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Research Paper

Convective Hot Air Drying of Pomegranate Peel and Study its Physcio-chemical Properties

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ABSTRACT

The aim of the present study was to determine the drying characteristics of pomegranate peel and its physicochemical and functional properties of pomegranate peel powder (PPP). Pomegranate peel were dried at different temperatures i.e. 40°C, 50°C, 60°C in convective hot air dryer and powdered. Drying experiments were performed at constant air velocity of 2.0 m/s and thickness of 5 mm for pomegranate peels. The drying time decreased with increase in drying air temperature. Drying models i.e. Newton, Page, Henderson and Pabis, Logarithmic and Verma were fitted to the experimental data on moisture ratio with respect to time. The Verma model fitted well $r^2 \geq 0.996$ and $MSE \leq 1.79910^{-3}$ among all the models tested for the experimental data. Effective diffusivity from this study was 1.65×10^{-8}, 1.975×10^{-7} and 1.90×10^{-7}during the drying temperature of 40°C, 50°C and 60°C respectively. The activation energy E_a for moisture diffusion was found to be 6.205 kJ/mole .Average Moisture content of 7.94 to 10.49 % (db) was observed, while average percent ash, fiber, protein and fat contents were 2.75to 3.19 %, 13.21 to 17.53 %, and 3.08 to 4.37 % and 1.80 to 2.20 % respectively. The ascorbic acid, bulk density, water holding capacity, oil holding capacity, colour *L*, *a*, and *b* was in the range of 6.01 to 6.75 mg/g, 0.51 to0.80 g/c, 2.43 to 2.69 ml/g, and 0.91to 0.98 ml/g respectively in the experimental temperature range studied. The ascorbic acid decrease, bulk density increase, water holding capacity decreases, oil holding capacity also decreases. The colour "*L*" value increases with increases in temperature.

Keywords: Pomegranate peel powder, Drying characteristics, Physico-chemical properties

Pomegranate fruits (*Punica granatum L.*) belong to *Punicaceae* family pomegranate grows well in semiarid, mild temperate to subtropical climates and is naturally adopted to regions with cool winters and summers. The fruit is nearly round ranging from 2.5 * to 5 * in diameter with a tough leathery skin or rind of yellow to red color. The interior of the fruit is separated by whitish spongy membranous walls into compartments packed with juicy corn arils which are pink red in appearance with sweet-tart taste. Each aril contains a soft to hard white or red angular seed. Seeds represents about 52% weight of the whole fruit (Morton, 1987).

The seed and surrounding pulp (arils) are the edible portion of the Pomegranate and are commonly used for the preparation of juice, syrup, jelly, food seasoning and colouring agents. Pomegranate fruits peel is a byproduct from juice processing industries was reported to contain a series of bioactive compounds, minerals and fiber for wide range of dietary requirement (Mirdeghan and Rahemi, 2007).

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Pomegranate fruits peel is an inedible part obtained during processing of pomegranate juice. Inedible part contain antioxidant phenolic compounds and flavonoids high quantities (Li *et al*. 2006). Pomegranate peel is a rich source of tannins, flavonoids and other phenolic compounds, and antioxidant and antibacterial properties. Pomegranate peel has received less attention as natural preservatives in meat (Li *et al*. 2006). The peel (outer thick skin or rind) provides a rich source of punicalins (PC), Punicalagins (PG) and elagic acids (EA) Punicalagins are reported their beneficial effects against dysentery, hemorrhage helminthiasis, diarrhea and acidosis. (Miguel *et al.* 2010.)

Pomegranate antioxidants have been identified as the active antioxidant compound and anticancer activities responsible for protecting cholesterol. Pomegranate peel contain luteolin, quercetin, kaempferol, gallagic, EA glycosides, EA punicalagin, punicalin, pendunculagin, constituents. Pomegranate peel have high moisture contents which can reduced to extraction higher added value product (Shabtay *et al*. 2008).

Pomegranate are cultivated and consumed globally. India is largest producers of pomegranate, followed by Iran and China, United State is among the top ten producers of pomegranate (World pomegranate Market, 2015).

Drying is an ancient process used to preserve and prolong shelf life of various food products (Ratti, 2009). The main aim of drying food of products is to remove water in the solid to a level at which microbial spoilage and deterioration resulting from chemical reactions is significantly reduced (Krokida *et al.* 2003; Chiewchan *et al.* 2015). This enables the product to be stored for longer periods since the activity of microorganisms and enzymes is inhibited through drying (Alibas *et al*. 2001; Jayaraman *et al.* 2000). Generally, drying involves the application of thermal energy which cause water to evaporate into the vapor phase. However, drying results in structural, chemical and phytochemical changes that can affect quality properties such as texture, color and nutritional values (Maskan *et al.* 2000; Attanasio *et al.* 2004. Di Scala *et al.* 2008). Various researchers reported the drying characteristics of agricultural byproducts, pomaces, and wastes including vegetable (Lopez *et al.* 2006), apple (Wang *et al*. 2007 and Sun *et al.* 2007), Olive, (Freire *et al.* 2001; Jumah *et al.* 2007; Meziane *et al.* 2011), grape (Celma *et al*. 2009), and tomato (Kaur *et al*. 2009; Al-Muhtasab *et al*. 2010). Studies on the drying characteristics of pomegranate peels is very scare.

Various researchers have used the dried pomegranate peel powder into the value added products like cookies, pan bread, bread, noodles (Ismail *et al.* 2014; Shrivastava *et al*. 2014; Mehder 2013; Bandal *et al.* 2014). Utilization of pomegranate peel powder and peel extracts has been successfully experienced in various food preparations including meat and meat products, edible oils, bakery products and jellies (Altunkaya *et al*. 2013; Devatkal *et al.* 2012; Iqbal *et al*. 2008; Kanatt *et al*. 2010; Naveena *et al.* 2008; Ventura *et al*. 2013).

In the present investigation the drying characteristics of pomegranate peel at 40°C, 50°C and 60°C has been studied. The dried product quality i.e. nutritional and functional quality has been evaluated i.e. Protein, fat, fiber, ash, carbohydrate ascorbic acid, bulk density, water absorption capacity, oil absorption capacity and color in terms of L, a ,b, has been studied .

MATERIALS AND METHODS

Collection of plant materials

Fresh, healthy disease free pomegranate fruit were obtained from the farmer's field from Akluj (Village) District Solapur, Maharashtra, India.

