Study on Drying Behaviour of Sapota (*Manilkara Achras*) In Solar Tray Dryer and Hot Air Cabinet Dryer

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Abstract: *The drying characteristics of sapota (Manilkara achras), a tropical fruit crop, were studied. The fruit were pretreated with 1% KMS and cut into slices of 5mm thickness and dried in solar tray dryer and hot air cabinet dryer at drying air temperatures 80˚C, 100˚C and 120˚C. Moisture content of the fruit were reduced from 67.78 - 80.68 (%wb) to 2.42 to 3.28(%wb) with drying time of 11 to 13 hours in hot air cabinet dryer and11 hours in solar tray dryer respectively. The different drying characteristics were studied in terms of drying curve, drying rate curve and moisture ratio and then the slices were processed into a value added powder to pass through a 105µ sieve and evaluated for use in preparation of milk shake. The proximate analysis was done. The sapota's natural color, aroma and flavor were close to the fresh sample. The best overall results were obtained in sapota powder of hot air drying at 80˚C.*
Keywords: *Sapota, pretreatment, drying, powder.*

I. Introduction

Among all the fruits produced and processed in India, nearly 30% is wasted due to improper post harvest handling, transportation and storage. Research data are abundant on organizing systems such as grading, cleaning, packaging, cold storage and distribution. The ultimate aim in fruit processing is to increase shelf life. Methods such as controlled atmosphere storage, modified atmosphere storage and dehydration are typical. Of these methods, dehydration is a cost effective and viable method.

Sapota, *Manilkara achras* (Mill.) is one of the most important tropical fruits belonging to the family sapotaceae. It is popularly known as chikku. It is one of the delicious fruits of humid tropical and subtropical regions. Sapota is mainly valued for its sweet and delicious fruits. It is primarily used as dessert fruit. Sapota fruit is a good source of digestible sugar, which ranges from 12 to 20 per cent and it is virtually a treasure of minerals such as iron and calcium. The fruits have an appreciable amount of protein, fat, fiber, calcium, phosphorus, iron, carotene and vitamin C (Shanmugavelu and Srinivasan, 1973). 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). 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 different countries about 2.693 thousand tonnes of sapota, India earned about Rs 4,28,34,567 in the year of 2011-12.

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. Considering the fast increasing area under sapota cultivation, preservation and processing technology needs to be developed in order to prevent huge post harvest losses and regulate price during glut period and thus protecting the interest of the growers.

Table1. State-wise area, production & productivity of sapota during 2011-12

State	Area ('000 Ha.)	Production ('000 MT)	Productivity (MT/Ha.)
Karnataka	19.8	211.2	10.7
Maharashtra	18.0	180.5	10.0
Tamil Nadu	2.8	72.1	25.8
Andhra Pradesh	7.2	71.0	9.9
West Bengal	3.3	39.7	12.2
Haryana	0.6	16.5	28.2
Daman & Diu	0.2	1.4	7.0
Pondicherry	0.1	1.0	10.0
TOTAL	**52.0**	**593.4**	**11.4**

Source: National Horticulture Board, Ministry of Agriculture ,Govt. of India.

Drying is a classical method of food preservation, which provides longer shelf life, lighter weight for transportation and small space for storage. It is defined as a process of moisture removal due to simultaneous heat and mass transfer. It can be done by solar dryers, cabinet dryer, freez dryer *etc.*

There is a strong demand for convenience foods. The sale of powder concentrates was $1.47 million in 1985, accounting for about 53% of soft drink concentrate sales in India (Bisya, R.K., 1998).

In response to the demand for powder concentrates for the fast convenience food industries, this study was conducted to investigate the feasibility of converting the dried sapota into a value added product.

Sapota remains a mostly unexplored fruits, although research has been reported on aspects of its post harvest treatment. Studies have been reported on the extension of shelf-life of the fruit by chemical treatments. Not many reports on the processing of sapota into value added products were found.

One way to increase the shelf-life of sapota would to process it in to powder, as is done with various other fruits. Dried powder can be stored much longer than fresh fruit.

The research project was under taken with the following objectives.
- To study the drying behavior of sapota by solar and hot air cabinet dryer.
- To transmute the dried sapota slices into powder form.
- To evaluate the milk shake made from the dried sapota powder.

II. Review Of Literature

This chapter deals with the literature collected regarding the studies of drying of sapota and similar fruits and vegetables using solar tray dryer and air convecting cabinet dryer.

A number of researchers have conducted experiments on drying of fruits and vegetables, to reduce moisture content to desired level for increased shelf life and for further preparation of value added products is also presented here under.

Kapoor (1966) conducted morphological studies in sapotaceae nodal anatomy of 16 species has been worked out of these, fifteen and three-traced trilacunar, the three traces uniting in the nodal cortex to form a single petiolar strand has been found to be one-traced unilacunar. These results are in disagreement with the earlier report of an exclusively unilacunar condition. The trilancular node has been considered to be primitive and the unilacunar dried from it.

Pazarincevic *et al.* (1970) studied the trans beta-carotene content in fresh carrots, blanched fresh carrots and carrots dehydrated by different processes. After steam blanching for 5 min the carrots were dried by conventional air-drying at 60, 70 and 80°C, by vacuum drying at 60 and 70°C and vacuum drying at the same temperature after N_2 purging. Results indicated major decrease in trans beta-carotene content after conventional air-drying, losses being more pronounced at lower temperature and longer drying periods. The losses of trans beta-carotene at 60, 70 and 80°C was 48, 40 and 38% in blanched carrots respectively. Only 21-22% losses in vacuum drying, 7% with purging also have been reported.

Grishin *et al.* (1973) studied the kinetics of dehydrating vegetables and changes in the main chemical constituents (ascorbic acid, carotenes, essential oils, total sugars) due to drying process. It was recommended that diced carrots (cubes 5-8 13 mm) should be dried at 160°C. Carrots and onions were suggested to be used as basic ingredients of the snacks.

Mulet (1987) observed the effect of air flow rate (1000-9000 kg/m2h) on kinetics of drying of 10 mm x 10 mm x 10 mm carrot cubes. For flow rates greater than 6000 kg/m2h, the value of D/r2 (where D = apparent diffusivity and r = half the thickness of the cube) remained almost constant, indicating that the higher air flow rates had no influence on the drying rate.

Ajibola (1989) determined the moisture equilibrium data and thin-layer drying rates for melon seeds at 40-70°C and 10-88% RH, using static gravimetric methods. A 19 nonlinear least-squares regression program

was used, to evaluate 5 desorption isotherm models and 3 thin-layer drying models. The modified Halsey model gave the least standard error of estimate (0.4% for equilibrium moisture content and 4.8% for equilibrium RH). The exponential model, in which the drying constant was a function of temperature and RH, was adequate for predicting thin-layer drying of melon seed.

Diamante and Munro (1993) used solar dryer for drying sweet potato. The drying rates were affected by the fluctuating chamber temperature. A mathematical model for solar drying of sweet potato was derived based on the simplified form of Fick's diffusion. The model could satisfactorily describe the solar drying of sweet potato slices.

Lopez *et al.* (1995) presented models for the kinetics of hot air drying of 2.5 mm thick potato slices. Potatoes were cleaned, peeled, sliced, blanched in boiling water for 7 min, and soaked in 0.001% sodium bisulphite solution for 2 min. The slices were then dried in a pilot plant at 60, 70, 80 or 85°C and air flow 0.5, 1.0 or 1.5 m/s at a drying load of 25 kg/m2. Results showed that there were 2 different drying rates; the 1st was a constant rate period lasting up to 70 min, for which equations correlating air flow rate and heat transfer coefficient were derived, followed by a falling rate period which could be described by Fick's equation. Dependence of moisture diffusivity on temperature was shown to follow an Arrhenius relationship.

Madamba *et al.* (1996) investigated the thin-layer drying characteristics of garlic slices for a temperature range 50 - 90°C, a relative humidity range 8-24%, and an airflow range 0.5-l.0 m/s. An analysis of variance (ANOVA) revealed that temperature and slice thickness significantly affected the drying rate while relative humidity and airflow rate were insignificant factors during drying. Effective diffusivity of water varied from 2 to 4.2 x 10-10 m^2/s over the temperature range investigated, with an energy of activation of 989 W/kg. Four mathematical models available in the literature were fitted to the experimental data, with the Page and the two-compartment models giving better predictions than the single-term exponential and Thompson's model. The temperature dependence of the diffusivity coefficients were reported to follow Arrhenius-type relationship.

Jain *et al.* (1998) investigated the sensory evaluation of an intermediate moisture product from sapota. Mature fruits were peeled, sliced and dried in three different ways namely in shade, forced air and forced hot air. Organoleptic study with a selected panel of judge had been carried out. It showed that the sapota dried under forced air conditions were preferred over the sapota dried under the shade or forced hot air of 55˚C.

Johnson *et al.* (1998) studied the drying behavior, shrinkage and moisture distribution within cylindrical piece of plantain, of varying thickness, and with different air temperatures in an experimental hot air dryer. Air temperature had the greatest influence on the drying behavior. The activation energy for air drying of plantain was estimated as 38.81KJ (g.mol)[-1]. Change in dimension was linearly related to moisture content. Fick's diffusion equation was used to predict the distribution of moisture within the plantain piece during drying.

