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EFFECT OF MICROWAVE PRETREATMENT ON QUALITY CHARACTERISTICS OF REFRACTANCE WINDOW DRIED ORANGE PESTIL

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Key words : *Microwave pretreatment, Orange pestil, Colour, Total phenolic content, Antioxidant activity, Refractance Window drying*

Abstract–The goal of the current investigation was to determine how microwave pre-treatment affected Refractance window drying of orange pestil based on its quality criteria like colour, ascorbic acid, total phenolic content, antioxidant activity, and rehydration ratio. Orange pulp was treated with microwave power levels of 300 W, 450 W, and 600 W at 70, 80, and 90 °C with two pulp thickness of 2 mm and 3 mm. The findings demonstrated that as the power level of microwave for pre-treating orange pulp increased the Refractance window drying colour parameters L* decreased, with the decrement ranging from 6.7% to 14.90%, a* increment ranging from 10.0% to 43.8%, and b* value decrement ranging from 17.7 to 23.60%. The dried and pre-treated samples were dark and crimson. A rising trend was observed in total phenolic content and antioxidant activity as microwave power level raised but ascorbic acid concentration declined with increasing microwave power level, declining from 19.71% to 25.91%. The highest reported total phenolic content was 40.90 mg GAE/g, and the lowest value was 28.20 mg GAE/g. In terms of their ability to scavenge diphenyl-2-picryl hydrazyl (DPPH) radicals, produced orange pestil's antioxidant activities improved. The maximum and minimum antioxidant activity concentrations were reported to be 87.70 μmol/g and 78.80 μmol/g, respectively. At increased microwave power, a reduced rehydration ratio was seen. The lowest rehydration ratio was 3.97, and the highest rehydration ratio was 5.03. Therefore, it can be inferred that a 600W microwave set at 70 °C might be used to treat orange pulp with a thickness of 2mm, protecting some specific nutrients while also increasing the pulp's overall total phenolic content and antioxidant activity.

INTRODUCTION

Citrus sinensis, also known as the sweet orange, is a representative of the citrus group, it is the most popular fruit worldwide, and according to the 3rd Advance Estimates (2019–20), India has 4.79 lakh hectares of land devoted to orange farming. The 3rd Advance Estimate states that 63.97 lakh tonnes of oranges were produced in India in 2019–20. It is also amongst the widely cultivated, utilized, and traded fruits in the world (Barbosa *et al*., 2020) and is distinguished for its distinctive flavour, appealing colour, taste, and aroma. It also contains high levels of nutrients such asVit C, phytochemicals like phenolics, minerals and carotenoids (Zou *et al*., 2016). Owing to its extreme level of Vit C content, oranges likewise have antioxidant, anticancer, and anti-inflammatory properties that support cardiovascular health (Oikeh *et al*., 2020). It can also be transformed into leather or orange pestil. Fruit pesto has a better nutritional value and can be a healthy alternative to "junk food" for kids because it is high in dietary fibre, low fat content and has plenty of antioxidants, minerals, and vitamins. Fruit pestils are dried fruit that has been reconstructed using a concentrate of a fruit juice or fruit pulp mixture and other components. Fruit pestils made from fruit pulp are palatable to consumers and filled with nutrients. They are rich in dietary fibres, carbs, minerals, vitamins, and antioxidants, all of which continue to be present in the final product (Singh and Singh, 2003). MCD Technologies, Inc. in Tacoma, Washington, created Refractance Window (RW) Technology, a cutting-edge drying technology. The RW drying set up is easy to use and maintain and the technology is relatively affordable. Conduction and radiation, as opposed to direct extreme temperature are used in this distinctive, self-contained dehydration technique to draw water from food in a Polyester film, often known as Mylar (Dupont Inc.). This is the preferred approach for conserving the priceless nutrients present in the samples, and it relies on water's thermal conductivity along with the Refractance of light. Significant organoleptic characteristics of the food, including colour, odour, sense of taste and nutritive value, are preserved during this process. Additionally, the Refractance Window drying process has a lower energy requirement when competed with other traditional dryers (Abony *et al*., 2002).

