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Changes in pH and colour of watermelon juice during ohmic heating

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Abstract

Watermelon is a highly perishable fruit with a niche for majority of microrganisms. It comprises of 91% water and hence it is very difficult to preserve watermelon based products by application of conventional means. Ohmic heating, also known as Joule heating is an electro-thermal technique of processing. In this study, the effect of ohmic heating on the electrical conductivity, pH and colour of the watermelon juice at various voltage gradients (10-23.33V/cm) was investigated. The change in the pH and colour of the watermelon juice during storage was studied. The bubbling of juice was observed above 60°C at all voltage gradients. As the voltage gradient increased the time required to reach the desired temperature decreased. The electrical conductivity was observed to increase with increase in temperature. Linear model gave the best fit to the electrical conductivity of watermelon juice. The change in pH and colour has increased with increase in voltage gradient, ohmic heating time and storage period. Ohmic heated watermelon juice showed better retention of physicochemical properties when compared to conventional heating.

Introduction

Watermelon is a nutritious fruit and widely consumed all over the world due to its potential attributes. It is a rich source of vitamin C, vitamin A and potassium. It is low in fat and cholesterol content. These juicy fruits are used to quench thirst in summers. The juice is believed to possess diuretic properties as it contains β-carotene pigments like lycopene, and potassium, in fair amounts (Ghosh *et al.*, 2004). Lycopene is a bright red phytochemical pigment that possesses antioxidant properties, and can reduce cardiovascular diseases, prostate cancer. Lycopene and vitamin C are well-known anti-oxidants which provide many health benefits to humans (Bramley, 2000). Due to its high water content and low acidic condition, watermelon is the niche for growth of many harmful microorganisms like *L. monocytogenes, E. coli,* and *Salmonella* (Sharma *et al.*, 2005) The US FDA (2001) has considered watermelon, a potentially dangerous food. Generally, fruits contain heat resistance enzymes like pectin methyl esterase, peroxidase and polyphenol oxidase. Enzyme activity and microorganisms can affect the quality of fruit juices. Therefore, thermal inactivation with the aid of conventional heating is mostly used (Ghosh *et al.*, 2004). The conventional process ensures food safety, but the high temperature leads to nutrient loss and organoleptic changes. In the recent times, electro thermal and non-thermal methods have gained the attention of industries for processing and preservation of food products.

Ohmic heating or Joule heating is a type of electrothermal process which involves heating of the food sample by passage of electric current. The food sample is heated by the dissipation of heat energy. The electrical resistance helps in generation of the heat. The amount of heat generated depends on the current induced by the voltage gradient, and the electrical conductivity. The presence of electrodes in contact with the food, frequency applied and the waveform; distinguishes ohmic heating from other electro heating methods (Oana *et al.*, 2013). This process involves a uniform distribution of heat. Research studies suggested that an ionic constituent, such as salt and acid present in food products, enables the conduction of electrical current. This process can heat materials rapidly, due to conversion of electrical energy to heat energy (Palaniappan *et al.*, 1991a; Marcos *et al.*, 2010). It provides uniform heating throughout the food sample at low frequency, which allows cells to build up charges. It is a low cost continuous process with heating obtained as in UHT processing. Ohmic heating depends on type of product, flow rate, temperature, viscosity, pH, heating rate and holding time. This technique can be used

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as a potential alternative for conventional heating. Many researches has been done on ohmic heating of liquid food products like juices and purees, which reveals that ohmic heating allows even heating of solid particles and liquid phase, in High temperature short time process (HTST) (Castro *et al*., 2004). The conventional process causes heterogeneous treatment and leads to quality loss. Unlike conventional process, in ohmic heating, heat is generated rapidly at high temperature, without causing fouling and damage to the heating surface. Mechanical damage is negligible as compared to conventional method.

