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Effects of pectinase treatment on the quality of red dragon fruit (*Hylocereus polyrhizus*) juice

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Abstract

The present work aimed to investigate the effect of pectinase supplementation on the quality of red-fleshed dragon fruit juice. Pectinase (400 ppm) was added at different concentrations (0, 1, 3, 5, 7, and 9%) and hydrolysis times (0, 15, 25, 35, and 45 min). The quality of fruit juice was monitored and evaluated by recovery efficiency, pectin content, betacyanin content, viscosity, and total phenolic content. Results showed that pectinase concentration of 5% and hydrolysis time for 25 min produced the highest hydrolysis efficiency (88.16 ± 0.05%), with low residual pectin content (0.49 ± 0.02 g), low viscosity (1.15 ± 0.06 cP), and high betacyanin content (20.06 ± 0.02 mg/100 mL) and total phenolic content (88.68 ± 0.46 mg/100 mL) in the recovered solution. These findings provided essential insights for beverage processing of dragon fruit juice.

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Introduction

Dragon fruit, also known as pitaya or pitahaya, *thangloy* (Vietnamese), *pitayaroja* (Spanish), and *la pitahaya rouge* (French), belongs to the Cactaceae family in two separate genera namely *Hylocereus* and *Selenicereus*. The commonly grown and commercially available varieties are from the *Hylocereus* genus, which includes about 16 varieties (Jalgaonkar *et al.*, 2020). This vine plant has spikes of usually about 6 meters long, three flattened light green petals, with many sepals and petals attached to the tubes. Many stamens, lower gourds, bear fruit with the remaining flower plates, thus they are suitable for areas with little rainfall (Paull, 2014). They are distributed in about 20 countries including Thailand, Indonesia, Taiwan, Vietnam, Sri Lanka, Bangladesh, Japan, Malaysia, Philippines, Australia, USA, and China. India is an importer of dragon fruit, yet the cultivated area is increasing. There are three commercially grown varieties including *H. undatus* (white-fleshed dragon fruit), *H. polyrhizus* (red-fleshed dragon fruit), and *S. megalanthus* (yellow dragon fruit) (Paull, 2014; Ibrahim *et al.*, 2018)

Dragon fruit, with great potentials for use in Brazilian cuisines, can be used in jams, juices, ice creams, and candies (Donadio, 2009). The nutritional and colour properties of dragon fruit make it an attractive ingredient for a variety of beverages, including fermented beverages (Ong *et al.*, 2012). Furthermore, besides its nutritional importance and culinary applications, dragon fruit can also be used in the pharmaceutical and cosmetic industries. The ancient Mayans traditionally used the leaves and flowers of *H. undatus* as a diuretic and blood sugar-lowering agent. Dragon fruit is also used for medicinal purposes. Its flowers can be consumed directly in the form of tea, and are used to treat kidney diseases. Meanwhile, the seeds and fruits have laxative and diuretic effects, respectively (Donadio *et*

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al., 1998). The vegetative parts of dragon fruit have numerous applications in the pharmaceutical industry (Stintzing *et al.*, 2005). The extracts from some dragon fruit have been implicated in central nervous system stimulation and regulation of blood pressure, sleep, hunger, and thirst (Franco-Molina *et al.*, 2003). Dragon fruit seeds contain oil (22%) that has a laxative effect, thus being capable of reducing total cholesterol and low-density lipoprotein (LDL) cholesterol in humans (Phebe *et al.*, 2009). This oil has a high content of functional lipids, and can be used as a novel and superior oil source, as compared to linseed and rapeseed oils (Ariffin *et al.*, 2009; Lim *et al.*, 2010), in addition to the extensive use in the food industry as a natural colorant (Esquivel and Araya Quesada, 2012). Recently, Patočka (2013) identified 24 components in the carbon dioxide extract of *H. polyrhizus* peel by using gas chromatography-mass spectrometry, of which 29.77 and 16.46% were triterpenoids and steroids, respectively. These studies agreed that the chemical constituents of these plants gave rise to the anti-cancer and anti-HIV activities.

Red-fleshed dragon fruit is enriched with betalain, which is a nitrogen-containing hydrophilic pigment commonly found in *Hylocereus* genus. They are divided into betaxanthin and betacyanin, which are yellow-orange and reddish-purple pigments, respectively. They can absorb radiation within the visible range from 476 to 600 nm. In contrast to anthocyanins, betacyanin has a carboxyl instead of hydroxyl functional group (Al-Alwani *et al.*, 2015). Betacyanin possesses a wide range of biological activities such as antioxidant, anti-inflammatory, hypoglycaemic, anti-proliferative, cardiovascular activator, radioactivity, neuroprotection, diuretic, hyponatremia, and bone pain relief (Esatbeyoglu *et al.*, 2014). Details of their biological activities have been discussed in previous study by Ibrahim *et al.* (2018).

