International Food Research Journal 20(4): 1595-1600 (2013)
Journal homepage: *http://www.ifrj.upm.edu.my*

Effects of blanching and drying on fiber rich powder from pitaya (*Hylocereus undatus*) peel

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Article history

Received: 24 December 2012
Received in revised form: 6 March 2013
Accepted:11 March 2013

Keywords

Pitaya peel
betacyanin
antioxidant
radical scavenging activity
blanching
drying

Abstract

The pitaya (*Hylocereus undatus* (Haw.)), a member of the Cactaceae, with white-flesh is a one of the famous varieties in Thailand and shows antioxidant activity from its pigment. However, its peels was handled as a waste, therefore the applying these materials could be get more benefits in producing fiber rich powder. The effects of blanching in hot water and drying at various temperatures (60°C, 70°C and 80°C) were investigated. The result showed that the blanched pitaya peel showed lower amounts of anthocyanin and betacyanin contents. Moreover, thermal degradation of anthocyanin and betacyanin could be occurred during drying process. However, the higher drying temperature trends to increase the antiradical activity of dried sample. This information provided that the pitaya peels is a valuable material for a manufacture of fiber-rich powder with high antiradical activity.

Introduction

Pitaya (*Hylocereus undatus* (Haw.)) or Dragon fruit, member of the Cactaceae, is originally from Mexico, Central and South America (Haber, 1983; Benzing, 1990) and has also been grown in Thailand. It has cladode stems and specific character, bracts or scales with a bright red color fruits (Wu *et al.*, 2006). The pitaya flesh contains small black seeds scattered in white-flesh (*H. undatus*) or red-flesh (*H. polyrhizus*) or yellow-flesh (*H. megalanthus*) (Barbeau, 1990) depending on the cultivar. In Thailand, the pitaya with white-flesh was a one of the famous varieties. Pitaya is found to be rich in nutrients, such as beta-carotene, lycopene and vitamin E in an edible portion, (Charoensiri *et al*., 2009) and contains essential fatty acids, i.e., 48% linoleic acid (C18:2) and 1.5% linolenic acid (C18:3) in the black seed of pitaya fruit (Ariffin *et al.*, 2008). Moreover, oligosaccharides extracted form pitaya showed prebiotic properties, which can stimulate the growth of lactobacilli and bifidobacteria (Wichienchot *et al*., 2010)

The pitaya is an interested agricultural product since its antioxidative activity from its fruit pigments, betalains group (Wybraniec *et al.*, 2001; Wybraniec and Mizrahi, 2002). The betalains also has been detected in Amaranthus (Cai *et al*., 2003) and beet roots (Escribano *et al*., 1998) which exhibited antiradical and antioxidant activity. Betalains consists of two important pigments, betacyanin (red-violet color) and betaxanthins (yellow color) which are water-soluble pigments (Wybraniec *et al.*, 2001). The betacyanins has been reported that it was found in both flesh and peels of pitaya peel (Wu *et al*., 2006; Esquivel *et al*., 2007) which give deep red–purple pigments and stable in a broad pH range, (Wybraniec and Mizrahi, 2002). Moreover, betacyanins has been reported that it exhibited the highest antioxidant activities in both DPPH and FRAP assays and its activity were almost 10 times higher in peels than in flesh of pitaya. (Tenore *et al*., 2012). These pigments may give a protection against certain oxidative stress-related disorders (Kanner *et al*., 2001). Morever, the red pitaya (*H. polyrhizus*) peel showed effectively inhibit the growth of melanoma cells (Wu *et al*., 2006).