Drying of Pomegranate peel

1. Moisture content Determination

The initial moisture content of the fresh pomegranate peel and peel dried at 40˚C, 50˚C and 60˚C, were determined by AOAC (2010). 10-15 g of the pomegranate peel samples was taken in to each three different moisture boxes. The initial weight of moisture box was recorded. The samples were exposed to 105˚C ± 1˚C for 24 hr. in a hot air oven (Make M/s: Aditi Associate, Mumbai. Model: ALO-136). The final weight was recorded. The moisture content of the sample were determined by equation (1) the experiment was repeated for three times for replication, the average reading reported.

$$\text{Moisture content (\% db)} = \frac{W_2 - W_1}{W_3 - W_1} \times 100 \quad \ldots(1)$$

Where,

W_1 = Weight of moisture box, *g*

W_2 = Weight of moisture box + sample *g*

W_3 = Weight of moisture box + oven dried sample, *g*

2. Convective hot air drying

Pomegranate fruit were washed to remove dirt; dust using tap water, diseased infected portion was removed. The Pomegranate fruits were peeled manually and peel was cut into slices. The peels were cut into small pieces having thickness 5mm. Convective hot air drying of Pomegranate peel was performed at the Department of Post-Harvest Engineering, Post Graduate Institute of Post-Harvest Management (PHM), Killa-Roha. Convective hot air dryer of capacity 60kg (Make: M/ Sagar Engineering work, Kudal (India) was used for this study. The size of the tray was 500mm×500mm×20mm there were 5.no. of trays. The temperature of the drying was kept 40˚C, 50˚C and 60˚C ± 1˚C. The pomegranate peel drying was carried out in a thin layer drying. The air velocity inside the dryer was 2 m/s. The weight loss w.r.t. time was recorded from the trays at different locations in the tray dryer. The moisture content w.r.t. time was calculated from the drying data the moisture ratio w.r.t. time was also determined the dried mass was then grounded by a grinder (Make: Jaipan, India) and sieved. Finally, the yellowish product was the desired Pomegranate peel powder. Fig (a) to (c) shows the powder prepared from various treatments of drying of pomegranate peel at 40˚C, 50˚C and 60˚C respectively.

3. Drying model

Moisture Content (% db) versus drying time (min) and drying rate (g of water removed/ 100g bone dry material/min) with respect to moisture content was determined for drying of pomegranate peel. Moisture ratio versus drying time (min) was also determined from the experimental data.

Table 1: Mathematical models tested with the moisture ratio of pomegranate peel

Sl. No.	Model	Equation	Reference
1	Newton	MR = exp (-kt)	Westerman *et al.* 1973
2	Page	MR = exp (-kt^n)	Zhang and Litchfield, 1991
3	Henderson and pabis	MR = a.exp (-kt)	Henderson and Pabis, 1961
4	Logarithmic	MR=aexp(−kt)+c	Wang *et al.* 2007
5	Verma *et al.*	MR=aexp(−kt)+(1−a) exp(−gt)	Akpinar *et al.* 2006

Various mathematical models listed in Table 1 were tested on the experimental data on moisture ratio versus drying time in minutes of pomegranate peel with convective hot air drying. The moisture ratio determines the unaccomplished moisture change, defined as the ratio of the free water still to be removed, at time t over the initial total free water (Henderson and Pabis, 1961).

4. Moisture ratio

The moisture ratio of pomegranate peel was calculated following formula (Chakraverty, 2005).

$$\text{Moisture ratio} = \frac{M - M_e}{M_0 - M_e} \quad \ldots(2)$$

Where,

MR = Moisture ratio

M = Moisture content at any time θ, %(db)

M_e = EMC, % (db)

M_0 = Initial moisture content, %(db)

The root mean square error was determined for the best fit of the model. The best fit of the model was determine for higher R^2 values and lower root mean square error.

$$\text{RMSE} = \left[\frac{1}{N}\sum_{i=1}^{n}(MR_{exp} - MR_{pre})^2\right]^{1/2} \quad \ldots(3)$$

Where,

MR_{exp} = experimental moisture ratio

MR_{pre} = predicted moisture.

N and *n* are the number of observations and the number of constants respectively (Togrul and Pehlivan, 2004).

5. Correlation regression coefficient and error analysis

The goodness of fit of the tested mathematical models to the experimental data was evaluated with the correlation coefficient (r^2), chi-square (χ^2) and the RMSE equation (3). The higher the r^2 value and lower the chi-square (χ^2) equation (3) and lower value of RMSE values, the better is the goodness of fit (Ozdemir *et al*. 1999; Ertekin and Yaldiz., 2004; Wang *et al.* 2007). According to Wang *et al.* (2007) reduced chi-square (χ^2) and root mean square error (RMSE) can be calculated as follows.

$$\chi^2 = \frac{\sum_{i=1}^{N}\left(MR_{exp,i} - MR_{pre,i}\right)^2}{N - Z} \quad \ldots(4)$$

Where,

$MR_{exp,i}$ = is the i^{th} experimental moisture ratio,
$MR_{pre,i}$ = is the i^{th} predicted moisture ratio ,
N = is the number of observations, and
z = is the number of constant.

The non-linear regression analysis was performed by using the statistical software SAS 6.5.

6. Effective moisture diffusivity

The effective moisture diffusivity for drying of pomegranate peel was calculated by using the simplified Fick's second law of diffusion model (Doymaz, 2011) as given in Eq (5).

$$\frac{\partial M}{\partial t} = D_{eff} \,.\, \nabla^2 M \quad \ldots(5)$$

Where,

M = is moisture content (kg water/kg dry matter);

t = is the time (s);

D_{eff} = is the effective moisture diffusivity, (m^2/s);

∇^2 = is the differential operator.

Solution of Fick's second law in slab geometry, with the assumption that moisture migration was caused by diffusion, negligible shrinkage, constant diffusion coefficient and temperature was given by Crank (1975) as follows:

$$MR = \frac{8}{\pi^2}\sum_{i=1}^{n}\frac{1}{(2n-1)^2}\exp\left(\frac{-(2n-1)^2\pi^2 D_{eff\,t}}{4H^2}\right) \quad \ldots(6)$$

Where,

H = is the half thickness of the slab m;

n = 1, 2, 3 … the number of terms taken into consideration.

For long drying time Eq (7) can be simplified further (Lopez *et al.* 2000; Doymaz, 2011) as:

$$\text{l}(MR) = \ln\frac{8}{\pi^2} - \frac{\pi^2 D_{eff\,t}}{4L^2} \quad \ldots(7)$$

The diffusivities are typically determined by plotting the experimental drying data in the terms of *ln* (*MR*) vs drying time (*t*) in equation (8), because the plot gives a straight line with the slope as follows:

$$\text{Slope} = \frac{\pi^2 D_{eff}}{4L^2} \quad \ldots(8)$$

Where,

L= half thickness

7.Activation Energy for drying of Pomegranate peel

The effective moisture diffusivity of the samples was estimated by using the simplified mathematical Fick's second diffusion model (Equation 7). The activation energy of the samples was obtained by plotting the natural logarithm of D_{eff} against the reciprocal of absolute temperature, then determining the slope of the straight line by using (Equation 8). Activation energy was obtained by plotting the natural logarithm of D_{eff} against the reciprocal absolute temperature. Lopez *et al*. (2000) and Simal *et al.* (1996) represented diffusivity as temperature dependent with Arrhenius expression as;

$$D_{eff} = D_o . exp.\left(\frac{-E_a}{R(T + 273.15)}\right) \quad \ldots(9)$$

Where,

D_o = the pre-exponential factor of the Arrhenius equation, m^2/s;

E_a = the activation energy (kJ/mol);

T = the temperature of air, °C;

R = the universal gas constant, kJ/ (mol·K)

Rearranging Equation (9) gives Equation (10):

$$(In)\ (D_{eff}) = In(D_o) - \frac{E_a}{R(T + 273.15)} \quad \ldots(10)$$

Energy of activation can thus be calculated from Equation (10), which gives a relationship between temperature and effective moisture diffusivity. The plot of Ln (D_{eff}) versus 1/ (T+273.15) gives a straight line (slope of $K_L = E_a/R$). Linear regression analysis was used to fit the equation to the experimental data to obtain the coefficient of determination (R^2).

