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CONVECTIVE HOT AIR DRYING OF KOKUM RIND AND ITS QUALITY EVALUATION

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ABSTRACT

Drying characteristics of kokum rind was investigated by convective hot air method at temperature 60^0C and air velocity of 2 m/s. kokum is a spice tree found in western peninsular coastal region of India has various medical applications. Kokum rind was dried from 85.55% to 10.55 % (wb) moisture content 24 hour. Seven drying models i.e. Newton, Page, Handerson and Pabis, Exponentials, Wang and Sing, Midilli and Verma were fitted for the experimental data on moisture ratio w. r. t time. Wang and Sing drying model best fitted with r^2=0.998 and *RMSE*=0.000496 to the experimental moisture ratio data w.r.t. time. Effective diffusivity for kokum rind was 2.56×10^{-9} m^2/s at 60^0C. Effect of quality parameters i.e. acidity, pH, reducing sugar, non reducing sugar, protein, carbohydrates, ash, anthocyanin, colour (L, a and b value) and calorific value on dried kokum rind were also determined and discussed.

Keywords: convective hot air drying, kokum rind, quality parameters

INTRODUCTION

Drying is simultaneous heat and mass transfer process. Cost-effective and hygienic way of preserving foods is of great importance given the prevailing inconsistency in food supplies throughout the world. The utilization of dryers can reduce crop losses and improve the quality of the dried product significantly when compared to the traditional methods of drying such as sun or shade drying (Akpinar et al., 2003).

Heat and mass transfer in the tray dryer is carried out by convection and partly conduction method. Hot air is used to supply heat to the food surface which heat up the food and increase its temperature, which result in evaporation of water from the food. In conduction heat transfer, supplied hot air also heats up the tray and surrounding material which when comes in contact with food the heat is transferred from contact material i.e. metal surface to the foods which evaporate the water and mass transfer process occurs. Several factors can influence hot-air drying of food i.e. velocity and temperature of air, water diffusion through material, load density, thickness of bed and shape of the product to be dried. However, the sudden removal of water decreases the nutritional and sensorial value of food and results in to shrinkage and hardening (Vega et al., 2007).

Kokum trees are found in the tropical rain forests of Western Ghats from Konkan southwards in Karnataka, Coorg and Waynaad and also in southern parts of Maharashtra (Krishnamurthy *et al*., 1982). It has been found that rind of the fruit contains hydroxyl citric acid (HCA), garcinol and the coloring pigment anthocyanin. HCA, which is claimed to have fat-reducing properties, is often used to reduce obesity (Jena et al., 2002), since it inhibits the enzyme, citrate lyase responsible for conversion of carbohydrates into fats. Kokum extract acts as a nerve reliever due to the presence of caffeine. Small amount caffeine will act as a selective antagonist for adenosine 2A thus stimulating locomotor nerves. If Kokum is taken in excess then high dose of caffeine will inhibit locomotor nerves and the person may fall asleep (Sutar et al., 2012). Kokum rind is responsible for antioxidant, antibacterial, antifungal, anticlastogenic, gastroprotective, cardioprotective, antineoplastic and chemopreventive effect. It is also responsible for inhibition of lipid peroxidation, carbonyl content, neuroprotection, antiobesity (Baliga *et al.*, 2011).

Kokum is traditionally preserved by sun drying. Although sun drying is the most common method used to preserve agricultural products, this technique is weather dependent, and has the problem of contamination with foreign matter, more surface area requirement, labour requirement. Also, the time required for drying can be quite long. Therefore, an effective means to overcome these problems are to dry the kokum rind by convective hot-air dryers.

