Energy and Environment Research; Vol. 4, No. 2; 2014
ISSN 1927-0569 E-ISSN 1927-0577
Published by Canadian Center of Science and Education

CSD Type Family Solar Drying Technology and Its Potential Impact on Rural Development and Nutrition – A Case Study

Sangeeta Sinha[1,2], Anil Roy[3] & S. N. P. Singh[4]

[1] Department of Physics, B. R. Ambedkar Bihar University, Muzaffarpur, Bihar, India

[2] Centre for Renewable Energy and Env. Res., Muzaffarpur, Bihar – 842001, India

[3] DA-IICT, Gandhinagar, Gujarat, India

[4] Department of Zoology, B. R. Ambedkar Bihar University, Muzaffarpur, Bihar, India

Correspondence: Sangeeta Sinha, Centre for Renewable Energy and Env. Res., Muzaffarpur, Bihar – 842001, India. Tel: 91-943-1239820. E-mail: prof.ssinha@gmail.com

Received: December 2, 2013 Accepted: March 7, 2014 Online Published: April 29, 2014

doi:10.5539/eer.v4n2p98 URL: http://dx.doi.org/10.5539/eer.v4n2p98

Abstract

Globalization has adversely affected development of rural areas in developing countries. Rural areas are unable to absorb new technologies due to low literacy rates. Local Products, mostly from agricultural produces, are increasingly replaced by cheaper products from organized mechanized farming from one or the other corner of the globe. In this paper, family type cabinet solar dryer designs are presented in commensuration with the contemporary requirement of rural Bihar. Design objective includes simplification of technology and process, easy maintenance and low price to dry exotic produces which has significant export potential. Field trials are conducted, social surveys are undertaken and nutritional values of the products are determined in actual condition. Results indicate that simpler technology with state-of-art control of temperature by a combination of high heat capacity material and phase change material is most suitable to dry vegetables and spices, commonly called "Cash Crops". Their nutritional values remain within 80% limits even after six months. The technology is appropriate as it uses local materials; sustainable as it is cost-effective and employment generating ability and; robust as it uses very simple way for controlled drying.

Keywords: CSD, rural development, solar drying, nutrition

1. Introduction

Rural areas in developing countries are typically characterized by low literacy rates, dependence on agriculture related activities, and absence of alternative means of development, poverty and unemployment. Agricultural markets in rural areas are regulated by demand and supply rule in local context. The system had self-balancing mechanism for any drop in the quantum of production due to reasons beyond control. However, the buffering ability of local markets has taken a retreat in recent times due to globalization. Now, as and when price of a commodity rises, market supply is immediately supplemented from other places. Organized mechanized farming at a faraway place is increasingly and decisively controlling markets at local levels in rural areas. Traditional farmers with hardly any means or competency to adopt new technology get trapped in the vicious circle of high input price and low return. They are slowly alienating from agriculture as the sector depends upon several risk factors, that includes but not limited to uncertainties in government policy, energy price, labour migration, support price and even climate change. It has contributed to destabilization of traditional system and have caused mass migration of able labor forces in rural areas. In rural Bihar, villages are now mostly inhabited by children, females and old people, whose working capacity is very limited. Their ability to absorb new technologies is hence further reduced.

Arid rural areas in rural Bihar are further hit by global climate changes. Options of sustainable development have shrinked at a faster pace than expected. At the same time, arid areas are also home to priceless medicinal and horticulture produces, rich in vitamins, essential minerals and medicinal values. These produces have short life and a large part of them gets rotten before they could reach markets, where they can fetch very high values. Scattered and small scale of production is limiting factors in introducing cost-effective preservation technology at local and small scale levels. Besides, the average labour requirement for fruit production is very high, which is very important for rural development. It is approximately 900 man days per hectare per annum as against 140 man days for cereal crops. A few horticulture crops even generate much larger employment, from 1000–2500 man days per hectare per annum.

