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SOLAR TUNNEL DRYING FOR SPICES: A NOVEL ALTERNATIVE TO TRADITIONAL SUN DRYING

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ABSTRACT

A solar tunnel dryer was developed (10 m × 5 m × 2.5 m) for drying of spices to eliminate constraints of open sun drying, *viz*., 15-20% PH losses, higher drying time, weather dependent as well as poor quality of the dried spices. The developed dryer could successfully dried 500±5 kg of fresh red chillies, 540±5 kg fresh turmeric rhizomes as well as 525±5 kg fresh ginger rhizomes per batch in drying time of 14 days, 22 days and 23 days, respectively. Solar tunnel drying of red chillies, turmeric and ginger reduces drying time (28 to 39%), minimizes PH losses (7.5 to 16%) as well as saves drying space (35 to 45%) as compared to open sun drying. In addition to these, higher retention of quality parameters, *viz*., anthocyanin (88.25 ± 0.95 mg/100 g) and ascorbic acid (6.32 ± 0.11 mg kg^{-1} DW), sensory score (7.5) for red chilli powder; curcumin (4.18 ±0.06 g/100 g), carbohydrates (65.11±0.92 g/100 g), ascorbic acid (61.35±1.25 mg/100 g), sensory score (8.0) for turmeric powder as well as crude oil (5.45 ± 0.46%), crude fiber (5.68 ± 0.40g/100 g), ascorbic acid (3.88 ± 0.18 mg/100 g) for ginger powder. Furthermore, higher sensory score and market prices of dried spices were obtained in solar tunnel drying as compared sun drying. So, the farmers are benefitted in terms of drying time, drying space, post-harvest losses, recovery of dried product, better

Key words : Drying performance, Solar radiation, Solar tunnel dryer, Spice drying, Sun drying.

Introduction

Solar energy is one of the most promising renewable energy sources in the world compared to non-renewable sources for the purpose of drying of agriculture and industrial products (Bala and Woods, 1994)). The concept of a dryer powered by solar energy is becoming increasingly feasible because of the gradual reduction in price of solar collectors coupled with the increasing concern about atmospheric pollution caused by conventional fossil fuels used for drying crops. Solar dryer is an improved form of sun drying in which drying is accomplished in a closed structure under relatively controlled conditions utilizing the thermal energy of sun. The open air drying or sun drying has many limitations and due to the rise of fuel prices, depletion of fossil fuels, the use of modern drying technologies are not economical for drying agricultural product. Hence, solar drying systems have been developed as a successful and economical tool for drying agricultural product.

Various types of solar dryers have been developed as an alternative to open air sun drying and other conventional drying methods. Solar tunnel dryers are becoming more and more popular due to ease of fabrication, higher capacity as well as better consistent products. Lutz and Muhlbauera (1984) had developed a multipurpose solar tunnel dryer consisting of a fan, solar heater, and tunnel dryer. The use of this dryer had reduced the drying time considerably with better end product quality.

India is one of the largest producers of spices in the world. Spices are also important foreign exchange earner for India. Drying of spice crops are very essential to remove excess moisture from the outer skin and neck to reduce storage rot and its shelf life also it’s easy to use in dried form.

Drying of agricultural produce is the oldest and still the most practiced preservation method. Demand of dried spices is increasing all over the world. In India drying of spices is generally done by open sun drying. The initial moisture content of the spices is the main factor behind the post-harvest losses and open sun drying is the oldest technique that preserve the products by reducing the moisture contents. The reduced moisture content of agricultural products not only slow down the deterioration, but also increases the safe storage period. The main drawback behind the open sun drying is that the products remain unprotected from the environmental conditions like rain, dust, dirt, and infestation by birds and animals. All these factors affect the quality of food and sometimes the quality is degraded to an extent that it becomes inedible. The loss in quality of dried products affect market value and consumer acceptance.

Kalbande *et al*. (2013) designed and fabricated a solar-biomass hybrid dryer. Experiments have been conducted to test the performance of the dryer, turmeric had been dried. The results indicate that the drying is faster. The quantitative analysis showed that the traditional drying i.e. open sun drying took 4 to 15 days to dry the rhizomes while solar biomass drier took only 1.5 to 4 days for the samples having different treatments and produced better quality produce.

