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Effect of some variables of Ohmic pasteurization on quality Attributes of Passion (*Passiflora edulis*) Fruit Juice

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Passion fruit (*Passiflora edulis*) juice was highly preferred for consumption due to its excellent antioxidants, fibers, carbohydrates, minerals useful for health benefits. It's commonly passed various processing steps such as removal of the insoluble particles, skin, and seeds and pasteurization to eliminate microbial load and enzyme activity. Conventional heating caused serious deterioration for the fruit juice characteristics. Ohmic heating was a thermal treatment as an alternative to overcome disadvantages of conventional method by passing alternating electric current through sample in a short period of time. In this research, passion fruit juice were treated by ohmic heating in different temperatures (60, 65, 70, 75, 80 °C) at 60 Hz frequency using voltage gradients (30, 35, 40, 45, 50 V/cm). The final passion fruit juice was then sampled to evaluate polyphenoloxidase and peroxidase activities; ascorbic acid, total phenolic and carotenoid content. Results showed that polyphenoloxidase and peroxidase activities were significantly inactivated by ohmic heating. Ascorbic acid and carotenoid content were nearly stable at temperature below 65°C and voltage below 35 V/cm. Accelerating temperature as well as voltage, ascorbic acid, and carotenoid content would be decreased gradually. Meanwhile, total phenolic content increased from voltage 30 V/cm to 40 V/cm and decreased afterward. It's suggested that the best formula in ohmic heating should be 65°C and 35 V/cm to effectively inactivate enzyme activities while retaining the most valuable phytochemical and functional components.

Keywords: Ascorbic acid, carotenoid, ohmic heating, passion fruit juice, peroxidase, phenolic, polyphenoloxidase

INTRODUCTION

In fruit processing, the contact between degradative enzymes and phenolics caused enzymatic browning. The inactivation of polyphenoloxidase and peroxidase was a crucial prerequisite and indicator of fruit juice quality (Cinzia et al. 2019). Conventional thermal treatment had been successfully applied to inactivate enzymatic reaction. However it negatively affected to nutritional and textural qualities as well as sensitive phytochemical components. Ohmic heating included the way of alternating electrical current through liquid medium, therefore generating internal heat as the result of electrical resistance (Reznick, 1996; Hosain et al. 2013). The heat intensity was strongly correlated with the current induced by the voltage gradient in the field and the electrical conductivity of sample (Sastry and Li, 1996). The energy generation was proportional to the square of the electric field strength and the electrical conductivity of sample. (Goullieux et al. 2001). Implemented electric field under ohmic heating created different modifications in textural characteristics and nutritional values including inactivation of enzymes and microbial load, degradation of thermal sensitive elements, conversion in cell membranes, viscosity, pH, color, and rheology. Ohmic heating rate relied on the electrical field strength and electrical conductivity of sample (Kaur et al. 2016). Ohmic heating was successfully applied in different areas of preheating, blanching, sterilization, extraction, evaporation, dehydration. Retained colour and nutritional value, short processing duration, high recovery were major benefits in application of ohmic heating over conventional heating (Wang and Sastry, 2002; Castro et al. 2004; Leizerson and Shimoni, 2005; Vikram et al. 2005).Ohmic heating has high energetic efficiency, low investment costs, and simple maintenance (Kim et al. 1996; Qihua et al. 1993).

Passion fruit (*Passiflora edulis*) was an attractive valuable crop containing orange colour pulpy juice with black pitted seeds. A ripe fruit was refreshing, delicate flavour with pleasing aroma and high nutritive value (Minh et al. 2019). Its' a rich source of carbohydrates, proteins vitamins, minerals, dietary fibres and with excellent nutritional and therapeutic functions (Bhandari and Howes, 1999; Vera et al. 2003). Yellow passion fruit (*Passifloraedulis*) it is predominantly utilized in juice processing (Meletti, 2011). This fruit was also processed into different kinds of products like jam, squash, cake, pie and ice-cream (Rocky and Goutam, 2017). Passion fruit was highly perishable at ambient temperature (Paula et al. 2015). Objective of our study effect of the ohmic heating in different temperatures and voltage gradients to degradation of polyphenoloxidase and peroxidase activities; ascorbic acid, total phenolic and carotenoid content.