The huge employment and export potential of these agri-produces comprising horticulture, medicinal plants and vegetables have also been fully recognized at various levels by government and non-government planning agencies. Tenth Plan draft acknowledges that the "horticulture sector only contributes about 24.5 per cent towards agriculture GDP from only about 8 per cent of the cultivated area" (GOI, 2001). It acknowledges that this sector provides nutritional and livelihood security and helps poverty alleviation and employment generation. This sector supports a large number of agro-industries, which generate huge additional non-farming employment opportunities. Despite all these admissions, in practice, it is not getting the kind of priority it actually deserves. The post harvest loss of these agri-produces is very high in Bihar, India. Horticulture sector alone shows a loss of 5% to 39%, mainly during transportation. Though losses of medicinal plants and vegetables are very difficult to quantify, it is estimated to be much more due to delayed market absorption. In recent years, the demand of these agri-produces has increased considerably. Inevitably losses have also increased proportionately. The losses due to supplies from remote areas are even higher than what has been estimated.

Family size solar dryers have many advantages (Choudhary et al., 2005, 2006). It can be handled by left over rural population of women, old people and children. Besides, single day solar drying of agri-produces (medicinal and horticulture) almost eliminates degradation possibilities due to insect attack. The end product falls into the category of organic category, which has high market demand in developed countries. These dried produces can be preserved for long time in simple packaging and can be transported without any requirement of specialized vehicles. However, most of these agri-produces need to be dried in particular temperature range to preserve vitamins, color and taste. Controlling temperature variation by increasing thermal mass increases drying time and therefore losses during off sunshine hours. Latent heat storage in a Phase Change Material (PCM) is very attractive option to overcome this lacuna because of its high storage density with small temperature swing.

Phase Change Materials (PCM) is latent heat storage material. When the source temperature rises, the chemical bonds within the PCM break up as the material changes phase from solid to liquid. It is an endothermic process. Upon storing heat in the storage material, the material begins to melt when the phase change temperature is reached. The temperature then stays constant until the melting process is finished. The heat stored during the phase change process of the material is called latent heat. Latent heat storage provides the flexibility of storing large amounts of heat with only small temperature changes and therefore to have a high storage density. As the change of phase at a constant temperature takes some time to complete, it becomes possible to smooth temperature variations. It can store 5 to 14 times more heat per unit volume than sensible storage materials such as water, masonry, or rock. Phase change materials themselves cannot be used as heat transfer medium. Latent heat energy storage system has three components; (a) PCM with its melting point in the desired temperature range; (b) compatible heat exchange surface; and (3) a container compatible with the PCM.

Cabinet solar drying (CSD) technology has been evolving to meet the dynamic rural kaleidoscope. Conventional solar drying technology at various stage of complexity has failed to make an impact in Rural India despite Government support and subsidies. The reason is mostly attributed to the abysmal understanding of the socio-cultural set-up, its ability to absorb the technology and its impact on adopting the technology. In this paper, family type cabinet solar dryer designs are presented in commensuration with the contemporary requirement of rural Bihar. Design objective includes simplification of technology and process, easy maintenance and low price to dry exotic produces which has significant export potential. The state-of-art CSD with PCM and HHCM (High Heat Capacity Material) is designed and developed for single day controlled temperature drying of medicinal agri-produces (especially with anti cancerous and curative properties). Field trials are conducted, social surveys are undertaken and nutritional values of the products are determined in actual condition. The technology uses local materials. It is cost-effectiveness and has employment generating ability. It is robust as it uses very simple way for controlled drying.

2. Materials and Methods

2.1 Design of Solar Dryer

Family size passive solar dryer was designed and constructed using galvanized iron sheets. Theoretical modeling of various parameters were done using standard program with the objective of maintaining a temperature range of 50–80 degree C for 6 to 14 hours while drying of 5 kg of the agri-produce selected. The dryers's outer and inner box is made of thin Galvanized Iron sheet measuring 0.65 m × 0.55 m × 0.25 m and 0.6 m × 0.5 m × 0.2 m. 2 mm thick toughened glass is used for upper cover. 5 cm gap between the outer and inner boxes is filled with insulating material locally available (rice husk, wooden particles etc). Inner box is painted in carbon black. Inner box has a perforated tray for holding the agri-produce. The dryer achieved 90 degree C during peak summer and dried even high water and sugar content agri-produce in a single day (12–14 Hrs). However, the design lacked in temperature control.

