

International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; SP-10(1): 1307-1313
www.biochemjournal.com
Received: 27-10-2025
Accepted: 30-11-2025

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Drying kinetics and quality aspects of seasonal vegetables dried in a tray dryer

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DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i1Sp.7280>

Abstract

Vegetables have contributed largely towards food and nutritional security of the people, particularly the poor. India is the second largest producer of vegetables in the world after China. In the world production of vegetables was 212 million metric tons and Area was 11.35 million hectares (NHB 2022-2023). Many vegetables are seasonal and available for some days in the year, but they have a great demand throughout the year. Among the seasonal vegetables spine gourd (310MT), bitter gourd (1369MT) and sweet potato (1159MT) (NHB 2022-23) are the vegetables for common people to meet their daily nutritional requirement.

Among the various preservation methods, drying is the most convenient and simplest method. It reduces weight and volume of the product which minimizes transportation cost and increase the shelf life. The present study is carried out to investigate drying characteristics of bitter gourd, spine gourd and sweet potato slices during osmotic and hot air tray drying. About 5-10 mm thick vegetables slices were osmosed with salt and sugar solution of 5, 10 and 15 °Brix at 30, 45 and 60 °C temperature and then dried in tray dryer. The tray drying behaviour was investigated for osmo-dehydrated bitter gourd, spine gourd and sweet potato, at air temperature of 40, 50 and 60 °C.

It was observed that the moisture content of the product was reduced with drying time and no constant rate period was observed in tray drying. There was a variation in drying time from 420 to 900 min for the range of drying air temperatures (40-60 °C) taken for study. Minimum drying time was observed for high air temperature (60 °C) and maximum time was recorded for low air temperature (40 °C) for all air velocities. Quality of dried product in respect to colour was superior. The osmo-tray dried samples were found more acceptable after tray drying at 60 °C.

Keywords: Osmotic dehydration, tray drying, bitter gourd, spine gourd, sweet potato, drying characteristics

Introduction

Bitter gourd (*Momordica charantia* L.) is a member of the cucurbit family. It is considered to be native to Tropical africa. It is cultivated widely in many tropical and subtropical regions of the world and is frequently used in India and orient as a foodstuff and a medicinal plant (Habicht *et al.*, 2011) [3]. The major states contributing to its production and area under cultivation are Uttar Pradesh, Tamil Nadu, Maharashtra, Andhra Pradesh, Karnataka, Odisha, west Bengal and Gujarat.

Spine gourd (*Momordica dioica* L.) is a cucurbitaceous, dioecious perennial vegetable and it fetches very good price in the market. In tropical regions of South America, Africa and Asia (India, Bangladesh, Pakistan & China), commonly known by different names i.e. small bitter gourd, bristly balsma pear, teasle gourd, prickly carolaho, kantola, jungle kerala etc. (Thiruvengadam *et al.*, 2016) [12]. It is indigenous to India and other parts of Asia and in India it is grown in Andhra Pradesh, Assam, Meghalaya, West Bengal, Uttar Pradesh, Bihar, Maharashtra, Madhya Pradesh, Gujarat and Andaman Islands. West Bengal and Karnataka are two major Indian states that grow spine gourd commercially (Talukdar and Hossain, 2014) [11]. In the Andrapradesh, production was 2.94 lakh tons and Area was 48.23 thousand hectares.

Sweet potato (*Ipomoea batatas* L.) is one of the five most important food crop in developing countries. It is one of the crops relatively easy to grow even in poor, dry soil. Tuber crops achieve levels of importance as great as cereal grains in providing the greater part of people's

daily caloric needs in the tropics. The sweet potato shows significant nutritional contributions to the diet and has high caloric value per cultivated area (Bouwkamp *et al.* 1985) [2]. In the Andhra Pradesh, production was 14.91 metric tons and area was 497 hectares.

