

Potential application of Solar Energy for Drying: A case study

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Abstract

This paper presents the analysis and results of a pilot survey regarding potential solar energy consumption for the drying of vegetables. Solar Drying is the simple and inexpensive preservation techniques of agricultural produce by promoting the mass transfer. Vegetables are dehydrated under the open sun in maximum places including sub-tropics. However, this approach of drying degrades the quality of the dried products due to interference from external impurities and leads to irregular drying rates. Numerous types of dryers have been designed and developed in various parts of the world, yielding anecdotal degrees of technical performance among which solar dryers seem to be most economical. A questionnaire was framed to gather the responses from the populace regarding the awareness about the solar dryers or other alternative drying methods. Approximately 350 households were interviewed regarding their drying method. It was found that common populace lack knowledge about the drying technology and open sun drying is the prevalent drying method.

Keywords: Electric Dryer, Moisture content, Oven Drying, Solar dryer, Water activity.

Introduction

Jammu and Kashmir covers the northern boundary of India and lies between the latitudes $32^{\circ} . 17'$ to $36^{\circ}.58'$ north and longitudes $73^{\circ} . 26'$ to $80^{\circ} .26'$ east. The state occupies a strategic position in India with borders touching Pakistan in the west, China & Tibet in the north & east and in the south Indian States of Punjab and Himachal Pradesh. J&K has a geographical area of 2,22,236 sq. kms comprising 6.93% of the total area of the Indian territory. Kashmir valley experiences severe frosty climate from December to February as evident in the data obtained from the Indian Metrological Department Srinagar Station summarized in Table 1 and winter temperature plot can be observed in Figure 1. Freezing temperature leads to acute scarcity of local fruits and vegetables as cultivation is not possible because of severe cold and harsh weather conditions as already quoted by Kumar (2005) and Aadil 2017. While as in the months from July to September there is suitable temperature leading to a glut of per capita vegetables, can be observed in the paper by Bhat (2009) which gets perished if not appropriately preserved.

The moisture content in foodstuff is foremost reason for its spoilage during the course of storage. Due to the moisture eatables are prone to fungal infection, invasion by insects, pests, moulds. The majority of the fruits and vegetables have the moisture content of 75-90 %.

Open sun drying is one of the traditional processes for the preservation of different food products in various parts of the world. The exclusion of moisture from food is necessary in order to extend the shelf life which is otherwise prone to microbial growth. Water acts as medium for heat storage and heat transfer. It provides H^{+} (proton) and OH^{-} (hydroxide) ions which can act as solvent, reactant in the food matrix as explained by Chiech (2006). The simplest method of drying is Open Sun Drying. Solar drying has positive economic,

environmental, and social effects on human life Pirasteh (2014). Since times immemorial, open sun drying is being used as preservation techniques for vegetables, fruits, medicinal plants, grains etc explained by Ratti (1997) as it does not require any capital cost. Open Sun drying is thus a common practice of dehydrating vegetables in Kashmir Valley. However, this technique often entails contamination, insect infestation, microbial attack, nutritional deterioration, bird droplets, blackish colour due to Ultra Violet radiation exposure already quoted by Ayensu 1997. Sun drying is still extensively used in numerous tropical and subtropical countries, but the quality of the dried products is far below the international standards. In order to overcome such problems different types of Dryers have been designed referred by different people [Pirasteh (2014), Tiwari A (2016), Ashish (2014)] and demand of dryers is increasing day by day. Dehydration can be done by supplementary methods, such as oven drying, electric drying and mechanical drying.

The energy needed for drying intention can be obtained from different sources, like electricity, fossil fuel, natural gas, and solar energy. Although the use of solar radiation for drying has existed since long back, but energy has not been harnessed for sophisticated drying in Kashmir Valley, particularly in the industrial sector. Considering the rapid depletion of natural fuel resources given by Mittal (2005), intensifying fossil fuel expenditure and increasing energy demand concerns solar drying is expected to become promising feature during present era. Besides if we take environmental considerations and damages caused by humans due to increasing consumption of fossil fuel, it will prompt people to use renewable energies as a clean and sustainable resource. Consequently, to make potential application of solar energy in different fields is need of hour.