Mechanism and needed manual intervention quite often. Thermal heat loss was also high. Hence, it is reconstructed with Fibre Reinforced Plastic (FRP) with double layer outer wall separated by 75 mm compressed wooden sheets. FRP protects the wooden structure from deformation and air leakage due to moist air, high temperature and direct sunlight. Dimension of the family size cabinet solar dryer is shown in the Figure 1a. Experimental model were constructed of clear base area 1 m × 1 m. 3 mm toughened glass is used to cover the upper portion of the dryer. A 1 inch perforated PVC pipe is placed at the bottom for controlled inlet of ambient air to supplement the moist air removal by PV operated fan from the back. A partition is created for ease of operability and to impart strength to steel mesh drawer. It can be moved outside for loading materials to be dried as shown in Figure 1b. Space below the mesh is used for storing HHCM and PCM.

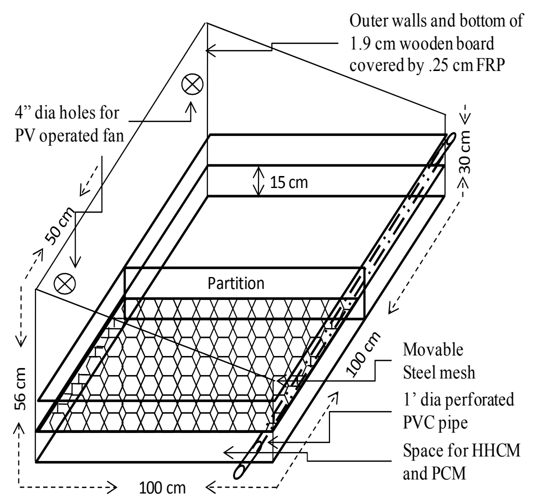

Figure 1a. Schematic diagram of family size solar dryer

Figure 1b. Family size solar dryer

Figure 1. Schematic diagram and actual family size solar dryer

At first suitable Phase Change Material (PCM) in the required temperature range for drying is selected. Latent heat of fusion, Melting Point, Density and thermal conductivity are most important parameters in selection of PCM (Dincer, 1999; Sukhatme, 1996). Theoretical modeling is used to optimize a combination of PCM and High Heat Capacity Material (HHCM) to stabilize temperature inside the dryer. Temperature range control mechanism is developed on the basis of HHCM to drying material ratio. Variation in this ratio allowed greater control of temperature for different types and quantity of materials to be dried.

2.2 Drying Experiment

A series of drying experiments were conducted in incubators to determine the optimum temperature ranges for each agri-produce. Once temperature range is fixed, theoretical modeling is used to determine the combination of PCM and HHCM for solar drying experiment. Existing literatures show that drying at temperature below 90 degree C has no impact on nutritional value of the material dried. Family size solar dryer are designed to achieve temperature less than 90 degree C. The following agri-produce with anti-cancerous properties were dried,

(a) Turmeric/Curcumin - It is one of the most important medicinal plant used as spice in India. It contains the polyphenol Curcumin, which promotes 'Apoptosis' (programmed cell death/cell suicide) that safely eliminates cancer breeding cells without posing a threat to the development of other healthy cells as in case of conventional radiotherapy and chemotherapy. It also effectively retards the growth of cancer cells causing prostate cancer, melanoma, breast cancer, brain tumour, pancreatic cancer and leukemia amongst a host of others.

(b) Fennel – It is also one of the most widely used medicinal spice. It has phyto-nutrients, antioxidants and an anti cancerous compound, ‘Anethole’. Anethole is known to resists and restrict the adhesive and invasive activities of cancer cells. It is also known to suppress the enzymatic regulated activities behind cancer cell multiplication.

(c) Cayenne Pepper/Capsaicin: Capsaicin is also known for its anti-cancerous activities besides several other medicinal properties. It induces the process of apoptosis that destroys potential cancer cells and reduces the size of leukemia tumour cells considerably.

(d) Ginger: In aurvedic medicine, the medicinal quality of ginger is known to help lowering cholesterol level, boost metabolism and kill cancer cells. It is being used almost all over the world due to these medicinal properties.

