain yam flour. The yam flours were sealed in polyester/aluminium foil/polypropylene laminated bags to prevent moisture absorption and stored in a freezer (−20 °C) until used for further tests.

### 2.2. Proximate compositions of yam flours

Moisture, crude protein, crude fat, ash, and crude fibre contents of yam flours were analyzed according to AOAC 15.950.01, 15.976.05, 15.920.39, 15.955.03, and 15.962.09, respectively (AOAC, 1990). The nitrogen free extract (NFE) was obtained by subtraction, i.e. 100−(moisture + crude protein + crude fat + crude fibre + ash). The reported values are means of triplicate samples with standard deviation.

### 2.3. Hunter L, a, and b values

The colour attributes (Hunter *L*, *a*, and *b* values) were measured with a colour differential meter (Σ90 Colour Measuring System, Nippon Denshoku, Japan). Each sample was randomly measured at 3 spots; means of five samples were reported. Whiteness index (WI) was calculated according to Sheen (1990) and Tsai (1994); and the calculation equation was as follow:

$$\mathrm{WI} = 100 - \sqrt{(100 - L)^2 + a^2 + b^2}$$

where: *L*, *a*, and *b* were Hunter *L*, *a*, and *b* values.

### 2.4. True density (TD), bulk density (BD), and porosity measurements

The volume displacement method described by Samejima, Irate, and Koida (1982) was used to determine true density (TD), bulk density (BD), and porosity of yam flours. A portion of yam flour (W2) was added to a pre-weighed volumetric cylinder (W1) and the volume was read as V1. After the same volume (V1) of displacement fluid (isobutyl alcohol:phthalic acid diethyl ester = 1:1) was added to the cylinder, the total volume of the flour plus solvent in the cylinder was taken as V2. TD, BD, and porosity were calculated according following equations.

$$\text{True density(TD)} = \frac{W2 - W1}{V2 - V1}$$

$$\text{Bulk density(BD)} = \frac{W2 - W1}{V1}$$

$$\text{Porosity} = 1 - \frac{BD}{TD}$$

### 2.5. Water solubility index (WSI) and water absorption index (WAI)

WSI and WAI were determined according to Anderson, Conway, Pfeifer, and Griffin (1969). Yam flour (2.5 g) and water (30 ml) were vigorously mixed in a 100 ml centrifuge tube, incubated in a 37 °C water bath for 30 min, and then centrifuged (4000×*g*, 10 min). The supernatant was collected in a pre-weighed beaker and the residue was weighed after the water was evaporated below 105 °C. The percentage of residue with respect to the amount of yam flour used in the test was taken as water solubility index (WSI). The weight ratio of centrifuged precipitate to the amount of yam flour used in the test was taken as the water absorption index (WAI).

### 2.6. Preparation of methanolic yam flour extracts

Yam flour (1.25, 2.5, 3.75, or 5 g) and methanol (20 ml) were mixed and kept in a rotary shaker overnight and then filtered (Whatman No. 1 filter paper). The filtrate was made up to 25 ml with methanol and stored at −20 °C until further used. The methanolic extracts represented 50, 100, 150, or 200 mg of yam flour per ml, respectively.

### 2.7. Free radical scavenging effect test

The removal of 1,1-diphenyl-2-picryl-hydrazyl radical ($DPPH^\bullet$, Aldrich, Milwaukee, WI, USA) was carried out according to the method described by Shimada, Fujikawa, Yahara, and Nakamura (1992) with some modifications. Aliquots of 1 ml methanolic yam flour extract and 5 ml of freshly prepared 0.1 mM $DPPH^\bullet$ methanolic solution were thoroughly mixed and kept for 50 min in the dark. The absorbance of the reaction mixture at 517 nm was read with a spectrophotometer (U-2000, Hitachi, Japan). Methanol (1 ml), replacing the extract, was used as the blank. The percentage of free radical scavenging effect was calculated as follows:

$$\text{Scavenging effect } (\%) = \left[1 - \left(A_{517\text{nm, sample}}/A_{517\text{nm, blank}}\right)\right] \times 100$$