Ohmic heating has applications in the field of blanching, dehydration, evaporation, fermentation, pasteurization, sterilization and extraction (Sarkis *et al*., 2013). It enhances the drying rate and extraction yields for certain food samples. It causes less soluble leaching in blanching as compared to conventional hot water blanching (Mizrahi, 1996). Ohmic heating can be used for aseptic processing of highly viscous fluids containing particulates. At high voltage gradient, this process can degrade peroxidase enzyme at a faster rate, as compared to water blanching (Icier *et al*., 2006). Ohmic heating is an environment friendly process as it does not involve any noise. Japan and United Kingdom is currently using ohmic heating for processing of whole fruits, syruped fruit salad and fruit juices (Sastry *et al*., 2000; Icier *et al*., 2005). The aim of this study was to obtain electrical conductivity data for watermelon juice during ohmic heating at different voltage gradients. The effects of temperature and voltage gradients on pH and colour of watermelon juice was also studied.

Materials and Methods

Sample preparation

The watermelon (PKM1 variety) was purchased from the local market. The fruit was washed, peeled, cut into small pieces; juice was prepared using laboratory blender and strained using muslin cloth.

Ohmic heating

Experiments were performed in a batch ohmic heating system in the laboratory. The frequency of the system was 50 Hz. The system consists of ohmic heating cell with titanium electrodes, rheostat, transformer, ammeter, voltmeter, teflon coated thermocouple to record the temperature. The ohmic heating chamber, made of polytetrafluroethane, has a capacity of 650 ml. The watermelon juice was poured between the electrodes in the ohmic heating cell, in order to ensure a uniform temperature profile, the temperature was monitored in the center of the ohmic cell and near the electrode (Darvishi *et al*., 2011).

The watermelon juice was treated at different voltage gradients of 10, 13.33, 16.66, 20 and 23.33V/cm at 50Hz frequency, until the temperature rose up to 95°C. The juice was held at 95°C for 1min, 3min and 5mins at particular voltage gradient. The ohmic heated juice was then stored in sterilized bottles for further analysis.

The electrical conductivity was calculated from the voltage and current data by using the following formula

$$\sigma = \frac{L}{AR} \quad \text{-----------(1)}$$

Where,

σ- Electrical conductivity(S/m); L- Distance between the electrodes (m); R-Resistance (Ω).

The ohmic heating curves were plotted by using the time-temperature data. Electrical conductivity was plotted against the corresponding time and temperature to obtain the electrical conductivity curve.

Conventional heating

Conventional heat treatment was performed using sterilized steel pan, heated on the direct flame. The temperature was continuously monitored using a thermocouple, which was inserted in the center of the pan. Watermelon juice was held 95°C, for 1 min, 3mins and 5 min during conventional heating. The treated juice was stored in sterilized bottles for further analysis.

Measurement of physicochemical properties

pH of the fresh juice and the treated juice was measured using a digital pH meter. The physical parameters were monitored at a three days interval, while it was stored at 4°C. Colour of the juice samples were measured using the Hunter Colourimeter (Colour Quest –XE Di8). Total colour difference was calculated using the equation

$$TCD = \sqrt{(L_o - L)^2 + (a_o - a)^2 + (b_o - b)^2} \quad \text{------(2)}$$

Where, TCD represents the total color change; L_o, a_o and b_o refers to reference values, i.e., colour parameters of fresh juice, and *L, a* and *b* refer to colour values at various times during heating process.

Statistical analysis

Linear regression coefficient and one way ANOVA was performed using the SPSS 20.0 statistical package (Icier *et al*., 2005)

Results and Discussion

The water melon juice was heated using batch type ohmic heating apparatus at 50 Hz frequency, at different voltage gradients. The bubble was observed above 60ºC at all voltage gradients tested. The different physico-chemical properties of fresh watermelon juice were analyzed and its is been found that the watermelon juice without any treatment has a pH of 5.2±0.048, acidity of 1.85%±0.009, ascorbic acid content of 13.83±0.00041 mg/100 ml and TSS of 7.8±0.047 ºbrix. The colour of the juice was found to have a L value of 33.12, a value of 15.46, and b value of 7.09.

