Available online at www.ijpab.com

DOI: http://dx.doi.org/10.18782/2320-7051.7477

ISSN: 2320 – 7051

Int. J. Pure App. Biosci. **7 (3):** 104-114 (2019)

Research Article

International Journal of Pure & Applied Bioscience

Optimization of Process Parameters of Ohmic Heating for Improving Yield and Quality of Tomato Seed Oil

Sangeetha Karunanithi, Akash Pare*, Sunil C. K. and M. Loganathan

Indian Institute of Food Processing Technology, Ministry of Food Processing Industries, Government of India

Pudukkottai Road, Thanjavur, Tamilnadu- 613005, India

*Corresponding Author E-mail: akashpare@iifpt.edu.in

Received: 5.04.2019 | Revised: 3.05.2019 | Accepted: 8.05.2019

ABSTRACT

The study was done to utilize the tomato seed waste since, the tomato seed is having good source of vegetable oil with higher antioxidant activity. This research is giving solution towards enhancing the oil yield by using ohmic heating. The influence of the electric field strength (10 – 14 V/cm), end point temperature (40 – 60 ^{0}C), and holding time of 5 to 15 mins on tomato seed oil extraction was determined. The optimal condition for oil extraction was found by using Box-Behnken Design. The optimization of process parameter was done based on higher extraction of tomato seed oil and process parameters were identified as, electric field strength of 14 V/cm, end point temperature of 50 ^{0}C, and holding time of 5 mins. The oil yield was significantly increased upto 10.84 % as by Ohmic treatment as compared to control sample (i.e. without treatment). The quality evaluation of ohmic assisted extracted oil was found and compared with the control sample. The quality of oil obtained by ohmic heating pretreatment was determined and its as equvalent as control sample. The range of all physicochemical quality parameters namely reftractive index, color, specific gravity, free fatty acids, saponification value, peroxide value, and iodine value fall under within the acceptable limits as stated by international standard for edible oils. From this study it can be conclueded that the tomato seed oil yield and quality can be improved by pretreatment of ohmic heating prior to oil extraction.

Key word: *Tomato seed waste, Optimization of process parameters, Oil yield, Ohmic heating, Quality parameters.*

INTRODUCTION

Tomato is considered to be the most popular fruity vegetable all over the world. These tomatoes underwent various processing stage to improve the economic values and for making plenty of products such as sauce, ketchup, and juice. Tomato skins and seed are considered to be the main waste in the tomato processing industry. This waste having serious economic and environmental problems in terms of handling and disposal of waste.

Cite this article: Sangeetha, K., Pare, A., Sunil, C.K. and Loganathan, M., Optimization of Process Parameters of Ohmic Heating for Improving Yield and Quality of Tomato Seed Oil, *Int. J. Pure App. Biosci.* **7(3):** 104-114 (2019). doi: http://dx.doi.org/10.18782/2320-7051.7477

The tomato processors demand to find the waste utilization techniques for maximizing the profits and minimizing the environmental pollution. Extraction of oil from tomato seed waste is one of the processing techniques to handle the waste of tomato processing industries. The tomato seed has good oil content around 20 to 36 % with high antioxidant properties than soybean and olive oil[24,25,26,]. The fatty acid composition present in the tomato seed oil was confirmed to prevent the various diseases like atherosclerosis, dilate blood vessels thrombosis and high cholesterol[22].

Pressing and solvent extraction are the two important process for defatting of the oil bearing materials. Pressing is beneficial when plant material having relatively higher oil content (> 25 % by weight) with 4 to 5 % residual oil content in the meal. Extraction with organic solvents are suitable for the lower oil content of the plant materials results in less residual oil in the meal at most <1% by weight[6,11]. Cellular layer is the resisting factor for oil extraction which can be overcome by giving adequate pretreatment. Higher solubility and mass diffusion rate is achieved by the solvent assisted extraction process for improving the oil extraction yield. The auguring method for food processing which consume the inherent electrical resistance of the sample to generate thermal energy is called ohmic heating[11]. This innovative method used to enhance the mass transfer effect and improving diffusion due to electroporation effect. Sucrose extraction from sugarbeat was improved by using electri field strength[15]. Application of ohmic heating improves the oil regaining from rice bran[8,18], soybean[20], sesame[14], rapeseed[7], mustard seed[27,28,].

Based on research can hypothesize that the oil yield improved by ohmic heating technology used as a pretreatment before oil extraction. Experiments were conducted to determine the effect of process parameters of ohmic heating namely ectric field strength (EFS), endpoint temperature (EPT) and holding time (HT) on oil recovery from tomato seed and compare the oil yield with the control sample.

MATERIAL AND METHODS

2.1 Raw materials:

The tomato seeds (PKM 1) were procured from T Stanes and company limited, Trichy and stored at room temperature until it is used. Tomato seeds were cleaned, ground and passed through the 0.5 mm sieves. Soxhlet apparatus (Model SOCS PLUS SIX PLACE 6, Pelican equipment) was used to quantify the oil content of raw tomato seeds powder[4]. Hot air oven method was used to found the moisture content of tomato seeds[12].

