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Effect of temperature, pressure, sugar, and citric acid content on quality of cashew apple juice produced by vacuum concentration

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Abstract

Cashew apples are a source of by-products in the cashew industry. In the present work, a juice product made from cashew apples was produced through vacuum concentration (VC). During VC, a temperature range of 60 to 90°C, and a pressure range of 500 to 650 mmHg were investigated. Total ascorbic acid (TAA), total tannin content (TTC), and total polyphenol content (TPC) after VC were also evaluated. The variation in VC time was observed when the temperature was investigated. The sensory value of the products after mixing citric acid and sugar was evaluated. The results showed that the nutritional parameters were affected by temperature and pressure. TAA and TPC reached their maximum value at 80°C. The TTC was strongly hydrolysed with increasing VC temperature. Furthermore, negative correlation between vacuum pressure and nutrition was observed. Cashew apple juice after VC diluted with water (1:5), and mixed with sugar (20 g/L) and citric acid (0.2 g/L) was preferred by consumers. TAA, TPC, and TTC were monitored for 42-day storage under two temperature conditions of 35 and 45°C. The shelf life of the product reached 117 d. These results set the platform for the development of beverage products from cashew apple by-products, thereby improving the economy of the cashew industry in Vietnam and the world.

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Introduction

Vacuum concentration (VC) is a technology that employs low temperature and vacuum environment to remove water from a liquid mixture. During this process, the liquid is placed in a low-pressure vacuum environment, causing the water within the liquid to evaporate at lower temperatures compared to natural conditions (Nhi *et al*., 2020). As a result, the liquid becomes denser, and has higher concentration. Performing concentration in a vacuum environment reduces the impact of temperature on the quality of the product, such as its nutritional content, colour, and flavour (Fadavi *et al*., 2018). Additionally, in a vacuum environment, oxygen levels are minimised, thus preventing oxidative processes. Furthermore, VC offers precise control over the product's concentration level (Darvishi *et al*., 2019). A previous report has applied vacuum environment in the distillation of date juice (Criscuoli and Drioli, 2020). A similar report also highlighted the effectiveness of applying vacuum in the sucrose solution concentration process (Mújica-Paz *et al*., 2003).

Cashew tree (*Anacardium occidentale* L.; family Anacardiaceae) is a tropical tree commonly grown in many countries such as West Africa, India, Nigeria, Vietnam, Brazil, and Indonesia (Divya Priya and Pydi Setty, 2019). In Vietnam, cashew trees play an important role in the agricultural sector, accounting for approximately 15% of total cashew nut production worldwide, and Vietnam is ranked as

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the third largest cashew nut producer in the world after India (23%) and West Africa (46%). Cashew tree is a perennial tree; cashew nuts and cashew apples are harvested every year from March until the end of the rainy season (Divya Priya and Pydi Setty, 2019). The size of cashew apples has an average length of 5 to 11 cm, and a diameter of 4 to 8 cm, depending on the growth conditions and harvest time.

Cashew apples contain minerals such as Ca, P, Fe (0.9 - 21.4 mg/100 g), K (1.53 g/L), and a high content of vitamin C (TAA = 180 mg/100 g), as well as TPC (215.1 - 412.8 mg GAE/100 mL) and some other components (*e.g.*, gallic acid, protocatechuic acid, B-cryptoxanthin, zeinoxanthin, and lutein) (Runjala and Kella, 2017). According to Dao *et al*. (2021), the vitamin C content in untreated raw cashew apple samples was 2.93 ± 0.13 mg/g DW, which is 5 - 6 times higher than that of lemon, and 7 - 8 times higher than mandarin and pomelo (Talasila *et al*., 2012; Dao *et al*., 2021). Previous studies on the use of cashew apples had shown that some components of cashew apples had the ability to prevent some diseases such as cancer, cardiovascular disease, stomach pain, and diarrhoea (Runjala and Kella, 2017; Dimoso *et al*., 2020). Some studies had also shown that cashew apples had the ability to prevent scurvy due to their high vitamin C content (Carr and Maggini, 2017). Vitamin C also contributes to strengthening the resistance of the body.