Nowadays, a lot of works have an attention to use the waste material from industry as a raw material for produce a new food ingredients with a good source of bioactive compounds. The pitaya peels are normally removed and handled as a waste, therefore the processing these materials could get more benefits such as for producing fiber rich powder. Dietary fiber (DF) is a food component and resistant to hydrolysis by human digestive enzymes. Some of by-products from the agricultural such as apples, citrus fruits, lemon, and carrot have already been reported in the production of dietary fiber (Grigelmo-Miguel and Martín-Belloso, 1999; Figuerola *et al*., 2005; Chantaro et al., 2008). The chemical composition and functional properties of dietary fiber powder depends on raw material and processing

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procedures. In order to inhibit unsuitable enzymatic reaction such as Lipoxygenases, Pectic enzymes, Polyphenoloxidases, Peroxidase, pretreatment is mostly done before drying process. However, the blanching steps may cause the loss of water soluble solid (vitamins, antioxidant compound etc.) and some polymer or smaller fragment (Nilnakara *et al*., 2009). Additionally, drying process, famous techniques to produce dietary fiber powder, also effected to antioxidants compounds and antioxidant activity of plant powder products. Chantaro *et al*. (2008) reported that thermal degradation during both blanching and drying was reason of a decrease in β-carotene and phenolic compounds and the loss of antioxidant activity of carrot peel powder.

In this work, the effects of hot water blanching and hot air drying temperature on the production of fiber-rich powder obtained from pitaya peel were investigated. The obtained fiber rich powder were determined crude fiber content, anthocyanin content, betacyanin content as well as antiradical activity of fiber-rich powder.

Materials and Methods

Raw materials

Pitaya fruits with white-flesh were purchased from local market. After removed the peels from its fruits, the peels were cleaned with tap water and then cut into 0.5 cm in width and 5 cm in length.

Preparation of fiber-rich powder

For pretreatment, the peels were blanched in hot water at 95 + 2°C for 1 min and then cooled in cold water (2°C). One kilogram of pitaya peel pieces (with and without blanching) were expanded on aluminum tray and subjected to hot air oven and dried at 60, 70 and 80°C. The drying process was performed until the mass of sample reached at the equilibrium value. The moisture content of sample was determined using Gravimetric method at 105°C (AOAC, 1995). The dried pitaya peel samples were ground using blender and then sieved and packed in the plastic bag until analysis.

Determination of crude fiber content

After lipid extraction, the crude fiber content in each sample was determined by acid and alkali digestion. Both fresh and dried samples were determined in triplicate in accordance with the AOAC method (1995).

Determination of anthocyanin content

The anthocyanin content in both fresh and dried samples were analyzed in triplicate using pH-differential method (Guisti and Wrolstad, 2011). Briefly, the sample was dissolved in pH 1 buffer (0.25M potassium chloride and HCl) and pH 4.5 buffer (0.4M sodium acetate). The absorbance of solution in each pH buffer was measured at the maximum absorbance wavelength and 700 nm. The determination was performed in duplicates. Then, the concentration of anthocyanin was calculated as follows;

$$\text{anthocyanin (mg/liter)} = A\ (MW)\ (DF) \times 1000 / \varepsilon\ L$$

when MW is molecular weight of anthocyanin which is 449.2 for cyanidin-3-glucoside, DF is dilution factor, L is path length, ε is molar absorptivity (26,900) and A is absorbance of sample which was calculated as follows;

$$A = (A_{\lambda vis\text{-}max} - A_{700})_{\text{pH 1.0}} - (A_{\lambda vis\text{-}max} - A_{700})_{\text{pH 4.5}}$$

Determination of betacyanin content

The betacyanin content was determined according to Wybraniec and Mizrahi (2002). Seven grams of fresh and dried sample were homogenized by 60% ethanol and then centrifuge at 6,000 rpm for 15 min. The supernatant was concentrated by using rotary evaporator at 45°C, then sample were diluted by 60% ethanol. The absorbance of solution was measured at 538 nm. The concentration of betacyanin content was calculated as follows;

$$\text{betacyanins (mg/g of dried extracts weight)} = A_{538}\ (MW)V\ (DF) \times 100/\ \varepsilon\ LW$$

Where A_{538} is the absorbance at 538 nm, MW = 550, L is path length, DF is the dilution factor, V is the solution volume (ml), W is the sample weight (g) and ε is molar extinction coefficient (65,000). Each sample was measured in triplicate and the results were expressed as an average.

