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Effects of Different Cooking and Drying Methods on Antioxidant and Dietary Fiber Properties of Red Pitaya (*Hylocereus polyrhizus*) Fruit

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Abstract: The aim of the present study was to study the influence of several thermal processing methods such as cooking and drying on biologically active compounds of red pitaya. Flesh of red pitaya was subjected to five different thermal processes: oven cooking at 95ºC 30 min, oven cooking at 95ºC 60 min, oven cooking at 105ºC 60 min, drum drying, and spray drying. Total phenolic content, scavenging activity, antioxidant activity and dietary fiber contents of the fresh and processed red pitaya were subsequently determined. The effect of oven cooking on antioxidant parameters of red pitaya were highly significant compared to fresh one ($p<0.05$). Whereas, drum drying and spray drying were the best methods for antioxidant preservation in this fruit, compared to the other thermal processes applied in this study. Among all of the heating temperatures applied in this study, drum drying was the best method for preservation of total phenolic content, radical scavenging and antioxidant activity, and 95ºC for 30 min oven cooking was the best process to preserve dietary fiber parameters of this fruit.

Key words: Dietary fiber, dragon fruit, phenolic content, scavenging activity, thermal processing

INTRODUCTION

Some non-thermal minimal processing technologies such as high pressure processing (Wolbang *et al*., 2008), high intensity pulsed electric field (Cortes *et al*., 2008), and osmotic dehydration (Panades *et al*., 2008), as the new methods of food processing are applied, even though the temperature range that is still being used in food engineering is -50 to 150ºC (Sun, 2006). Both the low and high temperatures, can damage nutrients, especially in water-rich foods like fruits and vegetables. The length of time of temperature is another damaging factor.

Fruits and vegetables are naturally rich in antioxidant, dietary fibers, and some other valuable nutrients. The retention and elimination of antioxidant contents and dietary fibers vary, because of not only their character but the heating methods used (Larrauri, 1999; Rehman *et al*., 2003; Amin and Lee, 2005; Amin *et al*., 2006; Park *et al*., 2006; Wennberg *et al*., 2006). It means certain thermal processes to preserve certain active components should be selected.

Most of the tropical fruits like some temperate fruits are rich in natural antioxidants and dietary fibers (Gorinstein *et al*., 1999; Nititham *et al*., 2004; Wu *et al*., 2006; Mahattanatawee *et al*., 2006). Among tropical fruits, the fruit of *Hylocereus* cacti, also known as red pitaya, have recently attracted the growers worldwide. Because of its red-purple color, it has economic value as food product (Wybraniec and Mizrahi, 2002). This fruit is native to the tropical forest regions of Mexico and Central and South America (Mizrahi *et al*., 1997); but nowadays it is being grown in some other countries (Wu *et al*., 2006). Also, it has been cultivated on a large scale in Malaysia. Not only the antioxidant capacity and phenolic contents, but its dietary fibers (Nititham *et al*., 2004; Mahattanatawee *et al*., 2006; Wu *et al*., 2006) are substantial.

Red pitaya is consumed fresh or made into processed products such as juice, powder, jam and jelly. As fresh pitaya contains all of the valuable biologically active components, consumption of its fresh one is ideal. However, the production of tropical fruit flavors in the form of powder enables the industry to expand products made from these fruits. The fruit powders are used in instant soups, snacks, bakery, beverage, dairy, candy, ice cream, baby food, pasta, etc. Furthermore, to encourage

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people to eat fruits, cooking and even making fruit kabobs are recommended (United State Department of Agriculture, 2009). But, the nutritional values of red pitaya, like other fruits, can be affected by preservation and thermal processing methods.

The objective of the present work was to study the influence of several thermal processing methods such as cooking and drying on biologically active compounds of red pitaya, such as phenolic content, radical scavenging activity, antioxidant activity, and dietary fiber contents, with the aim of determination the conditions that maximize retention of those valuable nutrients.

