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Impact of JEVA Evaporation on Storage Stability and Physiochemical Characteristics of Vietnam Red Dragon Fruit *(Hylocereus polyrhizus)*

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Red dragon fruit (*Hylocereus polyrhizus*) is a tropical fruit rich in nutrients vitamin C, vitamin A, protein, polyphenols, and flavonoids. The fruit can be, therefore, processed into different high valued products. Concentrated fruit juice had a long storage life with lesser transportation cost than that of fresh juice. Juice of red dragon fruit from Binh Thuan Province in Vietnam was concentrated using novel evaporation launched under ambient pressure and moderate temperature named JEVA. The obtained concentrates were from 13.8°Brix to above 60°Brix, while at the same time, it allowed retaining more than 90% polyphenol content (92.89%) and flavonoid content (98.58%); the retention of vitamin C and betacyanin content was 70.17% and 74%, respectively. Meanwhile, the evaporation under vacuum technology at 40°C allows retaining approx. 57% vitamin C and 40% betacyanin in red dragon fruit juice concentrate. With betacyanin retention of 85.76% and vitamin C retention of 81.55% after 8-weeks-storage at 4°C, dragon fruit concentrate obtained by JEVA evaporation at 35°C showed much higher stability than that of fresh juices. These obtained results suggested that JEVA evaporation can offer a better product than vacuum evaporation. JEVA evaporation is highly potential for launching in a large scale to process red dragon fruit juice.

1. Introduction

Red dragon fruit (*Hylocereus polyrhizus*) is one of the unique tropical and subtropical fruits native to Mexico, Central American, and South American countries. The composition of red dragon fruit is very diverse, including proteins, carbohydrates, fats, vitamin B1, vitamin B6, vitamin C, and other minerals (Jalgaonkar et al., 2020). Besides, red dragon fruit also contains antioxidant compounds belonging to the phenolic groups, flavonoids groups, and betacyanin (Ramli et al.,2014). The demand for red dragon fruit juice is increasing due to its attractive colour and high nutritional value. However, supplying dragon fruit juice to all markets worldwide has many difficulties due to the high cost of packaging, transportation, and storage.

Furthermore, the physical and chemical properties of fresh dragon fruit juice as colour, total polyphenol content (TPC), total flavonoid content (TFC), betacyanin content (BC), and vitamin C are easily degraded under the influence of temperature, oxygen, and light during prolonged storage. (Siow et al., 2017). Therefore, while keeping the physicochemical parameters less change, the concentration of dragon fruit juice is essential to help reduce transportation and storage costs and contribute to stabilizing product quality.

The production of concentrated juices is carried out by evaporation under vacuum, although this technology has been reported to deplete vitamin C (Elhadad et al., 2013); and volatile compounds (Cissé et al., 2011), but it is still being used to concentrate heat-sensitive fluids. The nanofiltration (NF) and reverse osmosis (RO) membrane technique is a promising process for concentrating juice at moderate temperatures (Bhattacharjee et al., 2017). However, the high investment costs and the membrane fouling clogging remain a significant challenge. Besides, a new evaporation technique called JEVA has been developed that allows the juice to be concentrated at moderate temperature and ambient pressure; therefore, it helps maintain the maximum quality of juice fruit. JEVA evaporation can be applied for the concentration of thermal sensitive solutions such as fruit

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juices, herbal extract, enzyme solutions, honey… (Nguyen and Samhaber, 2018). In this study, red dragon fruit juice from Binh Thuan province, Vietnam was concentrated using an evaporation concept at ambient pressure and moderate temperature named JEVA. Changes in physical and chemical properties (total soluble solids, vitamin C, TPC, TFC ...) before and after concentration has been determined and compared with that of vacuum evaporation. Furthermore, some physical and chemical parameters of fresh and JEVA concentrated dragon fruit juice after eight weeks of storage were also reported to clarify the role of JEVA evaporation process on the quality stability of red dragon fruit juice.

2. Material and methods

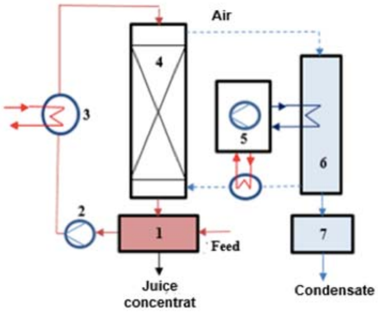
2.1 Fruit preparation

Red dragon fruit from Tan Tien Commune, Lagi Town, Binh Thuan Province in Vietnam supplied by Hao Hanh Co. Ltd., were washed with deionized water. The red dragon fruit is removed from the skins; the flesh is pressed using a juicer and filtered through a sieve (pore-size is 100 µm) to remove coarse seeds and residues.