Material and Methods

Determination of drying kinetics of osmotically dehydrated products during tray drying

The common method in the drying of food products is tray drying. In order to verify the influence of the drying process on the vitamin C content in dried products, some authors studied some conventional processes using tray drying method. Different kinds of fruits and vegetables and different cultivars have been studied by many researchers. Apples, tomato, mango, apricot, plum, fig, peppers, potato, brinjal, onions and others are examples of fruits and vegetables whose drying behaviour have been studied and their vitamin C retention has been determined.

There is very meagre data published on osmotic dehydration of the spine gourd, bitter gourd and sweet potato, hence by conducting preliminary experiments the parameters were selected and were classified in two major categories as a) independent parameters such as thickness of samples 5-10 mm, temperatures 40 °C, 50 °C and 60 °C and Immersion time 1 hour, 2 hour and 3 hour. b) dependent parameters such as colour in L a b values, ascorbic acid in milligrams per gram and rehydration ratio.

The osmosed bitter gourd spine gourd and sweet potato slices were dried in hot air dryer. This experiment was conducted on the laboratory using hot air tray dryer at different temperatures 40 °C, 50 °C and 60 °C. 100 g osmosed samples were weighed and spread uniformly on upper tray. During drying spine gourd, bitter gourd and sweet potato were weighed initially at 30 minutes interval for first hour and at 1 hour intervals for next two hours until completion of experiment.

Quality Evaluation

Quality of the osmo-convectively dehydrated product was evaluated by using colour, rehydration characteristics and sensory evaluation as described below.

Colour

Colour is one of the most important qualities for acceptance of a product, reflects sensation to the human eye. Colour is important to consumer as a mean of identification, as a method of judging quality and for its basic aesthetic value. Dried products are usually darker in colour, but darker colour does not mean better quality. Too dark may imply that the product is over dried. The advantage is that this parameter can be visually determined for assessing dryness quality. A laboratory colourimeter was used. Colour of the dried spine gourd, bitter gourd and sweet potato slices was measured using a Hunter Lab Colorimeter (Model CFLX/DIFF, CFLX-45). A cylindrical glass sample cup (63.5 mm in diameter x 40 mm height) was placed at the light port (31.75 mm diameter). The instrument was initially calibrated with a black as well as with standard white plate supplied with the equipment. The 3-dimensional scale L*, a* and b* is used in a Hunter Lab Colourimeter. The L* is the lightness coefficient, ranging from 0 (black) to 100 (white) on a vertical axis. The a* is purple-red (positive a* value) and blue-green (negative a* value) on a horizontal axis. A second horizontal axis is b*, that represent yellow

(positive b* value) or blue (negative b* value) colour. This 3D colour system can be seen in Plate 3.5. The values of L*, a* and b* can be converted to Chroma (C*) values, analogous to colour saturation or intensity (Mc Guire, 1992) [5].

Ascorbic acid (mg/g)

Ascorbic acid was estimated by titrimetric method using 2, 6-dichlorophenol-indophenol dye (Ranganna, 1995) [9]. One gram of bitter gourd, spine gourd and sweet potato samples were taken and ground well and using 10 ml of 4% oxalic acid solution was pipetted out in to a conical flask and titrated against dye. The dye factor, i.e., mg of ascorbic acid per ml of the dye was calculated. The value of ascorbic acid was estimated by titrating the sample solution against the dye for the appearance of a persistent pale pink colour.

$$\text{Ascorbic acid content} = \frac{\text{Titrate value} \times \text{dye factor} \times \text{volume made}}{\text{Volume taken} \times \text{weight of sample}} \times 100$$

$$= \frac{0.5 \times V_2 \times 50}{V_1 \times 5 \text{ml} \times \text{weight of sample}} \times 100$$

V₁ = volume of dye occupied by the working standard

V₂ = volume of dye occupied by samples

Rehydration characteristics

Every dried product cannot be consumed directly. Most need to be rehydrated by soaking in water prior to consumption. There are several factors affecting rehydration, such as the soaking period, temperature of the water and the rehydration capacity of the product.

