Observed performances of the hybrid solar-biomass dryer for fish drying

Y Yuwana¹, E Silvia¹, B Sidebang¹

¹Agricultural Technology Department, University of Bengkulu, Jl. WR. Supratman, Bengkulu, 38371, Indonesia

Corresponding author’s email address: yuwana@unib.ac.id

Abstract. This experiment aimed to configure the performances of hybrid dryer operated with solar and biomass energies for fish drying. The dryer consisted of a structure made of light steel frame and covered with UV plastic 12% equipped with drying chamber, a chimney, a heat collector, a furnace, and a heat exchanger. The biomass was coconut shell and the sample of fish was Pepetak Leiognatus spp. Operating with solar energy and without fish inside the dryer increased the temperature and relative humidity of the drying chamber respectively 13.4°C higher and 37.6% lower than those of the ambient air. When the dryer without fish was biomass operated using 3 kg fuel of the first supply and 1.5 kg fuel of subsequent supplies per 20 minutes, it was able to generate the drying chamber temperature and relative humidity about 60°C and nearly 0% in averages. Utilizing 20% fish moisture content as the threshold for dry fish, operating with solar energy, the dryer completed drying process in 20.47 h which was faster that of the sun drying (24.20 hours). The dryer needed to finish drying processes in 14.37 h and 15.43 h when operated by respectively biomass energy and solar energy continued with biomass energy. The rate of fuel supply for fish drying was 0.633 kg coconut shell per kg wet fish.

Keywords: Hybrid Dryer; Observed Performance; Biomass; Fish

1. Introduction

Drying is the most common mode of agricultural produce preservation, including fish in tropical and subtropical regions. Sun drying is the conventional method of drying widely employed in developing countries. Sun drying is conducted by exposing produce directly to sun radiation and its performance depends merely on the position of the sun and the weather condition. This drying is usually done by spreading products on a concrete floor, mats, tarred surface roads and other materials [1]. Sun drying is practicable, but requires large space [2] sometimes risks products of inferior quality and losses due to the existence of unwanted microorganisms, insects, pests, animals, dust, dirt, rains [3], [4]. To solve these problems solar dryers have been developed and based on the mode of solar energy manipulation might be classified in three types [5]: direct type solar dryers [6], [7], [8], [9], indirect type solar dryers [7], [10], [11], [12] and mix type solar dryers [3], [13], [14]. The direct type solar dryer is similar to the sun drying except the product being dried is covered with transparent materials and moisture is removed from the product from its top surface. In the indirect type, the drying air is heated by a
collector which accumulates solar energy from the sun, and the moisture of product is evaporated by the heated drying air. The mixed type solar dryer is the combination of direct and indirect types in which wet produce to be dried receives drying energy both directly from the sun and hot air heated by the collector.

Although many solar dryers have been equipped with heat storage, problems still exist, especially during the rainy season and long bad weather since the source of energy depends only on the sun. To overcome this disadvantage hybrid solar dryers have been introduced and widely explored. Solar hybrid dryers are basically solar dryer with any other drying energy combination or substitution, such as electric energy [15], [16], [17] and biomass [18], [19], [20], [21], [22]. In hybrid dryer supplied energy in drying chamber to evaporate product moisture may come directly from the sun, heat collector and heat exchange generated by the furnace. Most hybrid dryers are handicapped by electric power dependence, whether it is needed to substitute energy [23], [24], [25], [26], [27] or to create a flow of drying air [28], [29], [30], [31], [32]. This creates further problems for application in the remote area of developing countries where electricity supply is often inaccessible.

In case of Indonesia, fish is a staple source of protein for common people and coconut is abundant in this country. The coconut shell is by product with high energy content, 22000 kJ kg\(^{-1}\) at 5.3% moisture content. So it is important to find a design of hybrid dryer that will be able to operate without electricity and to make use of coconut shell as its energy supply for fish drying. This research aimed to configure the performances of a hybrid solar-biomass dryer having unique design for fish drying. Uniqueness of the dryer pertained to two heat collectors and the feature of heat exchanger. The performance of dryer was configured for three cases in which the dryer was operated by solar energy, biomass energy, and solar energy and biomass energy consecutively.

2. Methods

In this experiment a solar–biomass hybrid dryer was constructed and then tested to dry fish. The dryer comprised mainly of drying chamber equipped with a chimney, double heat collectors, furnace, heat exchanger and trays. The whole structure of the dryer was framed with the light steel bar and covered with 12% UV plastic. The dryer occupied 5 m\(^2\) x 2.4 m\(^2\) area in total and the upper end of the chimney was 4.3 m from the ground. It is schematically presented in Fig.1.

