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COMPARATIVE STUDY ON SOLAR DRYING OF DIFFERENT TOMATO VARIETIES

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ABSTRACT

India has significant potential to harness solar energy, as it lies between latitudes 70°N and 37°N, receiving substantial solar radiation. The total solar radiation falling on Earth is much greater than energy from all other sources, such as nuclear and fossil fuels. In fact, India receives solar energy that is 3000 times its current energy consumption. Regions like Gujarat, Rajasthan, Madhya Pradesh, and Maharashtra receive over 3000 hours of sunlight annually, with solar radiation exceeding 2000 kWh per square meter per year. Tomato (Lycopersiconesculentum), a major crop, is highly nutritious, rich in vitamins A and C, minerals like iron and phosphorus, and antioxidants like lycopene and beta-carotene. It is widely used in processed products such as ketchup, sauce, chutney, and soups. Due to its short growing period and high yield, tomato cultivation is economically important and continues to expand. Regarding tomato varieties, Hybrid Tomatoes have an average length of 57.37 mm, while Desi Tomatoes have a length of 47.25 mm. Desi Tomatoes have a greater average width (62.08 mm) than Hybrid Tomatoes (48.47 mm). The maximum average thickness is found in Hybrid Tomatoes (45.94 mm), and the minimum in Desi Tomatoes (47.18 mm). The aspect ratio is higher in Desi Tomatoes (96.10%) compared to Hybrid Tomatoes (84.70%). Hybrid Tomatoes have a larger average surface area (7368.27 mm²) compared to Desi Tomatoes (6596.91 mm²). Additionally, the sphericity is higher in Desi Tomatoes (0.98) than in Hybrid Tomatoes (0.84).

***Key word*: Sun drying, Solar tunnel draying, Tomato, Vitamins, Economy**

Introduction

Tomato is cultivated in the tropical and sub-tropical parts of the world. In India, tomato occupies an area of 812000 ha with annual production of 20573000 metric tonnes. Among the various vegetables, tomato occupies an area of 48420 ha with the production of 1394890 tonnes during the year 2020-2021 (Anon, 2020) in Gujarat state. Tomato is mainly grown in the states of Andra Pradesh, Karnataka, Tamilnadu, Orissa, Maharashtra, West Bengal, Bihar, Gujarat, Chhattisgarh and Jharkhand. It is mainly grown in the districts of Banaskantha, Baroda, Mehsana, Anand, Kheda, Bhavnagar, and Junagadh in Gujarat state. Tomato is generally grown as winter crop, while the summer and rainy seasons are the lean periods for its production. Shown the Table 1 is a nutrient value in tomato.

In the present investigation efforts have been made to study the drying characteristics of tomato. The carbohydrate content of dried jamun (Syzygiumcumini) leaves is reported to be 28.52 ± 1.59%. This means that, on average, dried jamun leaves contain 28.52% carbohydrates, with a variation of ± 1.59%(Amrutiya *et al.*, 2020). According to the latest estimates, India's tomato production in 2023-24 is expected to be around

Table 1: Nutrient values in tomato.

Sr. No.	Nutrients	Amount
1	Edible portion	95.0%
2	Moisture	94.1%
3	Food energy	19.0cal
4	Protein	1.0g
5	Fat	0.2g
6	Total carbohydrates	4.1g
7	Fiber	0.8g
8	Ash	0.6g
9	Calcium	18.0mg
10	Phosphorous	18.0mg
11	Iron	0.8mg
12	Sodium	4.0mg
13	Potassium	266.0mg
14	Riboflavin	0.04mg
15	Niacin	0.60mg
16	Ascorbic Acid	29.00mg

