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DRYING BEHAVIOR OF ACTIVE MODE ETSC DRYER TO DRY GREEN GRAPES

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Abstract:

In order to dry green grapes, the main goal of present research is to demonstrate the drying behavior of active mode dryer assisted by evacuated tube solar collector (ETSC) in Pune, Maharashtra, India. It is discovered that the inside air temperature of drying cabinet (DC) to be significantly high (53.8–11^{0}C) compared to outside air temperature of surrounding. In the ETSC dryer, this accelerates the drying rate of green grapes. Unlike passive mode ETSC dryer, which takes 2.2days, green grapes require only 1.6days to attain their final moisture level in active mode ETSC dryer. The dried specimen is thought to have higher grade. Dryer is determined to be non-pollutant because they require no traditional fuel.

Keywords: *Active Mode Drying, DC, Inside Temperature, Green Grapes*.

1. Introduction

The main challenge come across by every emerging nation is storage of food crops after harvesting. Since the majority of food crops have large amount of water. As a result, crops get lost [1]. Preservation is an important step in food storage for an extended period of time [2]. Drying is frequently utilized traditional technique for protecting food crops [3]. It is widely understood to be the simultaneous use of heat and mass transfer to take away moisture from a crop [4]. Drying is an ancient method of minimizing micro-biological movement which is frequently utilized to maintain the nutritional value and prolong the shelf life of wet crops so as to be consumed for a long period [5].

Currently, most of the conventional dryers widely use convective method of hot air drying. Moreover, the major drawbacks of the conventional dryers are their large fuel utilization and high price. Because of this issue in numerous nations, a solar dryer is a superior option over the convective dryers. This outcome has accelerated the development of multipurpose solar drying technique during recent times [6].

Grape is a seasonal and widely consumed fruit worldwide. It is a vital dietary crop having sufficient amount of vitamin and mineral. Grapes are regarded as beneficial crop for human diet and one of the largest global fruit rich of nutrients. Dried grapes are a famous breakfast cereal and are utilized to improve digestion [7].

Hamdi et al. presented the combined numerical and experimental research of grape drying using solar greenhouse dryer [8]. Essalhi et al. have conducted the theoretical and experimental analysis of an indirect solar dryer and in natural sun for grape drying. From the experiment, the effective moisture diffusivity of natural sun drying and indirect solar drying of grapes was evaluated to be $2.34 \times 10^{-11} m^2/s$ and $4.08 \times 10^{-11} m^2/s$ respectively [9].

Femenia et al. demonstrated the impact of drying pre-treatments on the cell wall composition of grape tissues. NaOH, citric acid, and $K_2S_2O_5$ pretreatments were applied prior to the drying process. The outcome shows that pretreatment has an impact on drying rate. The cell composition of NaOH and citric acid pretreated grape specimen shows greatly modification than the $K_2S_2O_5$ pretreated grape specimen [10]. Bauman et al. narrated the drying behavior of the batch fluidized beds for drying fruits. It is found that batch fluidized bed takes less time to generate enhanced quality of dried fruits than continuous belt dryer [11].

Shedame et al. investigated the effect of various osmotic pretreatment on grapes used in tray dryer and examined their chemical trait. Specimens were dipped in sugar syrup of various concentrations at different temperature and then dried in a commercial tray dryer. The osmoses grape specimen with high syrup concentrations in sugar show improved chemical trait compared to the lower concentration [12]. Pawar et al. evaluated the impact of abrasive pretreatments on grapes berries to the drying with chemical pretreatments [13].

Taşeri et al. evaluated the drying properties of heat pump for drying grape pomace. The finding reveals that the air velocity required reducing the drying time by 69% of grapes increased from 1.5 to 2.5m/s respectively during drying period [14]. Dabra et al. analyzed the effect of tilt angle on the thermal performance of the evacuated tube solar air collector. The test was carried out at two angle of collector tilt 30° and 45°. The outcome shows that 30° collector tilt angle had better thermal performance compared to 45° collector tilt angle [15].

Komolafe et al. fabricated the forced convection solar dryer with air collector to determine the thermal efficiency of fruit drying. The developed heat storage material was integrated for continuous drying. The finding shows that, it takes shorter time to dry product compared to other methods [16]. Hany et al. performed the mathematical modeling on convection hot air dryer for grapes drying. The investigation shows the drying temperature from 40 to 60°C and the drying velocity from 1.0 to 2.0m/s respectively [17].