MATERIALS AND METHODS

Chemicals: This study was conducted at the Faculty of Medicine and Health Sciences, Universiti Putra Malaysia from 2006 until 2009. Folin-Ciocalteu reagent, sodium acetate trihydrate ($C_2H_3NaO_2.3H_2O$) and ascorbic acid were purchased from Merck Co. (Darmstadt, Germany). Sodium carbonate came from Fisher Scientific (Leicestershire, UK). Ferrous sulfate ($FeSO_4.6H_2O$) was obtained from BDH Chemicals (USA). Gallic acid, DPPH (2,2-Diphenyl-1-picryl-hydrazyl), TPTZ (2,4,6-tri-pyridyl-s-triazine), ferric chloride ($FeCl_3.6H_2O$), heat-stable α-amylase solution, protease, amyloglucosidase, 2-(N-Morpholino) ethanesulfonic acid (MES), Tris (hydroxymethyl) aminomethane, and maltodextrin 20 DE were purchased from Sigma Chemical Co. (St. Louis, MO, USA).

Samples: Red pitaya (*Hylocereus polyrhizus)* fruit (Ayer Keroh Melaka, Chekap Harvest Sdn. Bhd), was washed and kept at -20ºC before analysis. Five kilograms (5 kg) of red pitaya were skinned, flesh chopped into small pieces and blended to make a homogeneous liquid. Then, it was divided into six portions. The first portion was stored at -20ºC to use as fresh pitaya sample. Five portions of the homogeneous liquid were thermally processed. Three portions were put in the oven at different temperatures and times. Two other portions were drum-dried and spray-dried. The procedures were carefully carried out with minimum exposure to light. All the portions of red pitaya (fresh and treated pitayas) were stored at -20ºC before extract preparation.

Thermal processing:

Oven cooking: The homogeneous liquid were put in the oven (Memmert, Germany) for the following heating temperatures and durations: first portion at 95ºC 30 min; second portion at 95ºC 60 min; and third portion at 105ºC 60 min.

Drum drying: Drum-dried red pitaya was obtained by feeding its homogeneous liquid in the trough of a heated double drum drier (R. Simon (Dryers) Ltd., England) set at 1 rpm, steam pressure of 2 bar and temperature of 125-135ºC. Before steam was supplied, the width of the gap between the cold drums was adjusted to 1 mm. The dried fruit, using two doctor's blades, was removed as a thin film from the drum surface; then, it was ground into powder and stored.

Spray drying: Before being dehydrated, the homogeneous liquid of red pitaya was diluted in distilled water until a total soluble solid content of 16 ºBrix. Fruit juices rich in fructose and glucose need the addition of a carrier to avoid clogging (Mosshammer *et al*., 2006). Because maltodextrin was found to be the best for spray drying of betacyanin pigments in some plants, for example *Amaranthus* (Cai and Corke, 2000), this carrier was used for encapsulation of red pitaya. Therefore, maltodextrin 20 DE (Sigma-Aldrich, St. Louis, USA) was added to the sample at concentration of 14% (w/w). Then, powder of red pitaya was obtained by means of spray dryer (Anhydro, Denmark). The inlet air temperature (T_{inlet}), and outlet air temperature (T_{outlet}) were 180-185ºC, and 90-95ºC for all the solution investigated, respectively. The liquid feed to the dryer was about 500 g/h. The powders were stored for further analysis.

Preparation of extract: The preparation of sample extract was followed the method of Wolfe *et al*. (2003). Fifty grams of fruit (fresh and heated pitayas) were blended with 200 g of 80% acetone solution in a blender for 10 min. The mixture, after filtration and re-extraction, was evaporated using a rotatory evaporator (BÜCHI Rotavapor R-200, Germany) at 45ºC to reach to less than 10% of the initial volume. The extracts were stored at -80ºC. These extracts were used later for determination of Total Phenolic Content (TPC), scavenging activity, and Ferric Reducing Ability of Plasma (FRAP) assay.

Determination of total phenolic contents: A modified method of Wolfe *et al*. (2003) was used to measure the total phenolic contents of pitaya extracts. Briefly, the extract (125 μL) was added to 500 μL of Folin-Ciocalteu reagent in the cuvette. It was vortexed for 15 seconds and allowed to stand for 6 min at 20ºC. Then, 1250 μL of 7% sodium carbonate solution was added to the cuvette, and the mixture was diluted to 3 mL with 1125 μL deionized water. After 90 min, absorbance was measured using a UV-Vis spectrophotometer (SECOMAN, France) at 760 nm. Gallic acid was used for standard calibration curve, and the results were expressed as mg Gallic Acid Equivalents (GAE) per gram of dried extract.