The main industrial application of pectinases is in fruit juice extraction and clarification. Pectin contributes to the viscosity and turbidity of the fruit juice. A mixture of pectinases and amylases is used to clarify fruit juices while decreasing filtration time by up to 50% (Blanco *et al*., 1999). Treatment of fruit pulps with pectinase also showed increased fruit juice volume from bananas, grapes, and apples (Kaur *et al*., 2004). Currently, the production of red-fleshed dragon fruit has several limitations. As dragon fruit is mainly consumed in the form of fresh fruit, the high pectin content interferes with the filtration process under mechanical influences such as rubbing, crushing, and grinding.

Therefore, the present work aimed to recover the dragon fruit juice during the processing of juice, fermented fruit juice, or beverage products. The use of pectinase is safe and highly effective as biological hydrolysis method. Pectinase helps breaking the 1-4 glycoside bonds in the pectin chain to increase the yield and improve the quality of the juice (Huang *et al*., 2021). Furthermore, the present work also investigated the effect of pectinase on pectin content, recovery yield, viscosity, and betacyanin content in recovered solution, and determined the appropriate concentration of pectinase and hydrolysis time during hydrolysis of red-fleshed dragon fruit juice.

Materials and methods

Sample preparation

Red-fleshed dragon fruits were purchased from Tra Vinh province (9°58'18'N longitude and 106°12'52'E latitude). The fruits were from 28 to 32 days old, collected after blooming, and weighed around 500 - 600 g. They were then washed, peeled, and the flesh was used immediately after pressing to preserve the product quality from oxidation.

Materials

The following chemicals were used in the present work: pectinase, 6,000 U/g; Folin-Ciocalteu, 99.5% (Merck, Germany); Na_2CO_3, 99.5%; sodium hydroxide, 96%; and potassium sodium tartrate (Xilong, China).

Pectinase treatment of fruit juice

Ripe and healthy dragon fruits were washed with water to remove dirt. Then, the fruit peel was removed to obtain the flesh. Dragon fruit flesh was pressed through a 0.5 cm sieve to break down the cell structure and facilitate the collection of juice. The samples were further pressed using a specialised grinding device, then filtered to obtain the juice, and diluted with water at a ratio of 1:1.

To reduce the viscosity of the extract, the dragon fruit juice was supplemented with pectinase at various concentrations ranging from 0, 3, 5, 7, and 9% for 25 min and incubated at room temperature. At the end of hydrolysis, pectinase was inactivated at 99 ± 1°C for 5 min, squeezed, and separated from the dragon fruit juice. The experimental results were

evaluated based on the recovery performance, pectin content, viscosity, betacyanin content, and total phenolic content.

Analytical methods

Pectin content (%) in solution was determined by calcium pectate precipitation method (Nguyen, 2001), using Eq. 1:

$$P = \frac{W \times 0.92}{B} \times 100 \quad \text{(Eq. 1)}$$

where, P = pectin content (%), W = mass of calcium pectate precipitate (g), 0.92 = conversion factor from calcium pectate to pectin (*i.e.*, pectin constitutes 92% by mass of calcium pectate), and $B = \frac{m \times V_2}{V_1}$ (g) = amount of pectin to saponify, where m = mass of material sample (g), V_1 = initial sample solution volume (mL), and V_2 = Volume of sample solution to be saponified (mL).

The yield of juice (%) was determined using Eq. 2:

$$Yield\ (\%) = \frac{m_0}{m} \times 100 \quad \text{(Eq. 2)}$$

where, yield (%) = extraction yield of dragon fruit juice, m = mass of materials, and m_o = volume of juice obtained.

Betacyanin content was determined using UV-Vis method at 538 nm according to Sengkhamparn *et al.* (2013). Betacyanin content (mg/100 mL) was calculated using Eq. 3:

$$Betacyanin\ content\ (\frac{mg}{100mL}) = \frac{A \times V \times F \times M \times 100}{\varepsilon \times L \times W} \quad \text{(Eq. 3)}$$

where, A = absorbance at 538 nm, V = volume of dilution volumetric flask, F = dilution factor, M = molar mass of betacyanin (g/mol), ε = 60,000 L/mol/cm, L = cuvette thickness, and W = mass (g).