2.2 Concentration experiments

JEVA evaporation

Figure 1 showed a schematic diagram of the pilot evaporation plant based on JEVA principle, in which red dragon fruit was concentrated at ambient pressure and temperatures between 35°C and 42°C.



1. Feed/Concentrate tank
2. Pump
3. Heat exchanger
4. Evaporation compartment
5. Heat pump
6. Condensation compartment
7. Condensate tank

Figure 1. Schematic diagram of the pilot evaporation plant based on JEVA principle (Nguyen and Samhaber, 2018)

In each evaporation batch, 20 kg red dragon fruit juice was put into the feed/concentrate tank (1) and pumped through a heat exchanger (3) at a flow rate of 3.6 l/min. Depending on the purpose of the experiment, red dragon fruit juice was warmed up to 35°C or 42°C. The juice was then led to the evaporation compartment (4) and evenly distributed over an air/liquid contact surface structure. Air was blown in the opposite direction makes direct contact with the juice and then was transferred to the condensation compartment (6). In this compartment, the vapour was condensed on the surface of an indirect plate heat exchanger. The condensate was taken to the condensate tank (7). A refractometer tested total soluble solids (TSS) in red dragon fruit juice in the concentration process. When the TSS was satisfied, the concentrated red dragon fruit juice was taken out and stored.

Vacuum evaporation

Vacuum evaporation of red dragon fruit juice was carried out in a rotary evaporator (RE100-Pro, model 6030110111, DLAB, USA) at P = 0.2 bar and temperature of 42°C and 50°C.

2.3 Analyses

Total soluble solids (TSS) and pH of juice samples were measured by Atago N-20 refractometer (Japan) and pH meter (pH90, WTW, Germany), respectively. Total acidity and vitamin C content were determined according to the A.O.A.C (2006) procedures and titration method (Mohammed et al., 2016). Total polyphenolic content (TPC) and total flavonoid content were determined according to the method described by Georgé et al., (2005) and Marinova et al. (2005). Total betacyanin content was determined according to the method described by Wybraniec and Mizrahi (2002).

The retention of a physiochemical characteristic includes vitamin C content, TPC and total flavonoid content after evaporation was calculated according to (Eq. 1):

$$R_X = \frac{X_1}{X_0} \qquad (1)$$

where: X is a physiochemical characteristic of juice such as vitamin C content, TPC and total flavonoid content; R_X is the retention of X after evaporation, %; X_1 is the value of X of reconstituted juice. X_1 is derived from X value of fruit concentrate, Total soluble solids (TSS) of concentrate and that of single strength juice; X_0 is the value of X of single strength juice (bevor evaporation)

2.4 Storage

Red dragon fruit juice and juice concentrate samples were stored at 4°C (refrigerator) and 27°C (room temperature), respectively. Samples were analyzed weekly for total betacyanin content, vitamin C content throughout eight weeks of storage.

2.5 Statistical analysis

All measurements were carried out in triplicate, and the data were expressed as means ± standard deviations (SD). One-way ANOVA analysis was implemented. Tukey's test was used to verify any significant differences among the mean values at confidence level $p < 0.05$.

3. Results and discussion

3.1 Physicochemical characterization

As shown in Table 1, red dragon fruit juice concentrates with TSS above 60°Brix can be achieved with both JEVA evaporation and vacuum evaporation. pH value of all concentrate samples fluctuated slightly in the lower range of 3.77 ± 0.06 and 3.89 ± 0.06 than fresh juices (4.23^{a} ± 0.11) ($p < 0.05$). The reason for that was the increase in the total acid content of fruit concentrates caused by the concentration process. The difference in pH value and total acid content between juice concentrate samples was not significant ($p > 0.05$). This showed that the concentration processes at a temperature range of 35°C - 50°C had negligible effects on pH and total acid content of the juice concentrates.

Table 1. Physiochemical characteristics of red dragon fruit juice samples.

