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RETENTION OF PHENOLICS, CAROTENOIDS, AND ANTIOXIDANT ACTIVITY IN THE TAIWANESE SWEET POTATO (*Ipomoea batatas* Lam.) CV TAINONG 66 SUBJECTED TO DIFFERENT DRYING CONDITIONS

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ABSTRACT

The effects of three drying methods on phenolic and carotenoid content and antioxidant activity (AOA) of Tainong 66 cultivar sweet potato (*Ipomoea batatas* Lam.) were investigated. Roots of 12 batches of freshly harvested tuberous root were washed in tap water, allowed to dry, peeled and cut into small pieces of 0.5 to 1 cm of thickness. Three samples of 500±2 g of each batch were dried at 25°C in a low-temperature dryer adjustable within the temperature range of 0 and 50°C, the second and third sets of three in hot air in an oven at 50 and 75°C. The last set of three served as control. The samples (dried and fresh) were then extracted and analyzed for total phenolics, total flavonoids, total carotenoids, β-carotene, and AOA. The AOA was assessed using 2,2-dipheny-1-picrylhydradzyl (DPPH) and anti-oxidative potency in linoleic acid system model (AOP) assays. The color parameters were also measured using a Color Quest II – Sphere Colorimeter (Hunter Lab, Reston, VA, USA) using the L, a, b scale. The results showed significant decrease as a result of drying in the color parameters and the contents of total phenolics, total flavonoids, total carotenoids and β-carotene. DPPH free radical scavenging activity (FRSA) and AOP also decreased significantly. Large variations of decrease were observed among the different treatments in terms of color change, phenolic and carotenoid content, and AOA during the drying process. On average, higher drying temperature corresponded to higher extent of losses of phenolics and AOA. The losses of DPPH FRSA were chiefly due to losses of phenolics during the drying process. Those results suggested that the thermal process is prejudicial to the Tainong 66 cultivar sweet potato in terms of phenolic and carotenoid content and AOA. When drying is to be done, low temperature drying (LTD) is more suitable to preserve the AOA of Tainong 66 cultivar sweet potato.

Key words: flavonoids, β-carotene, DPPH, antioxidative potency

INTRODUCTION

Damaging effects of free radicals such as superoxide (O_2^-), peroxide (O_2^{2-}), oxide (O^{2-}) and hydroxide (OH^-) ions on human tissues have been reported to cause many pathological disorders, including cardiovascular diseases, cancer, cataracts, neurological dysfunctions, deficiencies in immune response, age-related problems, among others [1] Some secondary metabolites in food have been reported to possess properties to counteract the oxidative stress in animal tissues, and these are called antioxidants. To delay the onset of deteriorative oxidation processes during storage, many food additives have been synthesized and are widely used in food industry [2]. In parallel, antioxidants such as phenolics and carotenoids known to protect plants in their natural environments against adverse conditions have been found to increase the storage life of foodstuffs, in addition to counteracting oxidative stress in animal tissues [3]. Nowadays, concerns about toxicity and carcinogenicity of synthetic food additives have been increasing, and it is commonly admitted that eating a diet rich in antioxidant-containing foods, has been linked to a reduced risk of some pathological conditions [4]. Consequently, consumers' demands for natural food ingredients have increased and there has been a general desire to replace synthetic food additives with natural options [5. Health promotion and disease prevention by appropriate diets have drawn the attention of the scientific community. Studies have suggested that antioxidants occur naturally in many fresh foods, particularly fresh fruits, vegetables including sweet potato (*Ipomoea batatas* Lam.), and whole grains, and great interest has been placed in screening and ranking plant materials and food commodities for total AOA [6]. Sweet potato is an easy-to-grow crop with good adaptability in diverse environmental conditions; it has high yielding ability and high energy content [7]. It is suitable for organic food production and other environmentally friendly agricultural practices. Sweet potato ranks as the fifth most important food crop in terms of fresh weight after rice, wheat, maize, and cassava in developing countries, where 95% of its annual production (more than 133 million tons) is concentrated [8]. Some varieties have anti-carcinogenic properties and/or AOA [9]. Thus, it is a promising crop for global food security, disease prevention, and health promotion.