The rehydration capacity can be influenced by the drying process. Drying processes that change product composition to a lesser extent are supposed to offer better rehydration characteristics of finished product. Due to drying process collapsing of cellular structure and shrinkage may eventually affect the rehydration characteristics. For rehydration capacity, pre weighed samples were soaked in ample amount of water for 5 hours at room temperature. This steeping is known as re-hydration. The ratio of mass of re-hydrated and dehydrated samples can be used to find following re-hydration characteristics (Pokharkar, 1994) [8]:

$$\text{Re-hydration ratio RR} = \frac{C}{D}$$

C = Weight of re-hydrated sample (g)

D = Test weight of dehydrated sample (g)

Results and Discussion

Determination of drying kinetics of osmotically dehydrated products during hot air tray drying.

Drying kinetics of osmotically dehydrated bitter gourd, spine gourd and sweet potato slices

Bitter gourd, spine gourd and sweet potato slices were osmotically dehydrated at optimum condition and were further dried in tray dryer. Drying was carried to reduce moisture content of osmotically dehydrated bitter gourd, spine gourd and sweet potato slices from 70% to 9% (d.b.), 69% to 9% (d.b.) and 55% to 9% (d.b.) Temperatures chosen to dry in tray dryer were 40, 50 and 60 °C. Initially, 500 g of osmotically dehydrated bitter gourd, spine gourd and sweet potato slices each at a time were taken and the sample was placed in tray dryer in order to dry them. Initial

mass of the sample was taken. During drying, the sample mass was taken at regular interval for every 30 min until it reaches the equilibrium moisture content i.e. no more mass loss (in 900, 780 and 480 min, 840, 600 and 420, 840, 600 and 420 at 40, 50 and 60 °C).

Effect of drying temperature and drying time on moisture content

In case of tray drying, osmotically dehydrated Bitter gourd, spine gourd and sweet potato slices were arranged on a rectangular mesh tray and were kept inside the dryer and temperatures maintained for drying the sample were 40, 50 and 60 °C. Drying temperature influenced the drying characteristics of osmotically dehydrated bitter gourd slices. Tray drying took 900, 780 and 480 min, 840, 600 and 420, 840, 600 and 420 min to dry Bitter gourd, spine gourd and sweet potato till it get constant weights at 40, 50 and 60 °C temperatures respectively. With an increase of drying temperature, time required for bitter gourd slices to attain equilibrium moisture content decreased. A plot (fig.1, 3, 5, 7, 9, 11, 13, 15 and 17) was drawn for moisture content versus drying time at three different temperatures during tray drying of bitter gourd slices. It revealed that with an increase of drying temperature, time required for bitter gourd slices to attain equilibrium moisture content. At initial stage of drying, moisture content rapidly reduced. This might be due to less resistance of water to diffusion and thus high rate of drying. Mundada *et al.* (2010) [6] also observed more moisture removal at initial stages while conducting drying experiments on pomegranate aril. Similar trend was also observed by Ranjith *et al.* (2023) [10] for dragon fruit slices. The optimization of dehydration process for bitter gourd was done. Bitter gourd slices were dried in a cabinet tray dryer at temperatures 50 °C, 60 °C and 70 °C. Temperature for drying was optimized on the basis of parameters such as drying rate, drying time required, moisture in final product, yield of powder and sensory quality by Kusat *et al.* (2021) [4]

Effect of average drying time on drying rate

To study the effect of average drying time on drying rate of Bitter gourd, spine gourd and sweet potato slices, a graph was plotted by taking average drying time on X-axis and drying rate on Y-axis (Fig.2, 4, 6, 8, 10, 12, 14, 16 and 18). At initial stage of drying, drying rates for tray drying process were 1.88, 2.055 and 2.94% d.b./min 2.20, 3.54 and 2.69% d.b./min 2.44, 2.01 and 2.13% d.b./min at 40, 50 and 60 °C temperatures, respectively. At final stage, drying rates were 0.26, 0.21 and 0.16% d.b./min 0.19, 0.24 and 0.29% d.b./min 0.39, 0.49 and 0.39% d.b./min at 40, 50 and 60 °C temperatures, respectively. The constant rate period was absent in tray drying of Bitter gourd, spine gourd and sweet potato slices. This might be due to drastic change in moisture content at initial stage of drying and entire drying took place in the falling rate period. Similar type of results were quoted in the case of dragon fruit slices (Ranjith *et al.*, 2023) [10], and jackfruit slices (Mithun and Kaleemullah, 2019) [17].

