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INVESTIGATION ON NATURAL CONVECTIVE SOLAR DRYING FOR AONLA PROCESSING

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Abstract: Drying is an essential operation in the preservation of agricultural products. Drying preserves foods by extracting enough moisture from food to protect from decay and spoilage. Drying of foods is the important process to remove moisture as early as possible at a temperature that does not cause any effect on flavor, texture and color of the food. Various drying methods are implemented to dry different agricultural products. It was found that the natural convective solar dryer could generate an adequate and continuous flow of high temperature air in the range of 45 to 55^0 C in normal sunny days which was used for drying of aonla candy. The overall efficiency of dryer was found to be 25 % and the dryer could be integrated in present energy context by considering its economic viability.

Keywords: Drying Rate, Moisture Ratio, Moisture Content, Drying Efficiency.

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INTRODUCTION

Aonla (*Pyllanthusemblilica*), is the richest source of vitamin C (Ascorbic acid) among all the fruits. Every 100g of amla contains nearly 700 – 750 mg of vitamin C. Aonla is also rich in vitamins and minerals like phosphorous, iron, calcium, carotene and vitamin B complex . The spherical, six lobed, light greenish yellow aonla fruit is sour, bitter and astringent to taste and is fibrous. It is found to have strong antioxidant properties. It is highly nutritious and has different medicinal properties that made it more popular. Many Ayurvedic and Unani preparation use aonla as a major constituent as it rejuvenates all the organ systems of the body and promotes health and wellness. Aonla helps in curing a number of ailments like fever, anemia, indigestion, liver disorder, piles, heart complaints and urinary problems. It has got antibacterial property and anti-ageing property.

The removal of moisture prevents the growth of the micro-organisms responsible for the spoilage of the foods. This can be achieved by drying or dehydration for removal of water (responsible for many deteriorative reactions) from a product. Natural sun dying has been used since time immemorial or agricultural products. Open sun drying has limitations to control the drying process and parameters, weather uncertainties, high labour cost, large drying area, insect infestation, dust and other foreign material and so on.

Drying is probably the oldest, favored and the most important preservation method for fruits and vegetables practiced by human. It improves the food stability by reducing the water and microbial activity and minimizing physical and chemical changes during storage (Dulawat, 2012).

MATERIALS AND METHODOLOGY

The experiment was carried out at the Department of Unconventional Energy Sources and Electrical Engineering, Dr. Panjab rao Deshmukh Krishi Vidyapeeth Akola.

A flat-plate solar collector having length of 1.20 m and width of 1.1 m(2 numbers), having an area of 1.31 m^2, consisted of absorber covered with single glass and painted black with insulation was fabricated. The absorber was made of black painted aluminum plate with thickness of 0.05 cm (28 SWG). The single layer of plane glass cover with thickness of 0.5 cm was applied on top surface of the collector. The glass was framed with the wooden plates. In the bottom surface back insulation was provided. The heated air goes up into the drying chamber due to the density difference. The distance between absorbed and glass cover was 0.12 m. The solar collector system was facing south tilted at an angle of 27^0 from the horizontal.

The bottom of collector system was insulated with 3.5 cm thick thermocol sandwiched between back plate and absorber plate. Plywood of thickness 18 mm was used for the sides. The edges or sides of the collector were not provided with insulation considering minimum heat losses from sides. The drying chamber, where the product is dried, was installed along with the collector.

Fig 1. Solar cabinet Dryer

Experimental Procedure

Performance evaluation of cabinet dryer-The performance of the solar cabinet dryer was evaluated for drying of aonla candyby conducting no load and full load test.(Janjaiand Tung, 2005).

No load testing of solar cabinet dryer- The variation of temperature, relative humidity and air velocity with corresponding ambient parameter were recorded to evaluate the solar cabinet dryer without product during winter season. The test was conducted between 9.00 to 17.00 pm.

Full load testing of solar cabinet dryer- In full load test the slices of aonla candy were spread over the perforated aluminum tray. The experiment was conducted in winter season (December 2015). The initial weight of the samples was recorded. The samples were weighed regularly at an interval of 1.00 h and simultaneously the temperature, solar irradiance, relative humidity and wind velocity was measured. Drying was conducted between 9.00 to 17.00 h daily.

