CHEMICAL ENGINEERING TRANSACTIONS

VOL. 75, 2019

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.cetjournal.it

Guest Editors: Sauro Pierucci, Laura Piazza

ISBN 978-88-95608-72-3; **ISSN** 2283-9216

DOI: 10.3303/CET1975008

Physicochemical Characteristics and Aroma Analysis of Passion Fruit Juice and Guava Juice Concentrated by a Novel Evaporation Concept

Duc Chinh Pham[a], Ngoc Ha Vu[a], Wolfgang M. Samhaber[b], Minh Tan Nguyen[a,*]

[a]Institute for R&D of Natural Products, Hanoi University of Science and Technology, 1 Dai Co Viet Road, Hanoi, Vietnam
[b]Institute of Process Engineering, Johannes Kepler University Linz, 4040 Linz, Austria
tan.nguyenminh@hust.edu.vn

This research focused on the performance evaluation of a new fruit juice concentration concept named JEVA, which is featured by the connection of moisture condensation with moderate warming of the juice in a circulation loop. The warming temperatures were between 30°C and 45°C and the process was carried out at ambient pressure. The evaluation is based on analysis of the changes in physicochemical and aroma characteristics (pH, acidity, total solids content, vitamin content and microbiological and aroma analysis) of concentrated passion fruit and guava juice in comparison with those of fresh fruit juices. Fresh fruits were enzyme treated, filtrated and concentrated by a JEVA based pilot-scale equipment system. The concentrated juices were then reconstituted and characterized.

1. Introduction

Fruit juice concentrate production has become a common practice in juice industries because juice concentrates are more stable and more resistant to bacterial development and reduced chemical degradation compared to the original juice. As a result, it can be stored for a long period of time and used to produce various products. Passion fruit (Passiflora edulis) is a rich source of vitamins and minerals for the human body and is flavoured for its unique attractive aroma (Muahammad et al., 2012). Guava (Psidium guajava) is recognized as a fruit with high nutritional value and has some inhibitory effect on the bacteria due to the presence of a large amount of vitamin C, polyphenols and carotenoids (Chopda et al., 2001; Mahattanatawee et al., 2001). Passion fruit and guava are grown mainly in tropical and subtropical climates. Therefore, the production of concentrated passion fruit juice and guava juice is necessary to provide nutritious juice products for all world markets.

Conventional thermal evaporation of juices is generally carried out at elevated temperatures (even under vacuum) causing a huge deterioration in the product such as degradation of colour, loss of nutrition characteristics, and the development of "cooked" taste. The use of membrane processes can be an alternative for thermal evaporation since they are able to concentrate juices at moderate temperature. However, the fruit pulp and macromolecules present in fruit juices create a cake on the membrane surface and decline in the permeate flux. Reverse osmosis processes have been applied for the production of concentrated fruit juice. Nevertheless, the increase in concentration leads to a remarkably increase in osmotic pressure, which could cause in greater operating cost. Especially, the limit of reverse osmosis is about 160 bar, corresponding to the concentration of fruit juice reaches 40 - 50 ° Brix (Bhattacharjee et al., 2017).

The newly developed evaporation concept named JEVA could offer a better alternative. The concentration process is realised by connection the moisture condensation with moderate warming of the juice in a circulation loop (Nguyen et al., 2018). Different fruit juices have been concentrated in a JEVA based pilot plant, which allowed the evaporation at moderate temperature and ambient pressure and therefore enabled high retention of fresh fruit juice quality satisfactorily. This research aimed at evaluation of the concentration of passion fruit juice and guava juice applying JEVA evaporation concept.

Paper Received: 25 June 2018; Revised: 24 September 2018; Accepted: 1 February 2019

Please cite this article as: Pham D.C., Vu N.H., Samhaber W., Nguyen M.T., 2019, Physicochemical Characteristics and Aroma Analysis of Passion Fruit Juice and Guava Juice Concentrated by a Novel Evaporation Concept , Chemical Engineering Transactions, 75, 43-48
DOI:10.3303/CET1975008

2. Experimental

2.1 Fruit preparation

Ripened guava and passion fruit with 80-90% maturity and free from visual blemishes and bruises were from Tue Vien farm, Hanoi, Vietnam, the fruits were washed with water. Then, passion fruits were cut and skin was removed while guava fruits were crushed.