(e) Oregano: Oregano is a potential agent against prostate cancer. It also consists of anti-microbial compounds. Phyto-chemical ‘Quercetin’ present in oregano restricts growth of malignant cells in the body, its potential as a drug against cancer-centric diseases is much more than grapes.

(f) Cumin: Cumin is called herb with anti-oxidant characteristics. Its seeds contain a compound called 'Thymoquinone' that checks proliferation of cells responsible for prostate cancer.

3. Results and Discussion

Temperature control mechanism by a combination of phase change material and high heat capacity material is achieved in harsh climatic conditions with large variation in climatic parameters. High heat capacity materials were used to offset any change in climatic parameters. On a typical day, Figure 2 shows the variation of ambient temperature and inside drier temperature of the proposed design for which temperature varies between 45 °C to 90 °C. Temperature and duration of drying is traded off by the combination of PCM and HHCM. Figure 3 shows typical variation of different combination of PCM ($NaOH{\cdot}H_2O$) and HHCM (boulders). It is evident that the temperature curve is flattened and thermal energy is preserved for longer period of time with use of PCM. Initial rise in temperature and maximum desired temperature can be controlled by the combination of HHCM and PCM. Spices like cumin and fennel needed slow drying. Hence, the amount of HHCM is increased to attain maximum temperature. At the same time, Cayenne Pepper is dried at high temperature for at least two hours. It is achieved by reducing HHCM in the drier. Table 1 shows the best option of PCM for drying of agri-produce known for anti cancerous properties. It also enlists weight/weight ratio of HHCM and DM (Material to be dried) for temperature control and single day drying. Dried weight is weight of DM with less than 5% moisture content except for ginger and fennel, where it is 10% and 8% respectively. The system is simple to operate and convenient for rural people particularly in developing countries.

Table 1. Selection of PCM and HHCM:DM ratio for single day solar drying of agri-produce, known for anti cancerous properties

PCM (10 kg/m^2)	M.P. (°C)	L. heat (kJ/kg)	Density (kg/m^3)	Drying Material (DM) – 5 kg /m^2	HHCM:DM (ratio)
$Fe(NO_3)_2{\cdot}9H_2O$	47	170	1684	Fennel, Cumin	80
$Na_2S_2O_3{\cdot}5H_2O$	48	209	1600	Fennel, Cumin	80
n- Pentacosane	54	238	769	Oregano	70
n- Octacosane	61	255	865	Cinnamon	60
$FeSO_4{\cdot}7H_2O$	64	200	1893	Ginger	60
Stearic acid	69	200	848	Turmeric	50
$Ba(OH)_2{\cdot}8H_2O$	78	270	1937	Cayenne Pepper	40

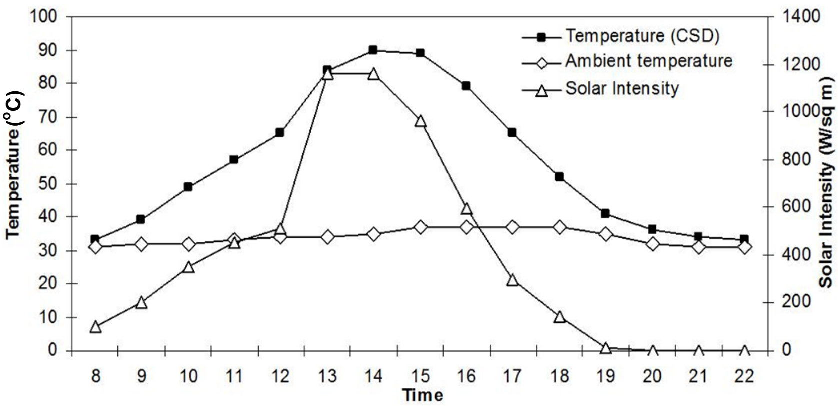

Figure 2. Variation of solar intensity, ambient temperature and temperature inside dryer on a typical day