The total phenolic content was determined by the Folin-Ciocalteu method (Nguyen *et al.*, 2020; Pham *et al.*, 2020; Dao *et al.*, 2021). Briefly, 0.1 mL of extract was placed into test tubes, and 0.5 mL of 10% Folin-Ciocalteu solution was added, followed by 0.4 mL of 7.5% Na_2CO_3 solution. The sample was homogenised using a Vortex machine, and left at room temperature in the dark for 1 h. The optical absorbance was then measured at 765 nm. The total phenolic content (mg/100g mL) was calculated using Eq. 4:

$$Total\ phenolic\ content\ \left(\frac{mgGAE}{100\ mL}\right) = \frac{a \times V_{solution} \times 10^{-3} \times V_1}{M_{sample} \times V_2} \quad \text{(Eq. 4)}$$

where, a = x-value from gallic acid calibration curve (μg/mL), $V_{solution}$ = volume of extract (mL), 10^{-3} = unit conversion factor from μg to mg, V_{1t} = volume of cuvette, M_{sample} = mass of sample in volume (g), and V_2 = sample volume.

Statistical analysis

Each data point was a result of triplicate experiments, and expressed as mean ± standard deviation. MS Excel was used to process the experimental data, and SPSS was used to perform One-way analysis of variance (ANOVA) test with the level of significance of 5%.

Results and discussion

Effect of pectinase concentration on fruit juice quality

The effect of pectinase concentration on hydrolysis yield and pectin content is shown in Figures 1a and 1b. The results showed that as pectinase concentration increased, the yield of juice recovery and pectin content significantly decreased ($p < 0.05$). The highest pectin content (0.701 ± 0.060 g) was obtained in the control sample. This value was decreased by 35.95% to 0.449 ± 0.004 g in the treatment with pectinase at 3% concentration. The samples treated with 5% concentration obtained the remaining pectin content of 0.374 ± 0.01 g, which was decreased by 46.65% as compared to the control sample. However, pectinase at 7 and 9% concentrations resulted in higher remaining pectin contents of 0.377 ± 0.012 and 0.376 ± 0.02 g, respectively. On the other hand, the control sample had a low recovery efficiency of 79.27 ± 0.01%, the pectinase-treated sample at 3% concentration had a higher recovery efficiency of 81.54 ± 0.01%, an increase of 5.27% as compared to that of the control sample. Accordingly, increasing pectinase concentration to 5% resulted in a recovery efficiency of 84.76 ± 0.04%, which was 3.22% increase as compared to the 3% sample. At 7 and 9% concentrations, the yield of recovered juice was 79.76 ± 0.014 and 79.94 ± 0.005%, respectively, which increased insignificantly as compared to the control sample.