Climate and Land Distribution

Kashmir valley experiences severe frosty climate from December to February as evident in the data obtained from the Indian Metrological Department Srinagar Station summarized in Table 1 and winter temperature plot can be observed in Figure 1

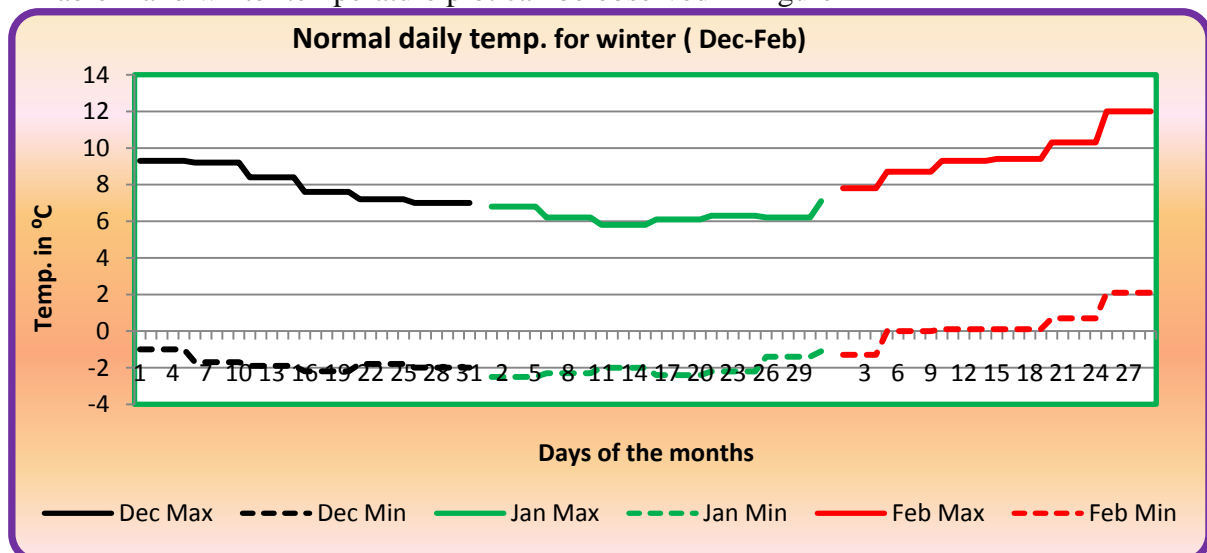


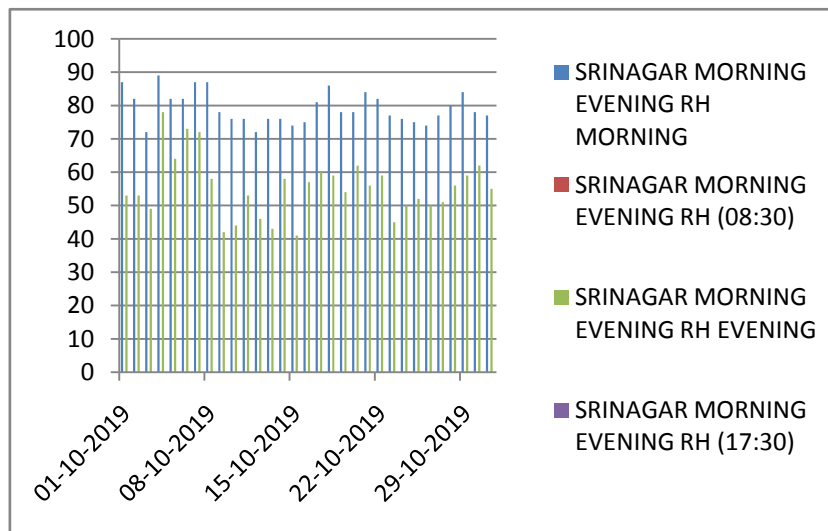
Figure 1. Temperature trend in Kashmir Division during Winters

Table 1: Mean

Month	Mean Max Temperature Deg. Celcius	Mean Min Temperature Deg.Celcius	Total Precipitation for the Month in millimeters
January	2.3	-4.3	125.6
February	2.7	-3.8	148.9
March	5.9	-0.5	75.9
April	10.2	2.3	121.6
May	15.7	9.6	108
June	22.3	14.3	126.1
July	24.2	14.9	71.6
August	25.8	15.3	17.4
September	20	9.7	48.8
October	14.2	7.3	7.4
November	8	5.3	50.8
December	4.4	-5.9	31

Maximum, Minimum Temperature and Precipitation in Kashmir Division (IMD)

It can be observed that the temperature during the months from June to September is ambient for cultivation of agricultural produce. Optimum precipitation in summer and Snowfall during winters remains as a reserve for the irrigation which leads to surplus growth of the vegetation during summer season. The Relative Humidity during the months of September and October remain ideal for the dehydration & concentration of the matter inside the vegetables as indicated in the figure 2 as per the data obtained from IMD, Srinagar Station.