MATERIALS AND METHODS

Material

Passion fruits were collected from HauGiang province, Vietnam. They were washed in cold tap water, drained, and then manually cut into two pieces to get juice. Chemical reagents were all analytical grade.

Researching method

Ohmic heater consisted of a power supply, an isolating variable transformer, power analyzer and a microprocessor board. The samples were placed in the test cell. The ohmic heating was operated at five voltage gradients (30÷50 V/cm) at 60 Hz from 60÷80 °C. The treated samples were then evaluated polyphenoloxidase and peroxidase activities; ascorbic acid, total phenolic and carotenoid content.

Physicochemical analysis

Polyphenol oxidase activity (U/ml/min) was determined by the method of Trejo-Gonzalezl and Soto-Valdez (1991). Peroxidase activity (U/ml/min) was evaluated by a continuous spectrophotometric method described by Połata et al. (2009).Ascorbic acid (mg/100g) was determined by using a 2,6-dichlorophenol indophenol visual titration method. Total phenolic (mg GAE/100g) was measured by Folin–Ciocalteu method (Abdullakasim et al. 2007). Carotenoid content (µg/100g) was measured according to Lee and Castle (2001) and Abdullakasim et al. (2007).

Statistical analysis

The experiments were run in triplicate with different groups of samples. The data were presented as mean±standard deviation. Statistical analysis was performed by the Statgraphics Centurion version XVI.

RESULTS AND DISCUSSION

Polyphenoloxidase

Polyphenoloxidase was an oxidoreductase which catalysed the oxidation of phenolics in o-quinones, which were subsequently polymerized into discoloration (Jayaraman et al. 1982). The effect of temperature and voltage gradients during ohmic heating to polyphenoloxidase activity was presented in table 1. It's significantly inactivated by the increased holding temperature and voltage. Our findings were similar to others in different reports. Temperature was important to quantify electrical conductivities (Marcotte et al. 1998). Inhibition of polyphenoloxidase activity in the accelerating temperature could be explained by protein denaturation (Chutintrasri and Noomhorm, 2006). High temperature leaded to an increase in the internal energy of the enzymes, thus consequently broken three-dimensional structure of enzymes (Bhat et al. 2017).Castro et al. (2004) noticed that ohmic heating caused faster inactivation of polyphenoloxidase than conventional heating. Ohmic heating caused less browning in grape juice by efficient inactivation of polyphenoloxidase with increasing time and temperature at voltage 30 V/cm (Icier et al. 2008). The residual polyphenoloxidase activity was 35% after 14 min with ohmic heating at 70◦C by applying 35 V/cm in grape juice (Goncalves et al. 2010). Sobhy et al. (2013) studied the effectiveness of ohmic heating in the processing of mango pulp comparing to conventional method.

Table 1:The effect of temperature (ºC) and voltage (V/cm) gradients during ohmic heating to polyphenoloxidase activity (U/ml/min)

Temperature (ºC)	Voltage (V/cm)				
	30	35	40	45	50
60	22.73±0.08^{a}	17.90±0.12^{b}	12.06±0.08^{c}	5.31±0.11^{de}	1.95±0.04^{f}
65	18.12±0.11^{b}	12.68±0.07^{bc}	8.17±0.05^{d}	3.09±0.15^{e}	1.03±0.07^{a}
70	13.39±0.06^{bc}	8.34±0.09^{d}	5.92±0.13^{de}	1.62±0.10^{fg}	0.45±0.03^{gh}
75	7.85±0.13^{d}	5.40±0.06^{de}	3.15±0.10^{e}	0.74±0.12^{g}	0.19±0.08^{h}
80	3.16±0.10^{e}	2.29±0.15^{f}	1.64±0.17^{fg}	0.31±0.06^{gh}	0.05±0.01^{h}

Note: the values were expressed as the mean of twenty two samples; the same characters (denoted above), the difference between them was not significant (α = 5%).