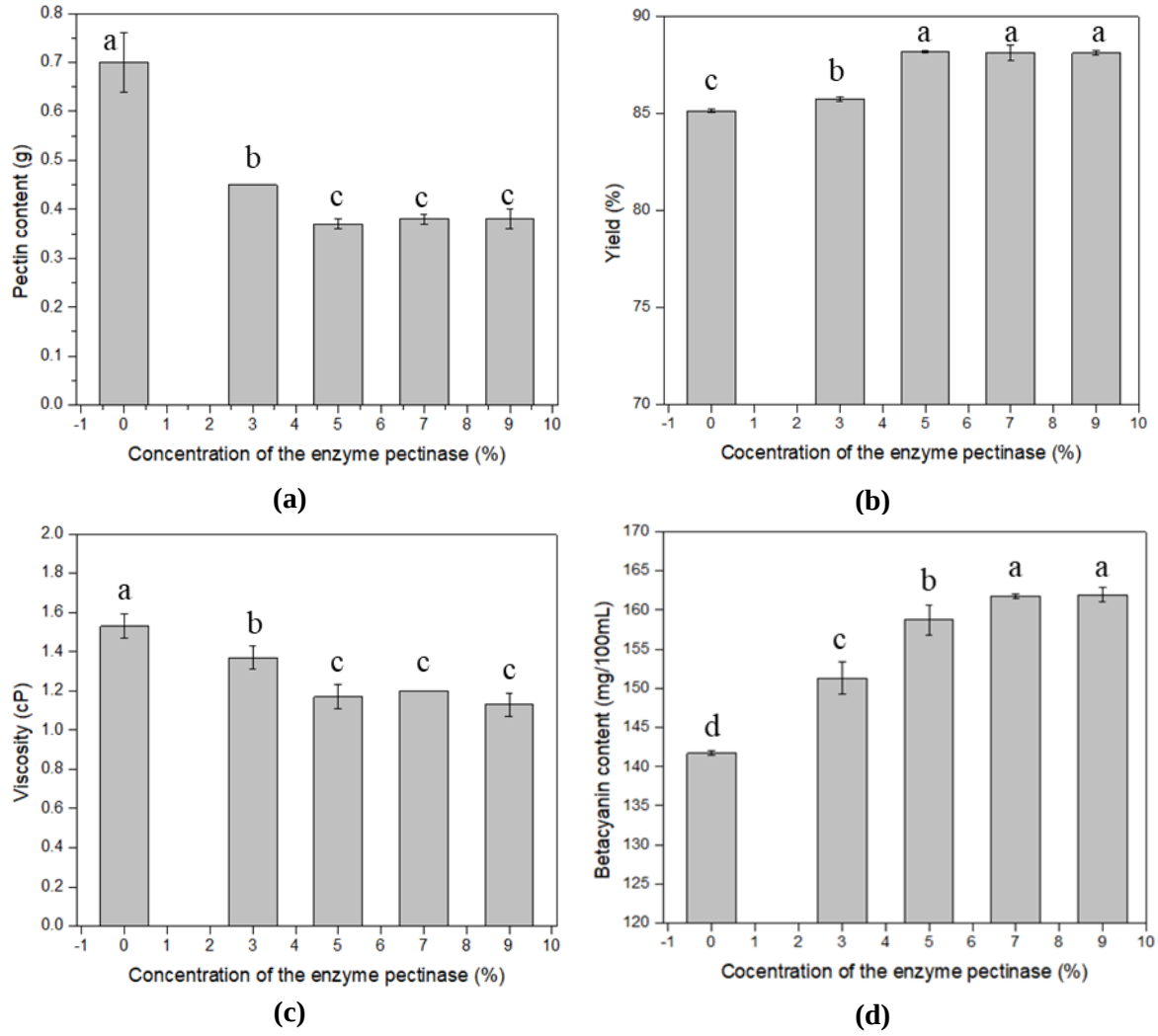

Figure 1. Effect of pectinase concentration on **(a)** pectin content, **(b)** recovery efficiency, **(c)** viscosity, and **(d)** betacyanin content of the solution. Lowercase letters indicate statistically significant difference ($p < 0.05$) between different concentrations of pectinase.

During the enzymatic hydrolysis with pectinase, the 1-4 glucoside linkage in the pectin molecule in the cellulose cell wall is broken to help release more fluid. This result was similar to the study of Hong *et al.* (2019), in which increasing pectinase concentration from 0.1 to 0.4% caused the pectin content to decrease from 1.18 to 0.67 g, and the recovery efficiency to increase from 81.67 to 88.24%.

The effect of pectinase concentration on the viscosity and betacyanin content is shown in Figures 1c and 1d. The results showed that the viscosity of samples treated with different pectinase concentrations and betacyanin content was significantly different ($p < 0.05$). Specifically, in the control sample without pectinase, the highest viscosity was 1.55 cP, and the lowest betacyanin content was 14.51 ± 0.03 mg/100 mL. When pectinase concentration was increased to 3%, the viscosity decreased to 1.35 cP, and the betacyanin content reached 15.49 ± 0.21 mg/100 mL, increased by 0.98 mg/100 mL as compared to the control sample. In the sample treated with 5% pectinase concentration, the betacyanin content continued to increase to 16.25 ± 0.2 mg/100 mL, while the viscosity value decreased to 1.15 cP as compared to 3%-treated sample. In a study by Pardo *et al.* (1999), where the effect of commercial pectinase on the extraction of anthocyanins and total phenolic content of grapes were evaluated, the presence of pectinase increased the total phenolic content and anthocyanins, as compared to non-enzymatic control. Chang *et al.* (1994) also reported an average of 30% of increase in the total anthocyanin content in pectinase-treated Stanley plum juice. Similar observations were found in the study of Gengatharan *et al.* (2021), where the author studied the application of betacyanin-

containing *H. polyrhizus* extract with the assistance of pectinase. The results showed that increasing pectinase content from 0.5 to 1.5% increased the betacyanin content to the maximum value of 17%. However, increasing pectinase concentration to 7 and 9% did not significantly changed the viscosity or betacyanin content, as compared to the 5% pectinase concentration sample, where the values being 1.2 and 1.15 cP for viscosity and 16.56 ± 0.03 and 16.58 ± 0.09 mg/100 mL for betacyanin content, respectively.

Upon the process of crushing the fruit pulp, pectin is released, enhancing the juice viscosity and breaking down the cells to increase the betacyanin content. As the enzyme concentration increases, the pectin content decreases, which also decreases the fluid viscosity and resistance, while helping to release betacyanin in the cell, and increase the betacyanin content. Hoa and Huong (2017) also showed that when pectinase concentration was increased from 0.1 to 0.4%, the resulting viscosity decreased from 1.22 to 1.19 cP.

The effect of pectinase concentration is shown in Figure 2.