Various researchers have reported the drying characterization of fruits and vegetables by using convective hot air dryer for carrots, white mulberry, okra, tomatoes, sweet potato cube, azarole red and yellow fruit, kale, sweet cherry, figs, kiwifruit, uryani plum, red pepper, bay leaves, red bell pepper, single apricot, apple, anola shreads, potato, etc. (Doymaz, for 2004a, 2004b, 2005 , 2007. Singh and Pandey 2012; Koyuncu et al. 2007; Mwithiga and Olwal 2005; Doymaz and Ismail 2011; Babalis et al. 2006; Orikasa et al. 2008; Sacilik et al. 2006; Doymaz and Pala 2002; Akpinar et al. 2003; Gunhan et al. 2005; Vega et al. 2007; Togrul and Pehlivan 2003; Sacilik and Elicin 2006; Prajapati et al., 2011; Nema and Dutta, 2004). No report is available so far for drying of kokum rind by convective hot air drying.

MATERIAL AND METHODS

Kokum fruits were collected from the Department of Horticulture, Dr. BSKKV, Dapoli. 100 kg of fruits were used in one treatment. Under ripe and over ripe fruits were discarded. Fruits were cleaned by removing unwanted portion like leaf and stalk material etc. and then washed in tap water. The cleaned fruits after removing surface moisture were cut into two halves. The fruit rind and seed separated manually. Initial moisture content of the kokum rind was calculated by using hot air oven at 105^{0}C±1 for 24 h. The final weight of kokum rind after 24 h was recorded. The moisture content of the kokum rind was determined by following formula (Chakraverty, 1994).

$$\text{Moisture Content (db)\%} = \frac{W_1 - W_2}{W_2} \times 100 \qquad ...(1)$$

Where,

W_1= weight of sample before drying, gram

W_2= weight of bone dried sample, gram

EXPERIMENTAL SETUP

Tray drying of kokum rind was performed at the Department of Agricultural Process Engineering, College of Agricultural Engineering and Technology, Dapoli. The drying was carried out in a tray dryer (Make: Rotex Industries, Pune) having capacity 60 kg. There were 24 no. of trays inside the tray dryer. The size of the tray was 54cm × 50cm × 2 cm. The temperature of the drying was kept 60^{o}C±1^{o}C. The kokum rind was dried in a thin layer drying. Air velocity inside the dryer was at 2 m/s. Rind was spread in single layer in the perforated trays. Mesh (round) size of the trays was 5mm diameter. 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. was calculated from the drying data.

Humidity and ambient air temperature was recorded by digital thermo hygrometer (Make: Crystal Instruments, Mumbai; Model: Temptec). Three sensors were inserted in the product for the measurement of product temperature during drying of kokum rind by using data logger (Make: Ambetronics; Model: TC800D). The drying data i.e. Initial moisture content, weight loss w.r.t. time, final moisture content of the rind were also recorded. Three replications were taken for each experiment. Fig 1 shows kokum rind drying in the tray dryer.

Figure 1- Drying of kokum rind in the tray dryer and weight was recorded by using small perforated trays

DRYING CHARACTERISTICS

Moisture Content (% db) versus drying time (min) and drying rate (kg of water/ 100g dry solid/min) with respect to moisture content was determined for tray drying of kokum rind. Moisture ratio versus drying time (min) was also determined from the experimental data. Various mathematical models listed in Table 1 were fitted to the experimental data on moisture ratio versus drying time in minutes of kokum rind dried with tray 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).

The moisture ratio is usually expressed as

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

Where, MR is the dimensionless moisture ratio, M is the moisture content at time t, and M_0 and M_e are the initial and equilibrium moisture contents, respectively, on dry basis.

Non linear regression analysis was performed to the experimental data by using SAS 6.0. The higher value of co-relation coefficient (*r*) and lower value of *RMSE* (Root Mean Square Error) indicate that the model is best fited to the experimental data (Togrul and Pehlivan, 2004). These parameters were calculated by using equations.

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

... (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).

Table 1 Mathematical models tested with the moisture ratio of Kokum rind

Sr. 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	Exponential	$MR = \exp(-kt)$	Liu and Bakker-Arkema, 1997
5	Wang and Sing	$MR = 1 + at + bt^n$	Ozdemir *et al.*, 1999
6	Midilli	$MR = a\ exp(-kt^n) + bt$	Sacilik *et al.*, 2006
7	Verma	$MR = a\ exp(-kt) + (1-a)\exp\ (-gt)$	Akpinar *et al.*, 2003

CALCULATION OF EFFECTIVE DIFFUSIVITY

Effective diffusivity was calculated by using Fick's Second law of diffusion (Doymaz, 2004) as given in equation (4). This equation assumes that effective diffusivity is constant and shrinkage of the sample is negligible.

