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Research paper

Open-Air Sun Drying of Sapota (*Achras sapota L.)* and it's Quality Evaluation

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ABSTRACT

Open sun drying (OSD) is most common method of sapota drying in Western Ghats of India. Crop temperature, around the crop, solar temperature and rate of moisture evaporation are the important parameters of OSD of sapota. In this paper, an attempt has been made to study the OS drying characteristics of sapota slices, i.e., moisture content versus time, drying rate versus moisture content and moisture ratio versus drying time. The convective heat transfer coefficient operating in open sun drying conditions (natural convection) of sapota slices has also been determined based on the values of constants, C and n, which were obtained by linear regression analysis from experimental data for sapota slices. The quality parameters of sapota slices, i.e., acidity, pH, reducing sugar, non-reducing sugar, protein, carbohydrates, ash, colour (L, A and B value) before OSD and after OSD of sapota slices have also be determined.

Keywords: Sapota slices, Crop drying, Heat transfer, Quality parameters

Food drying is one of the oldest methods of preserving food for later use. It is a complex operation involving heat and mass transfer who may cause change in food quality Open-air sun drying is the most commonly used method to preserve agriculture products such as grains, fruits and vegetables in most developing countries. In open sun drying (OSD), the crop is spread in a thin layer on the ground and exposed directly to solar radiation, wind and other conditions. In OSD, the solar radiation falling on the crop surface is partly reflected and partly absorbed. Part of this heat propagates to the interior of the crop (causing a rise in temperature and formation of water vapour), and the remaining amount is utilized in evaporation of moisture from the surface. The moisture from the interior diffuses to the surface to replenish the evaporated surface moisture.

Sapodilla, (*Manilkara zapota L.*) which belongs to the family *sapotaceae*, is underutilized tropical fruits commonly known as "sapota" in India and "chiku" in Malaysia. Immature fruits are hard, gummy and rich in tannin (astringent), while the ripe fruits are soft and juicy, with a sweet taste an attractive range colour, which makes them wonderful dessert fruit (Sallesh, 2016). In India production of sapota was 4.17 thousand hectares during the year 2005-2006 and 4.00 thousands hectares during the year 2010-2011. The growth rate is 4.08% and the production during 2005-2006 is 49.02 thousand tonnes and 43.58 thousand tonnes during 2010-2011. By exporting to

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different countries about 2.693 thousand tonnes of sapota, India earned about ₹ 4, 28, 34,567 in the year of 2011-12.

Sapota is grown on a commercial basis in India, the Philippines, Srilanka, Malaysia, Mexico, Venezuela, Guatemala and other Central American countries (Ganjyal *et al*. 2003).

In Maharashtra, Gujarat, Tamil Nadu and Karnataka states sapota is grown commercially (Shirol *et al.* 2009). Raw fruits of sapota are astringent, while ripe fruits are sweet. It is mainly used on dessert fruits beside many processed products are prepared from sapota namely Halwa, Juice, Milk Shake, Shrikhand, fruit Jam. Mature fruits are used for making mixed fruits jams and provide a valuable source of raw materials for manufacture of industrial glucose, protein and natural fruits jellies. They also are canned as slices (Gopalan *et al*. 1985).

Mature fruit contain about 72 to 78% moisture (wb) and TSS ranges from 12 to 18°brix. The most common cultivars grown are Kalipatti, Chaatri, Dhola Diwani, Long, Bhuri Bhurpatti, Jingar, Venjet, Pala, Cricket ball, Oval, Banglore and Calcutta round. India is the largest producer of sapota followed by Mexico, Guatemala and Venezuela. In the last ten years area under the crop has shown a tremendous increase of over 136 per cent (Maya *et al*. 2003). Sapota fruits is reported to contain sugar, (Siddappa and Bhatia, 1954), acids (Shanmugavelu and Srinivasn, 1973), protein, amino acid (Selvaraj and Pal, 1984), phenolics viz., galic acid, catechin, chlorogenic acid, leucodelphinidin, and leucodelargonidin and Leucopelargonidin (Matthew and Lakshminarayana, 1969), carotenoids, ascorbic acids, and minerals like potassium, calcium and iron (Selvaraj and Pal, 1984). Fruits contains carbohydrate (50.49 -100 g), protein (0.7 g – 100 g), fat (1.1 g – 100g), fibre (2.6 g -100 g), and minerals nutrient viz. calcium (28 mg -100 g), iron (2.0 mg -100 g), phosphorus (27 mg -100 g), ascorbic acid (6.0 mg -100 g) Golpalan *et al.* (1977).

An average sapota tree yields between 250-2500 fruits depending on its age. It has been observed that when there is bumper production of sapota the fruits go a waste for want of suitable preservation facilities. Sapota 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, and labour intensive. Also, the time required for drying can be quite long. Therefore, an effective means to overcome these problems are to dry the sapota slices by open sun-air drying.

