CHAPTER FIVE

EXTRACTION OF PHENOLIC COMPOUNDS FROM WHEAT BRAN USING OHMIC HEATING

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5.1 Introduction

The mechanism of ohmic heating, which is also known by Joule heating as well as resistive heating, is taken from Ohm's Law on the basis of the voltage, resistance and the current. It is considered as one of the modern technologies, where the food is converted into an electric resistance. The alternative current passes through the food, and the electrical energy is transformed into heat energy. The heat is distributed inside the food uniformly and rapidly. The heat direction shall be from inside to outside, on the contrary of using hot surfaces in the traditional methods in which heating direction is form outside to inside and slower ((Shirsat et al., (2004); Leizerson and Shimoni, (2005); Icier and Ilicali, (2005)).

The majority of foods contain ions such as salts and acids, therefore the electric current may pass through the food generating a heat therein (FDA, 2000). The ohmic heating efficiency depends on the nature of food conductivity (Zoltai and Swearingen, 1996). The ohmic heating technology is employed in the food industry as pasteurization and essential oils distillation (Al-Hilphy et al., 2012; Al-Hilphy, 2014). The fat self-oxidation is defined as the automatic oxidation occurring to fatty compounds when they are in contact with molecular Oxygen that end by the occurrence of undesirable flavor called (rancidity). The fatty acids with short chain, alcohols, aldehydes and ketones, the final products of self-oxidation are responsible for appearance of the undesirable odor and flavor in oxidized fat (Frankel, 1991). Currently, many industrial antioxidants are used in the commercial range such as Butylated Hydroxy Toluene (BHT) and Butylated Hydroxy Anisole (BHA). In the recent years, several doubts were raised about the safety of these antioxidants in terms of health, as they indicated that the use of antibiotics has resulted in carcinogenic or toxic substances (Ponchogu and Kaewsuwen, 2004), so the researchers turned to find antioxidants from natural sources including plants. The cereal products including wheat product contain many phenolic compounds such as phenolic acids, flavonoids and anthocyanids that are considered as effective and natural antioxidants (Okai *et al.,* 2004). The present study aims introducing a new technology to extract antioxidants from local wheat bran by ohmic heating through subjugating a system that depends in its work on both the heat and electric field.

5.2 Extraction System

A system was manufactured to extract antioxidants from wheat bran consisting of an extraction glass cylinder with a capacity of 500 ml, 7 cm diameter and 9 cm height that contains a slot at the top mounted with plastic cover. The cylinder contains also two electrodes made of stainless steel, with a distance of 5 cm between them and with a height and width of each electrode of 7 and 1 cm respectively. The two electrodes are fixed from the top on the plastic cover. The heating process occurs inside this cylinder as a result of the passage of electric current in the electrodes and the bran is converted to an electrical resistance through which the electric current passes and heats. The two electrodes are connected to the electrical circuit constituted of electric wires, voltmeter into variac, ammeter to measure the current and a source of voltage, in addition to an aeration slot in the plastic cover.