Colour (L-values)

Colour is often used as an indication of quality and freshness for food products. Hence it has become important for food processors to be able to evaluate and grade their products based on colour.

Colour values measured using a colour flex Hunter lab colorimeter, were relative to the absolute values of perfect reflecting diffuser as measured under the same geometric conditions (ASTM method). Observations were taken at room temperature 30.5 °C.

The colour of dried of Bitter gourd, spine gourd and sweet potato slices was measured in terms of L-value (brightness/darkness) and shown in table 1, 2 & 3. The L-values of osmo-convectively dried bitter gourd slices at various experimental conditions were ranged between 22.56 to 26.12, 23.08 to 25.14, 20.76 to 27.23. The individual effect of drying air temperature was increased L-value of colour means sample became lighter in colour from 40 °C to 60 °C. It is clear with respect to individual effect of temperature, that the sample dried with drying air temperature 60 °C was found better and recorded significantly highest colour (L-value = 26.12, 25.14 and 27.23 at 60 °C). Similar results were quoted by Vikaskumar *et al.*, 2014 [13]. The L value of fresh sapota slices was about 34.68. The L-values of osmo-convectively dried sapota sample at various experimental conditions were ranged between 52.04 and 61.61. As the temperature increased L-value of colour increased that means sample became lighter in colour from 50 °C to 70 °C. which may be due to discolouring the sample slightly because of elevated temperature. The drying air temperature 60 °C was found better and recorded significantly higher colour (L-value = 59.27).

Rehydration characteristics (RR)

The reconstitution qualities of Bitter gourd, spine gourd and sweet potato samples were determined by conducting rehydration tests as described in material methods. The dehydrated products were immersed in distilled water at 40 °C, 50 °C and 60 °C and the mass of the products after five hour was measured.

From the table 1, 2 & 3. It was clear that the maximum rehydration ratio was obtained 2.03, 2.24 and 2.13 at 60 °C when compared to other temperatures of 40 °C and 50 °C. for bitter gourd slices immersed in distilled water for 5 h. The rehydration ratio was increased as the temperature increased from 40 °C to 60 °C. Similar results were quoted by Vikaskumar *et al.*, 2014 [13]. The rehydration ratio of the osmotically dehydrated sapota slices at different temperatures ranges from 3.64 to 5.05.

Vitamin C content (mg/100g)

The vitamin C content of dried bitter gourd, spine gourd and sweet potato slices was measured in terms of mg/100g shown in table 1, 2 & 3. vitamin C values of osmo-convectively dried bitter gourd slices at experimental conditions were ranged between 51.84 to 50.12, 41.78 to 39.67, 32.78 to 30.98 (Table 4.16, 17&18). Individual effect of drying air temperature, revealed that as the drying temperature increased from 40 °C to 60 °C vitamin C value were decreased that means sample became lower in vitamin C from 40 °C to 60 °C. Individual effect of temperature on ascorbic acid revealed that the retention of ascorbic acid increased with decrease in drying temperature from 70 to 60 °C. The loss of ascorbic acid at higher temperature (70 °C) is maximum because it is thermo sensitive compound (Hawlder *et al.* 2006) Similar results are quoted by Vikas kumar *et al.* (2014) [13].