In order to mitigate the negative outcomes of dehydration and enhance the kinetics of drying, a variety of pre-treatments can be applied, including microwave, high hydrostatic pressure, pulsed electrical field, ultrasound and blanching (Zielinska and Markowski, 2016). Refractance Window drying has a lot of potential for quickening the drying process and cutting down on drying time, especially when microwave energy is used as a pre-treatment because instead of being transported, heat is produced within the tissue using this technique. Moreover, to improving drying kinetics, the use of microwaves as pre-treatment prior to drying also improves the overall quality of the finished sample. The drying characteristics of orange pulp, treated with microwave pre-treatment before Refractance Window drying, however, are not currently documented. Additionally, there are just a few studies in the literature describing the ascorbic acid content, rehydration capability, total phenolic content and total antioxidant capacity of dried orange slices. Therefore, the purpose of this study was to study the effect of Microwave pre-treatment on quality characteristics of Refractance window dried Orange Pestil at 300W, 450W, and 600W for 1 minute.

MATERIALS AND METHODS

Sweet Oranges (*Citrus sinensis*) were bought from neighbourhood market of Prayagraj, Uttar Pradesh, India. Visual assessment was used to choose oranges that were firm and had a thin, smooth skin. Peeling and deseeding of the fruits were done manually. To create a concentrated and smooth pulp, segments were blended in a mixer for one minute. The pulp was passed through a sieve until the additional juice collected in the bowl at the bottom and the resulting pulp was secured which was concentrated. The final TSS of pulp was increased to 25° Brix by adding 5% sugar powder. To ensure preservation, the pulp was frozen. Since oranges are a seasonal product in India and are only available from January to May, this step was essential to ensuring a steady supply of orange pulp. Experiments were carried out in triplicate to provide the optimum outcomes.

Refractance window drying

To conduct tests in batch mode, a float made of Mylar sheet (DuPont) with a 10 × 10 cm^2 area was used. The pulp was pre-treated in a microwave at power levels of 300, 450 and 600W before being spread out on the Mylar sheet. Orange pulp was spread on the top of mylar float in uniform thickness (2 mm and 3 mm) using a spreader. Refractance window drying was done in batch mode in a water bath at temperatures of 70, 80, and 90± 2 °C, respectively as reported by Zotarelli *et al*., 2015. In the hot water bath, the Mylar float was placed on the water's surface. The temperature of the product was always kept below 100 °C during drying. After the drying process was finished, the orange pestil was checked for residual moisture in a hot air oven (Orion, India). The orange pestil, which falls under the category of intermediate moisture food, had a desired moisture content that was maintained in the range of 15–25% (wb) (Shende *et al*., 2016).

Colour measurement

All of the microwave pre-treated samples had their colour evaluated using a Colorimeter (Konica Minolta, CM-5), and the findings were reported as L*, a*, and b* values L* denotes the product's lightness or darkness; +a* for colour, +b* for hue.

Ascorbic acid

The AOAC (1990) recommended 2, 6-dichlorophenol-indophenol titration method was used to measure ascorbic acid. The sample (10 g) was dissolved in metaphosphoric acid (3%), filtered through cheese cloth, and at that time the volume was increased to 100 ml using distilled water. A minute amount (5 ml) was then added to a 100 ml conical bottle and titrated alongside a dye, resulting in the appearance of a delicate pink hue that lasts for at least 15 seconds. Using equation (1), the total quantity of ascorbic acid was ascertained and stated as milligrams of ascorbic acid per 100 grammes of orange pestil sample.

$$\frac{\text{mg of ascorbic aicd}}{\text{100 g}} = \frac{\text{Titre × Volume made up × 100}}{\text{Aliquot extract taken × weight of a sample}}$$

Estimation of Total Phenolic Content

The Folin-Ciocalteu spectrophotometric technique was employed to evaluate the sample's total phenolic content (TPC). Gallic acid was utilized as the standard for the measurement of absorbance at 700 nm, and TPCs were reported as mg of gallic acid equivalents (GAE) per 100 g of dry weight (mg GAE/100 g dw).

Estimation of Antioxidant Activity

The antioxidant activity of the sample was determined by DPPH radical-scavenging activity and using the methods reported by (Liu *et al*., 2008).