Drying is an old and common practice of preserving food which brings food water activity to a level unfavorable for development of microorganisms during storage and facilitates food distribution by reducing bulk volume. However, thermal processing has long been perceived to cause the loss of some heat-labile nutrients [10], consequently lowering the nutritional value of food. Boiling has been reported to reduce the carotenoid content of sweet potato, and the magnitude of reduction varies from 14 to 59% among cultivars [11]. Depletion of β-carotene by 33 to 68% during deep-fat frying of sweet potato has also been reported [12]. Jaramillo-Flores *et al.* [13] reported that thermal treatments increase the extractability of carotenoids and phenolics from Cactus pears (*Opuntia ficus-indica*) and that their antioxidant activity is related to the carotenoids concentration. They also reported that total phenolic content of Cactus pears decreased after the thermal treatments, but that decrease had little effect on the antioxidant activity. Those results show large discrepancies among the effects of thermal treatments on the antioxidant contents and antioxidant activities.

Those discrepancies are related to the genetic material and the treatment methods and conditions, so that the results could not be predicted. Moreover, Tainung 66 sweet potato cultivar has never been investigated in such a way.

The suitability of any post harvest food treatment depends on its effect on nutritious and functional properties of the food [14]. Thus, assessing methods of post-harvest handling of foods, particularly drying and storage are important research topics.

Tainong 66 is one of the most important sweet potato cultivars in Taiwan along with other cultivars such as Tainong 57, Tainong 68, Tainong 70, Tainong 73, and Taoyuan No.1. It has a yellow color that makes it very attractive to consumers. Cultivars with similar characteristics may be found in other countries, including African countries. The objective of this study was to analyze the effects of three drying conditions on the content of phenolics and carotenoids and the AOA of Tainong 66 cultivar sweet potato.

MATERIALS AND METHODS

Materials

Freshly harvested tuberous roots of Tainong 66 cultivar sweet potato were purchased from a local traditional market in Pingtung city, Taiwan in Spring 2008. A spectrophotometer model Beckman Coulter DU 730 UV/VIS was used. A HPLC system consisting of a high-pressure pump (HITACHI L-7100, Japan) and a UV-visible detector (HITACHI L-7420, Japan) were also used. Separation was performed in a RP18 column (Microsorb, 5 μm, 4 nm × 250 nm).

Sample Preparation

The samples were divided into 12 batches of 10 roots each. The roots of each batch were washed in tap water, kept at room temperature (25°C) for 1 h to dry. They were then peeled, cut into small pieces (0.5 to 1 cm of thickness), and pooled. A sample of 500 ± 2 g was taken from each batch. Three samples were submitted to low-temperature drying (LTD) at 25°C using a low-temperature dryer adjustable within the temperature range of 0 to 50°C. Three were submitted to hot air drying (HAD) at 50°C, and three to HAD at 75°C in oven. The other three samples served as control (fresh sample). The lower drying temperature, 25 C, was chosen to mimic the effects of drying at room temperature on the antioxidant activity. This temperature was regarded as low in the experiments. The two other drying temperatures, 50 C and 75 C, were considered as moderate and high, respectively. They were chosen to analyse the trend in the antioxidant content and antioxidant activity of Tainung 66 sweet potato cultivar under increasing drying temperature. The three batches of each drying process (treatment) constituted three replicates of the treatment. A drying curve was established in each drying process to decide the end-point drying time. This end-point was set at the time the drying curve stabilized. The dried samples were ground into a fine powder using a laboratory miller model S102DS (Strand Manufacturing company, Inc), weighed, sealed in laminated plastic bag and kept in

desiccators until extraction. The sample dry matter of each treatment (control, LTD, HAD at 50°C, or HAD at 75°C) was measured according to the official methods of analysis of the Association of Official Analytical Chemists [15]. Water activity of the samples was measured in triplicate in an Aw Quick water activity meter (Rotronic Instrument Corp., Huntington, N.Y., U.S.A.).