DPPH radical-scavenging assay

The radical-scavenging capacities of fresh and dried sample were determined using DPPH Radical Scavenging Assay. Briefly, the sample was extracted by 60% ethanol and then was mixed with a 0.2 mM 2,2-diphenyl-1-picryl-hydrazyl-hydrate(DPPH) ethanol solution. After 10 min at room temperature, the absorbance of solution was measured at 520 nm. Radical scavenging capacity (%) is $(1\text{-}A_{sample}/A_{control})\times 100$, when A_{sample} is absorbance value of sample solution and $A_{control}$ absorbance value of control (60% ethanol).

Color measurement

Color of obtained fiber-rich powder was performed by measuring their reflectance using a colorimeter (JS 7555, China). Before each color measurement, the colorimeter was calibrated using a standard white plate (L^*= 98.28, a^* = -0.11, b^*= -0.36). Sample was filled in a glass cylinder and placed above the light source and covered with a black lid. The color of sample was represented in 3 parameters; L^* (Lightness), a^*(redness and greenness) and b^* (yellowness and blueness). Moreover, the color of sample also expressed as total color difference (ΔE) which calculated from L^*, a^* and b^* as follows;

$$\Delta E = ((L_1^*-L_2^*)^2+(a_1^* - a_2^*)^2+(b_1^*-b_2^*)^2)^{1/2}.$$

Each sample was measured in triplicate and the results were expressed as an average.

Statistical analysis

All experiment were designed in complete random. The results were expressed as mean values with standard deviations of triplicate. The Duncan's multiple range tests was used for statistical analysis of differences between mean values at a significance level of 95%.

Results and Discussion

Preparation of fiber-rich powder

The blanched and unblanched pitaya peel sample were subject to hot air oven for drying at various temperature until the moisture content of sample reached equilibrium value. Table 1 shows the drying time that moisture content of sample was equilibrium which in the range of 3.06 – 4.25 g/100 g dry basis. Expectedly, it exhibited that an increasing drying temperature resulted in a shorter drying time. This can be explained that at higher drying temperature, the driving force for heat transfer was higher. While the drying time for blanched peel sample showed faster compare with unblanched peel sample. These can be explained that the blanching pretreatment provides soften texture which make it easier to remove water during drying process. These results also was in agreement with other previous work such as cauliflower leaves (Lopez *et al.*, 2000), carrot peels (Chantaro *et al*., 2008) and cabbage outer leaves (Nilnakara *et al*., 2009). The faster drying process was blanched sample and drying at 80°C which took proximately 10 hours.

Crude fiber content

The crude fiber content of dried samples after lipid extraction was analyzed by using acid digestion and alkali digestion and the result was shown in Table 2. The crude fiber content of dried sample was higher than fresh sample and it was in the range of 26.97-30.15 g/100 g dry basis. Moreover, the blanching pretreatment increased the crude fiber content of dried sample compared with unblanched dried sample. These probably due to the losing of small molecule such as minerals, vitamins and sugar to blanching water hence varying in the total solid content of sample and resulted in a relatively increase of other dry matter (Wennberg *et al*., 2004; Nilnakara *et al.*, 2009). These result was also found in cabbage outer leaves (Nilnakara *et al*., 2009), white cabbages (Wennberg *et al*., 2006).

Additionally, the higher drying temperature, the lower crude fiber content was found. These maybe due to the degradation of pectin or other fiber such as cellulose or hemicelluloses during the drying process hence reduced the crude fiber content of dried sample. However, the range of drying temperature selected in this experiment has been reported that it did not has any effect on chemical composition (Faustino *et al*., 2007; Chantaro *et al*., 2008; Nilnakara *et al*., 2009).