Determination of Rehydration Ratio

A dried product's level of rehydration is a measure of its structural quality and is influenced by the processing parameters employed during pre-treatment and drying. Rehydration testing was used to determine the dried orange sheet's rehydration quality (Ranganna, 1986). Glass beakers containing the dehydrated samples, each weighing 10 g, were filled with 200 ml of water and heated between 40 °C and 45 °C for 60 minutes. Filter paper was used to drain the extra water. The samples after draining were weighed. Rehydration Ratio (RR) in the rehydrated samples was computed using formula (3):

$$\text{Rehydration Ratio} = \frac{\text{Drained weight of the rehydrated sample(g)}}{\text{weight of dehydrated sample sample (g)}}$$

$$RR = \frac{Wr}{Wd} \quad .. (3)$$

Where Wr is initial sample's weight and Wd is the sample's weight after dehydration.

Statistical Analysis

The investigation was carried out using a completely random data collection design. The "Analysis of Variance" method was used to analyse the data collected throughout the research (ANOVA). It is a process for running the test of significance regarding multiple elements and estimating the variations' component parts. The F factor was used to evaluate the importance of the treatment's effects (variance ratio). The effects of the treatment were said to be significant if the computed value of F was higher than the tabulated value of F. The level of significance in the current study was 5%.

RESULTS AND DISCUSSION

The outcomes of the quality criteria of the microwave pre-treated samples like Colour, Ascorbic Acid, Total Phenolic Content, Antioxidant Activity and Rehydration Ratio were analysed statistically and presented.

Colour

The importance of colour in consumer purchase decisions cannot be overstated. The orange pestil's colour specifications are shown in Table 1. (Fresh orange pulp and microwave pretreated orange pestil). After drying, the value of L* considerably ($p<0.05$) dropped, with the decline ranging from 6.7% to 14.90%. Dried orange pulp was substantially ($p<0.05$) darker than fresh orange pulp, according to this. The lowest L value (45.20) was displayed by sample T10 (2 mm, 450W and 70 °C, mylar sheet), and the greatest L* value (90 °C, 450W, mylar sheet) was displayed by sample T19 (56.10). L* value falls with the rise in pulp thickness and orange pestil gets darker. These outcomes are consistent with those published by Ozcan-Sinir *et al*. (2018), who found that the L*value of dried kumquats (*Citrus japonica*) was lower than that of a fresh sample. Its primary attribute, volumetric heating, where thermal energy was created directly inside the material, may be connected with the least degradation of carotenoid that gave the maximum L* value when microwave power level 450W was used.

The increment after drying, however, ranged between 10.0 and 43.8% according to a*value. Sample T10 (2 mm, 450W, 90 °C) displayed the greatest a*value of 16.07 whereas sample T19 (3mm, 600W, 90 °C) displayed the lowest value of 12.12. After drying, the b*value was lower than it was for the fresh samples. The sample T19 (3 mm, 450W, 90 °C) displayed the greatest value, 24.58, and the sample T20 (3 mm, 600W, 90 °C) displayed the lowest value, 19.20. The range of the b*value change was 17.7–23.60%. Due to the colour shifting from bright orange to reddish orange throughout the drying process, the value of b* decreased.

Due to the activity of polyphenol oxidase (PPO), orange pulp's colour changed as it dried out. According to Yemencolu *et al*., 1999, the copper-containing enzyme polyphenol oxidase (PPO) of oranges is associated with the conversion of phenolic chemicals to quinines. The orange pestil became darker and redder as the orange pulp's thickness increased. This could be because the thicker layer took longer to dry and was exposed to heat for an extended amount of time, which led to greater browning or discoloration. Orange pestil's colour could also alter as a result of pigment deterioration, the Maillard process, ascorbic acid oxidation, and enzymatic browning (Chong *et al*., 2013).