2.2 Experimental Design:

Box-Behnken Design (BBD) was employed for optimization of processing condition for ohmic assisted extraction (OAE) of tomato seed oil (TSO) with three-level and three-factor. *Table. 1* demonstrate that the range and center point values of the three independent variables. The experimental design comprised of 17 treatments with five replicates of the central point *Table. 2*. The EFS (10 –14 V/cm), desired EPT (40– 60 °C), and HT (5–15 min) were selected as the independent factors. Oil yield of TSO (%, Y) was selected as the response for the combination of the independent variables given in *Table. 3*. Variability in the observed responses was minimized by randomizing the experimentasl runs.

2.3 Ohmic heating:

The ohmic heating setup developed at IIFPT, Thanjavur was used for the experiment trials. Distilled warer was added to the raw tomato seed powder inorder to facilitate uniform conduction of electric current throughout the sample. The moisture content of slurry was brought in to 40 % (w.b.). based on the preliminary study. The tomato seed slurry was subjected to ohmic heating and stated EFS was applied. The slurry was heated homogeniously in such a way that the geometric center reaches the desired EPT and the temperature was maintained at different HT. Optic fiber sensor probe (Opticon optical sensors) was inserted into the tomato seed slurry in the ohmic heating tray to monitor temperature during heating. After the treatment the slurry was dried under shade to attain the moisture content of 10 to 12 % (w.b.). The dried seed powder was used to extract the oil.

2.4 Determination of Oil yield:

The oil was extracted from tomato seed powder using hexane as a solvent in soxhlet apparatus (Model SOCS PLUS SIX PLACE 6, Pelican equipment). The oil yield was calculated using the following formula. The ratio of weight of the obtained oil to that of the sample used for the extraction was the percentage of oil yield.

$$\text{Oil yield} = \frac{weight\ of\ Oil\ \ (g)}{weight\ of\ sample\ (g)} \times 100 \qquad ....Eqn.\ (1)$$

2.5 Physicochemical evaluation of extracted oil:

Hunter Lab Colorimeter (color Flex EZ *(45/0° color spectrophotometer, serial No CFEZ0925*) was used to found the oil color. The reftractive index (RI) was measured using an Abbe refractometer at 20 °C[9]. The free fatty acid (FFA) (% of oleic acid) and peroxide values (PV) determined according to[14]. Saponification value (SV) was determined by[12]. Iodine value (IV) was determined by[12].

2.6 Statistical analysis:

For the optimization part of this study, Design-Expert (version 11.1.2.0) was used for analysis the variance. (ANOVA) tables and the regression coefficients of individual linear, quadratic and interaction terms. The experimental data were evaluated to fit a statistical model (Linear, Quadratic, Cubic or 2FI). The coefficients of the model were represented by constant terms, A, B and C (linear coefficients for EFS, EPT, HT respectively), AB, AC and BC (interactive term coefficient), A2, B2 and C2 (quadratic term coefficient). Correlation coefficient (R^2), adjusted determination coefficient (Adj-R^2) and adequate precision were used to check the model adequacies; the model was adequate when its P value < 0.05, lack of fit P value > 0.05, R2 > 0.9 and Adeq Precision > 4. Differences among means were tested for statistical significance using analysis of variance (ANOVA). The statistical significance level was set at P < 0.05.

RESULT AND DISCUSSION

3.1 Effect of electric field strength on extraction of tomato seed oil

The influence of three EFS (10, 12, and 14 V/cm) at 50 ^{0}C for 10 min on tomato seed oil yield was studied as given in *Fig. 1*. which shows EFS had a noteworthy effect on tomato seed oil recovery. When the EFS increased from 10 to 14 V/cm, the yield of tomato seed oil was increased considerably and linearly from 18.415 to 29.25%. The oil yield was increased 10.84 % as compared to control. The increase in oil yield at higher EFS may be due to the effect of electroporation of the tissues[21]. It was hypothesized that an increase in tissue permeability may promote an accessibility of the solvent or extraction medium to the essential oil inside oil glands. This further enrich the rate of mass transfer and increases the leaching of cellular components into the the solvent[23]. This would be decisive from the literature[13] in which degree of tissue permeabilization significantly increased from 0.16 to 0.33 (p < 0.05), as the field strength increased from 25 to 50 V/cm, thus enhances the oil yield. This result is comparable with[13] and[14] on ohmic assisted extraction of oil from lime seed and sesame seed respectively.

3.2 Effect of end point temperature on extraction of tomato seed oil

A range of EPT from 40–60 ^{0}C was employed for 10 min HT with EFS of 12 V/cm to evaluate the effect on TSO extraction. As the temperature increase from 40 to 50 ^{0}C the oil yield was increased *(Fig. 2)* which would be because of the increased solubility of TSO. The crucial parameters of solvent deciding the TSO solubility such as, viscosity and density are decreased with the increase in temeperature. This inturn results in an increased mass transfer[30]. Nevertheless, when the EPT surpassed 50 ^{0}C, the oil yield exhibited a decrease. Therefore, 50 ^{0}C was chosen for subsequent treatment optimization.

