# DESIGN, FABRICATION AND PERFORMANCE EVALUATION OF OHMIC HEATER

**Prathu Raja Parmar, Sanjeev Tripathi, Saurabh Tiwari, Rongen Singh**

*Department of Food Process Engineering,*
*Vaugh School of Agricultural Engineering and Technology,*
*Sam Higginbottom Institute of Agriculture, Technology and Sciences,*
*Allahabad – 211007. (U.P.) INDIA*

## ABSTRACT

*Ohmic heating takes its name from Ohm's law: The food material switched between electrodes has a role of resistance in the circuit. Ohmic heating is an alternative heating method for food products. This study was aimed to design a laboratory scale ohmic heating system, concluded by evaluating the behavior of electrical conductivity of sweet lime juice with temperature and the effect of ohmic heating on the various physicochemical properties like pH, TSS, % acidity, ascorbic acid content, of the sweet lime juice, was studied. The ohmic heating chamber was build of grade 302 stainless steel with 320 ml sample batch processing capacity for working at a frequency of 50 Hertz and maximum voltage of 60 V with temperature range of 27.4°C to 85.4°C after regular 2 min intervals with electrical conductivity range of 1.519 to5.241 S/m. The physicochemical properties were observed to change with change in voltage gradient, treatment time. The properties were retained more with less treatment time.*

**Keywords:** *Ohmic heating, Temperature; Electrical conductivity; Sweet lime juice; pH, Acidity, Ascorbic acid.*

## 1. INTRODUCTION

Ohmic heating is also called as joule heating, electric resistance heating or electro-conductive heating is based on the principle that most food product though has electrical conductivity but still resist flow of electric current. In ohmic heating the food itself acts as conductor of electricity and it is the food that determines the current value that flows between the ground and electrodes. Heating occurs when current is passed through a food due to internal heating caused by electric resistance offered by the food. In ohmic heating foods are made part of an electric circuit through which alternating current is passed. The main advantage of ohmic heating is the rapid and relatively uniform volumetric heating in which we can use large size heating tubes with lower shear rates and it allows the heating of fragile particles. Electrical conductivity is the main parameter in ohmic heating and for purely liquid foods. Ohmic heating is distinguished from other type of electromagnetic heating like microwave and inductive heating in the fact that food product physically comes in contact with food thus we can term ohmic heating as '*direct ohmic heating'*.

The present research entitled "**Design, fabrication and performance evaluation of ohmic heater"** was carried out at Sam Higginbottom Institute Agriculture, Technology and Sciences, Allahabad-211007, Uttar Pradesh. The materials for the research were collected from local markets. Cylindrical Stainless Steel Body, Electrode, thermometer, Ammeter, Voltmeter, Voltage Regulator, Tap (valve).

## 2. MATERIAL AND METHOD

### 2.1 Sample preparation

Fresh and mature sweet lime fruits were washed, peel and cut in small pieces. Remove the seeds from the fruit and put the fruit pieces in juicer and grinded it. Filter the juices to remove soggy mass's.

### 2.2 Design of ohmic heater

The main body of ohmic heater was cylindrical stainless steel pipe with which two stainless steel plate lids were welded and the length of ohmic cell was 0.25m giving total sample capacity of 320 ml. A tap (valve) was welded into the ohmic cell for the discharge of liquid sample into storage equipment. Two SS 304 electrodes polished with Teflon coating having 0.25 m gap between them. Variable power supply was obtained using voltage regulator (0-250V) from domestic supply (220 V and 50 Hz).

### 2.3 Electrical conductivity

Electrical conductivity (σ) was determined from the resistance of the sample and the geometry of the cell using the following equation:

$$EC = \left(\frac{1}{R}\right)\left(\frac{L}{A}\right)$$

where σ is the electrical conductivity (S/m) L is the gap between two electrodes (m); A is the cross section area of the electrodes (m2), the ratio of L/A is known as the cell constant of the ohmic heating unit and its value is 157.232 $m^{-1}$ when filled to a volume of 320 ml. R is the resistance of the sample (Ω), determined from the voltage (V) and current (I).