Experimental Design

The study was carried out according to a single-factor experiment in a completely randomized design. Three drying methods (LTD at 25°C, HAD at 50°C, and HAD at 75°C) were tested against a control (fresh samples) in three replicates, yielding 12 experiment units. In each treatment, three different batches of peeled and cut sweet potato were dried, and each batch was regarded as a replicate. Contents of total phenolics, total flavonoids, total carotenoids, and β-carotene; DPPH FRSA; and AOP were the response variables. All measurements were carried out in triplicate for each replication to ensure reproducibility of the results.

Color Parameters Measurement

The color parameters were measured for the cross section of the fresh root (control) and powders of dried samples using a Color Quest II – Sphere Colorimeter (Hunter Lab, Reston, VA, USA) using the L, a, b scale. The 'L' value is the degree of lightness of the sample; it varies from 0=black to 100=white. The 'a' value means red color when it is positive (+) and green color when it is negative (–). The 'b' value corresponds to yellow color when it is positive (+) and blue color when it is negative (–). The hue angle (h°)= arc tangent (b/a) and chroma value = $\sqrt{a^2 + b^2}$ were calculated using Excel software. The hue angle values were interpreted according to the keys listed in Table 1. The chroma value is a measurement of the hue intensity [16].

The Crude Extract Preparation

Fresh sample (100 ± 0.1 g) was blended for 2 min with 400 mL ethanol and transferred into a 500 mL flask. Sweet potato powder (4 ±0.01 g) in ethanol (40 ml) in a 250 ml flask was placed in a water bath (25 °C) and shaken at 100 rpm for 24h in the dark for complete extraction [17]. The mixture was filtered through Whatman no. 1 filter paper (Whatman Inc., Clifton, NJ) and the residue was washed with an additional 100 mL ethanol (40 mL in the case of dried samples). The filtrate was evaporated to dryness using a rotary evaporator model BUCHI 111 equipped with a water-bath BUCHI 461 (Switzerland). The dried residue, referred to as crude extract, was weighted, re-dissolved in ethanol to a concentration of 10 mg/ml, and stored at -20 ºC until analysis. The extraction yield (% dry weight) was estimated by dividing the dry extract weight by the sample dry weight and multiplying by 100.

Carotenoids Extraction

Carotenoids were extracted according to Teow et al. [9]. The equivalent of 5 g dry weight was mixed with 2 g Na_2CO_3, 1 g diatomaceous earth, and 25 ml methanol. A hexane–acetone (1:1 v/v) mixture (50 ml) was added and stirred for 2 h in the dark.

The mixture was filtered through Whatman no. 1 filter paper. The residue was washed twice with 25 ml methanol, then once with 50 ml hexane–acetone mixture. The washings were combined in a 250 ml separatory funnel and completed to volume with distilled de-ionized water (ddH_2O). The aqueous phase was discarded and the upper layer was transferred into a 50 ml volumetric flask and made to volume (50 ml) with hexane for analysis.

Total Phenolic and Flavonoid Contents Assays

The total phenolic content was assayed according to the method of Folin and Ciocalteu [18] as reported by Miliauskas et al. [19] using GA as standard. The results were presented as mg GA equivalent (GAE)/100 g dry weight. The total flavonoid content was assessed by the aluminium trichloride colorimetric method as described in Marinova et al. [20] using catechin as standard. The results were reported as in mg catechin equivalent (CE)/ 100 g dry weight.