Arun et al. studied the drying behavior of grapes using solar tunnel greenhouse dryer and compared it with the natural sun drying method. The experiment demonstrates that the time period reduced by 63% as compared to the natural sun drying [18].

Solar evacuated tubular drying system were constructed and investigated for various vegetables like oyster mushroom, sliced radish, carrot, potato and fruits like apple, apricot by Lee [19] and Lamnatou et al. [20].

According to literature review, the performance of ETSC dryer is superior to those of other dryers. Additionally, it can be seen from the literature that ETSC dryers have not yet been used for drying of green grapes. The current research therefore aims to investigate the performance of an active mode ETSC dryer for green grape drying and distinguish it from passive mode ETSC drying.

2. Material and Methods

2.1 Drying Experiment

The four essential parts of the active mode ETSC dryer are blower, evacuated tube solar collector, drying cabinet and chimney. The schematic picture of the active mode ETSC dryer is presented in Figure 2.1 respectively.

In order to assess the initial moisture content of green grapes, 250g of new specimen to be dried is uniformly distributed in a hot air oven for 24hours at 105°C. Fresh boiled grapes are spread evenly across the two trays in the drying cabinet for solar drying. As soon as the blower is turned on, the air is transported into the collector, quickly heated, and forced to flow into the drying cabinet where the specimen is situated. The specimen begins to lose bulk as a result of the moisture being removed by the heated air. Hourly measurement of the specimen mass is carried out from 8:15a.m to 5: 15 p.m. till the time the green grapes attain its final moisture level. Also, the whole experiment is carried out for passive mode ETSC dryer.

2.2 Instrumental Measurement

The digital humidity meter and digital anemometer is used to measure the relative humidity, ambient temperature and wind speed respectively. The daily solar isolation is estimated using a digital solar power meter on an hour basis. The specimen items are weighed hourly using a digital electronic compact scale. Digital thermometers are used to measure temperature at different points situated throughout the ETSC dryer. Figure 2.2 and 2.3 shows the specimen before, during and after drying using an active mode and passive mode ETSC dryer respectively.

Figure 2.1: Picture of active mode ETSC dryer

Figure 2.2: Green grapes before, during and after drying in active mode ETSC dryer

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Figure 2.3: Green grapes before, during and after drying in passive mode ETSC dryer

3. Data Reduction

3.1 Moisture Loss

The amount of moisture loss is found by [21],

$$ML = (M_i - M_f) \quad (1)$$

Where

M_i and M_f are hourly recorded initial and final mass of green grapes.

3.2 Moisture Content

The moisture content is calculated by [23],

$$MC = (M_i - M_f)/M_f \quad (2)$$

Here

Moisture content is taken as percentage (%) on wet basis(wb).

3.3 Drying Efficiency

The drying efficiency of the ETSC dryer is determined by [22],

$$\eta D = M_w L / I_s A_c t \quad (3)$$

Where

M_w is the evaporated mass of water from the product; L is latent heat of water's evaporation, I_s is solar intensity, A_c is collector's effective area and t is drying time.

3.4 Drying Rate

The drying rate of the ETSC dryer is determined by [24],

$$DR = \Delta M / \Delta t \quad (4)$$

Where

ΔM is the mass lost from the product and Δt is the time period.

4. Results and Discussion

Table 3.1, 3.2 and 3.3 shows the fluctuation of drying parameters such as solar intensity (I_s), wind speed (V), ambient temperature (T_a) and relative humidity (RH_a) on hour basis during the whole experiment. The entry temperature (T_i) and exit temperature (T_o) of ETSC while the bottom tray temperature (T_b), top tray temperature (T_t) and chimney temperature (T_c) of DC for active mode ETSC dryer is measured in the month of April at Pune, Maharashtra, India.

The sun intensity is seen to range from 136.55 to 1111W/m^2 over the course of experimentation. The ETSC's exit temperature and surrounding temperature both seen to fall between 58.5 to 129.5^{0}C and 28 to 32.7^{0}C. It has been noted that the DC's inside temperature fluctuates between 39 and 86.5^{0}C. It is substantially warmer than the surrounding environment. This shows that the specific moisture extraction ratio in an active mode drying is higher as compared to passive mode drying, which shortens the drying period in an active mode ETSC dryer.

Table 3.4, 3.5 and 3.6 shows the moisture parameters that were found during green grapes active and passive mode drying. The variation in moisture loss with drying period to dry green grapes in an active mode and passive mode ETSC dryer is as shown in Figure 3.1 and 3.2. The moisture loss of green grapes for active mode ETSC dryer is more within 1.6days as compare to 2.2days in passive mode ETSC dryer.