(a) Sapota fruits

(b) Slices of sapota

Fig. 1. (a) Sapota fruits and **(b)** Sapota slices

Arslan and Ozcan, Maskan *et al.* (2010). And Mahmutoglu *et al.* (1996), studied the effect of sun drying on quality of onion slices, grape leather (pestil) and treated grapes, respectively and other conditions. In OSD, the solar radiation falling on the crop surface is partly reflected and partly absorbed. Part of this heat propagates to the interior of the crop (causing a rise in temperature and formation of water vapour), and the remaining amount is utilized in evaporation of moisture from the surface. The moisture from the interior diffuses to the surface to replenish the evaporated surface moisture. No reports are available in literature on drying of sapota slices by open-air sun drying.

The present study was undertaken to study the drying characteristics of open-air sun drying of sapota slices. The changes in quality parameters, i.e., acidity, pH, TSS, reducing sugar, non-reducing sugar, protein, fat, carbohydrates, ash and colour of dried sapota slices are also discussed.

Fig. 2: Experimental setup of sapota slices dried by open air sun drying

MATERIALS AND METHODS

MOISTURE CONTENT DETERMINATION:

Sapota fruits were collected from the Dapoli market. 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 seed separated manually. Initial moisture content of the sapota was calculated by using hot air oven at 105°C±1 for 24 h. The final weight of sapota slices after 24 h was recorded. The moisture content of the sapota slices was determined by following formula (Chakraverty, 1994).

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

Where,

W_1 = weight of sample before drying, gram

W_2 = weight of bone dried sample, gram

Experimental Setup

The cleaned fruits after removing surface moisture were cut into two halves and these was cut into four halves. The slices of materials were prepared by peeling, and cut into the thickness of 5 mm manually with a sharp stainless steel knife.

The weight loss of the sample was measured at various time interval, ranging from 10 min at beginning of the drying to 180 min and another weight loss after 30 min interval recorded during further drying process by a digital balance of 0.001 g accuracy. Each experiment was performed in triplicate (Wang *et al*. 2007). The size of the perforated tray was 81 cm × 41cm × 3.4 cm. The sapota slices were dried in thin layer drying. The slices were spread on the tray in single layer. The mesh (square) size of the tray was 1 × 1 mm.

The weight loss with respect to the time was recorded from trays at different location in the tray dryer .The moisture content with respect to the time was calculated from drying data, The drying data i.e. initial moisture content, weight loss, with respect to the time, final moisture content of the sapota slices were also be recorded. Three replication were taken for each experiment. Fig. 2 shown experimental set up of open-air sun drying of sapota slices. The experiments were performed from 8.00 am to 6.00 pm. The longitude for Roha was.....N-S and Latitude for Roha was ....N-S. The experiment was triplicate for each treatment and corresponding drying characteristics were studied.

Drying Characteristics

Moisture content (% db) versus drying time (min) and drying rate (kg of water/100 g dry solid/min) with respect to moisture content were determined for each day during open air sun drying of sapota slices. Moisture ratio versus drying time (min) was also determined from the experimental data. Various mathematical models listed in Table 1 were tested on the experimental data on moisture ratio versus drying time in minutes of driedsapota slices with open sun drying. The moisture ratio is usually expressed as,

$$MR = \frac{M - M_C}{M_O - M_C} \qquad \text{... (2)}$$

Where,

MR = Moisture ratio; M = Moisture content at any time θ, % (db); M_e = EMC, % (db); M_0 = Initial moisture content, % (db)

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).

Table 1: Mathematical models tested with the moisture ratio of sapota slices

Sl. No.	Model	Equation	References
1	Newton	MR = exp (-kt)	Westerman *et al.* (1973)
2	Page	MR = exp (-kt^n)	Zhang and Litchfield (1991)
3	Modified Page	MR = exp (-kt^n)	Zhang and Litchfield (1991)
4	Henderson and Pebis	MR = a exp (-kt)	Henderson and Pabis (1961)
5	Exponentials	MR = exp (-kt)	Liu and Bakker-Arkema, 1997
6	Thompson	MR = α exp (-kt^n) + bt	Sacilik *et al.* 2006
7	Logarithmic	MR = a exp (-kt) + c	Yagcioglu *et al.* (1999), Henderson SM (1974),
8	Modified Page equation	MR = exp (-(kt)^n)	Zhang and Litchfield, 1991

Non-linear regression analysis was performed to the experimental data by using SAS 6.0. These parameters were calculated by using equations, N and n are the number of observations and the number of constants respectively;

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

Where,

MR_{exp} = experimental moisture ratio

MR_{pre} = predicted moisture.