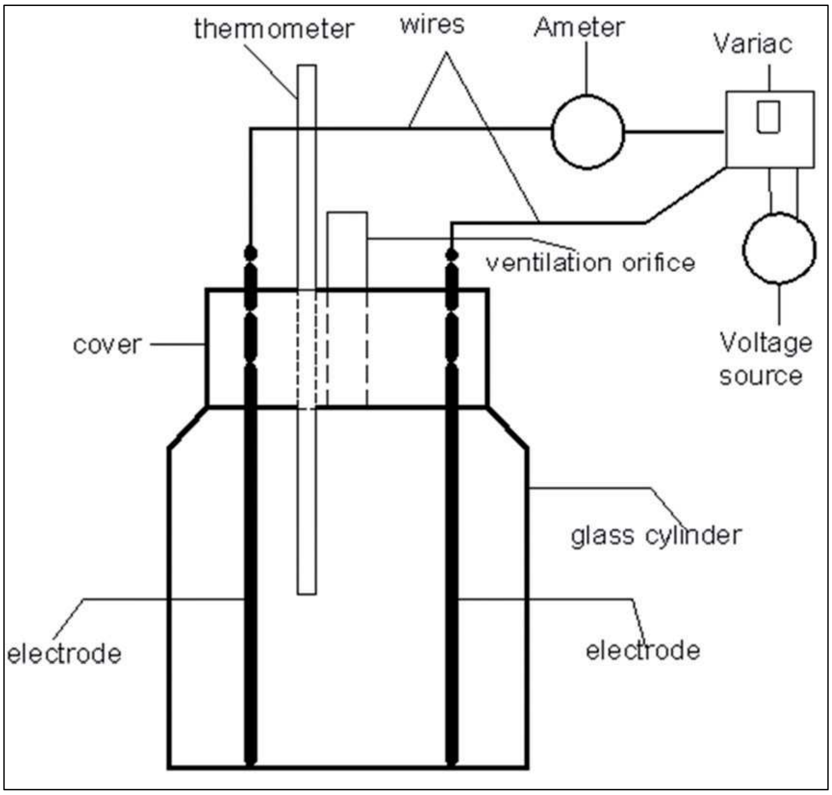

Figure 1. Layout of extractor of antioxidant using Ohmic heating. (Adapted from: Al-Hilphy et al., 2015)

5.3 Bran temperature

The figure (2) illustrates the changing in bran temperature with the increase of extraction time at different values of the electric field intensity (14, 20, 44 Vcm^{-1}). The temperature has increased significantly ($P \leq 0.05$) with the increase of the extraction time. In order that the bran temperature reaches 80 °C, at electric field intensities of 14, 20, 44 Vcm^{-1}, 20, 10, 6 min were needed respectively. This is due to the increase of the current passing through the bran with the increase of the voltage or electric field intensity, also the current consumption is increased when the heating time is increased for each value of the electric field intensities. Icier and Ilicali, 2005; Kong et al., 2008; Hosain et al., 2011; Mohsin, 2012; Al-Hilphy, 2014 have shown that the temperature is increased with the increase of voltage and the extraction time is decreased with the increase of the applied voltage.

5.4 Electrical conductivity

Figure (3) illustrates electrical conductivity for local wheat bran during the extraction time at different values of electric field intensity. Electrical conductivity has increased significantly ($P \leq 0.05$) with the increase of extraction time for all of the electric field intensity values. When the extraction time was 2, 10, 20 minutes, electrical conductivity reaches 1.03, 2.27, 3.92 Sm^{-1} respectively at an electric field intensity of 14 Vcm^{-1}. This is due to the increase in the temperature and current passing through the bran with the increase of the time. Also, Icier et al. (2008) have indicated that the relation between the electric current and conductivity is linear. The results have shown that the electrical conductivity has decreased significantly ($P \leq 0.05$) with the increase of the electric field intensity. This is due to that the electric field intensity is inversely proportional to the electrical conductivity, according to the following equations (Icier et al., 2008):