Study of drying characteristics

The drying mechanism depends on simultaneous heat and mass transfer phenomenon and factors dominating each process determined the drying behavior of the product. The drying rates were evaluated from the experimental data and drying characteristics curves i.e. moisture ratio (db) vs. time, drying rate vs. time and moisture content (db) were plotted. (Akbari and patel, 2002)

Determination of moisture content

Initial moisture content of sample was determined by the hot air oven drying method as recommended by Ranganna S. (1986). Samples and weighed using electronic weighing balance of least count 0.01g. The samples were placed in hot air oven at 75^{0}C for 24.00 h.

Determination of moisture ratio

The Moisture ratio of the produce was calculated by following formula (Chakraverty, 1988).

$$\text{Moisture Ratio (M.R.)} = \frac{(M - M_e)}{(M_0 - M_e)}$$

Where,

M = Moisture content (db), per cent

M_e = EMC, (db), per cent

M_0 = IMC, (db), per cent

Determination of drying rate

The drying rate of produce sample during drying period was determined as follows (Chakraverty, 1988).

$$\text{Drying rate } (D_R) = \frac{\Delta W}{\Delta t}$$

Where,

ΔW = Weight loss in one h interval (gm/100gm bdm min.)

Δt = Difference in time reading (h)

Drying efficiency (ŋ)-The drying efficiency of solar dryer is the ratio of heat gained to the heat input. The heat input was calculated by considering total solar radiation incident on collector area of solar dryer during total drying hours in day (Singh *et al* 2011).

$$\eta\ ,\% = \frac{(M \times \lambda)}{(I_{AC} \times A \times t)} \times 100$$

Where,

M = Mass of water evaporated, kg

λ = Latent heat of vaporization, MJ kg^{-1}

I_{ac} = Total solar radiation, MJ m^{-2}

A = Collector area m^2

t = Time, sec.

Sensory Evaluation

Sensory evaluation was carried out to estimate organoleptic qualities of dried product produced by drying method. For determining quality of products, color, taste and texture were the main attributes for predicting the quality and consumer acceptance of anola candy produced (Winkeler *et al.*, 1974).

For sensory evaluation, the aonla samples were placed in a coded paper and presented to all the ten judges. The parameters of the sensory evaluation were colour and appearance, texture, taste, flavor, overall acceptability. The judge were asked to evaluate the product on a hedonic scale (Gudagani *et al.,* 1978), with the following rating:

Table 1 Sensory evaluation rating scale

Rating	Scale	Rating	Scale
9	Like extremely	5	Neither like or dislike
8	Like very much	4	Dislike slightly
7	Like moderately	3	Dislike moderately
6	Like slightly	2	Dislike very much

RESULTS AND DISCUSSION

Table 2revealedtemperature and relative humidity variation in solar dryer with respect to solar radiation and time during no load condition for December month- 2015. From table it has been observed that maximum temperature attained in the dryer was found to be 47^{0}C in tray 4 at 13.00 h with corresponding solar radiation of 617. 10 W/m^2 and ambient temperature, 31.10^{0}C.

Table 2.Temperature and relative Humidity variation in solar dryer with respect to solar radiation and time during no load condition (Dec. 2015)

Time	T_a	T_1	T_2	T_3	T_4	T_{avg}	SR	RH_d	RH_a	V_{amb}
9.00	23.00	35.20	36.00	35.50	36.00	35.68	330.00	30.00	33.00	0.10
10.00	25.00	40.20	38.20	39.00	39.00	39.10	380.00	31.00	35.00	0.10
11.00	29.10	47.60	42.70	43.70	44.40	44.60	487.00	35.00	41.00	0.20
12.00	29.70	46.20	48.10	41.70	42.90	44.73	629.90	36.00	39.00	0.20
13.00	31.10	53.20	42.70	46.00	47.00	47.23	617.10	35.00	37.00	0.10
14.00	31.30	56.30	44.70	45.20	45.60	47.95	534.70	30.00	34.00	0.30
15.00	32.30	53.90	44.20	45.00	44.90	47.00	406.50	26.00	27.00	0.50
16.00	31.70	46.70	40.00	41.40	40.80	42.23	236.20	25.00	25.00	0.20
17.00	29.80	38.60	35.00	35.10	34.50	35.80	97.00	24.00	24.00	0.30

Table 3revealed the temperature and relative humidity variation in solar dryer with respect to solar radiation and time during full load condition for December month. From table it has been observed that at ambient temperature of 26^0 C the corresponding temperature in dryer was found to be 28^{0}C in tray 3 at 9 h and solar radiation at that time was recorded to be 170 W/m^2. Maximum temperature recorded in dryer in tray 1 was found to be 49^{0}C followed by tray 2, tray3 and tray 4 having maximum temperature of about 42.20, 45.50^{0}C and 45.20^{0}C with corresponding relative humidity of about 16%.