Total Carotenoids and β-carotene Analysis

The total carotenoid content was measured according to Gomes [21]. The absorbance of the extract was read in spectrophotometer at 450 nm and the total carotenoid content was calculated according to the following formula: $CT = \frac{A_{450}x1000}{250xLxW}$, where CT is the total carotenoid content in µg/g dry weight; A_{450}, the absorbance of the extract at 450 nm; L, the pathlengh of the cuvette used in the spectrophotometer; w, the initial amount (g) of sample divided by the final volume (ml) of extract obtained.

Identification and quantification of β-carotene was done by HPLC. 2 mL extract were filtered through a 0.45 μm Millipore membrane, and a 20 µL sample was injected in duplicate into the liquid chromatographic system consisting of a high-pressure pump (HITACHI L-7100, Japan) and a UV-visible detector (HITACHI L-7420, Japan). Separation was carried out in a RP18 column (Microsorb, 5 μm, 4 nm × 250 nm). Detection was monitored at 450 nm and the mobile phase consisted of methanol, ETOAC, and acetonitrile (70:20:10) at a flow rate of 1.0 mL/min. Quantification was done using standard β-carotene calibration curve. The HITACHI Chromatography Data Acquisition Software was used to collect and process the data. The peak area was used to compute the β-carotene content in µg/mL. The results were then converted into µg/g dry weight.

Determination of the Antioxidant Activity

The AOA was measured by DPPH and AOP assays. DPPH assay was conducted according to Molyneux [22]. Absorbencies were monitored at 517 nm (A_{517}) in a spectrophotometer Beckman Coulter DU 730 UV/VIS and DPPH FRSA was determined using the following formula: DPPH FRSA (%) =[(A_0-A_f)/A_0]*100, where A_0 is the blank absorbance and A_f, the test sample absorbance. AOP assay was carried out according to Jung et al. [23]. Absorbencies were read in spectrophotometer at 532 nm (A_{532}) against blank and the AOP (%) was calculated as follows: %AOP=[1-(A_{532} sample/A_{532}blank)*100].

Statistical Analysis

The data were submitted to analysis of variance according to Kuehl [24]. The SAS (Statistical Analysis System, v. 8.1; SAS Institute Inc., Cary, NC, USA) software was used. Treatment effects were evaluated by F test at α=0.05. The results are reported as mean±SE. Means comparison was done by Tukey's studentised range test at α level= 0.05. The relationship between DPPH and AOP assays, as well as the relationship of the AOA with the phenolic and carotenoid contents, was assessed by Pearson correlation coefficients (r).

RESULTS

Drying Control and Extraction Yield of the samples

The drying process took 24, 96, and 240 h in HAD at 75°C, HAD at 50°C, and LTD at 25°C, respectively. The water activity (a_w) of the fresh samples was 1 and their dry matter content was 30.69 %. The a_w of the dried samples fluctuated between 0.26 and 0.28 and the dry matter content varied from 91.30 to 95.51% (Table 2). The drying curve stabilized in the a_w range from 0.26 to 0.28 because the mobility of water was reduced in this range. The highest extraction yield value was observed in fresh samples, followed by those dried at 50°C. Samples dried at 25 and 75°C showed the lowest extraction yield.

Effects of the Drying Process on the Color parameters

The hue angle values listed in Table 3 outlined that the color of fresh samples of Tainong 66 cultivar sweet potato was reddish yellow. It shifted to yellow during LTD at 25°C and HAD at 50ºC. It remained yellow during HAD at 75ºC. Figure 1 shows a visual color appearance of the samples. The color lightness increased during HAD at 50 and 75ºC and decreased during LTD at 25ºC. The color intensity decreased in all drying methods. The loss of intensity increased with increasing drying temperature.