**Figure-2:** Relative Humidity in Kashmir Division during the month of October

According to statistical data, Geographical Area of J & K 42241 Km². The distribution of the land for the cultivation purpose is given in table 2. From the data it is evident that the

net cultivated area of Kashmir Division is less in comparison to Jammu division which leads to the lesser vegetation. Moreover due to the climate of Kashmir division the maximum cultivated land is not able to yield vegetables during the winter season. Thus procuring of vegetables from other parts of country is necessary for the fulfillment of requirement. It also becomes the reason that people dry the surplus vegetables during the Summer season to be used during the winter periods.

Particulars	Jammu division	Kashmir division
Farm Operating Families 1193211	546790	646421
Net Cultivated Area 7.52 lac ha	3.90 lac ha	3.49 lac ha
Gross Cultivated area 12.44 lac ha	7.54 lac ha	4.90 lac ha
Net area irrigated 3.48 lac ha	1.34 lac ha	2.14 lac ha
Un-irrigated 4.04lac ha	2.56 lac ha	1.35 lac ha

Table 2: Distribution of cultivated land in J&K.

Mechanism of Drying

Drying is the concentration of matter through the reduction of free water to a level that prohibits water activity without destroying the tissue, edibility or aesthetic appearance of the food. It involves heat and mass transfer and consequently leads to elimination of moisture from the foodstuff. Drying is accomplished in two stages. In first stage, the moisture inside the product is brought to the surface of the product and dried in air at a constant rate. The second stage involves a slow drying rate and its course is associated with the properties of the material to be dried. The movement of moisture in solid is the outcome from the concentration gradient developed, depending on the characteristics of solid as explained by Hii and Jagnam (2012)

In the moist food the value of free moisture or Water Activity (a_w) is high, which is determined by:

$$a_w = \frac{P}{P_w}$$

Where:

P = Partial pressure of water over the wet solid system

P_w = Equilibrium vapor pressure

The Water Activity (a_w) is one of the most critical factors in determining quality and safety of food. It affects the shelf life, safety, texture, flavor and smell of foods. For every food there exists an activity limit below which microorganisms stop to grow and multiply. Therefore lowering the value of water activity may be important for controlling spoilage of food, which is usually done by drying.

Free moisture in food becomes the reason for the microbial growth. Throughout the drying process the moisture content of the food is be reduced. The bound moisture content in the

food leads to severe deterioration like non enzymatic browning because of the milliard reactions, lipid oxidation, vitamin degradation [Osuna (1998)].

Moisture content is expressed as percentage wet basis and then converted to gram water per gram dry matter. The moisture Ratio is

$$M.R = \frac{M_x - M_e}{M_o - M_s}$$

M_x = Product moisture at time t

M_e = Moisture equilibrium,

M_o = Initial moisture.

Transport of moisture within the solid occur by following methods [Jangam, Majumdar(2010)]

Liquid Diffusion; If the wet solid is at the temperature below the boiling point of the liquid.

Vapor Diffusion; If liquid vaporizes within the material

Knudsen Diffusion; If drying takes place at very low temperature and pressure, like freezing

Surface Diffusion; Not yet established

Hydrostatic Pressure Difference; When internal vaporization rates exceed the rate of vapor transport through the solid to surrounding.

Combination of any two diffusion processes given above.

Laboratory Drying Equipments

There are various kinds of drying equipments which work on electricity and are massive in size.

Similarly there are numerous types of dryers available worldwide which include electric dryers, oven dryers, solar dryers [Ekechukwu (1999), Fudholi (2008), Bena (2002), Weiss (2012), Sopian (2009)] (convective, non-convective) etc. Normally the natural convective dryers incur lesser cost during the course of the manufacturing and are simple to operate.

Few of the Electric dryers are available in Department of Food Technology, Sher-e-Kashmir University of Agricultural Sciences (SKUAST) Kashmir. These dryers are used for research purposes which are shown in Figures 3,4,5.

