International Journal of ChemTech Research
CODEN (USA): IJCRGG ISSN: 0974-4290
Vol.8, No.1, pp 098-104, 2015

A Review on Solar dryer performance reaction on products

G.Padmanaban[1], P.K.Palani[2], S.Dharmalingam[1]*, K.Raja[3]

[1]Department of Mechanical Engineering, Rathinam Technical Campus, Coimbatore, Tamilnadu, India
[2] Department of Mechanical Engineering, Govt. College of Technology, Coimbatore, Tamilnadu, India
[3]Dept of Mechanical Engineering, University College of Engineering, Dindigul campus, Tamilnadu, India.

Abstract: Solar is one of the renewable and sustainable sources of power that attracted a large community of researchers from all over the world. This is largely due to its abundant in both direct and indirect form. As such the development of efficient and inexpensive equipment for the drying of agricultural and marine products using solar power evolved thereby improving the quality of the products as well as improving the quality of life. The use of solar dryers in the drying of agricultural products can significantly reduce or eliminate product wastage, food poisoning and at the sometime enhance productivity of the farmers towards better revenue derived. In this paper a review of the solar dryer is presented. The various design of the solar dryer is reported.
Keywords: Solar dryer performance reaction.

Introduction:

Drying may be required for several reasons. First and most often, water is removed from the fresh crop to extend its useful life. The dried product is later rehydrated prior to use in order to produce a food closely resembling the fresh crops, for example, in the use of dried vegetables. Second a crop may require drying so that it can be further processed. For example, many grains are dried so that they can be ground into flour. Third, fresh crops are sometimes dried so that a new product distinctly different from its original form can be produced.

Fundamentals of the drying process

Drying involves the removal of moisture and in thermal drying this is achieved through the application of heat to the product. The heat increases the vapor pressure of the moisture in the product above that of the surrounding air. Pressure and thermal gradient cause the moisture, both liquid and vapor, to move to the surface of the product. Evaporation takes place and water vapor is transferred to the surrounding air. This air may become saturated, but the process of drying continues if this surrounding moist air is replaced by less-saturated air.

Traditional sun drying

The traditional method of drying known as 'sun drying' involves simply laying the product in the sun. Major disadvantage of this method is contamination of the products by dust, destruction by insects and microorganism, and pecking by birds. Furthermore, some percentage will usually be lost or damaged during handling; it is labor-intensive, nutrients loss occurs, such as vitamin A, and is time-consuming. Lastly, the method totally depends on good weather conditions. The major advantage in the energy requirements for this open sun drying process is that the solar and wind energy is readily available freely in nature; hence, the capital requirement is marginal, making it the viable method of drying agricultural produce even in commercial scale especially in developing country. The safer alternative to open sun drying is drying in a solar dryer. This is a more efficient method of drying which produces better quality products; but in this case, initial investments are required.

Solar dryers

A solar dryer is an enclosed unit to keep the food safe from damage from birds, insects, microorganism, pilferage, and unexpected rainfall. The produce is dried using solar thermal energy in a cleaner and healthier fashion. Basically, there are four types of solar dryers:

1. Direct solar dryers. In these dryers, the material to be dried is placed in a transparent enclosure of glass or transparent plastic. The sun heats the material to be dried, and heat also builds up within the enclosure due to the 'greenhouse effect.' The drier chamber is usually painted black to absorb the maximum amount of heat.
2. Indirect solar dryers. In these dryers, the sun does not act directly on the material to be dried thus making them useful in the preparation of those crops whose vitamin content can be destroyed by sunlight. The products are dried by hot air heated elsewhere by the sun.
3. Mixed-mode dryers. In these dryers, the combined action of the solar radiation incident on the material to be dried and the air preheated in solar collector provides the heat required for the drying operation.
4. Hybrid solar dryers. In these dryers, although the sun is used to dry products, other technologies are also used to cause air movement in the dryers. For example, fans powered by solar PV can be used in these types of dryers.

In many parts of the world there is a growing awareness that renewable energy have an important role to play in extending technology to the farmer in developing countries to increase their productivity[1]. Solar thermal technology is a technology that is rapidly gaining acceptance as an energy saving measure in agriculture application. It is preferred to other alternative sources of energy such as wind and shale, because it is abundant, inexhaustible, and non-polluting[2].

Solar air heaters are simple devices to heat air by utilizing solar energy and employed in many applications requiring low to moderate temperature below 80 ^{o}C, such as crop drying and space heating. Drying processes play an important role in the preservation of agricultural products[3].