Krokida *et al.* (2003) examined the effect of air conditions (air temperature, air humidity and air velocity) and characteristic sample size on drying kinetics of various plant materials (potato, carrot, pepper, garlic, mushroom, onion, leek, pea, corn, celery, pumpkin, tomato) during air drying. A first-order reaction kinetics model was used, in which the drying constant was a function of the process variables, while the equilibrium moisture content of dried products within the range of 0.10–0.90 water activity at two temperatures (30 and 70°C) was fitted to GAB equation. The parameters of the model considered were found to be greatly affected by the air conditions and sample size during drying. In particular the temperature increment increased the drying constant and decreased the equilibrium moisture content of the dehydrated products.

Doymaz (2004) studied the drying kinetics of carrot cubes. Convective air drying characteristics of carrot cubes were evaluated in a cabinet dryer. Drying was carried out at 50, 60, 65, 70°C and drying data were analyzed to obtain diffusivity values from the period of falling drying rate. In the falling rate period, moisture transfer from carrot cubes was described by applying the Fick's diffusion model, and effective moisture diffusion coefficients were calculated. Effective diffusivity increased with increase in temperature. An Arrhenius relation with an activation energy value of 28.36kJ/mol expressed the effect of temperature on the diffusivity. Two mathematical models were fitted to the experimental data. The Page model gave better prediction than the Henderson and Pabis model and satisfactorily described drying characteristics of carrot cubes.

Lahsasni *et al.* (2004) examined the effect of drying air conditions on drying kinetics of the prickly pear fruit in a convective solar drier operating with an auxiliary heating system under air controlled conditions. Moreover, the prickly pear fruits were sufficiently dried in the ranges between 32 and 36°C of ambient air temperature, 50–60 °C of drying air temperature, 23–34% of relative humidity, 0.0277–0.0833 m^3/s of drying air flow rate and 200–950 W/m^2 of solar radiation. The results were verified with good reproducibility and drying air temperature was the main factor in controlling the drying rate. The drying followed at a falling rate period only. The expression of the drying rate equation was determined empirically from the characteristic drying curve. Eight different thin layer drying models were compared on the basis of their coefficients of

determination to estimate solar drying curves. The two-term model satisfactorily described the solar drying curves of prickly pear fruit with a correlation coefficient (r) of 0.9999.

Sacilik and Unal (2005) investigated the dehydration characteristics of the Kastamonu garlic in a convective hot-air dryer. The dehydration characteristics of garlic slices were examined at air temperatures of 40, 50 and 60° C and sample thicknesses of 3 and 5 mm. During the dehydration experiments, air velocity was kept stable at 0.8m/s. The effects of air temperature and sample thickness on the dehydration characteristics and quality parameters of the dehydrated garlic slices were determined. The transport of water during dehydration was described by Fick's equation and the effective diffusivity was between 195 and 335 $\mu m^2/s$. The effect of temperature on the effective diffusivity was described by the Arrhenius-type relationship. The activation energy was found as 23.48 kJ/mol. The experimental dehydration data of garlic slices obtained were fitted to the four well-known semi-theoretical drying models, i.e. the Henderson and Pabis, two-term, Lewis and Page 23 models. The accuracies of the models were measured using the coefficient of determination, mean relative percent deviation, root mean square error and reduced mean square of the deviation. All four models were acceptable for describing dehydration characteristics of garlic slices. However, the two-term model was more precise for predicting dehydration characteristics based on statistical analysis.

Chaughule *et al.* (2005) studied the formulation, drying and nutritional evaluation of RTE sapota extrudates. A new economical method has been developed for the value addition to this fruit into a neutraceutical ready -to- eat formulation using drying as the main step. The drying carried out in two steps. 1st step, blanched sapota pulp was partially dried (32% w/w on wb) in a convective dryer. In 2nd step different nutritional additive of interest were mixed with this partially dried pulp, subsequently. This mixture was extruded to a variety of shapes, which were finally dried using either a convective dryer or a fluidized bed dryer. The product quality was compared on the basis of color retention, texture, W_A, glucose content, total protein content, bulk density and sensory analysis.

Ganjyal *et al.* (2006) worked on processing of sapota –drying. Fruits were cut in sizes of half, quarter and 5mm slices and dried at temperature of 55˚C, 60˚C, 65˚C and 70˚C in convection air and vacuum ovens. Moisture content of the fruit reduced from 72 to 78% (wb) to 8.5 to 12.5 % (wb) with drying time of 15 to 35 hrs in a convectis on air oven and of 14 to 31 hrs in a vacuum oven. Log and modified log model were fitted for the drying constants as a function of drying temperature and size of samples with good correlation.

Doymaz (2007) investigated the air drying characteristics of pumpkin slices in a laboratory scale hot-air dryer. The thin-layer drying was carried out on three air temperatures of 50, 55 and 60°C at a constant air velocity of 1.0 m/s and relative humidity between 15% and 25%. Effective diffusivity and activation energy was also measured. The experimental moisture loss data were fitted to selected semi-theoretical and empirical thin-layer drying models. The mathematical models compared 26 according to the three statistical parameters such as the coefficient of determination (R^2), reduced chi-square (χ^2) and root means square error (RMSE) between the observed and predicted moisture ratios. The effective diffusivity values changed from 3.88 to 9.38 x 10^{-10} m^2/s within the given temperature range. An Arrhenius relation with an activation energy value of 78.93kJ/mol expressed the effect of temperature on the diffusivity.

Wang *et al.* (2007) studied the hot air convective drying characteristics of thin layer apple pomace in a laboratory scale dryer. The drying experiments were carried out at 75, 85, 95 and 105 °C and at the air velocity of 1.20 ± 0.03 m/s. Different mathematical models were tested with the drying behavior of apple pomace. The results indicated that the logarithmic model can present better predictions for the moisture transfer than other models; the drying process took place in two falling rate periods, the effective diffusivities in the second period were about six times greater than that in the first period. The general relationship of moisture ratio against drying duration in the thin layer convective drying of apple pomace was also developed.

Mortaza *et al.* (2008) simulated thin-layer drying using a laboratory scale hot-air dryer of the static tray type. Fick's second law was used as a major equation to calculate the moisture diffusivity with some simplification. The calculated value of moisture diffusivity varied from a minimum of 3.320 x 10^{-10} to a maximum of 9 x 10-9 m^2/s and the energy of activation ranged from 110.837 to 130.61 kJ/mol at 50°C to 70°C with drying air velocities of 0.5–2 m/s. The high value of the energy of activation for berberis fruit was related to the tissue of berberis fruit and high moisture content (about 74.28%w.b) and intensive changes in Deff values for a different air temperature at constant air velocity.

Basavaraj M *et al.* (2008) studied the dehydration of fig fruit by sun drying. This is a concern about safety of the end product. This can be overcome by hot air drying. Drying rate and moisture ratio of fig fruit by thin layer hot air drying method were determined by drying at air temperature of 55˚C, 65˚C, 75˚C with dry air velocities of 1 and 1.5 m/s. Data on sample mass, temperature and velocity of the dry air were recorded during each test and the rate of dehydration and quality were assessed. Falling dehydration rate period was observed where drying air temperature has the greatest effect on the drying rates and air velocity had the least effect.

Sachin *et al.* (2008) conducted the convective air drying of sapota pulp and compared with low-temp drying techniques such as heat pump-assisted drying and freeze drying. The sapota paste was dried in

convective dryer to study the effect of operating parameters such as air temperature, air velocity. The critical analysis of dehydrated sapota was carried out in terms of water activity, sugar content, color and rehydration ratio. The drying data were analyzed using page's model and Newton's model on the basis of root mean square (RMSE), reduced x square (x^2) and correlation coefficient (R^2).

Chung *et al.* (2009) studied on drying model and quality analysis of sun-dried chiku. Sun drying of chiku was carried out on different samples sizes to investigate the effects on drying kinetics. It was found that the maximum drying rates of sun-dried chiku decreased with larger product size. Three sunny–days are needed to dry the chiku slab to a chewiness of the dried samples were significantly different (p<0.05) compared to fresh chiku slabs and commercial dried fruit.

Miranda *et al.* (2009) investigated the effect of air temperature on the physicochemical and nutritional properties and antioxidant capacity of Aloe vera. The drying kinetics of Aloe vera gel was modeled using the Wang–Singh equation, which provided a good fit for the experimental data. Analysis of variance revealed that the drying temperature exerted a clear influence on most of the quality parameters.

Kaya *et al.* (2009) studied the thin-layer drying characteristics of some herbal leaves in a convective drier. Effects of the drying air parameters including temperature (35, 45 and 55°C), velocity (0.2, 0.4 and 0.6 m/s) and relative humidity (40%, 55% and 70%) on the total drying time were studied. The values of the moisture diffusivity (Deff) ranged from between 1.744×10^{-9} to 4.992×10^{-9} m^2/s for nettle leaves and 1.975×10^{-9} and 6.172×10^{-9} m^2/s for mint leaves from the Fick's diffusion model. Using Deff, the values of Ea were evaluated assuming the Arrhenius-type temperature relationship, which varied from 79.873 to 109.003 kJ/mol for nettle leaves and 66.873 to 71.987 kJ/mol for mint leaves.

III. Materials And Methods

This chapter deals with the details of material procured, the methods followed for study of drying behavior of sapota in solar tray drier and hot air cabinet dryer and development of milk shake from dried sapota powder, determination of proximate composition and sensory characteristics of the developed product.

Materials
The following are the specifications of the materials and equipments employed in the research work.

3.1 Procurement of raw material
Sapota (cv.kalipatti) fruits were procured from the local market of Bapatla. Initial moisture contents ranged from 72-78(%wb) were used in the studies. Fruits of similar size were selected. Typical chemical composition of fruit is shown in table (3.1).The physical properties of the selected fruits are shown in table (3.2).