Commercial electric dryer is available at the office of Department of Agriculture, Lal Mandi Srinagar where people can pay money for drying of the vegetables, but maximum people are unaware of that dryer.



Figure 3: Cabinet Dryer



Figure 4: Tray Dryer



Figure 5: Spray Dryer

For food drying, cabinet (electric) drying is good for quick drying but needs constant monitoring, care and heavy electric expenses are also occupied. Moreover, capital investment is too high which is unaffordable for common populace. Similarly other mechanical drying methods need humungous machinery which is inaccessible for common masses or homemakers. All such dryers are used either by the researchers or at the commercial level. Many types of such dryers have been designed which are being used at commercial level or at the laboratory level [Shahi, 2011]. These reasons force people to choose for Open Sun Drying, which does not necessitate any electric supply or any capital / maintenance cost. Open sun drying is the most common method of drying vegetables in Kashmir division but has many drawbacks associated with it like sudden rain, insect infestation, rodent attack, dust, uneven drying surface, microbial growth etc [Kadam (2006)].

Thus there arises need for solar dryers which helps to minimize the drawbacks and will lower the capital investment cost. Solar drying is the most attractive methods used to preserve fruits and vegetables. It can eliminate wastage, increase the productivity of agricultural, and improve the production of fruits and vegetables in term of quality and quantity [Hawladar, 2006].

Survey Methodology and Profile of Surveyed responses

A survey was carried out regarding the assessment of the awareness about the Solar drying systems, drawbacks of Open Sun Drying, problems faced by people during OSD among the masses by framing a questionnaire for the collection of responses. The survey was done in rural as well as urban areas and was circulated among the people associated with different professions belonging to different age groups. In this survey, a questionnaire was framed for the collection and compilation of responses regarding different aspects of food preservation by drying. The items of the questionnaire are summarized in the appendix which includes: household characteristics, size of household, occupation. The main items of questionnaire are awareness about the different drying systems and types of preservation methods used by the people.

The survey was done to observe the availability of kitchen garden in the local households. It was found that the 85% people residing in rural areas have the availability of kitchen gardens in their places. Maximum people cultivate land for growing vegetables and prefer to dehydrate the excess vegetables at home Owing to the organic growth of vegetables,

people residing in the urban areas also prefer to cultivate the vegetables at home though lack much space for kitchen garden. Some natives acquire vegetables during summer and dehydrate the same for winters.

The histogram in Figure 6, illustrates the percentage of people facing different troubles during open sun drying. On circulating the questionnaire among masses, it was observed that the people often encounter different difficulties while dehydrating vegetables in open sun. Most of the people (40%) inferred the fungal growth on the dried vegetables which is actually because of the improper drying rate. As the weather in Kashmir Valley is unpredictable, the 30% of populace face the problem of sudden rain due to which the food kept for drying is to either lift immediately as rain starts or gets spoiled due to the rain. The 25% people experienced the damage due to rodents and birds hence remain a liability to dry vegetables at home. A few people are aware about the hazards of the dried food and avoid the consumption of same. Degradation of the quality is also because of direct UV exposure leading to the blackish colour.