Table 1. Effect of microwave pre-treatments on colour parameters of Refractance Window dried orange pestil

Treatments	L*	a*	b*
T_0	60.10	10.69	28.26
T_1	49.10	13.12	20.95
T_2	48.19	13.15	22.10
T_3	48.05	13.24	22.95
T_4	55.56	13.35	23.10
T_5	55.15	13.42	23.10
T_6	48.15	13.24	21.20
T_7	49.20	14.02	21.45
T_8	47.48	13.85	22.00
T_9	47.50	14.91	22.00
T_{10}	45.20	15.10	22.10
T_{11}	46.26	14.98	22.15
T_{12}	51.55	15.00	22.75
T_{13}	51.24	15.22	22.98
T_{14}	51.90	13.10	23.00
T_{15}	52.00	13.00	23.22
T_{16}	52.13	13.25	23.98
T_{17}	53.10	13.95	23.00
T_{18}	54.20	14.15	23.12
T_{19}	56.10	16.07	24.58
T_{2O}	45.20	12.12	19.20

Ascorbic Acid

Ascorbic acid is a crucial determinant of the attributes of dried foods since it is susceptible to oxygen, light, and heat (Santos and Silva, 2008). Fig. 1 shows how the amount of ascorbic acid of all the orange pestil is affected by the drying conditions and microwave pre-treatments. All of the dried orange pestil had much less ascorbic acid than before ($p<0.05$). With increasing the microwave's power, the ascorbic acid content of orange pestil showed a trend toward decline. Fresh orange pulp's ascorbic acid level was determined to be 94.86 mg/ 100 g. A reduction in amount of ascorbic acid between 19.71% and 25.91% was brought on by the Refractance window drying procedure. The quick decrease in moisture content with drying temperature may be correlated to the reduction in ascorbic acid content (Mrad *et al*., 2012). The highest amount of ascorbic acid was obtained in sample T18 (3mm, 30W, 90 °C), and the lowest concentration was found in sample T11 (2mm, 600W, 90 °C). The retention at higher temperatures may be the result of a speedier drying process, which slows down ascorbic acid's oxidative destruction (Rajoriya *et al*., 2019).

Ascorbic acid content was significantly impacted by microwave processing. With an increase in microwave power, orange pestil's ascorbic acid level fell. Between 300W and 600W, it decreased greatest and least. Microwaves have a thermal effect; specifically, they induce polar molecules to rub against one another inside, creating a lot of heat (Jiang *et al*., 2005). In comparison to freshly harvested orange pulp, orange pulp processed with a microwave had a lower ascorbic acid level.

Total Phenolic Content (TPC)

The redox properties of crucial plant components known as phenolic compounds are what control their antioxidant action. (Soorbrattee *et al*., 2005). Fig. 2 displays the variations in the total phenolic content of dried orange pestil. Following pre-treatment by microwave and drying conditions, the TPC content of orange pestil rose from 28.20 mg GAE/g to 40.90 mg GAE/g. Sample T11 (2mm, 600W, 90°C) had the greatest TPC (40 mg GAE/g), while sample T15 (3mm, 300W, 80 °C) had the lowest (28.20 mg GAE/g). It might be caused by the induction of oxidative enzymes, elevated temperatures and prolonged drying times destroying phenolics, changes in chemical conmposition, and a decrease in extraction. The total polyphenol content of orange pulp showed an increasing trend after microwave pre-treatment. Additionally, a higher microwave pre-treatment of the orange pulp resulted in orange pestil that contained much more polyphenol ($p<0.05$). It may have been caused by the fruit tissue's enzymes being activated after microwave treatment of the orange pulp. Other chemicals are more effectively converted into flavonoids and polyphenols by the active enzymes. Additionally, several polyphenol molecules that were linked to proteins or amino acids were successfully liberated by microwave treatment. Furthermore, Kim *et al*. (2013) discovered that the total phenolic content of garlic exposed to various high temperature processing steps was greaterthan that of fresh garlic. They also discovered that high temperature processing altered the

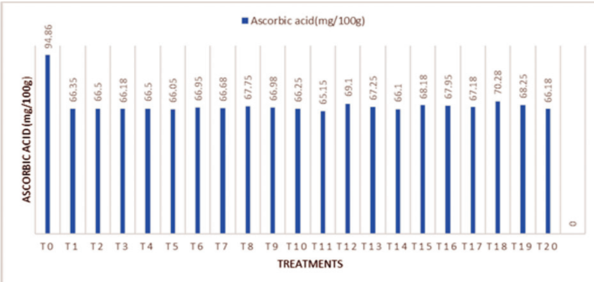

Fig. 1. Effect of microwave pre-treatments on ascorbic acid content (mg/100g) of Refractance Window dried orange pestil

