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Solar Dehydration and Storage Behavior of Coriander and Fenugreek Leaves

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ABSTRACT The present study was undertaken to study solar dehydration and storage behaviors of fenugreek and coriander leaves under different conditions. Dehydration of coriander and fenugreek leaves was carried out in three different conditions namely, open sun drying, and drying in solar cooker in covered and uncovered condition. The highest dehydration temperature of 52.57°C was attained when vegetables were dried in the uncovered condition in solar cooker. On an average, a 19-20°C temperature was noted inside the solar cooker higher than that of atmospheric temperature. In respect to evaporation rate per unit area, solar cooker dehydration method was significantly efficient over the open sun drying. Organoleptic scores during storage indicated that selected vegetables were acceptable till six months of storage period. The results concluded that black cloth covered condition of solar cooker drying was the best method for coriander leaves and for fenugreek leaves, all the methods of dehydration were at par.

INTRODUCTION

The relevance of solar energy as a drying practice of agriculture products has tremendous potential as it can easily provide the low temperature heating essential for drying. The drying practice using solar energy ranges from traditional open sun dryings to solar dryers. Open sun drying is widely used in many countries. However, open sun drying has many problems such as contamination by dust, insect, infestation, microbial attack and the required drying time for a given sample is somewhat large. The drying rate is slow and the quality of dried products is poor (Ghosal 2011). Fruits, vegetables and their products are dried to enhance storage stability, minimize packaging requirements and reduce transport weight. Nonetheless, in India, hardly any portion of perishables are dried, which leads to enormous loss in terms of money and labor, besides the steep rise in the prices of commodities during the off season. An optimal drying system for the preservation of fruits and vegetables should be cost-effective, have a shorter drying time and cause minimum damage to the product (Brackett 1987; Sagar and Suresh Kumar 2010). Therefore, the study was undertaken with the following specific objectives.

1. To study solar dehydration and storage behaviors of fenugreek and coriander leaves under different conditions during summer and winter season.
2. To compare observations of various criteria of dehydration of fenugreek and coriander leaves with the solar cooker and open drying.

MATERIAL AND METHODS

The present study was undertaken to investigate the potential of preservation of coriander and fenugreek leaves by means of sun drying and solar cooker drying, which can be useful in urban as well as rural areas to store coriander and fenugreek leaves for more time. Dehydration of coriander and fenugreek leaves was carried out in three conditions that is, open sun drying, and drying in solar cooker in covered and uncovered conditions. For the covered condition of dehydration in a solar cooker, a black colored cotton cloth was used for the experiment. A domestic type solar cooker recommended by MEDA (Maharashtra Energy Development Association, Pune) was selected for the experiment. All the solar cookers were similar in size that is, 49 x 49 x 16.5 cm with one reflector consisting of rectangular enclosures insulated at the sides and bottom and two glass covers on top. Solar radiation entered through the top and heated up the enclosures in which coriander and fenugreek leaves were placed for dehydration.

The selected vegetables used in the study were procured from the local market of Parbhani city. Coriander and fenugreek leaves were washed with running tap water and drained for 10 minute and only leaves were plucked by hand. Plucked coriander and fenugreek leaves, each

150 gm. were evenly spread on stainless steel trays. Trays were kept for dehydration in three conditions that is, open sun drying, and in solar cooker covered and uncovered conditions. The dehydration was carried to reduce moisture content by up to eight to ten percent from initial moisture content. The dehydrated coriander and fenugreek leaves were packaged in LDPE pouches (400 gauges) with the help of a sealing machine and stored in stainless steel and plastic containers at an ambient temperature. The moisture content of fresh coriander and fenugreek leaves was determined by the standard oven drying method (AOAC 1991). The temperature of open drying was measured using a laboratory thermometer and for solar cooker drying, a dialed thermometer was used. The weight of coriander and fenugreek leaves was measured using a digital top pan balance. Final moisture content was measured by using an infrared moisture balance. Moisture evaporation percentage was calculated using the difference in the initial and final moisture content. Evaporation rate, moisture removed per unit area and evaporation rate per unit area were calculated using the following formula (Nawle 1992).

$$\text{Evaporation rate} = \frac{TM_R \times 1\ \text{hr}}{D_t}$$

Where,

TM_R = Total Moisture removed (gm)

D_t = Total drying time

$$\text{Moisture removed per unit area} = \frac{TM_R \times 1\ \text{cm}}{S_a}$$

Where,

TM_R = Total Moisture removed (gm)

S_a = Total surface area used for drying (cm^2)

$$\text{Evaporation rate per unit area} = (g/cm^2/hr)\ \frac{M_R \times 1}{D_t}$$

Where,

M_R = Moisture removed (g/cm^2)

D_t = Total drying time (hr)

The dehydrated coriander and fenugreek leaves were stored for six months and the sensory evaluation was done at the intervals of 2 months. Sensory evaluation of coriander and fenugreek leaves was done in recipe form that is in the form of *wada* and vegetable salad, respectively. For the sensory evaluation panel, 10 semi-trained members from staff and students of the department were selected and evaluated for color, aroma, taste, texture and overall acceptability. A five-point scale was used for the evaluation, where 5 represents highly acceptable and 1 represents not acceptable (Patel 1994). The samples were served to the similar panelists in random order for evaluation after each interval of two months. The data was evaluated statistically.