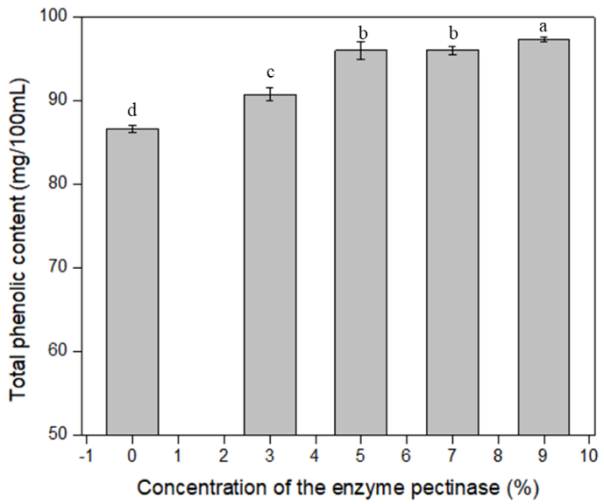

Figure 2. Effect of pectinase concentration on total phenolic content. Lowercase letters indicate statistically significant difference ($p < 0.05$) between different concentrations of pectinase.

With increasing pectinase concentration, the samples with 0, 3, 5, 7, and 9% pectinase concentration showed significant difference ($p < 0.05$). The pectinase concentration increased with the same trend as the total phenolic content in the sample. Specifically, the control sample without pectinase addition resulted in a total phenolic content of 86.58 ± 0.47 mg/100 mL. The value of total phenolic content continued to increase when increasing pectinase concentration to 3 and 5% (95.33 ± 1.08 mg/100 mL). However, such increase was not significant in the samples of 7 and 9% pectinase concentrations. Studies have confirmed that the polyphenolic compounds are abundant in the cell wall. Due to the rubbing process, solvent extraction, and action of enzymes, polyphenols are released into the fluid. This result is similar to Kunnika and Pranee (2011), in which by increasing the concentration of enzymes, the antioxidant activities against DPPH and the total phenolic content were also increased by three times and 44.31%, respectively, as compared to the control sample without enzymes. Therefore, 5% pectinase concentration was selected for further experiments.

Effect of hydrolysis time on juice quality

Hydrolysis time is considered as one of the main influencing factors in the inactivation of pectinase in dragon fruit juice. The results on the effect of hydrolysis time on fruit juice quality are shown in Figure 3. It can be seen that the prolonged hydrolysis time significantly increased the yield, and decreased the pectin content ($p < 0.05$). Specifically, the control sample had the highest pectin content of 1.678 ± 0.06 g, and had a recovery value of 85.15 ± 0.09%. This value then decreased to 0.853 ± 0.02 g, and the hydrolysis efficiency increased to 85.72 ± 0.13%, as the hydrolysis time was extended to 15 min. The pectin content continued to decrease to 0.49 ± 0.02 g, and the recovery efficiency increased to 88.16 ± 0.05% as compared to the control, when the hydrolysis time was increased to 25 min. When the hydrolysis time was extended from 35 to 45 min, the pectin content decreased, and the hydrolysis efficiency increased insignificantly ($p > 0.05$).

During hydrolysis, pectinase was filtered immediately after being added, thus could not react with the substrate, and resulted in high pectin content in the control sample. This hindered the filtration process, and led to the decrease in recovery efficiency. However, when increasing the reaction time to 15 and 25 min, pectinase reacted with the substrate, breaking the bonds, and reducing the pectin content in the sample. When the reaction time was increased to 35 and 45 min, the added pectinase fully reacted with the substrate, thus the pectin content in the obtained solution remained unchanged. This was similar to the study by Hong *et al.* (2019), in which in the presence of pectinase for a prolonged hydrolysis

