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Effect of Blanching Temperature and Convective Hot Air-Drying Temperature of Orange Peel Slices on its Quality Evaluation

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ABSTRACT
Drying characteristics of orange peel was investigated by blanching and convective hot air drying of orange peel slices (of 3mm thickness) at the temperature 40ºC, 50ºC and 60ºC. Drying models i.e. Lewis, Henderson and Pabis and Page were fitted to the experimental data on moisture ratio with respect to time. The page model fitted well $r^2 \geq 0.976$ and $MSE \leq 0.0012$ among all the models tested for the experimental data. Effective diffusivity (D_{eff}) at time (t) for orange peel were 0.086×10^{-8} m^2/s, 1.834×10^{-8} m^2/s and 2.017×10^{-8} m^2/s which was blanched at 72ºC:10 min, 82ºC:8min and 92ºC:5 min and dried at 40ºC; 0.0903688×10^{-8} m^2/s, 1.077×10^{-8} m^2/s and 1.898×10^{-8} m^2/s which was blanched at 72ºC:10 min, 82ºC:8min and 92ºC:5 min and dried at 50ºC; 1.168×10^{-8} m^2/s, 1.422×10^{-8} m^2/s and 1.579×10^{-8} m^2/s which was blanched at 72ºC:10 min, 82ºC:8min and 92ºC:5 min and dried at 60ºC. The activation energy (E_a) for moisture diffusion was found to be 2.244×10^4 kJ/mole, 2.523×10^4 kJ/mole and 1.262×10^4 kJ/mole. The quality parameter i.e. T.S.S was in 20 to 60(°B), acidity was in the range of 0.32 to 18.09 %, reducing sugar was in the range of 19.05 to 6.21 % non-reducing sugar was in the range of 2.56 to 10.13%, total sugar was in the range of 9.08 to 25.8%, pH was in the range of 5.4 to 3.6%, ascorbic acid was in the range of 18.2 to 34.76%, yellowness index was in the range of 77.76 to 154.40 and protein was in the range of 8.60 to 11.24% on orange peel powder prepared from blanching at 72ºC: 10 min, 82ºC: 8min and 92ºC: 5 min dried at 40ºC, 50ºC and 60ºC respectively were determined and discussed.

Keywords: Convective drying, moisture ratio, drying behavior, drying models, effective diffusivity (D_{eff}), activation energy (E_a) and chemical properties.

Introduction
Orange is a fruit of the citrus species *Citrus Sinensis* in the family Rutaceae. Important orange varieties cultivated in India are *Nagpur Santra, Coorg Santra, Khasi Santra, Mudkhed, Shrinagar, Butwal, Dancy, Kara (Abohar)* (Zaker, 2016). The global orange production is about more than 122.5 million tons (Jiang *et al*., 2014). Brazil is the world's leading producer, with an output of 36 million tons (2013); similar in total to the next three countries combined (the United States, China, and India). With an approximately 16 million tons produced in 2013, the United states is the second largest producer. Other

countries with significant production of oranges are China, India, Mexico, Spain and Egypt. India produces 86.08 Lakh tons of oranges (Kumar, 2010). Maharashtra is second largest state after Andhra Pradesh in the country and contributes to about 18.9 % of the total Citrus production (Anonymous, 2011).

Citrus fruits have long been valued as a part of nutritious and tasty diet. It is well established that citrus and citrus products are a rich source of vitamins, minerals and dietary fibers that are essential for normal growth and development and overall nutritional well-being (Economos and Clay, 1999). Orange juice is the most important products of citrus species worldwide (Hegazy and Ibrahium, 2012), and causes a higher amount of byproducts that could be used as good source of bioactive compounds (Saenz *et al*., 2007; Kong *et al*., 2010). The orange juice industry uses approximately 50 % of the total fruit, while the peel, rag (*membranes* and core) and seeds and albedo comprise 60 % of total byproducts (Fernandez – Lopez *et al*., 2009). Orange peel is composed of two distinct parts: external part (flavedo) particularly rich in essential oils and carotenoids and internal spongy part (albedo) rich in pectin and flavonoids. Fig. 1 shows the varies parts of orange peel, though some portion of these by-products is consumed as animal feed, the majority of the processing waste are thrown out, and consequently pollutes the environment. Disposal of byproducts not only leads to loss of potential revenues but also leads to the added and increasing cost of disposal of these products (Jayathilakan *et al*., 2012).

Food industry uses citrus peel as a source of molasses, pectin, oil and limonene (Braddock, 1995), and has been studied because it contains several bioactive compounds, such as flavanones, polymethoxylated flavones, flavonols and phenolic acids and dietary fibers; these compounds have a lot of uses as a natural antioxidants for pharmaceutical, biotechnological and food industries (Bocco *et al*., 1998). Orange peel is a good source of flavonoids that are related to the benefits in human health, such as antioxidant capacity, anticancer, antiviral and antinflammatory activities (Benavente - Garcia *et al*., 1997). Dietary fiber plays an important role in the prevention, reduction, and treatment of chronic diseases such as obesity, diabetes, cardiovascular disease, and gastrointestinal disorders (Anderson *et al*., 2009; Figuerola *et al*., 2005). The incorporation of dietary fiber into foods increases their fiber content and can result in healthier products. (Ramirez – Santiago *et al*., 2010). The peel of citrus fruit contains essential oils which are well-known antimicrobial agents (Braddock *et al*., 1986; Plessas *et al*., 2007). Orange peel typically contains 5.436 kg of oil per 1000 kg of oranges of which approximately 90% is D-limonene (Braddock *et al*., 1986; Hull *et al*., 1953) a hydrocarbon classified as a cyclic terpene. D-limonene is employed in the manufacture of food and medicines as a flavoring agent and has many applications in the chemical industry as well as cosmetics and domestics household products (Smyth and Lambert, 1998).

The bioflavonoids, hesperidin and naringin present in citrus fruits have been reported to exhibit biological and pharmacological properties like anti-inflammatory, anti: carcinogenic, lipid lowering and antioxidant activities (Bok *et al*., 1999; Choi *et al*., 2001). Hesperedin and naringin have also been shown to play an important role in preventing the progression of hyperglycemia (Jung *et al*., 2004). Naringin has been reported to serve as a potential therapeutic agent to treat wear- debries- associated osteolysis (Li *et al*., 2014), and osteoporosis (Wei *et al*., 2007). Some of these bioflavonoids are bitter to the taste and their presence in fruit juices and products developed from it are sometimes inevitable, which lowers the consumers acceptability. The fresh orange peel contains 319 ± 22.7 mg/100 g of naringin which can be reduced up to 122.04 ± 12.7 mg/ 100g after blanching (Jagannath and Kumar, 2016).

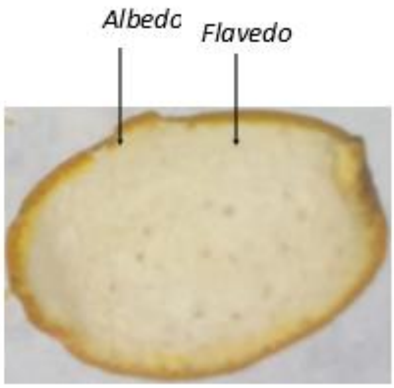
Blanching is a moderate heat treatment commonly used in the food industry to extend the shelf life of commodities by partially inactivating microorganisms and enzymes. More intensive blanching orange peel inhibited the activity of microorganisms and enzymes (Ashbell *et al*., 1988). Prior to drying, most food products are usually subjected to one form of pretreatments among which is hot water blanching. Blanching helps to inactivates enzymes that leads to some quality degradation and improves the acceptability of the final products. (Moreno-Perez *et al*., 1996; Babajide, *et al*., 2006). Blanching also leads to structural softening and hence facilitates moisture removal (Senadeera *et al*., 2000). In case of orange peel the bioflavonoids which are present i.e. hesperidin and naringin are bitter in tastes, to remove the bitterness of the final product and make it consumer acceptable the blanching is required. Blanching lower down the bitterness in orange peel (Jagannath and Kumar, 2016).

Orange peel could be dehydrated for different products such as powders, flakes and slices (Ruiz-Diaz *et al*., 2003). The development of new processing methods that preserve the quality of peels and improve their sensory acceptance is required to produce new peel foods.

Drying is an important method for preserving and increasing the shelf life of fruits and vegetables to limit microbial growth and create new uses. Numerous researchers have reported the dehydration kinetics of fruits and vegetables such as pomegranate (Daymaz, 2012); orange (Depilli *et al*., 2008); Kiwi fruit (Orikasa *et al*., 2014); Mandarin slices (Akdas and Baslar, 2015) limited studies have been reported on blanching and drying of orange peel. Drying reduces water activity in the products, thus hindering the developments of microorganism, is one of the oldest, and therefore best known, methods to preserve fruit and vegetables, and fruit powder can be very easily added to various food products. The most important aspects of drying technology is the mathematical model of drying processes and equipment (Akpinar *et al*., 2006). Knowledge of the drying kinetics of biological materials is essential to the design, optimization and control of drying process (Sacilik *et al*., 2006). The principle of modeling is based on having a set of mathematical equations that can adequately characterize the system. In particular, the solution of these equations must allow prediction of the process parameters as a function of time at any point in the dryer based only on the initial condition (Gunhan *et al*., 2005).

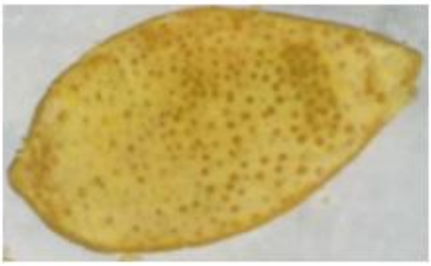
The present investigation was undertaken to study the effect of blanching and drying on quality aspects of orange peel slices. The Lewis, Henderson and Pabis and Page mathematical model were also fitted to the experimental data to study the effect of blanching temperature and temperature of drying on the diffusion coefficient

(a) Orange peel



(b) Parts of orange peel *Alebedo* and *Flavedo*

(c) Albedo removed from peel



(d) Orange peel after removal of Albedo

Fig. 1 Orange peel and its parts (a) Orange peel; (b) Parts of orange peel *Albedo* and *Flavedo*; (c) Albedo removed from peel; (d) Orange peel after removal of Albedo

2. Material and Methods

2.1 Raw material

The firm Oranges was procured for e: *Albedo* *Flavedo* the Agricultural Produce Market Committee (APMC) Vashi market (Mumbai). The Orange fruits were washed with tap water to remove dirt, dust adhered. The fruits outer layer flavedo was separated manually from albedo (Fig.1 (d)). The surface moisture of the orange peel removed with the help of muslin cloth.

2.2 Moisture content

Initial moisture content for fresh orange peel; blanched orange peel slices and blanched dried orange peel slices was determined by, hot air oven at 105±1°C for 24 h. The final weight of orange peel was taken after 24 h of drying was recorded. (Make: Aditi Associate, India; Model: ALO-136) The moisture content of orange peel was determined by the following equation (1) (Chakraverty 1994):

$$\text{Moisture content (d.b) \%} = \frac{W_1 - W_2}{W_2} \text{-100} \qquad \dots (1)$$

Where,

W_1=Weight of the sample before drying g and

W_2= Weight of the dried sample g

2.3 Blanching and Drying of Orange peel

The peels were cut into small pieces of size 10 mm having thickness 3 mm, and blanched in a tap water at 72°C for 10 min; 82° for 8 min and 92°C for 5 min and after blanching was completed the surface moisture was removed. The blanched slices were dried in a thin layer in a tray dryer at 40°C, 50°C and 60°C±1ºC. The size of the tray was 500mm×500mm×20mm. The blanched orange peel was spread in a single layer in the tray (non-perforated). Tray drying of orange peel was performed at the Department of Post-Harvest Engineering, Post Graduate Institute of Post-Harvest Management (PHM), Killa-Roha. Tray dryer of capacity 60kg (Make: M/s Sagar Engineering work, Kudal (India) was used to study. The weight losses w.r.t time was recorded from the tray placed at three different locations in the tray dryer. The moisture content w.r.t was calculated from the drying data. Table 1 shows the various treatments of blanching and drying of orange peel. The experiments were repeated three times for each treatment. The average values have been recorded.

Statistical analysis was performed using 3 Factorial completely randomized design (FCRD) for sample properties of TSS, Acidity, Reducing sugar, Non-reducing sugar, Total sugar, Ascorbic acid, pH, Protein, Yellowness index and sensory qualities like colour, flavour, texture, of blanched and dried orange peel which was carried out by Microsoft Excel 2007.

Table 1. Various treatments of blanching and drying of orange peel.