$$\sigma = \frac{I\ L}{V\ A} \tag{2}$$

$$E = \frac{V}{L} \tag{5}$$

$$\sigma = \frac{I}{E\ A} \tag{6}$$

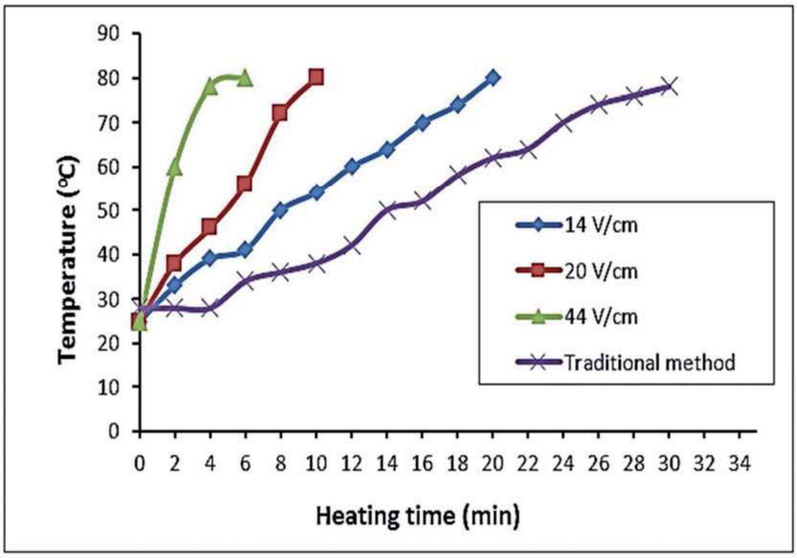

Figure 2. Bran temperature using different electric fields
(Adapted from: Al-Hilphy et al., 2015)

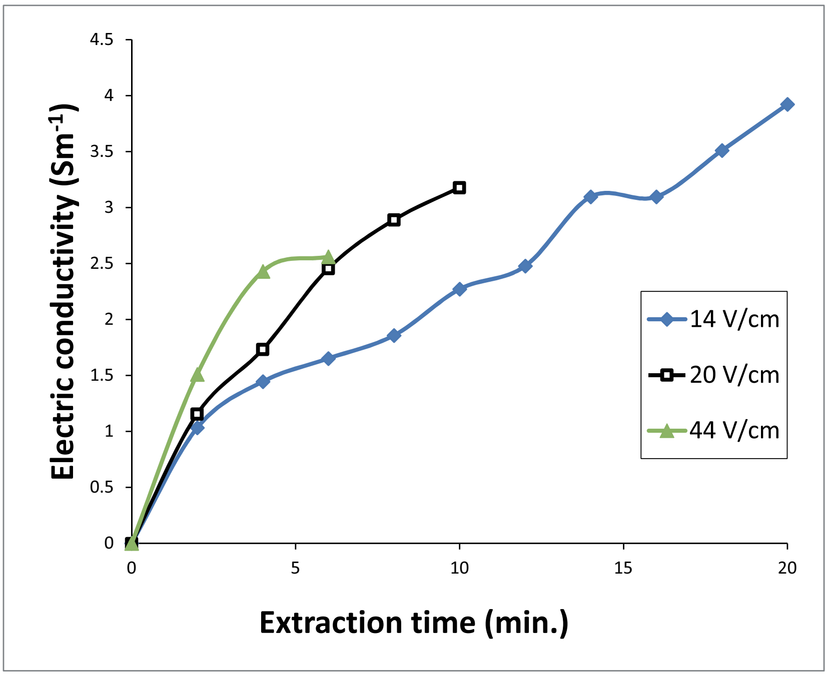

Figure 3. Electric conductivity of Bran vs. time at different electric fields (Adapted from: Al-Hilphy et al., 2015)

5.5 Electric resistance

It is noted from the figure (5) that the electric resistance of the local wheat bran has decreased significantly ($P \leq 0.05$) with the increase of the extraction time for all of the electric field intensity values. This is due to the increase of the wheat bran electrical conductivity with the increase of the extraction time, which is accompanied by an increase in the electric current passage in bran. In addition to that the electrical conductivity is a function for the food ingredients and that the ions and humidity increase the electrical conductivity, while lipids and fats decrease it (Bengston et al., 2006).