Although the growth potential and benefits of this by-product are relatively large, raw materials are susceptible to spoilage by microbial attack. Furthermore, without proper storage and transportation methods, cashew apples can be easily crushed, severely affecting the quality of the product. Cashew apples also contain high amount of tannin (0.2 - 0.4%), which causes an acrid taste, and greatly hinders their processing and consumption (Assis *et al*., 2007). About 1.9 thousand tons of cashew apple by-products are discarded after harvest, according to the General Department of Vietnam Customs in 2020.

In an attempt to overcome the aforementioned disadvantages, and utilise this large source of by-products, cashew apple juice was mixed with orange, grape, pineapple, and mango juices to increase the vitamin C content by up to 9 times, compared to the original juice (Akinwale, 2000). Previous study demonstrated astringent treatment combined with membrane by-membrane process to limit heat use, and maintain the vitamin C content in fruit juice at an almost equivalent level to vitamin C in fresh fruit. However, during enzyme treatments, some heat-sensitive substances, such as vitamin C and phenolic compounds, were significantly degraded, while total soluble solids (TSS), pH, and acid index were not affected (Emmanuelle *et al*., 2016). Dao *et al*. (2021) processed yellow cashew apples into dried jam product. After the pre-treatment where osmosis and drying were applied to reduce the moisture content of the product to less than 15%, the TAA, TTC, and TPC were significantly reduced due to prolonged heat treatment (Dao *et al*., 2022).

Therefore, in the present work, to maximise the nutrient content, cashew apples were processed to increase TSS and reduce water activity in the product, thus prolonging the shelf life of the product. In addition, experiments on juice concentration, flavour mixing recipes, and maximum product storage time were also carried out. The results obtained were expected to be the basis for the field of scientific research and the expansion of the product chain from this by-product.

Materials and methods

Materials

About 40 kg of ripe cashew apples (red, yellow, and orange) were harvested in Binh Phuoc province, Vietnam (coordinates: 11°45'N 106°55'E). Cashew apples were harvested 8 w after fruit formation, and immediately subjected to processing within 24 h under normal conditions. The raw materials must be intact, healthy, with smooth skin and characteristic of sour, sweet, and acrid taste. The raw materials were frozen and preserved for no more than two months (Wang and Wang, 2009).

Chemicals and reagents

Tannic acid ($C_{76}H_{52}O_{46}$), metaphosphoric acid (33.5 - 36.5%), thiourea (≥ 99%), ascorbic acid (> 99.75%), gallic acid (> 97.5%), and Folin-Ciocalteu (1 N) were purchased from Sigma Aldrich. 2,2-diphenyl-1-picrylhydrazyl (DPPH) (99.99%) was purchased from Merck. Na_2CO_3 (99.99%), acid acetic, 2,4-dinitrophenyl hydrazine (2,4 DNPH), Brom 3%, and H_2SO_4 85% were purchased from China. CH_3OH (98%), sugar (Saccaroza > 99.5%, moisture < 0.05%, reducing sugar < 0.1%), C_2H_5OH (98%), and citric acid (≥ 95.5%) were purchased from Vietnam. Tannase (EC 3.1.1.20) was purchased from Biochemifa Kikoman, Japan.

Cashew apple juice production

The prepared raw materials were pressed using a screw press. The juice was filtered using a filter cloth with a pore diameter of < 1 mm. Citric acid and $Ca(OH)_2$ were used to adjust the sample solution to pH 5. The juice tannins were hydrolysed by tannase (200 ppm) at 40°C for 60 min, and then filtered (Li *et al*., 2017). The filtrate was supplemented with polyvinylpyrrolidone (PVP 0.1%) (v/v), and allowed to settle for 20 min. The juice after hydrolysis was filtered using a cloth with a diameter of < 1 mm (Dagadkhair *et al*., 2018). The filtrate was concentrated at 60 to 90°C at 500 to 650 mmHg until TSS reached 50°Bx. The post-concentration solution was diluted with water at a ratio of 1/5 - 1/20 (v/v). A sugar content of 20 - 50 g/L and a citric acid concentration of 0.1 to 0.5% (w/v) were added to the diluted concentrate. The product was pasteurised at 75°C for 15 min (Bhattacherjee *et al*., 2011), and was bottled with a capacity of 330 mL. The storage was investigated at 35 and 45°C (Delouche and Baskin, 2021). After 7 d, the samples were collected for subsequent analysis.