Effect of temperature and voltage gradient

Figure 1 shows a plot between the processing time and temperature during ohmic heating of watermelon juice. The rate of heating was higher at higher voltages. The bubbles were observed at 60ºC, when the watermelon juice was heated at higher voltage gradient, as the rise in temperature was rapid. The heating time decreased with the increase in voltage. The current passing through the sample increased with the increase in voltage and temperature. As the amount of current increased during ohmic heating, the electrical conductivity also increased. The electrical energy which gets converted to the heat energy, depends on both voltage gradient as well as the current passing through the sample; hence the rise in temperature at a particular time is higher for high voltage gradients (Darvishi *et al.*, 2012). Due to high rate of energy generation at higher voltage gradients, the treatment time decreased. The time required to heat the water melon juice samples from 30°C to 95°C was observed to be 180 s,150 s,130 s,100 s and 90s for 10, 13.33, 16.66, 20 and 23.33 V/cm voltage gradients, respectively. Ohmic heating of lemon juice at 30-55 V/cm, for 45 s reached a temperature of 74ºC (Darvishi *et al.*, 2011). The ohmic heating of tomato juice at 50 to 70V/cm, took 48s to reach a temperature of 80ºC (Srivastav *et al.*, 2014). The ohmic heating of pomegranate juice and tomato paste was performed which suggested that the heating rate decreased with increase in voltage gradient (Darvishi *et al.*, 2013). Ohmic heating of tomato paste, at 6V/cm, showed that the time taken to reach 96ºC was 235s; whereas at 14V/cm the time taken to reach the same temperature was 38 s (Darvishi *et al.*, 2012). The grape juice was ohmic heated upto 90ºC at 20 to 40V/cm, for 120 s to deactivate polyphenolase enzyme (Icier *et al.*, 2008).

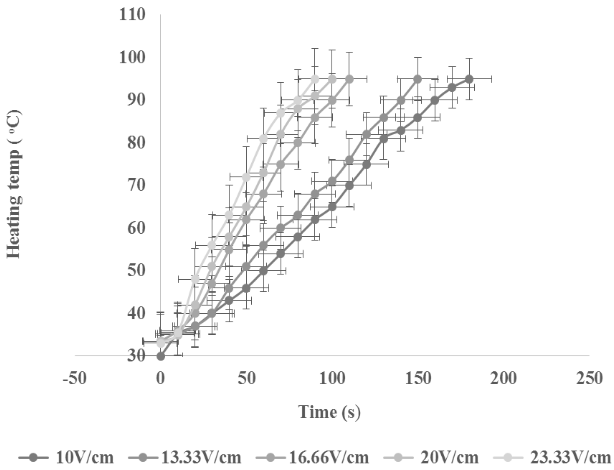

Figure 1. Time–temperature profile of watermelon juice ohmic heated at various voltage gradients

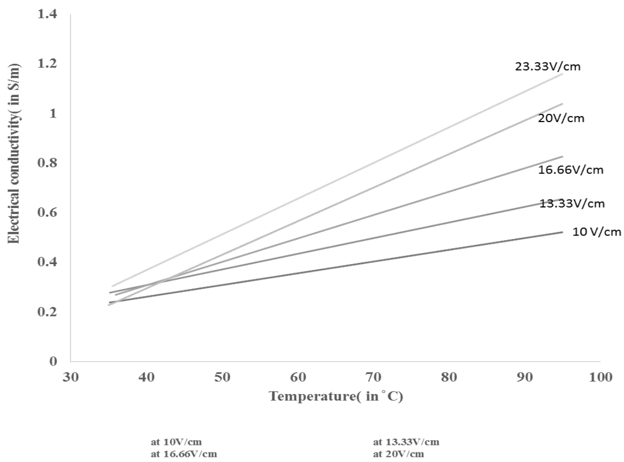

Figure 2. Electrical conductivity of watermelon juice with temperature at various voltage gradients

Electrical conductivity

The electrical conductivity was plotted against the corresponding temperature values as shown in the Figure 2. The electrical conductivity increases with increase in temperature. The electrical conductivity gradually decreased with increase in temperature after bubbling starts. Excessive bubbling was observed at higher temperature and at high voltage gradients. The red colored pigment or the lycopene settled at the bottom, and a separate water layer was observed at the top at high voltage gradients. The bubbles formed at high temperature, could be due to boiling of water due to high current density, or they can be by products of some oxidation or reduction reactions. The electrical conductivity increases with increase in temperature due to the increase in ionic mobility, which occurs due to the breakdown or structural changes in biological tissue (Darvishi *et al.*, 2012).

