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Effect of Voltage Gradient and Temperature on Electrical Conductivity of Grape (*Vitis vinifera* L.) Juice during Ohmic Heating

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A B S T R A C T

Ohmic heating is an alternative fast heating technique of foods. It is important to determine electrical conductivity in order to decide on the applicability of ohmic heating technology for specific food products. In this study, grape juice was heated at different voltage gradients 10, 20, 30 and 40 V cm^{-1} holding at different temperature 55, 65 75 and 85 ^{o}C using a laboratory scale static ohmic heating system. The effect of voltage gradient and temperature on electrical conductivity of grape juice was investigated. Electrical conductivity of grape juice samples was 0.25-0.81 S m^{-1} at 10-40 V cm^{-1} and 30-85 °C. The voltage gradient and temperature were statistically significant on the electrical conductivity for grape juice ($p<0.05$). As the voltage gradient was increased, electrical conductivity increased. The electrical conductivity of the sample linearly increased with temperature rise. The maximum EC of grape juice was found to be 0.81 S m^{-1} at 30 V cm^{-1} at 85 °C. Bubbling was observed at higher voltage gradients (40 V cm^{-1}) at higher temperature, especially above 75 ^{o}C.

Introduction

Grape (*Vitis vinifera* L.) is an important fruit of subtropical regions. It is known for its excellent flavour, colour, delicious taste and nutritional value. Grapes are very good source of copper, vitamin $B_{1,}$ B_2 and K (Rolle, 2011). Grape is one of the important commercial fruit crop in India. India holds 9th rank in grapes production in the world. India's overall production of grapes was 3.20 million tonnes in 2014-15 (NCAER, 2016). About 8% of total production of grapes worth of about Rs. 1,666 crores is exported every year (NRCG, 2015). The fruit is highly perishable in nature, and cannot be stored as such for longer periods under ambient conditions. In India per capita postharvest losses of grapes account for about 8.63% of production (Jha *et al.*, 2015), which calls for proper preservation and processing facilities in areas where surplus quantities are grown.

Therefore, development of suitable process technology is important through which value-added products could be prepared from Grapes. Grapes can be transformed into value-added products such as raisin, wine, juice, squash, syrup, jam, jelly, vinegar, pickles, chocolates, tartaric acid, oil, tannin etc. (Oulkar, 2009).

Fruit juices in general are characterized by high acidity conditions, which lead to the growth of yeast and mold, in addition to a few types of low-acid-tolerant bacteria. To avoid microbial spoilage, it is necessary to cause inactivation by applying heat by high temperature heating with very short exposition. Conventional heating processes are based on conduction and convection mechanism, results in very heterogeneous treatment and notable loss of product quality. The major drawbacks of conventional heating are the low energy efficiency and long processing times. To overcome these problems, ohmic heating technology utilizing electrical energy directly in food processing has attracted interests in the food industry in recent decades. Ohmic heating takes its name from Ohm's law; the food material switched between electrodes has a role of resistance in the circuit. Most foods contain a moderate percentage of free water with dissolved ionic salts and therefore conduct sufficiently well for the ohmic effect to be applied (Parrott, 1992).

On the passage of an alternating current through a sample, it responds by generating heat internally due to its inherent resistance (Fryer *et al.,* 1993). This technology provides a rapid and uniform heating and thermal abuse to the product in comparison with conventional heating (Leizerson and Shimoni, 2005). The energy generation is proportional to the square of the local electric field strength (Goullieux and Pain, 2005). It has high energy efficiency because 90% of electrical energy is converted into heat (De Halleux *et al.,* 2005). Ohmic heating was found to be more efficient for the required microbial and enzymatic inactivation due to a shorter residence time while released flavor compounds were not degraded as quickly as during conventional pasteurization (Leizerson and Shimoni, 2005). Its advantages compared to conventional heating also include the more uniform and faster heating, higher yield and higher retention of nutritional value of food (Vikram *et al.,* 2005). It does not create any noise and is environment friendly (Palaniappan and Sastry, 1991).