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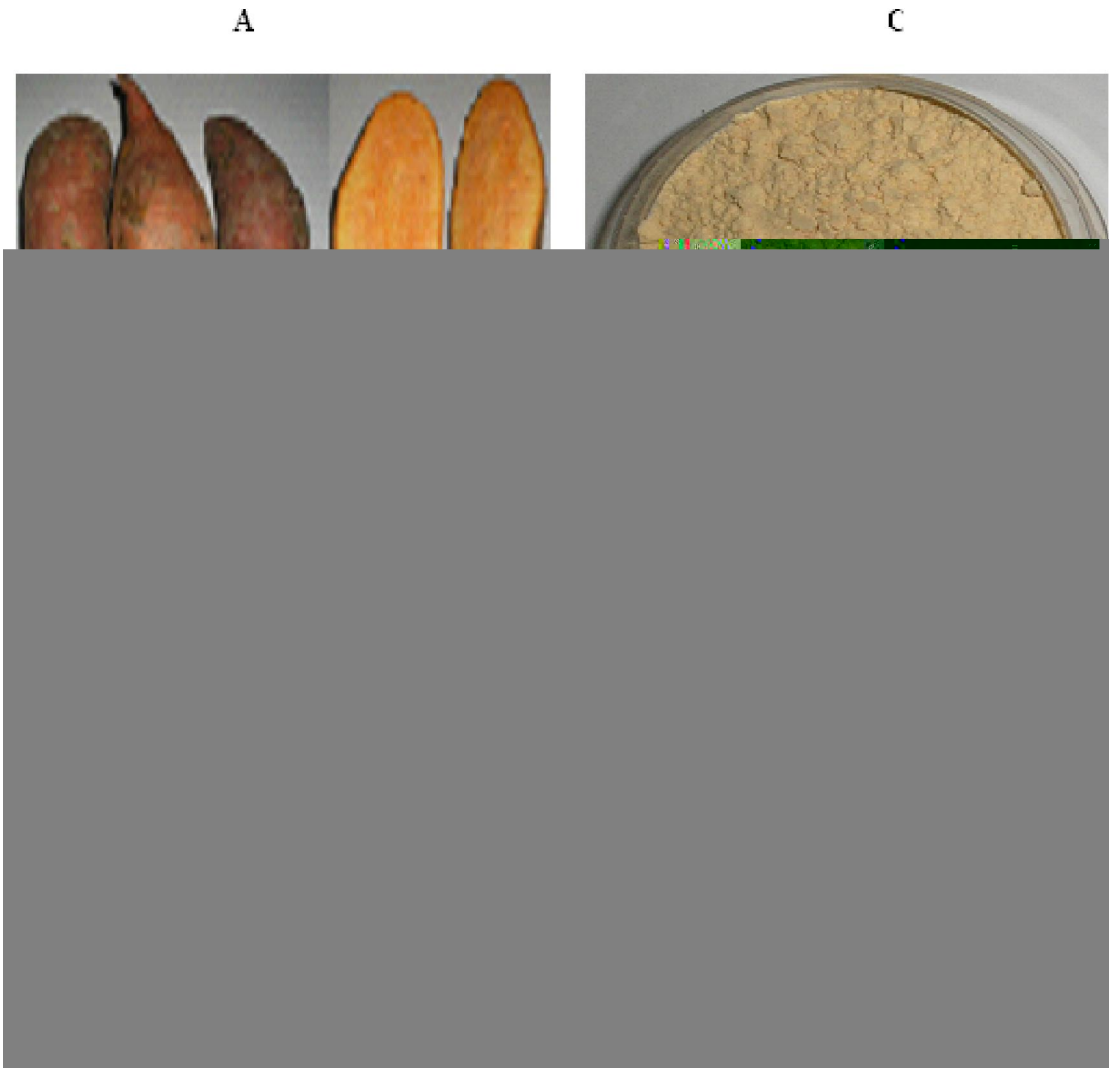

Figure 1: Visual color appearance of entire and cut root (A), and powder of sweet potato var. Tainong 66 dried at 25 (B), 50 (C), and 75°C (D), respectively

Effects of the Drying Process on Total Phenolic and Flavonoid Contents

The total phenolic content decreased by between 23.66 and 68.72% (Tables 4). The highest value of total phenolic was observed in fresh samples, followed by those submitted to LTD at 25°C. The total phenolic content decreased with the increase of the drying temperature. The decrease of flavonoids content was low in LTD and HAD at 50°C (6.05 and 6.32%, respectively), whereas it was high in HAD at 75°C (43.15%). There was also increase in loss of flavonoids with increase in temperature.