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

Where, R^2 = equivalent radius of the kokum rind being dried, m

n = positive integer

D_{eff} = effective diffusivity, m^2/s.

t = time, min

For long drying times, equation (4) can be simplified in straight line equation. The effective diffusivities could be determined using the method of slopes as discussed by Doymaz, 2005; Doymaz, 2007; Mwithiga, 2005; Doymaz and Ismail, 2011; Babalis et al., 2006. Effective diffusivities can be determined by plotting experimental drying data in terms of 'ln (MR)' versus 'time'.

$$\ln(MR) = \frac{-6\ \times t \times D_{eff}}{R^2} \quad \ldots(5)$$

The effective diffusivity can be determined from the slope of equation (5) as per the procedure discussed by Doymaz, 2005; Doymaz, 2007; Mwithiga, 2005; Doymaz and Ismail, 2011; Babalis et al., 2006.

$$Effective\ Diffusivity\ (D_{eff}) = \frac{R^2\ K}{\pi^2} \quad (6)$$

EVALUATION OF QUALITY PARAMETERS FOR THE DRIED PRODUCT

ACIDITY

Acidity was calculated by using titration method (Ranganna, 1986). 1g of ground dried kokum rind was taken. 20 ml distilled water was added to it. Pipette out 1 ml of this sample in conical flask and 100 ml distilled water was added to it. 2-3 drops of phenolphthalein indicator was added to it. The solution was titrated with 0.1 N NaOH. End point is feint pink colour.

pH

pH was recorded by digital pH meter. (Make: Hanna Instruments, Model: pH 211). The equipment was standardized by 4 and 7 pH standard solution. The pH of kokum was determined by adding 15 ml of distilled water to 5 g of ground Kokum rind.

REDUCING SUGAR

Reducing sugar was estimated by Fehling's method (Ranganna, 1986). The process was carried out in three steps. In first part, 5 g dried ground kokum rind was added with 100ml distilled water. 2-3 drops of phenolphthalein indicator was added to it. This sample solution was titrated with 1 N NaOH. The end point was feint pink colour. It was filtered after addition of lead acetate and potassium oxalate solution. In second part, Fehling solution A, B and distilled water were taken in proportion 1:1:1 in a conical flask. And in the third part, titration of first part solution against second part solutions was carried out by using methylene blue indicator in boiling condition. Titration was continued until the end point of brick red colour appears.

NON REDUCING SUGAR

Non reducing sugar was determined as per the Ranganna, 1986. In this method, part one solution of reducing sugar was used. 50 ml of this solution was neutralized with concentrated 20 N NaOH after overnight keeping with 1:1 HCL. By making 100 ml volume with distilled water, this solution was titrated with part two solutions i.e. first part and second part. In the third part same procedure was followed as discussed in reducing sugar.

PROTEIN

The protein content of ground dried Kokum rind was determined by Lowry's Method (Lowry et al., 1951) using spectrophotometer (Make: Systronics- UV Visible spectrophotometer; Ahmadabad; Model No: 106). In this method, 1 g dried ground Kokum rind was mixed with 5 ml of alkaline solution which was prepared from 50 ml of Part one (2% sodium carbonate in 0.1 N NaOH) solution and 1 ml of part two (0.5% copper sulphate in 1% sodium potassium tartarate) solution. Mixed solution i.e. part one and part two was rapidly diluted with folin-ciocalteu reagent. After 30 min, sample was loaded in the cuvet of spectrophotometer upto >3/4 of its level. The absorbance was read against standard protein solution at 750nm. Absorbance is recorded as protein content.