### 2.4 Testing of ohmic heater

Experiments were carried out with 1.5% NaCl solution at different voltages (20, 30, 40 and 50 V) to verify the apparatus

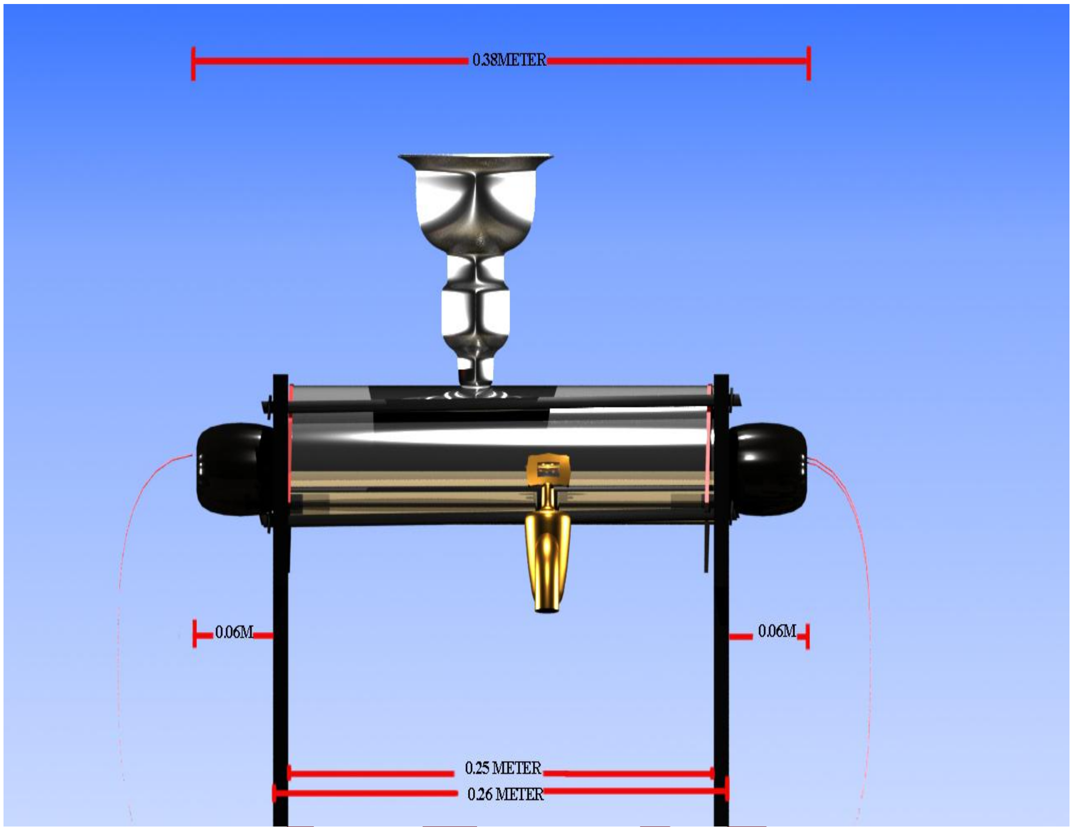


Fig. 1 3D Design at Maya



**2.5 Measurement of Physicochemical Properties**

The knowledge of physicochemical properties is fundamental in comprehending the processing technique. It is an indicator of many other parameters as well as the quality of foods. The physicochemical properties of ohmic heated sweet lime juice were observed after treatment at various voltages.

**2.5.1 The pH Value**

The pH of the fresh juice and the treated juice was measured using a digital pH meter.

**2.5.2 Total Soluble Solids (TSS)**

TSS was determined using a hand refractometer. A drop of juice was placed on the plane surface of the refractometer, and the corresponding TSS value was noted down. The TSS is expressed in °brix.

**2.5.3 Acidity (%)**

Acidity (%) was estimated using standard AOAC method, 90 ml of distilled water was taken and 10 ml sample was mixed in a 250 ml conical flask. Then 50 ml of 0.1N of NaOH was taken in a burette and started titration till got the end point. It was shaken vigorously during titration till end point from colorless to light pink came. (Ranganna, 1990).

$$\% \, Acidity = \frac{V \times N \times 80 \times 100}{\mathrm{W}}$$

Where, V = volume of 0.1 N NaOH, W= weight of sample, N = normality of NaOH

**2.5.4 Vitamin C**

Vitamin C was determined using 10ml of the processed sweet lime juice was measured with a pipette into 100 ml of volumetric flask and diluted to the mark with 3% $HPO_3$ and mixed thoroughly and then filtered. After that 10ml of filtrate was taken into a small flask and titrated with the standard dye to a faint pink end point persists for 15 sec. (Ranganna, 1986)

$$\text{Ascorbic acid mg/100g} = E \times V \times V_1 \times 100/V_2 \times W$$

Where: E = ascorbic acid equivalent of the dye in mg/ml, V = ml of the indicator used in the titration, $V_1$ = volume to which the juice is diluted, $V_2$ = volume of filtrate taken for the titration, W = initial volume of the juice taken for the determination

## 3. RESULTS AND DISCUSSION

**3.1 Testing of ohmic heater**

Ohmic heater was tested with relationship between temperature and electrical conductivity of 1.5% solution of NaCl as shown in Fig. 3.