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 root mean square error (*RMSE)*. The higher the r^2 value and lower the chi-square (χ^2) and RMSE values, the better are the goodness of fit (Ozdemir and Ozdemir and Devers, 1999; Ertekin and Yaldiz, 2004; Wang *et al.* 2007). According to Wang *et al.* (2007) (a) chi-square (χ^2).

$$\chi^2 = \frac{\sum_{i=1}^{N} \left(MR_{\exp.i} - MR_{pre.i} \right)^2}{N - Z} \qquad \text{...(4)}$$

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 observation, and

z = is the number of constant.

Calculation of Effective Diffusivity

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

$$\frac{\partial M}{\partial t} = D_{eff} . \nabla^2 M \qquad \text{...(5)}$$

Where,

M = moisture content (kg water/kg dry matter); t = is the time / s; D_{eff} = effective moisture diffusivity, m^2/s.

The 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:

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

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 Equation (7) can be simplified further (Lopez *et al*. 2000; Doymaz, 2004) as:

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

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.

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

Where,

L = half thickness

Evaluation of Quality Parameters for the Dried Product

Total soluble solids (°B)

Total soluble solids sapota fruits slices before drying and after drying were determined using Refractometer (M/s. Atago, Japan) and the values were corrected at 20°C. The equipment was calibrated with distilled water and the TSS of the sapota slices was determined. The experiment was replicated three times.

Titratable acidity

The Titratable acidity of sapota fruits slices before drying and after drying was determined by Ranganna (1997). A 15 g quantity of sample was blended in mortar and pestle with 20-25 ml distilled water. It was then 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, 1997). The acidity was calculated as given below and the results were expressed as percent anhydrous citric acid. The three replication were carried out and the average reading was reported.

$$\text{Titratable acidity (\%)} = \frac{N \times T \times E}{W \times V \times 1000} \times 100 \quad ... (9)$$

Where,

N = normality of alkali;

T = titrate reading;

E = equivalent mass of acid, g;

W = weight of the sample, g;

V = total volume of the sample, g.

pH

pH of sapota fruits slices before drying and after drying was measured using digital pH meter. The digital pH meter is firstly calibrated by using 4 pH and 7 pH buffer solution. The electrode was washed with distilled water and blot led with tissue paper. 10 ml of sapota slices was taken in beaker, and then the tip of electrode and temperature probe was then submerge in to the sample. The pH of fresh sapota slices was determined for three replication.

Reducing sugars

The reducing sugar sapota fruits slice before drying and after drying was estimated by using Lane and Eynon Method with modifications suggested by Ranganna (1997). A known weight of sapota slices were crushed with distilled water using lead acetate (45%) for precipitation of extraneous material and potassium oxalate (22%) to de-lead the solution. This lead free extract was used to estimate reducing sugars titrating against standard Fehling mixture (Fehling 'A' and 'B' in equal proportion) using methylene blue as an indicator to brick red end point. The three replication were carried out and the average reading was reported.

Reducing sugar =

$$\frac{100}{Buttereading} \times \frac{Volume\ prepared}{Inital\ volume} \times Gvoffchlingsso\ln. \quad ...(10)$$

Where,

GV = Glucose value.

Total sugars

Total sugars sapota fruits slices before drying and after drying was estimated by same procedure of reducing sugar after acid hydrolysis of an aliquot of deleaded sample with 50 percent of hydrochloric acid followed by neutralization with sodium hydroxide (40%) and calculated as below (Eq. 11). The experiment was repeated three times to get the replication.

$$\text{Total sugar} = \frac{Factor \times Dilution}{Titerading \times weight\ of\ sample} \times 100 \quad ...(11)$$

Carbohydrate

The carbohydrate of sapota powder before drying and after drying was estimated by anthrone method 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; and 1:0) by using spectrophotometer. One gram ground sapota pulp was mixed with 5 ml of 2.5 N HCL and then heated for 3 h in water bath. The mixture was allowed to cool for 1.3 h, 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 curvetted 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,

Concentration % =

$$\frac{\text{Absorbance of unknown} - \text{Concentration of standard}}{\text{Absorbance of standard}} \quad \dots (12)$$

Protein

The protein content of sapota powder before drying and after drying 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 sapota pulp 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 750 nm. Absorbance is recorded as protein content.

Fat

Fat of sapota powder before drying and after drying was determined using soxhlet fat extraction system (AOAC, 2010) by using Soxhlet apparatus (Make: Elico, Hyderabad). In this method, initially weight of empty flask was weighed. 2 g sapota pulp 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 was determined as fat content of sapota powder.

Ash

Ash percentages of the sapota slices were determined by using the procedure as described (AOAC, 2000). 2 g of the dried sapota powder sample was weighed accurately in the crucible. The crucible was heated gently on a burner for 5 min at first and then strongly in a muffle furnace at 550 ± 20°C for 2 hours, till grey ash was obtained. Cool the crucible in desiccators and weigh. The % ash (w/w) was calculated by using following equation (13).

$$\% \text{ Ash (w/w)} = \frac{\text{Weight of sample portion, } g - \text{weight loss on ashing, } g}{\text{Weight of sample portion, } g} \quad \text{... (13)}$$

Colour

The dried grounded sapota slicespowder before drying and after drying was used to measure the colour value by using colorimeter (Konica minotta, Japan model-Meter CR-400). The equipment was calibrated against standard white tile and black tile. Around 20 g dried sapota slices 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 Greenness (-60); b= yellowness (+60) to blueness (-60).