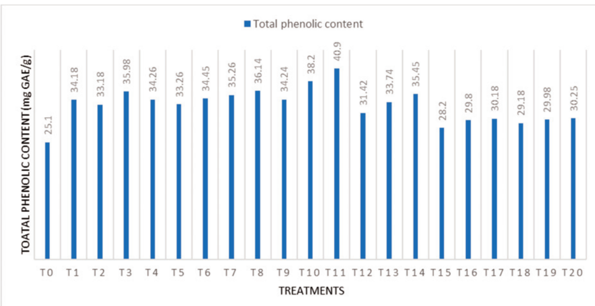

Fig. 2. Effect of microwave pre-treatments on ascorbic acid content (mg/100g) of Refractance Window dried orange pestil

quantities of each phenolic acid component.

Additionally, in the current study, phenolic compounds could have been protected against thermal and oxidative degradation by drying for a shorter period of time at 90°C as opposed to 70 °C. TPC was adversely impacted by 80°C, which may have been caused considering the impact of temperature and drying time together on nutrient retention. (Chin *et al*., 2017) noted a comparable tendency (2015).

Antioxidant Activity

It is known that the overall antioxidant activity of plant extracts studied contributes to the total phenolic content (Abdalla *et al*., 2019). Significant improvement in antioxidant capacity was seen in the current study. The antioxidant activity of orange pestil Fig. 3 increased in varied degrees compared to the fresh sample after microwave pre-treatment (p 0.05). Orange pestil produced with 450W and 600W pre-treatment shown greatest DPPH radical scavenging ability, while sample T11 (2mm, 600W, 90 °C) displayed the highest value of DPPH radical scavenging (87.70μmol /g) at 600W. Also, 300W (microwave) pre-treatment which was used to create orange pestil i.e., sample T15 (3 mm, 300 W, 80 °C, mylar sheet) exhibited the lowest capacity to scavenge DPPH radicals.

DPPH radical scavenging activity demonstrates orange pulp's capacity to deliver hydrogen atoms (Dawidowicz *et al*., 2012). The orange pulp's capacity to scavenge DPPH radicals was robust following 450W treatment of the raw material. This suggested that microwave pre-treatment could improve the content which donates hydrogen. The outcome presented above was consistent with higher levels of polyphenol. Increased flavonoid concentration and the Maillard process may be responsible for the improvement in chelating capacity. The manufactured orange pestil was able to efficiently scavenge superoxide anions and hydroxyl radicals after being exposed to 450W of microwave energy in the orange pulp. The findings indicated that the biological activity of orange pestil may be greatly increased by properly microwave-pre-treated orange pulp material. (Zhang and Zhang, 2014), who worked on apple juice, highlighted a similar discussion.

Rehydration Ratio

One of the most significant quality indicators for

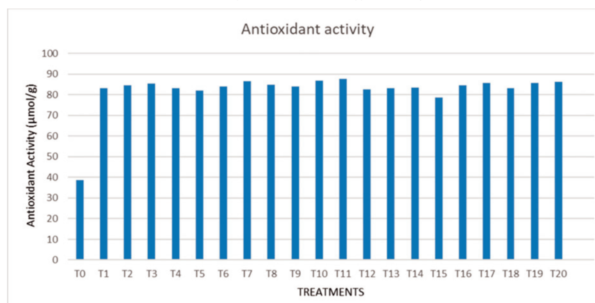

Fig. 3. Effect of microwave pre-treatments on antioxidant capacity (μmol/g) of Refractance Window dried orange pestil