Determination of TTC

TTC was performed as described by Kusirisin *et al*. (2009). Briefly, 1 mL of cashew apple juice sample was mixed with 0.5 mL of Folin-Denis, 1 mL of saturated Na_2CO_3, and distilled water to form 10 mL of sample solution. The sample was shaken vigorously using a vortex shaker, and incubated for 30 min before measuring the absorbance at 775 nm.

Determination of TPC

The Folin-Ciocalteu method was based on the description of Deshpande *et al*. (1986) and Dao *et al*. (2021). A total of 1 mL of cashew apple juice was mixed with 5 mL of Folin-Ciocalteau reagent in the test tube. After 5 min, 4 mL of 7.5% Na_2CO_3 solution was added to the test tube, homogenised, and then incubated in the dark for 60 min. The absorbance was measured at 765 nm.

Determination of TAA

The method was performed based on the description of Rahman *et al*. (1970) and Tran *et al*. (2020). A total of 25 mL of metaphosphoric and acetic acid mixture was added to 10 mL of sample solution, and homogenised using a vortex shaker (4,000 rpm) for 15 min. The supernatant was removed with a micropipette. A total of 4 mL of sample solution after centrifugation was mixed with 0.23 mL of 3% bromine water, 0.13 mL of 10% thiourea, and 1 mL of 2,4-dinitrophenylhydrazine. Then, the samples were conditioned at 37°C for 3 h, and cooled down on ice for 30 min. Finally, 5 mL of H_2SO_4 85% was added, and the absorbance measurement was performed at 521 nm.

Sensory evaluation

The method of sensory evaluation was based on Singh-Ackbarali and Maharaj (2014). A total of 60 panellists were involved, and the rating scale of preference was divided into five different levels, ranging from extremely dislike to extremely like. Samples were coded with three digits, and evaluated in random order.

Determination of product's shelf life

The shelf life of the product was determined based on accelerated aging at 35 and 45°C using Eqs. 1 and 2. The aging process at extreme conditions (45°C) was performed for 42 d (Patil *et al*., 2011; Minh *et al*., 2019).

$$\text{Coefficient } Q_{10} = \frac{N_o - N_{45}}{N_o - N_{35}} \quad \text{(Eq. 1)}$$

where, N_0, N_{30}, and N_{45} = nutritional content initially and after 7 d of storage at 35 and 45°C, respectively.

$$\text{Shelf life of the product} = \frac{A \times Q_{10} \times (t_2 - t_1)}{10} \quad \text{(Eq. 2)}$$

where, A, t_1, and t_2 = storage time, temperature during accelerated aging, and the normal temperature, respectively.

Statistical analysis

Results were analysed by Microsoft Excel software (Redmond, WA, USA). Statgraphics Centurion XV version 15.1.02 software was used to determine the difference between processing conditions (Vu *et al*., 2022).

Result and discussion

Effect of temperature on VC time and product's quality

TSS is one of the important parameters for juice products, and an indicator that directly affects the shelf life of the product. High TSS in raw material leads to a decrease in the percentage of water content

(Singh *et al*., 1999; Hosainpour *et al*., 2013; Sabanci and Icier, 2017). The growth and development of microorganisms are inhibited by reduced water activity (Reid, 2008; Azarpazhooh and Ramaswamy, 2009). VC is one of the solutions to increase TSS in the product, and prolong the shelf life. However, temperature is still the main factor affecting VC time (Kidron and Kronenfeld, 2016). The temperature range of 60 - 90°C had a statistically significant influence on VC time (p < 0.05). The vacuum pressure was fixed at 600 mmHg. At 60°C, the time to concentrate 4 L of juice was the longest (720 min). When the vacuum pressure was maintained at 600 mmHg, the four tested temperatures between 60 and 90°C were greater than or equal to the boiling point of the water in the juice. However, the boiling intensity and the evaporation rate increased as the VC temperature increased from 60 - 90°C, and was inversely proportional to the VC time; the time required to reach TSS = 50°Bx at 90°C was 43 min. The negative correlation between time and VC temperature is shown in Figure 1. At 600 mmHg with increasing temperature, the product temperature remained unchanged, while the boiling intensity increased, thus leading to an increase in the rate of water separation from the solution. Previous reports had shown positive correlation between temperature and water evaporation rate (Kidron and Kronenfeld, 2016), in which, at high evaporation rate, the product took a prolonged time to reach 50°Bx.