RESULTS AND DISCUSSION

Drying Kinetics

Fig. 3 shown change in moisture content (db) % w.r.t. time (min) of sapota dried slices by sun drying. The sapota slices dried from an initial moisture content of 271.33 % (db) to 10.49 % (db). It took around 65 h for drying of sapota slices. It took around 7 days to complete the drying process. Similar behaviour had been observed for onion slices and parsley leaves (Arslan and Ozcan M. 2010; Akpinar, 2008).

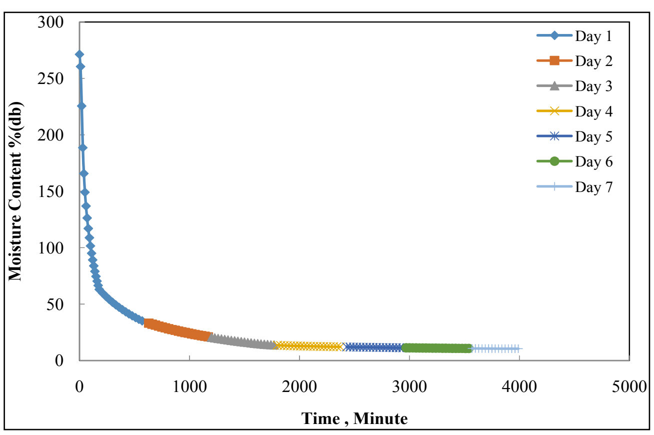

Fig. 3: Moisture content % (db) versus time (min) for open air sun drying of sapota slices

Fig. 4 shown the drying rate (kg water removal/100g dry solid / min) w.r.t. moisture content % (db) of dried sapota slices by open-air sun drying. The drying rate was 0.79 – 0.006 kg water / 100 g dry solid / min, the drying rate was 0.79 kg water / 100 g dry solid / min at the beginning of drying and gradually decreases up to 0.006 kg water removal / 100 g dry solid / min till the end of the drying 10.49% moisture content (db).

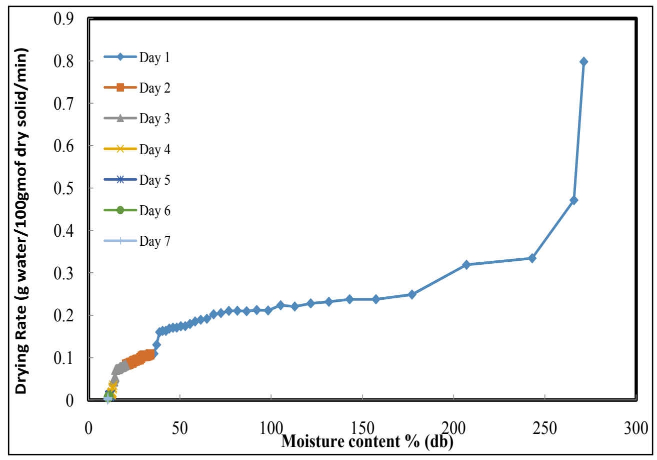

Fig. 4: Drying rate (kg water removal /100 g dry solid/ min) versus moisture content % (db) of sapota slices dried by open-air sun drying

The change in the moisture ratio with time drying of sapota slices in given in Fig. 5. The similar curves wereobserved for sapota fruits Kumari *et al.* (2016), Suchita *et al.* (2014), Sawant *et al.* (2013) for sapota slices.

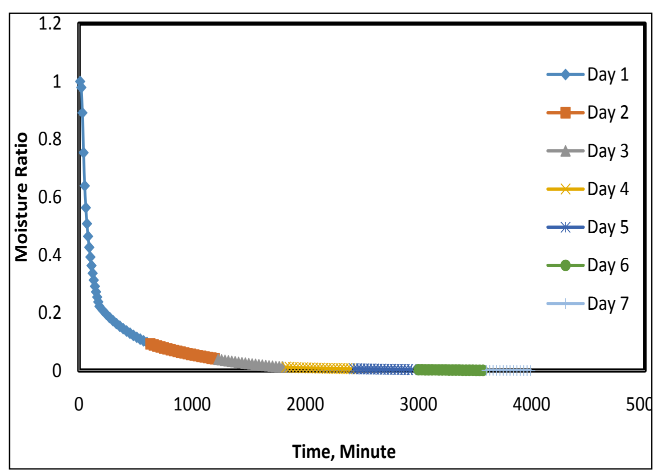

Fig. 5: Variation in the moisture ratio with respect to time (min) drying open-air sun drying of sapota slices

Fig. 6 shown the product temperature and ambient air temperature w.r.t time during 7 days sun drying of sapota slices. The average product temperature was 39 ± 1.98°C. The average ambient temperature was 38.27 ± 1.78°C. The ambient air temperature varied from 35 to 44 °C. The product temperature varied from 35 to 47 °C.