2.2 Enzyme treatment and juice extraction

200 ppm of a mixture of Vegazyme and Fructozyme (1:1, v/v) (Erbslöh Geisenheim GmbH, Germany) was added to fresh passion fruit. 180 ppm pectinase (Novozyme, Denmark) was added to guava mesh. Enzymatic treatment was performed in a jacketed stainless-steel tank with constant stirring (100 rpm), at 45 °C for 60 min. After that passion fruit juice was centrifuged at a speed of 600rpm and filtered by 50 µm cloth filter. Guava juice was filtered by plate and frame filter press with a 50 µm cloth filter at a pressure difference of 5 bar.

2.3 Concentration

The juice was concentrated with the JEVA based pilot juice concentration plant, which was batch-wisely operated at a temperature range from 35°C to 45°C and ambient pressure (P = 1 bar) with a feed loading from 30 to 60 litres juice. A schematic flow sheet of the pilot plant can be seen in Figure1.

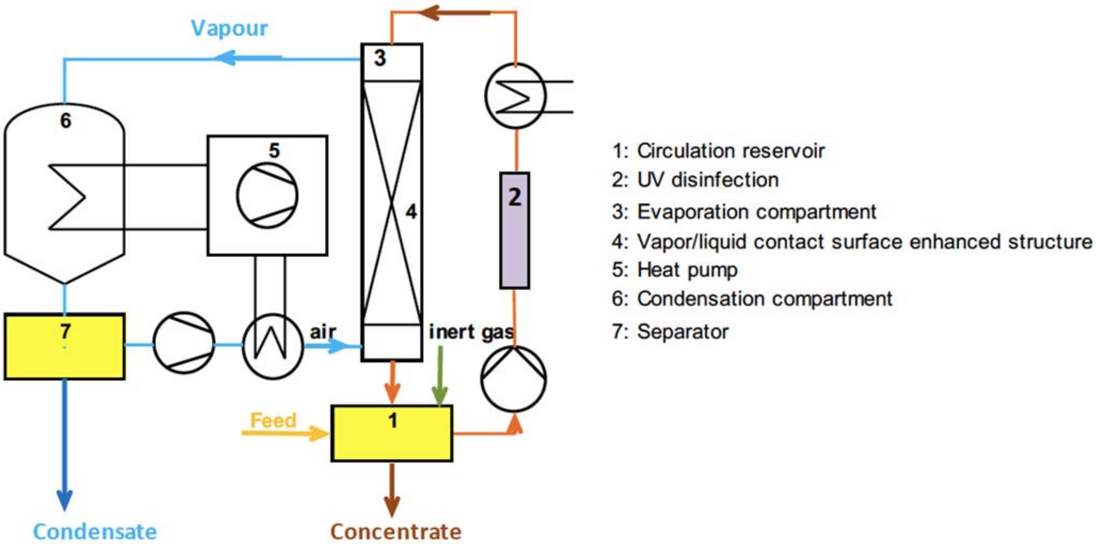

Figure 1: Schematic flow sheet of the JEVA based pilot juice concentration plant

Table 1: Operating conditions of the JEVA based pilot juice concentration plant

	Concentration of passion fruit juice	Concentration of Guava juice
Pressure, bar	1	1
Temperature, °C	42.5	43.6
Liquid Flow Rate, l/min	2.3	2.3
Feed volume, l	40	45
Max. obtained concentrate, °Brix	68	70

Fruit juice concentration processes were carried out in the pilot plan. The feed fruit juices were warmed up by a primary heat exchanger placed within a structure, which enhanced the vapour/liquid contact in the evaporation compartment. The liquid flow rate was kept at 2.3 l/min. Air was blown through the structure in the opposite direction of the fluid flow and joined the vapour from the evaporation compartment to condensation compartment through the connected space. The condensation of vapour was taken place on the surface of the indirect heat exchanger located within the condensation compartment. CO_2 as inert gas was introduced into the circulation reservoir in order to minimize the oxidation process to enhance the quality of fruit juice concentrates.

2.4 Physicochemical characterization

The juice samples were analyzed for pH, soluble solids, vitamin C and total acidity. Sugar content of juice was measured by Atago N-20 photon photoreceptor (Japan). Viscosity was determined by the Elcometer 2300 viscosity gauge, and the pH was determined by pH90 (WTW, Germany). Total acidity and vitamin C content were determined in turn according to the procedures described in the A.O.A.C (2006) and titration method (Majidi et al., 2016). Total polyphenolic content (TPC) was determined using the Folin–Ciocalteu reagent according to the method described by Georgé et al., (2005), was expressed as mg gallic acid (GAE) per 100 g of juice. Antioxidant activity was determined based on the L-ascorbic acid Equivalent Antioxidant Capacity (Deore et al., 2009).