Table 3 Temperature and relative humidity variation in solar dryer with respect to solar radiation and time during full load condition (Dec 2015)

Time	T_a	T_1	T_2	T_3	T_4	T_{avg}	RH_d	Rha	SR	V_{amb}
9.00	26.00	27.00	27.00	28.00	27.00	27.25	20.00	20.00	170.00	0.10
10.00	28.00	29.00	30.00	30.00	30.00	29.75	21.00	21.00	247.20	0.30
11.00	32.00	39.10	36.80	38.50	39.50	38.47	27.00	26.00	631.70	0.20
12.00	30.00	43.20	41.30	43.30	43.10	42.72	23.00	22.00	679.30	0.50
13.00	29.30	44.10	44.60	44.10	44.70	44.26	20.00	20.00	670.20	0.40
14.00	30.00	49.00	44.20	45.50	45.20	45.97	16.00	15.00	609.70	0.20
15.00	31.60	45.80	45.30	44.30	43.90	44.82	14.00	14.00	457.80	0.40
16.00	30.00	35.00	36.00	37.00	37.00	36.25	16.00	17.00	487.50	0.30
17.00	31.00	28.90	32.00	30.00	31.00	30.48	22.00	23.00	53.10	0.10

Fig.2 and Fig.3 revealed that the average moisture content percent (db) of aonla candy inside and outside sample IA and OA reduced from 63.48 to 7.14 and from 63.48 to 13.90 percent (db) in 31 h and 38 h in solar cabinet dryer and open sun drying, respectively. It was observed that the maximum moisture removal had taken place as 419.40 to 315.59 percent and 144.98 to 127.16 percent (db) upto 15 h during first day of drying.

Fig.2 and Fig.3 revealed that the drying rate varied from 0.25 to 0.001 and 0.22 to 0.0001 for drying of aonla in solar cabinet dryer and open sun drying, respectively. The average drying rate was found to be 0.897 and 0.9861 corresponding to average moisture ratio of 0.999 and 0.9922 for STD and OSD, respectively.

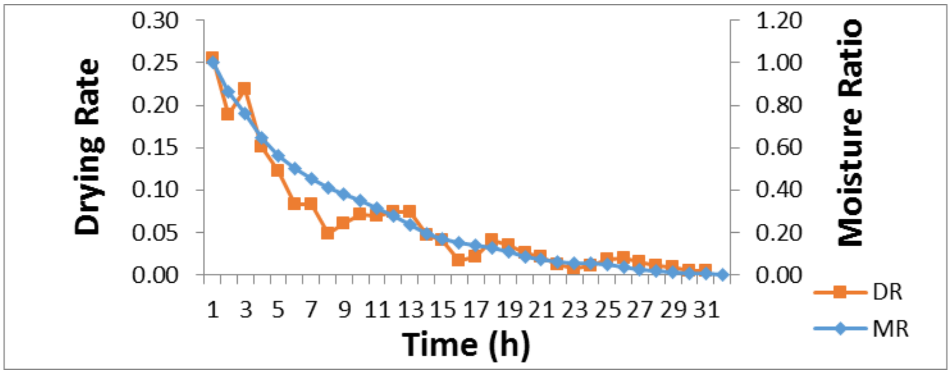

Fig 2. Variation of moisture ratio and drying rate of Aonla Candy in solar Cabinet dryer