Determination of scavenging activity: The radical scavenging activity of red pitaya was measured according to the method of Cai *et al*. (2003). A 100 μL of extract or

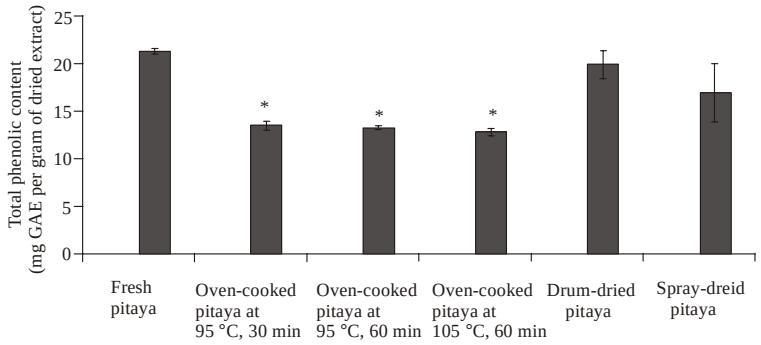

Fig. 1: Mean total phenolic content of fresh and heated pitaya extracts (mg GAE per gram of dried extract), Total phenolic content was measured using the modified Folin-Ciocalteu method. Data are means (±S.E) of three determinations. Asterisk (*) indicates significant difference at the level of $p<0.05$ between fresh and processed samples of red pitaya fruit

ascorbic acid was added to 3900 μL of an 80% ethanolic solution of 0.6 mM DPPH in the cuvette, and vortexed for 15 sec. Using a spectrophotometer (SECOMAN, France), absorbance of extracts was read at 515 nm after 180 min. The reaction time for vitamin C was less than 1 min. Ethanol (80%) was used as the blank, and DPPH solution without test samples (3.9 mL of DPPH + 0.1 mL of 80% ethanol) was used as the control. The results of radical scavenging activity were expressed as both μM and mg ascorbic acid equivalents per gram dried extract.

Determination of reducing power: the Ferric Reducing Ability of Plasma (FRAP) assay (Benzie and Strain, 1996) was used for measurement of antioxidant power of fresh and heated red pitayas. Fifty milliliter (50 mL) of 300 mM acetate buffer (pH 3.6), 5 mL of 10 mM TPTZ (2, 4, 6-tripyridyl-s-triazine) solution, and 5 mL of 20 mM ferric chloride ($FeCl_3.6H_2O$) solution were mixed to prepare FRAP reagent. The FRAP reagent was being kept in the water bath at 37ºC all the time of the experiment. The aqueous solutions of ferrous sulfate ($FeSO_4.7H_2O$), in the range of 100 to 1000 μM were used for calibration. A total of 1.5 mL FRAP reagent was added to a cuvette and blank reading was then taken at 593 nm using a UV-Vis spectrophotometer (SECOMAN, France). Then, 50 μL of extracts or ferrous sulfate solutions and 150 μL distilled water were added to the cuvette. The second reading at 593 nm was done after 4 min. The change in the absorbance after 4 min from the initial blank reading was then compared with the standard curve and expressed as both μM and mg ferrous sulfate equivalents per gram dried extract.

Dietary fiber analysis: The gravimetrical approach, based on AOAC International (Horwitz, 2000), was used in this study. The duplicate test portions of dried red pitaya fruit (fresh and heated pitayas) were gelatinized with heat-stable α-amylase and then enzymatically digested with protease and amyloglucosidase to remove protein and starch. Enzyme digestate was filtered using Fibertec system, and residue (insoluble dietary fiber) was washed with warm water; then it was dried and weighed. For soluble dietary fiber, combined filtrate and washes were precipitated with ethanol; afterwards, they were filtered, dried and weighed. Finally, insoluble and soluble dietary fiber values were corrected for protein, ash, and blank. The results were expressed as g/100 g of dried weight.

Statistical analysis: All the data were normally distributed and expressed as mean±S.E.M. One-way analysis of variance (ANOVA) to compare the means between groups was used. Differences were considered significant at $p<0.05$. The statistical analyses were conducted using the SPSS software (SPSS 15.0 for Windows, Chicago, Illinois).