213.20 lakh tonnes, with the area under cultivation reported as 8.50 lakh hectares. This represents a 4% increase compared to the previous year. 2023-24 is at 208.19 lakh tonnes. Major tomato producing states are Madhya Pradesh (34.98 lakh tonnes), Karnataka (24.43 lakh tonnes), Andhra Pradesh (21.86 lakh tonnes), Gujarat (14.44 lakh tonnes), Odisha (14.34 lakh tonnes), Tamil Nadu (13.12 lakh tonnes) and West Bengal (12.93 lakh tonnes)., APEDA Agri Exchange (2023-24). Tomato is mainly grown in the states of Andra Pradesh, Karnataka, Tamilnadu, Orissa, Maharashtra, West Bengal, Bihar, Gujarat, Chhattisgarh and Jharkhand. It is mainly grown in the districts of Banaskantha, Baroda, Mehsana, Anand, Kheda, Bhavnagar, and Junagadh in Gujarat state. Tomato is generally grown as winter crop, while the summer and rainy seasons are the lean periods for its production.

Materials and Methods

Materials and methods used for the study of drying of tomato using natural convection solar cabinet dryer. It also includes description regarding the different components of the solar dryer, instruments used for measurement of various parameters.

Solar Cabinet Dryer

The natural convection solar cabinet dryer available in the Department of Renewable Energy and Rural Engineering, College of Agricultural Engineering and Technology, Junagadh was used to carry out the experiments. The schematic view is shown in fig.1 and is briefly described below. The overall dimensions of solar cabinet dryer were 2000 × 1000 × 1000 mm with roof slope of cover glass as 30° with horizontal. The base and inner side walls made of plywood were completely painted with black color so as to work as an absorber for solar radiation. The drying surface inside the dryer consisted of the wire mesh screen of size 800 × 800 mm having 14- mesh opening. A door was provided on the northern side of the dryer for loading and unloading of the products for the dehydration purpose. The holes were provided at the lower end and at the upper end. The lower holes were used as an air inlet through which atmospheric air entered inside the dryer. The upper holes were used as an outlet for removing moist air. Due to natural convection, the hot air move upward and the ambient air entered through the inlet holes.

Fig. 1: Natural convection solar cabinet dryer.

Fig. 1: Cabinet dryer and open sun draying.

Size and Sphericity

The physical properties of whole tomatoes are random samples of 10 numbers of tomatoes were drawn from the different variety of tomatoes. The principal dimensions of the individual tomato in terms of length, width and thickness were measured by using digital verniercalipers having least count of 0.01mm. The thickness of tomato was measured from top to neak of the tomato. The average size factor and sphericity of the samples of tomatoes were calculated using the following relationship as described by Mohsenin (1986).

$$\text{Size Factor} = abc^{1/3} \quad (1)$$

$$\text{Sphericity, } f = \frac{abc^{1/3}}{a} \quad (2)$$

Were,

f = Sphericity,

a= length of tomato (mm),

b= width of tomato (mm),

c= thickness of tomato (mm).

Geometric mean diameter

The Geometric Mean Diameter (GMD) is calculated as the cube root of the product of the three orthogonal dimensions (length, width, and thickness) of an object. The formula is: The geometric mean diameter D_g was calculated by following relationship (Mohsenin, 1980).

$$\text{Geometric mean diameter, } D_g = (abc)^{1/3} \quad (3)$$

Were,

D_g= geometric mean diameter (cm),

a = length (cm),

b = width (cm),

c = thickness (cm).

Aspect ratio

The aspect ratio was calculated by following relationship.

$$\text{Aspect ratio, } R_a = \frac{b}{a} \times 100 \quad (4)$$

Were,

R_a = aspect ratio (%),

a = length (cm),

b = width (cm).

Surface area

The surface area of tomato was found by analogy with a sphere of same geometric mean diameter, using expression cited by Olajide and Ade-Omowaye (1999) and Sacilik, Ozturk, and Keskin (2003).

$$\text{Surface area, } S = \pi D_g^2 \quad (5)$$

Were,

S = surface area (cm^2),

D_g = geometric mean diameter (cm).