Proximate Compositions

1. Protein

Protein in the fresh pomegranate peel and powder prepared powder at 40 °C, 50 °C, and 60 °C was determined by a micro-Kjeldahl distillation method (AOAC 1990). The Pomegranate peel were digested by heating with concentrated sulphuric acid (H_2SO_4) in the presence of digestion mixture, potassium sulphate (K_2SO_4) and copper sulphate ($CuSO_4$). The mixture was then made alkaline with 40% NaOH. Ammonium sulphate thus formed. Released ammonia which was collected in 4% boric acid solution and titrated again standard HCL. The percent nitrogen content of the sample was calculated the formula given below. Total protein was calculated by multiplying the amount of percent nitrogen with appropriate factor (6.25). The experiment was repeated three times and average reading was repeated.

$$\%\ N = \frac{(Sample\ titre - Blank\ titre) \times N\ HCL \times 1.4 \times 100}{Weight\ of\ sample} \times 100 \quad \ldots(11)$$

% Protein = % N × Factor (6.25).

2. Ash Content

The ash content of fresh pomegranate peel and powder prepared at 40°C, 50°C, and 60°C was determined using the method of AOAC (1990) porcelain crucible were dried and cooled in desiccators before weighing. Five grams of the pomegranate peel were weighed into the crucible and the weight was taken. The crucible containing the samples were placed into the muffle furnace and muffle furnace at 500˚C. This temperature was maintained for three hours. The muffle furnace was then allowed to cool; the crucibles were then brought out, cooled and weighed. The ash content was calculated as follow. The experiment was repeated three times and average reading was repeated.

$$\%\ \mathrm{Ash} = \frac{W_2 - W_1}{\text{weight of sample}} \times 100 \quad \ldots(12)$$

Where,

W_1 = weight of empty crucible.

W_2 = weight of crucible + ash,

3. Fat Content

The fat content of the fresh pomegranate peel and prepared powder at 40°C, 50°C, and 60°C was determined using solvent extraction in a soxhlet apparatus as described by James, (1995) Two grams of each of the pomegranate peel were wrapped in a filter paper and placed in a soxhlet reflux flask which is connected to a condenser on the upper side and to a weighed oil extraction flask full with two hundred mile petroleum ether. The ether was brought to its boiling point, the vapor condensed into the reflux flask immersing the samples completely for extraction to take place on filling up the reflux flask siphons over carrying the oil extract back to the boiling solvent in the flask. The process of boiling, condensation, and reflux was allowed to go on for four hours before the defatted samples were removed. The oil extract in the flux was dried in the oven at 60˚C for thirty minutes and then weighed. The experiment was repeated three times and average reading was repeated.

$$\%Fat = \frac{W_4 - W_3}{W_2 - W_1} \times 100 \quad \ldots(13)$$

Where:

W_1 = weight of oven dried thimble,

W_2 = weight of sample used,

W_3 = weight of round bottom flask,

W_4 = weight of round bottom flask with fat residue.

4. Crude Fiber

About 2 g fat free residue of fresh pomegranate peel and prepared powder at 40°C, 50°C, and 60°C was taken and then transferred to the digestion flask. 200 ml boiling sulphuric acid was added and immediately the flask was connected to condenser. The flask was heated, boiled by frequently rotating for 30 min and the volume was maintained with hot water. Then filtered through filter cloth in a fluted funnel. The residue was washed on cloth with hot water or potassium sulphate solution. The residue was returned to digestion flask by washing with hot water. 200 ml boiling sodium hydroxide was added and boiled for 30 min. The volume was adjusted with boiling water, filtered it thorough the muslin cloth and the residue free of alkali was washed. The residue was transferred into crucible and washed with 15 ml alcohol and the crucible was dried at 110°C for 2 hrs. The crucible was cooled in desiccators and weighed the crucible was ignited in the furnace at 550 °C for 30 min then cooled and weighed. The loss in weight represented the crude fiber. The experiment was repeated three times and average reading was repeated.

$$Crude\ fiber\ (\%) = \frac{(W_1 - W_2)}{Weight of sample (g)} \times 100 \quad \ldots(14)$$

Where,

W_1 = Weight of material before ashing (g)

W_2 = Weight of material after ashing (g)

5. Carbohydrate Content

Carbohydrate content fresh Pomegranate peel and prepared powder at 40˚C, 50˚C and 60˚C were determined by subtracting the total sum of protein, fiber, ash and fat from the total dry matter (James, 1995). The carbohydrate was calculated by using following equation (15);

% Carbohydrate = 100 – (%protein + % fat + % fiber + % ash + % moisture content) …(15)

6. Ascorbic acid (Vit. C)

The ascorbic acid of fresh pomegranate peel and powder prepared by drying peel at 40°C, 50°C, 60°C was determined. Determination of ascorbic acid was done by 2, 6-dichlorophenol indophenol dye method of Johnson (1948) as described by Ranganna (1986).

A sample of 10 g was mixed with 3 per cent metaphosphoric acid solution and volume was made to 100 ml. The extract was filtered through filter paper and 10 ml aliquot was titrated against standard dye solution at room temperature to pink end point. The ascorbic acid content of the sample was calculated taking into consideration the dye factor as given below equation (16). The experiment was repeated for three times for replicated;

$$\frac{\text{Titre} \times \text{Dye factor} \times \text{Volume made up}}{\text{Aliquot of extract taken for estimation} \times \text{Wt. or volume of sample taken for estimation}} \times 100 \quad \ldots(16)$$

7. Bulk density (g/ml)

The bulk density of Pomegranate peel powder prepared from dried at 40°C, 50°C, and 60°C determined according to the method described by (Vengaiah *et al.* 2013). A graduated measuring cylinder of 10 ml was weighed pomegranate peel powder filled in to it by constant tapping until there was no further change in volume. The cylinder with the sample was weighed and the difference in weight was determined. The experiment was replicated for 5 times the average value of bulk density was reported. The bulk density was calculated by using following equation (17);

$$\text{Bulk density}\left(\frac{g}{ml}\right) = \frac{W_2 - W_1}{\text{volume of sample}} \times 100 \quad \ldots(17)$$

Where

W_1 = wt. of measuring cylinder

8. Water absorption capacity (g/ml)

Water absorption of Pomegranate peel powder dried at 40°C, 50°C, and 60°C was determined using the method of Sosulski (1962) with slight modifications. The sample, 3g was dispersed in 25ml of distilled water and placed in pre weighed centrifuge tubes. The dispersions were stirred occasionally. After a holding period of 30min, the dispersions were centrifuged at 5000 rpm for 25min. The supernatant was removed and the pellet was dried at 50 °C for 25min which was cooled and weighed. The water absorption capacity was expressed as grams of water retained in the material. The experiment was repeated for three times for replication.

$$\text{WAC}\left(\frac{g}{ml}\right) = \frac{(W_2 - W_1)}{W_0} \times 100 \quad \ldots(18)$$

Where,

W_0 = the weight of the sample, *g*;

W_1 = the weight of centrifuge tube plus sample, *g* and

W_2 = the weight of centrifuge tube plus the sediments.