The main critical factor in ohmic heating is the electrical conductivity. Electrical conductivity is the measure of how well a substance transmits electrical charge. In ohmic heating terminology, the electrical conductivity is a measure of the mineral or ionic content. It depends on temperature, applied voltage gradient, frequency, and concentration of electrolytes (Icier and Ilicali, 2005b). Therefore, it is very important to determine the electrical conductivity of the food product in the ohmic heating process because it measures the suitability of the product for ohmic heating. Icier and Ilicali (2005a) reported that the electrical conductivity increased linearly with increasing temperatures for orange juices at voltage gradients ranging from 20 to 60 V cm^{-1}. Palanippan and Sastry (1991) reported that the electrical conductivity of the orange, carrot and tomato juices increased with temperature and decreased with solids content. Similarly, Icier *et al.,* (2008) found that the electrical conductivity increased as the temperature increased ranging from 0.4 to 0.75 S m^{-1} for fresh grape juice. Amiali *et al.,* (2006) reported that the electrical conductivity (0.13 to 0.63 S m^{-1}) increased linearly with increasing temperatures for fruit juices (namely apple, orange, and pineapple juices). The ohmic heating of fruit juice was studied at different voltage gradients (7.5 to 26.25 V cm^{-1}) by Kong *et al.,* (2008). Results indicated that the voltage gradient and temperature significantly influenced the ohmic heating rates. The objective of the present work was to obtain electrical conductivity data for grape juice during ohmic heating and to study the effect of temperature and voltage gradients on electrical conductivity of grape juice.

Materials and Methods

Sample preparation

Grapes (*Vitis vinifera* L.) were purchased from a local market in Bapatla, Andhra Pradesh (India) and stored at refrigeration conditions (4 ^{o}C) prior to experiments. Berries were manually removed from bunches, washed in cold tap water and drained. The juice was extracted from grapes berries using Sujata Powermatic juicer (Mittal Electronics, Delhi) and filtered with four-fold of new and clean muslin cloth.

Ohmic heating system and procedures

Experiments were carried out on a lab scale ohmic heating system as shown in Figure 1 with technical specifications as shown in Table 1. The main components of ohmic heating system are - heating chamber, electrodes, power supply and data acquisition system. The heating chamber was made by cylindrical Borosil glass tube of internal diameter 4.5 cm and length 15 cm. One vertical tubular passage of 1 cm internal diameter and 3 cm length was made at the geometric center of heating chamber for removal of water vapour and to hold thermometer. Food grade stainless steel (SS 304) electrodes were secured at both ends of the chamber by anti-leakage rubber plugs. The diameter and thickness of electrodes were 4.4 cm and 0.2 cm, respectively. A hole of 0.3 cm was drilled at the center to fasten the electrodes with rubber plugs using screw and nuts. The distance between both electrodes was kept 10 cm resulting in a total chamber volume of 159 mL. The desired voltage gradient between the electrodes was obtained using a variable auto transformer (Sun Electrical Industries, Thane) of capacity (input-220 V, output-400 V) by supplying the power from domestic alternating current (AC) mains (220 V, 50 Hz). Temperature was continuously measured with the mercury thermometer. Current and voltage were measured with analog ammeter (Meco Instruments, India) ranging 0-15 amp and analog voltmeter (KEC, India) ranging 0-500 V, respectively.

The 150 mL of filtered grape juice sample was placed in the heating chamber, the thermometer was inserted. The electric current was supplied from domestic AC mains. Voltage gradient between electrodes for particular treatment was maintained with variable auto transformer by moving knob. The juice was heated at different combinations of 10 V cm^{-1}, 20 V cm^{-1}, 30 V cm^{-1} and 40 V cm^{-1} by holding at 55 ^{o}C, 65 ^{o}C, 75 ^{o}C and 85 ^{o}C. Temperature, current and voltage applied were monitored.

Electrical conductivity of grape juice

Electrical conductivity of the grape juice samples was calculated using the following equation (Icier *et al.*, 2008)

$$\sigma = \frac{LI}{AV} \quad (1)$$

Where,

σ=Electrical conductivity of the sample (S m^{-1})

L = Space between electrodes or the length of the ohmic chamber (m)

A = Heating surface area of the electrodes (m^{2})

I = Electrical current passing through the sample (amp)

V = Voltage applied between electrodes (V)

Accuracy

The accuracy of ohmic system was compared and calibrated with the standard conductivity. The calibration results for the accuracy of electrical conductivity of 0.1 M NaCl solution revealed that there was no significant difference between standard electrical conductivity of 0.1 M NaCl solution and the experiment data. The electrodes were thoroughly rinsed using a brush and dematerialized with twice-distilled water after each run.