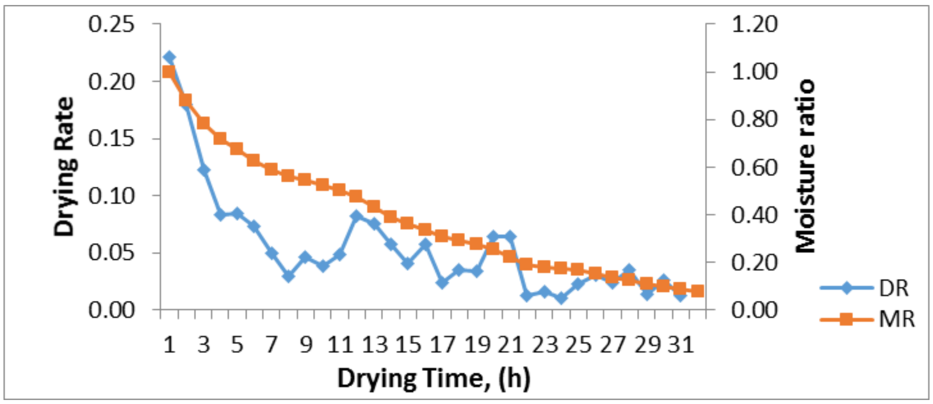

Fig 3.Variation of moisture ratio and drying rate of Aonla Candy in open sun drying.

Statistical analysis of sensory evaluation of candy.

The data obtained on sensory evaluation was statistically analyzed using ANOVA and results are depicted in Table 4. The data presented in table 4 indicated that the values obtained during sensory evaluation were significant for organoleptic characteristics viz. colour and appearance, texture, taste, flavor and overall acceptability. On the basis of standard error mean, critical difference and coefficient of variance, the aonla candy prepared in cabinet solar dryer was found acceptable and retain quality and found suitable for consumption

Attributes	Solar cabinet dryer				Open sun drying	S.E. (M)	CD at 5%	CV
	T1	T2	T3	T4	T_5			
Colour	7.1	7.4	7.8	7.4	5.5	0.07	0.1939	1.88
Appearance	7.3	7.3	7.3	7.2	5.3	0.09	0.2493	2.6
Texture	7.5	7.1	7.4	7.6	5.7	0.11	0.3047	3.15
Taste	7.6	7.5	7.8	7.9	6	0.14	0.3878	3.87
Overall Acceptability	7.6	7.5	7.7	7.7	5.7	0.14	0.3878	5.06

Table 4. Mean score of sensory characteristics of candy

It revealed that the drying efficiency of solar cabinet dryer was highest at first day i.e. 38.74% with maximum removal of moisture (21 kg) at corresponding average solar radiation 645 Wm^{-2} and average ambient temperature of 35^0C. The drying efficiency reduced with time simultaneously removal and decrease of M.C. of the product. During second and third day of drying less temperature, less solar radiation due to cloudy weather, results less removal of moisture. Therefore the drying efficiency on second and third day was found to be less as compared to first day further decreased till M.C. of the product reached to 7.6% (wb)The overall drying efficiency of solar cabinet dryer was found to be 25 %. Nearly same result for efficiency of solar cabinet dryer for drying of aonla candy was found by Pangavhane (2002). Table 6 revealed economic analysis of solar dryer for aonla candy and found that the system was economically viable.

Table 5. Daily efficiency of solar cabinet dryer

Day	Efficiency (%)
1	38.74
2	26.05
3	19.8

4	14.79

Table 6: Economic analysis of solar cabinet dryer for aonla candy.

S.N.	Description	Solar cabinet dryer
1.	Initial investment (Rs)	44,459.00
2.	Annual use no. of batches	22
3.	Cost of raw aonla (Rs yr^{-1})	27000
4.	Cost of labour for drying (Rs yr^{-1})	18000.00
5.	Operation and maintenance cost (Rs) (After every 5 yr)	4,445.90
6.	Total dried product (kg)	385
7.	Total cost of finished product @ Rs 350/kg	134750
8.	B:C ratio	1.72
9.	Payback period	8 months
10.	NPW (Rs.)	302029.11

CONCLUSIONS

The performance of natural convection solar dryer system was evaluated at no load and full load test for drying the aonla candy. The product drying time, drying temperature in dryer, solar intensity, moisture content of product, ambient temperature, and relative humidity were measured, during the test run. The solar dryer maintained temperature above the ambient air temperature at full load condition. It was found that during sensory evaluation all organoleptic qualities of candy produced in the solar cabinet dryer was better than open sun drying. It was found that the natural convective solar dryer could generate an adequate and continuous flow of high temperature air in the range of 45 to 55^{0}C. On the basis of NPW, B:C ratio and payback period, it is revealed that the investment in solar dryer is profitable and the system found economically feasible.

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