Fudholi *et al*. (2013) carried out an experiment on drying of Malaysian Red Chili dried by open and solar drying. Red chilies were dried down from approximately 80% (wb) to 10% (wb) moisture content within 33 h. The drying process was conducted during the day, and it was compared with 65 h of open sun drying. Solar drying yielded a 49% saving in drying time compared with open sun drying.

Arjoo *et al*. (2017) evaluated the performance of walk-in type solar tunnel dryer (10m × 3.75m × 1.98 m) for chili, garlic, fenugreek and aonla candy. A temperature of 15-30 ^{0}C higher than the atmospheric temperature was recorded inside the dryer The STD reduces the moisture content of chilli from 77% to 7% (wb) in 7 days, garlic from 65% to 8.5% (wb) in 8 days, fenugreek from 86% to 7.2% (wb) in 5 days and aonla candy from 44% to 16%(wb). STD dried products were of good quality, hygienic and highly acceptable as compared to direct sun drying.

Joy *et al.* (2001) studied on solar tunnel drying of red chillies. Wet samples of red chillies were dried in a tunnel dryer. Results of quality analyses of both tunnel-dried chilli samples and those dried by conventional open air sun drying were compared. A considerable reduction in drying time was noticed in tunnel-dried samples, which showed improved texture and hygienic quality over conventionally dried samples.

The solution to all these problems is the use of solar tunnel dryers based on solar energy. These kind of dryers uses only solar energy and does not require any other source of energy also temperature inside the dryer is more than the atmosphere when operated on natural convection mode. Therefore, solar tunnel dryer is an alternative for rural people to reduce the storage losses by drying their produce in a controlled and better environment. Also, the dried product is free from any dust particles and highly acceptable by consumers. Other advantages of solar tunnel dryers are substantial reduction of drying time and physical quality standards are maintained also solar tunnel dryers are easy to operate and maintain. This paper presents results of performance of the solar tunnel dryer for drying of spices in terms of drying parameters, quality analysis and economic feasibility.

Materials and Methods

Development of Solar Tunnel Dryer

The solar tunnel dryer was developed in the Department of Renewable Energy Engineering, CAET, Junagadh during March -2021 to December – 2021 as per the design. Each and every component of developed were design to accommodate 500 kg of fresh red chillies. However, solar tunnel dryer could be successfully used for drying of different spices, medicinal plants, leafy vegetables, etc. The details of the developed solar tunnel dryer mentioned hereunder.

Details of solar tunnel dryer (Plate 1)

- Crop : Red chillies
- Dimension : 10 m × 5 m × 2.5 m
- Shape : Hemi cylindrical
- Capacity : 500 kg (For red chillies)
- Size of Collector : 1.2 m × 2.4 m × 0.15 m (3 nos. of collector – optional)
- Size of drying tray : 70 cm × 70 cm × 5 cm
- Volume of tray : 0.0245 m^3
- No. of drying tray : 64 (arranged in 2 tier)
- Tray stand : 4 (accommodate total 16 trays, i.e., 8 trays in upper & 8 trays in lower tier)
- Total volume of 64 trays = 1.57 m^3
- Air vent dimensions : 16.5 cm × 16.5 cm
- Turbo fans required : 2
- Exhaust fans : 2

Plate 1 : Solar tunnel dryer on natural air convection mode and forced air convection mode.

Plate 2 : Solar tunnel drying of red chillies, turmeric rhizomes and ginger rhizomes.

Plate 3 : Open sun drying of red chillies, turmeric rhizomes and ginger rhizomes.

Solar Tunnel Drying of Spices (Plate 2)

Red chillies : Drying of red chillies (var. *Resham Patta*) by solar tunnel drying on natural air convection mode, solar tunnel drying on forced air convection mode and sun drying. Freshly harvested red chillies was procured from Village: Harmdiya (Ta:Gondal). Each drying tray was loaded with 7.75 kg of fresh red chilli fruits. Total : 496 kg of red chillies were accommodated in 64 drying trays dried in a batch for natural convection as well as forced air convection mode. The quality evaluation of dried red chilli powder was carried out on the basis of capsaicin content, anthocyanin content and ascorbic acid content as per the standard methods.