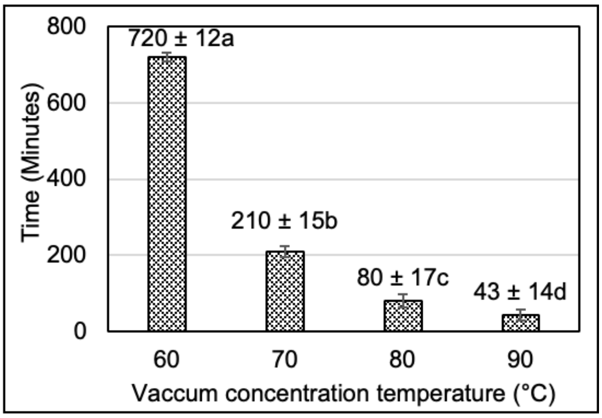

Figure 1. Relationship between time and temperature during VC. Different lowercase letters indicate significant difference (p < 0.05).

Effect of vacuum pressure on product's quality

In high temperature food processing, many vitamins, biologically active substances, and sensory quality of the product were lost (Maskan, 2006). The higher the pressure, the lower the boiling point. The process of separating water at low temperatures limited the decomposition of nutrients in the raw materials. The investigated pressure range from 500 to 650 mmHg had statistically significant effect on nutrients (p < 0.05). The pressure investigation revealed that at higher pressures, higher nutrient values were retained (Figure 2). At 600 - 650 mmHg, the nutritional values reached the highest content, with TPC and TAA reached 331.13 ± 3.43 mg GAE/100 mL and 827.01 ± 11.32 mg/100 mL,

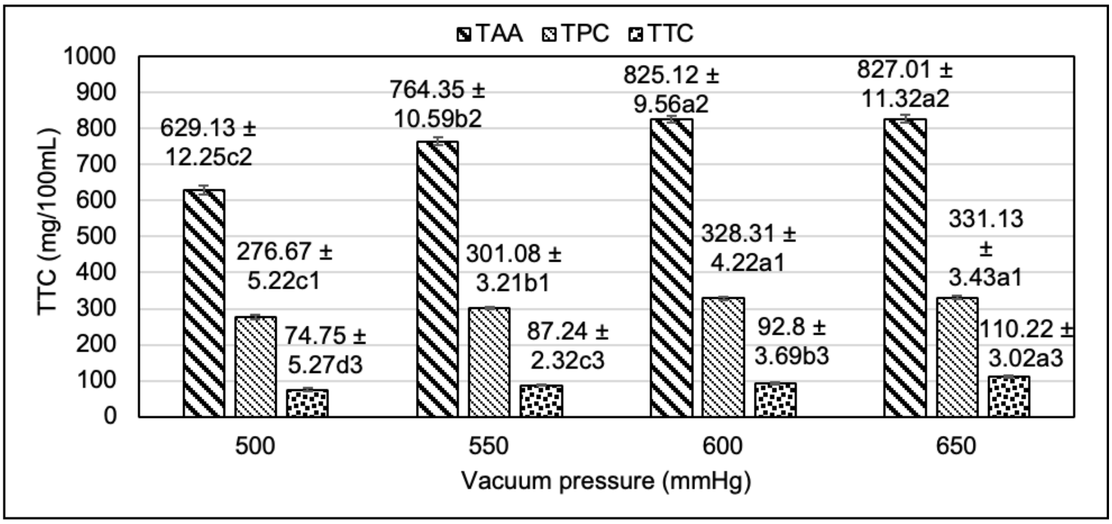

Figure 2. Effect of vacuum pressure on nutritional content after VC. Different lowercase letters indicate significant difference (p < 0.05). (1 - 3) distinguish TPC, TAA, and TTC.

respectively. On the contrary, at 500 mmHg, the lowest nutritional value was obtained, with TPC and TAA reached 276.67 ± 5.22 mg GAE/100 mL) and 74.75 ± 5.27 mg/100 mL, respectively. The TTC value gradually increased from 74.75 ± 5.27 to 110.22 ± 6.02 mg/100 mL with a gradual increase in pressure. At 500 - 650 mmHg and 60°C, the temperature of the product was not changed. However, at the same time of VC and higher pressure, the boiling intensity of the juice was greater, and it was directly proportional to the rate of separation of water from the juice (Bozkir and Tekgül, 2022). This led to an increase in the distribution of components per unit volume. The results were similar to the previous study on the effect of vacuum pressure during VC of grapefruit juice on the increase in TPC and other antioxidant activities (Nhi *et al*., 2020).