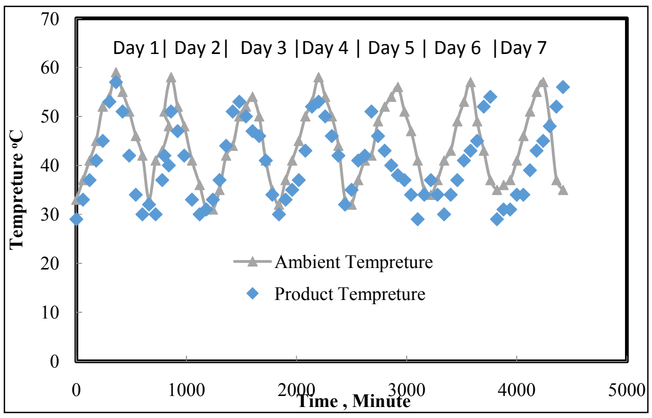

Fig. 6: Variation in product Temperature (°C) and Ambient Air Temperature (°C) versus time (min)

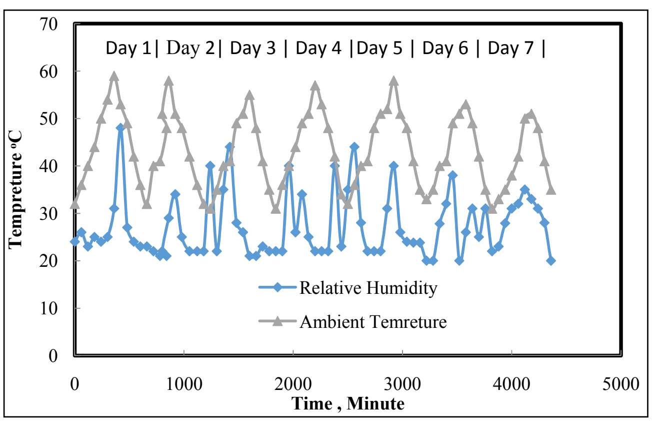

Fig. 7: Variation in ambient temperature and relative humidity with time in open sun drying of sapota slices

Fig. 8 is shown as the Ln(MR) versus time, minutes for effective diffusivity for open-air sun drying of sapota slices, and y = -0.0018x – 0.962 (R^2 = 0.932). Effective Diffusivity (D_{eff}) at time (t) for sapota drying by open air sun drying was 2.921 × 10^{-9} m^2/s. The effective diffusivity was in the range of 1.973^{-10} m^2/s to 8.059^{-11} m^2/s (Doymaz *et al.* 2011), 3.2^{-9} m^2/s to 11.2 $^{-9}$ m^2/s for red bell pepper (Vega *et al.* 2007), the effective diffusivity Cherry 1.23^{-11} m^2/s (Bilgchan *et al.* 2016), effective diffusivity Fig. 2.47^{-10} (Doymaz, 2005), Pineapple of sun drying effective diffusivity 6.89 $^{-11}$ (Olanipeckun *et al.* 2015), Seedless and Seeded Grapes in sun drying effective diffusivity 1.02^{-11} and 1.66^{-11} m^2/s (Doymaz, 2012).

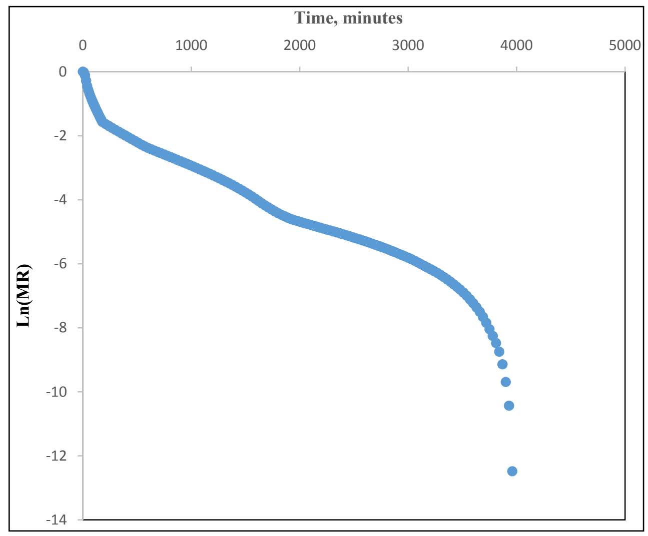

Fig. 8: Ln(MR) versus time, minutes for effective diffusivity for Open air sun drying of Sapota slices