3.3 Effect of holding time on oil yield:

The effect of HT: 5, 10, and 15 mins at desired EPT of 50 ^{0}C with 12 V/cm EFS was evaluated for oil yield. *Fig. 3.* demonstrates the increase in oil yield with reduced holding time. The tomato seed cells ruptured entirely within 5 mins HT during ohmic heating process, conferring higher solvent penetration through the cellular structures and boosting up the oil transfer out of the cell[20]. Besides, the redundant matters like cytosol, lipids and other insoluble substances hinders the permeability of the solvent[5,16]. Furthermore, the extracted oil may re-adsorb into the disrupted cells of increased surface area. Thus, lowering the yields of TSO[5]. Therefore, a longer extraction time is dispensable once it reach the maximum oil yield. Hence, 5 min HT was designated as optimum for higher oil extraction.

3.4 Optimization of ohmic extraction conditions:

The conditions of OAE of oil from tomato seeds was optimized for higher oil yield using Box-Behnken Design. *Table. 2.* shows the levels and factors (EFS, EPT, HT) involved in this study along with the response variable (oil yield). The quadratic regression model for yield is given below:

$$Y= -19.73813 - 3.86281\,A + 2.34069\,B + 1.68650\,C + 0.073875\,AB - 0.095875\,AC - 0.001925\,BC + 0.083125\,A^2 - 0.032900\,B^2 - 0.037450\,C^2 \quad \text{........}\textit{Eqn. (2)}$$

Where, Y is the response variable; A, B, and C are the independent factors; AB, AC, and BC are the interactive terms; A^2, B^2, and C^2 are the quadratic terms. The adequacy of the established model was estimated on the basis of correlation coefficient (R^2). The R^2 value was found to be 0.9880 i.e. quite nearer to unity. This explains that, better compliance is existing between the model predicted and experimental value. Similarly, the significancy of the model was analysed using ANOVA is given in *Table. 4.* The established model was found to be significant with F value of 59.07 and P-value < 0.0001. Also, independent variables, interaction terms (AB and AC), and quadratic terms (B^2 and C^2) are significantly influencing the response variable ($P < 0.01$) as given in *Table. 5.*

The influence of processing variable on the extraction yield of TSO was investigated using response surface plot and contour plots as given in (*Fig. 4. and Fig. 5.).* By fixing the HT for 10 mins, the optimal yield was achieved in the EFS of 12 to 14 at the temperature of 45 to 55 ^{0}C. Here, the highest TSO yield was achieved using EFS of 12 V/cm with EPT of 50 ^{0}C for 10 mins HT(*Fig. 4. and Fig.5. a*). By setting the extraction temperature 50 ^{0}C as constant value, the optimal value TSO yield falls in the range of 12.3 to 14 V/cm EFS with HT of 5 to 13 mins. but the hightest oil yield can be obtained at 14 V/cm EFS, holding at 5 mins and the EPT of 50 ^{0}C (Fig.4. and Fig.5.b). The EFS of 12 V/cm as constant value, the optimal value can be obtained from 46 to 52 ^{0}C with 5 to 8 mins HT. In this the highest yield was obtained at the EFS of 12 V/cm with end point temperature of 50 ^{0}C holding at 10 mins (*Fig.4. and Fig.5.c*).

The optimum conditions of extraction, as predicted from the model, were 13.99 V/cm, 51.45 ^{0}C, and 5.27 min for EFS, EPT and HT respectively. The maximum predicted yield of TSO was 29.27 % under optimal conditions. The predicted optimum condition was analysed for reliability with a number of experimental runs (N = 5) and average oil yield of 29.25 % was obtained (*Table. 6)*. Thus, the predicted model and optimum conditions were observed to be in accordance with laboratory trials.

3.5 Physicochemical property of extracted tomato seed oil.

The physicochemical properties of extracted TSO was found and depicted in the *Table. 7.* The extracted oil has RI of 1.4450 ± 0.04 and 1.4496 ± 0.01 for the control and OAE sample respectively. On comparing conventional methods with modern extraction technologies like ohmic heating, the major physical attribute of oils i.e. RI remains the same[10]. The color value (L*) was 2.293 ± 0.03 for untreated sample and 4.12 ± 0.02 for OAE sample respectively. This variation can be because of the damage of plant tissues during treatment given before extraction leading to more extraction of the pigments into the oil[3]. The specific gravity of extracted oil was 0.8037 ± 0.23 for untreated sample and 0.814 ± 0.02 for OAE treated sample. This increased value might be the consequence of polymerization by the thermal pre-treatments making the oil denser[2]. The FFA value (Oleic acid %) of the extracted oil was 2.312 ± 0.21 for untreated sample and 2.712 ± 0.12 for OAMH treated sample respectively. The increasing in the FFA is due to the Hydrolysis of triacylglycerol with higher temperature[2]. The SV of extracted oil was 195 ± 1.52 mg KOH/g for untreated and 198±1.63 mg KOH/g for OAE treated sample respectively. This maybe due to the infringement of oil triglycerides into smaller fragments of FFA and carbonyl compounds with lesser molecular weight[1,29]. The PV values were relatively low 0.73 ± 0.03 meq/kg for untreated sample and 0.86 ± 0.06 meq/kg for OAE treated sample respectively. This reveals the action of low degree of oxidation during combined treatment. The IV of the tomato seed oil obtained are 125±1.36 g I/100 g oil for control sample and 119±1.61 I/100 g oil for OAE treated sample respectively. The reduction of iodine value in the treated sample was due to reduction in the number of unsaturation sites due to additive and subtractive chemical reactions[2]. The obtained values are within the range authorized by codex standard 210[26].