Figure 3.3 and 3.4 depicts a graph between the moisture content and the drying period that is used to analyze how the moisture content of green grapes varies. It is believed that the moisture removal initially increases and then exponentially decreases. The maximum drying rate of active mode ETSC dryer is determined to be 0.3056kg/h/m^2, while the maximum efficiency for green grapes drying is evaluated to be 19.13%. Additionally, compared to passive mode dried green grapes, the active mode dried green grapes have greater taste, look, smell and color.

Table 3.1: Hourly fluctuation of various parameters for solar dried green grapes (Day 1)

Day Time (hrs:min)	Solar Intensity I_s (W/m^2)	Wind Speed V (m/s)	Relative Humidity RH_a (%)	Temperature at several positions					
				T_a (^{0}C)	T_i (^{0}C)	T_o (^{0}C)	T_b (^{0}C)	T_t (^{0}C)	T_c (^{0}C)
8:15	434	0.63	51.2	30.6	35.5	48	38	36	35
9:15	554.9	1.00	51.6	30.9	39.5	65	41.5	40.5	39.5
10:15	796.7	1.72	52.1	30.2	47.5	99.5	67	65	64
11:15	988	1.58	44.2	31.2	52	116	77.5	75	74
12:15	1078	0.58	37.9	32.2	54.5	125.5	82.5	81	80
13:15	1107.5	0.27	35.1	32.3	55.5	129.5	84.5	83.5	82.5
`14:15	1054	0.18	33.7	32	52	129	82.5	81.5	79
15:15	902.1	0.31	32.6	32.5	49.5	120.5	78	76.5	75
16:15	516.8	0.63	22.4	30.3	49	109	74	72	71
17:15	142.2	0.81	17.5	28.9	48.5	101	70	68	67

Table 3.2: Hourly fluctuation of various parameters for solar dried green grapes (Day 2)

Day Time (hrs:min)	Solar Intensity I_s (W/m²)	Wind Speed V (m/s)	Relative Humidity RH_a (%)	Temperature at several positions					
				T_a (⁰C)	T_i (⁰C)	T_o (⁰C)	T_b (⁰C)	T_t (⁰C)	T_c (⁰C)
8:15	430.45	0.95	67.3	29.6	37	48	35	33	32
9:15	559.7	1.14	63.5	29.8	41	65	45.5	44.5	43.5
10:15	818.2	0.76	55.8	30.1	49	99	66.5	65	63.5
11:15	984.4	1.36	46.9	31.4	53	115.5	77	74	73.5
12:15	1079	1.00	39.8	32.2	53	125.5	83.5	82	79.5
13:15	1111	0.31	35	32.2	54	129	86.5	85.5	82.5
14:15	952.5	0.84	31.8	32.7	54	126.5	84.5	80.3	79.5
15:15	613.4	1.11	29.1	32.4	50	119	79	78	75
16:15	292.15	0.90	25.8	31.7	50	100	70.5	69.5	67
17:15	136.55	0.71	23.7	31.9	52	74	59.5	58.5	56

Table 3.3: Hourly fluctuation of various parameters for solar dried green grapes (Day 3)

Day Time (hrs:min)	Solar Intensity I_s (W/m²)	Wind Speed V (m/s)	Relative Humidity RH_a (%)	Temperature at several positions					
				T_a (⁰C)	T_i (⁰C)	T_o (⁰C)	T_b (⁰C)	T_t (⁰C)	T_c (⁰C)
8:15	489.1	1.82	54.95	28	34	46.25	31	30	29
9:15	531.9	1.89	55.75	30.1	37	58.5	40	39	38.5
10:15	617.5	2.03	57.35	30.1	43	83	58	55.5	54.5

Table 3.4: Hourly fluctuation of moisture loss and moisture content of green grapes in active mode ETSC dryer and passive mode ETSC dryer (Day 1)

Drying Time (hrs)	Active Mode Drying (ETSC)			Passive Mode Drying (ETSC)		
	M_i (kg)	MC (% wb)	ML (kg)	M_i (kg)	MC (% wb)	ML (kg)
0	2.026	79.3		2.026	79.3	
1	1.974	76.7	0.052	1.979	76.9	0.047
2	1.903	73.15	0.071	1.915	73.8	0.064
3	1.760	66	0.143	1.786	67.4	0.129
4	1.592	57.65	0.168	1.635	60	0.151
5	1.431	49.6	0.161	1.491	52.8	0.145
6	1.251	40.55	0.180	1.328	44.8	0.162
7	1.111	33.55	0.140	1.202	38.6	0.126
8	1.015	28.75	0.096	1.116	34.3	0.086
9	0.963	26.15	0.052	1.069	32	0.047

