Prospects of solar drying in Uttarakhand

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Energy is a vital input for the progress of any country and for its economic and social development. It is one of the basic needs and a means to increase productivity, enhance employment opportunities, and improve the quality of life of the people. Conservation of energy has become the watchwords of countries worldwide. The extraction, conversion, and utilization of fossils fuels, coupled with increasing population, have led to serious environmental degradation. Fossil fuels, mainly coal and petroleum, lead to large-scale environmental degradation, loss of forests, water and air pollution, generation of wastes like fly ash, and emission of GHGs (greenhouse gases) that contribute to climate change. As the entire world is suffering from energy crisis and the traditional methodology of energy production is one of the major causes behind serious environmental degradation, attempts are being made worldwide towards environmental conservation through energy conservation. The same philosophy is finding place in the food industry. For instance, solar food dryers play an important role in the drying of agro-produce, which is an excellent way to preserve food. They are an appropriate food preservation technology for a sustainable world.

Drying is an important step of food and agro-produce processing, which include cultivation, storage, and so on. Drying of products that contain a high amount of moisture need a typical methodology, and the food and agro industries follow the electric-based control drying technology. This consumes a huge amount of energy.

However, solar thermal energy used in the drying process is fully suited to the need for sustainable development. The research work and practical experiences obtained in the last 30 years

Table 1 List of agro-products with moisture content and allowed temperature for drying

Agro-Product	*Moisture Content (% w. b.)*		*Max. Allowed Temp. (°C)*
	Initial	*Final*	
Paddy	22-24	11	50
Maize	35	15	60
Wheat	20	16	45
Corn	24	14	50
Rice	24	11	50
Green peas	80	5	65
Carrots	70	5	75
Onion	80	4	55
Garlic	80	4	55
Potato	75	7	75
Graphs	80	15-20	70
Bananas	80	15	70
Mulberries	80	10	65
Coffee	55	12	—
Cotton	50	9	75
Groundnuts	40	9	50
Soaked trees	60	12	50
Mahogany	35	11	—
Lather	50	18	35
Fabrics	50	8	75
Pulses	20-22	9-10	40-60
Oil Seed	20-25	7-9	40-60
Cauliflower	80	6	65
Chillies	80	5	65
Apples	80	24	70
Apricot	85	18	65
Guavas	80	7	65
Okra	80	20	65
Pineapples	80	10	65
Tomatoes	96	10	60
Brinjal	95	6	60
Figs	80	24	—
Yams	80	10	65
Copra	30	5	—
Peaches	85	10	65
Cabbage	80	4	55
Cocoa beans	50	7	—
Fish, raw	75	15	30
Fish, water	75	15	50
Nutmeg	80	20	65

show that solar drying technologies help to achieve controlled process of drying, reduce fuel consumption and drying costs, maintain high quality of products, and obtain high dries output under controlled industrial conditions. However, study on a localized basis is essential for estimating the drying potential for different products that are abundantly produced in these regions.

Research and development

There has been a constant interest in the country in respect to solar drying of products. This includes research activities in a number of R&D (research and development) institutions, designing and fabrication of prototypes, and field applications involving large solar dryers. Efforts are being made for the development, designing, and dissemination of solar dryers, both direct and indirect types, by various researchers.

It has been reported that a solar dryer with natural convection is usually slower than the forced convection dryers as far as drying rates are concerned. However, higher drying temperature can be reached in the former. Small portable batch dryers have also been developed in India using forced convection. A trolley-type batch dryer has been designed at Punjab Agricultural University, Ludhiana. A 1-tonne-per-day-capacity solar dryer has been designed, fabricated, and installed at the Modern Rice Mill at Manlur in Chidambaram, Tamilnadu, to dry parboiled paddy. A 5-tonne-per-day capacity drier based on the above design was installed at the Central Farm Corporation in Ludhiana, Punjab, to dry paddy harvested during the rainy season.