Table 8:
The levels of variables employed in the present study for the construction of Box– Behnken design (CCD).

Factor	Name	Units	Coded Level		
			-1	0	+1
A	Electric field strength	V/cm	10.00	12.00	14.00
B	End Point Temperature	°C	40.00	50.00	60.00
C	Holding Time	mins	5.00	10.00	15.00

Table 9: Design and Results of Box-Behnken Experiments

Run	Factor 1	Factor 2	Factor 3	Response 1
	A: Electric field strength	B: Temperature	C: Holding Time	Oil yield %
1	12	40	5	24.22
2	14	60	10	25.305
3	14	40	10	23.25
4	10	50	5	23.585
5	12	50	10	25.64
6	10	40	10	23.015
7	14	50	5	29.25
8	12	50	10	25.64
9	12	50	10	25.64
10	12	40	15	20.99
11	12	50	10	25.64
12	12	50	10	25.64
13	14	50	15	24.57
14	12	60	15	18.415
15	12	60	5	22.03
16	10	60	10	19.16
17	10	50	15	22.74

Table 10: ANOVA for Quadratic model testing the fitness of the regression equation

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	111.84	9	12.43	59.09	< 0.0001	significant
A-Electric field strength	24.06	1	24.06	114.43	< 0.0001	
B-Temperature	5.39	1	5.39	25.62	0.0015	
C-Holding Time	19.13	1	19.13	90.95	< 0.0001	
AB	8.73	1	8.73	41.52	0.0004	
AC	3.68	1	3.68	17.48	0.0041	
BC	0.0371	1	0.0371	0.1762	0.6872	
A^2	0.4655	1	0.4655	2.21	0.1804	
B^2	45.58	1	45.58	216.71	< 0.0001	
C^2	3.69	1	3.69	17.55	0.0041	
Residual	1.47	7	0.2103			
Lack of Fit	1.47	3	0.4907			
Pure Error	0.0000	4	0.0000			
Cor Total	113.31	16				
R^2 : 0.9870 **Adjusted R^2 :** 0.9703 **Predicted R^2 :** 0.7921 **Adeq Precision :** 30.2105						

Table 11: Coefficients in Terms of Coded Factors

Factor	Coefficient Estimate	df	Standard Error	95% CI Low	95% CI High	VIF
Intercept	25.64	1	0.2051	25.16	26.12	
A-Electric field strength	1.73	1	0.1621	1.35	2.12	1.0000
B-Temperature	-0.8206	1	0.1621	-1.20	-0.4372	1.0000
C-Holding Time	-1.55	1	0.1621	-1.93	-1.16	1.0000
AB	1.48	1	0.2293	0.9353	2.02	1.0000
AC	-0.9588	1	0.2293	-1.50	-0.4166	1.0000
BC	-0.0963	1	0.2293	-0.6384	0.4459	1.0000
A^2	0.3325	1	0.2235	-0.1960	0.8610	1.01
B^2	-3.29	1	0.2235	-3.82	-2.76	1.01
C^2	-0.9362	1	0.2235	-1.46	-0.4078	1.01

Table 12: Predicted Values and Experimental Values

Electric field strength	End point temperature	Holding time	Predicted yield %	Desirability	Experimental yield
13.993	51.456	5.269	29.265	1.000	29.5
14.000	50.000	5.000	29.276	1.000	28.9
13.983	51.366	5.061	29.279	1.000	29.1
14.000	48.437	5.000	29.078	0.984	28.75
14.000	49.869	7.750	28.635	0.943	29.25

Table 13: Physicochemical property of extracted tomato seed oil

Parameter	Oil obtained without ohmic heating	Oil obtained with hmic heating as pretreatment
RI	1.4450± 0.04	1.4496± 0.01
Color (L*)	2.293 ± 0.03	4.12 ± 0.02
Specific gravity	0.8037 ± 0.23	0.814 ± 0.02
FFA % Oleic acid	2.312± 0.21	2.712 ± 0.12
SV mg KoH/g	195±1.52	198±1.63
PV meq/kg	0.73± 0.03	0.86± 0.06
IV g I/100 g	125±1.36	119±1.61