Table 3.1 Composition of ripe sapota fruit/100gm of edible portion

Constituents	Approximate amount
Moisture content (%wb)	73.37
Protein (g)	0.70
Fat (g)	1.10
Minerals (g)	0.05
Fiber (g)	2.60
Carbohydrates (g)	21.40
Ascorbic acid (mg)	0.06
Energy (cal)	98.0
Phosphorous (mg)	72.0
Fe (mg)	1.25
Ca (mg)	28.0
Thiamine (mg)	0.02
Riboflavin (mg)	0.03
Carotene (mg)	97.00

Table 3.2 Physical properties of sapota fruit

Parameters of fruits	Minimum	Maximum	Average
Diameter(cm)	4.60	5.40	4.80
Weight(g)	74.90	78.00	76.40
Surface area(cm^3)	63.60	95.00	79.30
Volume(cm^3)	47.70	87.10	67.40
True density (gcm^3)	1.12	1.56	1.34
Bulk density (gcm^{-3})	0.80	0.83	0.815

3.2 Solar tray dryer

A laboratory solar drier (make; SEED, Hyderabad; model SDM-8) consisted of an enclosure with a glass sheet as cover. Solar radiation entering enclosure, heated the air inside was absorbed in the product and the surrounding internal surface of the enclosure. As a result helped in the removal of moisture from the product. Suitable openings were provided at bottom of the drier to ensure air draft. A fan was provided at the top to provide forced circulation of air. Fan was run with the help of solar photovoltaic cell. Temperatures ranging from 40-65˚c were usually attained.

3.3 Hot air cabinet dryer

Hot air cabinet dryer of model CD-5, 4 kw pipe heater, blow power (KW, 50/60 HZ), temperature range 250˚C, with 5 trays of 50 Kg capacity which can be placed one above the other with an equal space in between. The openings are provided both side of the dryer to remove moist air. An electrical heater is provided to heat the air which enters at the bottom opening of the dryer. To circulate this hot air in the dryer, a blower is provided. The movement of air inside the dryer is in cross flow.

3.4 Chemical - Potassium meta bisulphate (KMS) solution (1%)
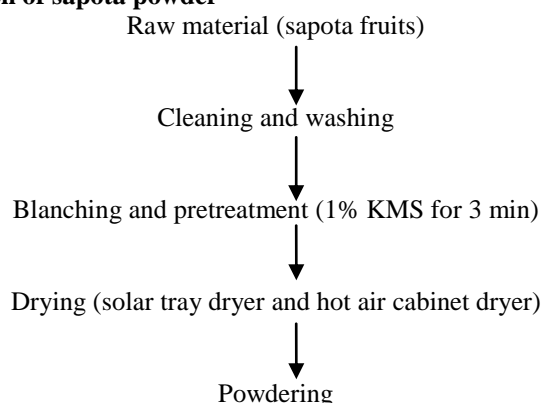
3.5 Procedure for preparation of sapota powder

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Raw material (sapota fruits)

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Cleaning and washing

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Blanching and pretreatment (1% KMS for 3 min)

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Drying (solar tray dryer and hot air cabinet dryer)

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Powdering

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Fig 3.1 flow chart for sapota powder preparation

3.6 Preparation of sapota fruit for drying

3.6.1 Cleaning and washing

Sapota fruits were washed thoroughly under running tap water and weighed. Discolored and infected parts were trimmed out and losses were noted.

3.6.2 Blanching and pretreatment

The outer skin of the ripened fruit was peeled off manually using a knife without damaging the pulp. Samples were weighed, blanched (60°C) in a 1% potassium metabisulphate (KMS) solution for 3min and then drain.

3.6.3 Drying (solar tray dryer and hot air cabinet dryer)

Pretreated peeled sapota fruits were cut into 3mm thick slices (cut from the middle of the fruits and thickness measured with a vernier caliper, to be 3 ± 5 mm all over) and dried using two drying methods, *viz* solar tray drying and hot air cabinet drying at 80˚C, 100˚C and 120˚C. The samples were dried and weight was recorded at every one hour. The experiments were triplicated for each treatment. The corresponding drying characteristics were studied.

Plate no.1 Fresh sapota slices
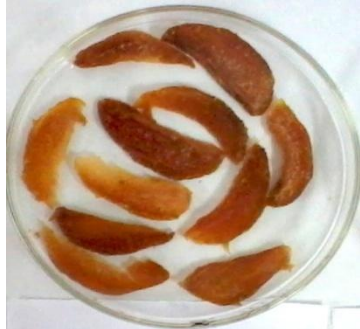

Plate no.2 After drying in solar tray dryer

Plate no.3 After drying in hot air cabinet drying (80˚C)

Plate no.4 After drying in hot air cabinet drying (100˚C)

Plate no.5 After drying in hot air cabinet drying (120˚C)

3.6.4 Drying characteristics

3.6.4.1 Moisture content (%db)

The moisture content of the slices of sapota was calculated on dry basis using following formula (Chakraverty, 2003).

$$M = W_M / W_d \times 100$$

Where,

M = moisture content, %dry basis

W_M = weight of moisture, g

W_d = weight of bone dry matter, g

3.6.4.2 Moisture content (%wb)

The moisture content of sapota slices was calculated on wet basis using following formula (Chakraverty, 2003).

$$M = W_M / W_s \times 100$$

Where,

M = Moisture content % wet basis.

W_M = Weight of moisture, g

W_s = Weight of sample, g

3.6.4.3 Drying rate
The drying rate of sapota slices was calculated on wet basis using following formula (Chakraverty, 2003).

$$R = \frac{W_r}{T \times W_d} \times 100$$

Where,

R = Drying rate (g/min)
W_r = Amount of moisture removed (g)
T = Time taken (min)
W_d = Total bone dry weight of sample (g)

3.6.4.4 Moisture ratio
The moisture ratio of sapota slices was calculated on wet basis using following formula (Chakraverty, 2003).

$$MR = \frac{M - M_e}{M_{o-M_e}}$$

Where,

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

3.6.4.5 Rehydration of sapota slices
In rehydration water is added to the product which is restored to a condition similar to that when it was fresh. This done by adding cold water to the dry sapota slices and is left to soak for 1 to 2 hours. (R.P. Srivastava, 2002).

3.6.4.5.1 Rehydration ratio

$$R = \frac{\text{Mass of sample rehydrated (g)}}{\text{mass of dried sample (g)}}$$

3.6.4.5.2 Coefficient of rehydration

$$\text{Rehydration coefficient} = \frac{\text{Drained wt of hydrated samples} \times \left[\begin{array}{c}100 - \text{Moisture content of} \\ \text{sample before drying}\end{array}\right]}{\left[\begin{array}{c}\text{wt.of dried sample} \\ \text{taken for rehydration} - \text{amount of moisture} \\ \text{present in the dried} \\ \text{sample taken for rehydration}\end{array}\right]} \times 100$$

3.7 Powdering of dehydrated sapota slices
The dehydrated sapota samples obtained at different drying temperature of cabinet dryer and solar tray dryer were ground in a mixer grinder (maker-Maharaja, model no. 1990.classic, power-600 watts, capacity-1/2 kg) to pass through a 105µ sieve.

3.8 Formulation of milk shake using sapota powder

Ingredients
Sapota powder- 20 parts by weight
Milk (boiled) - 100 parts
Sugar- 15parts

Method- Add sapota powder and sugar in a blender along with 100ml of milk. Blend it till it mixed properly. Add the remaining milk and blend again. Serve chilled.

**Plate no.6 Sapota powder
(Solar tray drying)**

**Plate no.7 Sapota powder
(Hot air cabinet drying at 80˚C)**

**Plate no.8 Sapota powder
(Hot air cabinet drying at 100˚C**

**Plate no.9 Sapota powder
(Hot air cabinet drying at 120˚C)**

3.8 Evaluation of dried sapota powder
Samples of dried sapota powder dried using solar tray dryer and hot air cabinet dryer at 80˚c, 100˚c, 120˚c were evaluated for the following parameters:
1) Organoleptic evaluation
2) Proximate analysis
3) Microbiological analysis.

3.8.1 Organoleptic evaluation of dried sapota powder
Organoleptic evaluation of dried sapota powder incorporated milk shake prepared as in 3.8 paragraph was carried out in this experiment. The 9 point Hedonic Scale was used to compare the samples.

Sensory evaluation was conducted in sensory evaluation laboratory, Department of Food Technology. The panelists were selected solely on the basis of interest, time available and lack of allergies to food ingredients used in study.

On every occasion, the panelists were provided with coded disposable paper cups containing the sample under investigation. Sensory evaluation was carried out under ambient conditions. A comfortable area without distractions (isolated booths) under fluorescent lighting and controlled temperature was used. Water was supplied to clean the pallets between the evaluations of two samples.

Samples were tested for different parameters like color, taste, flavor, consistency and overall acceptability. All these tests including the testing for consumer acceptance was done by sensory panelist according to 9 point hedonic scale for sensory evaluation as described by Peryac and Giradot (1952) (Appendix I).