RESULTS AND DISCUSSION

The effect of thermal processing on total phenolic content: Total Phenolic Contents (TPC) of fresh and heated pitayas are compared in Fig. 1. Based on this study, TPC of fresh red pitaya was 21.41±0.15 mg GAE per gram of dried extract. Using a modified Folin-Ciocalteu method, Wu *et al*. (2006) reported 4.55±0.03 and 25.4±2.10 mg GAE per g extract of flesh and peel of Thai red pitaya, respectively. The TPC value of the red pitaya used in this study was 4.7 times more than flesh and almost as same as peel of Thai red pitaya.

The concentration of TPC was decreased by thermal processing. The maximum damage of TPC was seen in oven-cooked pitaya at 105ºC 60 min by reduction of 8.49 mg GAE/g. The reduction of TPC in oven-cooked pitaya at 95ºC 60 min, and oven-cooked pitaya 95ºC 30 min were 8.23, and 7.98 mg GAE per gram, respectively. Generally, the effect of long times (30-60 min) high temperatures (95-105ºC) on TPC of red pitaya were

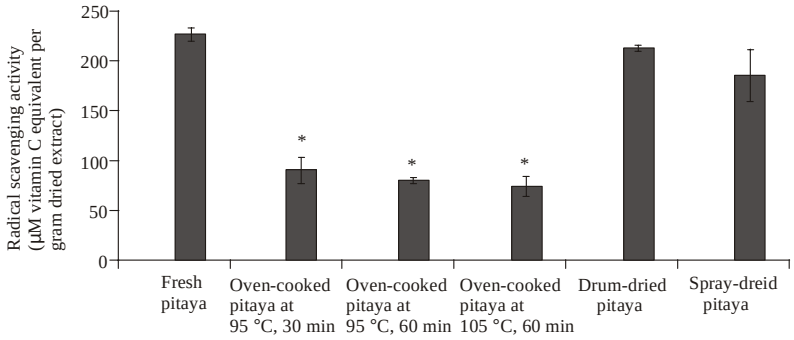

Fig. 2: Mean radical scavenging activity of fresh and heated pitaya extracts (μM vitamin C equivalents per gram dried extract), Radical scavenging activity was measured using the DPPH radical test. Data are means (±S.E) of three determinations. Asterisk (*) indicates significant difference at the level of $p<0.05$ between fresh and processed samples of red pitaya fruit

significant ($p<0.05$) compared to fresh one; but, the remaining of extractable TPC in these three samples were comparable (13.43±0.27, 13.18±0.12 and 12.92±0.26 mg GAE per gram of dried extract for oven-cooked pitaya at 95ºC 30 min, oven-cooked pitaya at 95ºC 60 min, and oven-cooked pitaya at 105ºC 60 min, respectively).

Heat sensitivity of TPC varies in different foods, thermal processing methods, times, temperatures and pH. For example, a significant reduction in the polyphenolic content of the wort even at the mashing temperature (65 to 75ºC) was reported by Mwanguma and Eze (1996). Amin and Lee (2005) reported 20, 50 and 55% loss of phenolic contents in the green cabbage (*Brassica oleracea* var *capitata*) by 5, 10 and 15 min blanching, respectively ($p<0.05$ for all). Whereas they observed different trend in the phenolic contents of Chinese cabbage (*Brassica rapa pekinensis* var *cylindrica*) against blanching; a decrease after 5 min, but increases after 10 and 15 min blanching. They suggested that heat treatment might have released phenolic contents. Betacyanins, the pigments found in *Hylocereus* cacti, also contributed to the total phenolics, due to a phenol structure in the molecule. Larrauri (1999) observed 50% reduction in the betacyanin content of red pitaya when it exposed to 90ºC within 22.6 min; whereas this temperature for 60 min damaged almost 90% of betacyanin content of beet root. The possible mechanisms of phenolic content loss in the dried samples at high temperature include:

1) Release of phenolic content bound
2) Partial degradation of lignin which could cause to the release of phenolic acid derivatives
3) Beginning of thermal degradation of the phenolic contents (Larrauri, 1999)

Although high heating temperatures affected the TPC of drum-dried and spray-dried red pitaya, these methods were not very damaging processes. The TPC in drum-dried pitaya was 19.96±1.1 mg GAE/g of dried extract, and was not significantly different compared to fresh pitaya. Spray dryer was the next option to dry this fruit by 16.88±2.02 mg GAE per gram of dried extract phenolic content ($p = 0.051$, compared to fresh pitaya). Table 1 shows the ratio of TPC of heated pitayas to fresh pitaya. Almost 93% of TPC was remained in drum-dried pitaya, whereas, 60% was left in oven-cooked pitaya at 105ºC 60 min. It indicates that the drum drying was the best method for TPC preservation in this fruit, compared to other thermal processes applied in this study.