Table 2: Model parameters, R^2, RMSE and Chi square values of Sapota slices dried by the Open air sun drying

Sl. No.	Model name	Model Parameters	R^2	MSE	χ^2 chi square
1	Newton	*k*=0.0090	0.9575	0.0017	0.2521
2	Page	*k*=0.0502 *n*=0.6274	0.9773	0.0009	0.1346
3	Modified Page	*k*=0.0085 *n*=0.6274	0.9773	0.0009	0.1346
4	Henderson and Pabis	*a*=0.9565 *k*=0.0084	0.9583	0.0017	0.2475
5	Exponential	*k*=0.0090	0.9575	0.0017	0.2521
6	Thompson	*a*=-1.91800E + 02 *b*=-1.484699134	0.9779	9.37918E + 04	1.34122E + 07
7	Logarithmic	*a*=0.9567 *k*=0.0094 *c*=0.0251	0.9705	0.0012	0.1747
8	Modified Page equation-II	*k*=1.4404 *L*=1.44981E+01 *n*=0.6274	0.9773	0.0009	0.1346

Table 2. Shows various drying model fitted to the open air sun drying data for i.e., Newton, modified page, page, Henderson, pabis, Thompson, Logarithmic and Modified Page equation 2. Among the all these model fitted to the experiment data Modified page, page and Modified page 2 was fitted best to the experiment data. The model parameter for Modified page equation was$k$ = 0.008511; n = 0.6274; r^2 = 0.977; MSE = 0.000941 and chi square (χ^2) = 0.1346. The Akpinar (2008) had found Wang and Singh model to fit well to the behaviour of Parsley leaves dried under open sun drying, Babalis *et al*. (2006) found the Two term exponential model well fitted to the open air sun drying of figs, Sacilik *et al*. (2006) found the Diffusion model well fitted to the open air sun tunnel drying of organic tomato.

Table 3: Chemical composition of sapota slices before and after drying

Sl. No.	Chemical constituents	Before drying	After drying
1	Moisture (% wb)	75.2±1.6	10.49 ± 0.09
2	TSS (°B)	19.45± 1.40*	62±2*
3	Acidity (%)	0.16±0.14*	0.22±0.05*
4	pH	5.72±0.14**	6.1±0.15**
5	Reducing sugar (%)	16.3 ±1.23*	29.69±1.50*
6	Total sugar (%)	48.50±1.58*	42.39± 1.86*
7	Carbohydrate (%)	19.50 ±3.47*	23.7±0.3*
8	Protein (%)	0.5±0.13*	0.82±0.01*
9	Fat (%)	0.49±0.44*	1.1±0.1*
10	Ash (%)	0.47±0.03**	1.74±0.83**
11	Colour L *	71.10±2.43*	66.81±0.01*
	a*	7.14±0.02*	8.42±0.015*
	b*	40.50±0.03*	26.80±0.015*

Table 4: Anova table

Sl. No.	Parameter	S.E (5%)	C.D (5%)
1	Acidity (%)	0.01	0.02
5	TSS (°B)	0.28	0.90
2	pH	0.04	0.14
3	Reducing sugar (%)	0.14	0.44
4	Non- reducing sugar (%)	0.17	0.55
6	Carbohydrate (%)	0.29	0.96
7	Protein (%)	0.02	0.06
8	Fat (%)	0.03	0.09
9	Ash (%)	0.01	0.04
10	Colour L *	0.07	0.23
	a*	0.15	0.50
	b*	0.23	0.74

Evaluation of quality parameter for the dried product

Moisture content

Table shows the chemical composition of sapota slices before and after drying. Moisture content of sapota 75.2±1.6 (wb) and after drying10.49 ± 0.09 (wb).

TSS° Brix

The TSS of sapota slices before drying was 19.45± 1.40 and increased up to 62± 2 (°Brix) after drying. The increase in TSS was significant at 0.05). Similar result were observed for sapota slices Gunjyal *et al.* (2005) TSS of sapota slices range is 22 to 28° Brix.

Acidity

Acidity of sapota slices before drying was 0.16±0.14 and after drying it was 0.22±0.05 %. This increase inacidity was significant at 0.05). The increase in acidity sapota slices might to be attributes due to concentration of constituents, such as water soluble. Similar kind of result has been observed during open air drying of grapes (Mahmutoglu, 1996).

pH

pH of sapota slices increase before drying was 5.72 ±0.14 and increased up to 6.1±0.15. Increase was non-significant at 0.05). Hande *et al.* (2016), found the pH of fresh kokum rind was 2.54 and after open air sun drying it was 2.50.

Reducing sugar (%)

The reducing sugar of sapota slices was16.3 ±1.23 before drying and reached up to 29.69±1.50 % after drying. The increase in reducing sugar was significant at 0.05). This might to be attributed due to concentration on fruits flavour and calories during drying. And open air sun drying was in agreement with the reported results in literature with 1.32 to 3.74% and 2.8 to 3.2 for the kokum rind and pumpkin fruit slices by the Hande *et al*. (2016) and Workneh *et al*. (2014).