Sr. No	Treatment	Blanching Temp and Time	Drying Temperature
1	T_1	72ºC for 10 min	40ºC
2	T_2	82ºC for 8 min	50ºC
3	T_3	92ºC for 5 min	60ºC
4	T_4	72ºC for 10 min	40ºC
5	T_5	82ºC for 8 min	50ºC
6	T_6	92ºC for 9 min	60ºC
7	T_7	72ºC for 10 min	40ºC
8	T_8	82ºC for 8 min	50ºC
9	T_9	92ºC for 5 min	60ºC

2.4 Drying Characteristics

Moisture Content (% db) versus drying time (min) and drying rate (kg of water removed/ 100g dry solid/min) with respect to moisture content was determined for tray drying of orange peel. Moisture ratio versus drying time (min) was also determined from the experimental data as per equation (2).

$$MR=\frac{(M-M_e)}{(M_0-M_e)} \quad \text{... (2)}$$

Where, M=Moisture content (% db) at time (t)

M_0=Initial Moisture content (% db)

M_e=Equilibrium moisture content (% db)

Various mathematical models listed in Table 2 were tested with the experimental data. Non-linear regression analysis was performed to the experimental data by using SAS 6.0 software. The higher values of correlation coefficient (r) and lower value of Root Mean Square Error (RMSE) of model indicated that it was best fit for the experimental data (Hande *et al*., 2017)

The correlation coefficient (r) was calculated as per equation (3)

$$r = 1 - \frac{\sum_{i=1}^{n}(MR_{exp}-MR_{pre})^2}{\sum_{i=1}^{n}(MR_{exp}-MR_{ang})^2} \quad \dots (3)$$

Where, MR_{exp}= Experimental moisture ratio

MR_{Pre}=Moisture ratio Predicted for this measurement

MR_{Avg}=Average moisture ratio value for the experimental value

Root Mean Square Error (RMSE) was calculated as per equation (4)

$$\text{RMSE} = 1\sum_{i=1}^{n}(MR_{exp} - MR_{pre})^2\}^{1/2} \quad \dots (4)$$

Where, N=No. of observations

n=No. of contents

Table 2 Mathematical models tested with the moisture ratio of orange peel powder

Model Name	Model	Reference
Lewis	MR=exp (-kt)	Lewis (1921), Bruce (1985)
Henderson and Pabis	MR=a exp (-kt)	Henderson and Pabis (1961)

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Page	MR=exp(-kt^n)	Page (1949)

2.5 Calculation of Effectivity Diffusivity

The Orange peel slice was assumed to be a slab of thickness 3mm. It has been accepted that the drying characteristics of biological products in falling rate period can be described by using Fick's diffusion equation (Wang *et al*., 2007). The solution to this equation developed by Crank (1975) can be used for various regularly shaped bodies such as rectangular, cylindrical and spherical products, and the form of equation (5) (Falade and Solademi; 2010) can be applicable for particles with slab geometry. It was assumed that the uniform initial moisture distribution in the orange peel.

$$MR = \frac{8}{\pi^2}\sum_{n=1}^{\infty}\frac{1}{2n-1}exp\left(-(2n-1)^2\frac{\pi D_{eff}t}{4L^2}\right) \quad \ldots (5)$$

Where, D_{eff} = effective diffusivity (m^2/s)

L = half thickness of slab (m)

where D_{eff} is the effective diffusivity (m^2/s^{-1}); L is the half thickness of slab (m). For long drying period, equation (5) can be further simplified to equation (6) only the first term of series (Tutuncu and Labuza, 1996). Thus, equation (6) can be written in a logarithmic form as follow.

$$\text{Ln (MR)} = \text{In}\frac{8}{\pi^2} - \frac{\pi^2 D_{eff}t}{4L^2} \quad \ldots (6)$$

Diffusivities are typically determined by plotting experimental drying data in terms of ln MR vs. drying time t in equation (6), because the plot gives a straight line with a slope as equation (7):

$$\text{Slope} = \frac{\pi^2 D_{eff}}{4L^2} \quad \ldots (7)$$

2.6 Calculation of Activation Energy

The temperature dependence of the effective diffusivity may be described by an Arrhenius-type relationship (Madamba *et al*., 1996; Ozdemir and Devers, 1999; Akgun and Doymaz, 2005), shown by equation (8).

$$D_{eff} = D_O \exp\left(-\frac{E_a}{RT_{abs}}\right) \quad \ldots (8)$$

Where, Do = pre-exponential factor of the Arrhenius equation (m^2/s^{-1}),

E_a= activation energy (kJ/mol^{-1}),

R = universal gas constant (kJ/mol^{-1} K^{-1}), (R= 8.314 kJ/mol/k)

T = absolute temperature (K).

2.6 Evaluation of Quality Parameter for the blanched dried of Orange peel

2.6.1 Partical size

Dried orange peel were grounded to partical size 0.386 mm with partical sizer (Make Bio Technics India: Model BIT-46)

2.6.2 TSS (°B)

The Total Soluble Solids of blanched and dried orange peel powder of various treatments (T_1-T_9) were determined by using Hand Refractometer (M/s Atago Japan, 0-32^{0}B) and the values were corrected at 20^{0}C with the help of temperature correction chart (A.O.A.C., 1975). The equipment was calibrated with the distilled water whose TSS is zero. The experiments were repeated four times and average value was reported.

2.6.3 Titratable acidity

A 10 gm of blanched and dried orange peel powder of various treatments (T_1-T_9) was performed as per (A.O.A.C., 1975) sample was titrated against 0.1 N NaOH solution using phenolphthalein as an indicator (A.O.A.C., 1975). The sample of known quantity with 20 ml distilled water was transferred to 100 ml volumetric flask, made up the volume and filtered. A known volume of aliquot (10 ml) was titrated against 0.1N sodium hydroxide (NaOH) solution using phenolphthalein as an indicator (Ranganna, 2003). The results were expressed as per cent anhydrous citric acid equation (9). The experiments were repeated for three times and average value was reported

$$\text{Titratable acidity}(\%) = \frac{\text{Normality of alkali X Titre reading X Volume made X Equivalent weight of acid}}{\text{Weight of sample taken X Volume of sample taken for estimation X 1000}} X100 \quad \ldots (9)$$

2.6.4 Reducing sugars

The reducing sugars were determined by the method described by Ranganna (2003). A known weight of blanched and dried orange peel powder of various treatments (T_1-T_9) was taken in 250 ml volumetric flask. To this, 100 ml of distilled water was added and the contents were neutralized by 1 N sodium hydroxide. Then 2 ml of 45 per cent lead acetate was added to it. The contents were mixed well and kept for 10 minutes. Two ml of 22 per cent potassium oxalate was added to it to precipitate the excess of lead. The volume was made to 250 ml with distilled water and solution was filtered through Whatman (No. 4) filter paper. This filtrate was used for determination of reducing sugars by titrating it against the boiling mixture of Fehling 'A' and Fehling 'B' solutions (5 ml each) using methylene blue as indicator to a brick red end point. The results were expressed on per cent basis equation (10).

$$\text{Reducing sugars } (\%) = \frac{\text{Factor X Dilution}}{\text{Titre reading X Weight of sample}} \text{ X } 100 \quad \ldots (10)$$

2.6.5 Total sugars

The total sugar of blanched and dried orange peel powder sample of treatments (T_1-T_9) was determined as per Ranganna (2003). For inversion at room temperature, a 50 ml aliquot of clarified deleaded solution was transferred to 250 ml volumetric flask, to which, 10 ml of 50 per cent HCl was added and then allowed to stand at room temperature for 24 hrs. It was then neutralized with 40 per cent NaOH solution. The volume of neutralized aliquot was made to 250 ml with distilled water. This aliquot was used for determination of total sugars by titrating it against the boiling mixture of Fehling 'A' and Fehling 'B' (5ml each) using methylene blue as indicator to a brick red end point. The results were expressed on per cent basis as per equation (11). The experments were repeated four three times and average value of total sugar have been reported.

$$\text{Total sugars } (\%) = \frac{\text{Factor X Dilution}}{\text{Titre reading X Weight of sample}} \text{ X } 100 \quad \ldots (11)$$

2.6.6 Non-Reducing sugar

The non-reducing sugar was determined by subtracting reducing sugar from Total sugar as per the equation (12).

Non-Reducing sugar = [(Total sugar % - Reducing sugar %) 0.95] … (12)

2.6.7 pH

The pH of blanched and dried orange peel powder sample of treatments (T_1-T_9) was reported as per the ready recorded by digital pH meter. Model (Make: Hanna Instruments, Model: HI98127) the equipment was standardized by 4 and 7 pH standard solution. The pH of orange peel powder was determined by adding 15 ml of distilled water to 5 g of ground orange peel

2.6.8 Ascorbic acid

Ascorbic acid of blanched and dried orange peel powder sample of treatments (T_1-T_9) was determined in triplicate by titration. 10g of sample was taken and blended with 3g/dL HPO_3. The total volume was made up to 100 ml with HPO_3. This was followed by titration. An aliquot of 10 ml HPO_3 was taken as extract of the sample. The sample was titrated with the standard dye to an end point (pink color) that was persisted for at least 15 second (AOAC 1995). Results will be expressed as mg of ascorbic acid/100 g of sample.

Mg of ascorbic acid/100 g of sample

$$= \frac{titre \times dye\ factor \times volume\ made\ up \times 100}{aliquot of\ extract\ taken\ for\ estimation \times weight\ of\ volume\ of\ sample\ taken\ for\ estimation} \quad \ldots (13)$$

2.6.9 Protein

The protein content of blanched and dried orange peel powder sample of treatments (T_1-T_9) was measured by Microkejdhal method (Ranganna, 1986). Around 0.25 g of orange peel powder was taken for the analysis. 10 ml H_2SO_4 was added in the orange peel powder and solution was allowed to predigest for 14 h (overnight). The predigested sample was heated on gas flame till the sample colour changes to colourless. Colour less sample was makeup up to volume 25 ml. The makeup sample (25 ml) was taken as volume of aliquot. After digestion distillation of sample was done in automatic distillation unit provided with receiver flask contained 4 ml boric acid indicator. The mixture of 10 ml colourless sample solution (aliquot), 10 ml NaOH and 10 ml water was taken for distillation. The outlet tube of distillation unit assembly was properly submerged into the indicator. Sodium hydroxide solution was allowed to drop into the digestion tube. Mixing chamber of the assembly was heated for 20-30 minute or until the colour of indicator solution was changed from pink to green. The distillate sample was titrated against 0.01N H_2SO_4 and % protein content was calculated by equation (14). The experiment was repeated three times and the average reading of protein was reported.

$$\%\ \text{Protein} = \frac{(\text{Sample titre} - \text{Blank titre}) \times \text{N} \times 0.014 \times \text{vol.of aliquot} \times 6.25 \times 100}{\text{weight of sample taken}} \quad \ldots (14)$$

2.6.10 Colour

The dried grounded orange peel was used to measure the colour value using a colorimeter (Konica Minolta, Japan Model- Meter CR-400). The equipment was calibrated against standard white tile. Around 20 g dried orange peel powder was taken in the petri dish, the petri dish was placed at the aperture of the instrument. The colour was recorded in terms of L= lightness (100) to darkness (0); a = Redness (+60) to Greeness (-60); b= yellowness (+60) to blueness (-60). The yellowness index of the orange peel powder was determined from the L, a, and b values as per the equation (15) reported by (Rhim *et al*., 1999).

$$\text{YI} = \frac{142.86\, b}{L} \quad \ldots (15)$$

2.6.11 Optimum product quality

The quality parameters of all these treatments T_1 to T_9 were compared with the orange peel dried at 40ºC, 50ºC and 60ºC with blanching treatment the desirable orange peel should have more TSS, acidity, reducing sugar, non-reducing sugar, pH, protein, ascorbic acid, moderate yellowness index. Based on their desirable proportion the product was optimized by superimposition of contour plots to get the common destination of the desirable parameters.

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3. Result and Discussion

3.1. Blanching of orange peel

Table 3. Change the moisture content after blanching of orange peel at different levels of blanching.

Sr. No.	Treatments	IMC of orange peel (% db)	Blanching temperature and time	FMC after blanching (% db)
1	T_1	298.32 (% db)	72ºC for 10 min	488.32 (% db)
2	T_2	286.10 (% db)	82ºC for 8 min	433.717 (% db)
3	T_3	295.25 (% db)	92ºC for 5 min	461.085 (% db)
4	T_4	289.10 (% db)	72ºC for 10 min	370.25(% db)
5	T_5	588.379 (% db)	82ºC for 8 min	686.823 (% db)
6	T_6	486.291 (% db)	92ºC for 9 min	511.7 (% db)
7	T_7	300.503 (% db)	72ºC for 10 min	488.32 (% db)
8	T_8	293.613 (% db)	82ºC for 8 min	482.48 (% db)
9	T_9	299.218 (% db)	92ºC for 5 min	495.443 (% db)

Table 3 shows the change in moisture content (% db) of the blanching of orange peel at 72°C for 10 min; 82° for 8 min and 92°C for 5 min. The moisture content of orange peel increase from 298.32 (% db) to 488.32 (% db), 286.10 (%db) to 433.717 (% db), 295.25 (% db) to 461.085 (% db), 289.10 (% db) to 370.25(% db), 588.379 (% db) to 686.823 (% db), 486.291 (% db) to 511.7 (%db), 300.503 (% db) to 488.32 (% db), 293.613 (% db) to 482.48 (%db), 299.218 (% db) to 495.443 (% db) respectively of treatments T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8 and T_9 after the blanching treatments.