### 2.8. Ferrous ion chelating capacity test

The method described by Decker and Welch (1990) was used to determine the ferrous ion chelating activities of yam flours. Methanolic yam flour extract (1 ml), 2 mM $FeCl_2{\cdot}4H_2O$ (0.1 ml, Merck, Darmstadt, Germany), 5 mM ferrozine (3-(2-pyridyl)-5,6-bis- (4-phenylsulfonic acid)-1,2,4-triazine, 0.2 ml, Sigma, St. Louis, MO), and methanol (3.7 ml) were mixed in a test tube and reacted for 10 min. The absorbance at 562 nm was measured; a lower absorbance indicated a higher ferrous ion chelating capacity, which was calculated as follows:

$$\text{Ferrous ion chelating capacity } (\%) = [1 - (A_{562\text{ nm, sample}}/A_{562\text{ nm, control}})] \times 100$$

### 2.9. Total antioxidant activity test

Total antioxidant activity was measured according to the method described by Miller and Rice-Evans (1997) and Arnao, Cano, and Acosta (2001) with some modifications. Peroxidase (4.4 units/ml, 0.2 ml, Sigma), $H_2O_2$ (50 μM, 0.2 ml, Merck), ABTS [2,2-azino-bis (3-ethylbenz-thiazoline-6-suflfonic acid), 100 μM, 0.2 ml, Sigma] and distilled water (1 ml) were mixed and kept in the dark for 1 h to form a bluish-green complex. After adding methanolic yam flour extract (1 ml), the absorbance at 734 nm was measured to represent the total antioxidant activity.

$$\text{Total antioxidant activity } (\%) = [1 - (A_{734\text{ nm, sample}}/A_{734\text{ nm, control}})] \times 100$$

### 2.10. Reducing power test

The reducing power of yam flours was measured according to the method described by Oyaizu (1986) and Duh and Yen (1997) with some modifications. Yam extract (1 ml), phosphate buffer (0.2 M, pH 6.6, 0.5 ml), and potassium hexacyanoferrate solution (1% v/w, 2.5 ml, Merck) were placed in a test tube and reacted for 20 min at 50 °C. The tube was immediately cooled over crashed ice and then an aliquot of 0.5 ml trichloroacetic acid (10%, Merck) was added. After centrifugation at 3000 *g* for 10 min, an aliquot 1 ml supernatant was mixed with 1 ml distilled water and 0.1 ml ferric chloride (0.1%) and reacted for 10 min. Then, the absorbance at 700 nm was measured with a spectrophotometer. Increased absorbance of the reaction mixture indicated increased reducing power.

### 2.11. Statistical analysis

Statistical analysis was conducted with a commercial statistic computing software package (STATISTICA®, 1999 edition, StatSoft Inc., Tulsa, OK, USA) in a personal computer. Results were considered statistically significant at $P < 0.05$.

## 3. Results and discussion

### 3.1. Approximate compositions of yam flours

The proximate compositions of yam flours manufactured by freeze-drying, hot air-drying and drum-drying are presented in Table 1. For each yam variety, flour made by freeze drying had the lowest moisture content, while drum-drying resulted in the highest moisture content product. Drum-drying results in products with the highest moisture contents, that might not be favourable for prolonged storage of yam flours. For each yam variety, drying methods showed no significant effects ($P < 0.05$) on the protein, lipid, fibre, or ash contents of flours. Yams, with relatively high protein contents, are important food in many African countries (Omonigho & Ikenebomen, 2000); the protein contents of Taiwanese yam flours in this study were between 10.2 and 11.7% (dry basis). Yam flours contained 3.96–5.06% of ash, which reflected the mineral contents of the yam tubes. Yams are reported to contain relatively high level of minerals (Afoakwa & Sefa-Dedeh, 2001; Liu et al., 1995). Low fat contents obtained in the yams flours were in accordance with previous studies (Afoakwa & Sefa-Dedeh, 2001). Since yams were peeled before drying, the crude fibre contents detected in yam flours ranged from