9. Oil absorption capacity (g/ml)

Oil absorption of Pomegranate peel powder at 40°C, 50°C, and 60°C was determined using the method of Sosulski (1962) with slight modifications. The sample, 3g was dispersed in 25ml of oil and placed in pre weighed centrifuge tubes. The dispersions were stirred occasionally. After a holding period of 30min, the dispersions were centrifuged at 5000 rpm for 25min. The supernatant was removed and the pellet was dried at 50 °C for 25min which was cooled and weighed. The oil absorption capacity was expressed as grams of water retained in the material. The experiment was repeated for three times for replication.

$$\text{OAC (g/ml)} = \frac{(W_2 - W_1)}{W_0} \times 100 \quad \ldots(19)$$

Where,

W_0 = the weight of the sample, *g*;

W_1 = the weight of centrifuge tube plus sample, *g* and

W_2 = the weight of centrifuge tube plus the sediments

10. Colour Determination

Colour of Pomegranate peel powder at 40°C, 50°C, and 60°C was measured by using Konica Minolta colour Reader. (Make: Minolta Camera Co. Ltd. Japan Model: (R-10). The colour of the pomegranate peel was measured in dark room. Pomegranate peel powder at 40°C, 50°C, and 60°C was placed on white surface and placing colour reader on the powder in a Petri dish and the colour was measured in *L, a, b* were reported. Where *L* value indicates degree of lightness or darkness, '*a*' value indicates redness or greenness and '*b*' value indicates the yellowness or blueness.

Convective hot air drying of Pomegranate peel

Fig. 1 shows moisture content % (db) with respect to time (min) of pomegranate peel dried by convective hot air dryer. The pomegranate peel were dried from average initial moisture content of 199.5% (db) to 10.480% (db) at 40°C; 166.2% (db) to 8.688% (db) at 50°C; 141.6% (db) to 8.584% (db) at 60°C respectively. It took around 20 h, 19h and 16 h time to dry the product at 40°C, 50°C, and 60°C respectively. Fig. 2 shows the drying rate (g water removed/100 g of bone dry material /min) with respect to moisture content % (db) of pomegranate peel dried by convective hot air drying at 40°C, 50°C, and 60°C. The initial drying rate of pomegranate peel was 0.347 g of water removed / 100 g of bone dry matter per minute and decreases up to the 0.022g of water removed / 100 g of bone dry matter per minute at 40°C; 0.397 g of water removed / 100 g of bone dry matter per minute and decreases up to the 0.022 g of water removed / 100 g of bone dry matter per minute at 50°C; 0.438 g of water removed / 100 g of bone dry matter per minute and decreases up to the 0.023 g of water removed / 100 g of bone dry matter per minute at 60°C.

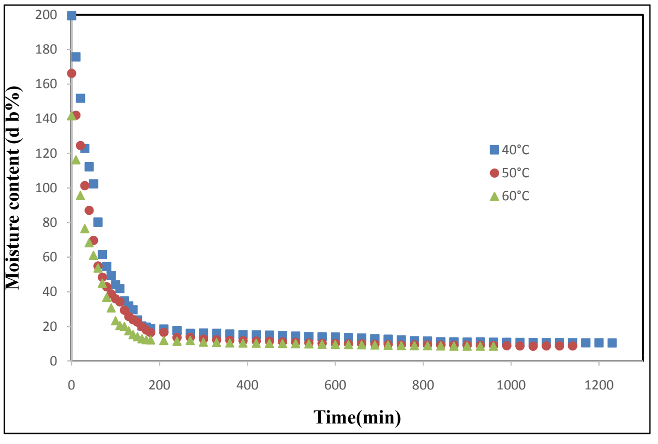

Fig. 1: Moisture content %(db) versus time (min) by convective hot air drying at different temperature for Pomegranate peel

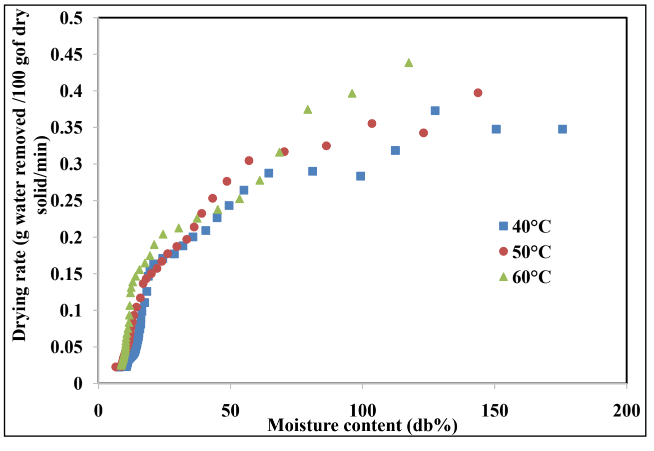

Fig. 2: Drying rate (g water removed/100 g of bone dry material/min) versus moisture content % (db) of Pomegranate peel dried by convective hot air drying method at 40°C, 50°C, and 60°C

From Fig. 2 it was observed that the drying took place in falling rate period. As the temperature of drying increases from 40°C to 60°C the drying rate increases. Moisture removal inside the pomegranate peel at 60°C was higher and faster than the other investigated temperature. Migration of surface moisture and evaporation rate from the surface to the air decreases with decrease of the moisture in the product. The shorter time of drying was observed at higher temperature thus increased drying rate (Zhu and Shen, 2014). This increase in drying rate because of the increased heat transfer potential between the air and pomegranate peel which favours the evaporation of water from pomegranate peel.

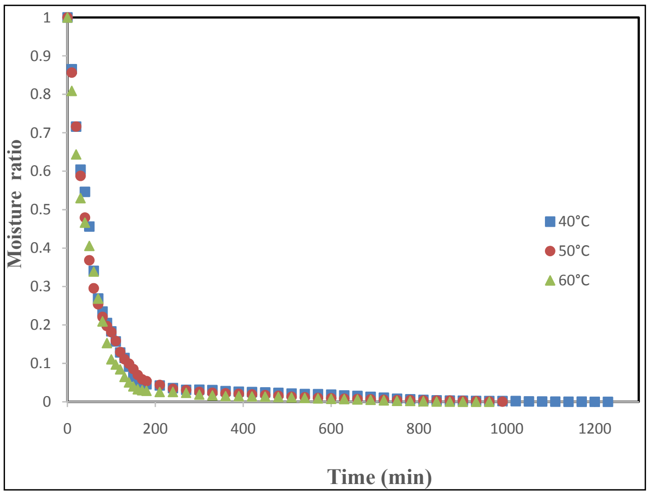

Fig. 3: Variation in Moisture ratio with respect to time, min for pomegranate peel during convective hot air drying at 40°C, 50°C, 60°C

Fig. 3 shows variation in moisture ratio with respect to time in minute. During the drying experiment moisture ratio decreases from 1 to 1.88×10^{-8}, 1 to 2.291×10^{-9} and 1 to 1.33×10^{-5} at the drying temperature of 40°C, 50°C and 60°C respectively.