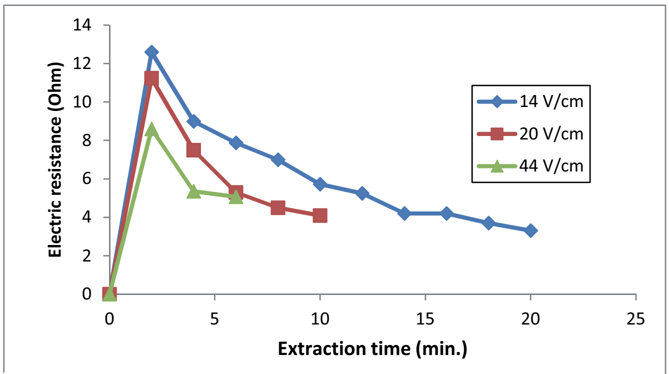

Figure 4. Bran electric resistance at different electric fields (Adapted from: Al-Hilphy et al., 2015)

5.6 Power requirements

The figure (5) shows the power requirements when using ohmic heating for different values of at electric field intensities of 14, 20, 44 Vcm^{-1}. The results have shown that the power was increased significantly ($P \leq 0.05$) with the increase of the electric field intensity. The highest power consumed was 171.6 W at the electric field intensity of 44 Vcm^{-1}, and this is due to that the electric field intensity is directly proportional to the power as a result of the increase in the current passing in the bran.

But the method of traditional heating has required a significantly higher power ($P \leq 0.05$) to the ohmic heating where amounted to 1320 W. This is due to that the traditional heating is indirect and the heat is transferred to the bran by conduction. This leaded to that it needs much more time than the ohmic heating, also it requires a higher electric current than the ohmic heating.

Both the electric conduction and heating time have a direct effect in the increase of power requirements, and as indicated in the following equation: (Qiu *et al*., 1998)

$$P = \frac{E^2 t\sigma}{n} \tag{7}$$

Where E is the electric field intensity, t is the extraction time, σ is the electrical conductivity, n is a constant and P is the power.

Alhilphy and AbdelSattar (2014) has shown that the power has increased with the increase of the electric field intensity during milk pasteurization.

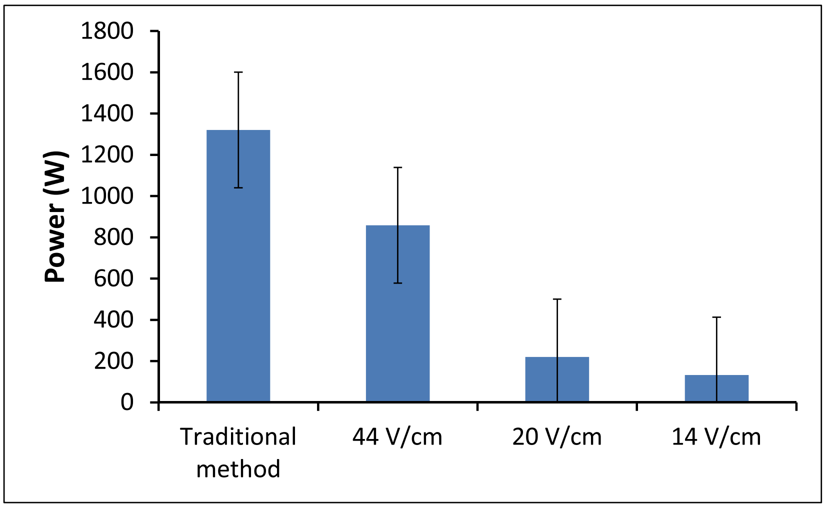

Figure 5. Consumed power at different electric fields
(Adapted from: Al-Hilphy et al., 2015)

5.7 Heating rate

The figure (6) illustrates heating rate of local wheat bran at different electric field intensities (14, 20, 44 Vcm^{-1}) to reach a temperature of 80 °C. There are significant differences ($P \leq 0.05$) appeared in the bran heating rate at different values of electric field intensity. So when electric field intensities of 14, 20, 44 Vcm^{-1} are used in heating the bran, the heating rates were 4, 8, 13.33 $°Cmin^{-1}$. The increase of the electric field intensity means an increase in the applied voltage, it also leads to an increase in the power and an increase in bran temperature occurs. Halleux et al. (2005) have indicated that the heating rate was increased with the increase of the applied voltage and they have a direct relation between them. The results have shown that the highest heating rate was 13.33 °C/min when using ohmic heating with an electric field intensity of 44 Vcm^{-1}. While the lowest heating rate was 2.5 $°Cmin^{-1}$ when traditional pasteurization has been used. This is because in the case of ohmic heating, heating shall be directly and the bran is converted to an electric resistance that heat and consume the current. Also, the heating direction shall be from inside to outside and the heat loss is too little. While in the traditional heating, the temperature moves to the bran and water by conduction and this needs a longer time, where heating moves from outside to inside also a heat loss occurs resulting in heating retard.