Table 1
Proximate compositions (%) of yam flours prepared by different drying methods

| Yam/drying method[a] | Moisture[b] | Crude Protein[b] | Crude Fat[b] | Crude Fiber[b] | Ash[b] | N.F.E.[b] |
|---|---|---|---|---|---|---|
| *Tai-Nung No. 2* | | | | | | |
| FD | 0.60±0.05c | 11.1±0.08a | 0.30±0.03a | 1.41±0.08a | 3.96±0.17a | 82.9±0.19a |
| AD | 5.39±0.03b | 11.1±0.09a | 0.30±0.01a | 1.24±0.16a | 4.30±0.09a | 83.0±0.12a |
| DD | 7.33±0.20a | 11.5±0.55a | 0.29±0.02a | 1.32±0.12a | 4.50±0.06a | 82.4±0.50a |
| *Ta-Shan* | | | | | | |
| FD | 1.86±0.11c | 10.7±0.30a | 0.29±0.02a | 1.39±0.14a | 4.77±0.09a | 82.9±0.25a |
| HAD | 4.73±0.40b | 10.2±0.32a | 0.30±0.02a | 1.44±0.07a | 4.92±0.06a | 82.1±0.32a |
| DD | 6.66±0.10a | 11.0±0.61a | 0.29±0.03a | 1.27±0.32a | 5.06±0.05a | 82.4±0.45a |
| *Ming-Chien* | | | | | | |
| FD | 0.48±0.03c | 11.1±0.31a | 0.30±0.01a | 1.34±0.11a | 4.75±0.07a | 82.5±0.37a |
| HAD | 4.32±0.15b | 11.3±0.23a | 0.29±0.02a | 1.49±0.27a | 4.68±0.12a | 82.2±0.29a |
| DD | 7.32±0.10a | 11.7±0.70a | 0.31±0.02a | 1.31±0.21a | 5.00±0.23a | 81.7±0.73a |

[a] FD: freeze-drying; HAD: hot air-drying; DD: drum-drying.

[b] Dry basis except for the moisture content. Reported values are the means ± S.D. ($n=3$). Data bearing different letters in the same column for each yam variety are significantly different ($P<0.05$).

1.24 to 1.49%. The largest components in yam products were nitrogen-free extracts (NFE), which were mainly contributed by starch in the yam tubers. Because many carbohydrate constituents besides starch might be found in yam and starch is not the primary bioactive ingredient in yam flours, the amount of starch alone was not quantified. In the proximate analysis, the nitrogen-free extract (NFE) of yam was obtained by subtraction, i.e. 100−(moisture + crude protein + crude fat + crude fibre + ash).

### 3.2. Physical properties of yam products

Since *D. alata* is a variety of white yam, the *L* values of yam flours made of Tai-Nung No. 2 and Ta-Shan were between 76.6 and 89.0 (Table 2). Although browned yam flour diet is popular in some African countries (Farombi et al., 2000), dark brown colour flour is not acceptable in Taiwan. In order to prevent the formation of dark colour during drying, fresh yams were blanched before freeze-drying and hot air-drying in this study. Freeze-drying results in lighter colour indicated by higher *L* values. The *L* values of yam flour from *D. purpurea* (a purple yam variety) ranged from 48 to 57. It is interesting to note that drum-drying gave the highest *L* value for Ming-Chien yam flour, which indicated a greater discoloration during drum-drying. Flours of Ming-Chien yam showed the strongest redness (indicated by "*a*" value) and the weakest yellowness (indicated by "*b*" value) compared to flours made from the other two yam varieties.