3.2 Drying Kineties

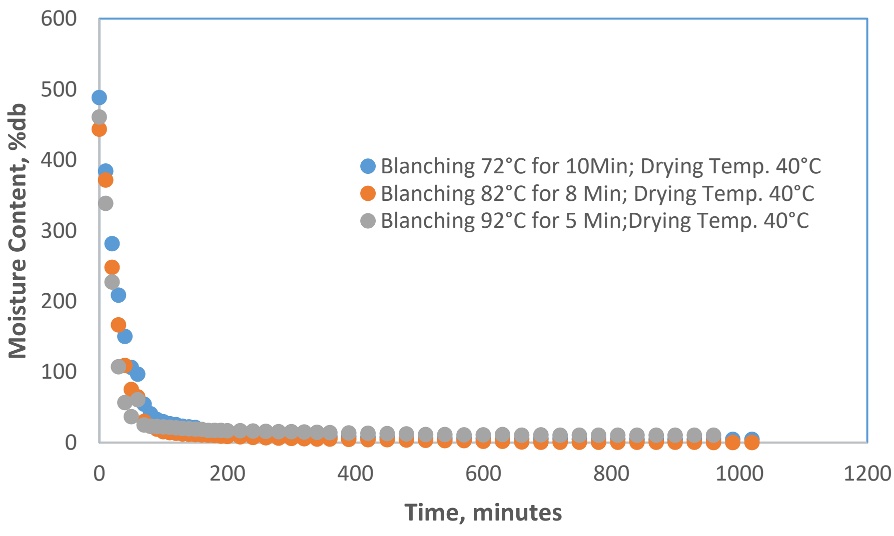

Fig.2 Effect of blanching Temperature and Temperature of drying on Moisture content of Orange peel

Fig 2 shows moisture content (%db) w.r.t time (min) of blanched orange peel dried by convective hot air drying at 40ºC. The orange peel were blanched for 72ºC:10 min, 82:8ºC min and 92:5ºC min and dried at 40ºC with an average initial moisture content 488.32 (db)% , 433.717 (db)% and 461.085 (db)% to 11.97(db)%, 11.69(db)%, and 13.166(db)% respectively. To complete this process it took around 1020 min, 990 min and 870 min for drying of blanched orange peel in convective hot air dryer at 40ºC.

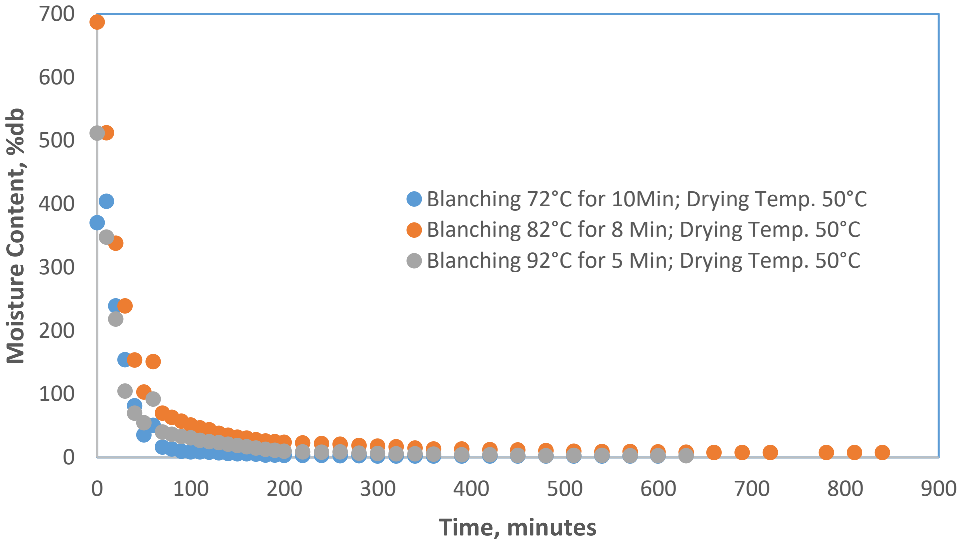

Fig3. Effect of blanching Temperature and Temperature of drying on Moisture content of Orange peel

Fig 3 shows that moisture content (db)% w.r.t time (min) of blanched orange peel dried by tray drying. The orange peel were blanched for 72ºC:10 min, 82:8ºC min and 92:5ºC min and dried at 50ºC with an average initial moisture content 370.25(db)% , 686.823(db)% 511.7 (db)% to final moisture content 8.186 (db)%, 15.379 (db)% 13.857 (db)% respectively. It took around 810min, 690 min and 570 min respectively for drying of blanched orange peel.

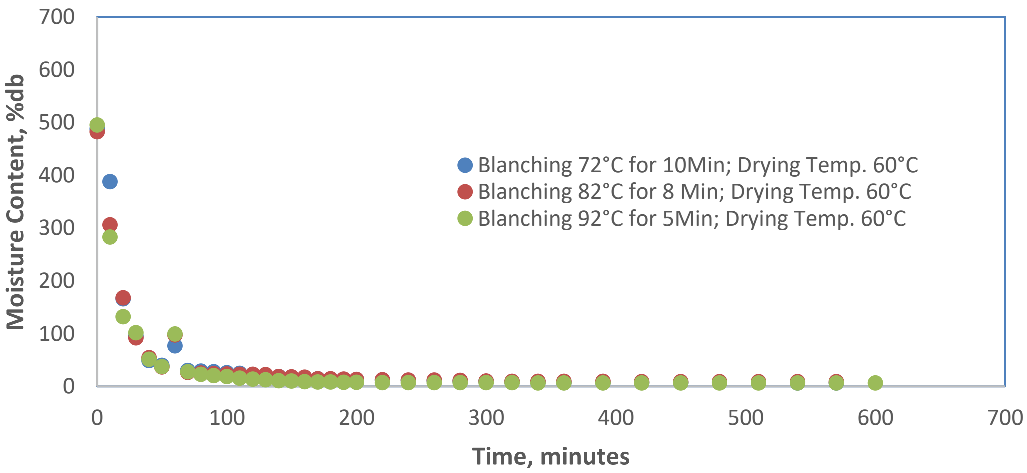

Fig. 4Effect of blanching Temperature and Temperature of drying on Moisture content of Orange peel

Similarly fig 4 shows the moisture content (db) % w.r.t. time (min) of blanched orange peel dried by tray dryer at 60ºC. The orange peel blanched for 72ºC:10 min, 82:8ºC min and 92:5ºC min and dried from an at 60ºC from an initial moisture content 488.32 (%db), 482.48 (%db) and 495.443 (%db) to final moisture content 6.344(%db), 13.419 (%db) and 13.253 (%db) respectively. It took around 600 min, 540 min and 480 min for drying the peel.

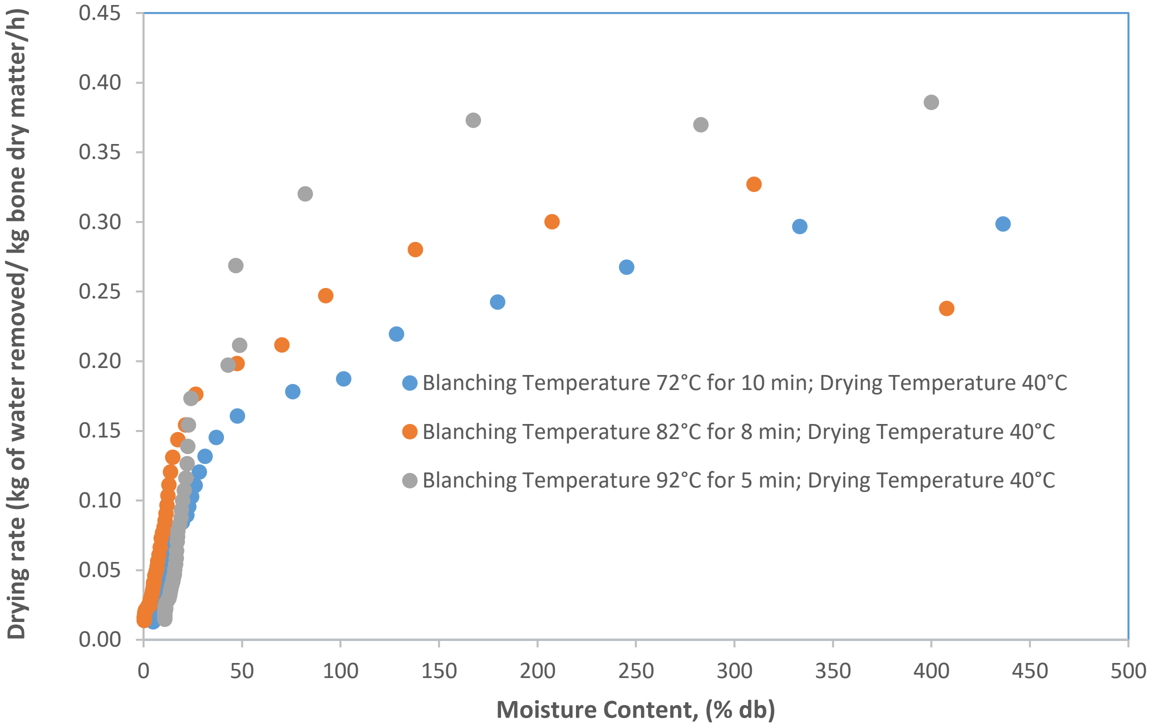

Fig 5 Drying rate(kg of water removed/kg bone dry material/h) versus Moisture content (%db) of Orange peel blanched at various conditions and dried at 40°C

Fig 5 shows the drying rate (kg of water removed/kg of dry material/h) w.r.t moisture content (%db) of blanched orange peel at 72ºC for 10 min; 82ºC for 8 min and 92 ºC for 5 min and dried at 40 ºC. The drying rate decreases from 0.30 to 0.01; 0.33 to 0.01 and 0.39 to 0.01 (kg of water removed/ kg of dried moisture/h) at blanching condition 72ºC for 10 min; 82ºC for 8 min and 92 ºC for 5 min respectively. The drying took place in a falling rate period.

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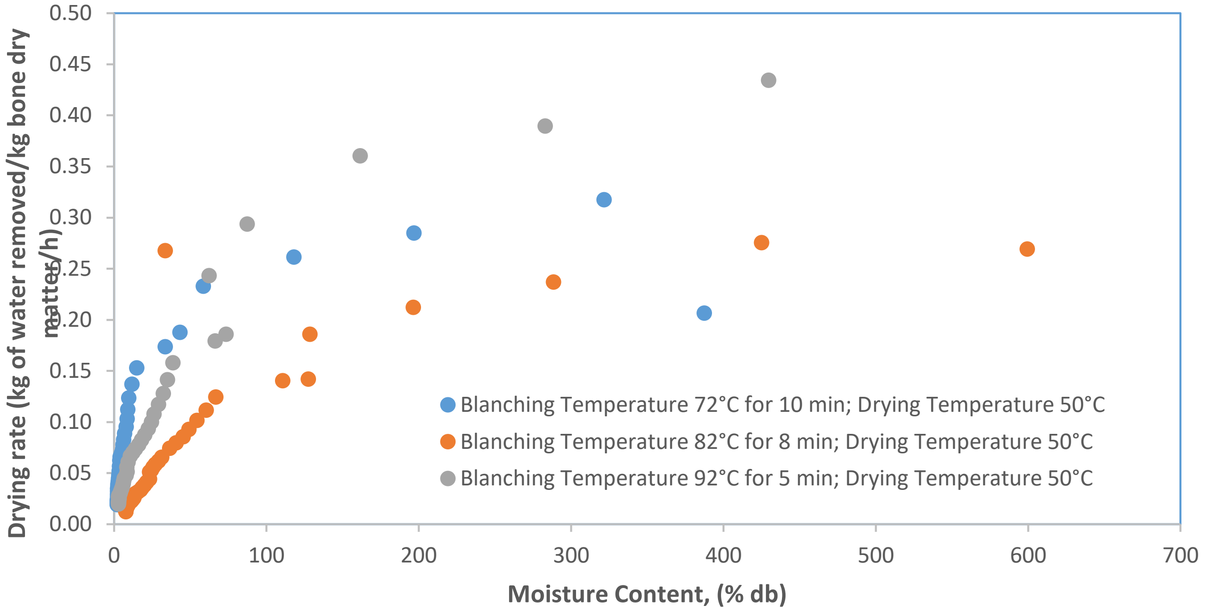


Fig 6 Drying rate(kg of water removed/kg dry matter/h) versus Moisture content (%db) of Orange peel blanched at various conditions and dried at 50°C

Fig 6 shows the drying rate (kg of water removed/kg of dry material/h w.r.t moisture content (% db) of blanched orange peel at 72ºC for 10 min; 82ºC for 8 min and 92 ºC for 5 min and dried at 50 ºC. The drying rate decreases from 0.45 to 0.03; 0.34 to 0.01 and 0.44 to 0.02 kg of water removed/per kg of dry material/h) at blanching condition 72ºC for 10 min; 82ºC for 8 min and 92 ºC for 5 min respectively. The drying took place in a falling rate period.