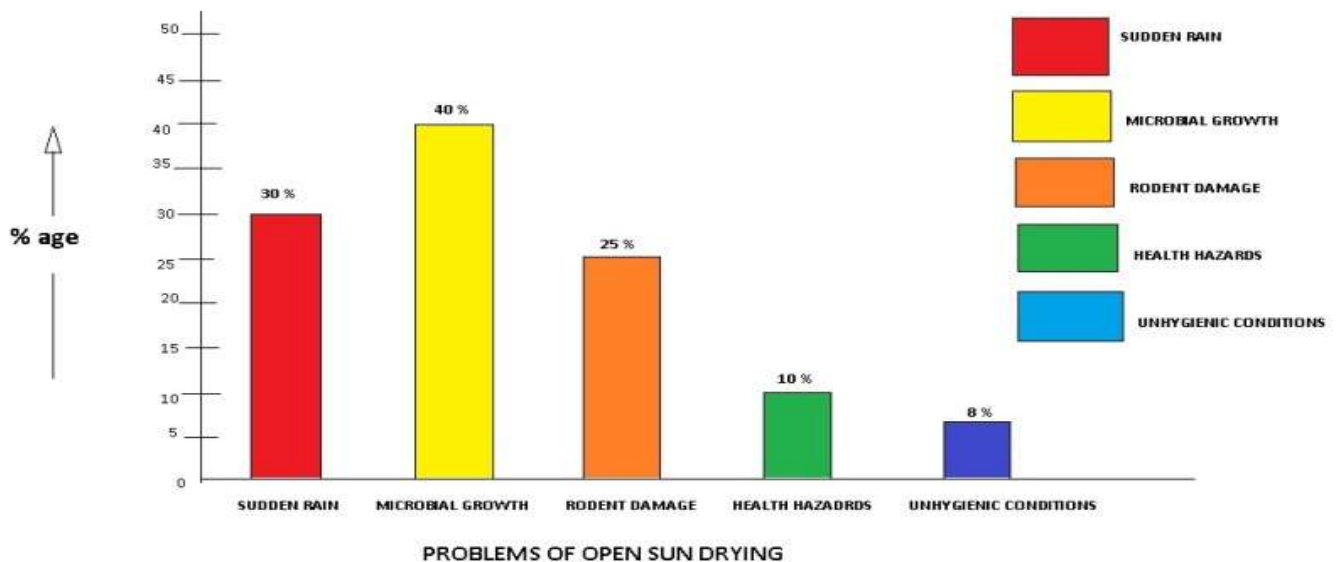


Figure 6: Percentage of people facing different problems during OSD

The survey was conducted to observe the awareness among the people regarding the different types of drying methods. In Figure 7 histogram illustrates the extent of knowledge that common people have about the drying systems. Open Sun Drying is the most prevalent method of drying, in rural areas almost 90% people dry vegetables in open sun and in urban areas around 70% people dry food stuff in open sun. It's observed that most of the people lack awareness about different types of drying systems, most of the people have not even heard about the dryers both in rural as well as in urban areas. Only 3%- 4% people are aware of drying systems but have never used the same. Though people related with Agricultural Research may claim to have some knowledge about the dryers but cannot realize the applied potential at home at home, reason being elephantine capital cost. 4%-5% people dry food for the experimental evaluation in the department of Food Technology.

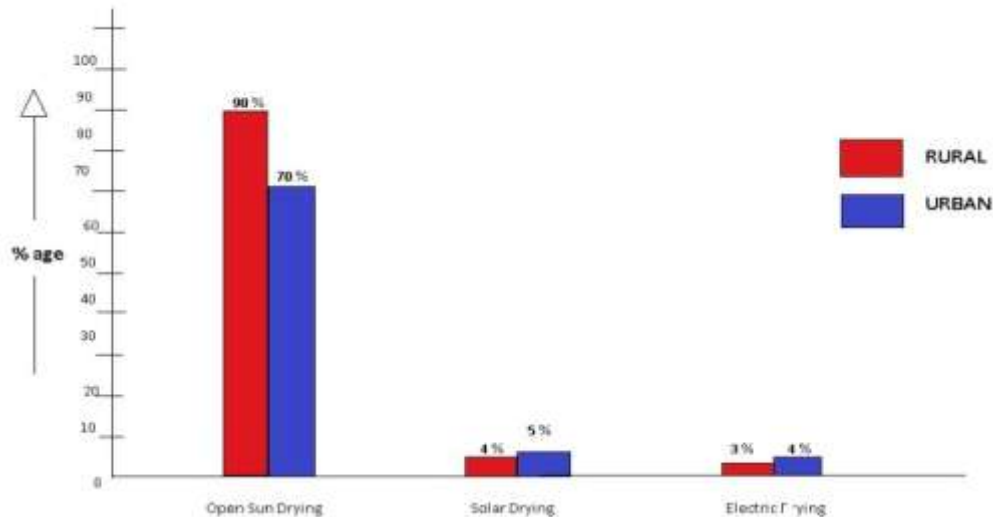


Figure 7: Awareness about different drying systems

Questionnaire incorporated procuring knowledge about the need of consuming dried vegetables in Kashmir Valley during the winter season which is illustrated in the histogram of Figure 8. It is a known fact that because of the geographical distribution of Kashmir division remains disconnected from the other parts of country due to National highway (NH44) blockade. Furthermore there is less vegetation due to harsh climatic conditions, so people are left with very little choice than to use dried vegetables. There is a potential market of dried vegetables in the division which can be seen in figure 9 and 30% people depend entirely upon dried vegetables to meet their nutritional requirements in the winter season. Moreover, the people use dried vegetable as a delicacy (40%), like people cook dried tomato (tamatar hatche) with fish in winter. Dried fish known as Hokh Gade are fried and cooked to serve taste buds of connoisseurs in the chilling cold. Dried turnips called as Gogji Aare is a household delicacy in the days spent in commemoration of a Sufi Saint popularly known as Batamaloo sahib. Dried vegetable is panacea in the winter from cough and cold.