Turmeric : Drying of turmeric rhizomes (var. *Salem*) by solar tunnel drying on natural air convection mode, solar tunnel drying on forced air convection mode and sun drying. Freshly harvested turmeric rhizomes was procured from Village: Sultanpur (Ta:Gondal). Each drying tray was loaded with 8.5 kg of turmeric rhizomes. Total : 544 kg of turmeric rhizomes were accommodated in 64 drying trays dried in a batch for natural convection as well as forced air convection mode. The quality evaluation of dried turmeric rhizome powder was carried out on the basis of curcumin content, carbohydrate content and ascorbic acid content as per the standard methods.

Ginger : Drying of ginger rhizomes (Var. Surbhi) by solar tunnel drying on natural air convection mode, solar tunnel drying on forced air convection mode and sun drying. Freshly harvested ginger rhizomes was procured from Village: Sultanpur (Ta: Mangrol). Each drying tray was loaded with 8.25 kg of fresh ginger rhizomes. Total: 528 kg of ginger rhizomes were accommodated in 64 drying trays dried in a batch for natural convection as well as forced air convection mode. The quality evaluation of dried ginger rhizome powder was carried out on the basis of curcumin content, carbohydrate content and ascorbic acid content as per the standard methods.

During these experiment climatic parameters, *viz*., temperature, intensity of solar radiation, relative humidity inside and outside solar dryer was measured using data logger and pyranometer at an interval of one hour. Drying parameters, *viz*., moisture content, drying rate and moisture ratio (MR) were also measured and calculated at an interval of one hour during the whole experiment.

Open sun drying of spices

The sun drying of red chillies, turmeric rhizomes and ginger rhizomes were carried out as per the method followed by local farmers (Plate 3). During the open sun drying climatic parameters, *viz*., temperature, intensity of solar radiation, relative humidity of the ambient air were measured using data logger and pyranometer at an interval of one hour. Drying parameters, *viz*., moisture content, drying rate and moisture ratio (MR) were also measured and calculated at an interval of 4 hour during the whole experiments.

Results and Discussion

Drying characteristics of red chillies, turmeric rhizomes and ginger by different drying methods, *viz*., solar tunnel drying on natural air convection (NAC), solar tunnel drying on forced air convection and sun drying are expressed in terms of moisture content (%(db)), drying rate (%/day) and moisture ratio (MR) in are given in Tables 1, 2 and 3, respectively. However, drying efficiencies in terms of drying constants for red chillies, turmeric rhizomes and ginger rhizomes were determined by plotting a curve between drying time vs. moisture ratio as illustrated in Figs. 1, 2 and 3, respectively.

Table 1 : Drying characteristics of red chillies for different methods.

Drying period, Day	Solar tunnel drying (FAC)			Solar tunnel drying (NAC)			Sun drying method		
	MC, %(db)	DR, %/day	MR	MC, %(db)	DR, %/day	MR	MC, %(db)	DR, %/day	MR
1	398.00		1.000	410.50		1.000	398.00		1.000
2	287.00	111.00	0.737	309.25	101.25	0.770	328.44	69.56	0.821
3	185.33	101.67	0.476	265.55	43.70	0.661	273.44	55.00	0.680
4	128.15	57.18	0.329	228.68	36.87	0.569	233.44	40.00	0.577
5	83.44	44.71	0.214	193.38	35.30	0.481	201.44	32.00	0.495
6	48.88	34.56	0.125	158.45	34.93	0.395	173.44	28.00	0.423
7	33.15	15.73	0.085	126.63	31.82	0.315	148.44	25.00	0.359
8	21.88	11.27	0.056	95.63	31.00	0.238	126.44	22.00	0.302
9	15.44	6.44	0.040	66.12	29.50	0.165	105.89	20.55	0.249
10	10.98	4.46	0.028	39.85	26.27	0.099	87.56	18.33	0.202
11	8.45	2.53	0.022	24.89	14.96	0.062	71.36	16.20	0.161
12				12.33	12.56	0.031	57.01	14.35	0.124
13				10.55	1.78	0.026	44.79	12.22	0.092
14				8.87	1.68	0.022	33.05	11.74	0.062
15							23.00	10.05	0.036
16							15.47	7.53	0.017
17							13.22	2.25	0.011
18							12.04	1.18	0.008
19							10.94	1.10	0.005
20							9.95	0.99	0.003
21							9.35	0.60	0.001
22							8.90	0.45	0.001