Many studies have shown that the electrical conductivity increases with increase in temperature

Table 1. The constants and regression coefficient of linear model of watermelon juice during ohmic heating

Voltage gradient(V/cm)	R^2	B	C
10	0.827	0.005	0.074
13.33	0.924	0.006	0.056
16.66	0.963	0.009	-0.072
20	0.893	0.014	-0.246
23.33	0.915	0.014	-0.205

for different fruit juice samples (Icier *et al*., 2008; Darvishi *et al*., 2011). In this study, the electrical conductivity increased from 0.23 to 1.23 S/m with increasing temperature and voltage gradient. The increase of electrical conductivity with temperature can be explained by reduced drag movement of ions. The value of electrical conductivity obtained is similar to that of peach puree as reported by Icier and Ilicali (2005). The electrical conductivity also showed a linear increase with time. The ohmic heating rate depends upon the electrical conductivity. At 23.33 V/cm, the watermelon juice was heated from 30°C-50°C in 20 s whereas the time increased upto 42 s for 10V/cm. The highest electrical conductivity was observed at 23.33 V/cm, followed by 20 V/cm, 16.66 V/cm and 13.33 V/cm. The electrical conductivity depends on concentration (brix) and temperature, for lemon juice (Darvishi *et al*., 2011). The voltage gradient was statistically significant on the ohmic heating rate ($P<0.05$).The experimental electrical conductivity increases linearly with temperature. The experimental electrical conductivity results for the water melon juice samples given in Figure 2 shows a linear trend with increase in temperature, a linear equation given in Eq. (1) is used to fit the experimental data. The constants and the linear regression coefficients are given in Table 1.

$$\sigma = BT + C$$

Where B and C are constant; and T is temperature (ºC).

Physicochemical characteristics

The pH and colour, of the fresh juice as well as the treated juice was determined. The treated juice sample was stored under refrigerated conditions for 21 days and the physicochemical characteristics were continuously observed at an interval of 3 days. The results shown in the table are the means of triplicate trials as performed. The voltage gradient and treatment time was statistically significant with change in pH and total colour difference ($P< 0.05$).

Changes in pH of ohmic heated watermelon juice during storage:

The initial pH of fresh water melon juice was found to be 5.2, whereas the pH after ohmic heating for 1 min, 3 min and 5 min was observed as 5.36, 5.23 and 5.18, respectively. The pH decreased with the increase in voltage gradient during storage. The pH of the watermelon juice, ohmic heated at 10V/cm, for 1min showed an increase of 3.8%, on the third day of storage. The juice ohmic heated for 1min at 20 V/cm and 23.33 V/cm showed 1.92% increase in pH on the third day of storage. Similar trend for pH was obtained by Darvishi *et al.* (2013) for ohmic heating of pomegranate juice. This change in pH can be due to the hydrolysis of juice that occurs during ohmic heating. During ohmic heating, corrosion of electrodes occurs due to change in voltage gradients and continuous heating; which might also account for the change in pH. Water melon contains about 91% water, which has an important role in change of pH. The pH of the juice ohmic heated at 23.33 V/cm, for 1min, showed an 18.46% decrease on the 21st day of storage. 10.43% and 6.95% decrease in pH was observed on the 21st day of storage; for the juices ohmic heated at 23.33V/cm for 3 min and 5 min, respectively as compared to the third day of storage. The pH of the watermelon juice, conventionally heated for 5 min was observed as 4.5 on the 9th day of storage. For ohmic heated juice, treated for 5mins, the pH was observed as 4.8, 5, 4.6, 4.6 and 4.6 at 10, 13.33, 16.66, 20, 23.33 V/cm, respectively. The value of the pH, for the ohmic heated juice at 23.33V/cm, further decreased to 4.28 on the 21 st day of storage. The pH of the conventionally heated juice was observed until 9th day of storage, as the sample spoiled when evaluated on 12th day. The stability of the pH depends on the treatment time and storage conditions. The pH values of the ohmic heated juice at different voltage gradients and treatment time are shown in Table 2.