3.8.2 Proximate analysis of dried sapota powder
The powder were evaluated for following chemical parameters
1) Estimation of fat
2) Estimation of protein
3) Estimation of total carbohydrate
4) Estimation of energy
5) Estimation of total ash
6) Estimation of TSS
7) Estimation of % Acidity
8) Estimation of % Ascorbic acid

3.8.2.1 Estimation of fat

Fat was determined by Soxhlet Method (AOAC, 1990). 1 g of the sample was accurately weighed into a dry cellulose thimble and extracted using petroleum ether (60° - 80°C b.p) as solvent in a Soxhlet Apparatus. The solvent was allowed to flow until it touched the bottom of the beaker. The stopper was opened to ensure whether the rate of condensation of solvent and the delivery of the solvent are at equilibrium. At the end of this rinsing stage, the stopper was closed and solvent was recovered from the extractor. The beaker along with fat was removed from the apparatus and kept on a hot plate for some time. The weight of the beaker was then taken and the fat content calculated. The fat content of the samples were expressed as g /100 g of sample. The amount of fat present in sample mix were calculated using the following equation,

$$\text{g of fat/ 100g of sample} = \frac{final\ wt.of\ beaker - Empty\ wt.of\ beaker}{wt.of\ sample} \times 100$$

3.8.2.2 Estimation of protein

Protein estimation of sample was carried out using the Folin-Lowry method (Ranganna 1986). The principle involved required the measurement of the final color intensity caused by the two reactions noted below:
1. The CO-NH groups in the protein molecule react with Copper Sulphate in alkaline medium to give purple color.
2. Reduction of the Phosphomolybdic –Phosphotungstic reagent by Tyrosine and Tryptophan present in the proteins.

Reagents Required
1) Alkaline Copper Reagent:
 a. 1% Potassium Sodium Tartarate (10 ml).
 b. 0.5% Copper Sulphate (10 ml).
 c. 10% Sodium Hydroxide (20 ml).
 d. 20% Sodium Carbonate (50 ml).
 e. Mix all the reagents and make up the volume to 100 ml with water.
2) Phenol Reagent: Dilute the readymade reagent as indicated (1 ml Phenol Reagent and 3 ml distilled water).
3) protein standard: weigh 5mg of Bovine Serum Albumin and dissolve in 5ml water (1 mg/ml). use 0.1 to 0.5 ml (100 μg – 500 μg) for standard graph.

Procedure
1. Take a known weight/volume of the sample (10 mg) and dissolve in a known volume of water (10 ml).
2. Pipette 0.1 ml to 0.5 ml of the standard protein solution into five test tubes.
3. Pipette 0.5 ml each of unknown sample into two test tubes (duplicates).
 4. Add 0.5 ml of alkaline copper reagent to all tubes. Mix and let it stand for 10 min.
5. Add 2 ml Phenol Reagent rapidly to each tube and mix immediately.
6. Heat in a water bath at 55 for 5 min.
7. Cool under running water and read the absorbance at 650 nm against blank.
 8. Draw a standard curve by plotting concentration of standard on X-axis and absorbance on Y-axis.
9. From the graph calculate the amount of protein present in the sample.

$$\text{g of protein present / 100g of sample} = \frac{\mu g\ of\ protein\ from\ graph}{0.5\ ml} \times \frac{10}{0.5} \times 100$$

3.8.2.3 Estimation of carbohydrates

Estimation of carbohydrates in the samples was carried out by Anthrone Method (AOAC 1990).

Reagents Required
1. 2.5 N HCl.
2. Anthrone Reagent: Dissolve 200mg of Anthrone in 100 ml of ice cold 95% H_2SO_4.
3. Stock Standard Glucose Solution: Dissolve 100mg of Glucose in 100ml of distilled water (1mg/ml).Working Standard Solution: Dilute 10 ml of stock standard solution to 100 ml with distilled water (1 ml/ 100mg).

Procedure
1. Weigh 100 mg of sample and place it in boiling test tube.
2. Hydrolyze by keeping it in a boiling water bath for 3 hrs. With 5 ml 2.5 N HCl and cool to room temperature.
3. Neutralize it with solid Na2CO3 until the effervescence ceases.
4. Make up the volume to 100 ml and then centrifuge and filter.
5. Collect the supernatant and take 0.5 ml and 1 ml aliquots from the supernatant.

6. Prepare the standards by taking 0.2 ml, 0.4 ml, 0.6 ml, 0.8 ml, 1 ml and run a blank simultaneously.
7. Make up the volume in all the tubes to 1 ml with distilled water.
8. Then add 4 ml of Anthrone Reagent.
9. Heat for 8 min. in a boiling water bath.
10. Cool the tubes under tap water and read the green color at wave length 630 nm.
11. Draw a standard curve by plotting concentration of standard on X-axis and absorbance on Y-axis.
12. From the graph calculate the amount of carbohydrates present in the sample, the graph calculate the amount of carbohydrates present in the sample.

$$\text{Amount of carbohydrates present (\%)} = \frac{mg \ of \ glucose \ from \ graph}{sample \ volume} \times 100$$

3.8.2.4 Estimation of energy
It is estimated on Iso-thermal oxygen bomb calorimeter (Ranganna 1986).
Reagents Required
1. Benzoic Acid (Heat of Combustion - 6.318Kcal/g). This reagent is used to calculate water equivalent of 2000g of water.
2. Standard Alkali Solution (Na_2CO_3) N/10. This solution is used to titrate the total acid produced due to burning of food sample and the reading of N/10 Sodium Carbonate is used for acid correction.
3. Methyl Orange Indicator.

Procedure
Filling of the Bomb
0.5 g of the sample was taken in a metal crucible and the crucible was placed in the crucible stand of the Bomb Calorimeter. The platinum wire (10 cm) was taken and the crucible was placed in the crucible stand of the bomb. The thread (20 cm) is tied to the wire and carried to the sample in the crucible. About 10 ml of distilled water was added to the bomb. The control valve was closed on the filling connection and the oxygen tank was opened. The filling connection valve was opened slowly, and the gauge was monitored allowing the pressure to rise slowly until 30 atmosphere was reached and then the control valve was closed.

Water Bucket Adjustment
Two liters of distilled water was added to the calorimeter bucket. The bucket was adjusted with water inside the calorimeter.

Assembling of the Calorimeter
The bomb was placed inside the calorimeter with the help of the handle provided on the bucket. The terminal point is attached to the bomb electrode. The cover is placed on the jacket. The thermometer reading is adjusted to 1-20˚C and immersed in the water bucket. Vibrator is started to achieve homogeneous temperature of water bucket inside.

Temperature Observations
The motor is run for 5min. The initial temperature is noted when the thermometer reading is constant. The button on the ignition unit is pressed to fire the charge. After firing, mercury starts rising. Final temperature is noted when the temperature reading is again constant.

Dissembling the Calorimeter
Once the thermometer is removed and covered with insulation, the bomb is lifted out of the bucket and all residual pressure inside the bomb is relieved. The screw cap is removed. The bomb head is lifted out and examine the wire left un-burnt. All interior surfaces of the bomb and crucibles are washed with distilled water. The washings are collected in a beaker for the estimation of H_2SO_4 and HNO_3 formed from sulphur and nitrogen present in the test sample. It is titrated with standard alkali solution using mixed indicator. Total value of standard alkali is noted.

Determination of Water Equivalent
Benzoic Acid is used as a standard material. It has a heat of combustion of 6318 cal/g.
Water equivalent of one calorimeter is computed from the following equation:

$$W = \frac{HM + C_1 + C_2 + C_3}{t}$$

Where,
 W = Water equivalent of calorimeter in cal/g.
 H = Heat of combustion of benzoic acid in cal/g = 6318 cal/g.
 M = Wt. of benzoic acid in g.
 t = Rise in temperature of water in the bucket.
 C1 & C2 = Correction of combustion (cal) of H_2SO_4 and HNO_3 respectively.
 C3 = Correction of combustion of fuse wire and thread.

The combustion of thread fuse wire may be taken as 3962 cal/g & 1400 cal/g respectively.

Calculations

$$\text{Gross heat of combustion (cal/g)} = \frac{t \times w - (c_1 + c_2 + c_3)}{M}$$

Where,

t = Rise in temperature.
W = Water equivalent.
M = Wt. of substance.

3.8.2.5 Estimation of ash content

The ash content was estimated according to the method described by AOAC. 5 g of samples were accurately weighed into a clean, dry, silica crucible and their weights measured (W1). The initial ashing was carried out over a low flame to char the sample. The crucible was then transferred to a muffle furnace initially maintained at 200°C. The furnace temperature was later raised to and held at 500 - 5500˚C to get ash. The crucible was then cooled until a constant weight (W2) was achieved and expressed as g / 100 g of sample.

$$\% \text{ Ash content} = \frac{w_2 - w_1}{weight \ of \ sample} \times 10$$

Where,

W1 = Weight of sample + crucible before ashing.
W2 = Weight of sample + crucible after ashing.

3.8.2.6 Estimation of TSS

The TSS of dried sapota juice is determined (Ranganna 1986). A 2 g dried and powdered sample was mixed with 2 ml of water. The clear juice was filtered using muslin cloth. A drop of the extracted juice was placed on the prism cover of the refractometer and the TSS value was read directly by viewing through the eyepiece. This was repeated 3 times for each sample.

3.8.2.7 Estimation of %Acidity

Reagents Required

1)   0.1 N NaOH
2)   Phenolphthalein indicator

Procedure

The % Acidity was calculated (Srivastava, 2002). About 10 ml of clear juice was extracted and diluted with distilled water to 100 ml (1:10). From this an aliquot of 25 ml was placed in a conical flask and 2 to 3 drops of phenolphthalein indicator were added. This was titrated against 0.1 N NaOH until the color changed to light pink and persisted. The titer value was recorded. Three readings were taken for each of the samples and acidity was calculated as

$$\% \text{ Acidity} = \frac{titer \ \times Normality of \ \ alkli \ \times meq \ wt \ of \ acid \ \times 100}{wt \ or \ volume \ of \ sample}$$

3.8.2.8 Estimation of % Ascorbic acid

The % Ascorbic acid content was determined (Ranganna 1986).