Evaluation of thin layer-drying model of Pomegranate peel dried by convective hot air drying

The Table 2 (a), 2(b) and 2 (c) shows the model parameters of various model fitted to the experimental data for Newton model, Page model, Henderson and Pabis, Logarithmic, Verma etc. at 40°C, 50°C and 60°C by convective hot air drying of pomegranate peel respectively. Among the models fitted to the experimental data at 40°C, 50°C and 60°C the Verma model was well fitted to the experimental data with $R^2 \geq 0.996$., MSE$\leq 1.799 \times 10^{-4}$ and chi square (χ^2) $\leq 9.176 \times 10^{-3}$ at 40°C and 50°C drying time and logarithmic model with $R^2 \geq 0.996$; MSE $\geq 1.90 \times 10^{-4}$; $\chi^2 = 7.799 \times 10^{-3}$ at 60°C. Non Linear regression analysis was done according to the five thin layer models for moisture ratio data. In conclusion, the proposed model gave better predictions than others, and satisfactorily described the drying characteristics of pomegranate peels, and similar results for different agricultural crops and byproducts i.e. grape, mango, tomato could be seen (Celma *et al*. 2009; Muhtasab *et al.* 2010; Demir *et al.* 2010; Celma *et al.* 2009).

Effective moisture diffusivity of Pomegranate peel dried by convective hot air drying

Fig. 4 shows Ln (MR) versus time (minute) for convective hot air drying of pomegranate peel dried at 40°C, 50°C and 60°C respectively. The graph shows the straight line curve. The straight line equation $y = mx + c$ where the m is the slope of line. Effective diffusivity (D_{eff}) at time for pomegranate

Table 2: Model parameters, R^2, RMSE and Chi square values (χ^2) of pomegranate peel dried by Convective hot air drying at 40°C, 50°C and 60°C.

Table 2(a): Convective hot air drying at 40°C temperature

Sl. No.	Model name	Temperature 40°C			
		Model Parameter	**R^2**	**MSE**	**χ^2**
1	Newton	k= 1.700×10^{-2}	0.9960	2.561×10^{-4}	1.35×10^{-2}
2	Page	k=1.457×10^{-2} n=1.0364	0.9965	2.495×10^{-3}	0.01.29×10^{-2}
3	Henderson and Pabis	a=1.015508963 k=1.727×10^{-2}	0.9963	2.518×10^{-3}	1.309×10^{-2}
4	Logarithmic	a=0.8943 k=5.2529 c=0.1056	0.2872	3.81×10^{-2}	1.9473
5	Verma	a= 0.9777 k=1.787×10^{-2} g=1.164×10^{-3}	0.9969	1.799×10^{-3}	9.176×10^{-3}

Table 2(b): Convective hot air drying at 50°C temperature

Sl. No.	Model name	Temperature 50°C			
		Model Parameter	**R^2**	**MSE**	**χ^2**
1	Newton	k= 1.806× 10^{-2}	0.9962	2.512× 10^{-4}	1.256× 10^{-2}
2	Page	k=2.14× 10^{-2} n=0.959	0.9962	2.399× 10^{-3}	1.175× 10^{-2}
3	Henderson and Pabis	a=1.003 k=1.81× 10^{-2}	0.9963	2.55941× 10^{-3}	1.254× 10^{-2}
4	Logarithmic	a=0.894 k=5.736 c=0.105	0.3077	3.6754135× 10^{-2}	1.764
5	Verma	a=0.944 k= 0.02.010× 10^{-2} g=2.931× 10^{-3}	0.9980	1.14926× 10^{-3}	5.516× 10^{-3}

Table 2(c): Convective hot air drying at 60° temperature

Sl. No.	Model name	Temperature			
		60°			
		Model Parameter	**R^2**	**MSE**	**χ^2**
1	Newton	$k = 1.985\times 10^{-2}$	0.9966	2.050×10^{-4}	8.817×10^{-3}
2	Page	k=1.000×10^{-4} n=10.205	0.3366	4.610×10^{-2}	2.0287
3	Henderson and Pabis	a=0.9917 k=1.969×10^{-2}	0.9965	2.069×10^{-4}	8.692×10^{-3}
4	Logarithmic	a=0.9888 k=2.005×10^{-2} c=5.774×10^{-3}	0.9966	1.902×10^{-4}	7.799×10^{-3}
5	Verma	a=0.992 k=2.021×10^{-2} g=3.363×10^{-4}	0.9966	1.912×10^{-4}	7.8409×10^{-3}

peel which was calculated by Eq (5). Table 3 shows the effective diffusivity of pomegranate peel dried at 40°C, 50°C and 60°C. The diffusivity values were in the range of 1.65×10^{-8} to 1.97×10^{-7} m²/s for all the temperature ranges studied. At temperature 40ºC the diffusivity value was from $1.65\times10^{-8}$and increasing up to 1.90×10^{-7} m²/s at 60°C respectively. The effective diffusivity used to explain the mechanism of moisture movement during drying and complexity of the process (Kashaninejad *et al.* 2007; Falade and Solademi, 2010.). Generally, effective moisture diffusivity increased with increased air temperature (Falade and Solademi, 2010).

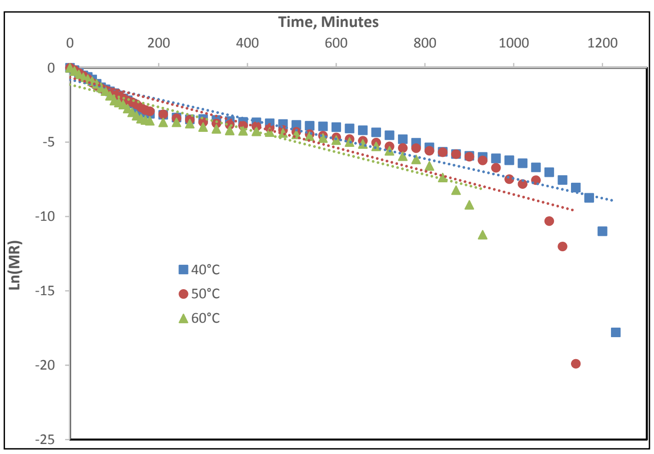

Fig. 4: Ln (MR) versus time, minutes for effective diffusivity for convective hot air drying of Pomegranate peel

It was observed that (D_{eff}) values increased greatly with increasing drying temperature When samples are dried at higher temperature, increased heating energy would increase the activity of the water molecules leading to higher moisture diffusivity (Xiao *et al.* 2010). The values obtained of effective diffusivity from this study was 1.65×10^{-8}, 1.975×10^{-7} and 1.90×10^{-7} m²/s during the drying temperature of 40°C, 50°C and 60°C respectively. The results were in agreement with the previous studies that the values of D_{eff} lie within the general range of 10^{-12} to 10^{-7} m² /s for food materials (Zogzas *et al.* 1996).