Anthocyanin and betacyanin content

Pitaya contains a red–purple color of peels which are more interested for economic value as a food

Table 1. Drying time and equilibrium moisture content of dried samples at various temperatures

Sample	Drying Temperature (°C)	Drying Time (hrs)	Equilibrium moisture content (g/100 g dry basis)
Unblanched pitaya peel	60	25	4.25
	70	22	3.90
	80	11	3.17
Blanched pitaya peel	60	18	4.08
	70	17	3.31
	80	10	3.06

Table 2. Crude fiber content of obtained dried sample at various drying conditions

Sample	Drying Temperature (°C)	Crude fiber content (g/100 g dry basis)
Unblanched pitaya peel	60	28.45±0.42^{b}
	70	27.30±0.11^{c}
	80	26.97±0.76^{c}
Blanched pitaya peel	60	30.15±0.74^{a}
	70	29.58±0.28^{a}
	80	28.00±0.71^{bc}

Same letters in the same column express that values are not significantly difference (p >0.05).

ingredient. It contains anthocyanin and betacyanin as an important fruit pigments (Wybraniec and Mizrahi, 2002; Wu *et al*., 2006), which showed the antioxidant activity. However, the pretreatment and thermal processing has been reported that it effected to antioxidants compounds and its antioxidant activity (Chantaro *et al*., 2008; Nilnakara *et al.*, 2009). Therefore, obtained fiber rich powder from pitaya peel were analyzed for antioxidant compounds and its activity in order to investigate the effect of blanching pretreatment and drying procedures.

The anthocyanin contents of obtained dried pitaya peel sample is shown in figure 1a which in the range of 38.57- 1.29 mg/g dry weight. The thermal pretreatment and thermal processing decreased the anthocyanin content. The results showed that the blanching pretreatment decreased the anthocyanin content in sample which dried at 60 and 70°C, probably due to these anthocyanin is a water soluble pigment and leached to blanching water during pretreatment. On the other hand, the increase of drying temperature (60 to 70°C) caused the decrease in anthocyanin content. These results may be due to the thermal degradation during drying process.

However, the blanched and dried at 80°C sample showed higher content of anthocyanin (33.13 mg/g dry weight) which probably because of drying time which was shortest. The highest content of anthocyanin was found in unblanched and dried at 60°C powder sample (37.84 mg/g dry weight). Contrary, Wu *et al.* (2006) reported that no founding of anthocyanin in flesh and peel of red pitaya, this is probably due to in our experiment which used spectrophotometer technique which may be influenced by the amount of betacyanin.

The betacyanin is the main pigment (red-purple color) found in pitaya, therefore, the betacyanin contents of power sample were investigated (Figure 1b). Similar to anthocyanin content, the pretreatment and thermal processing reduced the amount of betacyanin in dried sample. The blanched dried sample showed lower amount of betacyanin due to leaching process during blanching, while higher dried temperature also decreased the betacyanin content of dried sample due to thermal degradation. However, the unblanched and dried at 80°C showed highest content of betacyanin (1.18 mg/g dry weight) due to the shortest dying time. In addition, the unbalanced and dried at 60°C powder sample also exhibited the high content of betacyanin (1.15 mg/g dry weight).

Radical scavenging capacity

The radical scavenging capacity of obtained fiber rich power form pitaya peel were analyzed by

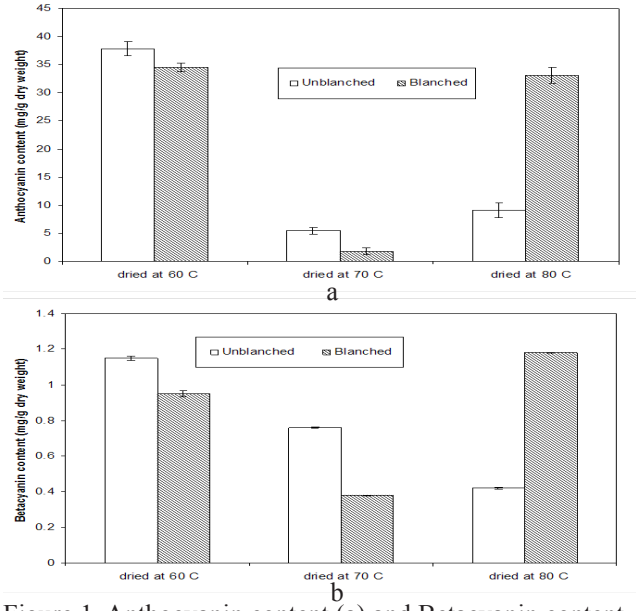

Figure 1. Anthocyanin content (a) and Betacyanin content (b) of fiber rich powder obtained from pitaya peel.