The application of dryers in developing countries can reduce post harvest losses and significantly contribute to the availability of food in these countries. Estimations of these losses are generally cited to be of the order of 40% but they can, under very adverse conditions, be nearly as high as 80%. A significant percentage of these losses are related to improper and/or untimely drying of foodstuffs such as cereal grains, pulses, tubers, meat, fish, etc[4].

An indirect forced convection solar drier integrated with different sensible heat storage maternal has been developed and tested its performance for drying chili under the metrological conditions of Pollachi, India. The system consists of a flat plate solar air heater with heat storage unit, a drying chamber and a centrifugal blower. Drying experiments have been performed at an air flow rate of 0.25 kg/s. Drying of chili in a forced convection solar drier reduces the moisture content from around 72.8% (wet basis) to the final moisture content about 9.1% in 24 h. Average drier efficiency was estimated to be about 21%. The specific moisture extraction rate was estimated to be about 0.87 kg/kWh[5].

In sun drying, the crop is spread in a thin layer on the ground and exposed directly to solar radiation and other ambient conditions. The rate of drying depends on various parameters such as solar radiation, ambient temperature, wind velocity, relative humidity, and initial moisture content, type of crops, crop absorptivity and mass of product per unit exposed area[6].

Solar driers using natural convection or forced circulation have been investigated to overcome these problems[7].

Normally thermal storage systems are employed to store the heat, which includes sensible and latent heat storage [8].

Common sensible heat storage materials used to store the sensible heat are water, gravel bed, sand, clay, concrete, etc[9].

A paper presents the design, construction and performance evaluation of a mixed-mode solar dryer for food preservation. In the dryer, the heated air from a separate solar collector is passed through a grain bed, and at the same time, the drying cabinet absorbs solar energy directly through the transparent walls and roof. The results obtained during the test period revealed that the temperatures inside the dryer and solar collector were much higher than the ambient temperature during most hours of the day-light. The temperature rise inside the drying cabinet was up to 74% for about three hours immediately after 12.00h (noon). The drying rate and system efficiency were 0.62 kg/h and 57.5% respectively. The rapid rate of drying in the dryer reveals its ability to dry food items reasonably rapidly to a safe moisture level[10].

A rotary wind ventilator incorporated into the dryer, to increase the rate of air circulation through the dryer. Dryer consists of an absorber back plate insulated with foam material. Graph was plotted between time and temperature and time of drying and weight loss. The results obtained show that the temperatures inside the dryer and the air-heater were higher than the ambient temperature during most hours of the daylight. The drying of food items in the dryer was compared with open air-drying of similar items. Comparatively, drying with the solar cabinet dryer showed better results than open air-drying. The results also revealed the dependence of the dryer performance on the proper air circulation through the system. The system efficiency increased as the air velocity through the system increased and 80% and 55% weight losses were obtained in the drying of pepper and yam chips, respectively, in the dryer. The average daylight efficiency of the system was 46.7% were studied[11].

The benefit over natural drying by using solar drying with and without auxiliary heat for drying beans and peas under different airflow rates .The solar heat may be supplemented by auxiliary heat of different types to reduce further drying time. It is often desirable to vary airflow rate through the system during the different stages of drying. An experimental study is conducted to investigate the performance of a solar drying system and a system equipped with an auxiliary heater as a supplement to the solar heat. The performances of both are compared to that of natural drying. Beans and peas are dehydrated in a system that consists of two flat plate collectors, a blower, and a drying chamber. Tests with four different airflow rates, namely, 0.0383, 0.05104, 0.0638, and 0.07655m^3 /s are conducted. It was found that the drying time was reduced from 56 hours for natural drying to 12–14 hours for solar drying and to 8-9 hours for mixed (solar and auxiliary) drying. The efficiency of the mixed drying system was found to increase by 25% to 40% compared to the solely solar drying. A weak relation was observed between the variation of airflow rate and the decreasing rate of the moisture content of the dried material, especially for the mixed drying was investigated[12].