Effects of the Drying Process on Total Carotenoid β-carotene Contents

The total carotenoid content was higher in fresh samples, followed by those subjected to LTD at 25ºC, and then those submitted to HAD at 75°C (Table 5). Samples dried at 50°C for 96 h exhibited lower content of total carotenoids because those conditions represented a higher heat stress to the samples in comparison to LTD at 25°C and HAD at 75°C for 24 h. Moreover, in HAD at 50°C, the exposition time to light and oxygen was longer than in HAD at 75°C, so that the oxidative degradation of the carotenoid molecules was more important in HAD at 50°C than in HAD at 75°C. The β-carotene content showed quite similar changes as total carotenoids during the thermal processing treatment.

Effects of the Drying Process on the Antioxidant Activity

The highest value of DPPH FRSA was observed in fresh samples followed by those submitted to LTD at 25ºC, then those submitted to HAD at 50ºC, and then those submitted to HAD at 75ºC (Table 6). The decrease of DPPH FRSA in LTD at 25ºC was low (5.82%), while in HAD at 50 and 75ºC, the DPPH FRSA decreased substantially, 22.57 and 47.58%, respectively. The highest value of AOP was observed in fresh samples. All drying treatments resulted in a slight decrease of AOP from 18.36 to 20.20%. These results suggested that the AOP of the samples resisted to heat treatments in the range of 25 to 75ºC. The high temperature (75ºC) corresponded to higher color lightness (Table 3) and higher decrease of the AOA (Table 6).

The Pearson correlation coefficients listed in Table 7 show positive and significant correlations between DPPH and AOP assays (r= 0.7797). This r value corresponds to a coefficient of determination r^2= 0.6079, meaning that 60.79% of the AOP variation may be explained by the DPPH FRSA variation. The results also showed higher correlations of the AOA indicators with the phenolics than the carotenoids.

DISCUSSION

Ethanol extracts of fresh samples and those dried at 25°C showed DPPH FRSA higher than 90%. These results were similar to those of methanol extracts of some medicinal plants [19]. Teow at al. [13] reported value of total phenolics in sweet potato ranging from 13 to 47.2 mg GAE/100g SFW of orange-flesh and from 47.7 to 94.9 mg GAE /100 g SFW of purple-flesh sweet potato. Asami et al. [25] found total phenolics content ranging from 150 to 280 mg GAE/100 g in fresh strawberry and 300 to 600 mg GAE/100 g in fresh marionberry. In light of those findings, sweet potato var.

Tainong 66 can be considered rich in phenolics. While HAD reduced the DPPH FRSA by more than 20%, the losses did not reach 6% in LTD. These results showed that the AOA decreased with increasing drying temperature. These decreases of the AOA during the drying process agreed with Larrauri et al. [26] who observed reduction of AOA by 28% in red grape pomace peels when dried with hot air at 100^{o}C. Total phenolics and flavonoids losses during the drying process also increased with increasing drying temperature, complying with Adebooye and Singh [27] who reported losses of total phenolics to the extent of 24.4 and 53% in Cowpea var. C-152 and S-1552, respectively, during cooking. In turn, Muchoki et al. [28] observed that heating and drying of vegetables lead to substantial loss of antioxidants.