RESULTS AND DISCUSSION

Observations of Dehydration of Coriander Leaves and Shelf Life

Dehydration of coriander leaves was carried out in a solar cooker and in direct sunlight during the summer and winter season. Results indicated that dehydration temperature attained in the solar cooker was 42-52^{o}C, which was 9-12^{o}C higher than the atmospheric temperature in both the seasons of summer and winter (Table 1). There was no significant difference found with respect to covered and uncovered conditions of dehydration in the winter season. Whereas, a significantly higher temperature (52^{o}C) was achieved in the summer season when dehydration was carried out in the uncovered condition of solar cooker drying. Weight of the coriander leaves after drying was the least in case of the covered condition as compared to other two methods that is, uncovered condition in solar cooker and open air-drying. Similarly, the final moisture content of dehydrated coriander leaves was least in case of the covered condition in the solar cooker in summer (8.95%) and winter (8.4%) season. The reason may be attributed to the fact that moisture evaporation percentage was found highest in case of the covered condition in the solar cooker in the winter (73.80%) and summer (72.35%) season.

The evaporation rate during dehydration of coriander leaves was calculated in terms of moisture loss per unit of time (g/hour). It was significantly higher in the solar cooker than open air-drying in both the seasons. But there was no significant difference between the covered and uncovered condition of solar cooker drying. Similarly, moisture removed per unit area (g/cm^2) was higher in the solar cooker than the open air-drying condition. However, statistically the difference was non-significant. Evaporation rate per unit area (g/cm^2/hour) was significantly higher in the solar cooker drying of coriander leaves in winter season. In the summer season, though the values of evaporation rate were higher for covered and uncovered conditions of solar cooker drying, statistically, the results were non-significant.

Table 1: Observations of various criteria of dehydration of coriander leaves in different conditions during summer and winter season

Treat- ments	*Tempe rature (°c) drying (g)*	*Weight after tion (%)*	*Moisture evapora- content (%)*	*Final moisture (g/hr)*	*Evapora tion rate per unit area (g/cm^2)*	*Moisture removed*	*Evapo- ration rate per unit area ($g/cm^2/hr$)*
Winter							
T_1	32.81	28.98	72.95	9.8	6.364	0.0805	0.007
T_2	45.36	28.71	73.8	8.95	15.487	0.082	0.0171
T_3	45.26	28.84	73.7	9.05	15.45	0.081	0.0171
F value	22.00**	NS	NS	20.44**	9.534*	NS	9.471*
SE±	1.53	1.37	1.456	0.102	1.702	0.00154	0.00189
CD	5.31	4.75	5.031	0.354	5.881	0.00535	0.00654
Summer							
T_1	42.95	29.21	71.5	9.25	11.071	0.0794	0.0122
T_2	51.6	28.86	72.35	8.4	21.112	0.0803	0.0234
T_3	52.57	29.16	71.8	8.95	20.952	0.0797	0.0232
F value	338.20**	NS	NS	10.79*	14.98**	NS	15.003
SE±	0.287	0.0884	0.232	0.131	1.485	0.00032	0.00165
CD	0.993	0.305	0.802	0.453	5.133	0.00113	0.0057

T_1 – Open air drying
T_2 – Covered condition in solar cooker
T_3 – Uncovered condition in solar cooker

* Significant at 5% level of significance
** Significant at 1% level of significance
NS – Non significant

Under constant drying conditions, evaporation rate per unit area is always constant (when surface moisture is removed). The whole drying of coriander leaves took place in falling rate only and there was no constant rate period in case of solar cooker drying. Whereas constant rate period was observed in case of open air-drying in winter season. Variations in relative humidity and evaporation rate during dehydration of coriander leaves were also observed. The relative humidity and evaporation rate at the beginning of drying were highest and it was indicated that drying of coriander leaves took place in falling rate. At the end of the drying period, the values of relative humidity and evaporation rate were minimum.

The observations of the dehydration of coriander leaves indicated that the moisture evaporation rate per unit of time and per unit of area was highest in solar cooker drying in the covered condition during both the seasons. Results obtained by Navale et al. (2014) also showed that the drying time for cabinet solar drying was found to be forty-three percent lesser than that of open sun drying. The black cloth covered condition for dehydration of coriander leaves in the solar cooker is a more suitable condition than the open air-drying. The organoleptic test revealed that the covered condition in solar cooker drying was the best method of dehydration for the retention of texture and aroma in the dehydrated coriander leaves. At the end of six months of storage, all the samples of dehydrated coriander leaves were considered moderately undesirable for all sensory characteristics. Statistically there was a highly significant effect of duration of storage on the physical characteristics of dehydrated coriander leaves.