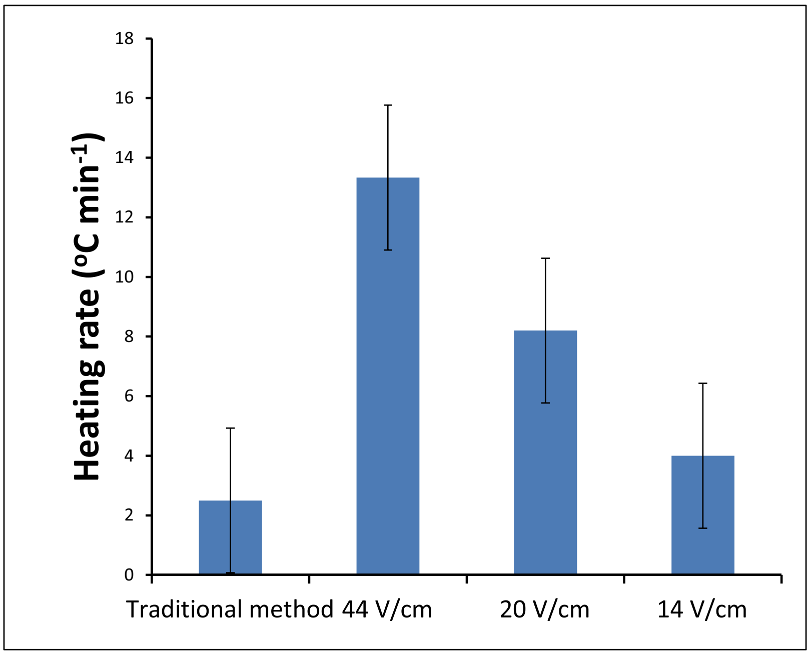

Figure 6. Heating rate of bran at different electric fields
(Adapted from: Al-Hilphy et al., 2015)

5.8 Phenolic Compounds and the antioxidant activity:

It is shown from the table (1) that the treatment by electric field 20 Vcm^{-1} is superior to the rest of other treatments, as the phenolic compounds concentration was (3150 mg/kg) and the antioxidant activity concentration was (82.3%). Then followed by the electric field treatment (44 Vcm^{-1}), where the phenolic compounds concentration of the extract was (2975 mg/kg) and the antioxidant activity concentration was (64.1%). The table shows that the increase in the phenolic compounds was accompanied by an increase in the antioxidant activity, which indicates that these compounds are primarily responsible for the antioxidant activity, and this is consistent with Okai *et al*., (2008).

Table 1. Phenolic compounds and Activity of antioxidant (mg/kg) of wheat bran treated with ohmic heating. (Adapted from: Al-Hilphy et al., 2015)

Electric field (Vcm^{-1})	Phenolic compounds concentration	Activity of antioxidant
14	2975^{b}	68.7^{b}
20	3150^{a}	82.3^{a}
44	2910^{b}	64.1^{c}
Control	2730^{c}	55.7^{d}

5.9 Fractionation by Dialysis:

The table (2) shows the fractionation by dialysis effect on the wheat bran extract by the ohmic method (20 Vcm^{-1}), which shows a higher antioxidant activity. Since it was shown that the antioxidant activity in the dialyzed part is higher than in the detained part. This indicates that the phenolic compounds with low molecular weight are primarily responsible for the antioxidant activity, which their molecular weights amount to less than 1000 Dalton. As its antioxidant activity have increased with the advancement of dialysis period, and this is consistent with Bersuder *et al*.,(2004).