Designed a direct natural- circulation solar dryer, and compare its performance with the traditional open-to-sun drying. The design of the dryer was made to suit the local farmer needs, as a small scale home drying unit with a capacity from 3 kg to 8 kg in relations to the product being dried. The purpose of this research was to study the performance of an integral-type Natural circulation solar energy dryer for the drying of different crops under tropical conditions. It consists of a chimney for getting buoyancy. A K-type thermo-couple complete with digital relative humidity meter was used to measure the drying air temperature and drying air relative humidity inside the dryer. A pyranometer was used to measure the global solar radiation. The velocity of drying air was measured by an anemometer. The moisture contents of dried crops were measured at the starting and the end of each run of experiments. To evaluate drying performance of the solar dryer, the system drying efficiency was calculated. The performance of the integral natural circulation solar dryer is compared with that used in Pucallpa traditional open-to-sun drying. The mean solar radiation values over all the tests varied between 260 W/ $m^2$and 390 W/m^2. Drying air temperatures were approximately over 39–70% higher than ambient air temperatures. The drying time required to reach 15% product moisture content in the integral natural circulation solar dryer varied between 7 and 24 hours. To achieve the same 15% product moisture by the traditional open -to-sun drying, from 25% to 85% longer drying time is required. In accordance with results of this research it is possible to conclude that using the integral natural -circulation solar dryer is a more appropriate technology to preserve agricultural products. Drying time is considerably reduced and the final product is acceptable in appearance and quality, because the dried crops are completely protected from rain, insects and dust. The solar dryer reported in this study was designed as a small scale home drying unit adaptable to local farmers[13].

Designed, constructed a forced convection solar dryer and tested for the purpose of drying yam in order to study the moisture removal pattern. In this paper the dryer comprises three main components namely the solar collector, the drying chamber and the PV-extractor assembly. Yam fillets weighing 0.52kg were dried in the dryer while an equal mass was dried in the open sun and the profiles obtained in both cases were compared. Quantity of heat used in evaporating moisture is found out. Efficiency of dryer and average drying rate is also found. The load test involved cutting 1.04kg of yam into slices of about 3mm, washed and weighed. This was divided into two parts, 0.52kg each. One part was spread into the first tray of the chamber which had earlier been checked for air tightness so as to avoid heat and moisture losses. The second part was spread in the open sun. An hourly measurement of the temperatures at specific locations and mass of the specimen was carried out between 10.00 and 17.00 hours each day for three days. Design parameters are Reynolds number, Nussult number, Coefficient of heat transfer, Heat removal factor, Total heat loss coefficient, Useful energy collected, mass flow rate, Collector efficiency. Evaluating the performance of the dryer; the collector and system efficiencies of 65.6% and 54.8% were obtained respectively. The moisture content removal of 75.0% was achieved as against 61.5% (control), indicating 13.5% difference, average drying rate of 0.0481kg/hr were recorded during solar drying of yam .The photovoltaic powered solar dryer designed, constructed and tested here can function on a continuous basis, that is, both during high intense sunshine and non insolation hours especially during cloudy weather[14].

Designed and developed solar drying system for maize with V-Groove collector of 2.04 m^2 area, drying chamber and blower. The thermal energy and heat losses from solar collector were calculated for each three tilt angles (30º,45º, 60º). The results obtained during the test period denoted that the maximum gained energy occurred at 11 o'clock hour and then gradually declined since the maximum solar radiation occurred at this time. Other many important results found are the theoretical thermal energy, the experimentally actual heats gain increase by increasing radiation intensity, the maximum values occurred at the 11 am and then gradually declined. The energy gained obtained at the angle tilt 45º is higher than the corresponding values obtained at 60º, 30º tilt[15].

Designed a mixed -mode natural convection solar crop dryer (MNCSCD) for drying cassava and other crops. A batch of cassava 160 kg by mass, having an initial moisture content of 67% wet basis from which 100 kg of water is required to be removed to have it dried to a desired moisture content of 17% wet basis, is used as the drying load in designing the dryer. A drying time of 30–36 h is assumed for the anticipated test location (Kumasi; 6.71N, 1.61W) with an expected average solar irradiance of 400W/m2 and ambient conditions of 25 1C and 77.8% relative humidity. They concluded that a minimum of 42.4m^2 of solar collection area, according to the design, is required for an expected drying efficiency of 12.5%. Under average ambient conditions of 28.2 1C and 72.1% relative humidity with solar irradiance of 340.4W/m^2, a drying time of 35.5 h was realised and the drying efficiency was evaluated as 12.3% when tested under full designed load signifying that the design procedure proposed is sufficiently[16].