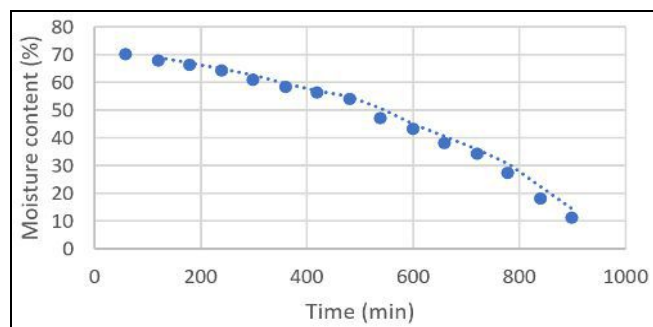


Fig 1: Drying time vs moisture content of bitter gourd slices at 40 °C

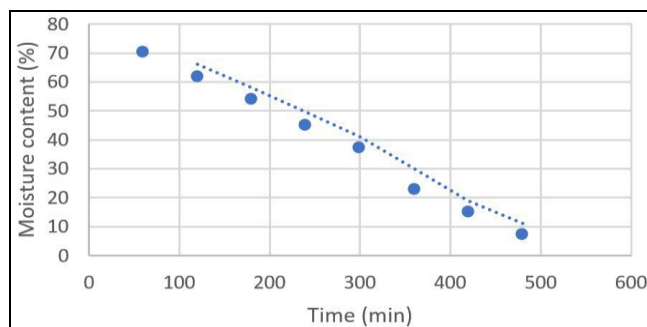


Fig 5: Drying time vs moisture content of bitter gourd slices at 60 °C

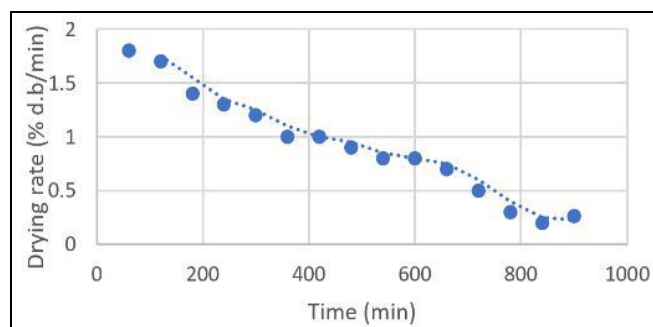


Fig 2: Average drying time vs drying rate of bitter gourd slices at 40 °C

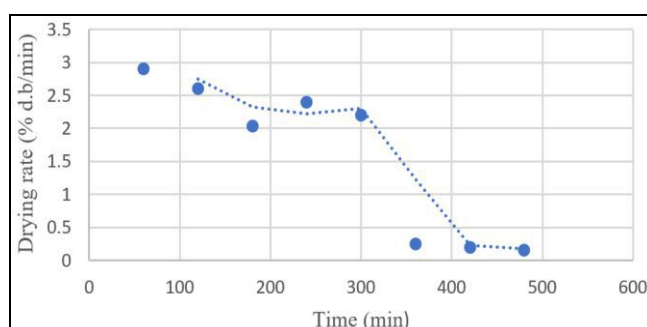


Fig 6: Average drying time vs drying rate of bitter gourd slices at 60 °C

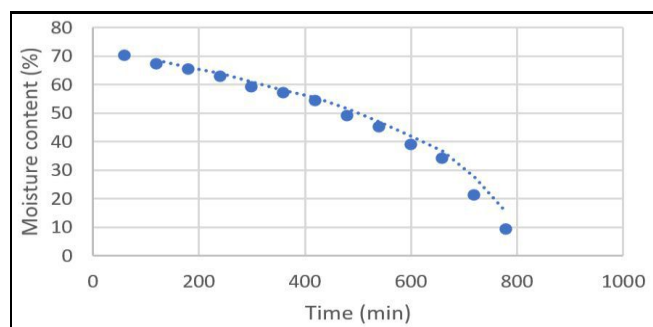


Fig 3: Drying time vs moisture content of bitter gourd slices at 50 °C

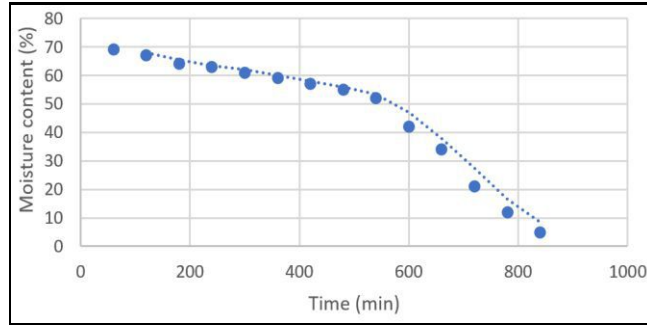


Fig 7: Drying time vs moisture content of spine gourd slices at 40 °C

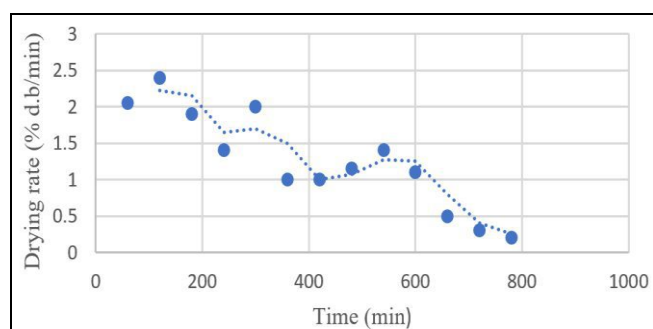


Fig 4: Average drying time vs drying rate of bitter gourd slices at 50 °C

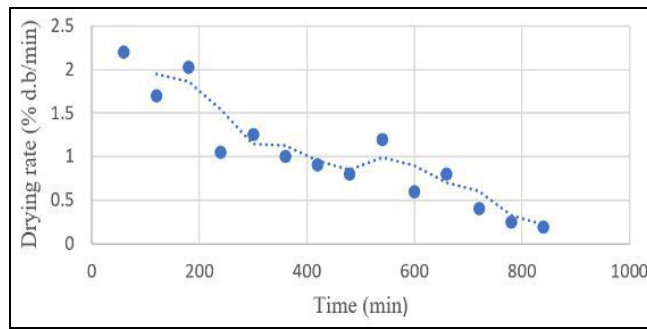


Fig 8: Average drying time vs drying rate of spine gourd slices at 40 °C

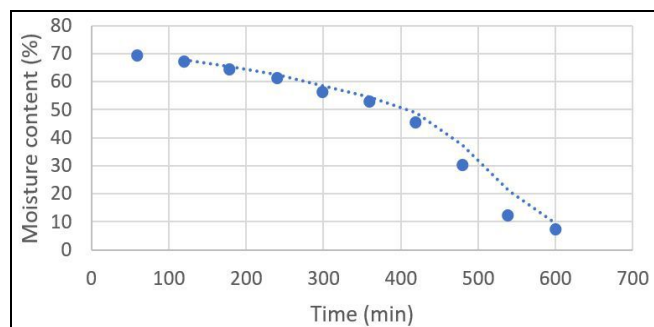