5.10 Effect of Bran Extract on the Oil Oxidation Retardation:

The table (3) shows the different concentrations effect of wheat bran extract by the ohmic method (20 Vcm^{-1}) on the olive oil oxidation retardation for different storage periods. Since it is clear that the extract concentration (0.25%)

gave a better result of anti-evolution in the peroxide number value, if the peroxide number at this concentration was (7.7 mg/kg).

Table 2. Effect of fractionation on the compounds of antioxidant by the dialysis (Adapted from: Al-Hilphy et al., 2015)

Dialysis time	Activity of antioxidant (%)	
	Retainer part	Penetrated part
12	41.7[a]	70.1[d]
24	31.3[b]	77.2[c]
36	27.2[c]	80.5[c]
48	23.3[d]	85.6[b]
60	19.2[e]	88.5[a]

Table 3. Effect of concentration on the peroxide value (mg/kg) at different storage periods (Adapted from: Al-Hilphy et al., 2015)

Concentration (%)	Storage period (day)					
	0	5	10	15	20	25
0.05	3.0	4.4	5.2	7.1	9.9	13.2
0.10	3.0	4.1	4.8	5.8	6.2	11.7
0.15	3.0	4.1	4.5	4.9	5.5	10.6
0.20	3.0	3.8	4.0	5.1	5.2	9.1
0.25	3.0	3.8	4.0	5.5	6.2	7.7
Control	3.0	4.6	7.2	11.4	15.1	18.0
BHT (0.05)	3.0	3.2	3.5	3.6	3.9	4.2

$RLSD_{0.05\ (\text{for Storage period} \times \text{Concentration})} = 0.105$

5.11 Conclusion

In conclusion, ohmic heating is used as an assisted of antioxidant extraction. On the other hand, the electric field intensity has a significant effect in the electric resistance, electric conductivity, heating rate, power and the time required for heating wheat bran. The possibility of benefiting from the waste of mills factories for the production of natural antioxidants as an alternative to artificial antioxidant which have a negative health effects and have high costs. The possibility of the use of antioxidants extracted from wheat bran by using ohmic heating at electric field intensity of 20 Vcm^{-1} to disrupt the self-oxidative in oils which have a high content of unsaturated fatty acids with a high degree. Electric conductivity, power and heating rate were increased with increasing electric field intensity, while the electric resistance has been reduced.

5.12 References

Al-Hilphy A R. S; Haider I.Ali & Ghassan F. M. (2012), Designing and Manufacturing Milk Pasteurization Device by Ohmic Heating and studying Its Efficiency. Journal of Basrah Researches (Sciences), 4(38),1-18.

Al-Hilphy, A. R. S., A.K.J. AlRikabi and A. M. Al-Salim (2015). Extraction of Phenolic Compounds from Wheat Bran using Ohmic Heating. Food Science and Quality Management. Vol. 43: 21-28. ISSN 2224-6088.

Al-Hilphy A. R. S. & A. R. Abdulsattar (2014), Design, manufacturing and testing of a non-thermal milk pasteurization apparatus by electrical field. (Patent) Central Agency for Standardization and Quality Control, No. 4010 Baghdad, Iraq.

Al-Hilphy, A. R. S. (2014), A practical study for new design of essential oils extraction apparatus using ohmic heating. International J. Agricaltural science.4 (12), 351-366.

Al-Hilphy, A. R. S., A.K.J. AlRikabi and A. M. Al-Salim (2015). Extraction of

Phenolic Compounds from Wheat Bran using Ohmic Heating. Food Science and Quality Management. Vol. 43: 21-28. ISSN 2224-6088.

Al-Jassabi,S. & Abulah, M. S. (2013), Extraction, purification and characterization of antioxidant fractions from Zizyphus spina-Chriti fruits. American Eurasian Journal of Toxicoligical Science, 5(3), 66-71.