**3.2 Electrical conductivity – The critical Parameter**

A laboratory scale OH was used to determine the electrical conductivity of sweet lime juice. The diameter of the electrodes was 0.045 m and distance between the electrodes was kept 0.25 m. Voltage was applied in the range of 30-60 V. The electrical conductivity of sweet lime juice was observed to be in the range of 1.519 to5.241 S/m in the temperature range of 27.4 – 85.4˚C. The changes in electrical conductivity of sweet lime juice with temperature during ohmic heating at four different voltage gradients are given in Fig. 2. Electrical conductivity increased with temperature, as is expected and consistent with literature data (Kumar et al., 2011; Icier et al., 2008; Darvishi et al., 2011; Kemp and Fryer, 2007; Icier and Ilicali, 2004,2005a; Amiali et al., 2006; Castro et al., 2004). Icier and Ilicali (2005a) reported that the increase in the electrical conductivity values with temperature has been explained by reduced drag for the movement.

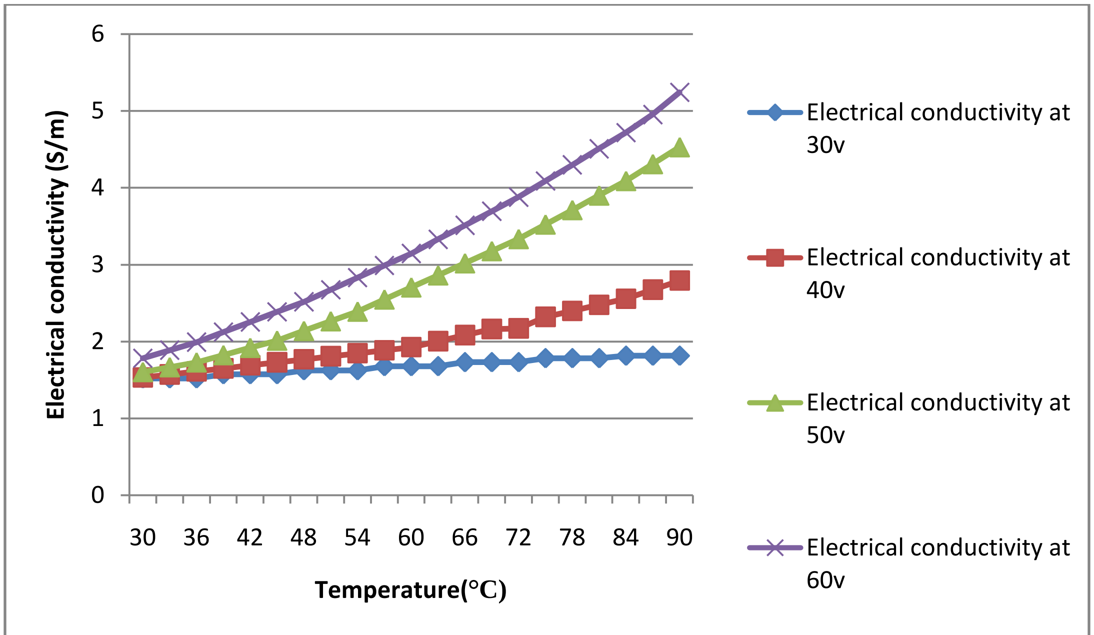