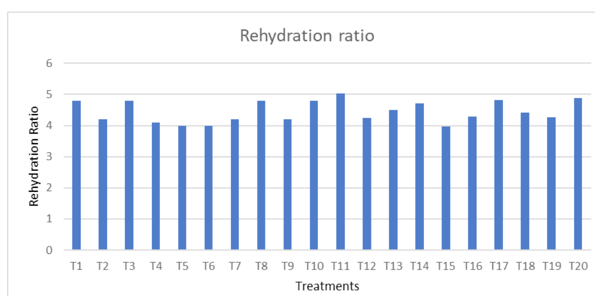

Fig. 4. Effects of microwave pre-treatments on Rehydration Ratio of Refractance Window dried orange pestil

dried samples is rehydration ratio. It also shows how much physicochemical alterations took place under pre-treatment and processing settings. Fig. 4 shows the orange pestil's rehydration ratio after it has been microwave-pre-treated and Refractance windowdried. It grew as microwave power increased. In comparison to the highest rehydration ratio of 5.03 with greater microwave power (600W) and lower temperature (90 °C), the rehydration ratio was found to be lowest at microwave power 300W and higher drying temperature (80 °C). Rapid drying may be to blame for this. However, the change was insignificant at lower microwave intensities and drying temperatures. Similar findings were reported for banana and kiwi fruit by Maskan in 2000. The degree of structural damage to the sample after microwave pre-treatment and drying determines how well orange pestil can be rehydrated (Horuz *et al*., 2017). Maximum cell disruption and the development of porous structure in orange pestil may have resulted after microwave pre-treatment at 300 W and drying at 90 °C (3mm pulp thickness). As a result, the dried orange pestil's rehydration ratio increased as microwave power was raised. Sample T11 (2 mm, 600 W, 90 °C) had the highest rehydration ratio (5.03) and sample T15 (3mm, 300 W, 80 °C) had the lowest rehydration ratio (3.97). This is in agreement with the research by (Sra *et al*., 2011).

CONCLUSION

According to the study, pre-treatment of orange pestil using a microwave (using varied power levels) before drying has a good impact on the pestil's quality. To create dehydrated orange pestil with colour change and a high ascorbic acid content, use a medium microwave power level. The highest total phenolic content, antioxidant capacity, and rehydration ratio can be produced at greater microwave power during the Refractance Window drying method. As a result, orange pulp dried by RW drying after microwave pre-treatment has higher quality features akin to the fresh sample.

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Conflict of Interest

The authors declare that they have no conflicts of interest.

REFERENCES

Abdalla, M.U.E., Taher, M., Sanad, M.I. and Tadros, L.K. 2019. Chemical properties phenolic profiles and antioxidant activities of pepper fruits. *Journal of Agricultural Chemistry and Biotechnology.* 10(7): 133-140.

Abony, B. I., Feng, H., Tang, J., Edwards, C.G., Mattinson, D.S. and Fellman, J.K. 2002. Quality retention in strawberry and carrot purees dried with Refractance Window System. *Journal of Food Science.* 67(3): 1051–1056.

AOAC, "AOAC 1990. *Official Methods of Analysis*. 15th edn. Association of Official Analytical Chemists, Arlington, VA,".

Barbosa, A.M., Rocha, T.A., Saldarriaga, J.F., Estiati, I., Freire, F.B. and Freire, 2020. Alternative drying of orange bagasse in vibrofluidized bed for use in combustion. *Chemical Engineering and Processing-Process Intensification.* 152: 107941.

Chin, S.K., Siew, E.S. and Soon, W.L. 2015. Drying Characteristics and quality evaluation of kiwi slices under hot air natural convective drying method. *International Food Research Journal.* 22 (6).

Chong, C.H., Law, C.L., Figiel, A., Wojdy³o, A. and Oziemb³owski, M. 2013. Colour, phenolic content and antioxidant capacity of some fruits dehydrated by a combination of different methods. *Food Chemistry*. 141(4): 3889-3896.

Dawidowicz, A.L., Wianowska, D. and Olszowy, M. 2012. On practical problems in estimation of antioxidant activity of compounds by DPPH method (Problems in estimation of antioxidant activity). *Food Chemistry.* 131(3): 1037-1043.

Horuz, E., Bozkurt, H., Karataº, H. and Maskan, M. 2017. Effects of hybrid (microwave-convectional) and convectional drying on drying kinetics, total phenolics, antioxidant capacity, vitamin C, color and rehydration capacity of sour cherries. *Food Chemistry.* 230 : 295-305.