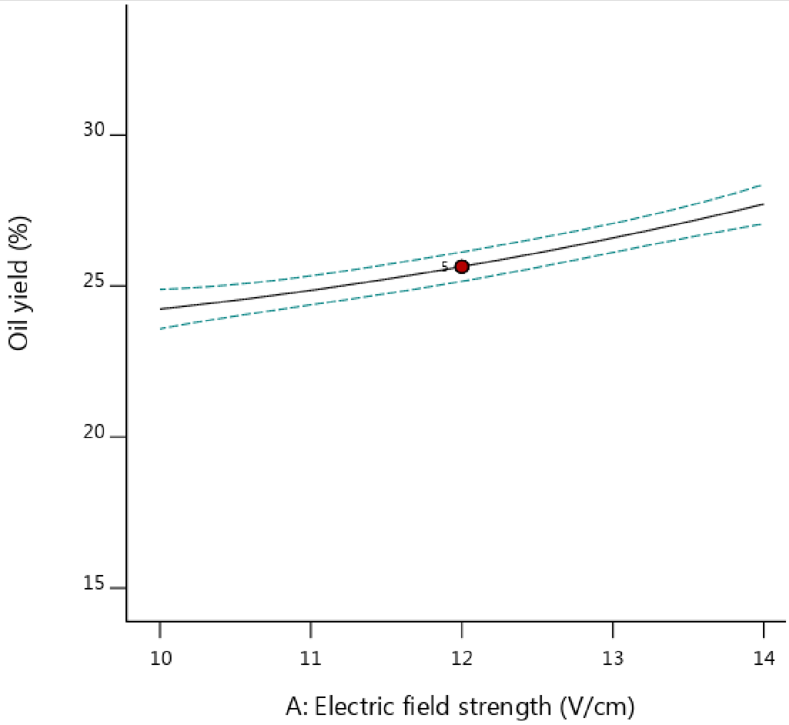

Fig. 6: Effect of Electric Field strength (V/cm) on oil yield with the end point temperature of 50^{0}C and holding at 10 mins

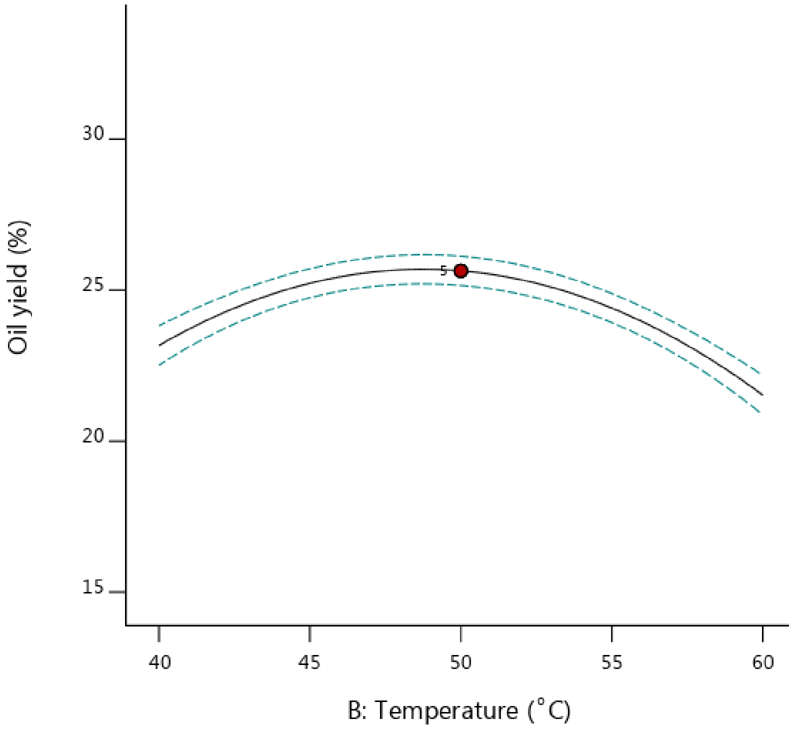

Fig. 7: Effect of end point temperature (^{0}C) on oil yield with the Electric Field strength of 12 (V/cm) and holding at 10 mins.