		JEVA evaporation		**Vacuum evaporation**	
Sample name	Flesh juice	Concentrated at 35°C	Concentrated at 42°C	Concentrated at 42°C	Concentrated at 50°C
Sample code	***FJ***	***JEVA.35***	***JEVA.42***	***VC.42***	***VC.50***
TSS, °Brix	13.8^{a} ± 0.2	62.3^{b} ± 0.2	62.0^{b} ± 0.2	60.1^{c} ± 0.4	61.8^{b} ± 0.3
pH	4.23^{a} ± 0.11	3.87^{b} ± 0.06	3.78^{b} ± 0.06	3.89^{b} ± 0.06	3.77^{b} ± 0.06
Total acid content, g/l	4.20^{a} ± 0.01	4.31^{b} ± 0.01	4.30^{b} ± 0.02	4.32^{b} ± 0.03	4.30^{b} ± 0.02
Colour					
L*	3.51^{a} ± 0.16	3.03^{b} ± 0.36	3.01^{b} ± 0.24	3.03^{b} ± 0.01	2.46^{c} ± 0.31
a*	2.96^{a} ± 0.29	3.23^{a} ± 0.12	3.74^{b} ± 0.11	3.74^{b} ± 0.08	4.15^{c} ± 0.18
b*	1.43^{a} ± 0.19	1.97^{b} ± 0.17	2.28^{b} ± 0.22	2.30^{b} ± 0.11	2.70^{c} ± 0.10
∆E	-	0.768	1.254	1.256	2.081

Results are given as mean ± SD (n = 3).
Different letters in the same row indicate a statistically significant difference ($p < 0.05$).

The change in colour of red dragon fruit after JEVA evaporation under ambient pressure and at 35°C and 42°C, were $\Delta E1=0.768$ and $\Delta E1=1.254$. The vacuum evaporation at 50°C led to the most significant increase in colour density of $\Delta E4=2.081$. During processing at high temperatures, oxidation and Maillard reactions caused the reduction in the juice colour. On the other hand, the samples concentrated at 42°C and under ambient and vacuum pressure had similar darkening levels compared to that of fresh juice. It indicated that, unlike the processing temperature, the operation pressure did not significantly influence the colour density changes after evaporation.

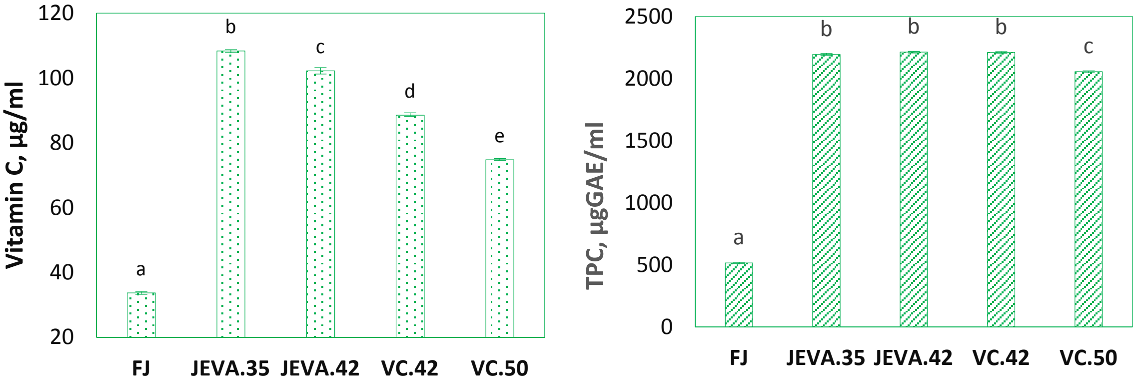


Figure 2. The changes of vitamin C and TPC in red dragon fruit juice after concentration

The effect of the operational conditions of the evaporation process on the vitamin C content of red dragon fruit juice was demonstrated in Figure 2. During JEVA evaporation under ambient pressure and at 35°C, the vitamin C content increased from 33.704 µg/ml for fresh dragon fruit juice up to 108.72 µg/ml for dragon fruit juice concentrate, corresponding to the retention of 70.17%. The vitamin C content of juice concentrate of 102.26 µg/ml equivalented to a vitamin C retention of 66.22% was obtained while the concentration process was carried out at 42°C. On the other hand, vacuum evaporation at 42°C and 50°C resulted in a vitamin C retention of 57.35% and 48.43%, respectively. It suggested that vitamin C retention closely depended on processing temperature. Elhadad et al. (2013) also reported that the vitamin C content in apricot and peach juices was reduced by 30.7% when concentration by evaporation under vacuum pressure at 45°C - 50°C.