Fig.2 Changes in Electrical Conductivity of Sweet Lime Juice with Temperature

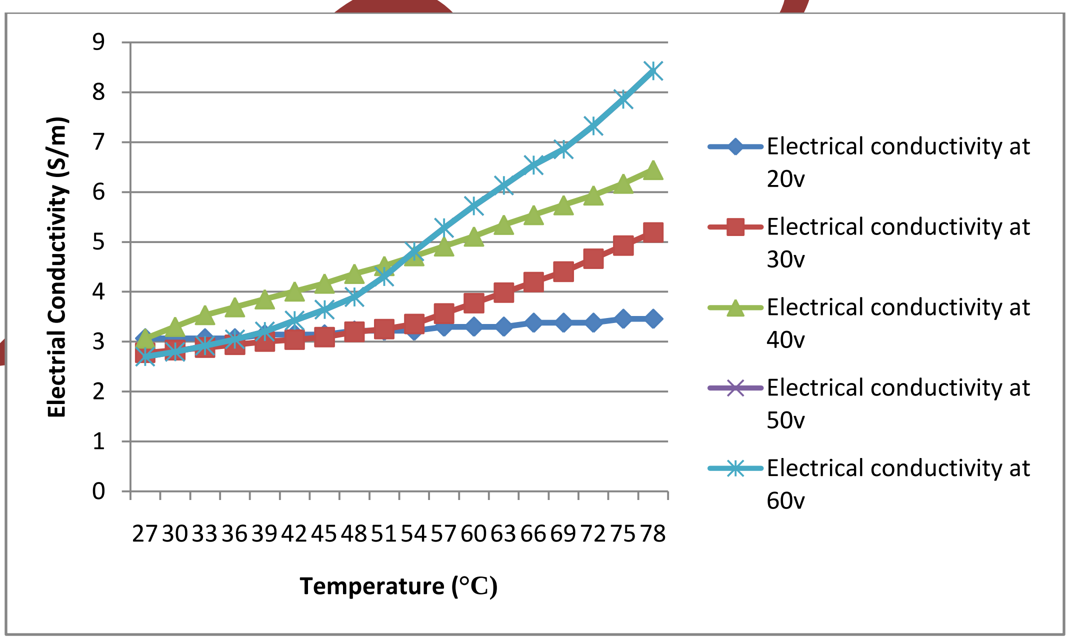


Fig. 3 Changes in Electrical Conductivity of 1.5% NaCl Solution with Temperature

### 3.3 Change in pH of Ohmic Heated Sweet lime juice at various voltages

Initially, the pH of the fresh juice was observed as 4.16, whereas after ohmic heating at various voltages 30V, 40V, 50V and 60V the pH was observed to be 4.30, 4.24, 4.20 and 4.22

respectively. It was observed that the pH decreased with increase in voltage gradient. During ohmic heating, hydrolysis of juice occurs which can affect and alter the pH. The change in voltage gradients and continuous heating causes corrosion of electrodes which accounts for change in pH. The pH values of the ohmic heated juice at various voltage gradients are shown in Table 3.1. Relationship between pH % and Voltage as shown in Fig. 4

Table 3.1: Change in pH of Ohmic Heated Sweet lime juice at various voltages

| Voltage(V) | ph |
|---|---|
| 60 | 4.22 |
| 50 | 4.20 |
| 40 | 4.24 |
| 30 | 4.30 |
| 0 | 4.16 |