Whiteness index (WI) represents the overall whiteness of food products that may indicate the extent of discoloration during the drying process. For white yams (Tai-Nung no. 2 and Ta-Shan), freeze-drying resulted in a higher WI than the other two drying methods (Table 2). In the case of white yam flours, higher WI

Table 2
Colour attributes of yam flours prepared by different drying methods

| Yam/drying method[a] | *L* value[b] | *a* value[b] | *b* value[b] | Whiteness index[b] |
|---|---|---|---|---|
| *Tai-Nung No. 2* | | | | |
| FD | 87.44±0.13b | −1.14±0.05c | 8.18±0.05c | 84.97±0.11b |
| HAD | 81.01±0.36c | −0.21±0.05b | 11.15±0.11a | 77.98±0.35c |
| DD | 89.00±0.04a | −0.11±0.05a | 9.20±0.10b | 85.66±0.07a |
| *Ta-Shan* | | | | |
| FD | 87.73±0.20a | −2.78±0.02c | 12.26±0.07c | 82.43±0.06a |
| HAD | 81.38±0.10b | −1.03±0.04b | 13.83±0.27b | 76.78±0.24b |
| DD | 76.60±0.20c | −0.32±0.06a | 17.17±0.10a | 70.97±0.22c |
| *Ming-Chien* | | | | |
| FD | 48.68±0.16c | 13.35±0.05a | −11.22±0.03c | 45.79±0.15c |
| HAD | 54.40±0.74b | 7.13±0.18c | −5.58±0.09b | 53.51±0.75b |
| DD | 57.30±1.77a | 12.63±0.03b | −4.92±0.06a | 55.20±1.70a |

[a] Drying methods as in Table 1.

[b] Reported values are the means ± S.D. ($n=3$). Data bearing different letters in the same column for each yam variety are significantly different ($P<0.05$).

means better consumer acceptability in Taiwan. On the other hand, lower WI of freeze-dried yam flour of Ming-Chien (purple yam variety) indicated less reduction in redness during drying; bright red is also a popular food colour for people in Taiwan.

Yam flours made by freeze-drying and hot air-drying showed significantly higher ($P<0.05$) bulk density than the yam flour made by drum-drying for each yam variety (Table 3). Although some statistical difference was found in true density of different yam flours, a relatively narrow range, between 1.33 and 1.55 (g/cm$^3$), was detected for all yam flours tested. Drum-dried flours had the lowest bulk density while hot air-dried flours had the highest values for each yam variety. The flours made by hot air-drying had the lowest calculated porosity that was consistent with the results of bulk density.

The water-solubility index (WSI) reflects the extent of starch degradation (Diosady, Patton, Rosen, & Rubin, 1985). Freeze-drying showed the least starch degradation of yam flour made of each type of yam variety, while hot air drying and drum-drying had more profound effects on starch degradation (Table 3). Water absorption index (WAI) indicates the extent of starch gelatinization. The highest WAI was found in the flour made by drum-drying because extra water was added before drying and this resulted in a higher degree of starch gelatinization during the drying/heating process. Hot air-drying resulted in the least extent of starch gelatinization.

### 3.3. Antioxidant activities of yam flours

Traditional Chinese herbal medicine literature reports that yam possesses anti-aging activity. It is generally believed that oxidation is one of the primary factors for developing many chronic degenerative processes, including aging (Benzie, 2000). There are many methods currently used for determining antioxidant activity; moreover, each method also can be used to elucidate the possible antioxidant mechanism of the testing material. Therefore, the yam flours were tested for their free radical scavenging effect, ferrous ion chelating capacity, total antioxidant activity, and reducing power.

Alkyl free radicals are formed during the induction period of lipid autooxidation. Hydrogen peroxide and hydrogen peroxide free radicals, derived from alkyl free radicals, are the major products during the propagation period. The chain reaction of lipid autooxidation stops if two free radicals combine together. One of the antioxidant mechanisms is to provide hydrogen atoms to free radicals and to stop the chain reaction. Drying methods showed profound effects on the DPPH radical scavenging effect of yam flours (Fig. 1). Freeze-dried yam flours had the strongest radical scavenging activity compared to the flours made by either hot air-drying or drum-drying. Furthermore, the Ming-Chien variety showed the greatest free radical scavenging effect among the three test yams. A dose–response relationship was also found in DPPH radical scavenging effect tests; the effect increased as the concentration increased for each individual yam flour (Fig. 1).