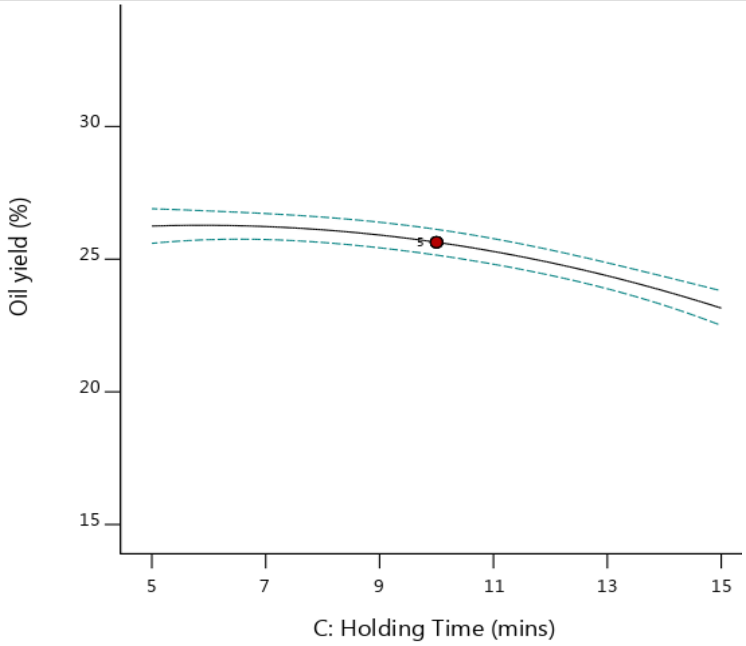

Fig. 8: Effect of holding time (mins) end point temperature (^{0}C) on oil yield with the Electric Field strength of 12 (V/cm) and end point temperature of 50 ^{0}C

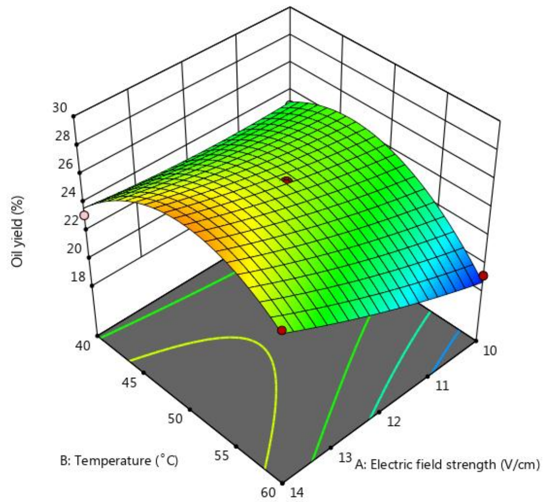

Fig. 4 a

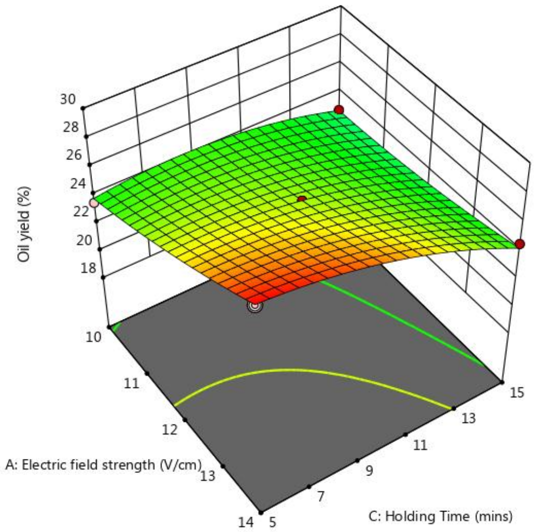

Fig. 4 b

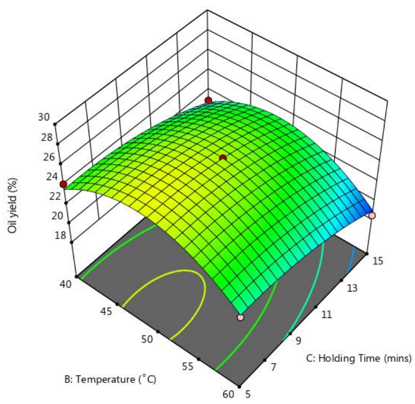

Fig. 4 c

Fig. 9: Tri-dimensional response surface contour plots showing the experimental factors and their mutual interactions on oil extraction: (a) Y = f (A, B, 10); (b) Y = f (A, 50, C); (c) Y = f (12, B, C)