Two industries that have attracted attention from solar drying point of view in the country are the tea and tobacco industries. TERI (The Energy and Resources Institute) has successfully demonstrated biomass-based drying technology for cardamom in the northeastern region of India. Solar air heating technology has also been used effectively under various programmes of the MNRE (Ministry of New and Renewable Energy) for drying/curing of agricultural products, regeneration of dehumidifying agents, seasoning of timber, tanning of leather, and many more industrial and agro processing activities. Various kinds of solar dryers (such as cabinet dryer, roof-integrated solar air heating systems, tunnel dryer, and solar-powered solar air dryer) have been developed and used in different field conditions in the country. Presently,

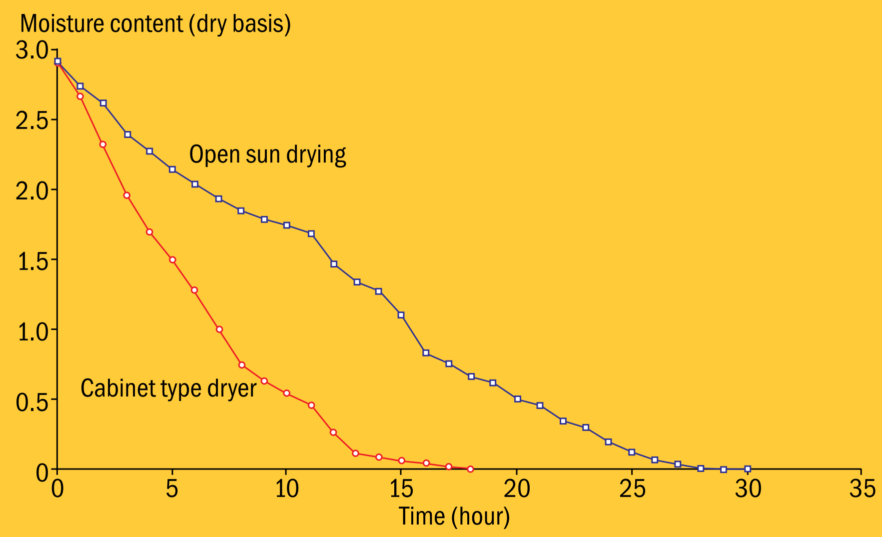

Figure 1 Solar drying vs open sun drying

there is a sizable solar industry and market in the country, which includes solar drying for industrial applications.

The potential of uttarakhand

The Himalayan regions of India are major sources of medicinal plants and fruits, aromatic plants, herbs, flowers, and a number of cash crops. In the hilly regions of Uttarakhand, a number of verities of agro-crops, fruits, vegetables, herbs, and typical cash crops are produced. The traditional method of drying these produce is open-air sun drying, which is subjected to high stage deterioration and losses. Furthermore, open-air drying does not protect the raw produce from contamination, dirt, debris, insects, and germs. Though electrical/fuel-fired drying systems help the farmers in drying their products at a relatively faster rate, they are not popular among the poor farmers of the hilly regions due to the higher initial cost of the dryers. Moreover, electricity is expensive and often, it is not available in the rural areas uninterrupted. Use of solar energy-based drying systems is the solution because of their low cost, sustainability factor, and environment-friendliness.

In addition, large areas are being brought under herbal cultivation. Local farmers are being encouraged to take up the cultivation of herbs and medicinal plants. The herbs are used in all forms—roots, steam, leaves, flowers, and fruits. Many of these are used in the form of dried products and others are used by solvent extraction. Due to the open drying methods, there is a large deterioration of the quality of the products due to dust, fungus, humidity, unfriendly climatic conditions, and so on. For the quality maintenance of some herbs, low drying temperature (~25–50 °C) is required, while for some other herbs rapid drying at high temperature is required. In the ongoing research project, some locally grown products with very high moisture content, which can have multiple applications as well as medicinal values, have been dried under moderate temperature range. These include lemon, orange, gooseberry (amla), mint (pudeena), and onion. However, it may be noticed that the solar drying technology has not effectively penetrated the hilly regions of Uttarakhand so far. In addition, tea production is on the higher priority of the state. This is in spite of the belief that these regions are bestowed with favourable conditions for applying solar drying technologies. It is in this context that a proper resource assessment and potential estimation of solar drying and design and development of various types of solar dryers in the hilly regions of Uttarakhand is much required.

