CHAPTER – VIII

CONCLUSION AND FUTURE SCOPE

8.1 Summary

The purpose of drying agricultural products using solar dryers is to improve the quality of drying and preserve the products. An indirect type forced convection solar biomass hybrid dryer has been designed and fabricated for drying of cashew nut. The cashew nut was tested in forced convection solar dryer, natural convection solar dryer, biomass dryer, hybrid dryer and open sun drying. All experiments led to the following important conclusions.

5 Energy intensity for the production of cashew kernel was estimated to be 265.68 MJ, 448 MJ and 510 MJ for electrical, steam and biomass based industries respectively. Difference of 356 MJ, 786 MJ and 1342 MJ was observed among Industries with same production capacity of 1000 kg raw nut.

6 The difference in energy intensity may be attributed to the fuel source, processing method and processing equipment. Energy required to process 1000kg of cashew nuts into cashew kernel was 300MJ. There is a vast potential of meeting the energy requirement of cashew processing industries through renewable energy based technologies.

7 The temperature of the drying chamber was almost uniform 60-65°C across the trays with time duration of 6 hours. The final moisture content 5% was obtained in the time period of 6 hours in forced convection mode, 10 hours in natural convection mode and 14 hours in open sun drying. The dryer does not depend on weather condition and can be operated for maximum of 3 batches per day. The average collector efficiency of the system in hybrid forced mode was 75.6%.

8 Temperature between 55ºC and75ºC was obtained depending on the weather condition and fuel used. Maximum biomass system/overall efficiency of 9.5 % was observed. Uniform drying of cashew was achieved with good quality nuts grade (W240). Experimental results revealed that biomass drying was more efficient than sun drying in significantly increasing drying rate and reducing drying time.

9 The solar biomass hybrid dryer has been fabricated for the purpose of drying 40kg of cashew nut per batch. This is a practical technology which can be used for dying of cashew as well as other agricultural products. This system could reduce drying time by half when compared to open sun drying and produces high quality cashew nut grade (W240).

10 In order to describe the drying behavior of cashew kernel eleven thin layer drying mathematical model were fitted to the drying data obtained from the experimental value. The drying behavior was studied based on their correlation co-efficient, reduced chi-square value and root mean square error value. Two term model showed the best curve fitting model for the experimental moisture ratio value for the forced solar dryer and page model for forced biomass and forced hybrid type of dryer respectively.

11 The objective of the simulation of the dryer is to find the most efficient design and operation mode for optimum temperature distribution. The numerical simulation of the temperature inside the solar biomass hybrid was validated with the real experimental data and there was no significant difference between real and simulated temperature inside the drying chamber. The simulated 3D model of hybrid dryer using Solid works was capable of predicting the system behavior in real situations. Among the three mode of operation forced solar mode was in good agreement with the experimental condition. The temperature profiles of all the three modes of operation achieved reasonable temperature required for drying

12 A techno economic analysis of solar dryer for drying cashew kernel was carried out and compared with biomass dryers and hybrid dryers. The cost of drying of cashew kernel is lowest (Rs 0.8/kg) for solar dryer with initial investment of Rs 61732. The estimated payback period of the hybrid dryer is about 1.99 years. The initial investment of biomass dryer (Rs 48,940) gives the lowest payback period of about 1.32 years which is much less than the expected life of the dryer. Biomass dryer gives the highest Rate of Return (75%) whereas the hybrid dryer gives the lowest Return nearly 50%. Solar dryer is the best option based on the cash discounted future worth of Rs. 3, 23,725 when compared to the other two types of dryers. Benefit cost ratio was also highest for solar dryer which was found to be 5.23.The developed system was found be economical suitable for processing of 40kg /batch of cashew kernel.

It can be concluded that the developed dryer is more suitable for drying cashew nut and other agricultural products

8.2 Recommendations

The study revealed that solar biomass hybrid dryer for drying cashew may benefit in reducing drying time and saving energy. The present system provides the constant heat to the product as well as retains its nutritional and organoleptic quality. Due to its economic effectiveness, this type of dryer can play a vital role in bringing sustainable energy to small scale cashew farmers in the rural communities of India. Based on the objective and findings of this study, the following are recommended.