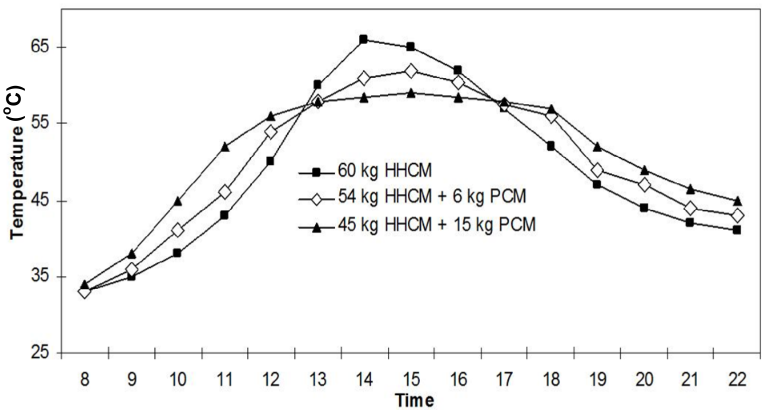

Figure 3. Variation of temperature inside dryer with a combination of PCM and HHCM

Table 2 shows the variation in drying time, drying wt. and moisture content after single day solar drying of these agri-produces. Figure 4 (a, b, c, d, e, f, g) shows the images of harvested and dried agri-produces - ginger, cumin and Cayenne Pepper.

Table 2. Variation in drying time of selected anti-cancerous produces in the proposed solar dryer

Drying Material	Drying Time (Hours)	Dried Wt. (%)	Moisture (%)
Cayenne Pepper	10	40	< 5
Turmeric	10	45	< 3
Ginger	10	50	< 10
Cinnamon	10	30	< 3
Oregano	10	10	< 3
Fennel	8	10	< 8
Cumin	8	8	< 5

(a) Harvested Ginger

(b) Dried Ginger knots

(c) Dried Ginger stems

(d) Harvested Cumin

(e) Dried Cumin

(f) Harvested Pepper

(g) Dried Pepper

Figure 4. Images of harvested and dried agri-produces - ginger, cumin and cayenne pepper

4. Conclusion

Organic farming of agro-produces with anti cancer properties has very high demand in global market. These produces are less labor intensive and most suitable for remote rural areas, where able labor forces have almost migrated to mega cities. Family size solar dryer developed provides an alternative route for economic development to rural areas. The temperature control mechanism developed can be handled by illiterate rural women. Drying in controlled low temperature range also preserves their medicinal properties, which has been investigated and documented by several scientists. Post harvest technology for these spices is based on the fact that drying below 70 degree C doesn't affect medicinal properties (Peter, 2001). Reduced weight, cheap packaging and ease of transportation from remote areas to cities, are some of the major factors, likely to drastically reduce wastage in this sector.

References

Choudhary, S., Baby, P., Sangeeta, S., & Sanjay, K. (2005). Trans-boundary Floods Induced by Global Climate Change: Development of Solar Fish Drying Technology to Combat Food Deficit in Seasonally Inundated Northern India. *Journal of Agricultural Meteorology, 60*(5), 581-584.

Dincer, I. (1999). Evaluation and selection of energy storage systems for solar thermal applications. *International Journal of Energy Research, 23*(12), 1017-1028. http://dx.doi.org/10.1002/(SICI)1099-114X(19991010)23:12<1017::AID-ER535>3.0.CO;2-Q

GOI. (2003). *Estimation Loss of Horticulture Produce due to Non-availability of Post Harvest & Food*

Processing Facilities in Bihar & UP. Socio-Economic Research, ASET, Planning Commission, Government of India. New Delhi, India. Retrieved from http://planningcommission.nic.in/plans/planrel/fiveyr/10th/10defaultchap.htm

Peter, K. V. (Ed.). (2001). *Handbook of Herbs and Spices*. Cambridge, London, Woodhead Publishing Limited.

Planning Commission. (2001). *Xth five year plan* (Vol. 2). Govt. of India.

Sanjay, K., Sinha, S., Kojima T., & Kato, S. (2006). Food Supplement and Protection in Deserts and Arid Areas by Solar Drying of Native Horticulture Products. *J. of Arid Land Studies, 16S*, 297-300.

Sukhatme, K., & Sukhatme, S. P. (1996). *Solar energy: principles of thermal collection and storage*. Tata McGraw-Hill Education.