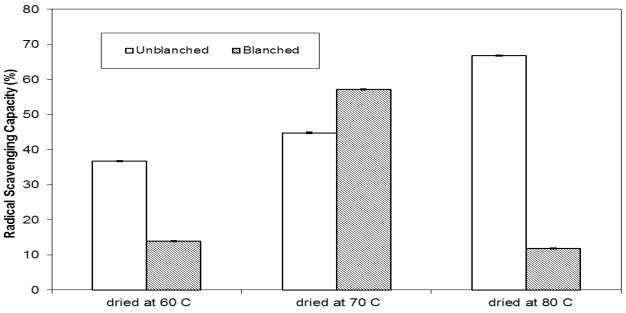

Figure 2. Radical scavenging capacity of fiber rich powder obtained from pitaya peel.

using DPPH assay which widely used for determine of antioxidant activity of colorant and polyphenols (Shi and Le maguer, 2000; Cai *et al*., 2003). The radical scavenging capacity of samples is shown in figure 2. The radical scavenging capacity of blanched pretreatment sample seems to be reduced which is probably because of the leaching of anthocyanin and betacyanin except for dried sample at 70°C. Moreover, the results showed that the higher drying temperature increase the radical scavenging capacity of sample and the blanched and dried at 80°C showed the highest radical scavenging capacity (66.81%).

Tenore *et al.* (2012) reported that betacyanins showed the highest antioxidant activities in both DPPH and FRAP assays and were found most in peels. Nevertheless, no link between the antocyanin and betacyanin content and radical scavenging activity were found in our result therefore the radical scavenging capacity of pitaya peel dried sample could be link to the other compound such as polyphenols as well as betanins. The other hydrogen-donating groups (-NH, -SH) or hydroxyl group (OH) in polyphenolic molecules may play an important function to higher

antioxidant activity (Cai *et al.*, 2003). However, betanins which is an important pigment in pitaya also show imino groups and hydroxyl groups that would give antioxidant activity.

The color measurement of fiber rich powder form pitaya peel

The color of dried samples was measured and expressed as the Hunter parameter (L^*, a^*, b^*) which was shown in Table 3. It was found that the color of sample was significantly changes in all values. The blanched fresh sample showed more slightly darker (lower L^*) and greener and less yellowness compare to unblanched fresh sample. Similarly, this trend also found for the dried samples. This probably was due to the loss of water soluble pigments, betacyanin (red-violet color) and betaxanthins (yellow color) (Wybraniec *et al.*, 2001), to blanching water.

Table 3. The color measurement of fresh and dried pitaya peel sample at various production condition[A]

Sample	Drying Temperature (°C)	L*	a*	b*	ΔE
Fresh pitaya peel		81.89±0.23^{d}	-21.74±0.31^{a}	-0.33±0.26^{g}	-
Unblanched pitaya peel	60	84.69±0.12^{c}	-17.12±0.13^{c}	0.46±0.17^{f}	5.46±0.19^{e}
	70	86.72±0.06^{a}	-15.52±0.09^{e}	4.33±0.05^{b}	9.15±0.11^{b}
	80	86.90±0.27^{a}	-15.61±0.30^{e}	5.05±0.33^{a}	9.57±0.52^{a}
Blanched fresh pitaya peel		80.90±0.00	-23.98±0.22	-0.69±0.18	2.48±0.20
Blanched pitaya peel	60	85.43±0.06^{b}	-16.13±0.01^{d}	1.38±0.21^{e}	6.85±0.08^{d}
	70	85.51±0.61^{b}	-16.10±0.10^{d}	2.54±0.03^{c}	7.29±0.21^{c}
	80	84.49±0.06^{c}	-17.60±0.05^{b}	1.79±0.11^{d}	5.33±0.10^{e}