Change in colour of watermelon juice during ohmic heating and storage

The voltage gradient has a significant effect on colour. A significant change in colour was observed during storage. The *L**, *a** and *b** values depicts the lightness, *a** represents the extent of redness or greenness; and *b** represents the extent of blueness or yellowness. The L value was observed to decrease with increase in voltage gradient, time and during storage. The L-value for the fresh watermelon juice was observed to be 33.12. The L-value for ohmic heated juice at 23.33 V/cm was observed as 33.06, 33.03 and 33.01 at 1 min, 3 min and 5 min, respectively, on the

Table 2. Change in pH of the processed watermelon juice at various voltage gradients during storage

Storage days	Voltage gradient (V/cm)														
	Ohmic heating														
	10			13.33			16.66			20			23.33		
	Time, min														
	1	3	5	1	3	5	1	3	5	1	3	5	1	3	5
3	5.4±0.007	5.1±0.007	5±0.03	5.3±0.02	5±0.05	5±0.05	5.3±0.015	5±0.04	4.8±0.1	5.3±0.02	4.81±0.04	4.8±0.02	5.3±0.01	4.6±0.03	4.6±0.02
6	5.1±0.01	5±0.05	5±0.064	5.1±0.005	4.9±0.015	5±0.015	4.9±0.005	5±0.01	4.8±0.2	4.8±0.02	4.8±0.02	4.6±0.05	4.8±0.02	4.6±0.02	4.6±0.01
9	5.2±0.028	4.8±0.03	4.8±0.03	4.9±0.35	4.9±0.014	5±0.014	4.89±0.01	4.8±0.02	4.6±0.05	4.6±0.02	4.7±0.03	4.6±0.08	4.6±0.056	4.48±0.02	4.6±0.03
12	5.1±0.01	4.78±0.025	4.7±0.007	4.8±0.09	4.8±0.085	4.8±0.085	4.86±0.02	4.75±0.03	4.42±0.03	4.6±0.05	4.6±0.04	4.46±0.02	4.45±0.03	4.42±0.02	4.5±0.04
15	5±0.02	4.76±0.01	4.7±0.01	4.9±0.02	4.6±0.085	4.7±0.085	4.79±0.02	4.6±0.05	4.36±0.02	4.5±0.01	4.6±0.05	4.31±0.03	4.36±0.02	4.36±0.01	4.45±0.02
18	5±0.005	4.7±0.02	4.65±0.01	4.8±0.03	4.6±0.06	4.6±0.06	4.7±0.042	4.6±0.02	4.3±0.01	4.45±0.014	4.5±0.03	4.3±0.01	4.28±0.02	4.24±0.04	4.36±0.03
21	5.1±0.01	4.7±0.02	4.63±0.014	4.7±0.014	4.54±0.01	4.54±0.01	4.6±0.02	4.53±0.01	4.3±0.01	4.3±0.02	4.5±0.02	4.26±0.02	4.24±0.01	4.12±0.03	4.28±0.03
	Conventional heating														
Storage days	**3**			**6**			**9**			**12**			**15**		
	1	3	5	1	3	5	1	3	5	1	3	5	1	3	5
	5.1±0.01	5.0±0.02	4.8±0.01	5.0±0.02	4.7±0.012	4.7±0.01	4.8±0.02	4.7±0.02	4.6±0.01	4.7±0.012	4.6±0.02	4.5±0.01	4.68±0.012	4.56±0.02	4.49±0.02

Table 3. Total colour difference of processed watermelon juice at various voltage gradients, time and during storage