However, the investigated pressure range of 600 to 650 mmHg was not significantly different ($p > 0.05$). This can be explained as when the pressure was excessively high (650 mmHg), the water content separated from the juice was large, and TSS in the solution proportionally increased with the increase in TAA. Besides, as the boiling point of the product increased, the nutritional composition of the product in the juice was negatively affected by the temperature factor. The nutritional value at 650 mmHg was affected by the increase in TSS, and the boiling point of the product.

Effect of VC temperature on product's quality

Polyphenols are compounds that are easily affected and degraded by heat. The increase in temperature from 60 to 90°C had statistically significant effect on TPC ($p < 0.05$) (Figure 3a). The TPC increased with increasing temperature to 80°C as heat affected the TTC present in the juice, which increased tannin hydrolysis capacity to produce gallic acid. The high temperature accelerated the hydrolysis rate (Hagerman *et al*., 1992; Bamidele *et al*., 2017; Dao *et al*., 2022). This led to more gallic acid being produced as the temperature increased. At the same time, gallic acid is also a substance in the group of polyphenols; the positive correlation between gallic acid and polyphenols was shown in previous report (Dao *et al*., 2022). So, the TPC increased when the temperature was increased to 80°C (323.29 ± 4.15 mg GAE/100 mL). However, TPC decreased when the temperature was increased further to 90°C (239.25 ± 5.22 mg GAE/100 mL). At an excessively high temperature, the high boiling intensity, rapid loss of water content, and a decrease in the amount of water involved in the hydrolysis of tannins led to low hydrolysis efficiency. At the same time, the temperature continued to degrade the polyphenols in the solution without an increase in the gallic acid content. Coating the compounds with water restricted their contact with the device. Therefore, the compounds were only affected by a temperature corresponding to a pressure of 600 mmHg. However, the evaporated water content gradually increased as the temperature increased from 60 to 90°C under the same vacuum pressure conditions. In addition, the compounds were limited to the coverage of water, which formed the conditions for the polyphenol compounds to contact the wall of the device; this led to increased polyphenol degradation. A previous study also reported that the increase in temperature during water separation led to rapid water loss, high TSS, and was directly proportional to the boiling point of the product centre, as well as a direct negative effect on TPC (Bozkir and Tekgül, 2022).

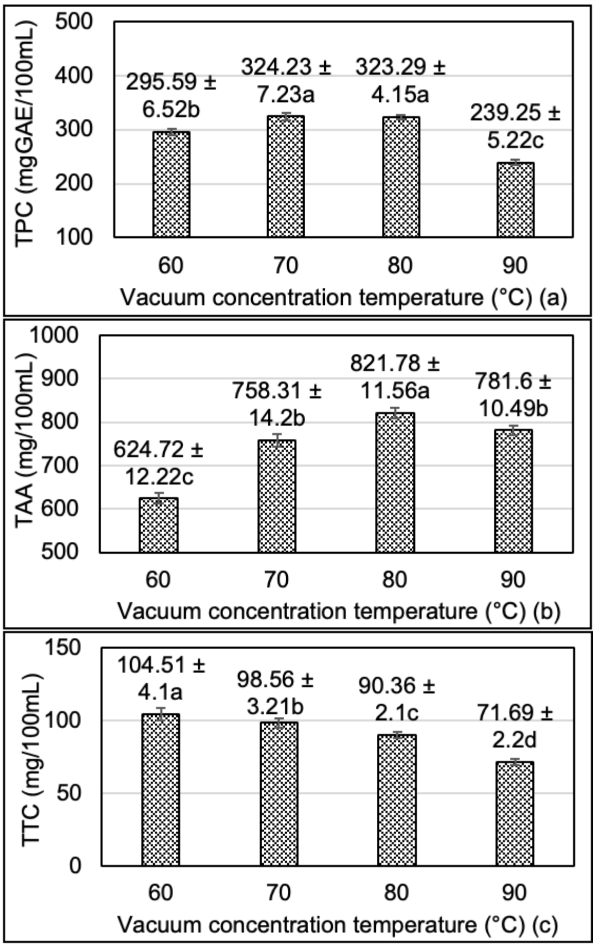

Figure 3. Effect of temperature on TPC **(a)**, TAA **(b)**, and TTC **(c)** after VC. Different lowercase letters indicate significant difference ($p < 0.05$).