Similar results are found to correspond well with those existing in the literature, such as 2.03-1.71 × 10^{-9} m²/s for drying olive-waste cake in temperature range of 50 and 90°C (Vega-Gálvez *et al.* 2010), 0.51-1.43 × 10^{-9} m²/ s for drying of tomato byproducts in temperature range of 100 and 160°C (Celma *et al. 2009*), and 3.47-6.47 × 10^{-9} m²/s for drying of apple pomace in temperature range of 55-75°C (Sun *et al*. 2007). Over the range of 50 - 80°C, moisture diffusivities varied from 9.92×10^{-8} to 1.02×10^{-7} and 0.829×10^{-6} to 1.298×10^{-5} m²/s⁻¹) for *D. alata* and *D. rotundata* respectively (Falade *et al*. 2007), the maximum value of D_{eff} at 60, 70 and 80°C were 40×10^{-8}, 66×10^{-8}, 91×10^{-8} m²s⁻¹, 2.13×10^{-8} m²s⁻¹, 2.62×10^{-8} m²s⁻¹, 4.74×10^{-8} m²s⁻¹ in hot air and short and medium wave infrared radiation drying (Chen *et al*. 2017). These values are consistent with the present estimated (D_{eff}) values for pomegranate peels.

Activation energy for Pomegranate peel dried by convective hot air drying

Fig. 5 shows the Ln (D_{eff}) vs $1/T_{abs}$ for dried Pomegranate peel at 40°C, 50°C and 60°C. The activation energy was calculated by plotting the natural logarithm of (D_{eff}) vs reciprocal of absolute temperature showed straight line in the range of air temperature studied. The activation energy E_a for moisture diffusion calculated from the slope of straight lines graphs are given in Table (3) the activation energy for moisture diffusion was found to be 6.205 kJ/mole. The energy of activation (E_a) are reported in the literature, for convective hot air drying of Pomegranate peel was 12.72 kJ/mole for the temperature ranges 50°C, 60°C, 70°C (Doymaz, 2011).

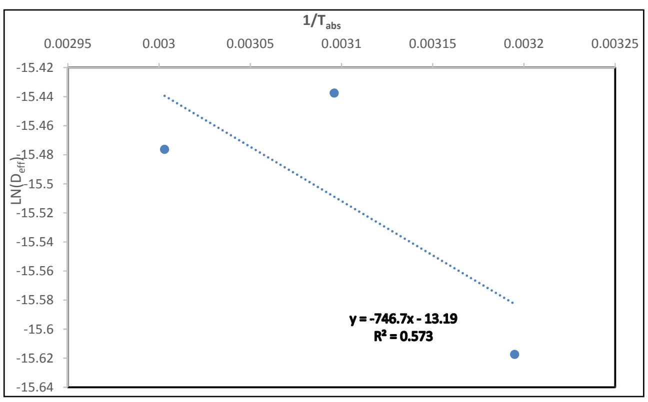

Fig. 5: Ln (Deff) vs $1/_{Tabs}$ for dried Pomegranate peel dried by convective hot air drying method

Table 3: Values of effective diffusivity and activation energy of Pomegranate peel at different temperatures

Temperature, °C	D_{eff}(m²/s)	E_a (kJ/mole)
40°C	1.65×10^{-8},	
50°C	1.975×10^{-7}	**6.205**
60°C	1.90×10^{-7}	

These values are similar to reported by other authors for different products: 19.82 kJ/mol in vegetable waste (Lopez *et al*. 2006); 29.75 kJ/mol in apple pomace drying (Sun *et al.* 2007); 19.27 kJ/mol in grape byproducts drying (Celma *et al*. 2009); 22.23 kJ/mol in tomato byproducts drying (Celma *et al.* 2009); 12.43 kJ/mol in olive-waste drying (Vega-Gálvez *et al.* 2010) respectively.

The results indicated a linear relationship between Ln (D_{eff}) and ($1/T_{abs}$) as plotted in Fig. 5 for Pomegranate peel dried by convective hot air drying at 40°C, 50°C and 60°C. The diffusivity constant or pre- exponential factor of Arrhenius equation (D_0) and activation of energy (E_a) calculated from the linear regression are 1.856×10^{-6} m²/s and 6.205 kJ/mol for Pomegranate peel. The equation (9) become like equation (20);

$$D_{eff} = 1.856 \times 10^{-6} \ .exp.\left(\frac{-6.205}{R(T+273.15)}\right) \quad \ldots(20)$$

Physico-chemical and functional properties of Pomegranate peel powder

Table 4 shows the physico-chemical and functional properties of dried pomegranate peel powder.

1. Moisture content

Table 4 (a) shows the moisture content for fresh pomegranate peel and pomegranate peel dried at 40˚C, 50˚C and 60˚C respectively. Initial moisture content of fresh pomegranate peel was 62.5 %. Moisture content varied for Pomegranate peel powder was, 8.543 ± 0.02 %, 8.410 ± 0.15 % and 7.943 ± 0.2 % (db) at 40˚C, 50˚C and 60˚C respectively. Lowest moisture content observed at 60˚C drying temperature pomegranate peel powder. As the temperature of drying increases from 40 ˚C to 60 ˚C moisture content decreases from 8.543 to 7.943 % The moisture content was significant at $p \le 0.05$ w.r.t. temperature of drying .The moisture content of fresh pomegranate peel reported in the literature was 73.6 % by Al-Rawahi *et al.* (2013). The moisture content of dried pomegranate peel reported in the literature was 5.32 %, 12.48 %, 6.02 % and 9.43 % by Bandal *et al.* (2014), Heena *et al.* (2018), Srivastava (2014), Ismail *et al*. (2014) respectively. The result supports the notion that increasing the temperature of the drying process decrease the moisture content and water activity of the powder produced (Saeleaw and Gerhard, 2011).