Statistical analysis

The effect of voltage gradient and heating temperature on electrical conductivity were statistically analyzed for analysis of variance (ANOVA) by using Statistical Package for Social Sciences (SPSS) version SPSS 16.0 at the 5 per cent level of significance i.e. $p<0.05$ (SPSS, 2008). The results were reported as an average of three replicates.

Results and Discussion

Results of the analysis of covariance are shown in Table 2. The results indicated that the voltage gradient and temperature had significant effect on the electrical conductivity value of grape juice ($p<0.05$).

Effect of voltage gradient on electrical conductivity of grape juice

Electrical conductivity of grape juice samples observed were 0.25-0.81 S m^{-1} at 10-40 V cm^{-1} and 30-85 °C. Icier *et al.*, (2008) reported conductivity of grape juice, 0.38-0.78 S m^{-1} at voltage gradient 20-40 V cm^{-1} and temperature 20-80 °C. The observed difference between the data presented here and earlier data could be attributed to the natural variation occurring in biological tissues and difference in voltage gradient and heating temperature range. The value of electrical conductivity of grape juice in this study is comparable with the reported values; 0.1-1.6 S m^{-1} for apple and sour cherry juices at 20-60 V cm^{-1} and 30-75 °C (Icier and Ilicali., 2004) and 0.4-1.0 S m^{-1} for lemon juice at 30-55 V cm^{-1} and 20-74 °C (Darvishi *et al.*, 2011).

The lowest electrical conductivity observed was 0.25 S m^{-1} at 10 V cm^{-1} and the highest was 0.81 S m^{-1} at 30 V cm^{-1}. Figure 2 shows changes in electrical conductivity as voltage gradient increased. Electrical conductivity initially increased with voltage gradient from 10-30 V cm^{-1} and then decreased at 40 V cm^{-1}. Electrical conductivity at 40 V cm^{-1} was found to be 0.78 S m^{-1}. At this voltage gradient formation of bubbles was observed, especially when the temperature of samples reached above 75 °C. It was observed that as the voltage gradients increased, the current passing through the system reached higher values and this caused violent evaporation of water in the samples and increase in electrical conductivity become slower due to bubble formation. Similar opinion was put forth by Icier and Ilicali (2004) for apple and sourcherry juice. It was felt that the bubbling could be the release of gas in the liquid due to some electro-chemical reactions. Darvishi *et al.*, (2013) concluded similar reason for bubbling at 55 V cm^{-1} and 81 °C in pomegranate juice.

Effect of temperature on the electrical conductivity of grape juice

The highest value of the electrical conductivity of grape juice was observed to be 0.81 S m^{-1} at 85 °C temperature. As shown in Figure 2, the electrical conductivity of the grape juice increased with temperature at all voltage gradients studied. It was felt that this may be due to reduced drag for the movement of ions.