TAA is a specific nutrient for cashew apple raw materials. Several previous studies had shown that TAA in cashew apples is 10 times higher than pineapple (Jayalekshmy and John, 2004). However, TAA is a heat-sensitive substance that is easily oxidised in the presence of air (Igwemmar *et al*., 2013). At the same vacuum pressure and time during VC (40 min, 600 mmHg), when the temperature was increased from 60 to 90°C, the product temperature did not change, but the boiling intensity increased significantly (Figure 3b). The high temperature is associated with the high boiling intensity and evaporation rate of the water (Bozkir and Tekgül, 2022). The effect of four temperature levels from 60 to 90°C showed that TAA increased with increasing temperature, the highest value was 821.78 ± 11.56 mg/100 mL at 80°C. After the cashew apple juice was concentrated under vacuum at 40 min/60°C/600 mmHg, the water separation efficiency of the solution was the lowest, and gradually increased with increasing VC temperature. Therefore, the distribution density of TAA per unit volume is lower than that of TAA during VC at 80°C. A similar report also showed an increase in the distribution of substances when the water content was high (Azarpazhooh and Ramaswamy, 2009). On the other hand, at 90°C, the water content evaporated rapidly, and the TAA was directly exposed to the temperature of the device case without water cover. At 90°C, TAA was degraded by approximately 5% compared to TAA at 80°C, and the remaining TAA was 781.6 ± 10.49 g/100 mL. The continued rise in temperature above 90°C negatively affected TAA. A similar report of an increase in TAA after VC of orange juice was reported (Petzold *et al*., 2019).

Tannins are natural compounds belonging to the polyphenol group, which are easily oxidised when subjected to the effects of temperature. In the presence of water and under catalysis of temperature, the hydrolysed tannins form gallic acids and polyols (Hagerman *et al*., 1992; Belmares *et al*., 2004). In the present work, VC within the temperature range of 60 to 90°C showed a significant effect on TTC ($p < 0.05$) (Figure 3c). As the temperature increased, TTC decreased. TTC reached the lowest value at 90°C (71.69 ± 2.2 mg/100 mL), and reached the highest value at 60°C (104.51 ± 4.1 mg/100 mL). Increasing the temperature to a suitable limit accelerates the hydrolysis of tannin. At high temperatures, the tannins were significantly hydrolysed. At the same time, in an acidic medium, condensed tannins decomposed to form anthocyanidins at high temperature (Hagerman *et al*., 1992). A similar report on effective separation astringency was obtained when persimmon (*Diospyros kaki* L.) were soaked in water at 20 - 80°C for 4 and 24 h (Osawa and Walsh, 1993).

Effects of dilution ratio after VC on sensory quality of products

The degree of dilution of the juice after VC directly affected the perception of consumers, where the dilution made the product easy to drink, and it also had light taste and bright colour. However, when the amount of water added to the post-concentration juice was too high, this resulted in discoloration and degradation of product aroma and flavour. Post-concentration juice dilution ratio had a statistically significant effect on consumer preference ($p < 0.05$). When the dilution ratio was increased, the product preference of more than 60 consumers decreased (Figure 4a).