Table 3.5: Hourly fluctuation of moisture loss and moisture content of green grapes in active mode ETSC dryer and passive mode ETSC dryer (Day 2)

Drying Time (hrs)	Active Mode Drying (ETSC)			Passive Mode Drying (ETSC)		
	M_i (kg)	MC (% wb)	ML (kg)	M_i (kg)	MC (% wb)	ML (kg)
1	0.933	24.65	0.030	1.042	30.7	0.027
2	0.863	21.15	0.070	0.979	27.6	0.063
3	0.784	17.2	0.079	0.908	24.1	0.071
4	0.729	14.45	0.055	0.857	21.6	0.051
5	0.668	11.4	0.061	0.802	18.8	0.055
6	0.605	8.25	0.063	0.745	16	0.057
7	0.568	6.4	0.037	0.712	14.4	0.033
8	0.552	5.6	0.016	0.698	13.7	0.014
9	0.540	5	0.012	0.687	13.2	0.011

Table 3.6: Hourly fluctuation of moisture loss and moisture content of green grapes in active mode ETSC dryer and passive mode ETSC dryer (Day 3)

Drying Time (hrs)	Active Mode Drying (ETSC)			Passive Mode Drying (ETSC)		
	M_i (kg)	MC (% wb)	ML (kg)	M_i (kg)	MC (% wb)	ML (kg)
1	0.520	4	0.020	0.669	12.3	0.018
2	0.497	2.85	0.023	0.648	11.2	0.020

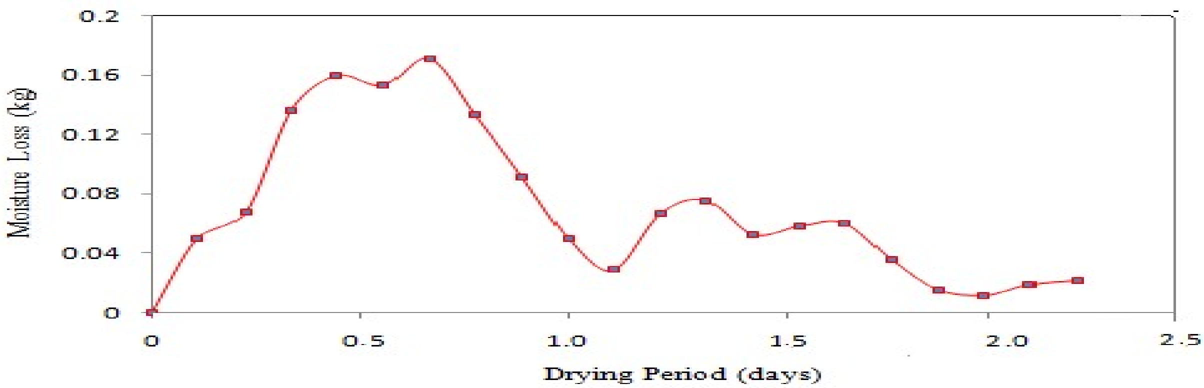

Figure 3.1: Fluctuation of moisture loss vs. drying period for dried green grapes in active mode ETSC dryer (Day 1, 2 and 3)