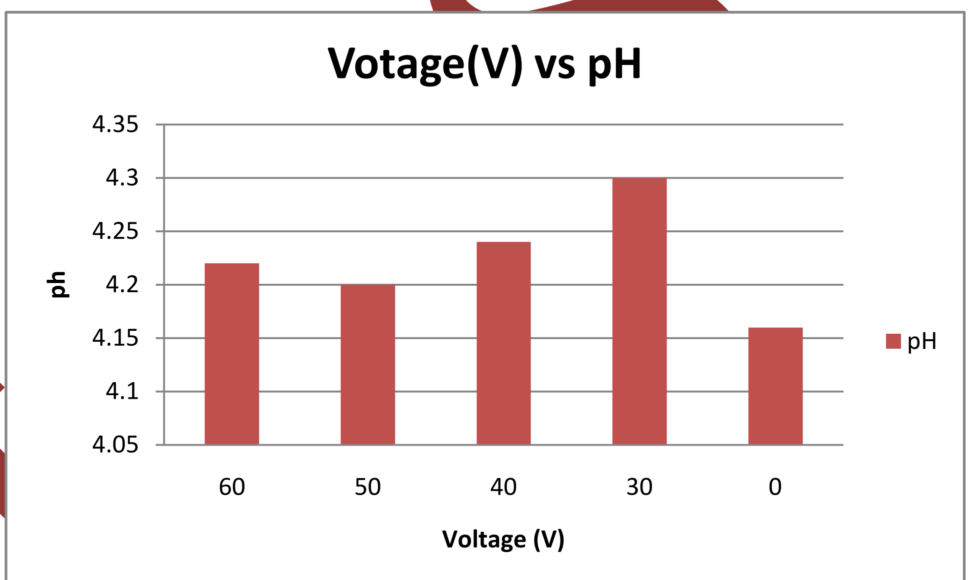


Fig. 4 Relationship between pH % and Voltage

**3.4 Change in Total Soluble Solids (°brix) of Ohmic Heated Sweet lime juice at various voltages**

Total soluble solids can be defined as the amount of sugar and soluble mineral salts present in the fruit juice. The initial TSS of the fresh juice was observed as 7.5 °brix. The TSS was observed to increase with increase in voltage gradient. The TSS of the sweet lime juice ohmic heated at various voltages 30V, 40V, 50V and 60V was observed to be 7.55 °brix, 7.6 °brix 7.7 °brix and 7.8 °brix respectively at various voltages. The probable reasons for increase in TSS can be the conversion of organic acids to sugars through gluconeogenesis. The degradation of cellulose, hemicellulose and pectin releases soluble components which affects the TSS. Table 3.2 shows the value of TSS of the ohmic heated sweet lime juice at various voltages. Relationship between TSS and Voltage as shown in Fig. 5

Table 3.2: Change in Total Soluble Solids (°brix) of Ohmic Heated Sweet lime juice at various voltages

| Voltage(V) | Tss(°**brix**) |
|---|---|
| 60 | 7.8 |
| 50 | 7.7 |
| 40 | 7.6 |
| 30 | 7.55 |
| 0 | 7.5 |

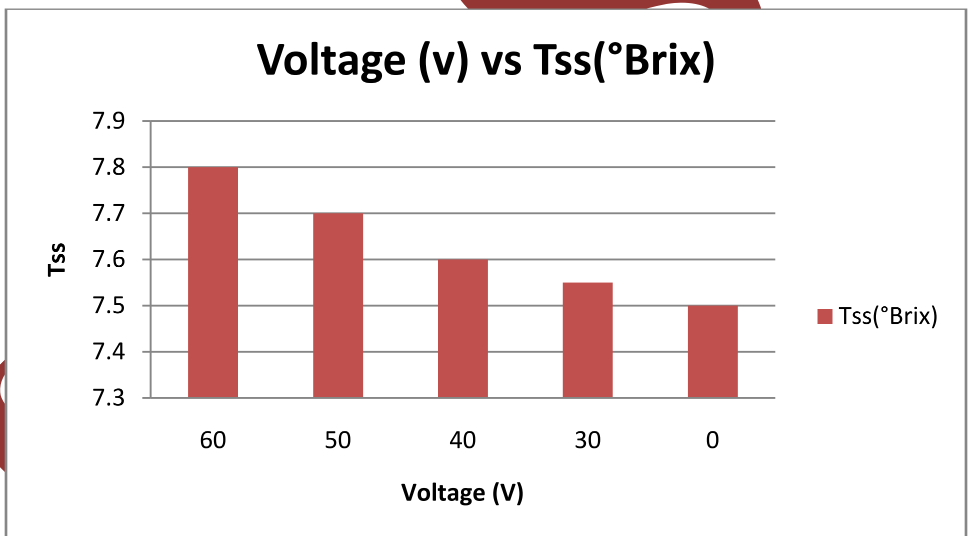


Fig. 5 Relationship between TSS and Voltage

**3.5: Change in Acidity of the Ohmic Heated Sweet lime juice at various voltages**

Table 3.3 shows the % acidity of the ohmic heated Sweet lime juice at various voltages. The titratable acidity of the fresh juice was observed to be 0.76%. Initially, at various voltages 30V, 40V, 50V and 60V, the titratable acidity of them ohmic heated juice was observed to be 0.74%, 0.72%, 0.71% and 0.7%. The acidity % decreases with increase in voltage gradient. The decrease in citric acid can be due to conversion of organic acids into sugars. Relationship between Acidity % and Voltage as shown in Fig. 6

Table 3.3: Change in Acidity of the Ohmic Heated Sweet lime juice at various voltages

| Voltage(V) | Acidity % |
|---|---|
| 60 | 0.7 |
| 50 | 0.71 |
| 40 | 0.72 |
| 30 | 0.74 |
| 0 | 0.76 |