Ferrous ion, commonly found in food systems, is well known as an effective pro-oxidant. The purpose of ferrous ion chelating activity test is to determine the capability of testing material to bind the oxidation catalytic ferrous ion. Although Ming-Chien yam flours made showed relatively high free radical scavenging activity, they had lower ferrous ion chelating capability compared to yam flours made from the other two yam varieties (Fig. 2). It is noteworthy that the three drying methods resulted in about the same effect in respect to this antioxidant test.

Table 3
True density (TD), bulk density (BD), porosity, water solubility index (WSI), and water absorption index (WAI) of yam flours prepared by different drying methods

| Yam/drying method[a] | TD (g/cm$^3$)[b] | BD (g/cm$^3$)[b] | Porosity[b] | WSI (%)[b] | WAI[b] |
|---|---|---|---|---|---|
| *Tai-Nung No. 2* | | | | | |
| FD | 1.49±0.02a | 0.75±0.01b | 0.50±0.00b | 9.26±0.11b | 4.36±0.02b |
| HAD | 1.55±0.02a | 0.93±0.01a | 0.40±0.00c | 11.98±0.20a | 4.01±0.07c |
| DD | 1.33±0.06b | 0.53±0.02c | 0.60±0.00a | 12.38±0.95a | 11.83±0.73a |
| *Ta-Shan* | | | | | |
| FD | 1.49±0.01a | 0.75±0.00b | 0.50±0.00b | 12.63±0.33c | 4.53±0.18b |
| HAD | 1.53±0.02a | 0.90±0.01a | 0.40±0.00c | 13.26±0.40b | 3.41±0.09c |
| DD | 1.39±0.07b | 0.63±0.03c | 0.55±0.00a | 15.31±0.85a | 9.37±0.26a |
| *Ming-Chien* | | | | | |
| FD | 1.49±0.03a | 0.75±0.01b | 0.50±0.00b | 9.41±0.17b | 4.15±0.04b |
| HAD | 1.52±0.06a | 0.89±0.02a | 0.42±0.03c | 12.52±0.13a | 3.57±0.02c |
| DD | 1.39±0.04b | 0.49±0.01c | 0.65±0.00a | 12.30±0.96a | 11.9±0.85a |

[a] Drying methods as in Table 1.

[b] Reported values are the means ± S.D. ($n=3$). Data bearing different letters in the same column for each yam variety are significantly different ($P<0.05$).