1. Advocacy of solar drying technology for product development and reducing post-harvest losses.

Since solar drying is simple in operation, cheap in cost compared to modern industrial machine, and the study has shown it retains substantial amount of biochemical and sensory parameters during drying, then there is a need to advocate its application in the country for development of solar dried based products and reducing postharvest losses which is currently amounting to 30-40%. The advocacy should begin at family levels through SMEs to the large companies.

2. Fabrication and more researches on Hybrid dryers

In this study, it was observed that Hybrid dryer was observed to perform better than solar dryers in almost all aspects tested. This suggest that, for successful and commercialization of solar drying, Hybrid dryer is recommended over local cabinet dryers. However, the dryer is little bit expensive for low income people and SMEs who need the dryer most. Therefore, it is recommended for fabrication of local and affordable hybrid dryer comparable to the industrial ones, using local available materials followed by researches/experiments to ascertain their performance comparative to the modern ones. If this succeeds, the solar biomass hybrid drying activities and quality of the dried products will be enhanced many folds.

3. Drying activities and weather conditions

While conducting solar drying activity, weather conditions should be conclusive for drying. Temperature and humidity are the main factors that had to be monitored carefully because high humidity will lead to loss of moisture hence simple equipment for measuring temperature and humidity is advisable. If the values are found to be out of range then the drying activity should be changed.

4. Supplementation with Solar PV

The Solar dryer can be operated by a Photovoltaic module independent of the electrical grid. Energy required for operating the blower can be met through solar PV. The photovoltaic driven solar dryers must be optimized for efficient operation.

5. Manpower training in solar drying

Indian economy is mostly depends on agriculture sector. Hence the agriculture should be empowered with practical experiment, guidance, establishment of enterprises by getting subsector and training to provide employment opportunity to the youngsters both men and women who actually face the post harvest losses in agriculture. Solar drying seems to offer hopes for the loss. To avoid such losses government and non government organizations should be friendly to farmers and encourage them by providing loan facilities, resource and assistant such as training, drying , providing land and market channels etc. By doing so employment opportunity will be more to the youngsters and it generates income to the country. Simultaneously poverty rate will also be reduced and it will reduce post harvest losses, enriches the food security of India.

8.3 Future scope

Certain design features of dryer can be modified which includes

- Providing parabolic reflector on both sides of the collector.
- Increasing the absorbivity of the absorber plate.
- Replacing copper plate with aluminum plate.
- Increasing the air flow rates.
- Providing PVT operated electrical heating coil.
- Incorporating PCM based thermal energy storage system in the dryer to maintain required temperature in the evening/night hours.

- Installing a swirl element at the entrance of the drying chamber to give rotation effect to the air and fixing bended sheet strips inside the chamber to direct the airflow.
- Increasing collector tilt angle length and breadth to a certain limit to raise the temperature of the dryer.
- Providing dehumidifier before the drying chamber for removing moisture in the air to improve the drying rate.
- Provision of parabolic trough solar collector instead of black coated aluminum absorber plate to be used as a concentrated solar power plant and industrial process heat with a temperature range of 100^{o}C – 250^{o}C.
- Provision of evacuated tube solar collector to increase the air temperature up to 125 ^{o}C.
- Decreasing the distance between the tray and bottom plate of the drying chamber using two layers of glazing to reduce the thermal loss from the collector.
- Providing copper tubes to the side wall of the dryer to recover heat from the sidewalls.
- Fabrication of double slope passive solar dryer to attain higher efficiency.

Improvements in the performance of the dryers could lead to the performance enhancement of the dryer for use in small scale business enterprises. Neural network model can be used to predict the potential of the dryer for different locations and can also be used in a predictive optimal control algorithm. Further study on other modeling software's is needed to uphold confidence in numerical simulation of drying process. Exergy is a measure of quality of energy and it can clearly take into account the loss of availability of heat in the solar drying systems. Therefore exergy analysis should be used to design solar drying systems with the highest possible thermodynamic efficiency.