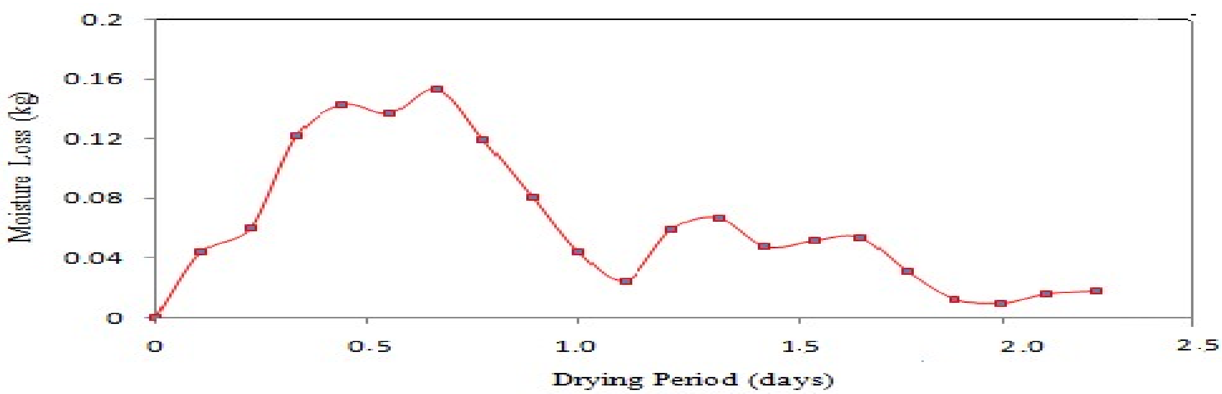

Figure 3.2: Fluctuation of moisture loss vs. drying period for dried green grapes in passive mode ETSC dryer (Day 1, 2 and 3)

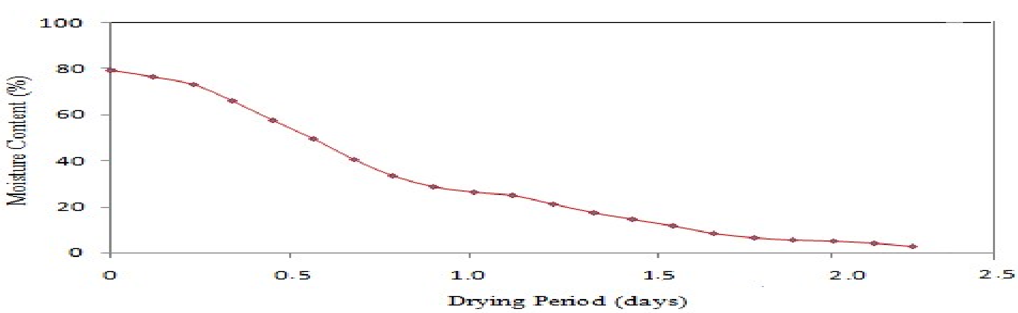

Figure 3.3: Fluctuation of moisture content vs. drying period for dried green grapes in active mode ETSC dryer (Day 1, 2 and 3)

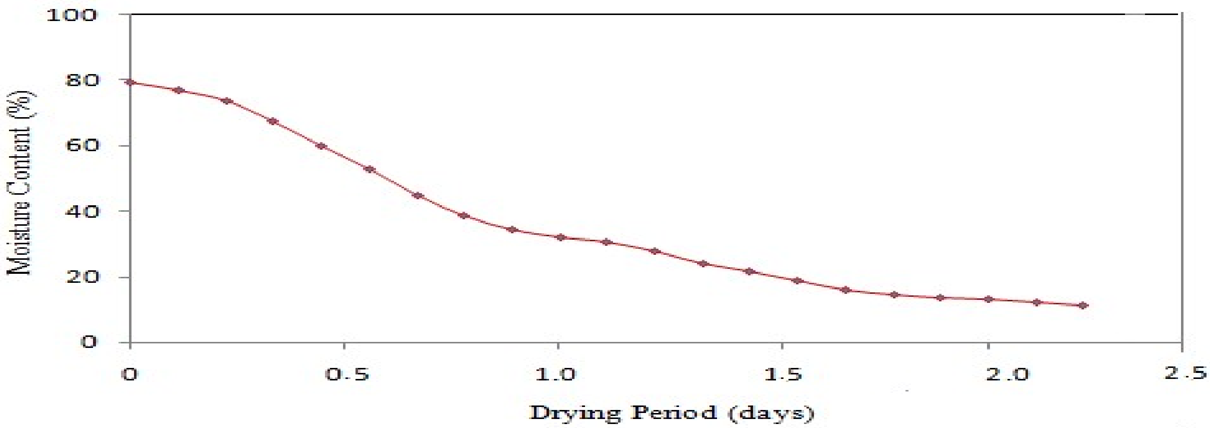

Figure 3.4: Fluctuation of moisture content vs. drying period for dried green grapes in passive mode ETSC dryer (Day 1, 2 and 3)

5. Conclusion

The experimentation on an ETSC dryer is carried out with the purpose to dry green grapes in an active mode and is distinguished from passive mode. Green grape drying period is reduced by an ETSC dryer. The existence of ETSC makes its exit air temperature substantially higher compared to the ambient air temperature. The dryer is observed to be 19.13% efficient at drying green grapes. Any form of food crops can be dried using an ETSC dryer, which is environmentally pleasant. Additionally, there are several opportunities to conserve traditional fuel. With the help of this dryer, the dried crops can be sold abroad and healthy return can be earned.

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