2.5 Determination of volatile component profile

In terms of volatile component profile, single strength juices and obtained concentrates were analyzed using gas chromatography (GC) technique.
Isolation of volatile components of juice samples: The volatile components in juice samples were isolated by adsorption. The adsorption column was 60 cm in height, 3 cm in diameter and contained 20 grams of Porapak-Q. When the experiment was conducted, 100 ml of the juice was diluted with 400 ml of water and passed through the adsorption column (concentrate samples need to be diluted to the concentration of fresh fruit, before proceeding with water mixing at a ratio of 1: 4, v/v.). After adsorption was completed, it was desorbed by a mixture of 300 ml of n-pentane and diethyl ether (1/1, v/v), the organic phase was separated and dehydrated with Na_2SO_4. Finally, it was evaporated at 39.5°C under vacuum to about 2 ml and analyzed by Shimazu QP2010 (Japan).
Analysis condition: The static phase of the GC was a DB-5 ms capillary with a diameter of 0.25 mm, length 30 m, static film layer 0.25 μm. The dynamic phase included helium gas with a rate of 1.5 ml/min. In the beginning, the furnace temperature was kept at 70°C for 2 minutes, then the oven temperature was raised by 3°C /min up to 230°C and held for 10 minutes. The temperature of the ionized source of the MS was 200ºC.

2.6 Microbiologically analysis

The feed and concentrate juice samples were microbiologically analyzed. Microbiological analyses were undertaken during the storage to determine mould and yeast according to ISO 21527-2:2008 standard. E-coli and coliform analyses were done according to A.O.A.C Test method 991.14.

3. Results and discussion

3.1 Physicochemical analysis

Physio-chemical characteristics of the passion fruit juice and guava juice sample are shown in Table 2. Passion fruit juice was concentrated from 3.2 to 4.3 times depending on the initial strength of the juice (feed juice), corresponding to a TDS range of 50°Brix to 68°Brix in the final concentrate. The acidity remained constant while increasing the concentration coefficient, on the other hand, the pH of the concentrated passion fruit juice decreased by 50% in comparison with initial feed juice. Only a slight difference in pH of concentrated juices and the single strength juice was observed. The vitamin C content of passion juice concentrated samples is higher than the feed juice. Vitamin C retention in case of passion fruit concentrate 50°Brix and 68°Brix are 90.6% and 87.5%, respectively. Considering the difference in the retention of vitamin C in these two cases of 50°Brix and 68°Brix, a reduction of 13% was determined. This reduction is possibly caused by the enzyme treatment carried out at 45°C. The viscosity of fruit juice concentrates increased sharply, mainly due to the increase in the concentration of soluble substances in the juice. The retention of polyphenol and antioxidant capacity in concentrates in comparison with the fresh juice is relatively high. For the case of guava juice, a similar tendency can also be observed with the retention of Vitamin C, polyphenol and antioxidant capacity are 91.8%, 79.2% and 82.5%, correspondingly. Elhadad (2013) reported a vitamin C retention after vacuum concentration of 42.2% and 37.4% for the case of apricot and peach juices, accordingly. The concentration process was carried out in a rotary evaporator under vacuum (22 mmHg) at 45-50°C. The fruit juice concentrates obtained by JEVA based concentration process achieved clearly higher quality than that of produced by conventional thermal evaporation.

3.2 Microbiologically analysis

The result of the microbiological analysis of the juice samples is presented in Table 3. E. Coli and Coliform was not found in single strength juices as well as in the obtained juice concentrates. Regarding to the yeast and mould count, the development of these microorganisms may affect their appearance, aroma, and taste. The yeast and mould counts of concentrates were lower than 100 cfu/g and can, therefore, fulfil food safety standards. Moreover, it emphases, that highly concentrated fruit juice contributes to inhibiting the growth of yeast and mould.

Table 2: Physicochemical characteristics of passion fruit and guava juice before and after JEVA based concentration process.