Bengeston, R., Birdsall, E., Feilden, S. Bhattiprolu, S., Bhale, S. & Lima, M. (2006), Ohmic and inductive heating in: Hand book of food science, Technology and engineering, Vol. 3 (ed. Y. H. Huij. CRC, Boca Raton, F.L. pp. 120, 1-8.

Bersuder, P.; Hose, M. & Smith, G.J. (2008), Antioxidant from a heated histidine-glugose of antoxidant rok of histidine and isolation of antioxidants by high performance liquid gromotograph Am. Oil Chem. 75:181-187. European Food Research and Technology, 220, 406- 414

Food and Drug Administration-Center for Food Safety and Applied Nutrition (FDACFSAN) (2000), .Kinetics of Microbial Inactivation for Alternative Food Processing Technologies-Ohmic and Inductive heating. www.cfsan.fda.gov/~comm/ift-ohm.html

Frankel, E. N. (1991) Recent advances in lipid oxidation. J. Sc. Agric. 150, 495-551.

Halleux, D.G.; Piette , M.L. & Butean ,D.M. (2005), Ohmic cooking of processed meats: Energy evaluation and food safety considerations. Canadian Biosystems Engineering Vol.47.

Hosain, D.; Adel, H.; Farzad,N.; Mohammad, H.K. & Hosain,T. (2011), Ohmic Processing: Temperature Dependent Electrica Conductivities of Lemon Juice. Published by Canadian Center of Science and Education Vol. 5, No. 1; February 2011.

Icier, F. & Ilicali , C . (2005), the effects of concentration on electrical conductivity of orange juice concentrates during ohmic heating.

Icier, F.; Yildiz, H. & Baysal, T. (2008), Polyphenoloxidase deactivation kinetics during ohmic heating of grape juice. Journal of Food Engineering, 85, 410–417.

Kong,Y.Q. ; Dong, Li. ; Wang, L.J. ; Bhandari ,B. ; Chen,X.D. & Mao, Z.H . (2008), Ohmic Heating Behavior of Certain Selected Liquid Food Materials, International. Journal of Food Engineering, Volume 4, Issue3.

Leizerson, S. & Shimoni, E. (2005), Stability and sensory shelf life of orange juice pasteurized by continuous, ohmic heating. J. Agric Food ohem. 53, 4012 - 2018.

Melo, E. A.; Filho, J. M. & Guerra, J. B. (1998), characterization of antioxidant compounds in aqueous coriander extract. Lebensm-Wiss. U.-Technol., 38, 15-19.

Mohsin, G. F. (2011), Ohmic milk Pasteurizer design, Manufacture and studying Its Pasteurization Efficiency. Msc. Thesis. Food Science Dept. Agriculture College, Basrah Univ.

Okai, K. H.; Kanbaro, K. A.; Hagiwara, K.; Sugita, A., C.; Mastumoto, A. & Okai, Y. (2004), Potent antioxidative and antigen toxic activity in aqueous extract of Japanese rice bran association with peroxidase activity phytother Re. 18, 628-633.

Ponchogu, P. & Kaewsuwen, S. (2004), Bio assay-guided isolation of the antioxidant constituent from Cassin alatin. J.Sc. Technol. 26(1), 103-107.

Qiu,X.; Sharma, S.; Tuhela, L. & Zhang, Q. H. (1998), An integrated PEF pilot plant for continuous nonthermal pasteurization of fresh orange juice. American Society of Agricultural and Biological Engineers, 41(4), 1069–1074.

Shirsat , N ., Lyng , J. G ., Brunton , N. P. &, McKenna , B . (2004), Ohmic processing: Electrical conductivities of pork cuts. Meat Science, 67, 507–514.

Wang, W. C. & Sastry , S . K. (1993), Salt diffusion into vegetable tissue as a Pre-treatment for ohmic heating : determination of parameters and mathematical model verification . Journal of Food Engineering, 20, 311-323.

Zoltai, P. & Swearingen, P. (1996), Product development consideration for ohmic processing. Food Technology 50, 263-266.