CARBOHYDRATES

The carbohydrate from dried kokum rind was estimated by Anthrone Method (Ranganna, 1986) in which prepared a series of Glucose solution and distilled water in the ratio (0:1; 0.2:0.8; 0.4:0.6; 0.6:0.4; 0.8:0.2; 1:0) by using spectrophotometer. 1 g ground dried kokum rind was mixed with 5 ml of 2.5N HCL and then heated for 3h in water bath. The mixture was allowed to cool for 1.3h and it is added with sodium carbonate till effervescence stops. It is seen by naked eyes. After filtration anthrone reagent (2 g anthrone powder + 100 ml H_2So_4) was added in filtered solution. The mixture was heated for 8 min and allowed to cool. The solution was taken in the cuvet of spectrophotometer and absorbance was recorded at 630 nm. A graph was plotted i.e. absorbance versus concentration (Glucose stock: Distilled water) and Concentration of unknown sample was measured by using formula,

$$\text{Concentration}(\%) = \frac{\text{Absorbance of unknown} \times \text{Concentration of Standard}}{\text{Absorbance of Standard}} \quad \ldots (4)$$

FAT

Fat of dried kokum rind was determined using soxhlet fat extraction system (AOAC, 2010) by using Soxhlet apparatus (Make: Elico, Hyderabad). In this method, initialy weight of empty flask was weighed. 2 g dried ground kokum rind wrapped in filter paper was siphoned for 9-12 times with the petroleum ether in soxhlet apparatus. After removing assembly, evaporation of petroleum ether was allowed by heating. Residue remained at the bottom of the flask and was reweighed with flask. The quantity of residue is determined as fat content of dried Kokum rind powder.

ANTHOCYANINE

Anthocyanin was determined by spectrophotometric method (Ranganna, 1986). In this method, Anthocyanine was extracted with ethanolic HCL (85:15). 1 g ground dried kokum rind mixed with 10 ml of ethanolic HCL and was kept overnight in refrigerator at 4^{0}C. Next day after making volume with ethanolic HCL, mixture was filtered. Absorbance of this filtered solution was recorded at 535 nm against blank solution. The absorbance was reported as anthocyanin content of dried kokum rind.

COLOUR

The dried grounded Kokum rind was used to measure the colour value by using colour flex meter (Hunter associates Laboratory, USA).The equipment was calibrated against standard white tile and black tile. Around 20 g dried kokum rind powder was taken in the glass cup, the cup was placed on 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).

CALORIFIC VALUE

The Digital bomb calorimeter (Make: Parr Instrument Company, USA; Model: 6110) was used for determination of calorific value. 1 g kokum rind was taken for the measurement of Calorific Value. The equipment gives the direct digital reading on calorific value (cal/g).

RESULT AND DISCUSSION

DRYING KINETICS

Fig. 2 shows moisture content (db) % w. r. t. time (min) of kokum rind dried by tray drying. The kokum rind was dried from an average initial moisture content of 593.13% (db) to 11.44% (db). It took around 24 h for drying of kokum rind by tray drying at 60^{0}C to complete the drying process.

Fig.3 shows the drying rate (g water removed/100g dry solid/min) w. r. t. moisture content % (db) of kokum rind dried by tray drying. The drying rate decreases from 1.58 to 0.40 g water removed/100g dry solid/min. only falling rate period was observed.

Fig 4 shows variation in moisture ratio with respect to time in min. During first 300 min of drying moisture ratio decreases from 0.99 to 8.12× 10^{-7}.

The ambient air temperature varied from 37.17 - 59.90^{0}C. The product temperature varied from 34.02 - 64.00^{0}C. The average product temperature was 55.54±5.32^{0}C and average ambient temperature was 55.76±4.55^{0}C. The average relative humidity (%) for the ambient air inside the dryer was 51.09±22.75% and was varied from 20 to 88.00%.