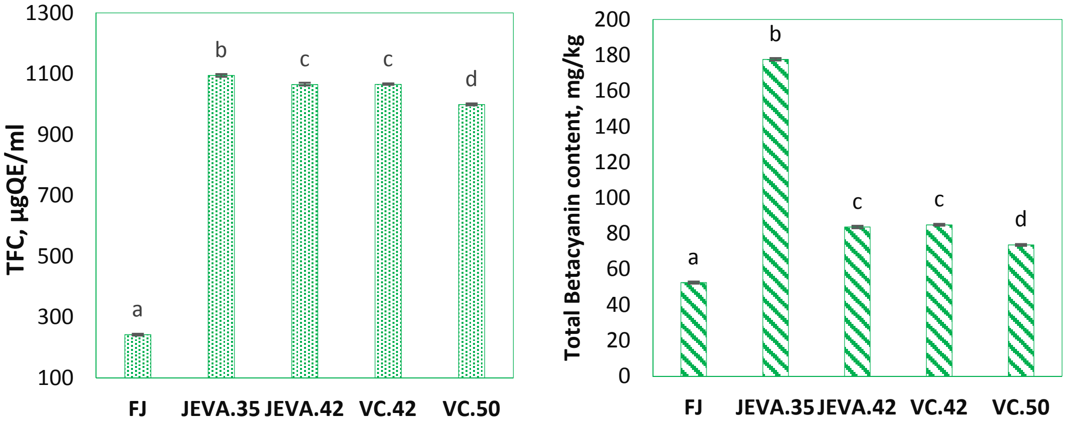


Figure 3. The changes of TFC and betacyanin content (Bc) in Red dragon fruit juice after the concentration process

The change in TFC, TFC, and total Bc after evaporation were illustrated in Fig. 2 and Fig 3. TPC, TFC, and total Bc of all concentrate samples were higher than that of fresh juice samples ($p < 0.05$), because the removal of water increased the concentration of these compounds. Vacuum evaporation at 50°C led to the retention of TPC and TFC of about 87-89%. In particular, the retention of betacyanin in red dragon fruit juice after JEVA evaporation under ambient pressure and at 35°C (JEVA.35) is 74%, which was much higher (nearly two times higher) than that of concentrates obtained at 42°C after both JEVA evaporation and vacuum evaporation. It pointed out that betacyanin was highly thermal sensitive and strongly decomposed at a temperature range higher than 40°C. In the interest of high betacyanin retention, JEVA evaporation has a clear advantage over vacuum evaporation. These obtained results suggested that JEVA evaporation can offer a better product than vacuum evaporation.

3.2 Stability of red dragon fruit juice and red dragon fruit juice concentrate during storage

This study was conducted to evaluate the effect of JEVA technology launched under ambient pressure and at 35°C on the quality stability of dragon fruit juice. Samples of dragon fruit juice (FJ) and red dragon fruit juice concentrated by JEVA evaporation at 35°C (JEVA.35) were stored in 100ml dark vials at 27°C (room temperature) and 4°C (refrigerator). The results showed that fresh red dragon fruit juice was layered and fermented after one week when stored at room temperature (27°C). When stored at 4°C, fresh dragon fruit samples were layered and fermented after three weeks. The high water content (corresponding to low soluble solids content) combined with microorganisms' presence causes the rapid fermentation of fresh juices. In dragon fruit juice concentrates, vitamin C and betacyanins are less stable compounds, susceptible to UV light, temperature and storage time. Degradation of vitamin C and betacyanin in fruit concentrate samples for eight weeks were also monitored.

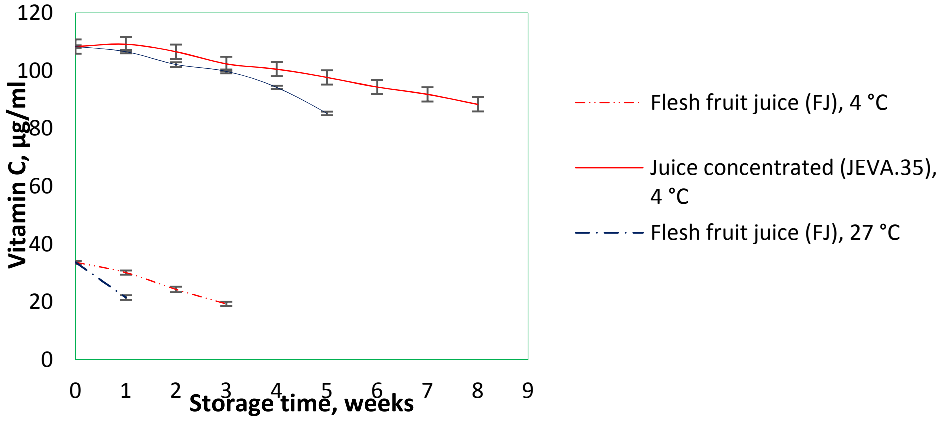


Figure 3. Changes in vitamin C content in single strength juice and concentrate samples stored at 4 and 27°C through 8 weeks storage