Table 1: Ratio of Total Phenolic Contents (TPC) of heated pitayas to fresh pitaya

Fresh pitaya and heated pitayas	Ratio of Total Phenolic Contents (TPC) of heated pitayas to fresh pitaya
Fresh pitaya	1.00
Oven-cooked pitaya at 95ºC 30 min	0.62
Oven-cooked pitaya at 95ºC 60 min	0.61
Oven-cooked pitaya at 105ºC 60 min	0.60
Drum-dried pitaya	0.93
Spray-dried pitaya	0.79

The effect of thermal processing on radical scavenging activity: Figure 2 shows the scavenging activity of fresh and heated pitaya extracts. Fresh red pitaya, with 226.51±3.99 μM vitamin C equivalents per gram dried extract, exhibited the highest scavenging activity, compared to heated pitayas. Wu *et al*. (2006) reported 22.4±0.29 and 118±4.12 μM vitamin C equivalents per gram of flesh and peel of Thai red pitaya, respectively. The radical scavenging activity of the red pitaya used in this study was about 10 times more than flesh and 1.9 times more than peel of Thai red pitaya.

As expected, thermal processing caused decreases in scavenging effects of treated pitayas. The lowest scavenging effect was revealed in oven-cooked pitaya at 105ºC 60 min by decrease of 151.39 μM vitamin C equivalents per gram. The reduction of the scavenging activity of oven-cooked pitaya at 95ºC 60 min, and

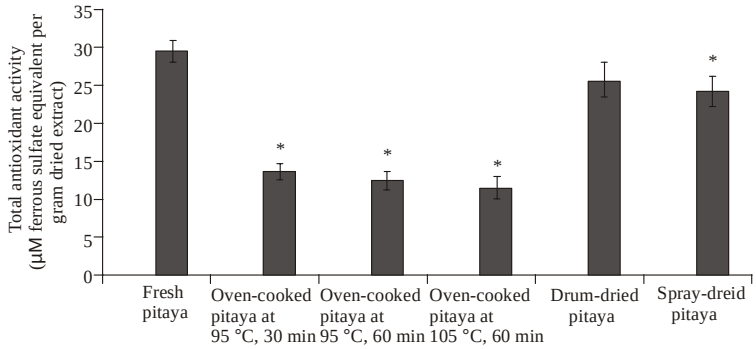

Fig. 3: Mean antioxidant activity of fresh and heated pitaya extracts (μM ferrous sulfate equivalent per gram of dried extract), Total antioxidant activity was measured using the FRAP assay. Data are means (±S.E) of three determinations. Asterisk (*) indicates significant difference at the level of $p<0.05$ between fresh and processed samples of red pitaya fruit

oven-cooked pitaya at 95ºC 30 min were 146.98 and 135.15 μM vitamin C equivalents per gram dried extract, respectively. The effect of long times (30-60 min) high temperatures (95-105ºC) on radical scavenging activity of red pitaya was considerable and significant ($p<0.05$) compared to fresh one. However, there was no significant difference between the remaining of scavenging effects in these three samples (91.36±6.2, 79.53±1.96 and 75.12±6.58 μM vitamin C equivalents per gram dried extract for oven-cooked pitaya at 95ºC 30 min, oven-cooked pitaya at 95ºC 60 min, and oven-cooked pitaya at 105ºC 60 min, respectively).

Drum and spray drying had no significant effect on radical scavenging activity of red pitaya. The scavenging effect in drum-dried, and spray-dried red pitayas were 212.64±0.83 and 184.61±22.34 μM vitamin C equivalents per gram dried extract, respectively. Their scavenging values were comparable with fresh pitaya ($p = 0.932$ and $p = 0.076$ for drum-dried and spray-dried red pitaya, respectively). Table 2 shows the ratio of radical scavenging activity of heated pitayas to fresh pitaya. Almost 92% of scavenging activity remained in drum-dried pitaya, whereas, only 24% was left in oven-cooked pitaya at 105ºC 60 min.