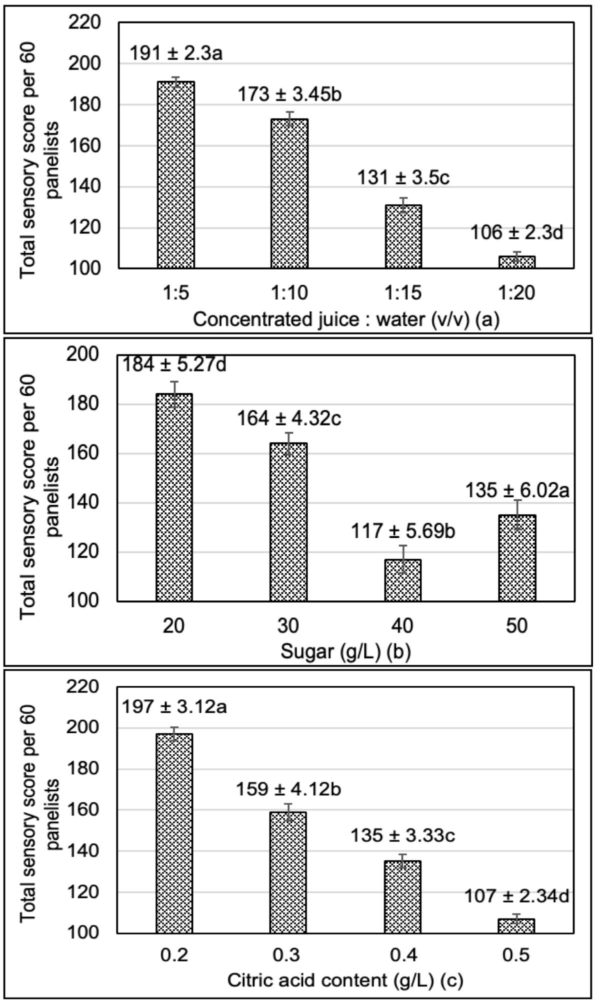

Figure 4. Total sensory score of product liking **(a)**, sweetness **(b)**, and acidity **(c)** which was assessed by 60 panellists (scale of 5 scores). Different lowercase letters indicate significant difference ($p < 0.05$).

At the lowest ratio (1:20), the product liking reached the highest value (106 scores). When the juice was diluted 5 times (1:5) with water, it obtained 191 scores. A similar report on the decrease in preference as the wine:water dilution ratio was increased from 1:0.5 to 1:2 (w/w) was reported elsewhere (Joshi *et al*., 2012).

Effects of sugar content on sensory quality of product

In order to give higher sweetness level based on consumers' preference, and prolong the shelf life of the product, and at the same time, a flavour that combines the acrid and sweet characteristics of the product, taste was evaluated by 60 consumers on a 5-score scale. Figure 4b shows that consumers rated the highest at 20 g/L with 184 scores. When the addition of sugar content reached 30 - 40 g/L, the trend of preference decreased when the sweetness was increased, and the characteristic acrid taste of the product was masked by the sweetness. However, a group of consumers preferred products with a strong sweet taste. Figure 4b shows that with 50 g/L added sugar content, 135 scores were reached. A previous report indicated a preference trend for low-sweetness products in most consumer goods (Drewnowski *et al*., 2012).

Effects of citric acid content on sensory quality of product

Citric acid is an additive that can be used in food products to adjust the sour taste of the product. The current trend in beverage production is to have sour taste in the product to stimulate the taste buds, and create a feeling of originality and uniqueness. The use of citric acid concentrations within the limits allowed by the regulations of each country, and a moderate sour taste, are suitable for consumer tastes. The citric acid content investigated ranged from 0.2 to 0.5 g/L. Figure 4c shows that 60 consumers preferred 0.2 g/L. The product had a moderate sour taste combined with a mild acrid taste, creating a unique character of the product (197 scores). However, higher citric acid content was not favourable due to sourness-associated numbness feelings (107 scores). A similar trend of favouring a mild sour taste in some beverages was also reported in previous studies (Tireki, 2021).

Aging rate and maximum shelf life of vacuum-concentrated cashew juice product

Over time, the nutritional components contained in food were degraded by oxidation and decomposition. Depending on the storage conditions of the product, the rate of deterioration of the nutrient content in the product can be fast or slow. The higher the temperature, the greater the rate of destruction of the active nutrients due to the influence of temperature for a long time (Mai *et al*., 2022). At room temperature, in addition to oxidation, the action of microorganisms also significantly affects the nutritional quality of the product. In the present work, storage of the product at room temperature (35°C) showed a slower deterioration rate than storage of the product at 45°C (Table 1).

Table 1. Relationship between time and nutrition content during storage at 35 and 45°C. Different lowercase letters in the same column indicate significant difference ($p < 0.05$).