Bulk density

The bulk density was calculated from the mass of bulk material divided by volume containing the mass. The bulk density was computed in g/cm^3. The bulk density was calculated using the following relationship. Bulkdensity of rice husk and rice straw was 331.59 kg/m^3 and 380.54 kg/m^3 respectively (Makavane *et al.*, 2018).

$$\text{Bulk density } \rho_b = \frac{W}{V} \quad (6)$$

Were,

ρ_b = bulk density (g/cm^3),

W = mass of tomato (gm),

V = volume (cm^3).

True density

The true density, defined as the ratio between the mass and the true volume of the material, was determined using the toluene (C_7H_8) displacement method (Mohsenin, 1980).

$$\text{True density, } \rho_t = \frac{M}{V} \quad (7)$$

Were,

ρ_t = true density (g/cm^3),

M = mass of individual tomato (g),

V = volume of tomato (cm^3).

Porosity

The porosity of bulk materials was calculated from bulk density and true density using the relationship as follows (Mohsenin. 1980).

$$\text{Porosity, } P = \frac{\rho t - \rho b}{\rho t} \times 100 \quad (8)$$

Were,

P = porosity (%),

$\rho_{t\,=}$ True density (g/cm^3),

ρ_b = Bulk density (g/cm^3).

Drying Rate

The moisture removal from tomatoes slice was determined by measuring heat loss at an interval of one hour by using the electronic balance. The drying rate (g/h/100g of bone dry wt.) of tomatoes during drying period was determined as follows.

$$\text{Drying rate (DR)} = \frac{dw}{dt} \quad (9)$$

Were,

d_w = Weight loss in one-hour interval (g/h/100g of bone-dry wt.)

d_t =difference in time reading (hr)

Moisture Ratio

The Moisture Ratio (MR) of tomatoes was computed using the initial moisture content and equilibrium moisture content as follows. The fuel moisture content (FMC) of biomass is determined by drying the known weight of sample he fuel moisture content (FMC) of biomass is determined by drying the known weight of sample (Makavana *et al.*, 2022). Both metrics are essential for food preservation, agricultural engineering, and bioenergy applications. shown in Fig. 2 is a tomatoes sample in solar Cabinate dryer and open sun draying.

$$MR = \frac{M - Me}{Mi - Me} \quad (10)$$

Were,

M =moisture content at given time (% d.b.) Me = equilibrium moisture content (% d.b.) Mi = initial moisture content (% d.b.).

Results and Discussion

Natural convection drying of tomatoes was studied using natural convection solar cabinet dryer. Drying of tomatoes was also carried out and compared with open sun drying. The physical properties such as Size, Sphericity, Bulk Density and Moisture Content of two variety of tomato were determined as per the standard procedure. All the three axial dimensions; length (a), width (b), and thickness (c) were measured individually using digital verniercalipers with a least count of 0.01mm. The average value of length (a), width (b), thickness (c) size, sphericity, geometric mean diameter, aspect ratio and surface area for different varieties are presented in Table 2.

The maximum average length was found as 57.37 mm in Hybrid Tomato and minimum average length was found in Desi Tomato *i.e.* 47.25 mm. The maximum average width was found as 62.08 mm in Desi Tomato and minimum average width was found in Hybrid Tomato *i.e.* 48.47 mm. The maximum and minimum average thickness was showed in Hybrid Tomato and Desi Tomato *i.e.* 45.94 mm and 47.18 mm respectively. The maximum average aspect ratio was found as 96.10% in Desi tomato. The minimum average aspect ratio was found as 84.70% in Hybrid tomato. The maximum and minimum average surface area was found in Hybrid tomato and Desi tomato *i.e.* 7368.27 mm^2 and 6596.91 mm^2 respectively. The maximum and minimum average size was found in Hybrid Tomato and Desi Tomato *i.e.* 48.41 mm and 46.36 mm respectively. The maximum and minimum average sphericity was found 0.98 and 0.84 in Desi Tomato and