Ohmic heating completely inhibited polyphenoloxidase activity due to the affective heating treatment. Polyphenoloxidase and peroxidase in orange juice were thoroughly eliminated by ohmic heating (Demirdoven and Baysal 2014). Polyphenoloxidase activity in watermelon juice was reduced to 8.87% in ohmic heating (Makroo et al. 2016). Saxena et al. (2017) showed the impact of ohmic heating on polyphenoloxidase activity in sugarcane juice. A high polyphenoloxidase inactivation was recorded by applying 32 V/cm at 90◦C for 5 min.

Peroxidase

The effect of temperature and voltage gradients during ohmic heating to peroxidase activity was presented in table 2. It's significantly inactivated by the increased holding temperature and voltage (table 2). Peroxidase was known to be one of the most heat stable enzymes in fruits and vegetables. Peroxidase was used as an important indicator for the adequacy of thermal treatments. It was a heme-containing enzyme catalyzing a large number of reactions in which a peroxide was reduced while an electron donor was oxidised. Peroxidase activity was accounted for off-flavours and off-colours. It located in plant tissues in the form of several isoenzymes varying in substrate specificity, thermal stability, molecular weight, isoelectric point and immunological characteristics. In the case of peroxidase, phenolics were oxidized at the expense of H_2O_2, leading to flavour changes (Hendrickx et al. 1998). The thermal stability of peroxidase varied considerably with the source and origin (Alina et al. 2010). Ohmic heating could affect biochemical reactions by modifying molecular spacing and increasing interchain reactions (Castro et al. 2004). Our findings were similar to others in different reports. Peroxidase in pea puree was inactivated in a shorter processing time, by ohmicheating, than by conventional heating (Icier et al. 2006). Cinzia et al. (2019) proved that ohmic heating achieved the inactivation by 90% for peroxidase and polyphenoloxidase when a temperature of 80 ◦C was applied for both carrot and apple mash.Kobsak and Veraya (2021) examined the Ohmic pasteurization to inhibit polyphenol oxidase and peroxidase in coconut water. Ohmic heating was effective to prevent pink discoloration in coconut water.

Ascorbic acid

Ascorbic acid was most sensitive to destruction when subjecting to adverse handling and improper storage condition. Damage increased by extended preservation, high temperature, low relative humidity, physical damage and chilling injury (Lee and Kader, 2000). In our research, ascorbic acidcontent wasnot significant different at temperature below 65ºC and voltage below 35 V/cm. Above these values, the ascorbic acid content was gradually decreased (table 3). Our results were similar to other findings. Lima et al. (1999) investigatedohmic heating to heat orange juice for 30 min at 90 C with an electric field of 18.2 V/cm, and ascorbic acid degradation was approximately 21%.Assiry et al. (2003) examined the ascorbic acid degradation in a buffer solution of pH 3.5 using a bath ohmic heater with uncoated stainless steel electrodes; after 10 min of heating at 80ºC, ascorbic acid degradation was approximately 13%. Castro et al. (2004) found that electric field did not affect the ascorbic acid degradation in straberry. Vikram et al. (2005) verified the kinetics of ascorbic acid degradation during ohmic heating of orange juice by applying an electric field strength of 42 V/cm; after 3 min of heating at 90ºC, ascorbic acid degradation was approximately 35%. Machado et al. (2010) demonstrated that ohmic heating was useful to inactivation of the microbial load and enzymes activity in a short period with a minordegradation of ascorbic acid compared to conventional heating. Ascorbic acid degradation in acerola pulp during thermal treatment by ohmic and conventional heating was evaluated. Ohmic heating performed with low voltage gradients promoted degradation of the ascorbic acid in a manner similar to conventional heating. However, high voltage gradients induced greater ascorbic acid degradation because of electrochemical reactions (Giovana et al. 2012) Demirdoven and Baysal (2014) found that the decrease in ascorbic acid for ohmic heating was lower than for conventional heating. Seyed et al. (2019) applied ohmic heating for pasteurization of cantaloupe juice. They confirmed that after 20 s and ohmic heating at 200 V, decreasing vitamin C content was significantly higher than microwave and conventional heating.