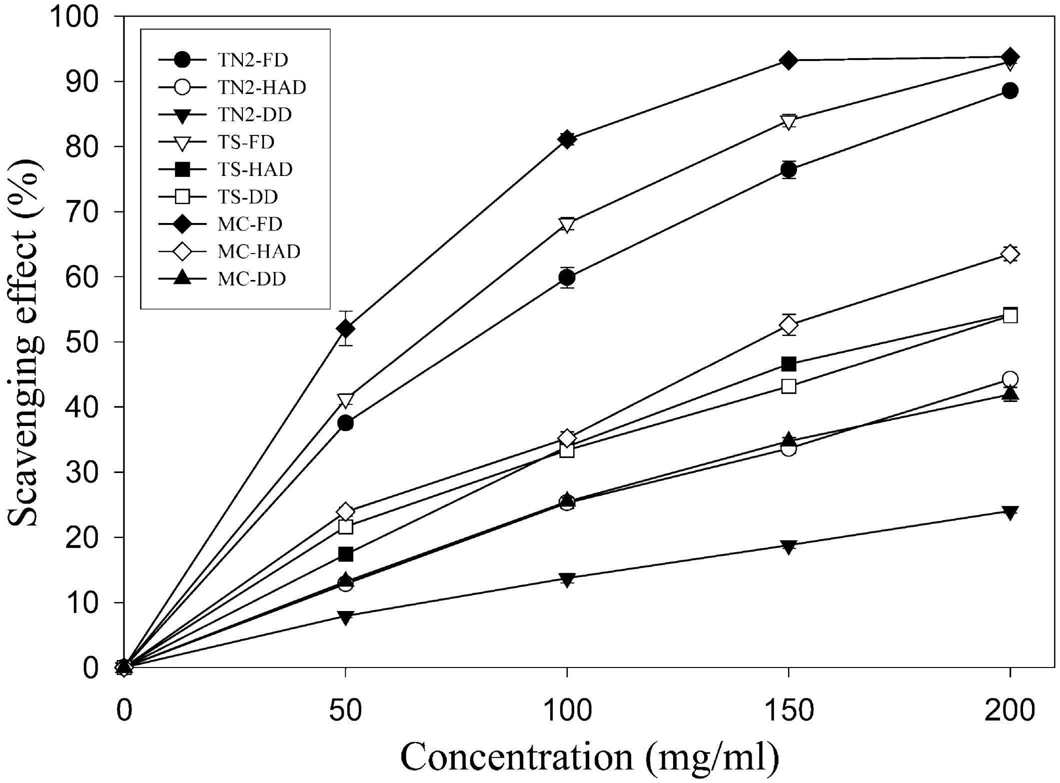

Fig. 1. DPPH free radical scavenging effect (%) of yam flours prepared by different drying methods. Means of triplicates; error bar; standard deviation. TN2: Tai-Nung No. 2 yam, TS: Da-Shan yam, MC: Ming-Chien yam; FD, freeze-drying; HAD, hot air-drying; DD, drum-drying.

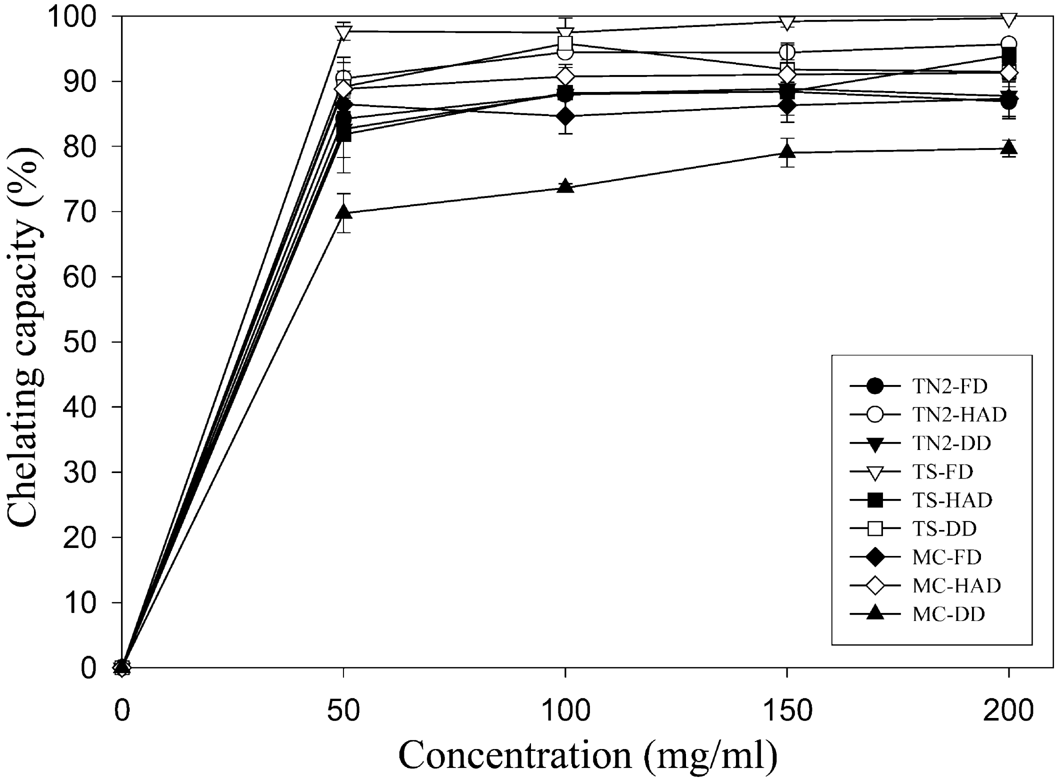

Fig. 2. Ferrous ion chelating capacity (%) of yam flours prepared by different drying methods. Means of triplicates; error bar, standard deviation. Notations for yam varieties and drying methods as in Fig. 1.