	Passionfruit juice			Guava fruit	
Name	Feed juice	Passion fruit 50°Brix	Passion fruit 68°Brix	Feed juice	Guava juice 70°Brix
Samples code	F.Ps	Ps.50	Ps.68	F.Gv	Gv.72
Sugar content, °Brix	15	50 ± 2	68 ± 2	11	72
pH	4.06	2.12	2.08	5.56	3.38
Viscosity, cP	18	212	268	7	286
Acidity, g citric acid/100 ml	3.12	10.32	13.61	0.88	56.42
Vitamin C, mg ascorbic acid/100 g	36.36	117.98	140.5	220.45	1323.1
Vitamin C in reconstituted juice (15.2°Brix), mg ascorbic acid/100 g	-	32.95	31.98	-	202.27
Vitamin C retention after concentration, %	**100**	**90.63**	**87.50**	**100**	**91.75**
TPC, mg GAE/100 g	175.17	533.66	433.67	378.64	1962.85
TPC in reconstituted juice (15 °Brix), mg GAE/100 g	-	153.93	96.63	-	229.88
Polyphenol retention after concentration, %	**100**	**87.87**	**54.60**	**100**	**79.20**
Antioxidant capacity in reconstituted juice (15 °Brix), IC50	0.68	0.72	0.82	0.62	0.68
Antioxidant capacity in reconstituted juice (15 °Brix) (equivalent L-ascorbic acid), mg L-ascorbic acid/100g	223.48	207.62	173.48	245.20	202.27
Antioxidant capacity retention after concentration, %	**100**	**88.90**	**77.60**	**100**	**82.50**

Table 4: Microbiologically analysis of the single strength juices and concentrates

	Passion fruit juice		Guava juice	
	Feed	Concentrate 68°Brix	Feed	Concentrate 70°Brix
Mould and yeast, cfu/g	17	53	19	47
E. Coli, cfu/g	0	0	0	0
Coliform, cfu/g	0	0	0	0

3.3 Aroma analysis

The loss of volatile compounds is inevitable during every fruit juices processing process. This is very essential for product quality evaluation since it will decide how near the reconstituted juice is to the fresh juice. Narain et al., (2004) found, that Butanoic acid, hexyl ester; Hexanoic acid, hexyl ester, etc. make up the dominant scent of passion fruit. Steven et al., (1970) and Chyau et al., (1992) have pointed out, that 3-Hexen-1-ol, alpha-Copaene, etc. are key volatile components in guava fruit. All these components were also detected in the aroma analysis of this research.

Tables 4 and 5 show the declines in the peak area of the key volatile components of passion fruit juice and guava juice, respectively. It is obvious because the fruit juices underwent an enzyme treatment at a temperature of 45°C in a relatively long time. But most of the constituents, which are responsible for the characteristic aroma of passion fruit and guava fruit, were still found in the concentrated samples. The strong decline only occurs with light hydrocarbon components, because they are volatile even at ambient temperatures.

Table 4: Aroma compounds detected in the single strength passion fruit juice and passion fruit concentrates

Name	Retention time (min)	Relative peak area, %		Volatile component loss, %
		Feed passion fruit juice	Passion fruit concentrate 68°Brix	
Cis-3-Hexenyl acetate	10.25	19.68	17.26	37.85
Heptane	13.60	0.64	-	
Undecane	14.66	0.81	0.22	
Butanoic acid, hexyl ester	19.17	2.38	1.97	
Docosane	24.36	3.47	0.09	
Hexanoic acid, hexyl ester	28.16	4.02	1.08	

Table 5: Aroma compounds detected in the single strength guava juice and guava juice concentrates

Name	Retention time (min)	Relative peak area, %		Volatile component loss, %
		Feed guava juice	Guava juice concentrate 70°Brix	
3-Hexen-1-ol	4.88	35.42	32.41	13.12
Decane	9.49	0.96	0.03	
alpha-Copaene	27.77	8.52	7.69	
1-Undecanol	28.57	1.04	0.13	
gamma-Muurolene	32.19	3.21	3.14	
(+)- delta-Cadiene	37.42	3.28	2.15	

The losses in key volatile components due to JEVA based concentration process for passion fruit and guava juice were 37.85% and 13.12%, respectively. This evidenced, that the loss of key volatile components of fruit juices caused by JEVA based concentration process is much lower than that of conventional vacuum evaporation, which ranged generally between 71% and 100% (Cissé et al., 2011). The higher retention of volatile components in the fruit concentrates produced by this concentration technique can be explained by the high tolerance of the pilot plant to the turbidity of the feed juices, which was filtered by a 50 µm cloth filter. Therefore, the feed juices still contained much pulp, which helped to retain more aroma in the obtained juice concentrates.