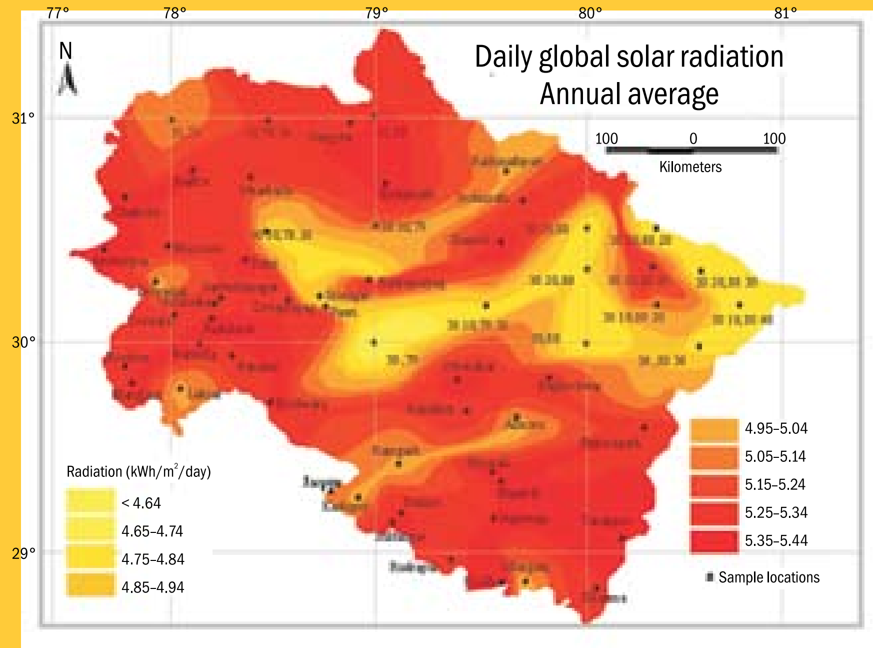

Figure 2 Solar radiation map of Uttarakhand

Solar radiation over uttarakhand

Uttarakhand has multiple micro-climatic zones. The hilly areas are close to 'cold and sunny' and 'cold and cloudy' climatic zones, while some locations like Dehradun lie under semi-moderate climate. In addition, the plains of the state like Haridwar and Kashipur lie in the composite climatic zone. The entire state receives good amount of solar radiation, about 4–6 kWh/m^2/day. Using satellite data, a solar radiation map has been plotted, which shows the potential areas of solar radiation. It has been observed that the potential areas of solar drying receive good amount of solar radiation over the year. The solar radiation mapping of the state has also been done for every month and correlated with the season of the harnessing of the agro produces, medicinal plants, and other produce. A good synchronization between these indicators has been observed in the hilly parts of the state.

Experimental investigations

In order to check the viability of the solar drying technology in the hilly areas of Uttarakhand, two prototypes of solar drying systems (one cabinet type and the second convective cabinet type) have been designed, fabricated, and installed at Srinagar, Uttarakhand (Latitude=30.13 °N, Longitude=78.47 °E, and Altitude=532 m). A number of

Table 2 Availability of medicinal plants/produces in the hilly areas of Uttarakhand by districts