Reagents Required

1)   Oxalic acid 4%
2)   Dye solution: weigh 42 mg sodium bicarbonate into a small volume of distilled water. Dissolve 52mg 2,6-dichlorophenol indophenols in it and make up to 200 ml with distilled water.
3)   Stock Standard solution: Dissolve 100 mg ascorbic acid in 100 ml of 4% oxalic acid solution in a standard flask (1 mg/ml).
4)   Working standard: Dilute 10 ml of the stock solution to 100 ml with 4% oxalic acid. The concentration of working standard is 100 μg/ml.

Procedure

1) Pipette out 5 ml of the working standard solution into a 100 ml conical flask.
2) Add 10 ml of 4% oxalic acid and titrate against the dye (v_1). End point is the appearance of pink color which persists for a few minutes. The amount of the dye consumed is equivalent to the amount of ascorbic acid.

3) Extract the sample (0.5-5g) depending on the sample in 4% oxalic acid and made up to a known volume (100 ml) and centrifuge.
4) Pipette out 5 ml of this supernatant and add 10 ml of 45 oxalic acid and titrate against the dye (v_2 ml).
5) Calculate the % Ascorbic acid content

$$\% \text{ Ascorbic acid mg/100 g} = \frac{0.5 \ mg}{v_1} \times \frac{v_2}{5 \ ml} \times \frac{100 \ ml}{wt \ of \ sample} \times 100$$

3.8.3 Microbiological analysis
Microbial Limit Test (MLT) was done to analyze the sample for its microbial quality (both bacterial and fungal). The procedure given in the Food Safety Act, 1990 (Govt. of United Kingdom) was followed for this purpose.

3.8.3.1 Bacterial limit test
Requirements
Medium- Nutrient Agar Medium was prepared for the purpose of bacterial limit test. 28 g of media was dissolved in 1000 ml of distilled water. This was later sterilised by autoclaving at 15 lbs pressure and 121°C for 15 minutes.
Diluent Solution- 0.1% peptone water solution was prepared by dissolving 100 mg of peptone in 100 ml of distilled water. This was also sterilised by autoclaving at 15 lbs pressure and 121°C for 15 minutes.
Technique Adopted**:** Pour Plate Technique.
Incubation Temperature: 37°C.
Incubation Period: 48 hours.
pH Adjustment**:** The pH of the sample is adjusted to 7 (neutral pH) by using 1N NaOH or 1N HCl as required.
Procedure
1.Transfer 1 ml. of diluted neutral sample (1 g in 10 ml of sterilized peptone diluent) into sterile petri plates.
2. Transfer 15 – 20 ml the sterilized media into the petri plate and allow it to solidify. Close the lids after the medium solidifies.
3. Incubate the solidified plates in an inverted position in an incubator for 48 hrs. at 37°C.
4. After 48 hrs. count the number of colonies and record the result.

Calculation
$$\text{No. of colonies (CFU/g), N} = A \times D$$
Where,
N = Number of colonies (CFU/g).
A = Average count of colonies in petri plates.
D = Dilution factor (D = 10 as 1:10 dilution of sample was taken).

3.8.3.2 Fungal limit test
Requirements
Medium- Sabouraud Dextrose Agar Medium was prepared for the purpose of fungal limit test. 65 g of media was dissolved in 1000 ml of distilled water. This was later sterilised by autoclaving at 15 lbs pressure and 121°C for 15 minutes.
Diluent Solution- 0.1% peptone water solution was prepared by dissolving 100 mg of peptone in 100 ml of distilled water. This was also sterilised by autoclaving at 15 lbs pressure and 121°C for 15 minutes.
Technique Adopted: Spread Plate Technique.
Incubation Temperature: 22 - 25°C.
Incubation Period: Upto 5 days.
pH Adjustment: The pH of the sample is adjusted to 7 (neutral pH) by using 1N NaOH or 1N HCl as required.
Procedure
1. Transfer 15 – 20 ml the sterilized media into the sterilized petri plate and allow it to solidify.
2. Transfer 1 ml of diluted neutral sample (1 g in 10 ml of sterilized peptone diluent) into the petri plates. Close the lids after evenly spreading the sample on the medium.
3. Incubate the solidified plates in an upright position in an incubator for upto 5days at 23°C.
4. After 5 days count the number of colonies and record the result.

Calculation
$$\text{No. of colonies (CFU/g), N} = A \times D$$
Where,
N = Number of colonies (CFU/g)

A = Average count of colonies in petri plates
D = Dilution factor (D = 10 as 1:10 dilution of sample was taken)

IV. Results And Discussion

This chapter deals with the results obtained from the work we did on study of drying behavior of sapota fruit by solar tray dryer and hot air cabinet dryer at temperature of 80˚C, 100˚C, 120˚C and powdering the dried slices of sapota for development of milk shake and the effect of drying temperature on nutritional and microbial load.

4.1 Drying characteristics
4.1.1 Temperature and relative humidity inside and outside of solar tray dryer

The whole drying process was carried out was achieved during the day between 9:00 am and 5:00 pm. So the Temperature and Relative humidity inside the solar tray dryer and outside is given in the table from 9:00 am to 5:00 pm.

Table 4.1 Temperature and relative humidity profile during experiment

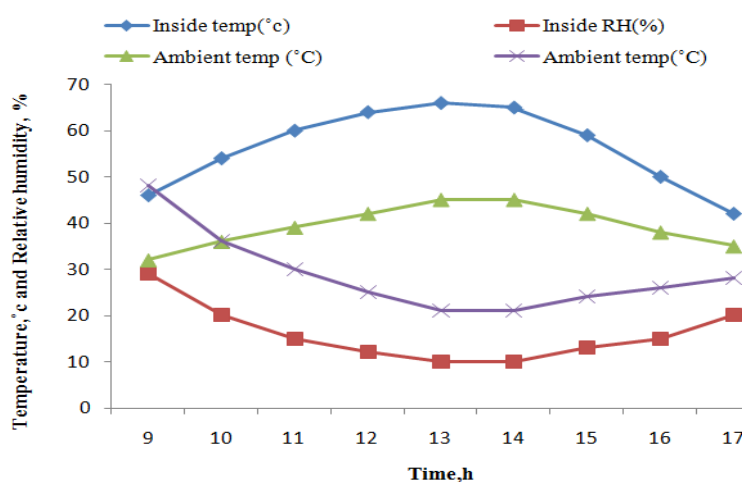| Time	Inside temp(˚C)	Inside RH(%)	Ambient temp(˚C)	Ambient RH(%)
9:0	46	29	32	48
10:0	54	20	36	36
11:0	60	15	39	30
12:0	64	12	42	25
13:0	66	10	45	21
14:0	65	10	45	21
15:0	59	13	42	24
16:0	50	15	38	26
17:0	42	20	35	28

Fig. 4.1 profile of weather parameters during experiment

From figure 4.1 it is observed that the ambient temperature ranged between 32- 45˚C and ambient relative humidity ranged between 48- 28%. The highest temperature 45˚C and lowest relative humidity 21% was observed at time 14:0 p.m. Similarly, the highest temperature inside the solar tray dryer was found to be 66˚C and the lowest relative humidity 10% was observed at time 13:0 p.m. it is evident that the temperature and relative humidity of the drying air is dependent on the ambient air parameters.

4.1.2 Moisture content (%db)

The moisture content of fresh sample taken for drying was ranges from 202.34-439.06 % and reduced to 2.42-3.28 after drying. Sample dried in solar tray dryer were drawn and analyzed for moisture content after every one hour. It was observed that the moisture of the sample reduced from 202.34 to 2.64 % in 11 hours.

Similarly in hot air cabinet drying at 80°C, 100°C and 120°C the initial moisture content were 363.76, 244.92 and 439.06 % respectively got reduced to final moisture content content of 2.83, 2.42 and 3.28% respectively. The time required for 80°C, 100°C and 120°C are 13, 12 and 11 hours respectively to reduced to final moisture content.

The moisture reduction of the sample for every one hour tabulated in the table in appendix II. A graph was placed by taking the drying time on x-axis and the % moisture content on y-axis.
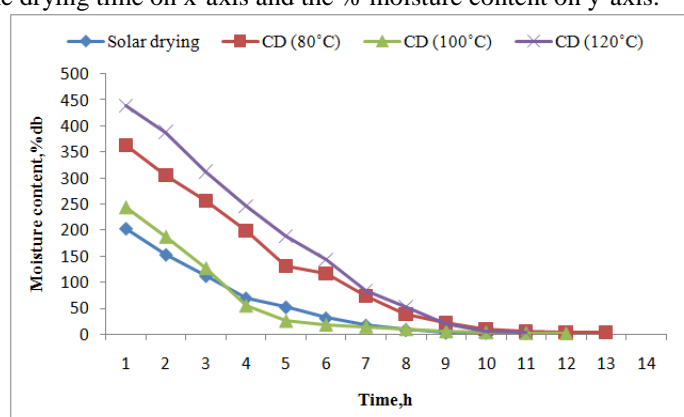
Fig.4.2 Moisture content (%db) VS Time,h

4.1.3 Moisture content (%wb)

The initial moisture content of the sample dried in solar tray dryer is 67.78% and the moisture content of the of the sample dried in hot air cabinet dryer at 80°C, 100°C and 120°C were recorded as 76.22, 70.92 and 80.68 % respectively.

The final moisture content of sample after drying in solar tray dryer for 11 hours it reduced to 2.64 % and the final moisture content of the sample after drying in hot air cabinet dryer at 80°C, 100°C and 120°C were 2.42 and 3.28 % and the time required is 13, 12 and 11 hours respectively.