Table 4: Physico-chemical and functional properties of Pomegranate Peel Powder

Sl. No.	Parameter		Fresh Peel 40˚C	Dried powder			SE 5%	CD (p≤0.05)
				50 ˚C	60˚C			
(a)	Moisture (%)		62.410	8.543±0.02	8.410±0.15	7.943±0.27	0.103	0.356
(b)	Protein (%)		5.955	4.373±0.18	3.500±0.06	3.080±0.10	0.070	0.241
(c)	Ash (%)		6 .494	3.193± 0.30	3.123±0.01	2.753±0.44	0.199	0.690
(d)	Fat (%)		3.408	2.203±0.01	2.037±0.06	1.800±0.00	0.018	0.064
(e)	Fiber (%)		11.344	13.210±0.02	16.667±0.61	17.533±0.01	0.006	0.022
(f)	Carbohydrate (%)		72.401	69.517±0.82	66.193±0.11	63.897±1.60	0.602	2.082
(g)	Ascorbic Acid(mg/g)		10	6.752±0.82	6.340±0.28	6.013±0.01	1.157	4.005
(h)	Bulk density (g/ml)			0.510±0.08	0.683±0.04	0.797±0.07	0.037	0.129
(I)	Water holding Capacity(ml/g)			2.690±0.08	2.547±0.01	2.430±0.02	0.008	0.027
(j)	Oil holding Capacity(ml/g)			0.980±0.01	0.927±0.02	0.907±0.01	0.009	0.030
(k)	Colour	L	79.116	73.070±0.01	76.090±0.02	77.437±0.01	0.008	0.027
		A	17.859	11.667±0.02	11.763±0.03	10.200±0.00	0.008	0.034
		B	38.144	33.660±0.000	34.600±0.010	31.020±0.000	0.003	0.012

2. Protein

Table 4 (b) shows the (%) protein content for fresh pomegranate peel and pomegranate peel dried at 40˚C, 50˚C and 60˚C respectively. Protein content of fresh pomegranate peel was 5.95%. Protein content varied for pomegranate peel powder 4.373±0.18 %, 3.500±0.06 % and 3.080±0.10 % at 40˚C, 50˚C, 60˚C respectively. Highest protein content observed at 40˚C of pomegranate peel powder. As the temperature of drying increases from 40 ˚C to 60 ˚C the protein content decreases from 4.373 to 3.080 %.The protein was significant at p ≤0.05 w.r.t.temperature of drying. The protein content of fresh pomegranate peel reported in the literature was 8.8 % and 3.95 % by Al-rawahi *et al.* 2013; Kushwaha *et al.* (2013) respectively. The protein content of dried pomegranate peel reported in the literature was 4.40 %, 3.77 %, 3.26 %, 3.38 % and 4.48 % by Bandal *et al.* (2014). Heena *et al.* (2018) Mehder (2013), Srivastava, (2014) Ismail *et al.* (2014) and Rowayshed *et al*. (2013) respectively.

3. Ash

Table 4 (c) shows the (%) ash content for fresh pomegranate peel and pomegranate peel dried at 40˚C, 50˚C and 60˚C respectively. Ash content of fresh pomegranate peel was 6.49 %. The Ash content for Pomegranate peel powder was 3.193 ±0.40 %, 3.123±0.02 % and 2.753±0.45 % at drying temperature 40˚**C**, 50˚**C**, 60˚**C**respectively. Highest ash content observed at 40˚C of Pomegranate peel powder. As the temperature of drying increases from 40 ˚C to 60 ˚C the ash content decreases from 3.19 to 2.75 %.The ash was non-significant at p≤0.05 w.r.t. temperature of drying. The ash content of fresh pomegranate peel reported in the literature was 3.3 %, 5.49 % by Al-rawahi *et al*. (2013) and Kushwaha *et al.* (2013). The ash content of dried pomegranate peel reported in the literature was 3.05 %, 3.31 %, 6.02 %, 4.23 % and 3.30 % by Bandal *et al.* (2014). Heena *et al.* (2018) Mehder (2013), Srivastava, (2014) Ismail *et al*. (2014) and Rowayshed *et al*. (2013) respectively. The ash content decreases with increase of drying temperaturefr0m 45 to 60 ˚C (Chavan *et al.* 1995).

4. Fat

Table 4 (d) shows the (%) fat content for fresh pomegranate peel and pomegranate peel dried at 40˚C, 50˚C and 60˚C respectively. The fat content in fresh pomegranate peel was 3.40 %. Fat content varied for Pomegranate peel powder was 2.203±0.01%, 2.037±0.06 % and 1.800 ±0.00 % at 40˚**C**, 50˚**C**, 60˚**C**respectively. Highest fat content was observed at 40˚C of Pomegranate peel powder. As the temperature of drying increases from 40 ˚C to 60 ˚C the fat content decreases from 2.203 to 1.800 % The fat was significant at p≤0.05. The fat content in fresh pomegranate peel reported in the literature was 2.40%, 1.30 % by Kushwaha *et al.* (2013) and Al-rawahi *et al*. (2013) respectively. The fat content of dried pomegranate peel reported in the literature was 1.75 %, 1.08 %, 4.23, 0.41 and 1.73 % respectively by Heena *et al.* (2018) ,Mehder (2013), Srivastava, (2014) Ismail *et al*. (2014) , and Rowayshed *et al*. (2013).

5. Fiber

Table 4 (e) shows the (%) fiber content for fresh pomegranate peel and Pomegranate peel dried at 40˚C, 50˚C and 60˚C respectively. The fiber content in fresh pomegranate peel was 11.344 %. Fiber content varied for Pomegranate peel powder was 13.210±0.02 %, 16.667± 0.01 % and 17.533± 0.60% at 40˚C, 50˚C, 60˚C respectively. . As the temperature of drying increases from 40 ˚C to 60 ˚C the fiber content increases from13.210 to 17.533 %. Highest fiber content observed at 60˚C of Pomegranate peel powder. The fiber was significant at p≤0.05 w.r.t temperature of drying. As the temperature of drying increases from 40 ˚C to 60 ˚C fiber content increases from 13.210 to 17.533 %. The fiber content in fresh pomegranate peel reported in the literature was 12.61%, 21.6 % by Kushwaha *et al.* (2013) and Al-rawahi *et al*. (2013) respectively. The fiber content of dried pomegranate peel reported in the literature was 15.14 %, 12.52 %, 31.10 %, and 11.22 by Bandal *et al.* (2014), Mehder (2013), Srivastava, (2014) Ismail *et al*. (2014) and Rowayshed *et al*. (2013).

6. Carbohydrate

Table 4 (f) shows the (%) carbohydrate content for fresh pomegranate peel and Pomegranate peel dried at 40˚C, 50˚C and 60˚C respectively. The carbohydrate content in fresh pomegranate peel was 72.45%. Carbohydrate content varied for Pomegranate peel powder was 69.517±0.82 %, 66.193 ± 0.11 % and 63.897 ± 1.60 % at 40˚C, 50˚C, 60˚C respectively. . As the temperature of drying increases from 40 ˚C to 60 ˚C the carbohydrate content decreases from 69.517 to 63.897 %. Highest carbohydrate content observed at 40˚C of Pomegranate peel powder. The carbohydrate was significant at p≤0.05 w.r.t. temperature of drying. As the temperature of drying increases from 40 ˚C to 60 ˚C carbohydrate decreases from 69.517 to 63.897%. The carbohydrate content of fresh pomegranate peel reported in the literature was 86.40% by Al-rawahi *et al.* (2013).The carbohydrate content of dried pomegranate peel reported in the literature was 76.61%, 78.67% and 80.50 % respectively by Mehder (2013), Ismail, (2014) and Rowayshed *et al*. (2013).