Fig.1 Developed ohmic heating system

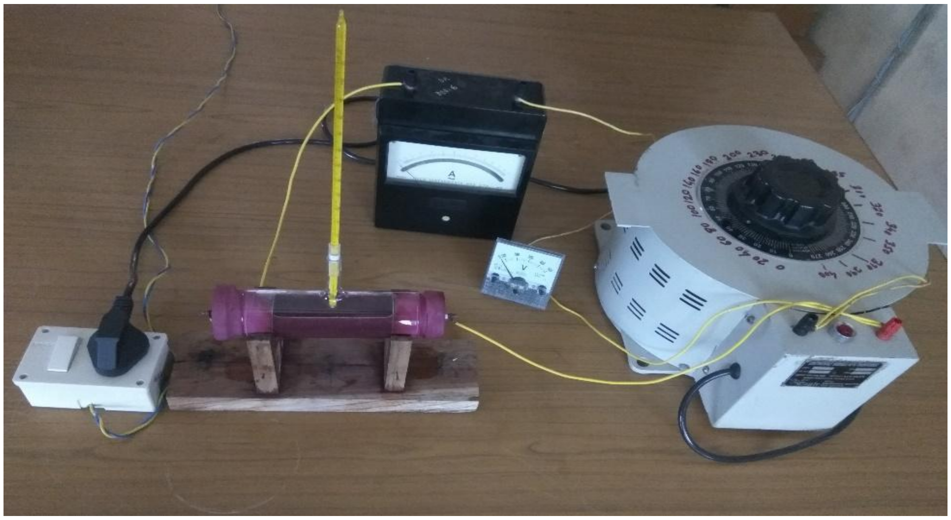
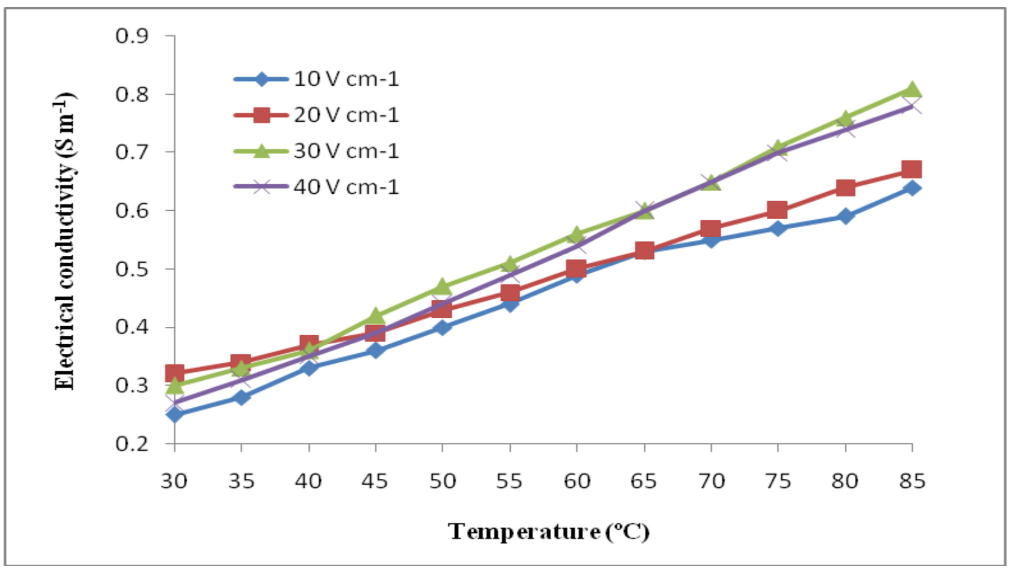


Fig.2 Changes in electrical conductivity of grape juice with temperature at different voltage gradients



List of Abbreviation

ANOVA	Analysis of variance
et al.,	And others people
NCAER	National Council of Applied Economic Research
NRCG	National Research Centre for Grapes
Rs.	Rupees
SPSS	Statistical Package for Social Sciences
SS	Stainless steel

Table.1 Technical specifications of the ohmic heating system

Component	Specification	
Ohmic heating chamber	Material	Borosil glass
	Diameter×length, cm	4.5×15
	Capacity, mL	159
Electrode	Material	SS 304
	Diameter×thickness, cm	4.4×0.2
	Heating surface area, cm^2	15.21
	Distance between electrodes, cm	10
Variable autotransformer	Input	220 V, 50 Hz
	Output	400 V, 50 Hz
Voltmeter	0-500 V	
Ammeter	0-15 amp	
Thermometer	0-100 ^oC	

Table.2 Analysis of variance table for electrical conductivity of grape juice

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.294[a]	18	.072	71.785	.000
Intercept	16.724	1	16.724	1.670E4	.000
Voltage gradient (V)	.105	3	.035	35.096	.000
Temperature (T)	1.060	4	.265	264.575	.000
V×T	.033	11	.003	3.018	.006
Error	.038	38	.001		
Total	18.785	57			
Corrected Total	1.332	56			
[a]R^2 =.971 (Adjusted R^2 =.958)					

This phenomenon occurs because of structural changes in the tissue like cell wall breakdown and lowering in viscosity and thus increases in the ionic mobility. Similar result was reported by Icier and Ilicali (2005a) in orange juice; Icier *et al.*, (2008) in grape juice and Darvishi *et al.*, (2011) in lemon juice.

It can be concluded that the electrical conductivity of grape juice was strongly dependent on voltage gradient and temperature. The voltage gradient was statistically significant on electrical conductivity grape juice. In all cases considered the electrical conductivity increased linearly with temperature. The rate of change of the electrical conductivity of grape juice with temperature for 30 V cm^{-1} at 85 ^oC was higher as compared to other voltage gradients applied. The results of the present work can be used industrially to determine processing effectiveness when ohmic heating technology is applied.