Observations of Dehydration of Fenugreek Leaves and Shelf Life

Observations of dehydration of fenugreek leaves carried out in the solar cooker and direct sunlight in two different seasons of summer and winter indicated that the dehydration temperature attained in the solar cooker (44°-45°C) in the winter season was 13°-15°C was higher than that of the atmospheric temperature (31°C). Whereas, in the summer season it was 19°-20°C higher in the solar cooker (51°-52°C) than the atmospheric temperature (33°C). Ghosal (2011) also reported that the outlet temperatures in the dryer were found to be around 8-9°C higher than that of the ambient air temperature.

There was no significant difference found in dehydration temperatures in covered and uncovered conditions of solar cooker drying. Weight of the dehydrated sample of fenugreek leaves did not differ significantly as per the condition of drying in both the seasons. Whereas, moisture evaporation percentage was similar in all the three conditions of drying in the summer and winter season (Table 2).

Final moisture content of dehydrated fenugreek leaves was not significantly different in open air-drying and solar cooker drying in the winter season. But during the summer, it was significantly higher in the covered condition in the solar cooker because the dehydration temperature observed in the covered condition in the solar cooker was higher than that of the uncovered condition.

Evaporation rate (g/hour) during dehydration of fenugreek leaves in solar cooker was significantly higher than that of open air-drying in both the seasons of summer and winter. A similar trend was found in case of moisture removed per unit area (g/cm^2) and evaporation rate per unit area (g/cm^2/hour). The drying rate of fenugreek leaves under different drying conditions showed a faster rate of drying in case of the solar cooker than open air-drying. Open air-drying necessarily had to be carried out over a period of two days to achieve the final moisture content. The whole drying process took place at a falling rate only and there was no constant rate period in case of solar cooker dehydration. These observations are in line with those reported by Pande et al. (2000). A comparative study conducted by Singh et al. (1997) revealed that green leafy vegetables did not have any constant rate-drying period and the whole drying process took place in falling rate. The literature available supports the present study results that the constant rate period was absent during dehydration of fenugreek leaves. Data illustrated that relative humidity had no significant influence on evaporation rate. This was due to the intense heat and limited air circulation inside the solar cooker. From the above results, it can be said that at the end of the experiment, the dehydrated samples of fenugreek leaves were almost similar in terms of final weight and moisture content under all the selected conditions. Whereas in terms of the evaporation rate, moisture removed per unit area and evaporation rate per unit area, the solar cooker drying was a superior method for drying fenugreek leaves than open air-drying. There was not much difference found in covered and uncovered conditions of solar cooker drying.

Sensory evaluation indicated that the color of fenugreek leaves in case of solar cooker dehydration in the uncovered condition was not acceptable and the texture of the dehydrated fenugreek leaves in case of open air-drying and covered condition in solar cooker drying was

Table 2: Observations of various criteria of dehydration of fenugreek leaves in different conditions during summer and winter season

Treatments	*Tempe rature (°c) drying (g)*	*Weight after tion (%)*	*Moisture evapora- content (%)*	*Final moisture (g/hr)*	*Evapora tion rate per unit area (g/cm²)*	*Moisture removed*	*Evaporation rate per unit area (g/cm²/hr)*
Winter							
T_1	31.175	29.41	76.55	9.5	6.378	0.0849	0.0072
T_2	45.76	28.43	77.05	9	10.318	0.0835	0.0132
T_3	44.73	28.66	76.55	9.5	11.857	0.085	0.0131
F value	5.62*	NS	NS	NS	8.32*	NS	39.74**
SE±	3.43	1.119	0.534	0.408	0.979	6.158	0.00056
CD	11.85	3.868	1.84	1.41	3.385	0.00212	0.00195
Summer							
T_1	33.071	28.045	76.6	9	11.844	0.0845	0.0131
T_2	51.1	28.66	75.6	10	18.9	0.0835	0.0205
T_3	52.155	30.165	76.5	9.1	15.3	0.0845	0.0169
F value	58.56**	NS	NS	273.00**	160.43**	NS	109.41**
SE±	1.401	1.015	3.28	0.0333	0.278	0.00028	0.00035
CD	4.843	3.507	1.134	0.115	0.962	0.0004	0.00122

T_1 – Open air drying
T_2 – Covered condition in solar cooker
T_3 – Uncovered condition in solar cooker

* Significant at 5% level of significance
** Significant at 1% level of significance
NS – Non significant

less acceptable. Hence, it can be concluded that the method of dehydration and duration of storage had significant effects on the acceptability of physical characteristics of dehydrated fenugreek leaves. Further, it can be stated that at the end of six months of storage, all sensory characteristics scores were at par as all the dehydrated methods. Hence, no selected dehydration method is recommended for the dehydration of fenugreek leaves.

CONCLUSION

It can be concluded that the black cloth covered condition of solar cooker drying was the best method for coriander leaves and all the methods of dehydration were at par for fenugreek leaves.

RECOMMENDATIONS

It is recommended that dehydration of green leafy vegetables in the solar cooker is feasible and these vegetables can be stored for six months.

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