4. Conclusions

The JEVA based concentration process is proved to be a promising method to produce passion fruit and guava juice concentrates at moderate temperature and ambient pressure. The concentrated products achieved up to 70 °Brix. Retention of vitamin C, polyphenol and antioxidant capacity in concentrate was in the range of 87.5% - 91.8%, 54.6% - 87.7% and 77.6% - 88.9%, respectively, is much higher than that of produced by conventional thermal evaporation. Especially, the volatile constituents, which are responsible for the characteristic aroma of fruits, have shown a minor loss and were still found in concentrated form in the juice products. Therefore, the obtained juice concentrates produced by the process could meet a high acceptance of consumers.

Acknowledgements

The authors are grateful to the Ministry of Science and Technology (MOST) of Vietnam and the Federal Ministry of Education, Science and Research (BMBWF) of Austria for the financial supports through cooperation projects 05/2014/HĐ-NĐT and WTZ VN04/2015.

References

A.O.A.C. 2006, Official methods of analysis (18th ed.). Gaithersburg, MD: Association of Official Analytical Chemists

Bhattacharjee C., Saxena V.K., Dutta V.K., 2017, Fruit juice processing using membrane technology: A review. Innovative Food Science and Emerging Technologies, 43, 136-153

Chopda C. A., Barrett D. M., 2001, Optimization of guava juice and powder, J. Food Process Preserv. 25, 411-430

Chyau C.C., Chen S.Y., Wu C.M., 1992, Differences of volatile and nonvolatile constituents between mature and rip guava (Psidium guajava L.) fruits, Lebensmittel-Wissenschaft and Technologie 22, 104-106

Cissé M., Vaillant F., Bouquet S., Pallet D., Lutin F., Reynes M., 2011, Athermal concentration by osmotic evaporation of roselle extract, apple and grape juices and impact on quality, Innovative Food Science and Emerging Technologies, 12(3),352–360

Deore S. L., Dr. S. S., Khadabadi, Baviskar B. A., Khadabadi S. S., 2009, In vitro Antioxidant activity and Phenolic Content of Croton caudatum, International Journal of ChemTech Research, 1(2),174-176

Elhadad A.S., Alwakdi O.M., Abusheta A., Abdulsalam F., Effect of Vacuum Concentration on the Properties of Apricot and Peach Juices, 3rd International Conference on Ecological, Environmental and Biological Sciences (ICEEBS'2013) January 26-27, 2013,Hong Kong (China)

Georgé S., Brat P., Alter P., Amiot M. J., 2005, Rapid determination of polyphenols and vitamin C in plant-derived products, Journal of Agricultural and Food Chemistry, 53 (5), 1370–1373

Mahattanatawee K. J. A., Manthey G., Luzio S. T., Talcott K., Goodner A., Jiménez-Escrig M., Rincón R., Pulido F., Saura-Calixto, 2001, Guava fruit (Psidium guajava L.) as a new source of antioxidant dietary fibre. J. Agric. Food Chem., 49, 5489-5493

Muhamed S., Jasum A., Maria G. L, Ferhan O., 2012, Tropical and Subtropical Fruits: Postharvest Physiology, Processing and Packing, Wiley-Blackwell, Canada, 321-332

Mohammed Idaan Hassan A.L., Majidi, Hazim Y., Qubury A.L., 2016, Determination of Vitamin C(ascorbic acid) Contents in various fruit and vegetable by UV-spectrophotometry and titration methods, Journal of Chemical and Pharmaceutical Sciences, 9, 2972-2974

Narain N., Almeda J.N., Galvao M.S., Madruga M.S., Brito E.S., 2012, Volatile compounds in passionate fruits (Passiflora edulis forma Flavicarpa) and yellow mombin fruits (Spondias mombin L) are obtained by aerodynamic techniques, Food Science and Technology (Campinas) Cience. Technol. Aliment. 24 (2), 212-216

Nguyen, M.T., Samhaber W.M., 2018, WO2018102835A, Retrieved from https://patentscope.wipo.int/search/en/detail.jsf?docId=WO2018102835, accessed 15.04.2018

Stevens K., Brekke J.E., Stern D.J., 1970, Volatile constituents in guava, Journal of Agricultural and Food Chemistry, 49, 598-599