DEVELOPMENT OF SOLAR-BIOMASS HYBRID DRIER AND STUDIES ON HEAT AND MASS TRANSFER FOR DRYING OF SPICES

By

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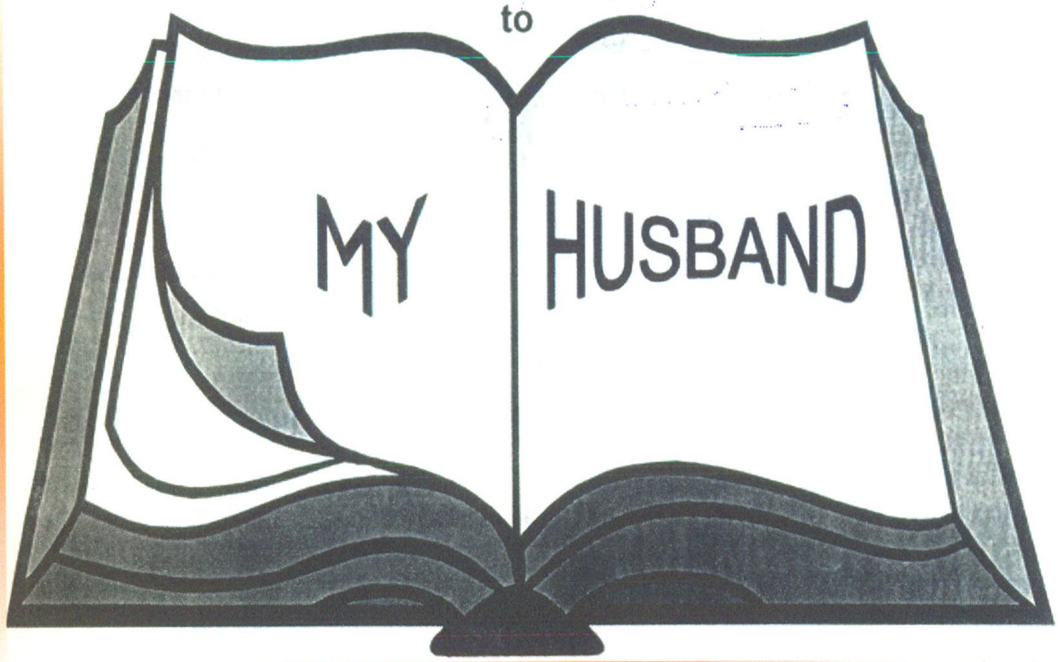

Certificate

This is certified that the thesis entitled "**DEVELOPMENT OF SOLAR-BIOMASS HYBRID DRIER AND STUDIES ON HEAT AND MASS TRANSFER FOR DRYING OF SPICES**" being submitted by **Ms. Jai Shree Prasad nee Solanki** to the Indian Institute of Technology, Delhi is worthy of consideration for the award of the degree of '**Doctor of Philosophy**' and is a record of the original bonafide research work carried out by her under my guidance and supervision.

The results contained in the thesis have not been submitted, in part or full, to any other university or institute for the award of any degree or diploma.

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Abstract

Drying is an important process required for crops, vegetables, fruits and other medicinal herbs for safe storage. Conventional as well as non-conventional energy sources are used for drying. Solar energy is the most common non-conventional energy source for drying in rural areas. There are some limitations of using solar energy for drying which can be overcome by biomass energy. Very limited work on crop drying with solar-biomass energy has so far been carried out in India.

A survey conducted in Saharanpur (Uttar Pradesh) in India revealed the problems faced by rural people for drying of spices and medicinal herbs. The survey reveals that in spite of their hard work in collecting and processing of these plants, they are not getting fair monetary returns. There is lack of adequate drying system and the method commonly used for crop drying i.e. open sun drying does not yield good quality products.

Considering these problems a solar cabinet drier coupled with a biomass stove was developed. The hybrid system consists of a single glazed solar cabinet above a biomass unit. During daytime, solar energy was utilized and in night biomass energy was used for drying of crops kept in the cabinet drier. This solar-biomass hybrid drying system overcomes the limitation with use of solar energy in crop drying i.e. its dependence on nature. The drying processes have been carried out under the three modes of drying i.e. (i) solar-biomass hybrid drying (ii) solar drying (iii) open sun drying and their comparative performance and efficiency was evaluated based on various factors.

Experiments were conducted on drying of ginger (*Zingiber officinale*) and turmeric (*Curcuma longa.*) considering the three factors (crop thickness, crop treatment and climatic conditions) to evaluate the performance of the hybrid system. The hybrid system

extended the working time of the solar drier and resulted in good quality of the dried products due to continuous drying of crop. Experiments were also carried out with solar drying and open sun drying of ginger and turmeric for comparison. In the solar and open sun drying, some cracks were developed within the dried product due to thermal stresses resulting from alternate heating and cooling of the crops during day and night. Quality of the dried product was not good in open sun drying.

Convective, evaporative and radiative heat and mass transfer coefficients were evaluated in all the three modes for drying of ginger and turmeric. It was observed that values of these heat and mass transfer coefficients differ from crop to crop, mode of drying and certain other factors. The results are based on Dunkle's model with rigorous experimental study for all the three modes.

Overall thermal efficiency was determined under the three drying modes considering the three factors viz. thickness, crop treatments and climatic conditions and found that these factors significantly affect drying efficiency of the system. Efficiency was highest for solar drying followed by solar-biomass hybrid drying and open sun drying.

Quality analysis of the crops was made in terms of their volatile oil content, total ash, acid insoluble ash, water-soluble extractives and alcohol-soluble extractives. Curcumin content of turmeric was also determined. The results were compared with the standard values as per Bureau of Indian Standards. Microbiological analysis of the crops was performed for total plate count and yeast & mould count.

The present design of the solar-biomass hybrid drier is simple in construction, low in cost and can be fabricated by rural farmers. The economic evaluation shows that the proposed hybrid system is technically feasible and economically viable. This simple drier assists in value addition of the crops at primary level. It also offers better monetary returns to the farmers apart from employment generation in rural areas.

Organization of Thesis

Chapter 1 contains role of energy in socio-economic development, limitations of nonrenewable sources of energy and solar energy as well as prospect of solar and biomass energy as the major renewable energy sources and their potential in India particularly for crop drying. It further contains the information about medicinal plant wealth of India, commercial potential of spices and their drying. Relevant information about the two crops selected for the present study i.e. ginger and turmeric has also been mentioned. Basics of heat and mass transfer have also been described.

Chapter 2 presents detailed literature review regarding solar energy-based crop drying systems, theory of heat and mass transfer coefficients, earlier studies on these coefficients, thermal efficiency of the drying systems, quality aspects of spices and cost economic analysis. Experimental uncertainty in terms of percent uncertainty has also been discussed in this chapter.

Chapter 3 contains informations on field survey, details of development and operation of solar-biomass hybrid drier, drying parameters, different factors and cases in the present study along with methodology and observation tables of all the experiments.

Chapter 4 reveals the findings of the field survey, results and discussion of drying time, heat and mass transfer coefficients, per cent uncertainty, thermal efficiency, quality analysis and cost economic analysis.

Chapter 5 presents the conclusions that have been drawn based on the results of the study and accordingly some recommendations have been made. Further scope as well as some limitations of the present work have also been mentioned.

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