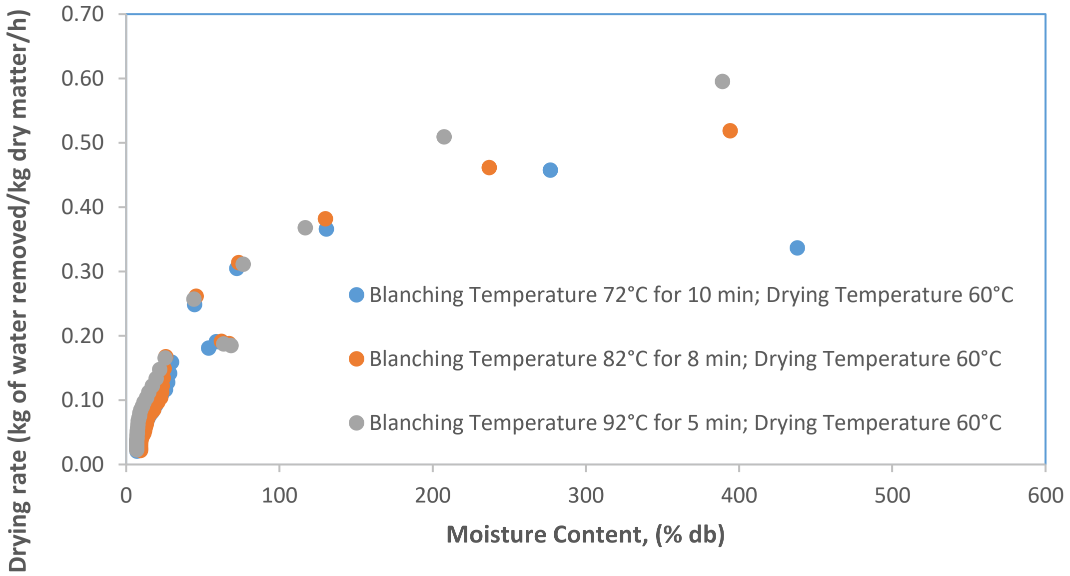


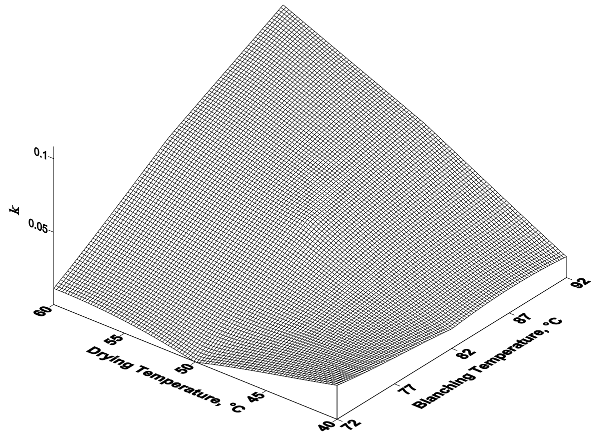
Fig 7 Drying rate(kg of water removed/kg dry matter/h) versus Moisture content (%db) of Orange peel blanched at various conditions and dried at 60°C

Fig 7 shows the drying rate (kg of water removed/kg of dry material/h) w.r.t moisture content (%db) of blanched orange peel at 72ºC for 10 min; 82ºC for 8 min and 92 ºC for 5 min and dried at 60 ºC. The drying rate decreases from 0.30 o 0.01; 0.50 to 0.02 and 0.59 to 0.03 kg of water removed/kg of dry material/h) at blanching condition 72ºC for 10 min; 82ºC for 8 min and 92 ºC for 5 min respectively. The drying took place in a falling rate period. In all the three figures, Fig.5, Fig.6, and Fig.7 the drying rate was common to many fruits and vegetables reported in the literature Falade *et al*., 2010 in air drying of fresh and blanched potato slices Chen *et al.*, 2016 reported the falling rate period of blanch carrot slices, Sobukola *et al*., 2008 reported the similar falling rate period of hot air drying of blanched yam slices, Hande *et al*., 2014 reported falling rate period of kokum rind.

3.3 Modelling of Drying curve

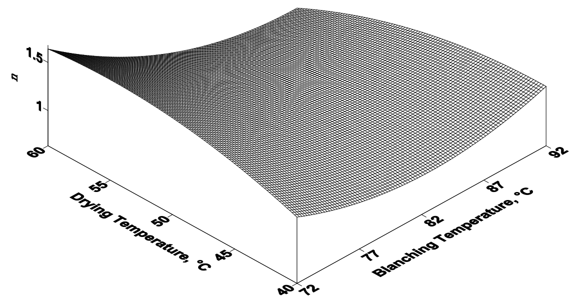
Table 4, 5 and 6 shows various models i.e, Lewis model (1921), Page model (1961) and Henderson and Pabis (1949) fitted to the experimental data of moisture ratio vs time of blanched and dried orange peel of various temperatures. From the all these three models based of higher r^2 value and lower RMSE, the Page model fitted well with $r^2 \geq 0.976$ and MSE ≤ 0.0012. k and n value of Page models are constant which are temperature dependent.

Fig.8 Page constants 'k' and 'n'



a) Effect of Blanching temperature and the Drying temperature on the Page 'k';

Fig 8 (a) shows effect of temperature of blanching and temperature of drying of orange peel on 'k' value of Page model. The 'k' value was in the range of 0.0006 to 0.0239. It is observed that as the blanching temperature increases at lower drying temperature there is no much change in 'k' value. As the temperature of drying increases at higher blanching temperature the 'k' value increases.



(b) Effect of Blanching temperature and the Drying temperature on the Page 'k' of Orange Peel blanching and drying

Fig 8 (b) shows the effect of blanching temperature (°C) and drying temperature on 'n' value of the Page model fitted to the orange peel drying. The 'n' value was in the range of 0.8673 to 2.1000. as the blanching temperature increases from 72°C to 92°C the 'n' value decreases. As the drying temperature increases from 40°C to 60°C the 'n' value increases. As both the blanching temperature and drying temperature increases the 'n' value decreases.

Table 4. Various parameter for r^2, RMSE Lewis model (MR=exp(-kt))

Treatment	k	R^2	RMSE
72ºC:10 min	0.0291	0.9969	0.0001
82ºC:8 min	0.0320	0.9902	0.0004
92ºC:5 min	0.0436	0.9850	0.0005
72ºC:10 min	0.0307	0.9395	0.0045
82ºC:8 min	0.0335	0.9879	0.0005
92ºC:5 min	0.0429	0.9814	0.0008
72ºC:10 min	0.0466	0.9699	0.0014
82ºC:8 min	0.0513	0.9815	0.0007
92ºC:5 min	0.0568	0.9784	0.0008

Table 5. Page model (MR=exp(-kt^n))

Treatment	k	n	R^2	RMSE
72ºC:10 min	0.0239	1.0526	0.9970	0.0001
82ºC:8 min	0.0141	1.2292	0.9946	0.0002
92ºC:5 min	0.0150	1.3281	0.9912	0.0003
72ºC:10 min	0.0006	2.1000	0.9831	0.0013
82ºC:8 min	0.0497	0.8890	0.9894	0.0004
92ºC:5 min	0.0664	0.8673	0.9829	0.0007
72ºC:10 min	0.0117	1.4496	0.9760	0.0012
82ºC:8 min	0.0659	0.9194	0.9820	0.0007
92ºC:5 min	0.1081	0.7908	0.9828	0.0007

Table 6. Henderson and Pabis (MR=a exp(-kt))

Treatment	a	k	R^2	RMSE
72ºC:10 min	1.0185	0.0296	0.9969	0.0001
82ºC:8 min	1.0529	0.3362	0.9919	0.0003
92ºC:5 min	1.0281	0.2938	0.9935	0.0003
72ºC:10 min	1.1713	0.0349	0.9545	0.0035
82ºC:8 min	0.9949	0.0333	0.9879	0.0005
92ºC:5 min	0.9991	0.0429	0.9814	0.0008
72ºC:10 min	1.0478	0.0448	0.9714	0.0014
82ºC:8 min	1.0019	0.0551	0.9815	0.0008
92ºC:5 min	0.0344	0.0344	0.9764	0.0011

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3.4 Calculation of Effective Diffusivity

Effective diffusivity and activation energy of orange peel drying by convective hot air drying

Table 7. Table Values of Effective Diffusivity attained for various treatments of Orange Peel drying

Blanching Temperature and Time	Drying Temperature	Effective Diffusivity(D_{eff}) $\times 10^{-8}$ (m^2/s)
72°C for 10 minutes	40°C	0.0867
82°C for 8 minutes	40°C	1.8347
92°C for 5 minutes	40°C	2.0173
72°C for 10 minutes	50°C	0.0903
82°C for 8 minutes	50°C	1.0771
92°C for 5 minutes	50°C	1.8986
72°C for 10 minutes	60°C	1.1684
82°C for 8 minutes	60°C	1.4422
92°C for 5 minutes	60°C	1.5791

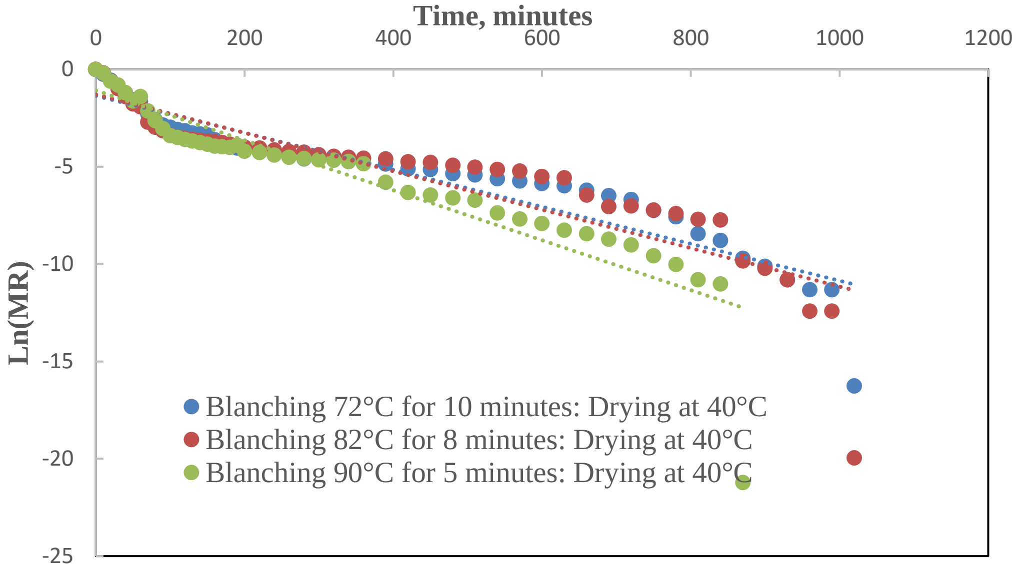

Fig.9 Ln(MR) versus time, minutes of Orange peel blanched at various temperature and dried at 40°C

Fig 9 shows graph of Ln (MR) versus time, min for orange peel blanched at 72ºC:10 min, 82ºC:8 min and 92ºC:5min at temperature at 40ºC. Equations obtained from the graph were compared with the standard equation i.e. $y= mx+c$. *"m"* value indicates the slope of line. Table 7 shows the effective diffusivity obtained for various treatments of blanching and drying of orange peel. Effective diffusivity (D_{eff}) at time (t) for orange peel were 0.0867×10^{-8}, 1.8347×10^{-8} and 2.0173×10^{-8} m^2/s which was blanched at 72ºC:10 min, 82ºC:8min and 92ºC:5 min and dried at 40ºC

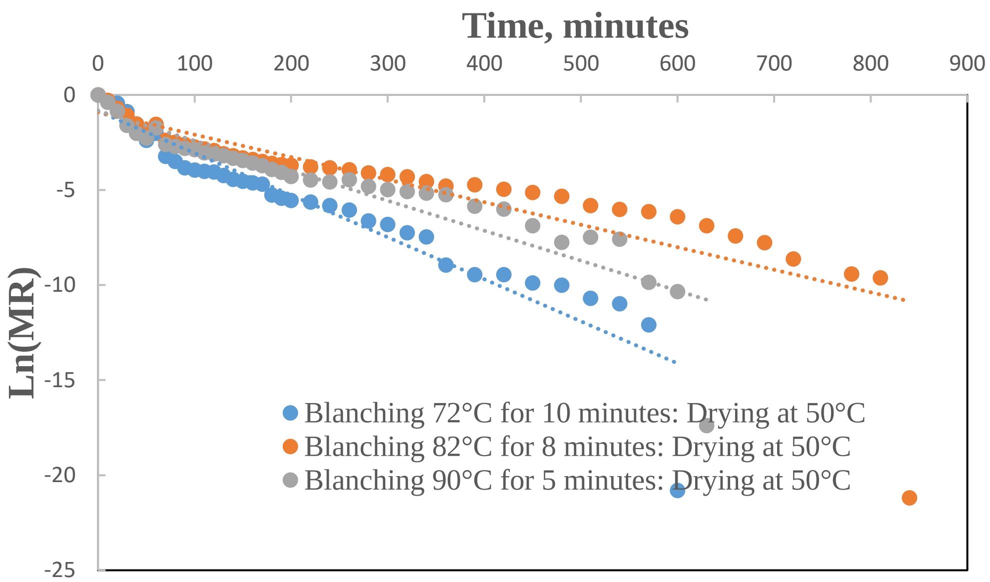

Fig10. Ln(MR) versus time, minutes of Orange peel blanched at various temperature and dried at 50°C

Fig 10 shows graph of Ln (MR) versus time, min for orange peel blanched at 72ºC:10 min, 82ºC:8 min and 92ºC:5min at temperature at 50ºC. Effective diffusivity (D_{eff}) at time (t) for orange peel were 0.0903×10^{-8}, 1.0771×10^{-8} and 1.89866×10^{-8} m^2/s which was blanched at 72ºC:10 min, 82ºC:8min and 92ºC:5 min and dried at 50ºC show in Table 7