The moisture reduction of the sample for the sample for every one hour tabulated in the table given in appendix II. A graph was plotted by taking the drying time on x-axis and the % moisture on y-axis.
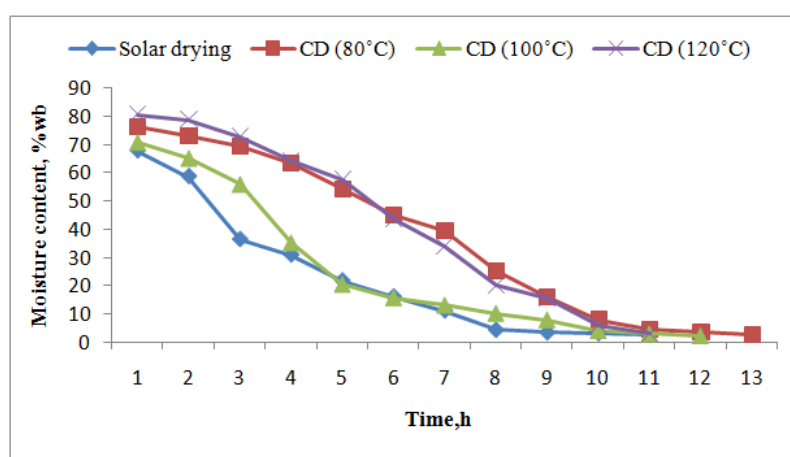

Fig.4.3 Moisture content (%wb) VS Time,h

4.1.4 Drying rate (g/gmin)

The maximum drying rate ranges from 3.44 to 8.15 g/g min during of sapota slices at different temperature and the lowest rate was recorded from 0.01 to 0.02 g/g min.

In solar tray drying the 3.44 g/gmin was recorded as maximum drying rate and 0.05g/gmin as lowest. The drying rate was found to be the highest during the first hour of drying period and gradually decreases to 0.05g/gmin in 11 hours of drying.

In hot air cabinet dryer at 80˚C, 100˚C and 120˚C the 6.05, 8.15 and 7.31g/gmin respectively as maximum drying rate and 0.04, 0.01 and 0.02 g/gmin as lowest drying rate respectively.

The drying rate was found to be highest during the early stage of dryig and gradually decreases because the inability of moisture to be conveyed from center of body to the surface of the sapota at rate comparable with the moisture evaporation from surface to the surrounding.
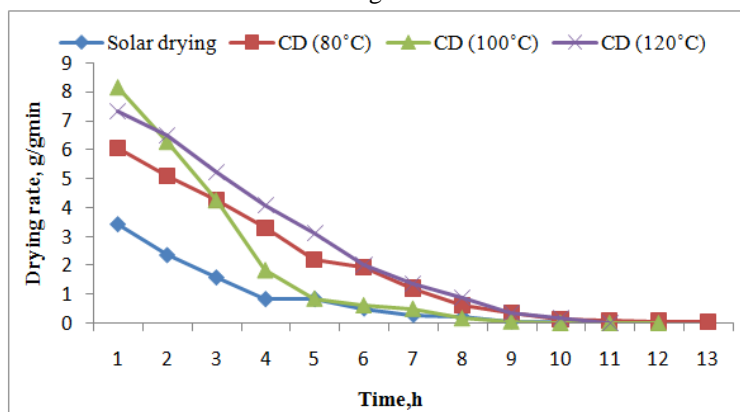

Fig.4.4 Drying rate, g/g min VS Time,h

4.1.5 Moisture ratio

The moisture ratio was recorded 1 for both the solar tray drying and hot air cabinet drying at 80˚C, 100˚C and 120˚C for first hour of drying afterwards it gradually decreases.

For solar tray drying the least moisture ratio 0.05 was recorded after 1o hours of drying.

For hot air cabinet drying at 80˚C, 100˚C and 120˚C the least moisture ratio 0.008, 0.001 and 0.002 was recorded after drying for 12, 11 and 10 hours respectively.
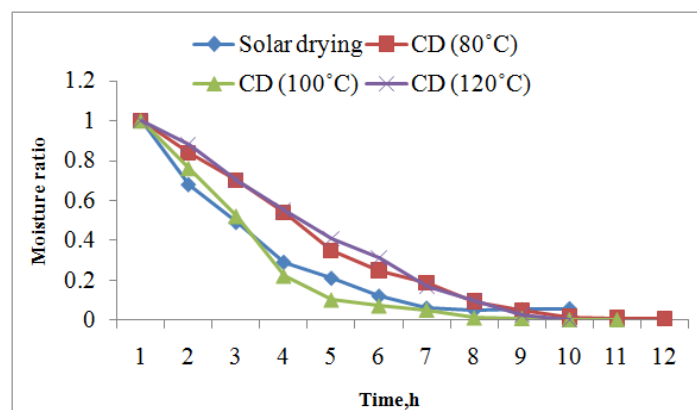

Fig.4.5 Moistue ratio VS Time,h

4.1.6 Rehydration ratio

The Rehydration ratio was found to be the highest 15:5 in hot air cabinet dryer at 80˚C, 120˚C and 14:5 in hot air cabinet drying at 100˚C. Solar tray drying shows the least 13.5:5 rehydration ratio.

Table.4.2 Rehydration ratio with respect to different drying temperature

S.No	Drying method	Weight of dehydrated sample	Weight of rehydrated sample	Rehydration ratio
1	Solar tray drying	5 gm	13.5	13.5:5
2	Hot air Cabinet drying (80˚C)	5 gm	15	15:5
3	Hot air cabinet drying (100˚C)	5 gm	14	14:5
4	Hot air cabinet drying (120˚C)	5 gm	15	15:5

4.1.7 Rehydration coefficient

The Rehydration coefficient was greatest in hot air cabinet drying at 80˚C is 0.916 followed by hot air cabinet drying at 120˚C and 100˚C 0.827, 0.634 respectively. The least rehydration coefficient is for solar tray drying 0.540.

Table 4.3 Rehydration coefficient with respect to different drying temperatures.

S.No	Drying method	Rehydration coefficient
1	Solar tray drying	0.540
2	Hot air cabinet drying (80˚C)	0.916
3	Hot air cabinet drying (100˚C)	0.634
4	Hot air cabinet drying (120˚C)	0.827

4.2 Organoleptic evaluation of milk shake added with dried sapota powder

Sensory evaluation (Peryac and Giradot, 1952) of the dried sapota powder milk shake was conducted using 4 test samples. The milk shake was prepared as in 3.8 paragraph. Duplicates were used to check for and prevent redundancy in the scores among the panelists. The samples were evaluated by twenty member panels. The scores were subjected to statistical analysis to reduce errors in evaluation. The values are presented in the form of their arithmetic means. The scores are given in table (4.4) below and are illustrated in the bar graph below in fig (4.6).

Table 4.4 Sensory evaluation of milk shake prepared from dried sapota powder.

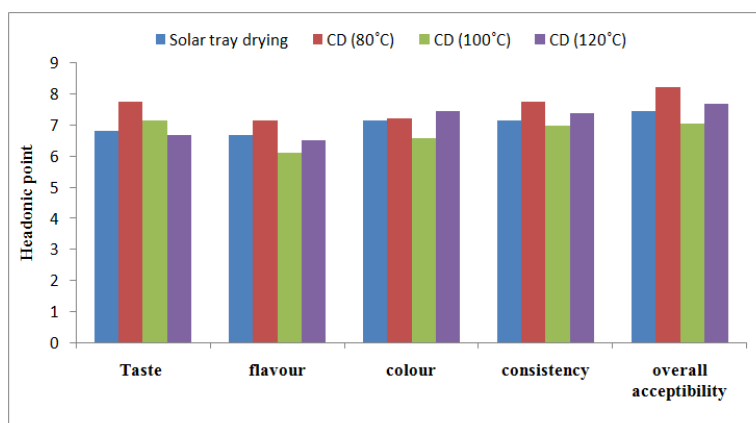| Attributes	Solar tray drying	Hot air cabinet drying (80˚C)	Hot air cabinet drying (100˚C)	Hot air cabinet drying (120˚C)
Taste	6.82	7.76	7.17	6.70
Flavor	6.70	7.17	6.11	6.52
Color	7.17	7.23	6.58	7.47
Consistency	7.17	7.76	7	7.41
Overall acceptability	7.47	8.23	7.05	7.7

Fig.4.6 Organoleptic evaluation of dried sapota powder milk shake

The sensory evaluation was conducted for taste, flavor, colour, consistency and overall acceptability for the four samples of solar tray drying and hot air cabinet drying at 80˚C, 100˚C and 100˚C. From the above chart it can be clearly seen that sample of hot air cabinet drying at 80˚C has better taste, flavor, color, consistency and overall acceptability compared to the samples of solar tray drying and the hot air cabinet drying at 100˚C and 120˚C.

Plate no.10 Sapota milk shake
(Solar tray drying)

Plate no.11 Sapota milk shake
(Hot air cabinet drying at 80˚C)

Plate no.12 Sapota milk shake
(Hot air cabinet drying at100˚C)

Plate no.13 Sapota milk shake
(Hot air cabinet drying at 120˚C)

4.3 Proximate analysis of dried sapota powder

The results obtained after analysis of different treatment of sapota powder is compiled in the Table (4.5) given below.

Table 4.5 Proximate composition of sapota slices dried under different conditions.