Time (d)	Temperature					
	35°C			45°C		
	TAA (mg/100 mL)	TTC (mg/100 mL)	TPC (mg GAE/100 mL)	TAA (mg/100 mL)	TTC (mg/100 mL)	TPC (mg GAE/100 mL)
0	759.36 ± 10.32^{a}	90.41 ± 2.23^{a}	324.23 ± 5.02^{a}	759.36 ± 10.32^{a}	90.41 ± 3.12^{a}	324.23 ± 5.02^{a}
7	738.91 ± 5.23^{a}	79.390 ± 2.21^{b}	320.15 ± 9.05^{a}	703.50 ± 19.56^{b}	73.60 ± 2.41^{b}	316.64 ± 6.66^{ab}
14	686.47 ± 7.32^{b}	75.210 ± 2.31^{c}	315.63 ± 5.36^{a}	622.45 ± 17.52^{c}	67.42 ± 2.72^{c}	309.43 ± 3.44^{b}
21	660.19 ± 10.19^{c}	73.120 ± 2.42^{c}	294.27 ± 10.02^{b}	630.14 ± 12.32^{c}	61.10 ± 3.41^{d}	286.84 ± 9.21^{c}
28	610.42 ± 19.12^{d}	69.01 ± 2.10^{d}	279.44 ± 11.12^{c}	590.11 ± 12.20^{d}	59.10 ± 2.21^{de}	265.29 ± 6.10^{d}
35	590.24 ± 22.21^{de}	64.31 ± 2.01^{e}	250.23 ± 5.03^{d}	581.92 ± 10.26^{de}	55.10 ± 3.01^{e}	246.07 ± 12.21^{e}
42	581.25 ± 17.22^{e}	58.44 ± 2.72^{f}	244.21 ± 5.22^{d}	560.35 ± 17.11^{e}	49.42 ± 2.65^{f}	239.10 ± 7.16^{e}

After 42-day storage, TAA was degraded by 23.46% (581.25 mg/100 mL) and 26.21% (560.35 mg/100 mL) at 35 and 45°C, respectively, compared to the original sample (759.36 mg/100 mL). However, the degradation of TPC after 42-day storage at two temperature conditions was not significantly different. At 35 and 45°C, TPC decreased by 24 and 26%, respectively, compared to the original (324.23 mg GAE/100 mL). As tannin belongs to the group of polyphenols, it can easily be affected by factors such as storage temperature and time. At 35 and 45°C, TTC was reduced by 35.36 and 45.34% less than the original sample, respectively. Accelerated aging of the product under storage conditions of 45 and 35°C during 42-day storage showed that TAA and TPC were stored for a maximum of 172 and 117 d, respectively. A similar report on storage at two conditions of room temperature and 40°C previously also showed a decrease in TAA and TPC in fresh soursop pulp (*Annona muricata* L.) (Tran *et al*., 2020). A report by Ros-Chumillas *et al*. (2007) showed that TAA during orange juice storage slowly degraded during the first 50 days, and rapidly declined until the 200th day. The juice was stored in PET bottles (similar to this study). The maximum time for the product to degrade by 62% from the original TAA was 180 d (Ros-Chumillas *et al*., 2007). The prolongation of storage time may be due to the influence of the mixed citric acid content in the process of adjusting the sour taste of the product. A similar report on the storage of fresh cashew apple juice took up to three months for TAA to reduce by 20% (Talasila *et al*., 2012).

Conclusion

The present work successfully investigated the effect of temperature, pressure, sugar, and citric acid content on the quality of the cashew apple juice produced by VC. VC at 80°C with 600 mmHg pressure was the most suitable to obtain products with satisfactory nutritional quality at a reduced production time and cost. The remaining TPC, TAA, and TTC after VC were 328.21 ± 3.22 mg GAE/100 mL, 825.12 ± 9.56 mg/100 mL, and 92.8 ± 5.69 mg/100 mL, respectively. Furthermore, water was added to the concentrated cashew apple juice in a 5:1 ratio, and sugar (20 g/L) and citric acid (0.2 g/L) were highly preferable in terms of sensory perception of 60 consumers. The results of the storage of the product at 35 and 45°C for 6 w based on the accelerated aging method showed that the maximum time to retain nutritional values such as TAA and TPC was 172 d and 117 d, respectively. These findings contributed to the diversification of products for the cashew apple industry, thus promoting the growth of domestic and foreign economies.

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