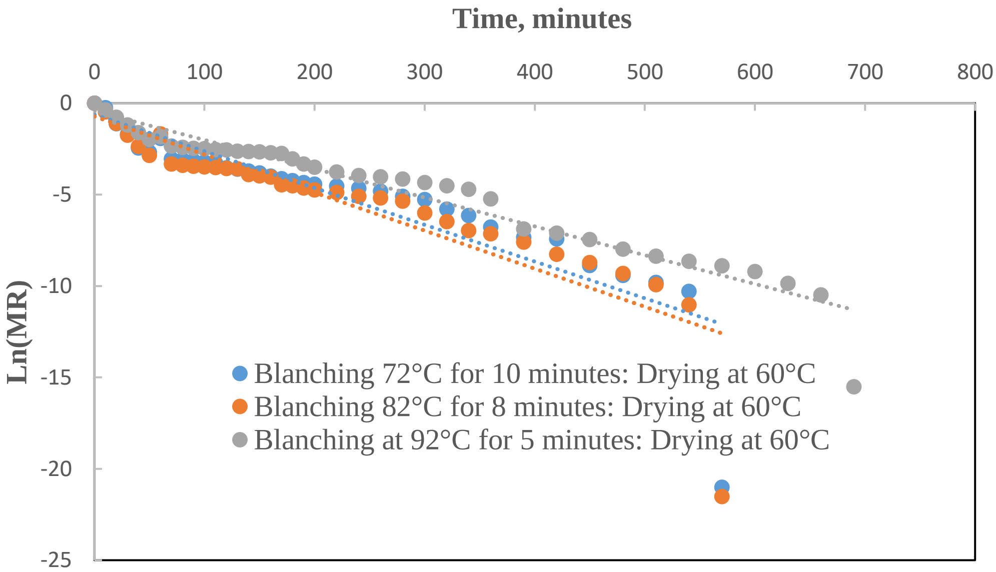

Fig11. Ln(MR) versus time, minutes of Orange peel blanched at various temperature and dried at 50°C

Fig 11 shows graph of Ln (MR) versus time, min for orange peel blanched at 72ºC:10 min, 82ºC:8 min and 92ºC:5min at temperature at 60ºC. Effective diffusivity (D_{eff}) at time (t) for orange peel were 1.1684×10^{-8}, 1.4225×10^{-8} and 1.5791×10^{-8} m^2/s which was blanched at 72ºC:10 min, 82ºC:8min and 92ºC:5 min and dried at 60ºC shown in Table 7. The effective diffusivity increases with an increase in blanching temperatures in all the drying temperature 40ºC, 50ºC and 60ºC respectively. For all the drying temperature the effective diffusivity value are in agreement with the literature value of effective diffusivity range from 9.14×10^{-11} to 1.78×10^{-9} and 6.36×10^{-11} to 8.14×10^{-10} at 50 to 80ºC for blanched sweet potato slices (Flade *et al.*, 2010). (Srikiatden *et al.*, (2003) also reported the moisture diffusivity range for potato, carrot core, carrot cortex and apple as 4.68×10^{-10} to 1.02×10^{-9} (m^2/s^{-1}). Over the range of 50-80ºC, moisture diffusivities varied from 9.92×10^{-8} to 1.02×10^{-7} and 0.829×10^{-6} to 1.298×10^{-5} (m^2/s^{-1}) for *D. alata* and *D. rotundata* respectively (Falade *et al.*, 2007), the maximum value of D_{eff} at 60, 70 and 80ºC were 40 $\times10^{-8}$, 66×10^{-8}, 91×10^{-8} m^2s^{-1}, 2.13×10^{-8}, 2.62×10^{-8}, 4.74×10^{-8} m^2s^{-1} in hot air and Short and medium wave infrared radiation drying (Chen *et al.*, 2017).

Table 8. Pre-Exponential factor D_0 of Arrhenious equation and the activation energy Ea (KJ/mole) at varied Conditions of Blanching and dried at varied temperature

Blanching Temperature and Time	$D_0\times10^{-5}$(m^2/s)	$E_a\times10^4$ (kJ/mole)
72°C for 10 minutes	6.1783	2.2440
82°C for 8 minutes	13.7092	2.52307
92°C for 5 minutes	0.1530	1.26227

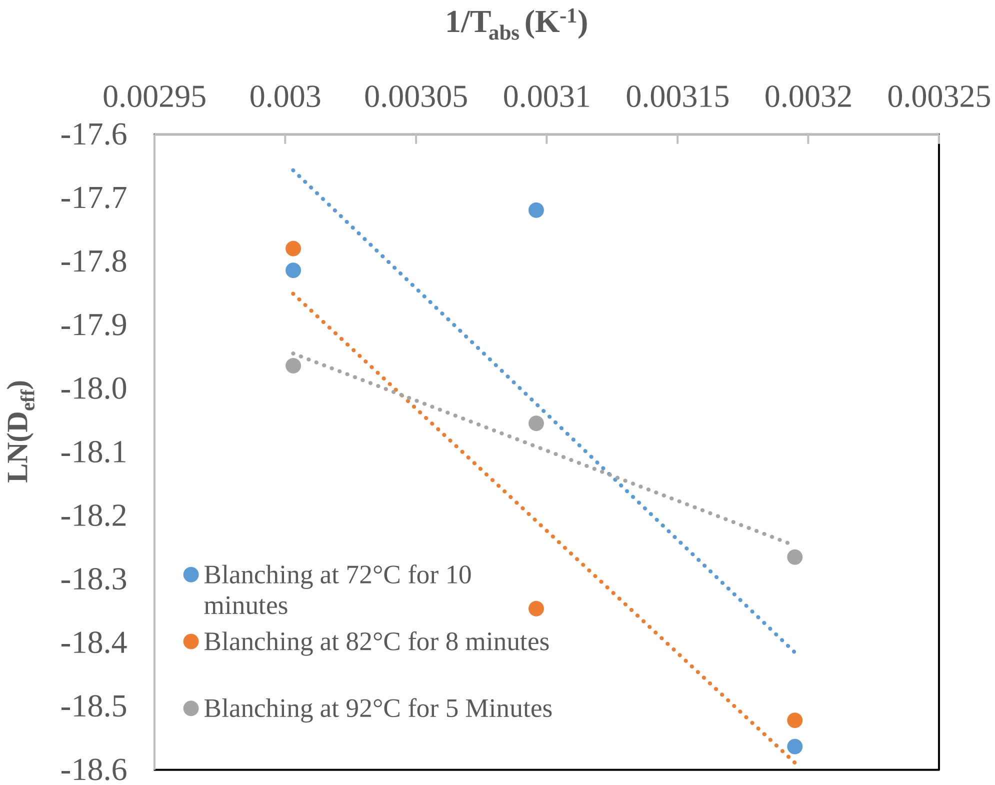

Fig12. Arrhenius-type relationship between the effective diffusivity and absolute temperature of orange peel blanched at various conditions

Fig 12 shows the Ln (D_{eff}) vs $1/T_{abs}$ (k^{-1}) of orange peel blanched at various temperature and dried at 40º, 50ºC and 60ºC respectively. For the particular blanching temperature. The Ln (D_{eff}) vs $1/T_{abs}$ (k^{-1}) shows the linear relationship, based on the slope an intercept the pre-exponential factor (D_0) and activation energy was determined. Table 8 shows the pre-exponential factor (D_0) and activation energy (kJ/mole) of orange peel blanched at 72ºC:10 min, 82ºC:8min and 92ºC:5 min and dried at 40, 50 and 60ºC. The pre-exponential factor D_o decreases from 6.1783×10^{-5} (m^2/s) to 0.1530×10^{-3} (m^2/s) and the activation energy decreases from 2.2440 kJ/mole to 1.26227 kJ/mole as the blanching temperature increase from 72ºC:10 min, 82ºC:8min and 92ºC:5 minutes.

The activation energy are reported in literature i.e, (25.26 to46.46 kJ mol^{-1}) for *D. alata* and (41.75 to 72.47 kJ mol^{-1}) for *D. rotundata* yam (Falade *et al.*, 2007), 18.9 to 14.8 $kJmol^{-1}$, 12.7 to 11.1 $kJmol^{-1}$ and 13.5 to 12.1 $kJmol^{-1}$ for blanched sweet potato slices (Flade *et al.*, 2010).

3.5 Evaluation of quality parameters for Dried Orange Peels

3.5.1 Total Soluble Solid (°B)

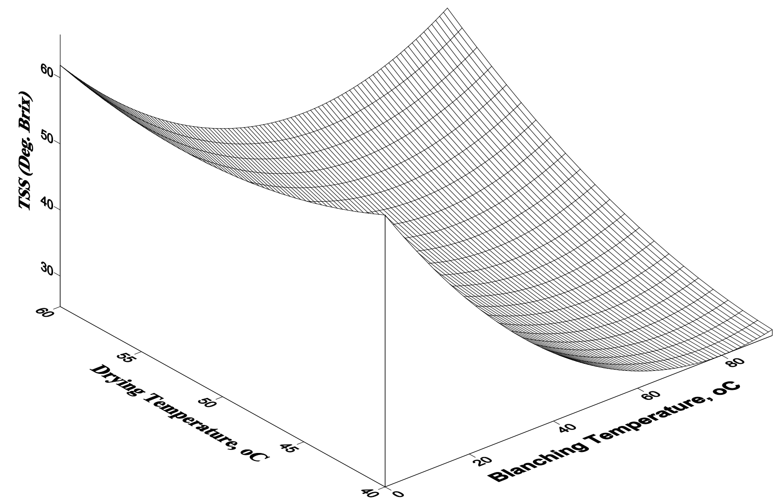

Fig.13 (a) Surface plots showing effect of Blanching temperature and convective hot air drying temperature on TSS of orange peel powder

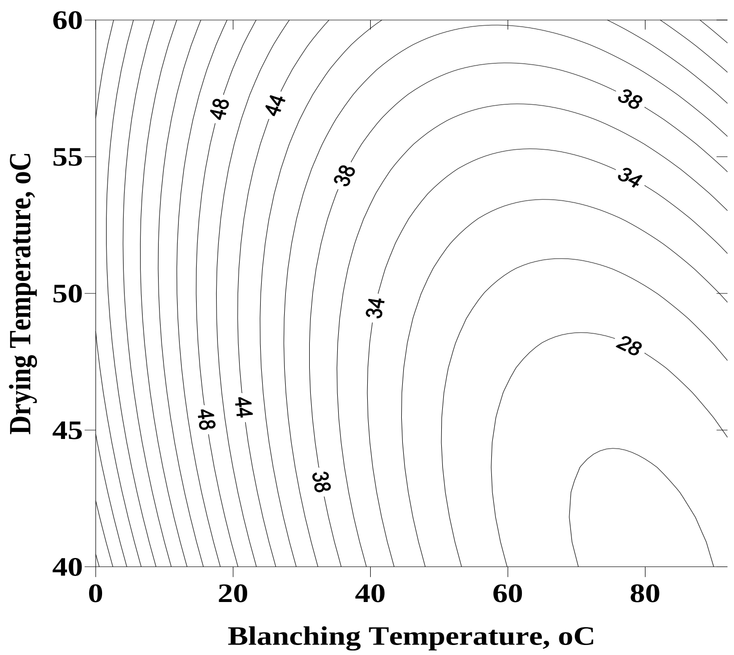

Fig.13 (b) Contour plots showing effect of blanching temperature and convective hot air drying temperature on TSS of orange peel powder

Fig.13 (a) the surface plot showing effect of blanching temperature (ºC) and drying temperature (ºC) on TSS (ºB) of orange peel. The TSS varies in the range of 20 to 60 (ºB). As the blanching temperature increases from 0 to 92ºC the TSS decreases. Similarly as the drying temperature increases from 40 to

60ºC the TSS decreases from 40 to 50ºC and start slight increasing trend up to 60ºC. Fig 13 (b) shows the contour plot of effect of blanching temperature (ºC) and drying temperature (ºC) on TSS. As both the blanching temperature and drying temperature increases the TSS decreases. Table 9 (a) shows the ANOVA for effect of blanching temperature (ºC) and drying temperature (ºC) on TSS. TSS shows the significant effect at $p \leq 0.05$ on drying temperature 40, 50 and 60 ºC with blanching temperature. Blanching temperature and the drying temperature has a significant effect on TSS, the interaction of blanching temperature and drying temperature also shows the significant effect on TSS of orange peel $p \leq 0.05$. Similarly (Manjarres-Pinzon *et al*., 2013) reported that the orange peel dried at 30°C having high °Brix i.e values 49 °Brix, it has been reported that as the drying temperature increases TSS decreases. (Pilli *et al*., 2008) reported that combination system of microwave and hot air dehydration of orange slices decreases TSS from 66.75 to 79.19 (ºB) at the higher values of temperature and air speed.