Non- reducing sugar (%)

The non-reducing sugar of sapota slices before drying decrease from 48.50 ±1.58 to 42.39±1.86 %. After drying decreases in non-reducing sugar was non-significant 0.05). Similar result for Cholera *et al.* (2016) reported that non-reducing sugar dried sapota powder 40.32 (%). The increase of total sugar in sapota slices after drying in open air sun drying was in agreement with the reported results in literature with 4.7 to 5.3; 18 to 22 % for the pumpkin fruit slices and grape by the Workneh *et al*. (2014) and Shahat *et al.* (2016).

Carbohydrate

Carbohydrate of sapota slices before drying was 19.50 ±3.47 and increased it up to 23.7±0.3 after drying. The carbohydrates content was significant at 0.05). Kumari *et al.* (2016) reported the Carbohydrate content of sapota slices after drying was 25%.

Protein

The protein of sapota slices was 0.5±0.13 before drying and increased up to 0.82±0.01 after drying by sun drying. The increase in protein content was significant at 0.05). Guruswami *et al.* (2002) reported the protein content in open dried sapota powder was 6.5(%).

Fat

Fat of sapota slices before drying was 0.49±0.44 and increase up to 1.1±0.1 after drying the increase was significant at 0.05). Kumari *et al.* (2016) reported sapota power fat is 1.3(%).

Ash

Ash of the sapota slices before drying was 0.47 ±0.03 and increase up to before drying up to 1.74±0.83 non-significant at 0.05). And Kumari *et al.* (2016) sapota powdering is 1.84(%).

Colour

Colour of the sapota slices after drying in L value 71.10±2.43 decreased up to 66.81±0.01 and a value of colour of sapota slices was 7.14±0.02 increased up to 8.42±0.015. '*b*' value of sapota slices was 40.50±0.03 and decreased up to 26.80±0.015. The value 'L', 'a' and 'b' are significant at 0.05). Decreased in 'L' value and 'b' value might be due to pigment degradation due to exposition to long drying duration.

CONCLUSION

1. Open- air drying of sapota slices took around 65 h (7 days) to dry it from initial moisture content 271.33- 10.49 % (db.).
2. The drying rate was initially 0.79 kg water removal / 100 g dry solid /min, and gradually decreased up to 0.006 kg water removal /100 g dry solid / min.
3. Open sun drying of sapota slices indicated that Modified Page model was fitted well to the experimental data. The characteristics constant on Modified Page model are k = 0.008511; n = 0.6274; r^2 = 0.977; MSE = 0.000941 and chi square (χ^2) = 0.1346.
4. The quality parameter of sapota slices in open-air sun drying is acidity, pH, reducing sugar, carbohydrate, protein, fat and ash is also increasing. The total sugar and colour value L and b was also decreasing. Acidity is increase from 0.16±0.14 to 0.22±0.05; pH of sapota slices is increase from 5.72 ±0.14 to 6.1±0.15; reducing sugar increase for16.3 ±1.23to 29.69±1.50; the total sugar of sapota slices decrease for 48.50 ±1.58 to 42.39±1.86; colure of sapota slices is L* is decrease for 71.10±2.43 to 66.81±0.01; colour of sapota slices b* decrease for 40.50±0.03 to 26.80±0.015.

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

REFERENCES

Anwar, S.I. and Tiwari, G.N. 2001. *Evaluation of convective heat transfer coefficient in crop drying under open sun drying conditions*, **43**: 1121–1127.

Arslan, D. and Ozcan, M.M. 2010. Study the effect of sun, oven and microwave drying on quality of onion slices. *Food Sci. Technol. Energy Convers Manag.*, **42**: 627–637.

Akpinar, K.E. 2008. Drying of parsley leaves in a solar dryer and under open sun: modeling, energy and exergy aspects. *Journal of Food Process Engineering*, **34**: 27–48.

ChienHwa Kong, Choung Lim Law, MichaclCloke, Wan Ramil wan Daud. 2008. Drying Kinetics, Texture, Colour and Determination of effective Diffusivity of sun drying of chempedale.

Ganjayl, G.M., Hanna, M.A. and Devdattram, D.S.K. 2003. Processing of sapota (*sapodilla*): drying, *Journal of Food Science*, **68**(2): 517-528.

Gopalan, C., Ramashastri, B.V. and Balasubramanyam, S.C. 1985. Nutritive value of Indian foods. Ansari Nagar, New Delhi, Indian comical of medical research, pp. 1-59.

Henderson, S.M. 1974. Progress in developing the thin-layer drying equation. *Trans ASAE.*, **17**(6): 1167–1168.