The effect of thermal processing on reducing power: The results of FRAP method for determination of total antioxidant activity (TAA) of fresh and heated pitayas are illustrated in Fig. 3. The TAA of fresh red pitaya was 29.39±0.66 μM ferrous sulfate equivalents per gram of dried extract, and the highest, compared to heated products. The TAA of red pitaya was decreased by thermal processing. The maximum reduction of TAA was seen in oven-cooked pitaya at 105ºC 60 min by 17.91 μM ferrous sulfate equivalents per gram. The reduction of reducing power of oven-cooked pitaya at 95ºC 60 min, and oven-cooked pitaya at 95ºC 30 min were 16.76, and 15.56 μM ferrous sulfate equivalents per gram dried extract, respectively. Evidence showed that the effect of long times (30-60 min) high temperatures (95-105ºC) on TAA of red pitaya was substantial and significant ($p<0.05$) compared to fresh one; however, there was no significant difference between the remaining of TAA in these three samples (13.82±0.58, 12.62±0.76 and 11.47±0.79 μM in oven-cooked pitaya at 95ºC 30 min, oven-cooked pitaya at 95ºC 60 min, and oven-cooked pitaya at 105ºC 60 min, respectively).

The effect of temperature on TAA of spray-dried red pitaya was significant ($p<0.05$). It showed 24.24±1.37 μM ferrous sulfate equivalents per gram dried extract of reducing power. The reduction of TAA in drum-dried pitaya was 3.92 μM ferrous sulfate equivalents per gram dried extract, and comparable with fresh pitaya ($p = 0.141$). Table 3 shows the ratio of TAA of heated pitayas to fresh pitaya. The results demonstrated that almost 87% of TAA was still remained in drum-dried pitaya, whereas, 39% was left in oven-cooked pitaya at 105ºC 60 min.

Table 2: The ratio of scavenging activity of heated pitayas to fresh pitaya

Fresh pitaya and heated pitayas	Ratio of radical scavenging activity of heated pitayas to fresh pitaya
Fresh pitaya	1.00
Oven-cooked pitaya at 95ºC 30 min	0.32
Oven-cooked pitaya at 95ºC 60 min	0.26
Oven-cooked pitaya at 105ºC 60 min	0.24
Drum-dried pitaya	0.92
Spray-dried pitaya	0.79

Table 3: The ratio of Total antioxidant activity of heated pitayas to fresh pitaya

Fresh pitaya and heated pitayas	Ratio of TAA of heated pitayas to fresh pitaya
Fresh pitaya	1.00
Oven-cooked pitaya at 95ºC 30 min	0.47
Oven-cooked pitaya at 95ºC 60 min	0.43
Oven-cooked pitaya at 105ºC 60 min	0.39
Drum-dried pitaya	0.87
Spray-dried pitaya	0.82

Correlation between TPC, scavenging activity and antioxidant activity: The correlation between scavenging activity and TPC of fresh and heated pitayas is presented in Fig. 4. It showed very high significant correlation ($R = 0.977$, $p<0.05$) between scavenging activity and TPC in all the samples, suggesting that the phenolic content was likely prominent contributor to scavenging effect in the fruit extract, fresh and heated pitayas. Kalyoncu *et al*. (2009) examined the antioxidant capacity and total phenolic content of 22 apricot cultivars produced in Malatya region. Reasonably well correlation was observed with free radical scavenging activity and total phenolic compounds.

Figure 5 shows the correlation between antioxidant activity and TPC of fresh and heated pitayas. The antioxidant activity of fresh and thermal processed pitaya extracts correlated well and significant ($R = 0.972$, $p<0.05$) with their total phenolic contents. The result is consistent with significant correlation of scavenging activity and TPC, which indicated that phenolic contents are the major antioxidants in red pitaya. Also, Kho *et al*. (2009) observed a positive correlation between Ferric Reducing Antioxidant Power (FRAP) level of *Auricularia auricula-judae* extracts and their total phenolic contents.