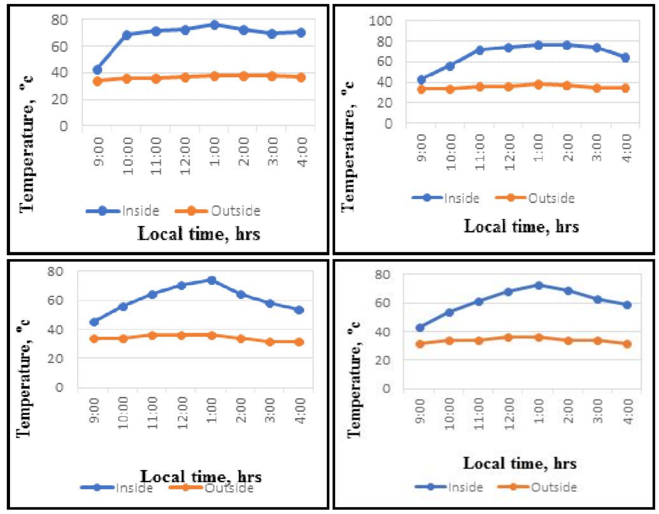

Fig. 2: Effect on temperature inside and outside dryer for natural convetion solar drying of tomatoesin April month 2024.

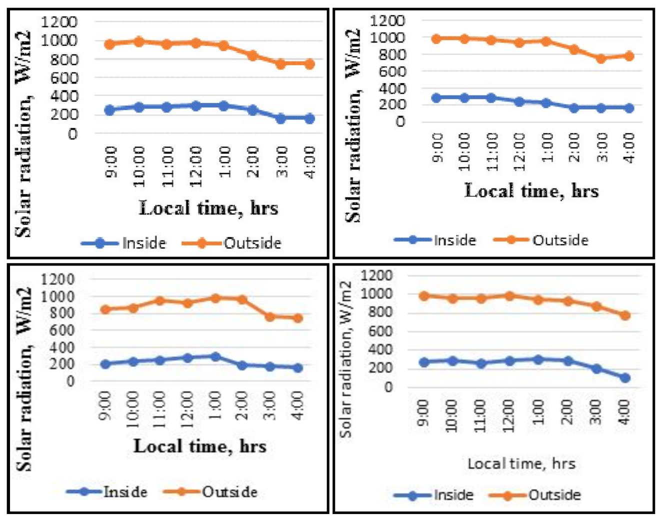

Fig. 3: Effect on solar radiation inside and outside dryer for natural convetion solar drying of tomatoesin April month 2024.

Table 2: Average value of length(a), width(b), thickness(c), size, Sphericity, geometric mean diameter, aspect ratio and surface area.

Variety	Length (mm)	Width (mm)	Thick-ness (mm)	Size	Sphericity	Aspect Ratio	Surface Area (mm^2)
Desi	47.25	62.08	47.18	46.36	0.9811	96.10	6590.91
Hybrid	57.37	48.47	45.98	48.41	0.8450	84.70	7368.27

Table 3: Average value of Moisture Content, Bulk Density, True Density and Pporosity.

Variety	Moisture Content, %	Bulk Density, g/cm³	True Density, g/cm³	Porosity, %
Desi	96.09	0.578	0.9930	41.71
Hybrid	93.91	0.572	0.9974	42.56

Hybrid Tomato respectively.