Name of the district	Local name of the medicinal/herbal plants
Pauri	Awala, Bharmil, Banashpa, Bahara, Bheeal, Bharami, Cahnar, Chirata, Choru, Coranda, Ghantil, Giloie, Hearda, Hishar, Jawan, Kachnar. Kali-ghass, Karonda, Kingod, Kunja, Mint, Morada, Timaru
Chamoli	Ashawa ghanda , Atish, Awala, Baal chari, Baharmi, Baheara, Bajukijad, Bal charri, Ban haldi, Bandarmul, Basila, Bazardantti, Beal, Bhang, Bharami, Bhutakesh, Chippi, Chiraie, Chirata, Chitarak, Chouru, Dollu, Eshawa goal, Faran, Gadrain, Gamhar, Giloie, Hathjari, Heara, Jamboofaran, Jatamashi, Jiruna, Jiyapota, Kalazeera, Kalihari, Kapporhaldi, Katuki, Kirmadkijad, Kukrodha, Kunju, Kuut, Ladumfarin, Lasora, Makku, Malkagani, Mandtharai, Mashi, Mint, Mitha, Moria, Muskdana, Padal, Pashanbhad, Pipli, Prisnparani, Puranwa, Reahtta, Sahajan, Sajiwa, Salaparai, Samawa, Sanya, Sapiwa, Sarpgandha, Satawari, Silajeet, Silpahara, Sitaashok, Warmau, Waarun, Wigala, Wirhati
Rudraprayag	Archu, Atish, Awala, Ayar, Banashpa, Beahra, Beal, Brahami, Chandan, Chooru, Faran, Ghula-ghass, Gilaoie, Mishwa, Neem, Retha
Tehri	Atish, Awala, Beal, Bahara, Bhang, Burans, Chirata, Chouru, Coranda, Faran, Giloie, Heara, Hing, Hishar, Kadwi, Kingod, Kunja, Giloie, Makku, Mint, Moria, Silphara, Timaru
Uttarkashi	Atish, Awala, Beeal, Baheara, Bhang, Burans, Chiratya, Chorru, Coranda, Faran, Giloie, Heara, Hing, Hishar, Kadwi, Kingod, Kunja, Giloie, Makku, Silphara, Timaru
Almora	Awala, Ritha, Tejpat, Ashwa –Ghantha, Pashan –Bhead, Samawa, Kapor-Kachari, Zerinem, Lamon –Grass, Bhang
Bageshwer	Herde, Bahera, Kirmod, Simor, Guraza, Basil
Nainital	Awala, Harada, Ram-tulsi, Tajpat, Bharda, Ritha, Tamur, Padam, Harsingar
Champawat	Awala, Ganya, Ghudwaj, Jhula, Coliyas, Lapor Chari, Maas, Manijitha, Ritha, Satawar, Tajpat, Timur
Pithoragarh	Amla, Aniya, Atish, Badi elachi, Bahera, Ban andawa, Ban Haldi, Ban Kakadi, Ban Tulasi, Banashpa, Basil, Bazara Danti, Bhi Kafal, Dandas, Dhup Jad, Dhup Lakad, Dolu, Dolu beej, Dy Skoria, Dyas Koria, Eshb Gol, Gandasha, Gadari, Gadryani, Ghucchi, Ghud Wach, Gi Gada, Gin Jadi, Gin Zaru, Gola Tharia, Guraza, Hath Jadi, Herde, Indra Yani, Indra Yani beej, Jambu, Jata Mashi, Jhula, Kuut beej, Ka KoliCir, Kakda Sringi, Kala Chirita, Kala Zira, Kapal Ki chal, Kapoor-achrr, Kirmod, Kuppor Kachari, Kutakibeej, Ktaki, Lah Su Nia, Maha Meada, Manari, Mar Pati, Mi Rak, Mitha, Mor, Mos-Grass, Near Pati, Pashan Bhad, Pathar Loong, , Prunia, Ratan Joot, Ridhhi Wardhi, Ritha beej, Roots and ofchestnut, Ritha phal, Salammesri, Samawa, Samawa , Gaath, Samawa Panchang, Simor, Som Tala, Stu Wa, Teaj pat beej, Teaj Pat, Talish Patra, Tatari, Thoyia, Timur chaal, Timur beej, Wach

experiments have been carried out on the systems throughout the years using various agro and medicinal produces at various load and weather conditions. The stagnation test was conducted on both the dryers and it has been found that these can achieve the temperature of more than 70 °C. Some products (like potato, chilli, turmeric, and ginger) have been selected for the experimental study on the basis of their production data. The experimental studies have been undertaken for a variety of pre-specified testing conditions (load) as well as operating conditions. The thermal performance parameters have been identified from the detailed literature survey. On the basis of these parameters, the moisture content, drying rate, and the efficiency of solar drying system were decided.

The experimental investigations have been carried out for various products as mentioned in Table 3. It has been observed that solar drying can effectively reduce drying time and provide indirect benefits. The suitability of the convective drying technology is observed for high moisture containing produces like mint, plash, lemon slices, and so on. Table 4 presents the results of few of the experiments.

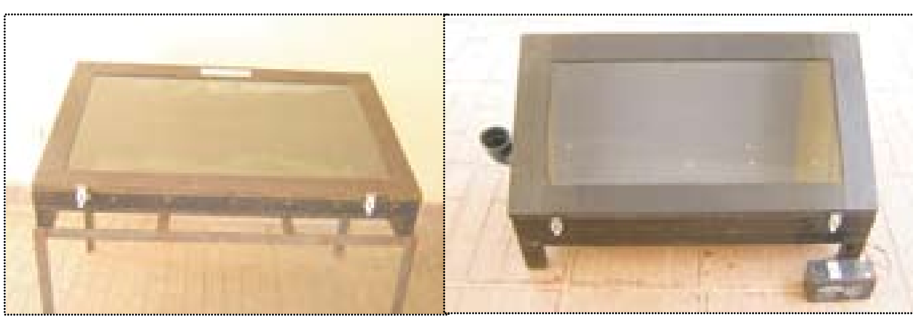

Figure 3 Prototypes of simple cabinet and convective cabinet solar dryers

Table 3 Critical moisture content in drying rate curves at specific drying times

Product	*Critical moisture content (Dry weight basis)*	*Time (hour) [Cabinet type solar dryer]*	*Time (hour) [Open sun drying]*
Amla (Phyllanthus emplica L.)	11.98%	13	25
Bahera (Terminalia chebula Retg.)	11.00%	3	8
Harde (Terminalia belerics Roxb.)	13.06%	17	51
Ginger	30.76%	7	10
Potato	25.0%	7	9
Chilli	23.4%	7	34
Turmeric	11.0%	9	12