Carotenoid

Passion fruit has a great source of natural antioxidants including carotenoid. Carotenoid was sensitive to light, temperature and chemical exposure. Carotenoid content in passion fruit juice was also recorded during ohmic heating. It's not significant different at temperature below 65ºC and voltage below 35 V/cm. Above these values, the carotenoid content was gradually decreased (table 4). Our results were similar to findings by other reports (Lee and Coates, 2003; Gama and Sylos, 2007). Nawel et al. (2016) assessed the effect of ohmic heating on the carotenoid profile of two citrus fruit juices. Carotene species (lycopene and β-carotene) were stable regardless of the treatment. Debora et al. (2016) evaluated the non-thermal effects of electricity on ascorbic acid and carotenoid degradation in acerola pulp during ohmic heating. The presence of the oscillating electric field did not influence the mechanisms and rates of reactions associated with the degradation process.

Total phenolic content

Phenolic components were highly sensitive to high temperature. In our research, total phenolic content in passion fruit juice was carefully noticed during ohmic heating. It's not significant different at temperature below 65ºC. Increasing temperature above 65ºC, the total phenolic content decreased significantly. Total phenolic content increased from voltage 30 V/cm to 40 V/cm and decreased afterward. (table 5). Increasing of the total phenolic content could be responsible for the increased extractability of total phenolic components due to the modification in the tissue matrix induced by heating (Mcinerney et al. 2007), or a disruption of complexes between polyphenols and proteins (Girgin and El, 2015). During ohmic heating, the alternating current had a synergistic effect on the release of total phenolic contents (Roy et al. 2009).Bhat et al. (2017) applied ohmic heating treatment (1–5 min) to total phenolic content of bottle gourd juice. The total phenolic content increased at 80 ◦C for 4 min. Tarek et al. (2018) optimized ohmic heating parameters for pasteurization of apple juice as a potential mild thermal treatment. The reduction of polyphenoloxidase, ascorbic acid, total carotenoid were recorded. Meanwhile, total phenolic content and color value increased under ohmic heating. Bethania et al. (2019) evaluated peroxidase activity, phenolic compounds and color during ohmic heating of sugarcane juice. They confirmed that peroxidase was completely inactivated at 80°C. There was no variation of phenolics. The color of the juice was modified using low frequency.

Table 2:The effect of temperature (ºC) and voltage (V/cm) gradients during ohmic heating to peroxidase activity (U/ml/min)

Temperature (ºC)	Voltage (V/cm)				
	30	35	40	45	50
60	16.25±0.04^{a}	13.57±0.11^{ab}	8.63±0.05^{b}	4.32±0.14^{bc}	2.05±0.08^{c}
65	13.41±0.07^{ab}	8.53±0.19^{b}	4.41±0.07^{bc}	2.12±0.11^{c}	1.06±0.03^{cd}
70	8.69±0.11^{b}	4.37±0.04^{bc}	2.05±0.01^{c}	1.09±0.09^{cd}	0.62±0.05^{d}
75	4.52±0.06^{bc}	2.08±0.07^{c}	1.13±0.03^{cd}	0.59±0.02^{d}	0.20±0.01^{de}
80	2.11±0.13^{c}	1.06±0.03^{cd}	0.60±0.02^{d}	0.22±0.05^{de}	0.07±0.00^{e}

Note: the values were expressed as the mean of twenty two samples; the same characters (denoted above), the difference between them was not significant (α = 5%).