Phenolic compounds comprise a large group of biologically active substances. Quercetin, catechin, ferrulic acid, caffeic acid, gallic acid, coumaric acid, and rutin, are among the most common naturally occurred antioxidant phenolic compounds in foods. Other natural antioxidants include glutathione peroxidase, superoxide dismutase, tocopherols, and vitamin C, and carotenoids. The results of the present study suggested that the decreases in AOA of Tainong 66 cultivar sweet potato during the drying process were chiefly due to losses in total phenolics, as suggested by the correlation coefficients listed in Table 7. Those correlations agreed with Islam et al. [29] who reported significant correlation between DPPH FRSA and total phenolic content of sweet potato leaves. Similarly, Stintzing et al. (2005) [30] reported high and significant correlation between the phenolic content and AOA of cactus pear (*Opuntia spp.*) clones. Lower correlations were observed between the AOA and carotenoids. The most important losses observed in total carotenoids and β-carotene during the drying process occurred in HAD at 50 C. This treatment corresponded to longer exposition time to combined effects of heat, light and oxygen. Carotenoids are highly sensitive to light and oxygen, which accelerate their oxidative degradation into aromatic compounds. For instance, at molecular level, under the combined effects of heat, light, and oxygen, the oxidative degradation of β-carotene results in formation of β-cyclocitral and β-ionone [10]. Phenolic compounds also are degraded on heating. For instance, 4-vinylguaicol is formed by thermal degradation of ferulic acid [10].

CONCLUSION

Tainong 66 cultivar sweet potato had high AOA and considerable concentration of phenolics and carotenoids, in particular, β-carotene. It maintained a high DPPH FRSA during LTD at 25°C, but the AOA decreased with increasing drying temperature. The decreases in AOA during the drying process at high temperature were due to losses of phenolic and carotenoid contents. These results suggested that the thermal process is prejudicial to sweet potato Tainong 66 cultivar in terms of AOA. When drying is to be done, LTD is more suitable to preserve the AOA. However, low-temperature drying is time consuming and, consequently, costly and difficult to scale up. Thus, it is recommended that the existing large range of sweet potato genotypes be investigated in order to identify cultivars suitable for drying at high temperature for shorter times in food industry.

Table 1: Interpretation keys of the hue values (h°) corresponding to the visible color of the samples analyzed

Hue (h°)	Corresponding visible color
0<α≤22.5	Red
22.5<α≤45	Yellowish red
45<α≤67.5	Reddish yellow
67.5<α≤112.5	Yellow
112.5<α≤135	Greenish yellow
135<α≤157.5	Yellowish green
157.5<α≤202.5	Green
202.5<α≤225	Bluish Green
225<α≤247.5	Greenish blue
247.5<α≤292.5	Blue
292.5<α≤315	Reddish blue
315<α≤337.5	Bluish red
337.5<α≤360	Red

Table 2: Water activity, dry matter content, and extraction yield of the samples of Tainong 66 cultivar sweet potato 66 as affected by the drying conditions[1]

Drying process[2]	Water activity	Dry matter (%)	Extraction yield (% dry weight)
Control	1.00±0.00a	30.69±0.31c	28.61± 1.82a
LTD at 25ºC	0.28±0.01b	91.23±0.30b	12.99±0.92c
HAD at 50ºC	0.27±0.01bc	95.51± 1.39a	19.43±1.01b
HAD at 75ºC	0.26±0.00c	94.71±1.28a	13.84±0.93c

[1] Means (mean±SE, n=3) with same letter in a column are not significantly different (p>0.05);
[2]LTD: Low-temperature drying; HAD: Hot air drying.

Table 3: Changes induced in hue angle, color lightness, and color intensity expressed as chroma of Tainong 66 cultivar sweet potato during the drying process[1]

Treatment[2]	Hue (hº)	Lightness (L)	Chroma (C)
Control	56.73±5.93b	63.40±0.93c	34.33±0.54a
LTD at 25ºC	78.22±4.00a	25.29±0.00d	7.60±0.00d
HAD at 50ºC	71.90±3.04a	74.80±0.00b	21.64±0.00c
HAD at 75ºC	63.26±3.45b	75.90±0.02a	24.26±0.01b

[1]Means (mean±SE, n=3) with same letter in a column are not significantly different (p>0.05);
[2]LTD: Low-temperature drying; HAD: Hot air drying.