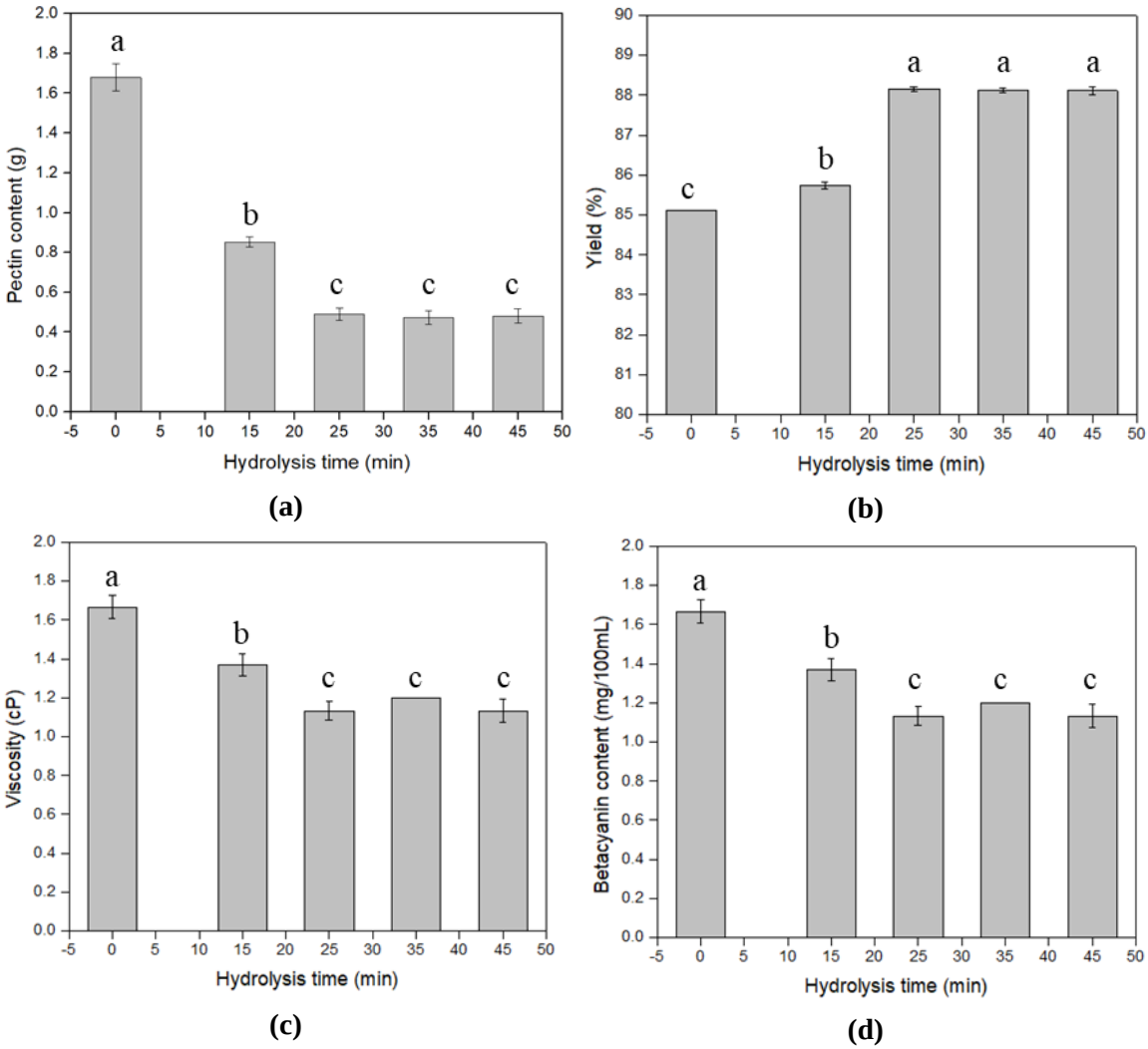

Figure 3. Effect of hydrolysis time on **(a)** pectin content, **(b)** recovery efficiency, **(c)** viscosity, and **(d)** betacyanin content of the solution. Lowercase letters indicate statistically significant difference ($p < 0.05$) between different hydrolysis times.

time, the recovery efficiency of melon (*Cucumis melo*) juice increased by 1.78% while the pectin content decreased by 0.17 g when compared with the control sample.

The effect of hydrolysis time on viscosity and betacyanin content is shown in Figures 3c and 3d. It can be seen that with increasing hydrolysis time, the viscosity decreased and the betacyanin content increased. Specifically, the control sample resulted in the highest viscosity (1.678 ± 0.06 cP) but the lowest betacyanin content (17.72 ± 0.01 mg/100 mL). These values increased with increasing hydrolysis time, reaching the highest values of 1.15 ± 0.06 cP and 20.06 ± 0.02 mg/100 mL after 25 min of hydrolysis.

Increasing the hydrolysis time helps pectinase to react completely with the substrate, thus reducing the pectin content and the viscosity of the solution, while increasing the betacyanin content released by the broken cells. However, when pectinase has fully reacted within a certain period of time, the values of viscosity and betacyanin content did not change.

When increasing the hydrolysis time, the content of the compound increased significantly ($p < 0.05$) (Figure 4). Specifically, the results showed that the control sample had a total phenolic content of 88.68 ± 0.46 mgGAE/g. This value increased by 14.17% to 101.25 ± 0.58 mgGAE/g when the hydrolysis time was extended to 25 min, as compared to the control sample. However, when the time was increased to 35 and 45 min, the total phenolic content increased slightly from 103.18 ± 0.6 to 104.17 ± 0.55 mgGAE/100 g, as compared to the sample at 25 min.