3.5.2 Acidity

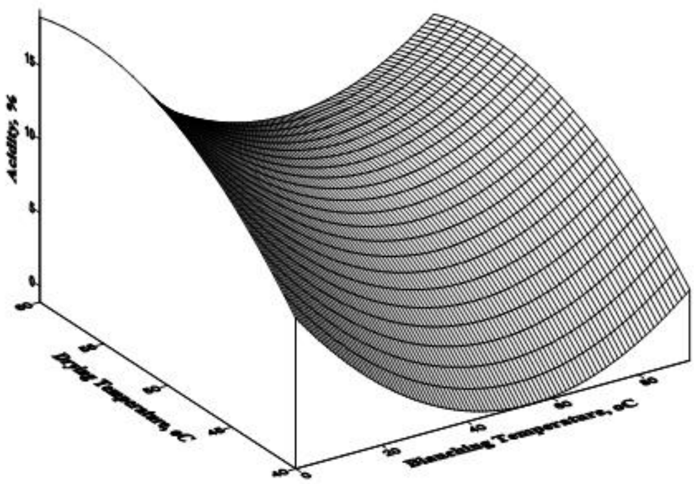

Fig.14 (a) Surface plots showing effect of blanching temperature and convective hot air drying temperature on acidity of orange peel powder.

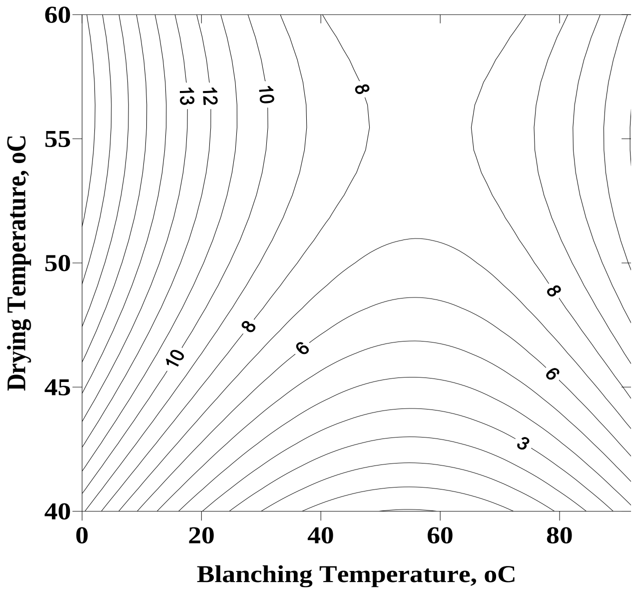

Fig.13 (b) Contour plots showing effect of blanching temperature and convective hot air drying temperature on acidity of orange peel powder

Fig.14 (a) the surface plot showing effect of blanching temperature (ºC) and drying temperature (ºC) on acidity of orange peel. The acidity varies in the range of 0.32 to 18.07%. As the blanching temperature increases from 0 to 60ºC the acidity decreases and start slightly increasing from 60 to 92ºC. Similarly as the drying temperature increases from 40 to 60ºC the acidity decreases. Fig 14 (b) shows the contour plot of effect of blanching temperature (ºC) and drying temperature (ºC) on acidity. As both the blanching temperature and drying temperature increases the acidity decreases. Table 9 (b) shows the ANOVA for effect of blanching temperature (ºC) and drying temperature (ºC) on acidity. Acidity shows the significant effect at p≤0.05 on drying temperature 40, 50 and 60 ºC with blanching temperature. Blanching temperature and the drying has a significant effect on acidity; the interaction of blanching temperature and drying temperature has also significant effect on acidity of orange peel. Similar report was shown by (Hande *et al*., 2014) that acidity of kokum rind increases from 0.85±0.19 to 3.187±0.16% due to drying. Similar result was also been observed during drying of grapes, for carrot, white mulberry, okra, tomatos (Mahmutoglu *et al*., 1996) and (Doymaz 2002, 2004(a), 2004(b), 2005, 2007).

3.5.3 Reducing Sugar

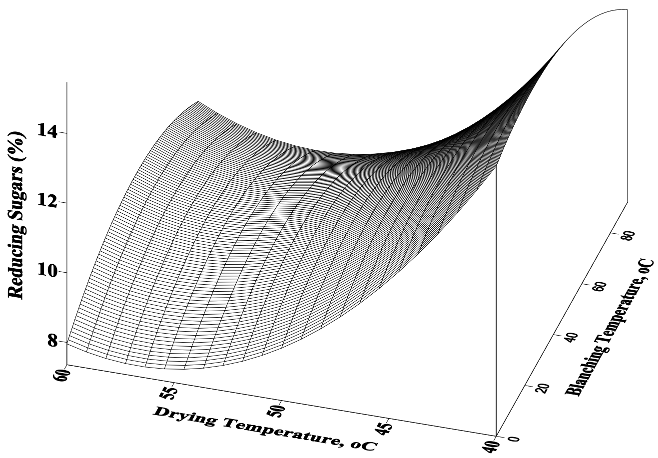

Fig.15 (a) Surface plots showing effect of blanching temperature and convective hot air drying air temperature on reducing sugar of orange peel powder

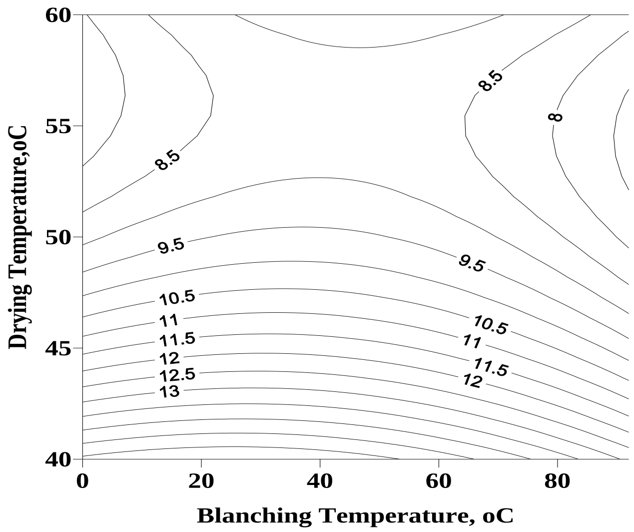

Fig.15 (b) Contour plots showing effect of blanching temperature and convective hot air drying temperature on reducing sugars of orange peel powder.

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Fig 15 (a) shows that as the blanching temperature increases from 0 to 92ºC reducing sugar increases. Reducing sugar range from 19.05 to 6.21 %. Similarly as drying temperature increases from 40ºC to 60ºC. The reducing sugar decreases from 40ºC to 60ºC and there is slight increases at 60ºC. Fig 15(b) shows the contour plot of effect of blanching temperature (ºC) and drying temperature (ºC) on reducing sugar. As both the blanching temperature and drying temperature increases the reducing sugar decreases. Table 9 (c) shows the ANOVA for effect of blanching temperature (ºC) and drying temperature (ºC) on reducing sugar. Reducing sugar shows the significant effect at p≤0.05 on drying temperature 40, 50 and 60ºC and with blanching temperature 72ºC for 10 min; 82ºC for 8 min and 92 ºC for 5 min. Blanching temperature and the drying has a significant effect on reducing sugar, the interaction of blanching temperature and drying temperature has also significant effect on reducing sugar of orange peel at p≤0.05. It was reported by Hande *et al*., (2014) that the reducing sugar increase in tray dry of kokam rind powder. Cholera (2010) reported that reducing sugar in osmo-air guava dried powder decreases and Costa *et al*., (2009) reported that reducing sugar in cashew apple fruit decreases.

3.5.3 Non-Reducing sugar

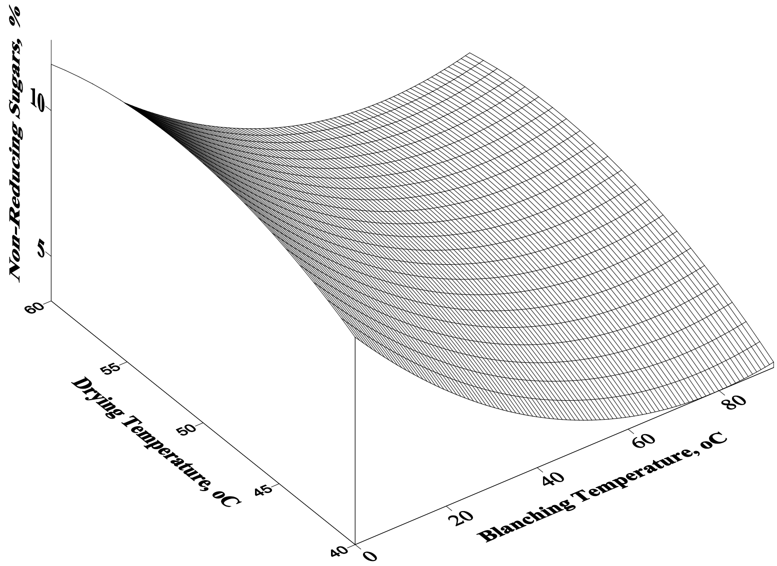

Fig.16 (a) Surface plots showing effect of blanching temperature and convective hot air drying air temperature on non-reducing sugar of orange peel powder.

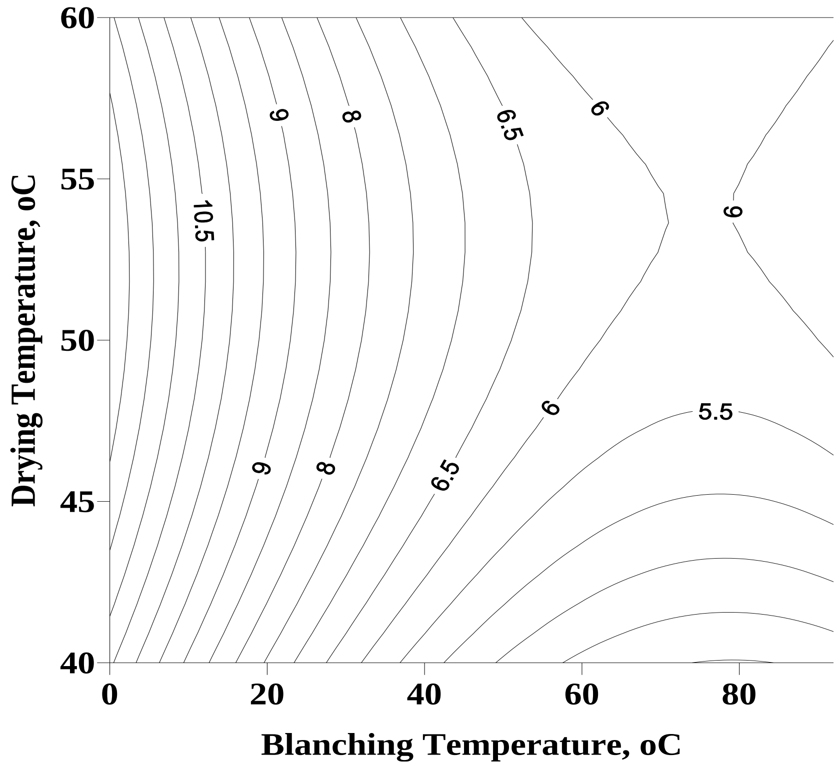

Fig.16 (b) Contour plots showing effect of blanching temperature and convective hot air drying temperature on non-reducing sugars of orange peel powder

Fig.16 (a) the surface plot showing effect of blanching temperature (ºC) and drying temperature (ºC) on non-reducing sugar of orange peel. The non-reducing sugar varies in the range of 2.56 to 10.13%. As the blanching temperature increases from 0 to 92ºC the non-reducing sugar decreases. Similarly as the drying temperature increases from 40 to 60ºC the non-reducing sugar decreases. Fig 16 (b) shows the contour plot of effect of blanching temperature (ºC) and drying temperature (ºC) on non-reducing sugar. As both the blanching temperature and drying temperature increases the non-reducing sugar decreases. Table 9(d) shows the ANOVA for effect of blanching temperature (ºC) and drying temperature (ºC) on non-reducing sugar. non-reducing sugar shows the significant effect at $p \leq 0.05$ on drying temperature 40, 50 and 60 ºC with blanching temperature 72ºC for 10 min; 82ºC for 8 min and 92 ºC for 5 min. Blanching temperature and the drying has a significant effect on non-reducing sugar, the interaction of blanching temperature and drying temperature has also significant effect on non-reducing sugar of orange peel. It was reported by Hande *et al*., (2014) that non reducing sugar decreases.