Table 4: Total phenolic and flavonoid content of Tainong 66 cultivar sweet potato as affected by the drying conditions[1]

Treatment[2]	----------Total phenolics[3]----------		-------Total flavonoids[4]-------	
	A	B	C	D
Control	501.69±10.88a	-	241.28±3.10a	-
LTD at 25ºC	128.84±0.05b	23.66±0.01c	76.26±0.15b	6.05±0.03b
HAD at 50ºC	100.04±0.02c	37.94±0.00b	73.24±0.15b	6.32±0.03b
HAD at 75ºC	50.85±0.06d	68.72±0.01a	44.45±0.11c	43.15±0.02a

[1]Means (mean±SE, n=3) with same small letter in a column are not significantly different (p>0.05);
[2]LTD:low-temperature drying, HAD: Hot air drying;
[3]A: results in mg gallic acid equivalent/ 100 g dry weight, and B: extent of decrease (%) of A with regard to the control values;
[4]C: results in mg catechin equivalent /100g dry weight, and D: extent of decrease (%) of C with regard to the control values.

Table 5: Total carotenoid and β-carotene content of Tainong 66 cultivar sweet potato as affected by the drying conditions[1]

Treatment[2]	Total carotenoids (µg/g dry weight)	----------β-carotene----------	
		(µg/g dry weight)	% total carotenoids
Control	510.39±0.12a	464.61±29.78a	91.05±5.09
LTD at 25ºC	223.63±0.29b	201.33± 0.87b	90.03±0.21
HAD at 50ºC	48.36±0.64d	45.03±1.43d	93.12±1.67
HAD at 75ºC	199.14±0.74c	177.54±4.43c	89.15±1.93

[1]Means (mean±SE, n=3) with a same letter in a column are not significantly different;
[2]LTD: low-temperature drying HAD: Hot air drying

Table 6: DPPH FRSA and AOP of Tainong 66 cultivar sweet potato as affected by the drying conditions[1]

Treatment[2]	----------Antioxidant activity[3]----------			
	A	B	C	D
Control	95.82±0.48a	-	67.04±0.24a	-
LTD at 25ºC	90.76±0.03b	5.82±0.00c	54.46±0.14b	18.77±0.05a
HAD at 50ºC	74.19±0.23c	22.57±0.05b	53.50±0.24b	20.20±0.10a
HAD at 75ºC	50.23±0.30d	47.58±0.04a	54.73±0.48b	18.36±0.13a

[1]Means (mean±SE, n=3) with the same small letter in a column are not significantly different (p>0.05);
[2]LTD:low-temperature drying, HAD: Hot air drying;
[3]A: 2,2-dipheny-1-picrylhydradzyl (DPPH) free radical scavenging activity (FRSA) (%); B: extent of decrease (%) of A with regards to the control value; C: anti-oxidative potency in linoleic acid system model (AOP) (%); and D: extent of decrease (%) of C, with regards to the control value.

Table 7: Pearson correlation coefficients between DPPH and AOP assays and the relationship of the antioxidant activity indicators with phenolic and carotenoid contents of the samples

Variables[1]	DPPH FRSA	AOP
AOP	0.7797*	1.000
Total phenolics	0.6213 *	0.9732**
Total flavonoids	0.6249 *	0.9758**
Total carotenoids	0.3938 NS	0.8110 *
β-carotene	0.4017 NS	0.8179 *

[1]Anti-oxidative potency in linoleic acid system model (AOP); DPPH FRSA: 2,2-dipheny-1-picrylhydradzyl free radical scavenging activity. *: Significant correlation (p<0.05), **: highly significant correlation (p<0.01), NS: non significant correlation (p>0.05).

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