Attributes	Solar tray drying	Hot air cabinet drying (80˚C)	Hot air cabinet drying (100˚C)	Hot air cabinet drying (120˚C)
Fat (%)	1.3	1.2	1.3	1.1
Protein (%)	0.92	0.83	0.89	0.78
Carbohydrate (%)	25	29	27	23
Energy(kcal/100g)	102	105	103	100
Ash (%)	84.6	84.2	85.02	84.4
%TSS	17.23	18.36	15.73	16.6
% Acidity	0.22	0.20	0.16	0.14
% Ascorbic acid (mg/100g)	0.65	0.74	0.82	0.90

4.3.1Fat

Solar tray drying and hot air cabinet drying at 100˚C recorded the highest fat content 1.3 %. The slices dried with hot air cabinet drying at 80˚C and 120˚C recorded fat content of 1.2% and 1.1% respectively.
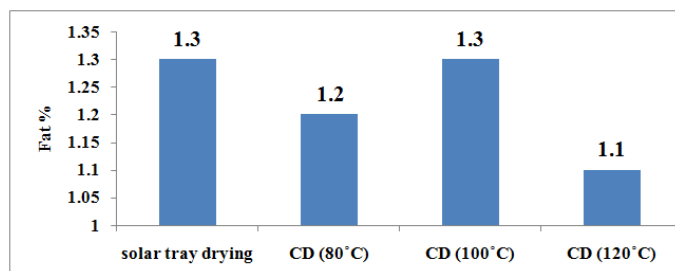
Fig.4.7 Fat percentage recorded from dried sapota powder dried under different conditions

4.3.2 Protein
Solar tray drying was found to have the highest protein content 0.92% followed by slices dried using hot air cabinet dryer at 100˚C and 80˚C with 0.89% and 0.83% respectively. The hot air cabinet drying at 120˚C recorded lowest protein content of 0.78%.
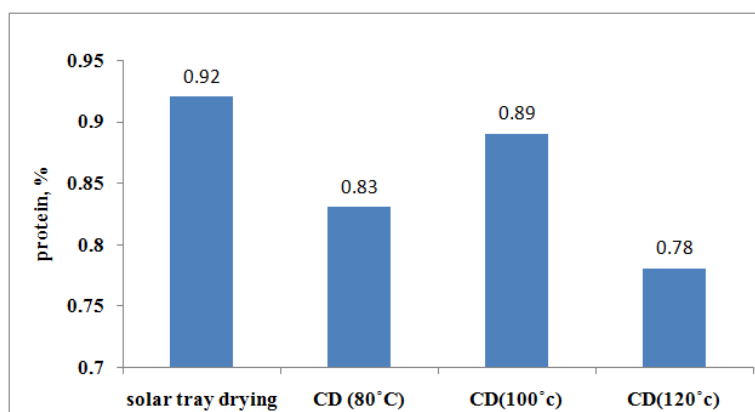

Fig .4.8 Protein percentage recorded from dried sapota powder dried under different conditions

4.3.3 Carbohydrate
The carbohydrate content was found to be the highest in hot air cabinet drying at 80˚C is 29%. The carbohydrate values for hot air cabinet drying at 100˚C, 120˚C and solar tray drying were 27%, 23%, and 25% respectively.
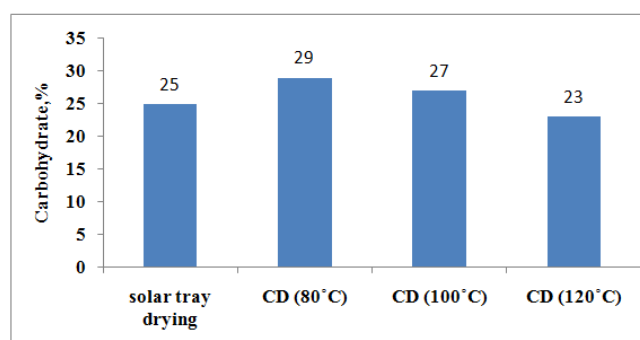

Fig 4.9 Carbohydrate percentage recorded from dried sapota powder dried under different conditions

4.3.4 Energy
Hot air cabinet drying at 80˚C had the highest energy value providing 105 Kcal/100g followed by hot air drying at 100˚C, solar tray drying and hot air tray drying at 120˚C providing 103 Kcal/100g, 102 Kcal/100g , 100 Kcal/100g respectively
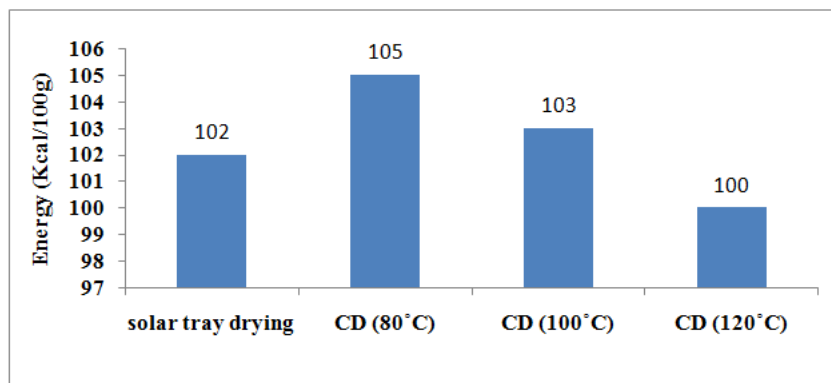
Fig 4.10 Energy content recorded from dried sapota powder dried under different condition

4.3.5 Ash

The highest ash content was found in hot air cabinet drying at 100˚C was 85.02 %. The hot air cabinet drying at 80˚C was 84.2% had the lowest ash content followed by solar tray drying and hot air cabinet drying at 120˚C was 84.6%, 84.4% .
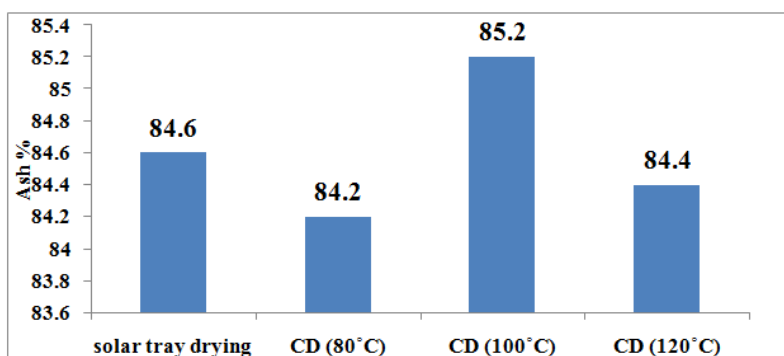

Fig 4.11 Ash percentage recorded from dried sapota powder dried under different conditions

4.3.6 TSS

The hot air cabinet drying at 80˚C was found to the highest %TSS was 18.36% followed by solar try drying and hot air cabinet drying at 120˚C was 17.23% and 16.6%. The lowest %TSS was found in hot air cabinet dying at 100˚C was 15.73%.
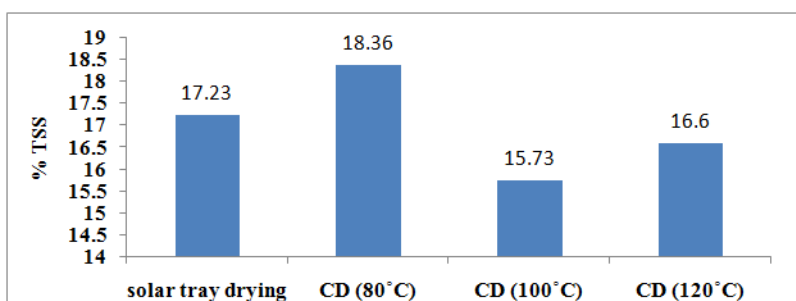

Fig.4.12 Percentage TSS recorded from dried sapota powder dried under different conditions

4.3.7 Acidity

The highest acidity was found in the solar tray drying, followed by the hot air cabinet drying at 80˚C, 100˚C and 120˚C was 0.22%, 0.20%, 0.16%, 0.14% respectively.
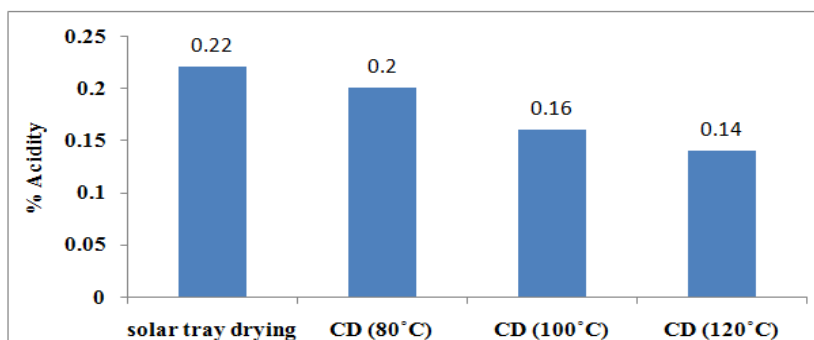
Fig.4.13 Acidity percentage recorded from dried sapota powder dried under different conditions

4.3.8 Ascorbic acid

The ascorbic acid content was found to be greatest in hot air cabinet drying at 120˚C was 0.90% followed by hot air cabinet drying at100˚C and 80˚C and lowest content in the solar tray drying was 0.82% , 0.74% , 0.65% respectively.
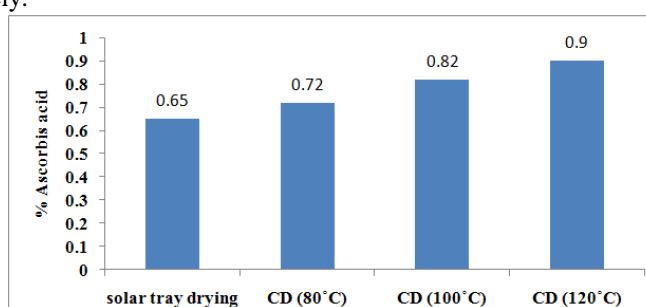
Fig.4.14 ascorbic acid percentage recorded from dried sapota powder dried under different conditions