3.5.4 Total sugar

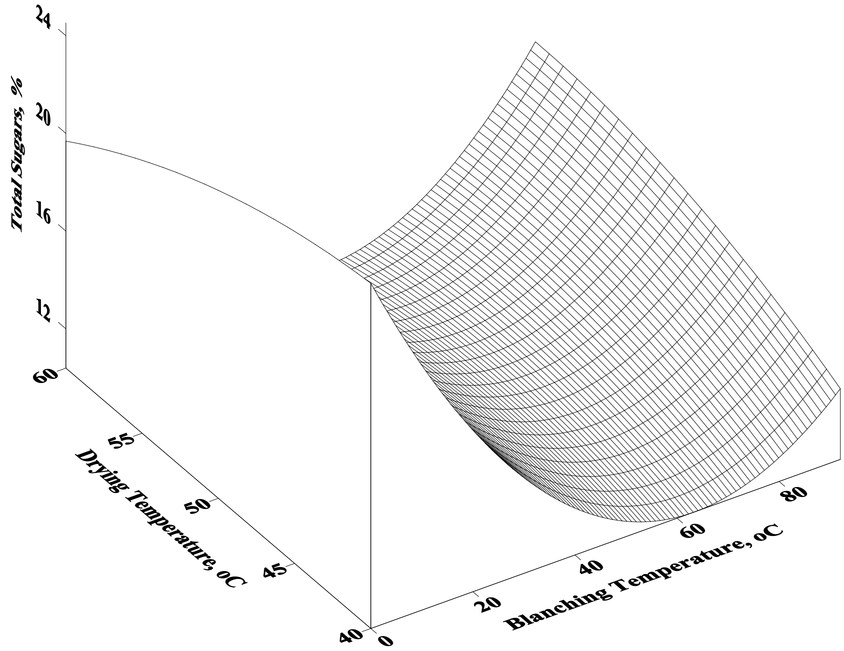

Fig.16 (a) Surface plots showing effect of blanching temperature and convective hot air drying air temperature on total sugar of orange peel powder

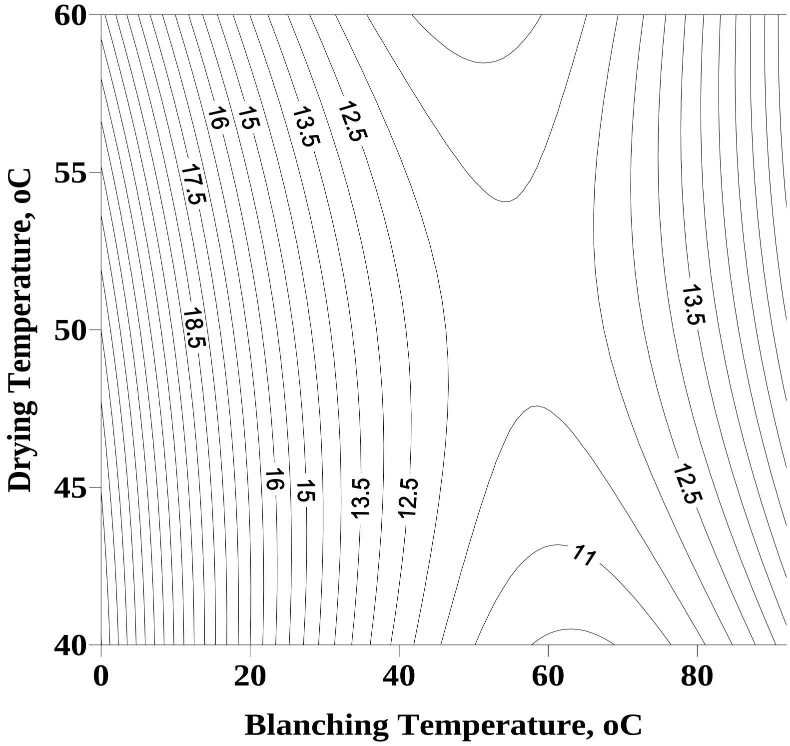

Fig.16 (b) Contour plots showing effect of blanching temperature and convective hot air drying temperature on total sugars of orange peel powder

Fig.17 (a) the surface plot showing effect of blanching temperature (ºC) and drying temperature (ºC) on total sugar of orange peel. The total sugar varies in the range of 9.08 to 25.8 %. As the blanching temperature increases from 0 to 60ºC the total sugar decreases and start slightly increasing from 60 to 92ºC. Similarly as the drying temperature increases from 40 to 60ºC the total sugar decreases from 40 to 60ºC and the total sugar decreases. Fig 17 (b) shows the contour plot of effect of blanching temperature (ºC) and drying temperature (ºC) on total sugar. As both the blanching temperature and drying temperature increases the total sugar decreases. Table 9(e) shows the ANOVA for effect of blanching temperature (ºC) and drying temperature (ºC) on total sugar. Total sugar shows the significant effect at $p \leq 0.05$ on drying temperature 40, 50 and 60 ºC with blanching temperature 72ºC for 10 min; 82ºC for 8 min and 92 ºC for 5 min. Blanching temperature and drying has a significant effect on total sugar, the interaction of blanching temperature and drying temperature has also significant effect on total sugar of orange peel. (Ghanem *et al*., 2012) reported mandarin had high amount of total sugar as the temperature increase 18.275±0.784g/100 DM. Talens *et al*., 2017 reported that sugar content 0.1±0.1kg in orange peel due to effect of hot air drying process. Drying of orange peel powder at 50ºC for 24h the sugar content 9.20±0.22g/100gDW reported by (Zaker *et al*., 2016)

3.5.5 pH

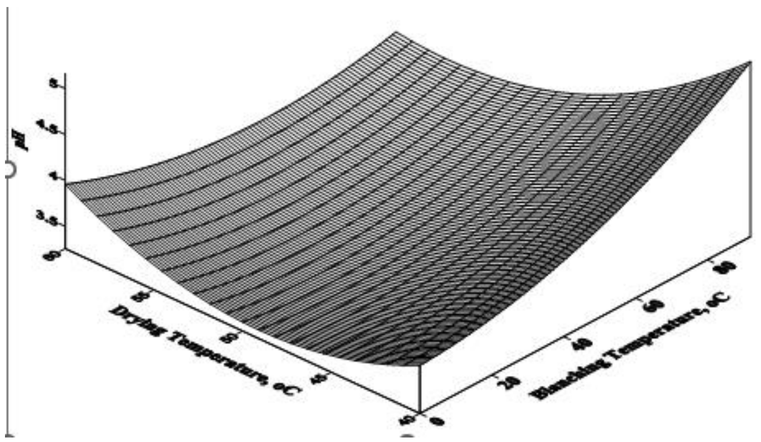

Fig.18 (a) Surface plots showing effect of blanching temperature and convective hot air drying air temperature on pH of orange peel powder

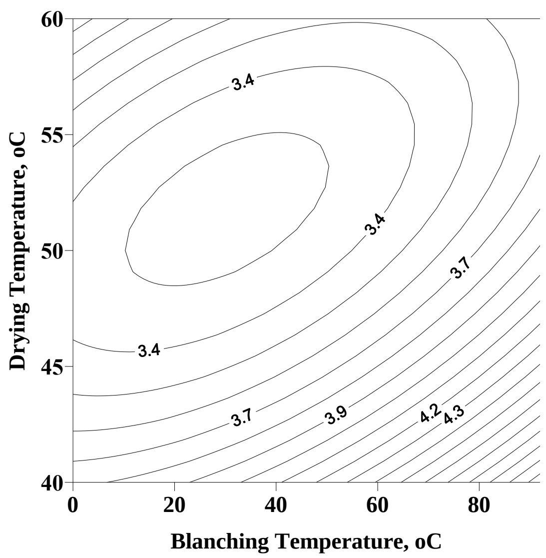

Fig.18 (b) Contour plots showing effect of blanching temperature and convective hot air drying temperature on pH of orange peel powder

Fig.18 (a) the surface plot showing effect of blanching temperature (ºC) and drying temperature (ºC) on pH of orange peel. The pH varies in the range of 5.4 to 3.6 %. As the temperature increases of blanching pH increases from 0 to 92ºC. Similarly as the drying temperature increases from 40 to 60ºC the pH decreases from 40 to 50ºC and start slight increasing trend up to 60ºC. Fig 18 (b) shows the contour plot of effect of blanching temperature (ºC) and drying temperature (ºC) on pH. As both the blanching temperature and drying temperature increases the pH decreases. Table 9 (f) shows the ANOVA for effect of blanching temperature (ºC) and drying temperature (ºC) on pH. pH shows the significant effect at p≤0.05 on drying temperature 40, 50 and 60 ºC with blanching temperature 72ºC for 10 min; 82ºC for 8 min and 92 ºC for 5 min. Blanching and drying has a significant effect on pH, the interaction of blanching temperature and drying temperature has also significant effect on pH of orange peel. Similar result were reported by (Hande *et al*., 2014) the pH of Kokam rind was 2.54±0.24 before drying and after drying the pH value was 2.079±0.21. Drying of cashew apple fruit powder pH 3.97±0.00 (Costa *et al*., 2009); Osorio *et al*., (2010) reported that guava powder pH value range from 4.11 and 4.28, Mahendran *et al*., (2010) reported that freeze dry guava juice powder pH 0.44 after drying.

3.5.6 Ascorbic acid

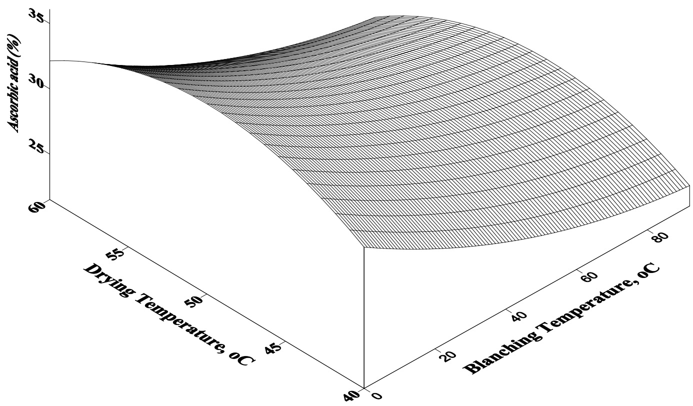

Fig.19 (a) Surface plots showing effect of blanching temperature and convective hot air drying air temperature on ascorbic acid of orange peel powder

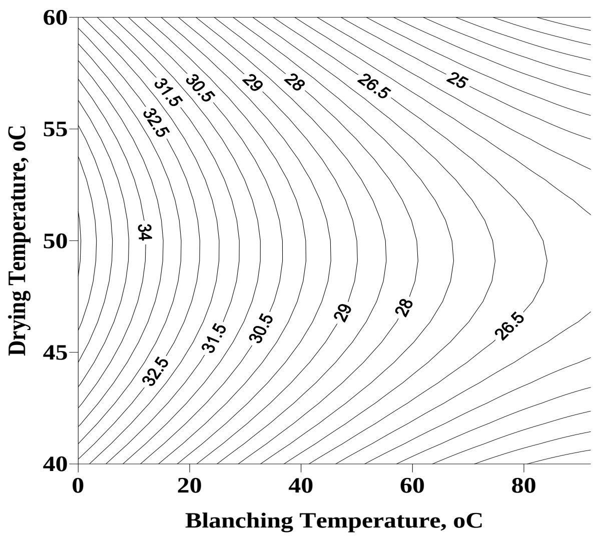

Fig.19 (b) Contour plots showing effect of blanching temperature and convective hot air drying temperature on ascorbic acid of orange peel powder

Fig.19 (a) the surface plot showing effect of blanching temperature (ºC) and drying temperature (ºC) on ascorbic acid of orange peel. The ascorbic acid varies in the range of 18.2 to 34.76%. As the blanching temperature increases from 0 to 92ºC the ascorbic acid decreases. Similarly as the drying temperature increases from 40 to 60ºC the ascorbic acid increases from 40 to 60ºC. Fig 19 (b) shows the contour plot of effect of blanching temperature (ºC) and drying temperature (ºC) on ascorbic acid. As both the blanching temperature and drying temperature increases the ascorbic acid decreases. Table 9(g) shows the ANOVA for effect of blanching temperature (ºC) and drying temperature (ºC) on ascorbic acid. ascorbic acid shows the significant effect at p≤0.05 on drying temperature 40, 50 and 60 ºC with blanching temperature 72ºC for 10 min; 82ºC for 8 min and 92 ºC for 5 min. Blanching temperature and drying has a significant effect ascorbic acid, the interaction of blanching temperature and drying temperature has also significant effect on ascorbic acid of orange peel. Hernandez-Carranza *et al*., 2016 reported that, in orange peel ascorbic acid reduced by pretreatments (blanching and drying), affecting between 3.23and 20.6% of the original content; (Ojha *et al*., 2016) reported that ascorbic acid content were found to be low due to blanching and drying of mandarin peel powder. The amount of water used during blanching affect the amount of ascorbic acid lost due to leaching of water soluble compound into blanching water (Lin *et al*., 2005), Also, loss of ascorbic acid during blanching could be attribute to the fact that the vitamin C is soluble in water and not stable in high temperature (Dewanto *et al*., 2002).