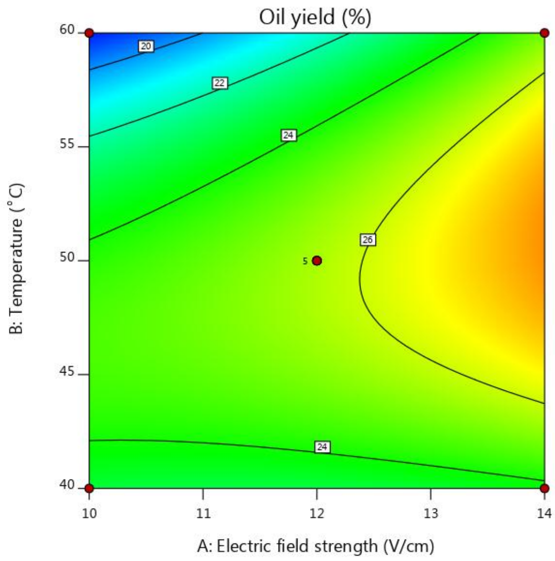

Fig. 5 a

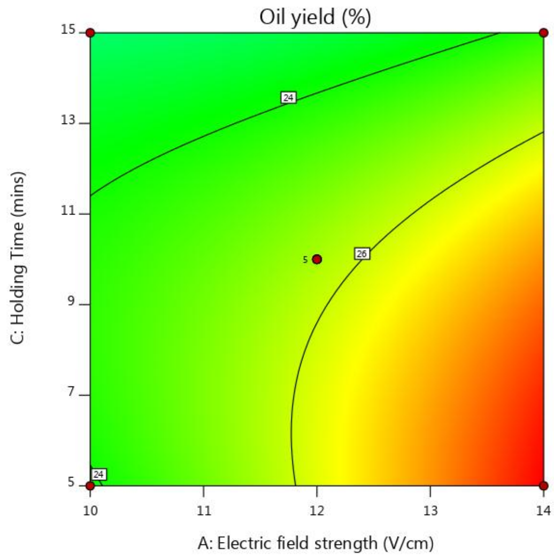

Fig. 5 b

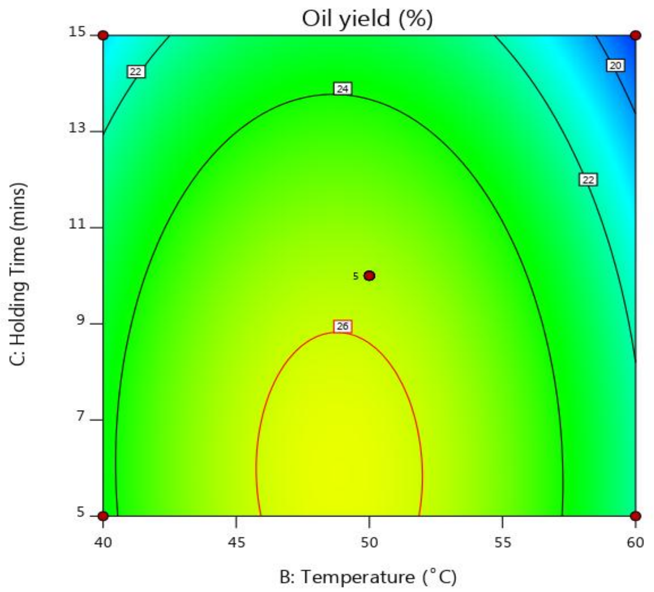

Fig. 5 c

Fig. 10: Two-dimensional response surface contour plots showing the experimental factors and their mutual interactions on oil extraction: (a) Y = f (A, B, 10); (b) Y = f (A, 50, C); (c) Y = f (12, B, C)

CONCLUSION

The effect of different process variable involved in ohmic assisted extraction on the oil yield of tomato seed waste was investigated and the higher oil extraction yielding parameter were optimized using advanced experimental design (BBD). Ohmic treatment significantly increases the oil yield by 10.84 % with regards to the control. The extraction conditions providing the highest oil yield (29.27 %) were identified as, electric field strength of 14 V/cm, end point temperature of 50 ^{0}C, and holding time of 5 min using the developed regression model. The model and the optimal conditions were verified by ANOVA for their efficacy. And the oil yield at the optimum conditions was affirmed to be 29.25 % at the laboratory trials. The physicochemical properties of extracted tomato seed oil were analysed and all the values were falls within the range. This study helps to explore the potential of novel thermal technique in magnifying the utilization of tomato seed waste into a valuable product.

Acknowledgement

The authors express their sincere gratitude to the Director, Indian Institute of Food Processing Technology, Thanjavur, Tamil Nadu for the support and facilities provided.