The effect of thermal processing on dietary fibers: The values of fiber contents soluble (SDF), insoluble (IDF), and total (TDF) dietary fibers) of fresh and heated pitayas are shown in Fig. 6. Based on this study, SDF, IDF, and TDF of fresh red pitaya were 0.95±0.02, 2.18±0.02 and 3.13±0.01 grams per 100 g of dried weight, respectively.

Different methods of thermal processing affected SDF, IDF, and TDF of red pitaya differently. The concentration of SDF was decreased by thermal processing. There was the minimum reduction of SDF in oven-cooked pitaya at 95ºC 30 min by 0.07 g (8%), and the maximum decrease in oven-cooked pitaya at 105ºC 60 min by 0.55 g (58%) /100 g dried. The effects of high temperatures in short time (drum and spray drying) on the SDF were considerable. However, the difference of SDF of thermal processed to fresh pitaya was significant for oven-cooked pitaya at 105ºC 60 min ($p<0.05$). The SDF of samples were in the order of fresh pitaya > oven-cooked pitaya at 95ºC 30 min > oven-cooked pitaya at 95ºC 60 min > spray-dried pitaya > drum-dried pitaya > oven-cooked pitaya at 105ºC 60 min.

Thermal processing decreased TDF of red pitaya samples. The minimum damage of TDF was observed in oven-cooked pitaya at 95ºC 30 min, by 0.07g /100 g dried reduction). The effects of various temperatures on TDF of red pitaya were significant in drum-dried pitaya, oven-cooked pitaya at 95ºC 60 min, and spray-dried pitaya, compared to fresh sample ($p<0.05$). The TDF of samples were in the order of fresh pitaya > oven-cooked pitaya at 95ºC 30 min > oven-cooked pitaya at 105ºC 60 min > drum-dried pitaya > oven-cooked pitaya at 95ºC 60 min > spray-dried pitaya.

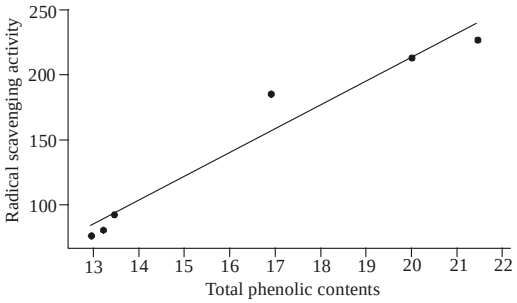

Fig. 4: Correlation between radical scavenging activity (μM vitamin C equivalents /g dried extract) and total phenolic content (mg Gallic acid equivalents /g dried extract) in fresh and heated pitayas ($r = 0.977$, $p<0.05$)

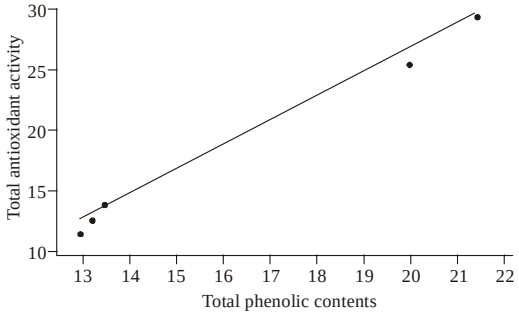

Fig. 5: Correlation between antioxidant activity (μM ferrous sulfate equivalents /g dried extract) and total phenolic content (mg Gallic acid equivalents /g dried extract) in fresh and heated pitayas ($r = 0.972$, $p<0.05$)

Insoluble dietary fiber of red pitaya behaved quite differently against thermal stress. It was intact after 30 minutes oven cooking at 95ºC, and even significantly increased in oven-cooked pitaya at 105ºC 60 min ($p<0.05$), compared to fresh pitaya. The minimum content of IDF was seen in oven-cooked pitaya at 95ºC 60 min, with 0.48 g /100 g dried reduction ($p<0.05$). IDF in other samples were comparable to fresh red pitaya. The IDF of samples were in the order of oven-cooked pitaya at 105ºC 60 min > fresh pitaya and oven-cooked pitaya at 95ºC 30 min > drum-dried pitaya > spray-dried pitaya > oven-cooked pitaya at 95ºC 60 min. Table 4 shows the ratio of soluble, insoluble, and total dietary fiber of heated pitayas to fresh pitaya.