Drying of Local Spices

Drying of red chillies

Drying of time required to reduce the initial moisture contents of freshly harvested red chillies from 398.00 % to 410.50 % (db) to 8.45 to 8.90 % (db) 11 days, 14 days and 22 days for solar tunnel drying (FAC), solar tunnel drying (FAC) and sun drying method, respectively (Table 1). Drying efficiency in terms of drying constant (h^{-1}) of 0.42 h^{-1}, 0.33 h^{-1} and 0.30 h^{-1} were obtained in solar tunnel drying (FAC), solar tunnel drying (FAC) and sun drying method, respectively (Fig. 1). Higher drying rates (%/day) were obtained in solar tunnel drying (FAC) followed by solar tunnel drying (NAC), whereas lower drying rates were obtained in sun drying method.

Drying of turmeric rhizomes

Drying of time required to reduce the initial moisture contents of fresh turmeric rhizomes from 425.00% to 432.00% (db) to 9.70 to 9.84% (db) were 19 days, 23 days and 36 days for solar tunnel drying (FAC), solar tunnel drying (FAC) and sun drying method, respectively (Table 2). Drying efficiency in terms of drying constant (h^{-1}) of 0.18 h^{-1}, 0.15 h^{-1} and 0.11 h^{-1} were obtained in solar tunnel drying (FAC), solar tunnel drying (FAC) and sun drying method, respectively (Fig. 2). Higher drying rates (%/day) were obtained in solar tunnel drying (FAC) followed by solar tunnel drying (NAC), whereas lower drying rates were obtained in sun drying method.

Table 2 : Drying characteristics of turmeric rhizomes for different methods.

Drying period, Day	Solar tunnel drying (FAC)			Solar tunnel drying (NAC)			Sun drying method		
	MC, %(db)	DR, %/day	MR	MC, %(db)	DR, %/day	MR	MC, %(db)	DR, %/day	MR
1	425.00		1.000	432.00		1.000	425.00		1.000
2	355.22	69.78	0.833	372.00	60.00	0.872	390.11	34.89	0.916
3	288.12	67.10	0.694	328.00	44.00	0.790	358.00	32.11	0.863
4	225.18	62.94	0.543	286.00	42.00	0.689	326.00	32.00	0.786
5	198.32	26.86	0.478	248.00	38.00	0.597	295.00	31.00	0.711
6	172.15	26.17	0.415	216.00	32.00	0.520	263.50	31.50	0.635
7	154.11	18.04	0.371	181.85	34.15	0.438	232.75	30.75	0.561
8	138.42	15.69	0.334	152.26	29.59	0.367	215.00	17.75	0.518
9	121.30	17.12	0.292	133.43	18.83	0.321	198.32	16.68	0.478
10	104.16	17.14	0.251	114.58	18.85	0.276	185.24	13.09	0.447
11	88.17	15.99	0.212	96.99	17.59	0.234	172.15	13.09	0.415
12	74.10	14.07	0.179	81.51	15.48	0.196	161.85	10.30	0.390
13	59.43	14.67	0.143	65.37	16.14	0.157	151.22	10.63	0.365
14	47.21	12.22	0.114	51.93	13.44	0.125	140.11	11.11	0.338
15	35.08	12.13	0.085	38.59	13.34	0.093	131.08	9.03	0.316
16	24.50	10.58	0.059	26.95	11.64	0.065	122.09	8.99	0.294
17	17.35	7.15	0.042	22.90	4.05	0.055	113.47	8.62	0.274
18	12.12	5.23	0.035	19.06	3.84	0.046	104.78	8.69	0.253
19	10.15	1.97	0.030	16.28	2.78	0.039	96.17	8.61	0.232
20	9.71	0.44	0.027	13.88	2.40	0.034	88.17	8.00	0.213
21				11.42	2.46	0.031	81.14	7.03	0.196
22				9.32	2.10	0.029	74.33	6.81	0.179
23							66.77	7.56	0.161
24							59.43	7.34	0.143
25							53.32	6.11	0.129
26							47.21	6.11	0.114
27							41.15	6.06	0.099
28							35.08	6.07	0.085
29							29.79	5.29	0.072
30							24.50	5.29	0.059
31							19.47	5.03	0.047
32							14.88	4.59	0.036
33							12.08	2.80	0.029
34							10.88	1.20	0.026
35							10.18	0.70	0.025
36							9.84	0.34	0.024