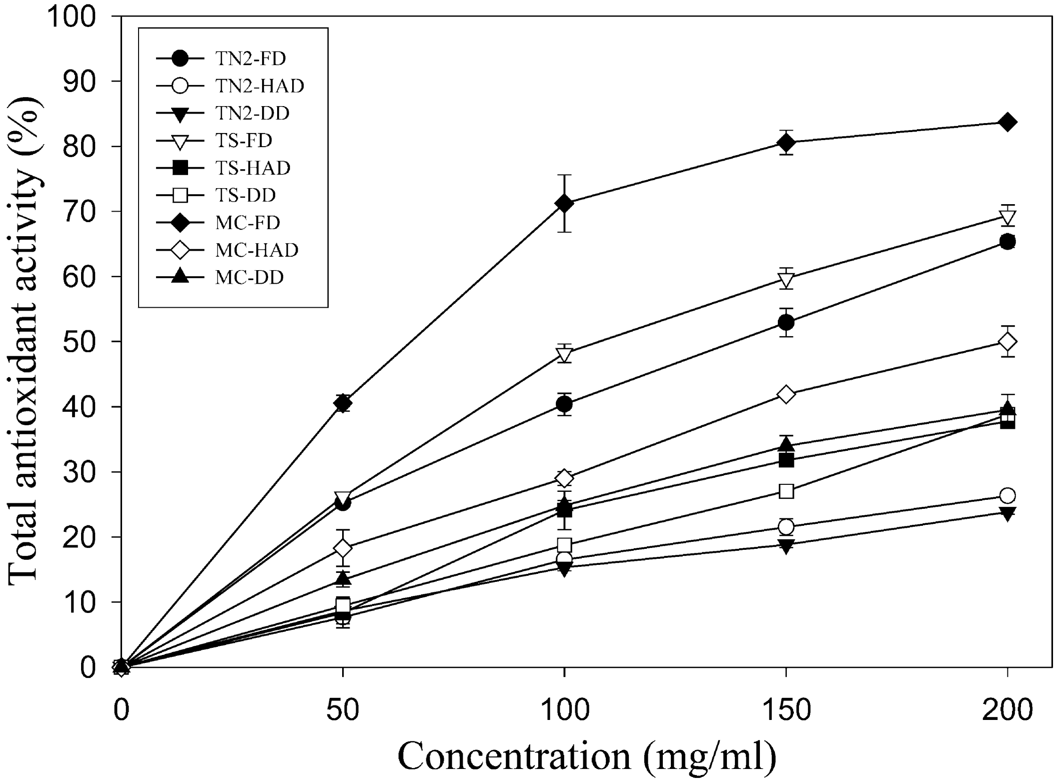

Fig. 3. Total antioxidant activity (%) of yam flours prepared by different drying methods. Means of triplicates; error bar, standard deviation. Notations for yam varieties and drying methods as in Fig. 1.