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References

Amiali, M., M. O. Ngadi, V. G. S. Raghavan and Nguyen, D. H. 2006. Electrical conductivities of liquid egg product and fruit juices exposed to high pulsed electric fields. International Journal of Food Properties, 9(3): 533-540.

Darvishi, H., A. Hosainpour, F. Nargesi, M. H. Khoshtaghza and Torang H. 2011. Ohmic processing: temperature dependent electrical conductivities of lemon juice. Modern Applied Science. 5(1): 210-216.

Darvishi, H., M. H. Khostaghaza and Najafi, G. 2013. Ohmic heating of pomegranate juice: Electrical conductivity and pH change. Journal of the Saudi Society of Agricultural Sciences. 12(2): 101-108.

De Halleux D., G. Piette, M. L. Buteau and Dostie M. 2005. Ohmic cooking of processed meats: Energy evaluation and food safety considerations. Canadian Biosystems Engineering 47: 3.41-3.47.

Fryer, P. J., A. A. P. de Alwis, E. Koury, A. G. F. Stapley and Zhang, L. 1993. Ohmic processing of solid-liquid mixtures: heat generation and convection effects. Journal of Food Engineering. 18(2): 101-125.

Goullieux, A., and Pain, J. P. 2005. Ohmic Heating. In Sun, D.W. (Ed.), Emerging Technologies for Food Processing, Elsevier Academic Press, London. 469-505.

Icier, F., and Ilicali, C. 2004. Electrical conductivity of apple and sourcherry juice concentrates duringohmic heating. Journal of Food Process Engineering. 27(3): 159-180.

Icier, F., and Ilicali, C. 2005a. The effects of concentration on electrical conductivity of orange juice concentrates during ohmic heating. European Food Research and Technology. 220(3): 406-414.

Icier, F., and Ilicali, C. 2005b. Temperature dependent electrical conductivities of fruit purees during ohmic heating. Food Research International. 38(10): 1135-1142.

Icier, F., H. Yildiz and Baysal, T. 2008. Polyphenoloxidase deactivation kinetics during ohmic heatingof grape juice. Journal of Food Engineering. 85(3): 410-417.

Jha S. N., R. K. Vishwakarma, T. Ahmad, A. Rai and Dixit A. K. 2015. Report on assessment of quantitative harvest and post-harvest losses of major crops and commodities in India. ICAR-All India Coordinated Research Project on Post-Harvest Technology, ICAR-CIPHET, Ludhiana.

Kong, Y. Q., D. Li, L. J. Wang, B. Bhandari, X. D. Chen and Mao, J. H. 2008. Ohmic heating behavior of certain selected liquid food materials. International Journal of Food Engineering. 4(3): 1-13.

Leizerson, S., and Shimoni, E. 2005b. Stability and sensory shelf life of orange juice pasteurized by continuous ohmic heating. Journal of Agricultural and Food Chemistry. 53(10): 4012-4018.

NCAER. 2016. Agricultural Outlook and Situation Analysis Reports: Rabi Outlook Report. National Council of Applied Economic Research, New Delhi. January 2016. 91.

NRCG. 2015. Vision-2050. Indian Council of Agricultural Research-National Research Centre for Grapes, Pune. July 2015. 3.

Oulkar D. P. 2009. Metabolic fate of contaminant residues in grapes at various stages of processing to raisins and wines. Ph. D. Thesis. Shivaji University, Kolhapur, Maharashtra, India. 224.

Palaniappan, S., and Sastry, S. K. 1991. Electrical conductivities of selected solid foods during ohmic heating. Journal of Food Process Engineering. 14(3): 221-236.

Parrott D. L. 1992. Use of ohmic heating for aseptic processing of food particulates. Food Technology, 46, 68-72

Rolle, L., S. Giacosa and Gerbi, V. 2011. Comparative study of texture properties, color characteristics and chemical composition of ten white table grape varieties. American Journal of Enology and Viticulture. 62: 49-56.

SPSS. 2008. Statistical Package for Social Sciences. Version SPSS 16.0. SPSS Incorporation, Chicago, IL, USA.

Vikram, V. B., M. N. Ramesh and Prapulla S. G. 2005. Thermal degradation kinetics of nutrients in orange juice heated by electromagnetic and conventional methods. Journal of Food Engineering. 69(1): 31-40.

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