4.4 Microbial analysis

Table 4.6 Microbial count (cfu/g) of dried sapota powder

Group	Control	Solar tray drying	Hot air cabinet drying (80˚C)	Hot air cabinet drying(100˚C)	Hot air cabinet drying(120˚C)
Bacterial count	0	49	41	38	42
Fungal count	0	70	82	65	85

Fig.4.15 Bacterial and Fungal limit test for sapota powder

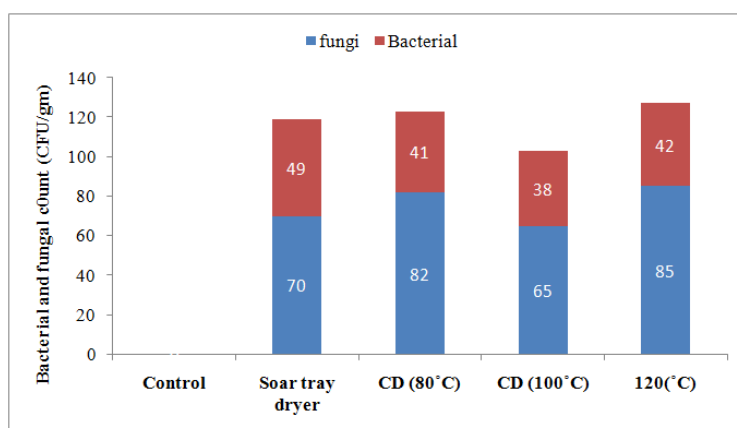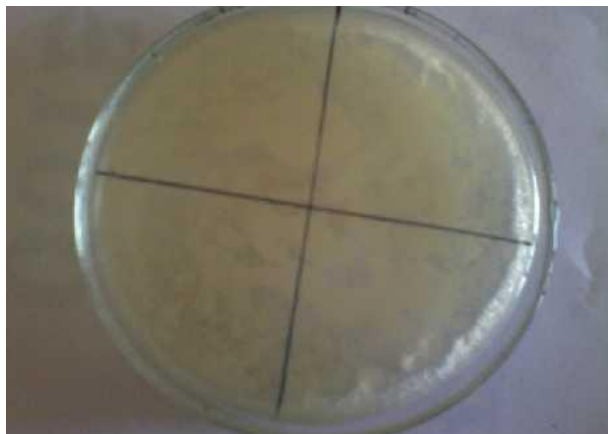**Plate no.14 Bacterial colonies in sapota powder**

Plate no.15 Fungal colonies in Sapota powder

V.   Summary

An under- utilized tropical fruit Crop was studied as a prelude to its processing. Sapota (CV.Kalipatti) with initial moisture content ranging between 67.78- 80.68(%wb), were dried in solar tray dryer and hot air cabinet dryer at 80˚C, 100˚C, 120˚C. The various aspects of drying behavior of sapota in thin layer drying was studied. The aspects studied were summarized below:

1) Moisture content %db
2) Moisture content %wb
3) Drying rate
4) Moisture ratio
5) Rehydration ratio
6) Coefficient of rehydration

Then the dried sapota slices were grounded to powdered to use it in milk shake and the organoleptic characteristics were studied. The proximate analysis were conducted to determine the nutritional value of the dried sapota powder.

VI.   Conclusion

The initial moisture content of the sapota fruit were in the range of 202.34- 439.06 (% db) and after drying it reduced to 2.42-3.28 (% db) and initial moisture content (% wb) were ranges from 67.78-80.68(%wb) and got reduced to 2.42-3.28 (%wb). It took 11hours to reach this moisture content, by solar tray dryer and 13, 12, 11 hours for hot air cabinet drying at 80˚C, 100˚C and 120˚C respectively.

After 15 days of storage the dried sapota slices were analyzed. The study of rehydration characteristics after 15 days of storage revealed that the hot air cabinet drying at 80˚C absorbs more moisture than the others.

The rehydration ratio for sapota slices dried in hot air cabinet dryer at 80˚C, 100˚C, 120˚C and solar tray drying were found to be 15:5, 14:5, 15:5 and 13.5:5 respectively.

From the proximate analysis it was concluded that the drying temp at 100˚C and 120˚C in hot air cabinet dryer was adversely affected on the carbohydrate content , protein content , energy content and % acidity compared to drying at 80˚C and the solar tray dryer. In those cases temperature effect on ash content was not that affected. The % ascorbic acid got increased as the temperature increased used for drying.

From the entire analysis of sensory evaluation it was observed that the mean score of color, flavor, taste, consistency and overall acceptability was found to be more for hot air cabinet drying at 80˚C than the other 100˚C, 120˚C and the solar tray drying.

The study can be useful in to increase the shelf life of the sapota would be process it into powder and using it as a value added products.

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Appendix
Sensory Evaluvation Score Card
Product name: Saopta powder milk shake
Name of the panel member:
Date:
Hedonic Rating Scale

You have been given four samples of beef balls incorporated with angkak. Kindly taste the sample and rate them based on your personal feel. An honest expression your feeling will help us.

Sl.No.	Feeling/Attribute	Rating
1.	Like extremely	9
2.	Like very much	8
3.	Like moderately	7
4.	Like slightly	6
5.	Neither like nor dislike	5
6.	Dislike slightly	4
7.	Dislike moderately	3
8.	Dislike very much	2
9.	Dislike extremely	1

Score card:

Attributes	Sample			
	S_1	S_2	S_3	S_4
Taste				
Flavor				
Color				
Consistency				
Overall acceptability				

Signature

Appendix II
1) Moisture content(%db)

Sl.No.	Time(h)	Moisture content(%db) Solar tray drying	Moisture content(%db) Hot air cabinet drying (80°C)	Moisture content(%db) Hot air cabinet drying(100°C)	Moisture content(%db) Hot air cabinet drying(120°C)
1.	1	202.34	363.76	244.92	439.06
2.	2	152.40	306.43	188.32	388.69
3.	3	111.86	256.68	127.86	312.62
4.	4	69.46	198.11	55.57	246.18
5.	5	52.22	131.12	26.21	188.44
6.	6	31.25	116.25	19.06	143.01
7.	7	17.49	72.63	15.42	83.58

8.	8	8.76	37.1	10.25	53.3
9.	9	3.54	21.70	6.43	19.53
10.	10	3.31	8.97	4.29	5.2
11.	11	2.64	4.91	3.24	3.28
12.	12	-	3.05	2.42	-
13.	13	-	2.83	-	-

2) Moisture content(%wb)

Sl.No.	Time(h)	Moisture content(%wb) Solar tray drying	Moisture content(%wb) Hot air cabinet drying (80˚C)	Moisture content(%wb) Hot air cabinet drying(100˚C)	Moisture content(%wb) Hot air cabinet drying(120˚C)
1.	1	67.78	76.22	70.92	80.68
2.	2	58.70	73.06	65.27	79.0
3.	3	36.41	69.51	56.11	72.68
4.	4	30.96	63.54	35.39	64.37
5.	5	21.81	54.16	20.67	57.61
6.	6	16.13	45.21	15.98	43.68
7.	7	11.18	39.70	13.34	33.98
8.	8	4.33	25.44	10.45	20.34
9.	9	3.42	16.28	8.15	15.52
10.	10	3.17	8.04	4.28	6.21
11.	11	2.64	4.60	3.17	3.28
12.	12	-	3.85	2.42	-
13.	13	-	2.83	-	-

3) Drying rate (g/gmin)

Sl.No.	Time(h)	Drying rate(g/gmin) solar tray dryer	Drying rate(g/gmin) Hot air cabinet drying (80˚C)	Drying rate(g/gmin) Hot air cabinet drying(100˚C)	Drying rate(g/gmin) Hot air cabinet drying(120˚C)
1.	1	3.44	6.05	8.15	7.31
2.	2	2.37	5.1	6.27	6.5
3.	3	1.59	4.27	4.25	5.20
4.	4	0.84	3.3	1.84	4.09
5.	5	0.84	2.18	0.86	3.13
6.	6	0.51	1.93	0.63	2.04
7.	7	0.29	1.20	0.51	1.38
8.	8	0.21	0.61	0.18	2.04
9.	9	0.07	0.36	0.07	1.38
10.	10	0.056	0.14	0.02	0.19
11.	11	0.05	0.07	0.018	0.02
12.	12	-	0.06	0.013	-
13.	13	-	0.04	-	-

4) Moisture ratio

Sl.No.	Time(h)	Moisture ratio (solar tray dryer)	Moisture ratio (Hot air cabinet drying at 80˚C)	Moisture ratio (Hot air cabinet drying at 100˚C)	Moisture ratio (Hot air cabinet drying at 120˚C)
1.	1	1	1	1	1
2.	2	0.68	0.84	0.76	0.88
3.	3	0.49	0.7	0.52	0.7
4.	4	0.29	0.54	0.22	0.55
5.	5	0.21	0.35	0.1	0.41
6.	6	0.12	0.25	0.07	0.31
7.	7	0.06	0.19	0.05	0.17
8.	8	0.05	0.095	0.01	0.1
9.	9	0.053	0.05	0.008	0.029
10.	10	0.058	0.017	0.002	0.0023
11.	11	-	0.011	0.001	-
12.	12	-	0.0086	-	-