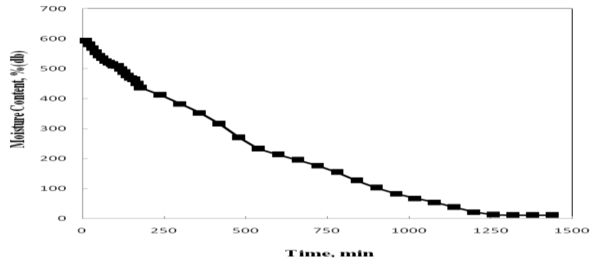

Figure 2. Moisture content %(db) versus time (min) by convective air drying at 60^{0}C for kokum rind

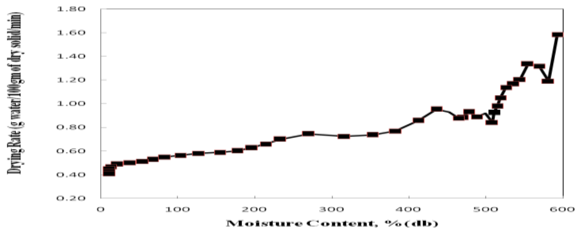

Figure 3- Drying rate (g water removed/100g dry solid/min) versus moisture content % (db) of kokum rind dried by convective air drying method at 60^{0}C

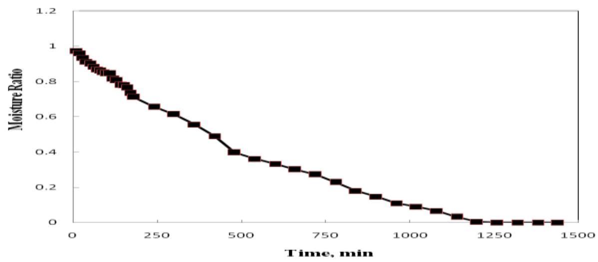

Figure 4- Variation in moisture ratio with respect to time, min for kokum rind during tray drying

MODELLING OF DRYING CURVE

Table 2 shows various models i.e. Newton, Page, Handerson and Pabis, Exponentials, Wang and Sing, Midilli, and Verma were fitted to the experimental data i.e. Moisture ratio versus time (min). The Wang and Sing model fitted well (R^2= 0.998; $RMSE$= 0.0004) among all the models tested for the experimental data. a and b are the characteristics constants, which are temperature dependant.

Table 2- R^2, RMSE and constant values for Kokum rind

Sr. No.	Drying Model	Constants	R^2	RMSE
1	Newton	k =0.001950938	0.996026033	0.001634433
2	Page	k =0.000795772 n =1.144418105	0.997673741	0.000981933
3	Henderson and Pabis	a =1.021704494 k =0.002013615	0.996315573	0.001555227
4	Exponential	k =0.001950938	0.996026033	0.001634433
5	Wang and Sing	a = -0.001442524 b =0.000000525	0.998822760	0.000496923
6	Midilli	a =0.884285967 k =-2.28227× 10^4 n = -4.29916× 10^1 b = -0.000747012	0.925895935	0.031279940
7	Verma	a = -0.0000000001 k = -0.010244770 g = 0.001888993	0.995854720	0.001797048

CALCULATION OF EFFECTIVE DIFFUSIVITY

Fig 5 shows graph of Ln (MR) versus time, min. Linear equations obtained from the graph i.e. *y= -0.007 x+ 1.221* was compared to standard equation i.e. *y= mx+c. m* value indicates the slope of line. Effective diffusivity (D_{eff}) at time (t) for kokum rind which was calculated from equation (6) for kokum rind by convective hot air method was 2.56×10^{-9} m^2/s.

The values of D_{eff} are reported to vary between 5.683×10^{-10} and 1.544×10^{-9} m^2/s for the pre-treated and control samples of sweet cherry (Doymaz, 2011), 2.231×10^{-10} to 6.909×10^{-10} m^2/s for white mulberry at 50^0C and air velocity with 1 m/s (Doymaz, 2004b), 4.27×10^{-10} to 1.30×10^{-9} m^2/s for okra (Doymaz, 2005), 3.79×10^{-12} to 7.53×10^{-12} m^2/s for kiwifruit (Orikasa *et al.*, 2008), 2.66×10^{10}, 3.49×10^{10} and 4.56×10^{10} m^2/s at temperature 50^0 60^0 and 70^0C for uryani plum (Sacilik et al., 2006), 3.2×10^{-9} and 11.2×10^{-9} m^2/s for red bell pepper (Vega et al., 2007), $4.76\times10^{9,}$ to 8.32×10^{9} m^2/s for apricot at 50^0, 60^0, 70^0 and 80^0C (Togrul and Pehlivan, 2003).