Storage days	Voltage gradient (V/cm)														
	Ohmic heating														
	10			13.33			16.66			20			23.33		
	Time, min														
	1	3	5	1	3	5	1	3	5	1	3	5	1	3	5
3	0.12±0.01	0.06±0.024	0.17±0.02	0.22±0.03	0.07±0.01	0.17±0.01	0.18±0.0012	0.11±0.01	0.29±0.04	0.18±0.01	0.10±0.003	0.19±0.002	0.27±0.012	0.18±0.01	0.26±0.02
6	0.16±0.01	0.08±0.01	0.18±0.01	0.25±0.014	0.17±0.021	0.24±0.03	0.19±0.01	0.11±0.005	0.38±0.012	0.37±0.03	0.18±0.01	0.26±0.03	0.38±0.02	0.28±0.02	0.74±0.013
9	0.18±0.15	0.09±0.03	0.36±0.02	0.26±0.03	0.18±0.014	0.26±0.02	0.24±0.012	0.13±0.014	0.42±0.01	0.35±0.014	0.28±0.014	0.23±0.01	0.48±0.01	0.28±0.014	0.88±0.01
12	0.27±0.03	0.12±0.01	0.39±0.03	0.26±0.15	0.27±0.03	0.67±0.014	0.28±0.03	0.18±0.012	0.44±0.03	0.39±0.02	0.28±0.012	0.39±0.013	0.84±0.012	0.29±0.02	1.4±0.02
15	0.36±0.01	0.21±0.01	0.54±0.02	0.26±0.02	0.24±0.01	0.94±0.013	0.71±0.03	0.24±0.002	0.62±0.02	0.83±0.01	0.28±0.02	0.76±0.02	0.71±0.02	0.63±0.01	2.45±0.03
18	0.37±0.03	0.16±0.02	0.6±0.01	0.36±0.01	0.24±0.02	1.24±0.02	0.81±0.012	0.26±0.012	1.03±0.01	0.84±0.01	0.37±0.01	1.41±0.01	0.84±0.03	0.73±0.01	2.51±0.02
21	0.38±0.01	0.16±0.012	0.74±0.01	0.66±0.014	0.26±0.01	1.20±0.012	0.81±0.02	0.26±0.003	1.21±0.01	1.2±0.01	0.47±0.02	1.94±0.03	1.61±0.02	0.82±0.012	2.69±0.02
	Conventional heating														
days	3			6			9			12			15		
	1	3	5	1	3	5	1	3	5	1	3	5	1	3	5
3	33.13±0.02	33.15±0.03	32.12±0.013	33.01±0.03	32.89±0.012	32.89±0.02	32.56±0.03	32.09±0.03	32.78±0.015	32.89±0.0013	32.56±0.03	32.78±0.015	32.89±0.0013	32.67±0.01	31.57±0.012

3rdday of storage. The juice ohmic heated at 10 V/cm for 1 min, 3 min and 5 min showed the L- value as 33.11, 33.08 and 33.09, respectively. The decrease in colour can be associated with browning of the juice (Darvishi *et al.*, 2013). The storage conditions play an important role in occurrence of browning. Browning can also occur due to presence of oxygen and metal ions. Oxidative enzymes like POD can cause or influence on the discolouration of fruit juices (Icier *et al*., 2008). Degradation of ascorbic acid, releases active carbonyl groups which can act as precursors for enzymatic browning (Leizerson *et al*., 2005). During heating, the water content got separated as a layer and the red pigment settled at the bottom. The conventionally heated juice showed a light yellow tint on the upper layer. The total colour difference of the watermelon juice ohmic heated at various voltage gradients, time and storage is given in Table 3. The total colour difference increased with the increase in voltage gradient and storage time. The juice that was conventionally treated for 5 min showed L-value of 31.57 on the 9th day of storage. The L-value for the ohmic heated juice for 5 min, at voltage gradients 10, 13.33, 16.66, 20, 23.33 V/cm was observed to be 32.98, 32.89, 32.87, 32.86, and 32.86, respectively on the 9th day. The conventionally heated juice could not be analyzed on the 12thday due to discolouration and spoilage.

Conclusion

Watermelon is highly perishable and its products are difficult to preserve. The watermelon juice was heated on a static ohmic heater of 650 ml capacity by applying voltage gradients in the range from 10-23.33 V/cm. The heating time have decreased with increase in voltage gradient. The electrical conductivity has increased with increase in temperature and followed a linear trend. Ohmic heating retains the physicochemical properties of the juice for a longer time than observed in conventional heating. This study concludes that ohmic heating can be applied for the preservation of watermelon juice.

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