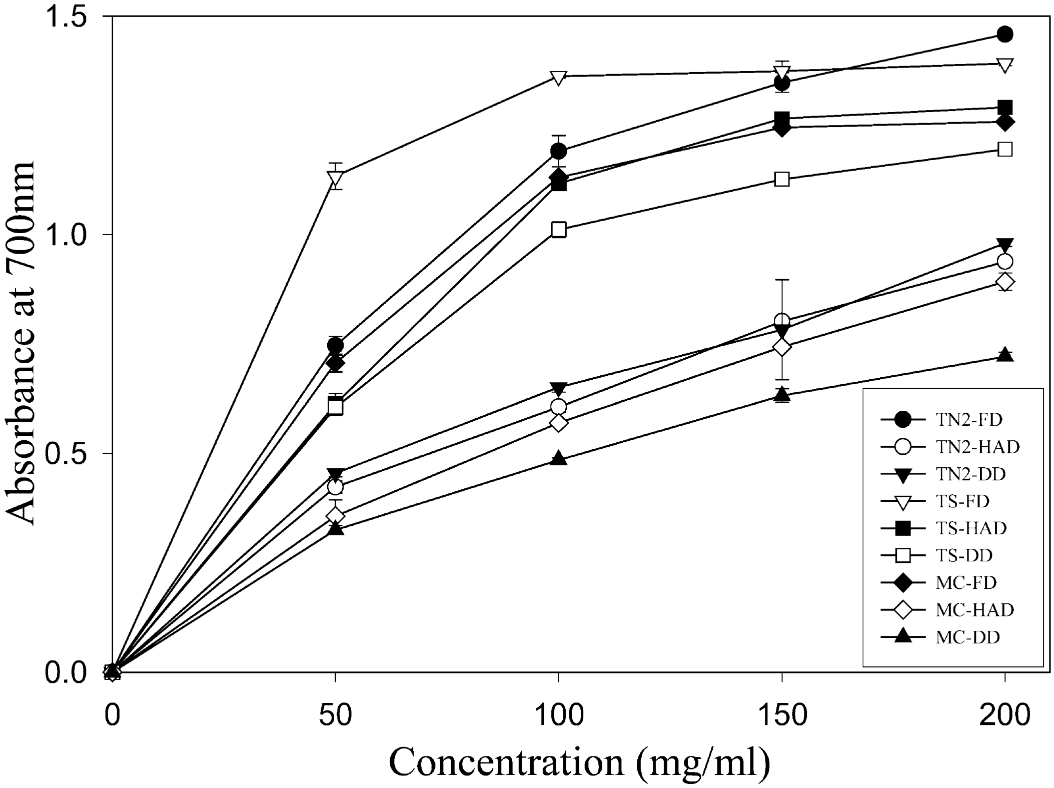

Fig. 4. Reducing power of yam flours prepared by different drying methods. Means of triplicates; error bar, standard deviation. Notations for yam varieties and drying methods as in Fig. 1.

The ABTS/$H_2O_2$/HRP decoloration method is reported to represent the total antioxidant activity of browned yam flour diet (Farombi et al., 2000) and tomato juice and vegetables (Arnao et al., 2001). Freeze-dried purple yam (Ming-Chien) flours exerted nearly 100% total antioxidant activity at a level of 200 mg/ml (Fig. 3). Furthermore, freeze-drying again was the best drying method for preparing yam flour in regard to the preservation of total antioxidant activity.

Reducing power has been used as one of the antioxidant capability indicators of medicinal herbs (Duh & Yen, 1997). The reducing power may accord with overall antioxidant activity. In general, freeze drying preserved most of the reducing power of yam flours (Fig. 4). Hot air-drying and drum-drying had about the same effects on the reducing power. Comparing the difference among yams, Tai-Nung No. 2 yam flours possessed higher reducing power than the other two types of yams. Although Ming-Chien yam flours had better free radical scavenging activity and total antioxidant capacity, the flours were inferior to flours made from the other two types of yams in this test. Since there was hardly any browning during drying, the antioxidant activity of yam flour could not be accounted for by the Maillard reaction products, as in the case of browned yam flour diet (Farombi et al., 2000).

In conclusion, drying methods showed significant effects on the moisture contents of yam flours, but had no marked effects on other components of yam flours. Colour attributes and physical properties were all affected by drying methods to different extents. While freeze-drying usually preserved more of the antioxidant activities of yam flours, the predominant antioxidant mechanisms for each variety of yam were different.

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