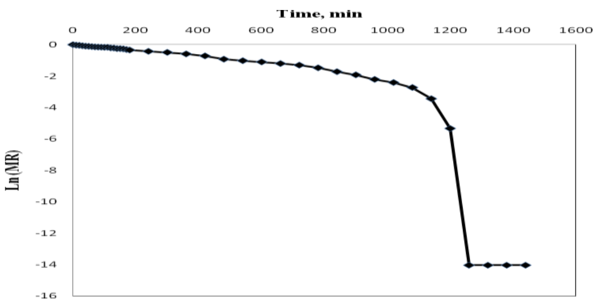

Figure 5- Ln (MR) versus time, min for effective diffusivity

EVALUATION OF QUALITY PARAMETERS FOR THE DRIED PRODUCT

ACIDITY

Table 3 shows the chemical composition of kokum rind before and after drying. Acidity of kokum rind increases from 0.85±0.19 to 3.187±0.16%. This increase in acidity was significant at $p \leq 0.01$. The increase in acidity of kokum rind after drying might be attributed due to concentration of constituents such as water soluble like Hydroxy citric acid, which are present in rind. Similar kind of result has been observed during drying of grapes, for carrots, white mulberry, okra, tomatoes, sweet potato cube, azarole red and yellow fruit, kale, sweet cherry, figs, kiwifruit, uryani plum, red pepper, bay leaves, red bell pepper, single apricot, apple, anola shreads, potato, etc. (Mahmutoglu et al., 1996, Doymaz, for 2004a, 2004b, 2005 , 2007. Singh and Pandey 2012; Koyuncu et al. 2007; Mwithiga and Olwal 2005; Doymaz and Ismail 2011; Babalis et al. 2006; Orikasa et al. 2008; Sacilik et al. 2006; Doymaz and Pala 2002; Akpinar et al. 2003; Gunhan et al. 2005; Vega et al. 2007; Togrul and Pehlivan 2003; Sacilik and Elicin 2006; Nazni and Anbumalar, 2012; Prajapati et al., 2011; Nema and Dutta, 2004).

pH

The pH of kokum rind was 2.54±0.24 before drying. There was non significant ($p \leq 0.01$) variation after drying of kokum rind with final pH as 2.079±0.21.

REDUCING SUGAR

The reducing sugar increases from 1.32±0.005 to 5.884±1.22%. This increase in reducing sugar was not significant at $p \leq 0.01$. This increase in reducing sugar might be attributed due to concentration of fruit flavors and calories during drying. Similar behavior has been observed by Maskan et al., (2002) during drying of grape leather (Pestil).

NON REDUCING SUGAR

The non reducing sugar were 3.76±0.005% for fresh kokum rind and it was 5.687±0.34% after the drying this decrease was significant maybe the concentration and loss of moisture at $p \leq 0.01$.

Table 3- Chemical composition of kokum rind before and after drying

Sr. No.	Chemical Constituents	Before drying	After drying
1	Moisture, % wb	85.32 ± 0.19	10.55±0.479
2	Acidity, %	0.85 ± 0.19*	3.187±0.16*
3	pH	2.54 ±0.24**	2.079±0.21**
4	Reducing sugar, %	1.32 ± 0.005**	5.884±1.22 **
5	Non Reducing Sugar, %	3.76 ± 0.005*	5.687±0.34*
6	Protein, %	1.75 ± 0.005*	4.833±0.41*
7	Fat, %	9.53 ± 0.33*	9.283±0.09*
8	Carbohydrates, %	3.52 ± 0.07*	31.133±0.35*
9	Ash, %	1.25 ± 0.21*	5.130±0.04*
11	Anthocyanin, %	2.79 ± 0.08*	1.321±0.02*
12	Color L	19.17 ± 0.12*	12.294±0.80*
	a	4.25±0.12*	1.77±0.34*
	b	3.3± 0.16*	0.781±0.20*
13	Calorific Value, cal/g	2626.81 ± 103.57*	3583.01±126.42*