Fig 9: Drying time vs moisture content of spine gourd slices at 50 °C

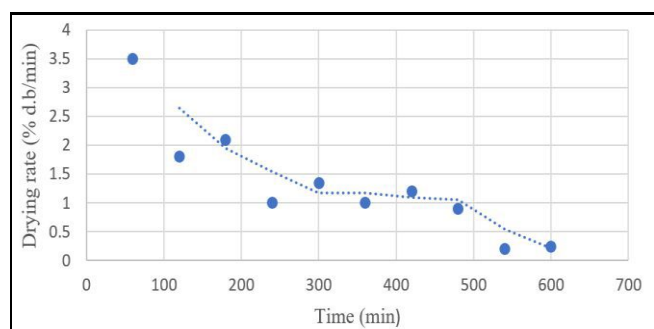


Fig 10: Average drying time vs drying rate of spine gourd slices at 50 °C

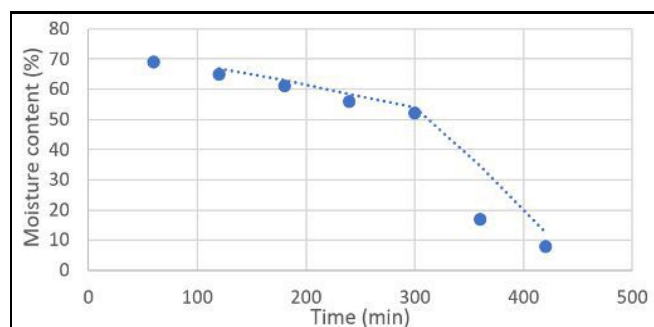


Fig 11: Drying time vs moisture content of spine gourd slices at 60 °C

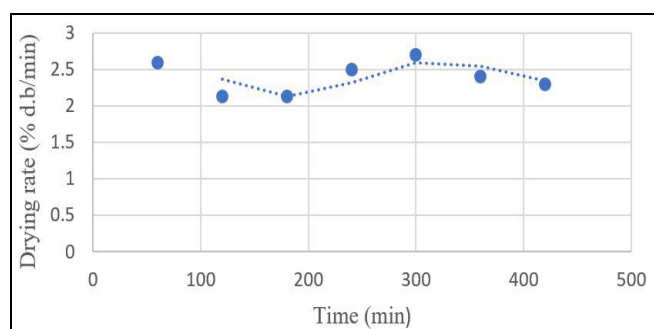


Fig 12: Average drying time vs drying rate of spine gourd slices at 60 °C

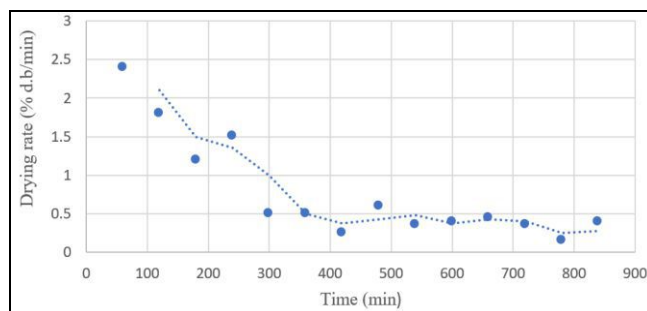


Fig 13: Drying time vs moisture content of sweet potato slices at 40 °C

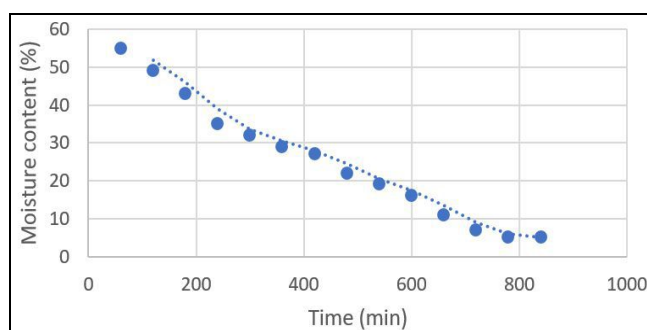


Fig 14: Average drying time vs drying rate of sweet potato slices at 40 °C

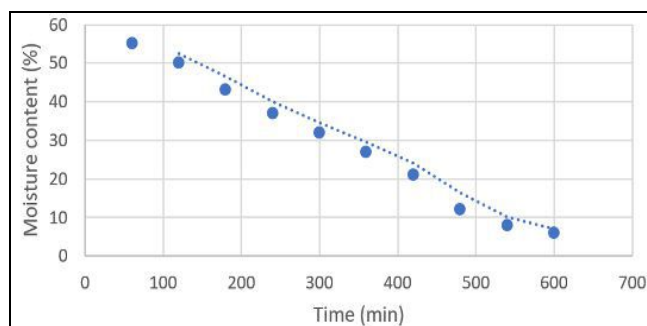


Fig 15: Drying time vs moisture content of sweet potato slices at 50 °C

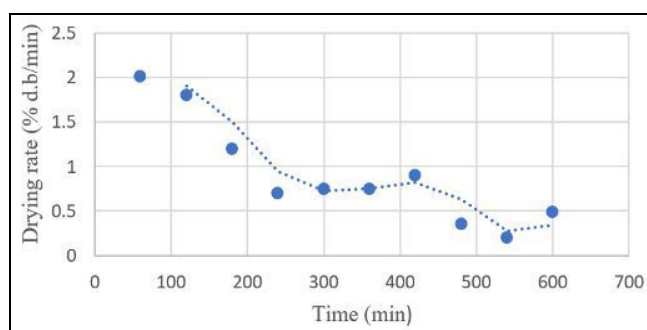


Fig 16: Average drying time vs drying rate of sweet potato slices at 50 °C

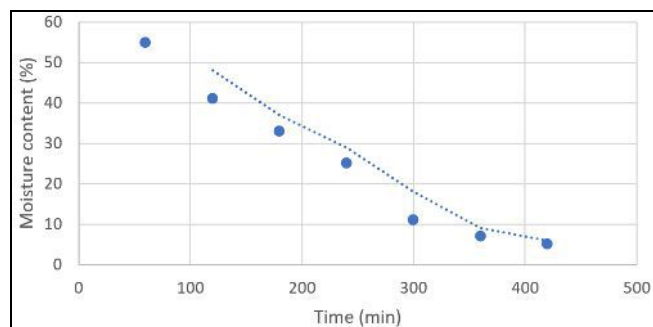


Fig 17: Drying time vs moisture content of sweet potato slices at 60 °C