Enzymes that hydrolyse plant cell walls release the extracts and phenolic compounds from the cells;

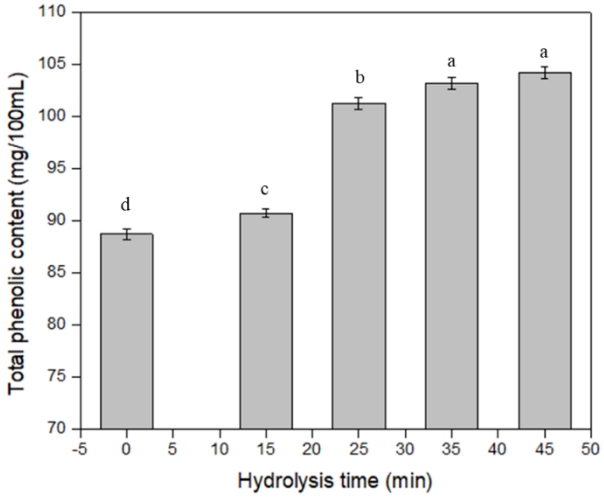

Figure 4. Effect of hydrolysis time on total phenolic content. Lowercase letters indicate statistically significant difference ($p < 0.05$) between different hydrolysis times.

hence, increasing the time to hydrolyse the cell walls would increase the concentration of additional enzymes, thus releasing more compounds. The results were similar to Kunnika and Pranee (2011) who reported that when increasing the hydrolysis time, the total phenolic content and total flavonoid content increased 2 - 3 and 5 - 7 times, respectively.

Conclusion

The addition of pectinase improved the quality of dragon fruit juice, as indicated by the recovery efficiency, pectin content, betacyanin content, viscosity, and total phenolic content. Specifically, when hydrolysis was carried out for 25 min, and pectinase was added at 5% concentration, low pectin content of 0.49 ± 0.02 g was obtained in the post-hydrolysis solution, and high recovery efficiency of 88.16 ± 0.05%, low fluid viscosity 0.49 ± 0.02 cP, betacyanin content of 20.06 ± 0.02 mg/100 mL, and total phenolic content of 88.68 ± 0.46 mg/100 mL were obtained. These results provided essential knowledge for subsequent beverage processing of dragon fruit juice.

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References

Al-Alwani, M. A., Mohamad, A. B., Kadhum, A. A. and Ludin, N. A. 2015. Effect of solvents on the extraction of natural pigments and adsorption onto TiO_2 for dye-sensitized solar cell applications. Spectrochimica Acta Part A - Molecular and Biomolecular Spectroscopy 138: 130-137.

Ariffin, A. A., Bakar, J., Tan, C. P., Rahman, R. A., Karim, R. and Loi, C. C. 2009. Essential fatty acids of pitaya (dragon fruit) seed oil. Food Chemistry 114(2): 561-564.

Blanco, P., Sieiro, C. and Villa, T. G. 1999. Production of pectic enzymes in yeasts. FEMS Microbiology Letters 175(1): 1-9.

Chang, T. S., Siddiq, M., Sinha, N. K. and Cash, J. N. 1994. Plum juice quality affected by enzyme treatment and fining. Journal of Food Science 59: 1065-1069.

Dao, T. P., Vu, D. N., Nguyen, D. V., Pham, V. T. and Tran, T. Y. N. 2021. Study of jelly drying cashew apples (*Anacardium occidentale* L.) processing. Food Science and Nutrition 10(2): 363-373.

Donadio, C. D., Nachtgal, J. C. and Sacramento, C. K. 1998. Exotic fruits. Brazil: FUNEP.

Donadio, L. C. 2009. Pitaya. Revista Brasileira de Fruticultura 31(3): 637-929.

Esatbeyoglu, T., Wagner, A. E., Motafakkerazad, R., Nakajima, Y., Matsugo, S. and Rimbach. G. 2014. Free radical scavenging and antioxidant activity of betanin: Electron spin resonance spectroscopy studies and studies in cultured cells. Food and Chemical Toxicology 73: 119-126.

Esquivel, P. and Araya Quesada, Y. 2012. Pitahaya (*Hylocereus* sp.): Fruit characteristics and its potential use in the food industry. Revista Venezolana de Ciencia y Tecnologia de Alimentos 3(1): 113-129.

Franco-Molina, M., Gomez-Flores, R., Tamez-Guerra, P., Tamez-Guerra, R., Castillo-Leon, L. and Rodríguez-Padilla, C. 2003. *In vitro* immunopotentiating properties and tumour cell toxicity induced by *Lophophora williamsii* (peyote) cactus methanolic extract. Phytotherapy Research 17(9): 1076-1081.