Table 3:The effect of temperature (°C) and voltage (V/cm) gradients during ohmic heating to ascorbic acid content (mg/100g)

Temperature (°C)	Voltage (V/cm)				
	30	35	40	45	50
60	28.64±0.02[a]	28.55±0.03[a]	26.41±0.00[ab]	24.15±0.01[bc]	22.23±0.01[c]
65	28.49±0.03[a]	28.47±0.01[a]	25.96±0.02[b]	22.11±0.03[c]	20.07±0.00[cd]
70	25.83±0.01[b]	23.96±0.00[bc]	22.02±0.03[c]	20.06±0.01[cd]	18.22±0.02[d]
75	24.08±0.00[bc]	22.13±0.02[c]	20.15±0.01[cd]	18.17±0.00[d]	16.49±0.03[de]
80	22.11±0.02[c]	20.29±0.01[cd]	18.41±0.00[d]	16.45±0.02[de]	15.08±0.01[e]

Note: the values were expressed as the mean of twenty two samples; the same characters (denoted above), the difference between them was not significant (α = 5%).

Table 4:The effect of temperature (°C) and voltage (V/cm) gradients during ohmic heating to carotenoid content (μg/100g)

Temperature (°C)	Voltage (V/cm)				
	30	35	40	45	50
60	67.86±0.01[a]	67.79±0.02[a]	62.19±0.00[ab]	57.33±0.02[b]	51.98±0.00[bc]
65	67.73±0.00[a]	67.70±0.03[a]	57.28±0.01[b]	51.65±0.03[bc]	46.19±0.02[c]
70	62.08±0.02[ab]	57.51±0.01[b]	51.35±0.00[bc]	46.30±0.02[c]	41.36±0.03[cd]
75	57.44±0.01[b]	51.86±0.00[bc]	46.23±0.03[c]	41.57±0.01[cd]	36.19±0.00[d]
80	51.15±0.03[bc]	46.24±0.02[c]	42.04±0.01[cd]	36.25±0.00[d]	35.82±0.02[d]

Note: the values were expressed as the mean of twenty two samples; the same characters (denoted above), the difference between them was not significant (α = 5%).

Table 5:The effect of temperature (°C) and voltage (V/cm) gradients during ohmic heating to total phenolic content (mg GAE/100g)

Temperature (°C)	Voltage (V/cm)				
	30	35	40	45	50
60	43.27±0.02[e]	54.29±0.01[cd]	74.93±0.03[a]	62.07±0.01[bc]	31.45±0.02[g]
65	43.19±0.01[e]	54.11±0.00[cd]	74.84±0.02[a]	61.98±0.00[bc]	31.34±0.01[g]
70	39.24±0.03[f]	49.31±0.02[d]	70.52±0.01[ab]	57.25±0.03[c]	27.22±0.00[gh]
75	35.17±0.00[fg]	45.26±0.03[de]	65.93±0.00[b]	53.01±0.02[cd]	23.09±0.03[h]
80	31.06±0.02[g]	41.34±0.01[ef]	42.04±0.03[f]	48.77±0.01[d]	22.93±0.00[h]

Note: the values were expressed as the mean of twenty two samples; the same characters (denoted above), the difference between them was not significant (α = 5%).

CONCLUSION

Passion fruit juice had high acidity with a characteristic and intense flavor, a good source of niacin, riboflavin, ascorbic acid and carotenoid. Ohmic heating was an innovative thermal technique for food processing where heat was internally generated in a product due to electrical resistance when electric current was passed through it. It offered quick and uniform heating, efficient inactivation of the undesired microorganism and enzymatic activities with minimum effect on the quality properties of fruit juices.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

Nguyen Phuoc Minh arranged the experiments and also wrote the manuscript.

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