The average values of the moisture content of selected varieties are presented in Table 3. The maximum and minimum moisture content was found in Desi Tomato and Hybrid Tomato *i.e*. 96.09% (w.b.) and 93.91% (w.b.) respectively. The average values of bulk density for selected varieties are presented in Table 3. The maximum and minimum bulk density was found in Desi Tomato and Hybrid Tomato *i.e*. 0.578 g/cm^3 and 0.572 g/cm^3 respectively. The average values of true density for selected varieties are presented in Table 3. The maximum and minimum true density was found in Desi Tomato and Hybrid Tomato *i.e*. 0.9930 g/cm^3 and 0.9974 g/cm^3 respectively. The average values of porosity for selected varieties are presented in Table 3. The maximum and minimum porosity was found in Hybrid Tomato and Desi Tomato *i.e*. 42.565% and 41.71% respectively. Potato slices ware subjected to various pre-drying treatment *viz*., blanching in hot water at temperature, *i.e*., 60, 70, 80, 90 and 100^{o}C and blanching time (Kapadiya *et al*., 2018). Moisture content, ash content, volatile matter and fixed carbon of shredded cotton stalk biomass were found as, 12.5, 5.27, 80.22, and 14.51 (%, d.b) respectively (Makavana *et al*., 2020). The average pod-vine ratio for groundnut variety GG-22 was observed as 0.3353 having moisture content of pods and vine as 11.73 and 11.53% (d.b.) respectively (Amrutiya *et al*., 2019).

Environmental parameters

The hourly variation of environmental parameters *i.e*. air temperature, relative humidity and solar radiation inside and outside the dryer recorded during the drying period of tomatoes from 9.00 hrs to 17.00 hrs daily are presented in graphical from and analyzed here under. Shown Fig. 2 and 3 is an effect on temperature and solar radiation inside and outside dryer for natural convention solar drying of tomatoes.

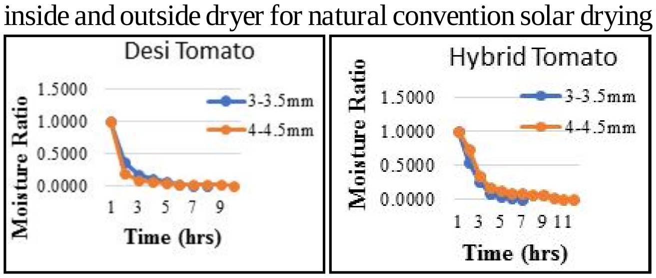

Fig. 4: Effect of moisture ratio with drying time during open sun drying of tomato slices.

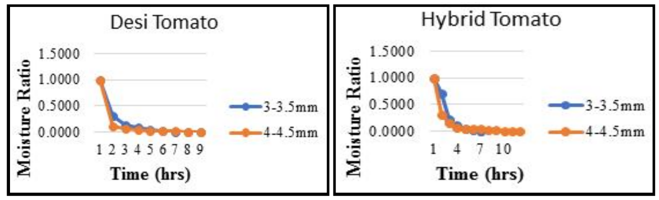

Fig. 5: Effect of moisture ratio with drying time during natural convention solar drying of tomato slices.

Solar Radiation

The diurnal effect of air temperature inside the dryer during the drying period of tomatoes was varied from 43ºC to 70°C. The ambient air temperature during open sun drying of tomatoes was varied from 34°C to 38°C. Effect in solar radiation inside and outside the dryer during the drying period of tomatoes was varied from 160 W/m^2 to 250 W/m^2 and 750 W/m^2 to 980 W/m^2 respectively.

Moisture Ratio

The moisture ratio is a crucial parameter in drying processes, particularly in food engineering, agriculture, and material science. It represents the amount of moisture present in a material at any given time relative to the initial and equilibrium moisture contents. Shown the Fig. 4 and 5 is an effect of moisture ratio with drying time during natural convention solar drying and open sun drying of tomato slices. Moisture content was reduced in case both natural convection solar dryer and open sun drying from 98.50 to 9.7 % (w.b.) and 96.40 to 9.5 % (w.b.) respectively. The moisture ratio decreased with increase in drying time and observed to be minimum at the completion of drying process. Dangar and Samnani, (2012) similar results were found in drying characteristics of chillies. Yola (2023) was performance Evaluation of Natural Convection Indirect Solar Dryer for drying white yam slices. Onifade *et al*., (2013). Some physical

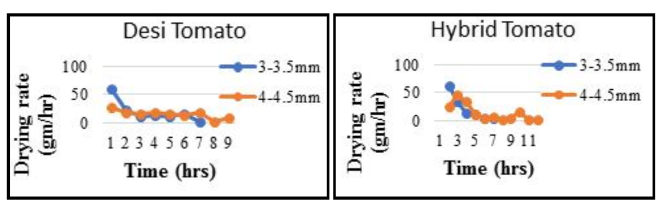

Fig. 6: Effect of drying rate with drying time during open sun drying of tomato slices.