REFERENCES

1. Adeeko, K., & Ajibola, O., Processing factors affecting yield and quality of mechanically expressed groundnut oil. *Journal of Agricultural Engineering Research,* **45:** 31-43 (1990).
2. Anjum, F., Anwar, F., Jamil, A., & Iqbal, M., Microwave roasting effects on the physico-chemical composition and oxidative stability of sunflower seed oil. *Journal of the American Oil Chemists Society,* **83(9):** 777-784. doi:10.1007/s11746-006-5014-1 (2006).
3. Bakhshabadi, H., Mirzaei, H., Ghodsvali, A., Jafari, S. M., & Ziaiifar, A. M., The influence of pulsed electric fields and microwave pretreatments on some selected physicochemical properties of oil extracted from black cumin seed. *Food science & nutrition,* **6(1):** 111-118 (2018).
4. Cunniff, P., *AOAC. Official Methods of Analysis of AOAC International*. Retrieved from USA: (1997).
5. Dong, J., Liu, Y., Liang, Z., & Wang, W., Investigation on ultrasound-assisted extraction of salvianolic acid B from Salvia miltiorrhiza root. *Ultrasonics Sonochemistry,* **17(1):** 61-65 (2010).
6. Erickson, D. R., & Erickson, D., *Handbook of soy oil processing and utilization*: Springer (1980).
7. Gavahian, M., Chu, Y. H., & Sastry, S., Extraction from food and natural products by moderate electric field: Mechanisms, benefits, and potential industrial applications. *Comprehensive Reviews in Food Science and Food Safety,* **17(4):** 1040-1052 (2018).
8. Gavahian, M., & Farahnaky, A., Ohmic-assisted hydrodistillation technology: A review. *Trends in Food Science & Technology,* **72:** 153-161 (2018).
9. Giuffrè, A., & Capocasale, M., Physicochemical composition of tomato seed oil for an edible use: the effect of cultivar. *International Food Research Journal,* **23(2):** 583 (2016).
10. Gorji, N., Golmakani M, T., Mesbahi Gh, R., Niakosari, M., Eskandari M, H., & Mazidi, S., Studying the physicochemical properties of orange seed oil that is extracted with different methods. *Iranian Journal of Food Science and Technology*, **54(13):** 121 (2016).
11. Hamm, W., Hamilton, R. J., & Calliauw, G., *Edible oil processing*: Wiley Online Library (2013).
12. Horwitz, W., Official methods of analysis of AOAC international 17th edition. *Association of Analytical Chemists International, Gaithersburg, MD* (2000).
13. Kowittaya, A., & Asavasanti, S., *Enhancement of lime oil extraction using ohmic pretreatment.* Paper presented at the International congress on food engineering and technology (IFET2012), March (2012).
14. Kumari, K., Mudgal, V. D., Viswasrao, G., & Srivastava, H., Studies on the effect of ohmic heating on oil recovery and quality of sesame seeds. *Journal of Food Science and Technology-Mysore,* **53(4):** 2009-2016. doi:10.1007/s13197-016-2176-1 (2016).
15. Lima, M., & Sastry, S. K., The effects of ohmic heating frequency on hot-air drying rate and juice yield. *Journal of Food Engineering,* **41(2):** 115-119 (1999).
16. Liu, G., Xu, X., Hao, Q., & Gao, Y., Supercritical CO2 extraction optimization of pomegranate (Punica granatum L.) seed oil using response surface methodology. *LWT-Food Science and Technology,* **42(9):** 1491-1495 (2009).
17. Lou, Z., Wang, H., Zhang, M., & Wang, Z., Improved extraction of oil from chickpea under ultrasound in a dynamic system. *Journal of Food Engineering,* **98(1):** 13-18 (2010).

18. Loypimai, P., Moongngarm, A., Chottanom, P., & Moontree, T., Ohmic heating-assisted extraction of anthocyanins from black rice bran to prepare a natural food colourant. *Innovative food science & Emerging technologies,* **27:** 102-110 (2015).
19. Paniwnyk, L., Beaufoy, E., Lorimer, J., & Mason, T., The extraction of rutin from flower buds of Sophora japonica. *Ultrasonics sonochemistry,* **8(3):** 299-301 (2001).
20. Pare, A., Nema, A., Singh, V., & Mandhyan, B., Combined effect of ohmic heating and enzyme assisted aqueous extraction process on soy oil recovery. *Journal of food science and technology,* **51(8):** 1606-1611 (2014).
21. Praporscic, I., Lebovka, N. I., Ghnimi, S., & Vorobiev, E., Ohmically heated, enhanced expression of juice from apple and potato tissues. *Biosystems Engineering,* **93(2):** 199-204. doi:10.1016/j.biosystemseng.2005.11.002 (2006).
22. Roche, H. M., Unsaturated fatty acids. *Proceedings of the Nutrition Society,* **58(2):** 397-401 (1999).
23. Samavati, V., & Adeli, M., Isolation and characterization of hydrophobic compounds from carbohydrate matrix of Pistacia atlantica. *Carbohydrate polymers,* **101:** 890-896 (2014).
24. Shao, D., Atungulu, G., Pan, Z., Yue, T., Zhang, A., & Chen, X., Separation methods and chemical and nutritional characteristics of tomato pomace. *Transactions of the ASABE,* **56(1):** 261-268 (2013).
25. Shao, D., Atungulu, G. G., Pan, Z., Yue, T., Zhang, A., & Li, X., Study of optimal extraction conditions for achieving high yield and antioxidant activity of tomato seed oil. *Journal of food science,* **77(8):** E202-E208 (2012).
26. Shao, D., Venkitasamy, C., Li, X., Pan, Z., Shi, J., Wang, B., McHugh, T., Thermal and storage characteristics of tomato seed oil. *LWT-Food Science and Technology,* **63(1):** 191-197 (2015).
27. SHIVDAS, V. G., *STUDIES ON THE EFFECT OF OHMIC HEATING ON OIL RECOVERY FROM MUSTARD SEED.* MPUAT, Udaipur (2013).
28. Shrestha, K., Gemechu, F. G., & De Meulenaer, B., A novel insight on the high oxidative stability of roasted mustard seed oil in relation to phospholipid, Maillard type reaction products, tocopherol and canolol contents. *Food research international,* **54(1):** 587-594 (2013).
29. Tyagi, V., & Vasishtha, A., Changes in the characteristics and composition of oils during deep-fat frying. *Journal of the American oil chemists' society,* **73(4):** 499-506 (1996).
30. Zhang, Z. S., Wang, L. J., Li, D., Jiao, S. S., Chen, X. D., & Mao, Z. H., Ultrasound-assisted extraction of oil from flaxseed. *Separation and Purification Technology,* **62(1):** 192-198 (2008).