Previous studies showed that heat stability of dietary fibers varies in different food, times, temperatures and pressures. The fluctuations of each component of dietary fiber contents (total, soluble and insoluble) can be different, as well. For example, Wennberg *et al*. (2006) reported that 5 min boiling of treated white cabbage with

Table 4: The ratio of soluble, insoluble, and total dietary fiber of heated pitayas to fresh pitaya

Fresh pitaya and heated pitayas	Ratio ofSDF of heated to fresh pitaya	RatioofIDF of heated to fresh pitaya	Ratio of TDF of heated to fresh pitaya
Fresh pitaya	1.00	1.00	1.00
Oven-cooked pitaya at 95ºC 30 min	0.92	1.00	0.98
Oven-cooked pitaya at 95ºC 60 min	0.81	0.78	0.79
Oven-cooked pitaya at 105ºC 60 min	0.42	1.15	0.93
Drum-dried pitaya	0.58	0.90	0.80
Spray-dried pitaya	0.61	0.86	0.78

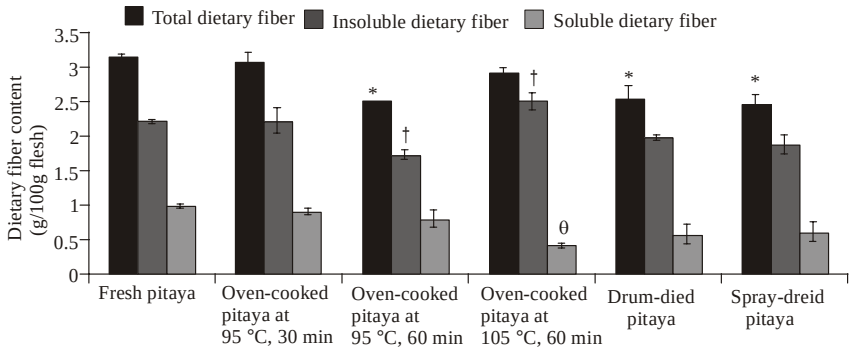

Fig. 6: Mean total, insoluble and soluble dietary fiber of fresh and heated pitaya extracts (g per 100 g dried), Dietary fiber content was measured using the gravimetrical method. Data are means (±S.E.M) of three determinations. Asterisk (*) indicates significant difference at the level of $p<0.05$ between total dietary fiber of fresh and heated samples. Cross (†) indicates significant difference at the level of $p<0.05$ between insoluble dietary fiber of fresh and heated samples. Theta (θ) indicates significant difference at the level of $p<0.05$ between soluble dietary fiber of fresh and heated samples

acetic acid decreased 9.7-11, 4.9-14 and 6-19% of TDF, IDF, and SDF, respectively. Whereas, Manzi *et al*. (2004) observed that 10 minutes cooking of commercial mushrooms resulted in 42, 29 and 46% increases in the TDF, IDF and SDF, respectively. In other experiment, Perez-Hidalgo *et al*. (1997) measured the dietary fibers of raw, soaked, cooked and fried chicken peas. They observed total and insoluble dietary fiber increases of 25 and 24% after boiling, respectively; whereas the soluble fraction decreased. They reported a slight increase in total dietary fiber after soaking; the insoluble fraction increased by 2%, but its soluble part decreased slightly. In other study, Vidal-Valverde *et al*. (1992) reported that the cooking of previously soaked lentils in 0.1% citric acid and 0.07% sodium bicarbonate reduced the amount of dietary fiber, due to a drastic loss of hemicellulose, although cellulose and lignin increased. Total pectic substances content of cooked lentil was still higher than in raw lentil. Park *et al*. (2006) observed almost no reduction in the dietary fiber content (total, soluble and insoluble) of persimmon during 12 h dehydration or one month sun-drying; whereas these thermal stresses significantly decreased its total polyphenols.

CONCLUSION

Generally, the length of the temperature time was more damaging to TPC, radical scavenging, and total antioxidant activity of red pitaya fruit (*Hylocereus polyrhizus*) compared to high heating temperatures. Statistically no significant differences among antioxidant parameters of drum-dried, spray-dried and fresh red pitaya showed that these thermal processes could be the best methods for antioxidant preservation in this fruit, compared to other thermal processes applied in this study.

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