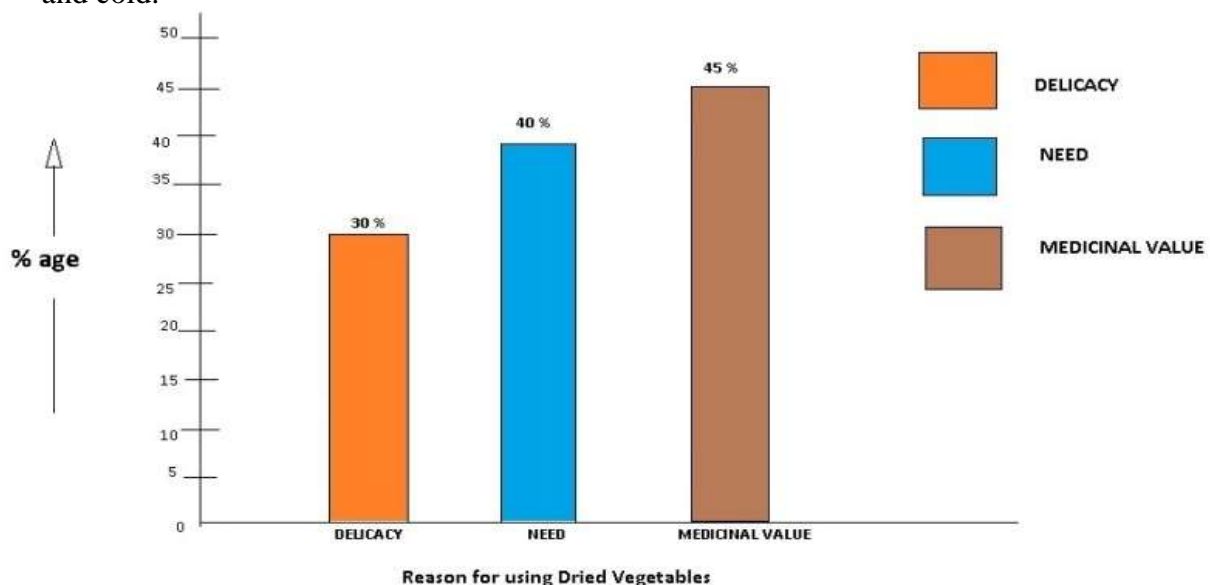


Figure 8: Reason for using dried vegetables



Figure 9: Dried vegetables in Market

Certain dried vegetables are considered to have medicinal values around 45%, like Wopal Haakh [Nepalese Teasel (*Dipsasus Inermis*)], Bam Tsunth [Quince (*Cydonia Oblonga*)] Ali (2015), Hand [Dandelion (*Taraxacum officinale*)], Kretz [Iberian starthistle] etc. Kretz is usually consumed by Gold smiths for a food fad of sharp eyesight. As a part of folklore Dried Dandelion is being essentially served to this day to female folk after child birth, faith is that it raises the Hemoglobin. Kashmiri Pandit cook Wopal Haakh in the dried form as a blessed food with austerity. Kashmiri Pandits cook it in the dried form and relish it. Apart from it being a must on the menu during Religious rituals especially while breaking the Fast. Much sought after in winter, Diaspora craves for it as one of the culinary blessings prescribed by the Rishis-the hermit sages. Even dried Egg Plant is cooked in the marriage ceremonies of Kashmiri Pandits.

Survey also incorporated procuring the knowledge about health hazards of dried vegetables dried in open Sun. Though the some people associated with medical fraternity are principally aware about the health hazards of dried vegetables yet may consume dried vegetables during winter season for reasons more traditional and spiritual than logical.

Conclusion

It is observed that the consumption of dried vegetables is almost indispensable in Kashmir division during winter due to various reasons which include non availability of fresh vegetables, health reason and delicacy related with dehydrated products. There should be some hygienic, economic, non hazardous, easy to handle method of drying for the people living in this division. The problem can be solved by a Solar Dryer. The Dryer should be energy efficient, economical and consume less duration of time for drying as the weather changes anytime in this region.

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