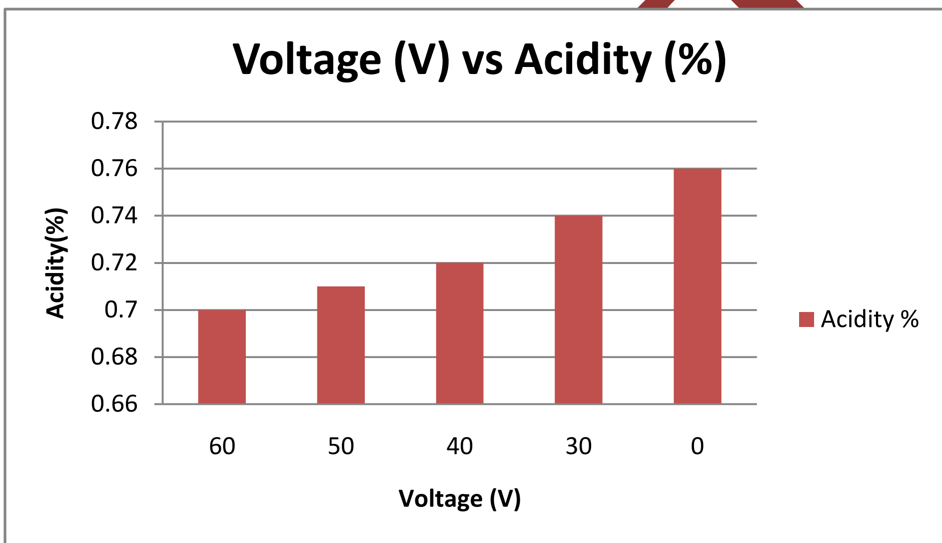


Fig. 6 Relationship between Acidity % and Voltage.

**3.6 Change in Vitamin C of the Ohmic heated Sweet lime juice at various voltages**

The vitamin C loss is higher at high treatment time.

The data regarding Change in Vitamin C of the Ohmic heated Sweet lime juice at various voltages are presented in Table 3.4.

Table 3.4: Change in Vitamin C of the Ohmic heated Sweet lime juice at various voltages

| Voltage(V) | Vitamin C content per 100 mg Serving |
|---|---|
| 60 | 17.8 mg |
| 50 | 16.1 mg |
| 40 | 15.6 mg |
| 30 | 14.2 mg |
| 0 | 34.12 mg |

## 4. CONCLUSION

1. Rate of increase of temperature was similar at various voltages but there was flex point for rate of temperature increase at 60 V and 50 V after 30 min when there was a sudden increase in temperature. This might be due to sudden increase in electrical conductivity of sweet lime juice.

2. The electrical conductivity values were in the range of 1.59 to 5.24 S/m having an increasing trend with increasing temperature.

3. Ohmic heating times are dependent on the voltage gradient used.

4. Sweet lime is a highly nutritious fruit with rich content of vitamin C. It imparts a strong aroma, flavor and a pleasant taste. The physicochemical properties are the fundamental characteristics in food processing and should be well retained. This study concludes that ohmic heating can be used as an alternative technique in preservation and processing of sweet lime juice.

## REFERENCES

1. Abdullah ET, Naje AN (2011) AC electrical and dielectric properties of PVCMWCNT nanocomposites. *Indian Journal of Science and Technology*. 4(7):731-735.
2. Awuah GB, Ramaswamy HS, Economides A (2007) Thermal processing and quality: Principles and overview. *Chemical Engineering and Processing: Process Intensification*. 46(6): 584–602. DOI: 10.1016/j.cep.2006.08.004.
3. Akanbi CT, Adeyemi RS, Ojo A (2006) Drying characteristics and sorption isotherm of tomato slices. J Food Eng 73: 157-163.
4. Akinwale, T.O,(2000) Cashew apple juice.Its use in fortifying the nutritional quality of some tropical fruits.Europe food research technology vol.211:205-207.
5. Alklint,(2004) Effects of deaerationand storage under a modified atmosphere on the shelf life of carrot juice. Journal of food science and technology. Vol.213:120.
6. Bhardwaj, Mukherjee,(2005) Influence of enzyme, sodium benzoate and yeast immobilization on fermentation of plum must by SchizosaccharomycesPombeyeast. In: ISHS ActaHorticulturae 696. VII International Symposium on Temperate Zone Fruits in the Tropics and Subtropics Part Two..
7. Bigelow WD, Bohart GS, Richardson AC, Ball CO (1920). Heat penetration in processing canned foods. National Canners Association Bulletin 16-L. Research Laboratory National Canners Association , Washington ,D.C.