Henderson, S.M. and Pabis, S. 1961. Grain drying theory. I. Temperature effect on drying coefficient. *J. Agric. Eng. Res.*, **6**: 169–174.

Hande, A.R., Swami, S.B. and Thakor, N.J. 2014. Open-air sun drying of kokum (*Garcinia indica*) rind and its quality evaluation. *Agricultural Research Journal.*

Hande, R., Swami, S.B. and Thakor, N.J. 2014. Convective hot air drying of kokum rind and its quality evaluation. *International Journal of Food and Nutritional Sciences*, **3**(6).

Jain, D. and Tiwari, G.N. 2003. Thermal aspects of open sun drying of various crops. *Energy*, **8**: 37–54.

Krishnamurthy, N., Lewis, Y.S. and Ravindranath, B. 1982. Chemical constituents of Kokum fruit rind. Central Food Technological Research Institute, Mysore, India. *J. Food Sci. Technol.*, **19**: 97–100.

Lahsasni, S., Kouhila, M., Mahrouz, M. and Kechaou, N. 2002. Experimental study and modelling of adsorption and desorption isotherms of prickly pear peel (*Opuntiaficus indica*). *J. Food Eng.*, **55**(3): 201–207.

Liu, Q. and Bakker-Arkema, F.W. 1997. Stochastic modelling of grain drying. Part 2: Model development. *J. Agric. Eng. Res.*, **66**: 275–280.

Mahmutoglu, T., Ferhunde, E. and Birol, S.Y. 1996. Sun/solar drying of differently treated grapes and storage stability of dried grapes. *J. Food Eng.*, **29**: 289–300.

Maskan, A., Kaya, S. and Maskan, M. 2002. Hot air and sun drying of grape leather (pestil). *J. Food Eng.*, **54**: 81–88.

Maskan, M., Gogus, F. Sortion. 1998. Isotherms and drying characteristics of mulberry (*Morus alba*). *Journal of Food Engineering*, **37**: 437-449.

Pangavhane, D.R., Sawhney, R.L. and Sarsavadia, P.N. 2002. Design, development and performance testing of a new natural convection solar dryer. *Energy*, **27**: 579–590.

Rahman, M.S., Perera, C.O. and Theband, C. 1998. Desorption isotherm and heat pump drying kinetics of peas. *Food Res. Int.*, **30**: 485–49.

Rajkumar, P., Kutahaisami, S., Raghavan, G.S.V., Gancpy, Y. and Orsat, V. 2007. Drying kinetic of tomato slices in vacauumassited solar and open drying methods. *Drying Technology*, **25**: 1349-1357.

Sallesh, R.M., Ying, T.L. and Mousavi, L. 2016. Development of fruits bar using Sapodilla (*Manilkara zapota* L.), *Journal of Food Processing and Preservation*, pp. 01-07.

Seemakumarai, N. Kranthi Kamari, J. Joythi, J. Lakshami Lavanaya, I. Swaranalatha. 2016. Study of Drying Behaviour of sapota (*Manikara achras*) in solar tray dryer and hot air cabinet dryer.

Selvaray, Y. and Pal, D.K. 1984. Change in the chemical composition and enzyme activity of two- sapodilla cultivars during development and ripening. *Journal Horticulture Science*, **59**: 275-281.

Shanmugavala, K.G. and Srinivasan, G. 1973. Proximate composition of fruits of sapota cultivars. *South Ind. J. Hortic.*, **21**: 107-108.

Shirol, A.M., Kanamodi, V.C., Patil, S. and Thamnaiah. 2009. Studies on the performance of new sapota cultivars under Ghatoprabha command area, *Karnataka J. Agric. Sci.*, **22**(5): 1056-1057.

Siddappa, G.S. and Bhatia, B.S. 1954. Identification of sugar in fruits by paper chromatography, *Ind. J. Hortic.*, **11**: 19-23.

Suchita V. Gupta, Bhagyashree N. Patil. 2014. Convective drying of Osmo-Dehydrated sapota slices.

Togrul, I.T. 2003. Determination of convective heat transfer coefficient of various crops under open drying conditions. *Int. Commun. Heat Mass Transf.*, **30**(2): 285–294.

Westerman, P.W., White, G.M. and Ross, I.J. 1973. Relative humidity effect on the high temperature drying of shelled corn. *Trans ASAE.*, **16**: 1136–1139.

Yagcioglu, A., Degirmencioglu, A. and Cagatay, F. 1999. Drying characteristic of laurel leaves under different conditions. *In:* Bascetincelik, A. (ed) Proceedings of the 7th international congress on agricultural mechanization and energy, Adana, Turkey: Faculty of Agriculture, Cukurova University, pp. 565–569.

Zhang, Q. and Litchfield, J.B. 1991. An optimization of intermittent corn drying in a laboratory scale thin layer dryer. *Drying Techno.*, **9**: 383–395.