7. Ascorbic Acid

Table 4(g) shows the (%) ascorbic acid content for Pomegranate peel at 40˚C, 50˚C and 60˚C respectively. The ascorbic acid in fresh pomegranate peel contain 10mg/g Ascorbic acid content varied for Pomegranate peel powder was 6.752 ± 0.82 mg/g, 6.340 ± 0.28 mg/g and 6.013 ± 0.01 mg/g at 40˚**C**, 50˚**C**, 60˚**C** respectively. Highest ascorbic acid content observed at 40˚C of Pomegranate peel powder. It decreases as the temperature of drying from 40 to 60 ˚C. The ascorbic acid was significant at p≤0.05 w.r.t. temperature of drying. Bandal *et al.* (2014) who reported that the ascorbic acid content of Pomegranate peel powder was 12.60 mg/g which was dried at 45 °C. The degradation of vitamin C is considerably affected from the drying conditions. Increasing drying air temperature increases degradation of vitamin C in the dried fruits. Conversely, degradation of vitamin C is reduced with increasing relative humidity the variation of the retention of vitamin C for various drying air conditions. Similar behaviors were reported for roseship, granular edmame, tomato and lemon juice fruits by Erenturk *et al.* (2005), Qing-guo *et al.* (2006), Goula and Adamopoulos (2006) and Al-Zubaidy and Khalil (2007) respectively.

8. Bulk density

Table 4 (h) shows the bulk density for Pomegranate peel powder. Bulk density varied for Pomegranate peel powder ranged was of 0.510 ± 0.08, 0.683 ± 0.04 and 0.797 ± 0.01 g/ml for 40˚C, 50˚C and 60˚C respectively. Highest bulk density observed at 60˚C Pomegranate peel powder it increases as the temperature of drying increases from 40 to 60 ˚C. The variation in bulk density of Pomegranate peel powder was significant at $p \leq 0.05$. The bulk density of the dried pomegranate peel fractions reported by Zhong *et al.* (2009) ranged from 0.653 to 0.751 g /ml. Bulk density depends on the proportion of air volume in the sample, which is affected by the drying method and by the collapse of the matrix (Koç, Eren, & Ertekin, 2008).

9. Water absorption capacity

Table 4 (i) shows the water absorption capacity for Pomegranate peel powder. Water absorption capacity varied for Pomegranate peel powder were 2.690±0.01 (ml/g), 2.547±0.01 (ml/g) and 2.430 ±0.02 (ml/g) respectively. Highest water absorption capacity observed at 40˚C of Pomegranate peel powder and it decreases with increase in dying temperature 40 to 60˚C. The water absorption was significant at $p \leq 0.05$ w.r.t to temperature of drying. Bandal *et al.* (2014) reported that the water holding capacity of dried pomegranate peel was 2.35ml/g. Heena *et al.* (2018) reported that the water holding capacity of pomegranate peel was 4.84ml/g. The water-holding capacity is the ability of a moist material to retain water when subjected to an external centrifugal gravity force or compression. It consists of the sum of bound water, hydrodynamic water and, mainly, physically trapped water (Vázquez-Ovando *et al.* 2009).

10. Oil absorption capacity

Table 4 (j) shows the oil absorption capacity for Pomegranate peel powder. Oil absorption capacity varied for Pomegranate peel powder was 0.980±0.01 (ml/g), 0.927±0.02 (ml/g) and 0.907±0.01 (ml/g) respectively. Oil absorption capacity decreases with increase in temperature. Highest oil absorption capacity was observed at 40˚C of Pomegranate peel the oil absorption capacity was significant at $p \leq 0.05$ w.r.t. temperature. Bandal *et al.* (2014) reported that the oil absorption capacity of dried pomegranate peel was 0.9 ml/g. Heena *et al.* (2018) reported that the oil holding capacity of pomegranate peel was 5.83 ml/g. The oil absorption capacity is also a technological property related to the chemical structure of the plant polysaccharides and depends on surface properties, overall charge density, thickness, and hydrophobic nature of the fibre particle (Figuerola *et al*. 2005; Fernandez-Lopez *et al*. 2009); it is also related with the insoluble dietary fiber (IDF) content (Thebaudin *et al.* 1997), particle size and drying. When insoluble dietary fiber (IDF) is added to any formulation it can absorb the oil present, the extent of this absorption is being measured as fat absorption capacity (Raghavendra *et al.* 2006). Particle size: the lower the particle size, the higher the oil holding capacity because smaller particles have relatively largest surface areas and therefore would theoretically be able to hold more oil than large particles and drying: in general, dehydration promotes a general decrease in fiber oil absorption capacity compared with the fresh fibre.

10. Colour

Table 4 (k) shows the colour *L, a* and *b* value for pomegranate peel dried at 40, 50 and 60˚C. Colour of fresh pomegranate peel *L, a* and *b* was 79.11, 17.85, 38.14 respectively. L value for pomegranate peel dried 40˚C, 50˚C and 60˚C was 73.070± 0.01, 76.090± 0.02 and 77.437±0.01 respectively, a value for for pomegranate peel dried 40˚C, 50˚C and 60˚C was 11.657±0.02, 11.763 ±0.03 and 10.200±0.00 respectively and b value for pomegranate peel dried 40˚C, 50˚C and 60˚C was 33.660±0.00, 34.600±0.01and 31.020±0.00.L value for pomegranate peel powder increases w.r.t increase in temperature. '*a*' value for pomegranate peel powder shows no trend w.r.t. temperature and 'b' the variation of '*L*', '*a*', '*b*' w.r.t. temperature was significant at $p \leq 0.05$. Heena *et al.* (2018) reported that pomegranate peel colour L, a, b value was 64.14, 7.23, 16.86 respectively which was dried at 60°C for 12 hrs. The changes of color in the dried fruits or vegetable materials are mainly due to Maillard reactions, which involve reducing sugars. As compared to the fresh product, drying increased the values of the lightness, *L**, and *b**, while *a** reduced its value. These changes led to a lighter, greener, and more yellow dried products as compared to the fresh material. (Cano-Lamadrid *et al.* 2018).

CONCLUSION

The Pomegranate peel were dried from average initial moisture content of 199.5% (db) to 10.480% (db) at 40°C; 166.2% (db) to 8.688% (db) at 50°C; 141.6% (db) to 8.584% (db) at 60°C respectively. It took around 20 h, 19h and 16 h time to dry the product at 40°C, 50°C, and 60°C respectively. Among the models fitted to the experimental data at 40°C, 50°C and 60°C the Verma model was well fitted to the experimental data. The effective diffusivity of pomegranate peel dried at 40°C, 50°C and 60°C, the diffusivity values were in the range of 1.65×10^{-8} to 1.97×10^{-7} for all the temperature. The drying of Pomegranate peel occurred in the falling rate period The pomegranate peel powder obtained at 40ºC had better physicochemical i.e. protein, fat, carbohydrate, ascorbic acid and functional properties i.e. bulk density water absorption capacity and oil absorption capacity than the samples obtained at other different temperatures selected for the study. Pomegranate peel at 40ºC contains protein 4.37±0.18%, fat 2.20±0.01%, carbohydrate 69.52±0.82%, the functional properties at 40°C was i.e. was bulk density g/c, water absorption capacity and oil absorption capacity was 0.51±0.08, 2.69±0.01 (g/ml), 0.98±0.01 (g/ml) respectively

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