Drying of ginger rhizomes

Drying of time required to reduce the initial moisture contents of fresh ginger rhizomes from 434.15% to 440.00% (db) to 9.70 to 9.84% (db) were 19 days, 23 days and 32 days for solar tunnel drying (FAC), solar tunnel drying (FAC) and sun drying method, respectively (Table 3). Drying efficiency in terms of drying constant (h^{-1}) of 0.19 h^{-1}, 0.17 h^{-1} and 0.14 h^{-1} were obtained in solar tunnel drying (FAC), solar tunnel drying (FAC) and sun drying method, respectively (Fig. 3). Higher drying rates (%/day) were obtained in solar tunnel drying (FAC) followed by solar tunnel drying (NAC), whereas lower drying rates were obtained in sun drying method.

Table 3 : Drying characteristics of ginger rhizomes.

Drying period, Day	Solar tunnel drying (FAC)			Solar tunnel drying (NAC)			Sun drying method		
	MC, %(db)	DR, %/day	MR	MC, %(db)	DR, %/day	MR	MC, %(db)	DR, %/day	MR
1	434.18		1.000	440.00		1.000	434.18		1.000
2	355.22	78.96	0.856	372.00	68.00	0.872	385.00	49.18	0.904
3	288.12	67.10	0.694	328.00	44.00	0.790	347.12	37.88	0.813
4	225.18	62.94	0.543	286.00	42.00	0.689	310.00	37.12	0.723
5	198.32	26.86	0.478	248.00	38.00	0.597	275.00	35.00	0.639
6	172.15	26.17	0.415	216.00	32.00	0.520	245.00	30.00	0.567
7	154.11	18.04	0.371	181.85	34.15	0.438	221.00	24.00	0.509
8	138.42	15.69	0.334	152.26	29.59	0.367	198.00	23.00	0.454
9	121.30	17.12	0.292	133.43	18.83	0.321	178.91	19.09	0.408
10	104.16	17.14	0.251	114.58	18.85	0.276	161.27	17.64	0.365
11	88.17	15.99	0.212	96.99	17.59	0.234	144.26	17.02	0.324
12	74.10	14.07	0.179	81.51	15.48	0.196	128.62	15.64	0.287
13	59.43	14.67	0.143	65.37	16.14	0.157	114.24	14.39	0.252
14	47.21	12.22	0.114	51.93	13.44	0.125	103.96	10.28	0.227
15	35.08	12.13	0.085	38.59	13.34	0.093	94.70	9.26	0.205
16	24.50	10.58	0.059	26.95	11.64	0.065	85.88	8.82	0.184
17	16.22	8.28	0.042	22.90	4.05	0.055	76.50	9.38	0.161
18	10.15	6.07	0.031	19.06	3.84	0.046	68.25	8.25	0.141
19	9.14	1.01	0.025	16.28	2.78	0.039	64.15	4.10	0.132
20				14.26	2.02	0.034	57.44	6.71	0.115
21				12.32	1.94	0.031	51.40	6.04	0.101
22				10.85	1.47	0.029	46.15	5.25	0.088
23				9.41	1.44	0.027	41.15	5.00	0.076
24							36.65	4.50	0.065
25							32.40	4.25	0.055
26							28.29	4.11	0.045
27							24.26	4.03	0.036
28							20.50	3.76	0.026
29							17.00	3.50	0.018
30							13.60	3.40	0.010
31							10.40	3.20	0.009
32							9.49	0.91	0.002

Quality Evaluation of Dried Local Spices

The quality of dried spices, *i.e.*, red chillies, turmeric powder and ginger powder was evaluated on the basis of retention of different biochemical parameters as mentioned in Table 2.