[A]Same letters in the same column express that values are not significantly difference ($p>0.05$)

In addition, the blanching step which can be inhibited enzymatic browning resulted less red color in blanched fresh sample and dried sample. The blanched dried sample at 80°C showed higher loss of red color probably due to the higher temperature of drying, similarly unblanched and dried at 60°C sample also showed higher loss of red color resulted from longest drying time (25 h). The blanching and thermal process may cause the damage of betacyanin in pitaya so less red color was found in dried sample. Moreover, at higher drying temperature or longer drying time caused the batacyanin damage in sample. Betalanins which compose of betacyanin pigments which gave a red-purple color and betaxantin which gave a yellowed color was sensitive to heat, pH, light, moisture and oxygen (Woo *et al*., 2011). In accordance with red values, betaxanthin which gave the yellow color was also damage during thermal process led to less yellowness found in dried sample. However, the total different color (ΔE) of dried sample, compare with fresh sample, showed the lowest total different color in unblanched and dried at 60°C as well as in blanched and dried at 80°C.

Conclusions

In this study, we found that pitiya peel can be used as a raw material for producing fiber rich powder which was a good source of bioactive compounds. However, pretreatment (blanching) and drying process (60, 70 and 80°C) was affected to antioxidant compound and its radical scavenging capacity as well as its appearances. In summary, the blanching pretreatment and high drying temperature caused the decrease in antioxidant compound, anthocyanin and betacyanin content, as well as radical scavenging capacity even though the drying time was shorter. The unblanched and dried at 60°C or blanched and dried at 80°C remained the high amount of anthocyanin and betacyanin content and provided a good color which less difference form fresh pitaya peel. Nevertheless, our results could not related anthocyanin and betacyanin content to radical scavenging capacity. In a further research, the relation between antioxidant activity and other antioxidant compound of pitaya peel should be studied, as well as other pretreatment. Moreover, the functional properties of obtained fiber rich powder is also recommend.

References

AOAC. 1995. Official Methods of Analysis (15th ed.). Association of Official Analytical Chemists, Gaithersburg, MD.

Ariffin, A. A., Bakar, J., Tan, C. P., Rahman, R. A., Karim, R. and Loi, C. C. 2008. Essential fatty acids of pitaya (dragon fruit) seed oil. Food Chemistry 114: 561–564.

Barbeau, G. C. 1990. La pitahaya rouge, un nouveau fruit exotique (the red pitahaya, a new exotic fruit). Fruits 45: 141–147.

Benzing, D. H. 1990. Vascular epiphytes, general biology and related biota. Cambridge: Cambridge University Press.

Cai, Y., Sun, M. and Corke, H. 2003. Antioxidant activity of betalains from plants of the Amaranthaceae. Journal of Agricultural and Food Chemistry 51: 2288–2294.

Chantaro, Prawta , Devahastin, Sakamon and Chiewchan, Naphaporn. 2008. Production of antioxidant high dietary fiber powder from carrot peels. LWT - Food Science and Technology 41: 1987-1994

Charoensiri, R., Kongkachuicha, R., Suknicom, S. and Sungpuag, P. 2009. Betacarotene, lycopene, and alpha-tocopherol contents of selected Thai fruits. Food Chemistry 113: 202–207.

Escribano, J., Pedreòo, M. A., Garcia-Carmona, F. and Munoz, R. 1998. Characterization of the antiradical activity of betalains from *Beta vulgaris* L. roots. Phytochemical Analysis 9: 124–127.

Esquivel, P., Stintzing, F. C. and Carle, R. 2007. Pigment pattern and expression of colour in fruits from different *Hylocereus* sp. genotypes. Innovative Food Science and Emerging Technologies 8: 451–457.