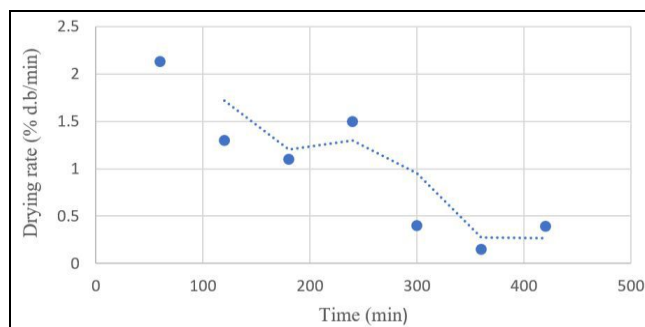


Fig 18: Average drying time vs drying rate of sweet potato slices at 60 °C

Table 1: Rehydration, vitamin-C and colour of osmo-convectively dried bitter gourd

Temperature (°C)	Drying Rate (% d.b/min)		Rehydration ratio (RR)	Vitamin-C (mg/100 g)	Colour (L- values)
	Initial	Final			
40	1.88	0.26	1.859	51.84	22.56
50	2.055	0.21	1.63	50.98	24.89
60	2.94	0.16	2.03	50.12	26.12

Table 2: Rehydration, vitamin-C and colour of osmo-convectively dried spine gourd

Temperature (°C)	Drying Rate (% d.b/min)		Rehydration ratio (RR)	Vitamin-C (mg/100 g)	Colour (Lvalues)
	Initial	Final			
40	2.20	0.19	1.85	41.78	23.08
50	3.54	0.24	1.80	40.34	24.91
60	2.69	0.29	2.24	39.67	25.14

Table 3: Rehydration, vitamin-C and colour of osmo-convectively dried sweet potato

Temperature (°C)	Drying Rate (% d.b/min)		Rehydration ratio (RR)	Vitamin-C (mg/100 g)	Colour (Lvalues)
	Initial	Final			
40	2.44	0.39	1.58	32.78	20.76
50	2.01	0.49	2.07	31.45	24.23
60	2.13	0.39	2.13	30.98	27.23

Conclusion and Discussion

The samples blanched in boiling water and dehydrated at 60 °C were observed most acceptable in terms of rehydration property and nutritional quality. seasonal vegetables (bitter gourd, spine gourd and sweet potato) slices dehydrated in tray dryer at 60 °C were of the best quality followed by tray dryer at drying temperature of 40 and 50 °C.

It was observed that the moisture content of the product was reduced with drying time and no constant rate period was observed in tray drying. There was a variation in drying time from 420 to 900 min for the range of drying air temperatures (40-60 °C) taken for study. Minimum drying time was observed for high air temperature (60 °C) and maximum time was recorded for low air temperature (40 °C) for all air velocities. Quality of dried product in respect to colour was superior. The osmo-tray dried samples were found more acceptable after tray drying at 60 °C.

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