Quality evaluation of dried red chillies

Higher retention of Ascorbic Acid and Anthocyanin 88.25 ± 0.95 mg/100 g and 6.32 ± 0.11 mg kg-1DW were obtained in Solar Tunnel Drying of red chillies on NAC, whereas lower ascorbic acid and anthocyanin content of 84.32 ± 0.73 mg/100 g and 5.54 ± 0.34 mg kg^{-1} DW were found in Solar Tunnel Drying of red chillies on FAC mode (Table 2). Higher retention of Capsaicin content of 0.288 ± 0.04% was found in in Sun Drying method, whereas lower of 0.235 ± 0.02% was found in Solar Tunnel Drying of red chillies on FAC mode. Higher overall acceptability score of 7.50 on the basis of 9-point hedonic test, *i.e.*, colour, appearance, aroma, taste was found in red chillies dried by Solar Tunnel Drying on NAC mode, whereas lower of 6.40 was found in red chillies dried by Sun drying method.

Quality evaluation of turmeric powder

Higher retention of Curcumin, Carbohydrates and

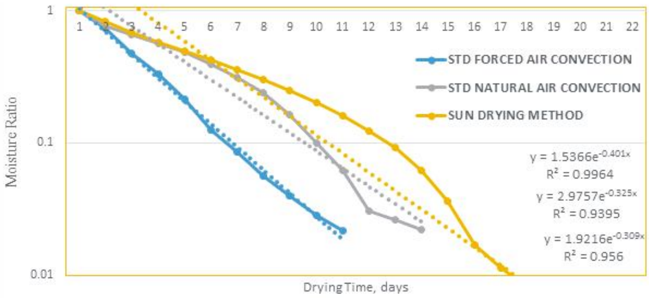

Fig. 1 : Relationship between moisture ratio and drying time.

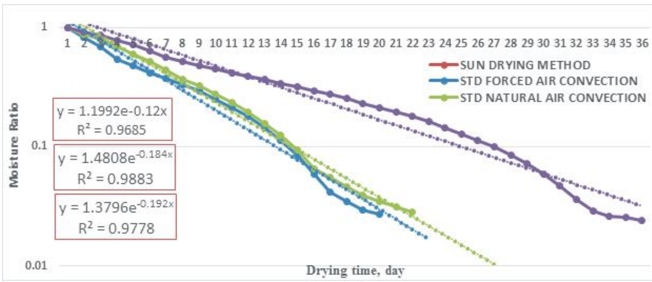

Fig. 2 : Relationship between drying rate and drying time.

Ascorbic Acid Content of 4.18 ± 0.06 g/100 g , 65.11 ± 0.92 g/100 g and 61.35 ± 1.25 mg/100 g, respectively, were obtained in Solar Tunnel Drying of turmeric rhizomes on NAC mode, whereas lower Curcumin, Carbohydrates and Ascorbic Acid Content of 3.81 ± 0.08 g/100 g , 57.23 ± 0.61 g/100 g and 54.11 ± 0.81 mg/100 g, respectively, were found in Solar Tunnel Drying of turmeric rhizomes on FAC mode. Higher overall acceptability score of 8.00 on the basis of 9-point hedonic test, *i.e.*, colour, appearance, aroma, taste was found

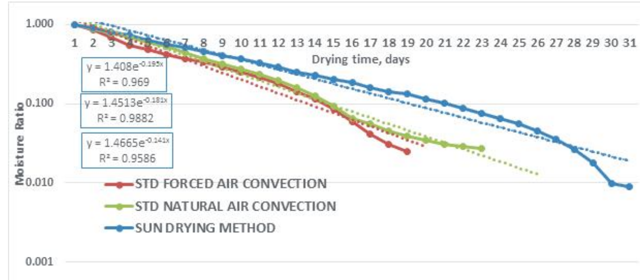

Fig. 3 : Relationship between drying rate and drying time.

turmeric rhizomes dried by Solar Tunnel Drying of turmeric rhizomes on NAC mode, whereas lower of 6.75 was found in turmeric rhizomes dried by Sun drying method.