Jiang, Y.H., Jiang, X.L., Wang, P. and Hu, X.K. 2005. *In vitro* Antioxidant activities of water-soluble polysaccharides extracted from Isariafarinosa B05. *Journal of Food Biochemistry*. 29(3) : 323–335.

Kim, J.S., Kang, O.J. and Gweon, O. C. 2013. Comparison of phenolic acids and flavonoids in black garlic at different thermal processing steps. *Journal of Functional Foods.* 5(1): 80-86.

Liu, X., Cui, C., Zhao, M., Wang, J., Luo, W., Yang, B. and Jiang, Y. 2008. Identification of phenolics in the fruit of emblica (*Phyllanthus emblica* L.) and their antioxidant activities. *Food Chemistry*. 109(4): 909-915.

Maskan, M. 2000. Microwave/air and microwave finish drying of banana. *Journal of Food Engineering*. 44(2): 71-78.

Mrad, N.D., Boudhrioua, N., Kechaou, N., Courtois, F. and Bonazzi, C. 2012. Influence of air-drying temperature on kinetics, physicochemical properties, total phenolic content and ascorbic acid of pears. *Food and Bioproducts Processing*. 90(3): 433-441.

Oikeh, E. I., Oviasogie, F.E. and Omoregie, E.S. 2020. Quantitative phytochemical analysis and antimicrobial activities of fresh and dry ethanol extracts of *Citrus sinensis* (L.) Osbeck (sweet Orange) peels. *Clinical Phytoscience*. 6(1): 1-6.

Ozcan-Sinir, G., Ozkan-Karabacak, A., Tamer, C. E. and Copur, O. U. 2018. The effect of hot air, vacuum and microwave drying on drying characteristics, rehydration capacity, color, total phenolic content and antioxidant capacity of Kumquat (*Citrus japonica*). *Food Science and Technology*. 39: 475-484.

Rajoriya, D., Shewale, S.R. and Hebbar, H.U. 2019. Refractance window drying of apple slices: Mass transfer phenomena and quality parameters. *Food and Bioprocess Technology*. 12(10): 1646-1658.

Ranganna, S. 1986. *Handbook of Analysis and Quality control for Fruit and Vegetable Products*. Tata McGraw-Hill Education.

Santos, P.H.S. and Silva, M.A. 2008. Retention of vitamin C in drying processes of fruits and vegetables -A review. *Drying Technology*. 26(12): 1421-1437.

Shende, D., Shrivastav, A. and Datta, A.K. 2016. Effects of thickness of mango puree on refractance window drying to make mango leather. *Emerging technologies in agricultural and food engineering (ETAE-2016)*. Excel India Publisher, New Delhi, India, IIT Kharagpur. 170-177.

Singh Gujral, H. and Singh Brar, S. 2003. Effect of hydrocolloids on the dehydration kinetics, color, and texture of mango leather. *International Journal of Food Properties*. 6(2): 269-279.

Soobrattee, M.A., Neergheen, V.S., Luximon-Ramma, A., Aruoma, O.I. and Bahorun, T. 2005. Phenolics as potential antioxidant therapeutic agents: mechanism and actions. *Mutation Research/Fundamental and Molecular Mechanisms of Mutagenesis*. 579(1-2): 200-213.

Yemenicioðlu, A., Özkan, M. and Cemeroðlu, B. 1999. Some characteristics of polyphenol

Zhang, S. and Zhang, R. 2014. Effects of microwave pretreatment of apple raw material on the nutrients and antioxidant activities of apple juice. *Journal of Food Processing, 2014*.

Zielinska, M. and Markowski, M. 2016. The influence of microwave-assisted drying techniques on the rehydration behavior of blueberries (*Vaccinium corymbosum* L.). *Food Chemistry*. 196:1188-1196.

Zotarelli, M. F., Carciofi, B. A. M. and Laurindo, J. B. 2015. Effect of process variables on the drying rate of mango pulp by Refractance Window. *Food Research International*. 69: 410-417.

Zou, Z., Xi, W., Hu, Y., Nie, C. and Zhou, Z. 2016. Antioxidant activity of Citrus fruits. *Food Chemistry*. 196: 885-896