(*= significant at p≤0.01; **=non significant at p≤0.01)

NON REDUCING SUGAR

The non reducing sugar were 3.76±0.005% for fresh kokum rind and it was 5.687±0.34% after the drying this decrease was significant maybe the concentration and loss of moisture at p≤0.01.

PROTEIN

The protein content of fresh kokum rind was 1.75±0.005% and it increases upto 4.833±0.41%. After drying the protein content of kokum rind increases significantly p≤0.01.

FAT

The fat content of fresh kokum rind was 9.53±0.33% and it was decreased upto 9.283±0.09% after drying. The decrease of fat content was significant at p≤0.01.

CARBOHYDRATES

The carbohydrate of fresh kokum rind was 3.52±0.07% and it increases upto 31.133±0.35% after drying. The increase in carbohydrate was significant at p≤0.01.

ASH

The ash content of fresh kokum rind was 1.25±0.21% and it increases upto 5.130±0.04% after drying. The increase of ash content was significant at p≤0.01.

ANTHOCYANIN

The anthocyanin (%) content of fresh kokum rind was 2.79±0.08%. Krishnamurthy, (1982) reported the presence of Anthocyanin B_1 and Anthocyanin B_2 in kokum rind. The Anthocyanin content of dried kokum rind decreased to 1.321±0.02%. This decrease in anthocyanin after drying might be attributed due to factors such as heat, light, presence or absence of O_2, metals and other chemicals affect the stability of red pigment (Clydesdale et al., 1978).

COLOUR

The L* value of kokum rind was 19.17±0.12 before drying and it decreases up to 12.294±0.80 after drying. This decrease in darkness was significant at p≤0.01. Similarly before drying redness was 4.25±0.12 and after drying it decreases up to 1.77±0.34 which was significant at p≤0.01. This variation in color is due to pigment degradation because of long drying duration. Same finding was observed by Chong et al., (2009) for ciku.

CALORIFIC VALUE

Calorific value was recorded as 2626.81±103.57 cal/g before drying and it increased up to 3583.01±126.42 cal/g. This increase in calorific value was significant at p≤0.01. This increase in calorific value might be attributed due to concentration of fruit flavors and calories during drying. Similar behavior has been observed by Maskan et al., (2002) during drying of grape leather (Pestil).

NOMENCLATURE

MR	Moisture Ratio
a, b, c, g, k, n and l	Constant
t	Time, min
M	Moisture Content at time t, % db
M_e	Equilibrium Moisture Content, % db
M_0	Initial Moisture Content, % db
r	Co-relation Coefficient
RMSE	Root Mean Square Error
MR_{exp}	Experimental Moisture Ratio
MR_{pre}	Predicted Moisture Ratio
D_{eff}	Effective diffusivities, m^2/s
R^2	Radius, m

CONCLUSIONS

From this study it was concluded that tray drying of kokum rind took 24 h to dry rind from 593.13% to 11.44% moisture content on dry basis. The drying rate decreases from 1.58 to 0.40 g water removed/100g dry solid/min till the end of the drying. Wang and Sing model found well fitted to experimental moisture ratio data with r^2= 0.9988; *RMSE*= 0.0004; *a* = -0.001442524 and *b* =0.000000525 for kokum rind drying by convective hot air method. The Effective diffusivity for kokum rind was 2.56×10^{-9} m^2/s at 60^0C. The quality parameters of kokum rind before and after solar drying has significant influence on acidity, RS, NRS, protein, Carbohydrates, ash, anthocyanin and color at p≤0.01 and calorific value

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