Table 4 Critical moisture content in drying rate curves at specific drying times

Time * (h)	Plash Charge size (500 gm) Butea Monosperma		Mint Charge size (500 gm) Mentha Piperita		Lemon slices Charge size (1000 gm)	
	Moisture Content (dry basis)	Drying rate	Moisture Content (dry basis)	Drying rate	Moisture Content (dry basis)	Drying rate
0	6.23	—	5.00	—	7.00	—
1	5.74	0.483	3.42	1.57	5.41	1.59
2	5.33	0.446	2.65	1.17	4.63	1.19
3	4.85	0.458	2.00	1.00	3.03	1.32
4	4.27	0.488	0.06	1.097	2.04	1.24
5	3.60	0.524	0.04	0.951	1.81	1.04
6	3.09	0.524	0.02	0.825	1.20	0.97
7	2.35	0.553	0.01	0.712	0.95	0.86
8	1.72	0.563	—	—	0.80	0.78
9	1.18	0.561	—	—	0.73	0.70
10	0.57	0.565	—	—	0.33	0.67
11	0.34	0.536	—	—	0.14	0.62
12	0.007	0.513	—	—	0.04	0.58
13	0.006	0.478	—	—	0.01	0.54

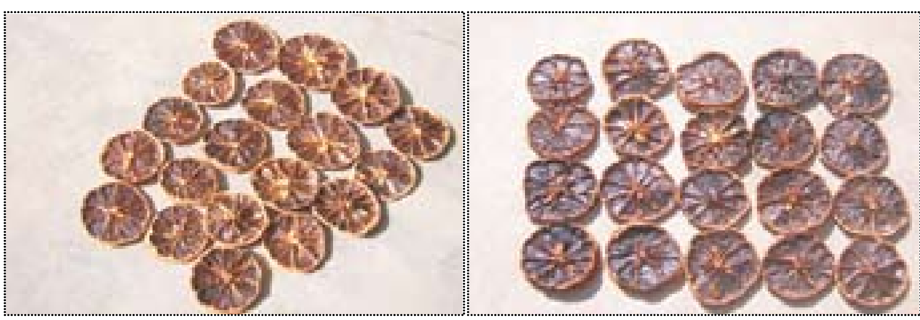

Figure 4 Colour patter of lemon slices dried under open sun (left) and solar dryer (right)

Conclusion

The solar radiation pattern, climatic study, and the study of agro and medicinal plant production in the hilly regions of Uttarakhand show a large potential for solar drying in the state. The Government of Uttarakhand has announced the state to be a 'herbal state' and thus, a number of efforts have been made in this direction. The companies involved in the field of medicinal plants or produce import the raw material from the typical areas and process them in-house for production of various end-products. Once the local farmers get the facility of solar drying at their locations, the transportation of these products in bulk will be easier and a large amount of energy used for drying will be saved. Local manufacturing of the systems would also enhance the employment opportunities. And the technology would improve the income level of local farmers who can sell dried products at high cost, instead of the raw materials at a much lower cost.

Solar drying

Solar drying is a traditional practice for the preservation of food and agriculture crops; which was done particularly by sun drying under the open sky. The open sun drying method has several disadvantages like spoilage of product due to adverse climatic conditions like rain, wind, moisture, and dust; loss of material due to birds and animals; deterioration of the material by decomposition; growth of insects and fungi; and so on. In addition, the process is highly labour-intensive, time-consuming, and requires a large area. This process is also highly energy-intensive and expensive, which ultimately increases the product cost. Solar drying is the best alternative—a solution to all the drawbacks of open sun/natural drying and artificial mechanical drying. Solar dryers, used in agro-produce food and crop drying and for industrial drying process, can prove to be the most useful device from the energy conservation point of view. Solar dryer is a very useful device for drying of agro produces, dehydration of fruits, potatoes, and so on in food processing industries, production of milk powder, casein, and other such products in dairy industries, seasoning of wood and timber, and so on.