A natural convection solar dryer (Cabinet Type) was designed and constructed to dry mango slices. They concluded that the designed dryer with a collector area of 16.8m2 is expected to dry 195.2kg fresh mango (100kg of sliced mango) from 81.4% to 10% wet basis in two days under ambient conditions during harvesting period from April to June. A prototype of the dryer is designed and constructed that has a maximum collector area of 1.03 m^2 Doubled Pass Solar Dryer (DPSD) was designed for drying red chilli in central Vietnam and DPSD is compared with cabinet dryer (CD) and traditional open sun drying. They found that average drying temperatures were 60ºC, 52ºC and 35.8ºC and corresponding relative humidity 34%, 45% and 62% for DPSD, CD and open air sun drying, respectively. The overall drying efficiency of DPSD is 20% which is typical for forced convection solar dryer. The moisture content of fresh red chilli was almost similar during all drying tests where as the initial values were 9.18kg/kg,9.17kg/kg and 9.30kg/kg (db) for DPSD, CD and open air sun drying, respectively. Where the final moisture content in case of DPSD 0.05kg/kg was reached after 23 h, 0.09kg/kg after 29h for CD and 0.18kg/kg after 36 h in case of open sun drying (excluding nights).The performances of a new designed DPSD have been compared with those of a typical CD and a traditional open air sun drying for drying of red chilli. The DPSD resulted in the shortest drying time to meet desired moisture content of chilli (10% w.b.), which corresponds to the highest drying rate comparing to other methods. Although the construction cost of DPSD was higher than CD the overall drying efficiency was more than two times higher in case of DPSD compared to CD. Hence, Double pass solar drier was found to be technically and economically suitable for drying of red chillies under the specific conditions in central Vietnam [17].

Designed and developed a Mixed mode type forced convection solar tunnel drier to dry hot red and green chillies under the tropical weather conditions of Bangladesh as shown in figure .The dryer consists of (1.air inlet 2. fan; 3. solar module; 4. solar collector; 5.side metal frame; 6.outlet of the Collector 7.wooden support; 8. plastic net; 9.roof structure for supporting the plastic cover; 10.base structure for supporting The dryer; 11.rolling bar; 12, outlet of the drying tunnel.) Moisture content of red chilli was reduced from 2.85to 0.05 kg/kg(db) in 20 h in solar tunnel drier and it took 32 h to reduce the moisture content to 0.09 and 0.40 kg/kg (db) in improved and conventional sun drying methods, respectively[18].

A cylindrical section solar drying system was designed and analysis of performance takes place. The system consists of a solar collector flat plate with length of 1.10 m and width of 1.10 m drying chamber cylindrical section and a fan was built and designed for the purpose of drying 70 kg of bean crop. The performance of the solar air collector using three air flow rates has been tested. The highest temperature (71.4°C) of the outlet solar collector has been obtained at 11 am. At radiation intensity 750 W/m² for air flow rate of 0.0401 kg/s was obtained and minimum temperature (40.0°C) was obtained when air flow rate was 0.0675 kg/s at radiation intensity 460 W/m² was obtained. The maximum value of average thermal efficiency 25.64% of the solar air collector obtained at air flow rate of 0.0675 kg/s, and minimum average thermal efficiency is 18.63% at air flow rate of 0.0405 kg/s. The initial moisture content of beans was 70% and final 14% when the air flow rate was 0.0405 kg/s 18% d.b at air flow rate of 0.0540 kg/s and 20% d.b at air flow rate of 0.0765 kg/s [19].

Designed, constructed and tested the solar wind -ventilated cabinet dryer in Nigeria on latitude 7.5 ^{o} N. Comparatively, drying with the solar cabinet dryer showed better results than open air-drying. During the period of test, the average air velocity through the solar dryer was 1.62 m/s and the average daylight efficiency of the system was 46.7%. The maximum drying air temperatures was found to be 64oC inside the dryer. The average drying air temperature in the drying cabinet was higher than the ambient temperature in the range of 5^{o}C in the early hours of the day to 31^{o}C at mid-day.80% and 55% weight losses were obtained in the drying of pepper and yam chips, respectively, in the dryer[20] .

Drying is an essential process in the preservation of agricultural products. Various drying methods are employed to dry different agricultural products. Each method has its own advantages and limitations. Choosing the right drying system is thus important in the process of drying agricultural products. Care must be taken in choosing the drying system. Study comparing traditional drying and other drying methods for the reduction of the drying time and to a significant improvement of the product quality in terms of color texture and taste. Drying reduces the possibilities of the contamination by insects and microorganisms so that product is prevented. An experimental study was performed to determine the drying characteristics of okra using hot air dryer, solar dryer and open sun drying methods. For the hot air drying, the test samples were dried in a laboratory scale hot air dryer at a constant air velocity of 1 m/s and air temperature in the range of 40–90 ^{o} C. For solar drying experiments locally made a solar dryer with vents for natural convection type is used[21].