8. Castro I, Teixeira J A, Salengke S, Sastry SK, Vicente AA (2004) Ohmic heating of strawberry products: electrical conductivity measurements and ascorbic acid degradation kinetics. Innovative Food Science and Emerging Technologies 5: 27- 36.
9. Chang CH, Lin HY, Chang CY, Liu YC (2006) Comparisons on the antioxidant properties of fresh, freeze-dried and hot-air-dried tomatoes. J Food Eng 77: 478- 485.
10. Darvishi H, Hosainpour A, Nargesi F, Khoshtaghza MH, Torang H (2011) Ohmic processing: temperature dependent electrical conductivities of lemon juice. Modern Applied Science 5: 210-216.
11. Duan ZH, Jiang J, Wang J, Yu XY, Wang T (2010) Drying and quality characteristics of tilapia fish fillets dried with hot air-microwave heating. Food and Bioproducts processing 89: 472-476.
12. Darvishi H, Khostaghaza MH, 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. DOI: 10.1016/j.jssas.2012.08.003.
13. Fellows P (2000). *Food processing technology: principles and practice*, Woodhead.
14. Godéreaux ESC, Zuber F, Goullieux A(2011). Processing and stabilization of cauliflower by ohmic heating technology. *Innovative Food Science & Emerging Technologies*. 2(4): 279–287.DOI: 10.1016/S1466-8564(01)00047-9.
15. Goyeneche R, Scala KD, Roura S (2013). Biochemical characterization and thermal inactivation of polyphenol oxidase from radish (*Raphanus sativus* var. *sativus*). *Food Science and Technology*. **54:**57-62. DOI: 10.1016/j.lwt.2013.04.014.
16. Holdsworth SD (1985). Optimization
17. Icier F, Bozkurt H (2011) Ohmic heating of liquid whole egg: rheological behavior and fluid dynamics. Food and Bioprocess Technol 4: 1253-1263.
18. Icier F, Ilicali C (2005) The effects of concentration on electrical conductivity of orange juice concentrates during ohmic heating. Eur Food Res Technol 220: 406-414.
19. Jakób A, Bryjak J, Wójtowicz H, Illeová V, Annus J, Polakovič M (2010). Inactivation kinetics of food enzymes during ohmic heating. *Food Chemistry*.123(2): 369–376. DOI: 10.1016/j.foodchem.2010.04.047.
20. Kaur N, Singh AK, Chopra S (2013). Electrical Conductivity Of Oat Flour As Influenced By Ohmic Heating. *International Journal of Agricultural Science and Research*. 3(4): 57-64.
21. Louarme L, Billaud C(2012). Evaluation of ascorbic acid and sugar degradation products during fruit dessert processing under conventional or ohmic heating treatment. *Food Science and Technology*. 49(2):184–187. DOI: 10.1016/j.lwt.2011.12.035.
22. Marra F, Zell M, Lyng JG, Morgan DJ, Cronin DA (2009) Analysis of heat transfer during ohmic processing of a solid food. J Food Eng 91: 56-63.
23. Munsch and Simard,(1990) Fruit Processing Science and Technology,Wiley eastern publication and printing company limited.

24. Nolsoe H, Undeland I (2009) The acid and alkaline solubilisation process for the isolation of muscle proteins: state of the art. Food and Bioprocess Technol 2: 1-27.
25. Odake,(1990) Fruit and vegetable juice.
26. Suzuki,(2002) Methods of manufacture of stale juice.
27. Talcott, S.T, Haword, L.R and Brenes C.H,(2007) Commercial food processing. Pearson Education
28. Teter,(2003) Pastuerisation could not prevent cloud coagulation.
29. USA-CDC (2008). United States of America. Department of Health and Human Services. Centers for Disease Control and Prevention. (2008). Multistate outbreak of Salmonella infections associated with frozen pot pies-United States, 2007. MMWR Morb Mortal Wkly Rep. Nov 28, 57(47), 1277e1280.
30. Zell M, Lyng JG, Morgan DJ, Cronin DA(2011). Minimising heat losses during batch ohmic heating of solid food. *Food and Bioproducts Processing*. 89(2): 128– 134. DOI: 10.1016/j.fbp.2010.04.003.