As can be seen in Fig 3, average vitamin C content in red dragon fruit juice concentrates over eight weeks of storage at 4°C, and room temperature (27°C) were 99.87 µg/ml and 99.36 µg/ml, respectively. No apparent difference in vitamin C content of concentrates stored at 4°C and 27°C over the storage time was observed. The average vitamin C content in single strength juice (26.66 µg/ml) was much lower than that of concentrates.

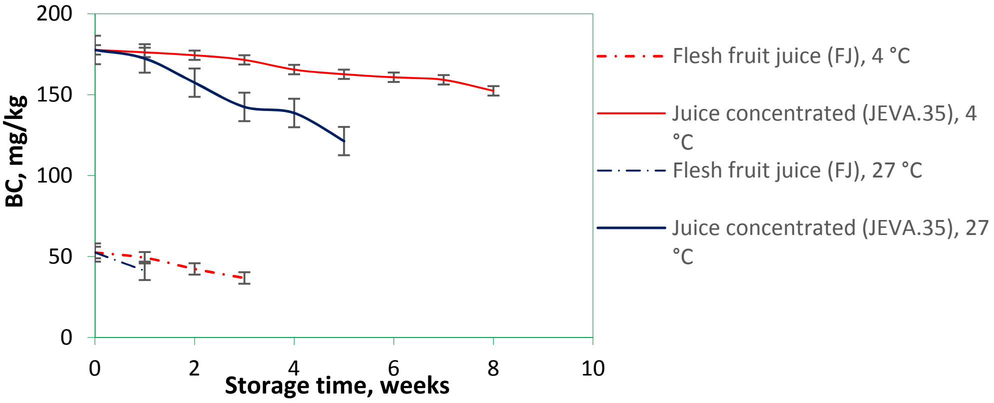


Figure 4. Changes in Betacyanin content (BC) in single strength juice and concentrate samples stored at 4 and 27°C through 8 weeks storage

Figure 4 exhibited the changes in Betacyanin content (BC) in single strength juice and concentrate samples stored at 4 and 27°C through 8 weeks storage. The average BC in red dragon fruit juice concentrates over eight weeks of storage at 4°C and room temperature (27°C) were 165.32 mg/kg and 146.46 mg/kg, respectively. A notable difference between BC of concentrates stored at 4°C and 27°C was found. Average BC single strength juice (42.78 mg/kg) was again noted to be much lower than that of concentrates.

The retention of betacyanin and vitamin C degradation after 8-weeks-storage of concentrates samples obtained by JEVA evaporation at 35°C were 85.76% and 81.55%, respectively. The finding on BC degradation was consistent with what Siow et al. (2017) reported that a first-order pseudo-kinetic model could describe the degradation of betacyanin at 27°C.

4. Conclusions

The comparison of the physicochemical characteristics of the red dragon fruit juice before and after concentration found that all parameters were sensitive to the thermal treatment, particularly the BC. JEVA evaporation carried out under ambient pressure and at 35°C enabled to concentrate red dragon fruit juice from 13.8°Brix to above 60°Brix, while at the same time it allowed retaining more than 90% TPC (92.89%) and TFC (98.58%); the retention of vitamin C and BC were recorded at 70.17% and 74%, respectively. The impact of JEVA evaporation on the quality of dragon fruit concentrate is lower than that of vacuum evaporation since JEVA evaporation can be performed at 35°C, which is lower than the operating temperature range of the vacuum evaporation. With Betacyanin retention of 85.76% and vitamin C retention of 81.55% after 8-weeks-storage at 4°C, dragon fruit concentrate obtained by JEVA evaporation at 35°C showed much higher stability than that of fresh juices. The obtained results suggested that JEVA evaporation can offer a better product than vacuum evaporation. JEVA evaporation is highly potential for launching on a large scale to process red dragon fruit juice.

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