Quality evaluation of ginger powder

Higher retention of Curcumin, Carbohydrates and Ascorbic Acid Content of 5.45 ± 0.46%, 5.68 ± 0.40 g/ 100 g and 3.88 ± 0.18 mg/100 g, respectively, were obtained in Solar Tunnel Drying of Ginger rhizomes on NAC mode, whereas lower Curcumin, Carbohydrates and Ascorbic Acid Content of 4.11 ± 0.22%, 5.12 ± 0.39 g/100 g and 2.72 ± 0.17 mg/100 g, respectively, were found in Solar Tunnel Drying of ginger rhizomes on FAC mode. Higher overall acceptability score of 8.50 on the basis of 9-point hedonic test, *i.e.*, colour, appearance, aroma, taste was found of ginger rhizomes dried by Solar Tunnel Drying of red chillies on NAC mode, whereas lower of 6.50 was found in of ginger rhizomes dried by Sun drying method.

Table 4 : Effect of Drying Methods on Quality of dried Red Chillies (Sample size : 7.75 kg).

Drying Method	Capsaicin content (%)	Ascorbic acid (mg/100 g)	Anthocyanin (mg kg^{-1} DW)
Solar tunnel drying (Natural Air Convection)	0.249 ± 0.03	88.25 ± 0.95	6.32 ± 0.11
Solar tunnel drying (Forced Air Convection)	0.235 ± 0.02	84.32 ± 0.73	5.54 ± 0.34
Sun drying	0.288 ± 0.04	80.52 ± 1.12	4.62 ± 0.09

Table 5 : Effect of Drying Methods on Quality of Dried Turmeric (Sample size : 8.50 kg).

Drying Method	Curcumin content (g/100 g)	Carbohydrate (g/100 g)	Ascorbic acid (mg/100 g)
Solar tunnel drying (Natural Air Convection)	4.18 ± 0.06	65.11 ± 0.92	61.35 ± 1.25
Solar tunnel drying (Forced Air Convection)	3.95 ± 0.12	60.12 ± 1.13	55.41 ± 1.76
Sun drying	3.81 ± 0.08	57.23 ± 0.61	54.11 ± 0.81

Table 6. Effect of Drying Methods on Quality of Dried Ginger (Sample size : 8.25 kg)

Drying Method	Crude oil content (%)	Crude fibre (g/100 g)	Ascorbic Acid (mg/100 g)
Solar tunnel drying (Natural Air Convection)	5.45 ± 0.46	5.68 ± 0.40	3.88 ± 0.18
Solar tunnel drying (Forced Air Convection)	4.11 ± 0.22	5.12 ± 0.39	2.72 ± 0.17
Sun drying	5.32 ± 0.449	5.56 ± 0.41	3.65 ± 0.26

Economic feasibility of solar tunnel dryer for local spices

The economic feasibility analysis of solar tunnel dryer for red chillies, turmeric and ginger was carried out as suggested by Jagdish Sahay (2008) as mentioned hereunder.

Red Chillies

There is no any kind of loss of red chillies was observed during solar tunnel drying. The recovery level of dried red chillies was higher in the solar tunnel dryer (24.80 kg/q) as compared to traditional sun drying method (21.15 kg/q).

Turmeric

There is no any kind of loss of turmeric was occurred during drying of turmeric using Solar Tunnel Dryer. The recovery level of dried turmeric rhizomes was higher in the Solar Tunnel Dryer (22.40 kg/q) as compared to traditional sun drying method (21.30 kg/q).

Ginger

There is no any kind of loss of ginger was occurred during drying of ginger using Solar Tunnel Dryer. The recovery level of dried ginger rhizomes was higher in the Solar Tunnel Dryer (22 kg/q) as compared to traditional sun drying method (21.00 kg/q) in terms of quantity 1 kg/q and in terms of Rs. 1275 per 100 kg ginger rhizomes.

Conclusion

The use of a solar tunnel dryer, operated in natural and forced air convection modes, significantly improved the drying process and quality of spices compared to traditional sun drying. Drying times for fresh red chilies, turmeric rhizomes, and ginger rhizomes were reduced by 28 to 39%, accompanied by higher drying efficiencies and rates. Additionally, solar tunnel drying demonstrated superior retention of quality parameters, particularly in red chilies dried using natural air convection. This method also mitigated post-harvest losses by 7.5 to 16% and proved to be economically feasible, offering better recovery rates and reduced costs for dried spices compared to conventional sun drying.

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