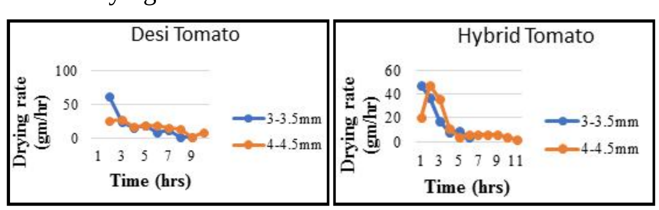

Fig. 7: Effect of drying rate with drying time during natural convention solar drying of tomato slices.

properties obtained that the initial moisture content of grapes on the dry basis of 5.91 g water/g dry matter was reduced to a final moisture content of 0.15 g water/g dry matter in about 12 h with a thermal drying efficiency of 12.5%, which is very close to the FC drying mode (10 h and 13.5%) and higher than the NC drying mode (15 h and 9.7%).

Drying Rate

The drying rate in drying processes is a key concept, particularly in fields like food processing, agriculture, and materials science. It describes how quickly moisture is removed from a material over time. Understanding and controlling the drying rate is essential for optimizing the drying process to ensure quality, efficiency, and energy use. Shown the Fig. 6 and 7 is an effect of drying rate with drying time during natural convention solar drying and open sun drying of tomato slices. The total drying time was ranged from 7 hrs to 12 hrs for the slice thickness of 3-3.5 to 4-5.5 mm in natural convection dryer whereas the total drying time was increased from 7 hrs to 16 hrs during open sun drying in that order of the thickness of slices. In general, solar cabinet dryers tend to achieve faster drying rates compared to open sun drying due to more controlled and higher temperatures inside the dryer. This controlled environment reduces moisture content more efficiently, shortening the overall drying time in the study mentioned, the drying rate for tomatoes in a solar dryer reduced moisture from 98.50% to 9.7% (w.b.) in a shorter time than open sun drying, which reduced moisture from 96.40% to 9.5% (w.b.). This indicates a more efficient moisture removal process in solar dryers.

Conclusion

The study on tomato drying reveals several key findings regarding moisture reduction and drying efficiency. Bulk density varied between 0.572 g/cm³ (Hybrid Tomato) and 0.578 g/cm³ (Desi Tomato), while true density ranged from 0.9930 g/cm³ (Desi Tomato) to 0.9974 g/cm³ (Hybrid Tomato). Porosity was highest in Hybrid Tomato at 42.565%. Moisture content decreased from 96.09% (w.b.) for Desi Tomato to 93.91% (w.b.) for Hybrid Tomato. The drying process showed a significant reduction in drying time when using a solar cabinet dryer compared to open sun drying, with moisture content dropping from 98.5% to 9.7% in the former and 96.4% to 9.5% in the latter. This indicates that solar cabinet dryers are more efficient than open sun drying for tomato dehydration. Solar cabinet dryers are beneficial for farmers as they allow for the long-term storage of dehydrated vegetables, helping them avoid selling perishable produce at low prices soon after harvest. These dryers are effective for drying vegetables, preserving their quality and increasing farmers' profits. Understanding the physical properties of tomatoes, such as size, shape, mass, and moisture content, is essential for developing post-harvest techniques and improving agricultural processes like harvesting, cleaning, and drying. These properties are crucial for maintaining product quality and facilitating quality control.

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