A hot-air supplemented solar dryer was designed and fabricated for drying white yam slices Dioscorea rotundata. The capacity of the designed hot -air supplemented solar dryer was 14 kg. The equipment was tested in Federal University of Technology Akure (FUTA) using white yam Dioscorea rotundat to establish the effect of incorporating the hot-air section into the solar dryer. Drying experiments were conducted using a temperature of 60 °C for the hot-air supplemented solar drying process at a drying air velocity of 0.8 m/s. After the experiment, it was deduced that the total drying time used to reduce the moisture in the white yam slices to safe storage moisture content (SSMC) differs for the two different drying conditions giving a total drying time of 18 hours for solar dryer and 13 hours for hot - air supplemented solar dryer. The average dryer thermal efficiency for the solar dryer was 31.45 %, and the average dryer thermal efficiency is 42.10 % at solar/mechanical drying at 60 ºC, and also the solar collector highest efficiency was calculated to be 83.28 % at solar radiation intensity of 1199.46 W/m^2 and lowest efficiency of the solar collector was 23.89 % at solar radiation intensity of 300.40 W/m^2 [22].

An indirect forced convection solar drier integrated with recirculation of air has been developed and its performance is tested for drying grapes under the metrological conditions of Coimbatore, India. The system consists of a flat plate solar air heater with lens and recirculation tube, a drying chamber and micro controller. Drying experiments have been performed at an air flow rate of 3.197kg/s. Drying of grapes in a forced convection solar drier reduces the moisture content from around 80% (wet basis) to the final moisture content about 10.6% in 22.6h. Average drier efficiency was estimated to be about 20.92%. The specific moisture extraction rate was estimated to be 0.87 kg/kWh [23].

A greenhouse type solar dryer for small-scale dried food industries was developed and disseminated. The dryer consists of a parabolic roof structure covered with polycarbonate sheets on a concrete floor. The system is 8.0m in width, 20.0 m in length and 3.5m in height, with a loading capacity about 1,000kg of fruits or vegetables. To ensure continuous drying operation, a 100kW-LPG gas burner was incorporated to supply hot air to the dryer during cloudy or rainy days. Nine 15-W DC fans powered by three 50-W PV modules were used to ventilate the dryer. This dryer was installed for a small-scale food industry at Nakhon Pathom in Thailand to produce osmotically dehydrated tomato. To investigate its performance, the dryer was used to dry 3 batches of osmotically dehydrated tomato. Results obtained from these experiments showed that drying air temperatures in the dryer varied from 35°C to 65°C. In addition, the drying time for these products was 2-3 days shorter than that of the natural sun drying and good quality dried products were obtained. A system of differential equations describing heat and

A moisture transfer during drying of osmotically dehydrated tomato was also developed. The simulated results agreed well with the experimental data [24].

Conclusion

In this paper, a review of the research paper is state that, the solar dryer is beneficial than the sun drying techniques. Solar dryers do have shortcomings. They are of little use during cloudy weather. During fair weather they can work too well. Although solar dryers involve an initial expense, they produce better looking, better tasting, and more nutritious foods, enhancing both their food value - and their marketability. They also are faster, safer, and more efficient than traditional sun drying techniques.

References:

1. Waewsak, J.; Chindaruksa, S.; and Punlek, C. 2006. A mathematical modeling study of hot air drying for some agricultural products. Thammasat Int. J. Sci. Technol. 11(1): 14-20.
2. Akinola, A.O. 1999. Development and Performance Evaluation of a Mixed-Mode Solar Food Dryer. M. Eng. Thesis, Federal University of Technology, Akure, Nigeria.
3. Kurtbas, I.; and Turgut, E. 2006. Experimental investigation of solar air heater with free and fixed fins: efficiency and energy loss. Int. J. Sci. Technol. 1(1): 75-82.
4. Bassey, M.W. 1989, Development and use of solar drying technologies, Nigerian Journal of Solar Energy 89: 133-64.
5. M. Mohanraj, P. Chandrasekar, Performance of a Forced Convection Solar Drier Integrated with Gravel as Heat Storage Material for Chili Drying, Journal of Engineering Science and Technology Vol. 4, No. 3 (2009) 305 – 314.
6. Jain, D.; and Tiwari, G.N. (2003). Thermal aspects of open sun drying of various crops. *Energy,* 28(1), 37–54.
7. Ong, K.S. (1999). Solar dryers in the Asia-pacific region. *Renewable Energy*, 16 (1-4), 779-784.
8. Hawlader, M.N.A.; Uddin, M.S.; and Khin, M.M. (2003). Microencapsulated PCM thermal energy storage system. *Applied Energy*, 74 (I-2), 195-202.
9. Ahmad, A.; Saini, J.S.; and Varma, H.K. (1996). Thermohydraulic performance of packed bed solar air heaters. Energy conversion and Management 37 (2), 205-214.
10. Bukola O. Bolaji and Ayoola P. Olalusi, Performance Evaluation of a Mixed-Mode Solar Dryer, AU J.T. 11(4): 225-231 (Apr. 2008).
11. Bukola O. Bolaji aΨ, Tajudeen M.A.Olayanjub and Taiwo O. Faladec, Performance Evaluation of a Solar Wind -Ventilated Cabinet Dryer ,The West Indian Journal of Engineering Vol.33, Nos.1/2, January 2011, pp.12-18.

12. Abdul Jabbar N. Khalifa, Amer M. Al-Dabagh and W.M. Al-Mehemdi, An Experiment al Study of Vegetable Solar Drying Systems with and without Auxiliary Heat, International Scholarly Research Network ISRN Renewable Energy Volume 2012, Article ID 789324.
13. Ehl P., Banout J., Lojka B., Polesný Z., Lojková J., Post Harvest Processing Of Selected Tropical Crops Using a Natural Circulation Solar Dryer Agricultura Tropica Et Subtropica Vol. 43 (2) 2010.
14. A.O. Adelaja, O.S. Asemota and I.K. Oshiafi, Experimental Determination of the Moisture Content Pattern in Yam during Drying, Journal of Applied Sciences Research, 6(8): 1171-1181, 2010.
15. Ahmed Abed Gatea. Design, construction and performance evaluation of solar maize dryer; Iraq;Journal of Agricultural Biotechnology and Sustainable Development Vol. 2(3), pp. 039-046, March 2010;
16. F.K. Forson,M.A.A. Nazha, F.O. Akuffo,H.Rajakaruna. Design of mixed - mode natural convection solar crop dryers: Application of principles and rules of thumb; Renewable Energy 32 (2007) 2306–2319;
17. EL-Amin Omda Mohamed Akoy, Mohamed Ayoub Ismail, El-Fadil Adam Ahmed and W. Luecke. Design and Construction of A Solar Dryer for Mango Slices.
18. J. Banout, P. Ehl, J. Havlik, B. Lojka, Z. Polesny, V. Verner. Design and performance evaluation of a Double-pass solar drier for drying of red chilli, Dec 2010.
19. M.A. Hossaina and B.K. Bala. Drying of hot chilli using solar tunnel drier; Bangladesh Agricultural University, Mymensingh-2202, Bangladesh, June 2006.
20. Ahmed AbedGatea. Design and construction of a solar drying system, a cylindrical section and analysis of the performance of the thermal drying system. University of Baghdad, Iraq, July 2010
21. P.K.Wankhade, R.S.Sapkal, V.S.Sapkal. Drying Characteristics of Okra Slices using Different Drying Methods by Comparative Evaluation, Proceedings of the World Congress on Engineering and Computer Science 2012 Vol II WCECS 2012, October 24-26, 2012, San Francisco, USA.
22. T. O. Aduewa, A. S. Ogunlowo and S. T. Ojo, ,Development of Hot-Air Supplemented Solar Dryer for White Yam (Dioscorea Rotundata) Slices , IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS) volume 7, Issue 12 Ver. II (Dec. 2014), PP 114-123.
23. C.Velmurugan, S.Sivakumar, Ashwin Bala, N. Harish Kumar and S. Prithviraj, Experimental & Analytical Investigation on Modified Solar Dryer with Recirculation of Air, International Journal of Engineering Research and Technology. Volume 6, Number 4 (2013), pp. 441-448.
24. Serm Janjai, A greenhouse type solar dryer for small-scale dried food industries: Development and dissemination, international journal of energy and environment, Volume 3, Issue 3, 2012 pp.383-398.

***** *****