Gengatharan, A., Dykes, G. and Choo, W. S. 2021. Betacyanins from *Hylocereus polyrhizus*:

Pectinase-assisted extraction and application as a natural food colourant in ice cream. Journal of Food Science and Technology 58(4): 1401-1410.

Hoa, M. X. and Huong, D. T. T. 2017. Effects of pectinase and ultrasound treatment on juice extraction efficiency from red-fleshed pitaya (*Hylocereus polyrhizus*). Vietnam: University of Technology.

Hong, N. T. T., Tuan, T. M. and Hung, N. T. 2019. Effect of enzyme treatment and pasteurization regime on the quality of cantaloupe juice. Can Tho University Science Journal 55: 241-249.

Huang, Y., Brennan, M. A., Kasapis, S., Richardson, S. J. and Brennan, C. S. 2021. Maturation process, nutritional profile, bioactivities and utilisation in food products of red pitaya fruits: A review. Foods 10(11): 2862.

Ibrahim, S. R. M., Mohamed, G. A., Khedr, A. I. M., Zayed, M. F. and El-Kholy, A. A. E. S. 2018. Genus *Hylocereus*: Beneficial phytochemicals, nutritional importance, and biological relevance—A review. Journal of Food Biochemistry 42(2): e12491.

Jalgaonkar, K., Mahawar, M. K., Bibwe, B. and Kannaujia, P. 2020. Postharvest profile, processing and waste utilization of dragon fruit (*Hylocereus* Spp.): A review. Food Reviews International 38(4): 733-759.

Kaur, G., Kumar, S. and Satyanarayana, T. 2004. Production, characterization and application of a thermostable polygalacturonase of a thermophilic mould *Sporotrichum thermophile* Apinis. Bioresource Technology 94(3): 239-243.

Kunnika. S. and Pranee. A. 2011. Influence of enzyme treatment on bioactive compounds and colour stability of betacyanin in flesh and peel of red dragon fruit *Hylocereus polyrhizus* (Weber) Britton and Rose. International Food Research Journal 18: 1437-1448.

Lim, H. K., Tan, C. P., Karim, R., Ariffin, A. A. and Bakar, J. 2010. Chemical composition and DSC thermal properties of two species of *Hylocereus cacti* seed oil: *Hylocereus undatus* and *Hylocereus polyrhizus*. Food Chemistry 119(4): 1326-1331.

Nguyen, N. Q., Minh, L. V., Trieu, L. H., Bui, L. M., Lam, T. D., Hieu V. Q., … and Trung, L. N. Y. 2020. Evaluation of total polyphenol content, total flavonoid content, and antioxidant activity of *Plectranthus amboinicus* leaves. IOP Conference Series - Materials Science and Engineering 736: 062017.

Nguyen, V. M. 2001. Biochemistry practice. Vietnam: Vietnam National University.

Ong, Y. Y., Tan, W. S., Rosfarizan, M., Chan, E. S. and Tey, B. T. 2012. Isolation and identification of lactic acid bacteria from fermented red dragon fruit juices. Journal of Food Science 77(10): 560-564.

Pardo, F., Salinas, M. R., Alonso, G. L., Navarro, G. and Huerta, M. D. 1999. Effect of diverse enzyme preparations on the extraction and evolution of phenolic compounds in red wines. Food Chemistry 67: 135-142.

Patočka, J. 2013. Biologically active pentacyclic triterpenes and their current medicine signification. Journal of Applied Biomedicine 1: 7-12.

Paull, R. E. 2014. Dragon fruit: Postharvest quality - maintenance guidelines. Fruit, Nut and Beverage Crop 28: F_N-28.

Pham, T. N., Nguyen, V. T., Toan, T. Q., Cang, M. H., Bach, L. G. and Muoi, V. N. 2020. Effects of various processing parameters on polyphenols, flavonoids, and antioxidant activities of *Codonopsis javanica* root extract. Natural Product Communications 15: 9.

Phebe, D., Chew, M. K., Suraini, A. A., Lai, O. M. and Janna, O. A. 2009. Red-fleshed pitaya (*Hylocereus polyrhizus*) fruit colour and betacyanin content depend on maturity. International Food Research Journal 16: 233-242.

Sengkhamparn, N., Chanshotikul, N., Assawajitpukdee, C. and Khamjae, T. 2013. Effects of blanching and drying on fiber rich powder from pitaya (*Hylocereus undatus*) peel. International Food Research Journal 20(4): 1595-1600.

Stintzing, F. C., Herbach, K. M., Mobhammer, M. R., Carle, R., Yi, W., Sellappan, S., … and Bunch, R. 2005. Color, betalain pattern, and antioxidant properties of cactus pear (*Opuntia* spp.) clones. Journal of Agricultural and Food Chemistry 53: 442-451.