Faustino, J.M.F., Barroca, M.J. and Guiné, R.P.F. 2007. Study of the drying kinetics of Green Bell Pepper and chemical characterization. Food and Bioproducts Processing 85(3): 163–170.

Figuerola, F., Hurtado, M. L., Estevez, A. M., Choffelle, I. and Asenjo, F. 2005. Fiber concentrates from apple pomace and citrus peels as potential fiber sources for food enrichment. Food Chemistry 91: 395-401.

Giusti, M.M. and Wrolstad, R. E. 2001. Characterization and Measurement of Anthocyanins by UV-Visible Spectroscopy. Current Protocols in Food Analytical Chemistry.

Grigelmo-Miguel, N. and Martı´n-Belloso, O. 1999. Comparison of dietary fiber from by-products of processing fruits and greens and from cereals. Lebensmittel-Wissenschaft und-Technologie 32: 503-508.

Haber, W. A. 1983. Hylocereus costaricensis (pitahaya silvestre), wild pitahaya. In D.H. Janzen (Ed.), Costarican natural history (pp. 252–253). Chicago: University of Chicago Press.

Kanner, K., Harel, S. and Granit, R. 2001. Betalains – A new class of dietary cationized antioxidants. Journal of Agricultural and Food Chemistry 49: 5178–5185.

Lopez, A., Iguaz, A., Esnoz, A. and Virsed, P. 2000. Thin-layer drying behavior of vegetable wastes from wholesale market. Drying Technology 18: 995–1006.

Nilnakara, Sivarin, Chiewchan, Naphaporn and Devahastin, Sakamon. 2009. Production of antioxidant dietary fibre powder from cabbage outer leaves. Food and Bioproducts processing 87: 301–307.

Shi, J. and Le Maguer, M. 2000. Lycopene in tomatoes: chemical andphysical properties affected by food processing. Critical Reviews in Food Science and Nutrition 40: 1–42.

Tenore, Gian Carlo, Novellino, Ettore and Basile, Adriana. 2012. Nutraceutical potential and antioxidant benefits of red pitaya (*Hylocereus polyrhizus*) extracts .Journal of functional foods 4: 129-136.

Wennberg, M., Ekvall, J., Olsson, K. and Nyman, M. 2006. Changes in carbohydrate and glucosinolate composition in white cabbage (*Brassica oleracea* var. capitata) during blanching and treatment with acetic acid. Food Chemistry 96: 226–236.

Wennberg, M., Engqvist, G. and Nyman, E. 2004. Effects of boiling on dietary fibre components in fresh and stored white cabbage (*Brassica oleracea* var. capitata). Journal of Food Science 68: 1615–1621.

Wichienchot,S, Jatupornpipat, M. and Rastall, R.A. 2010. Oligosaccharides of pitaya (dragon fruit) flesh and their prebiotic properties. Food Chemistry 120: 850–857.

Woo, K.K., Ngou, F.H., Ngo, L.S., Soon, W.K. and Tang, P.Y. 2011. Stability of betalain pigment from red dragon fruit (*Hylocereus polyrhizus*). American Journal of Food Technology 6: 140-148.

Wu, Li-chen, Hsu, Hsiu-Wen, Chen, Yun-Chen, Chiu, Chih-Chung, Lin, Yu-In and Annie Ho, Ja-an. 2006. Antioxidant and antiproliferative activities of red pitaya. Food Chemistry 95: 319–327.

Wybraniec, S., Platzner, I., Geresh, S., Gottlieb, H. E., Haimberg, M., Mogilnitzki, M. and Mizrahi, Y. 2001. Betacyanins from vine cactus *Hylocereus polyhizus*. Phytochemistry 58: 1209–1212.

Wybraniec, S. and Mizrahi, Y. 2002. Fruit flesh betacyanin pigments in *Hylocereus cacti*. Journal of Agricultural and Food Chemistry 50: 6086–6089.