3.5.7 Yellowness Index

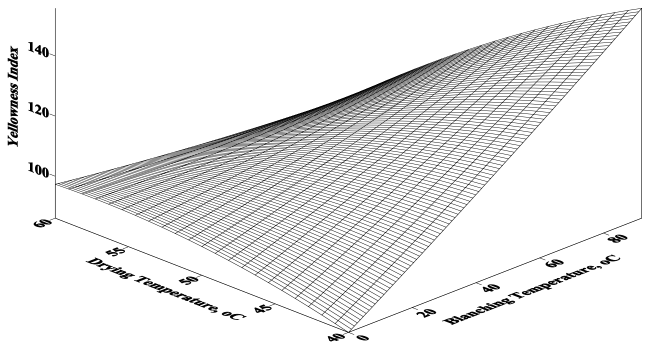

Fig.20 (a) Surface plots showing effect of blanching temperature and convective hot air drying air temperature on Yellowness Index of orange peel powder

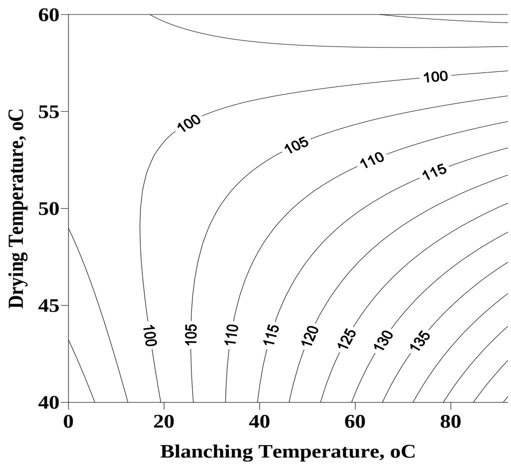

Fig.20 (b) Contour plots showing effect of blanching temperature and convective hot air drying temperature on Yellowness Index of orange peel powder

Fig.20 (a) the surface plot showing effect of blanching temperature (ºC) and drying temperature (ºC) on yellowness index of orange peel. The yellowing index varies in the range of 77.96 to 154.40. As the temperature of blanching increases yellowness index increases from 0 to 80ºC. Similarly as the drying temperature increases from 40 to 60ºC the yellowing index increases. Fig 20 (b) shows the contour plot of effect of blanching temperature (ºC) and drying temperature (ºC) on yellowness index. As both the blanching temperature and drying temperature increases the yellowness index increases. Table 6 shows the ANOVA for effect of blanching temperature (ºC) and drying temperature (ºC) on yellowness index. Yellowness index shows the significant effect at p≤0.05 on drying temperature 40, 50 and 60ºC with blanching temperature. Blanching temperature and drying has a significant effect on yellowness index p≤0.05, the interaction of blanching temperature and drying temperature has also significant effect on yellowness index of orange peel. It was reported by (Manjarres-Pinzon *et al.*, 2013), (Moraes Crizel 2013) and (Liu *et al.*, 2016) in orange peel that the use of higher temperature and the length of the drying process can cause non enzymatic browning reaction, such as Millard reaction. The increase in yellowness at higher temperature might be attribute due to the non-enzymatic browning reactions.

3.5.8 Protein

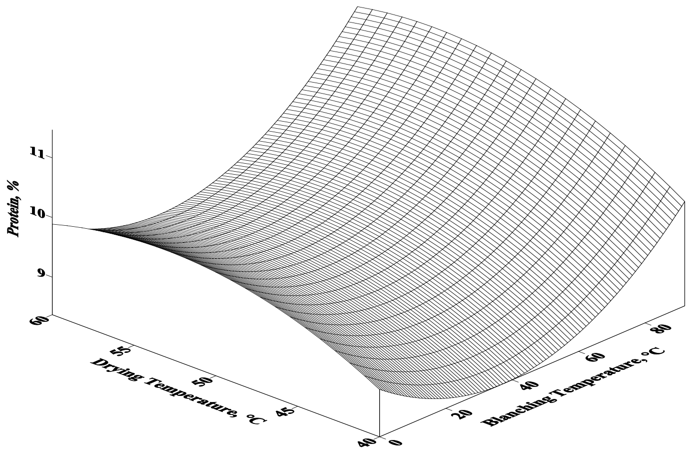

Fig.21 (a) Surface plots showing effect of blanching temperature and convective hot air drying air temperature on protein of orange peel powder

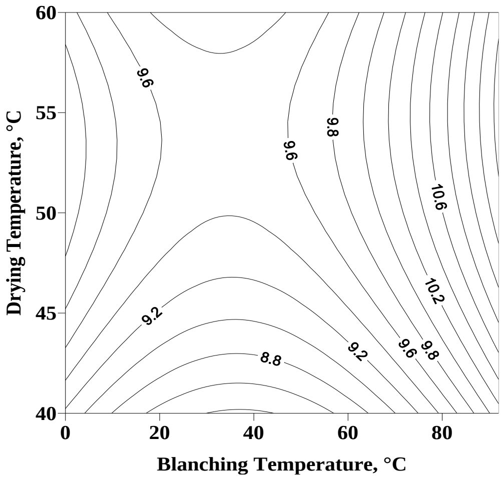

Fig.21 (b) Contour plots showing effect of blanching temperature and convective hot air drying temperature on protein of orange peel powder

Fig.21 (a) the surface plot showing effect of blanching temperature (ºC) and drying temperature (ºC) on protein of orange peel. The protein varies in the range of 8.60 to 11.24%. As the blanching temperature increases from 0 to 40ºC the protein decreases and start slightly increasing from 40 to 80ºC. Similarly as the drying temperature increases from 40 to 60ºC the protein increases. Fig 21 (b) shows the contour plot of effect of blanching temperature (ºC) and drying temperature (ºC) on protein. As both the blanching temperature and drying temperature increases the protein increases. Table 6 shows the ANOVA for effect of blanching temperature (ºC) and drying temperature (ºC) on protein. Protein shows the significant effect at p≤0.05 on drying temperature 40, 50 and 60ºC with blanching temperature. Blanching temperature and drying has a significant effect on protein, and the interaction of blanching temperature and drying temperature has also significant effect on protein of orange peel. The decreases in protein content by the various treatments could be attributed to the fact that some of the proteins were leached off by water during soaking and blanching reported by (Oboh, 2005). Protein content were found to be low in blanched mandarin peel powder (3.82 and 1.93%) as compare to raw mandarin peel powder (4.39 and 3.36%) reported by (Ojha *et al.*,2016). After drying the orange peel protein was 8.015±0.374g/100g dreported by (Bejar *et al*., 2011). Microwave dehydration of citrus peel shows the protein content 8.559±0.533g/100g DM reported by (Ghanem *et al*., 2012).

3.6 Optimum condition of orange peel powder.

The desirable qualities of orange peel powder was, the powder should have more TSS (°B), acidity %, reducing sugar %, non-reducing sugar %, total sugar %, ascorbic acid %, moderate yellowness index. Based on desirable parameter the contour plot of all responses were superimposed in Fig. 22. The desirable properties of orange peel were observed at 82°C; 8 min Blanching temperature and 50°C drying temperature. The properties of of the zone are TSS 33ºBrix, Acidity 7%, pH 3.7%, reducing sugar 8.75%, Non-Reducing sugar 5.75 %, Total sugar 14.2%, Ascorbic acid 31%, Yellowness index 130 and Protein 10.7%.

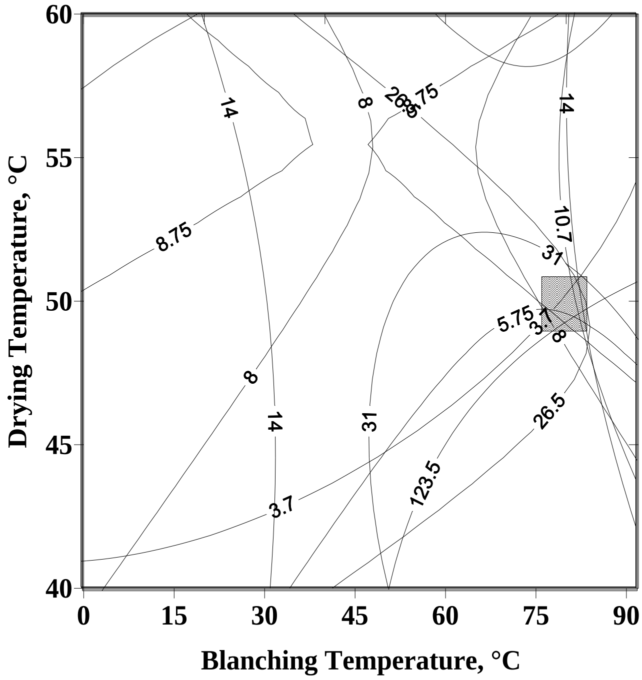

Fig. 22 Superimposed contour plots of desirable properties.

Conclusion:

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1. Hot air cabinet drying of orange peel slices indicated that Modified page model was fitted well to the experimental data. The characteristics constants of Modified Page model for blanched orange peel at 82°C:8 min at 50°C are k=0.04976618 with R^2=0.9894722 and $RMSE$=0.0004923.
2. Activation Energy needed for the moisture movement from the orange peel slices during drying was found to be 2.52307 (kJ/mole).
3. The desirable properties of orange peel powder should have more TSS (°B), acidity %, reducing sugar %, non-reducing sugar %, total sugar %, ascorbic acid %, moderate yellowness index. At Blanching temperature 82ºC for 8 min 50ºC drying temperature. The properties at the zone are TSS 33ºBrix, Acidity 7%, pH 3.7%, reducing sugar 8.75%, Non-Reducing sugar 5.75 %, Total sugar 14.2%, Ascorbic acid 31%, Yellowness index 130 and Protein 10.7%. by using orange peel at blanching temperature 82ºC for 8 min and drying temperature 50ºC value added product such as cookies can be prepared from it.

Table 9 Statistical analysis of orange peel powder

(a) TSS					
Treatment	**T_1**	**T_2**	**T_3**	**T_4**	**Mean**
D_1	20.280	25.033	31.067	68.020	36.100
D_2	25.047	31.007	35.000	60.000	37.763
D_3	52.000	44.000	40.000	60.000	49.000
Mean	32.442	33.347	35.356	62.673	40.954
		S.Em ±			**CD at 5%**
Treatment (T)		0.045			0.129
Temperature (D)		0.039			0.112
Interaction (T×D)		0.078			0.078
(b) Acidity					
Treatment	**T_1**	**T_2**	**T_3**	**T_4**	**Mean**
D_1	0.320	0.320	4.800	8.960	3.600
D_2	7.680	7.680	11.627	18.027	11.253
D_3	8.747	8.960	10.773	17.840	11.580
Mean	5.582	5.653	9.067	14.942	8.811
		S.Em ±			**CD at 5%**
Treatment (T)		0.056			0.160
Temperature (D)		0.048			0.139
Interaction (T×D)		0.097			0.284
(c) Reducing sugar					
Treatment	**T_1**	**T_2**	**T_3**	**T_4**	**Mean**
D_1	6.350	7.893	13.697	14.697	10.659
D_2	7.157	8.273	9.560	8.663	8.413
D_3	10.360	6.210	9.010	8.020	8.400
Mean	7.956	7.459	10.756	10.460	9.158
		S.Em ±			**CD at 5%**
Treatment (T)		0.291			0.834

Temperature (D)		0.252			0.722
Interaction (T×D)		0.505			1.475
(d) Non-reducing sugar					
Treatment	**T_1**	**T_2**	**T_3**	**T_4**	**Mean**
D_1	2.597	2.567	2.587	10.323	4.518
D_2	5.453	5.623	6.957	11.910	7.486
D_3	3.407	7.430	5.647	12.133	7.154
Mean	3.819	5.207	5.063	11.456	6.386
		S.Em ±			**CD at 5%**
Treatment (T)		0.071			0.203
Temperature (D)		0.061			0.176
Interaction (T×D)		0.123			0.360
(e) Total sugar					
Treatment	**T_1**	**T_2**	**T_3**	**T_4**	**Mean**
D_1	9.087	10.420	14.063	25.383	14.738
D_2	12.090	14.200	16.890	21.203	16.096
D_3	13.950	14.040	14.960	20.197	15.787
Mean	11.709	12.887	15.304	22.261	15.540
		S.Em ±			**CD at 5%**
Treatment (T)		0.073			0.209
Temperature (D)		0.063			0.181
Interaction (T×D)		0.127			0.370
(f) Ascorbic acid					
Treatment	**T_1**	**T_2**	**T_3**		**Mean**
D_1	49.080	49.480	49.973	50.000	49.633
D_2	49.793	49.383	49.553	50.000	49.683
D_3	49.950	46.353	45.000	45.333	46.659
Mean	49.608	48.406	48.176	48.444	48.658
		S.Em ±			**CD at 5%**
Treatment (T)		0.255			0.731
Temperature (D)		0.221			0.633
Interaction (T×D)		0.443			1.294
(g) pH					
Treatment	**T_1**	**T_2**	**T_3**	**T_4**	**Mean**
D_1	5.500	4.900	5.100	5.000	5.125
D_2	3.600	3.600	3.567	3.500	3.567
D_3	3.400	3.400	3.400	3.400	3.400
Mean	4.167	3.967	4.022	3.967	4.031
		S.Em ±			**CD at 5%**
Treatment (T)		0.005			0.015
Temperature (D)		0.004			0.013
Interaction (T×D)		0.009			0.028

(h) Yellowing Index					
Treatment	**T_1**	**T_2**	**T_3**	**T_4**	**Mean**
D_1	134.242	149.994	154.727	88.266	131.807
D_2	132.113	130.083	110.096	88.943	115.309
D_3	77.951	78.962	104.963	102.939	91.204
Mean	114.769	119.680	123.262	93.383	112.773
		S.Em ±			**CD at 5%**
Treatment (T)		0.771			2.206
Temperature (D)		0.578			1.654
Interaction (T×D)		1.157			3.321
(i) Protein					
Treatment	**T_1**	**T_2**	**T_3**	**T_4**	**Mean**
D_1	8.603	9.183	10.790	9.327	9.476
D_2	10.123	10.893	11.247	10.067	10.583
D_3	10.743	10.890	10.723	9.767	10.531
Mean	9.823	10.322	10.920	9.720	10.196
		S.Em ±			**CD at 5%**
Treatment (T)		0.139			0.397
Temperature (D)		0.120			0.344
Interaction (T×D)		0.240			0.702

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