The drying chamber had 2 m x 2 m base area and 2.8 m high, and a chimney measured about 40 cm x 40 cm x 1.5 m and was equipped with an outlet air at its upper end. This chamber was also provided with a front door to facilitate in-out movements of trays. The heat collector measured 1.5 m x 2 m and was made of an aluminium sheet of 0.8 mm thickness painted in black on the upper surface. It is placed on 3 mm thickness plywood as an insulator and covered with 12% UV plastic. There were two heat collectors, right and left, and inlets of fresh air were provided at their lower ends. The furnace had 42 cm x 34 cm x 2 m dimensions made of 1.5 mm thickness metal sheet with metal basket for fuel holding inside, a door for full entry on its front side and an exhausted funnel at its backside. The bottom of the furnace was perforated for fresh air entry. The heat exchanger was made of 0.8 mm thickness aluminium sheet and consisted of 2 m x 2 m x 0.18 m cavity with 10 hollow fins (5 right, 5 left) having 0.8 m x 2 m x 0.03 m dimensions each. There were 10 trays and each tray was constructed from anti-corrosion of wire mesh, framed with the metallic rafter and measured 2 m x 0.76 m. The trays were placed in between the fins of heat exchanger and were both installed in the drying chamber. So there existed 5 stories of trays (two trays for each story).
The dryer was installed in an open area of Department Agricultural Technology, Faculty of Agriculture, the University of Bengkulu, Bengkulu, Indonesia situated at longitude 3°43'49" - 4°01'00" south latitude 102°14'42" - 102°22'45" east longitude. During the solar energy operation, the collector accumulated solar radiation heat from the sun, heated air entering the inlet and supplied it in the drying chamber. At the same moment the drying chamber also harvested directly heat of solar radiation from the sun. Drying air moved from the inlets at the lower end of the heat collectors, passed through the trays on which product to be dried was placed, and then escaped from the chimney through the outlet. Due to evaporation mechanism, product moisture content decreased in function of time until the product reached a certain level as the indication of the drying process to be terminated.

Utilizing biomass energy, the dryer was operated as follows. Fuel was weighted to meet a certain measure and placed in the metal basket. The furnace’s door was opened and the basket was pushed into it and the fuel was then flamed in order to burn gradually. The furnace’s door was closed and the
fuel was burned continuously due to supply fresh air from the perforations at the bottom of the furnace. The heat exchanger received the energy content of hot air generated by the fuel burning in the furnace. Heat transferred by the heat exchanger increased the temperature of air in the drying chamber supplied from the inlet. Drying air passed through the trays loaded with wet product and then the drying process ran.

Coconut shell was used as fuel in the experiments. This material was obtained from the coconut milk retailers and sun dried up to 9.03 (± 0.40) % moisture content. This moisture content was determined by placing the sample in the oven having the temperature of 102°C for 24 hours. The moisture content was calculated based on wet basis.

_Pepetak Leiognatus spp._ fish measured 15 cm to 18 cm length, 3 cm to 5 cm width and 13 mm to 18 mm thickness were used for experiments. With this specified measure, the capacity of the dryer was about 100 kgs.

Main instruments prepared for the experiments were the digital thermo hygrometer for temperature and humidity measurements, analytical balance (0.1 g accuracy) for fish weighting, platform scale (1 g accuracy) for fuel weight measurement, and the oven for fish moisture determination.

During experiments five thermo hygrometers were installed on every story of trays in the drying chamber and a thermo hygrometer was placed outside the dryer. By doing this representative value of temperature and relative humidity for drying chamber and ambient air were obtained.

The experiments were grouped into 5 series : 1) testing drying performance without load (fish to be dried) for the dryer operating with solar energy, 2) testing drying performance without load for the dryer operating with biomass energy, 3) testing drying performance for the dryer loaded with fish and operated by solar energy, 4) testing drying performance for the dryer loaded with fish and operated by biomass energy, and 5) testing drying performance for the dryer loaded with fish, and operated by solar energy, and then continued by biomass energy. The experiment was carried out in July to October, the transition period from dry season to rainy season, at the Laboratory, Agricultural Technology, Department of Agricultural Technology, Faculty of Agriculture, University of Bengkulu, Bengkulu Indonesia.

The first series of experiments was conducted on 19th to 21st July from 09.00 AM to 04.00 PM local time. The drying chamber and ambient air temperature and humidity were recorded in every 30 minutes and experimental data were analysed per day (justified as three repetitions).

The second series of experiments were performed in 17 hours, and based on the preliminary experiments, 3 kg fuel of the first supply and 1.5 kg fuel of subsequent supplies per 20 minutes was employed here. The Recording was also done in the 30 minutes period for drying chamber and ambient air temperature and humidity. For the day time the experiment, the dryer was shaded with dark colour plastic.

The third series of experiments were conducted in three times, at 19th to 21st August, 4th to 6th September, and 8th to 10th September respectively from 09.00 AM to 04 PM. The dryer was loaded with wet fish, and a sample of 20 fish for each tray was prepared for observation. A sample of 20 fish was also prepared for sun drying and observation was done in the same manner. Drying chamber and ambient air temperature and humidity were regularly recorded every 30 minutes while fish samples were periodically weighted in an hour interval.

In the fourth series of experiments, the biomass energy was generated by the same procedure as in the second series of experiments while the drying parameters were observed by the same technique as in the third series of experiments. Three experiments were conducted for 18 hours period and taken place on 21st to 22nd September, 25th to 26th September and 28th to 29th September respectively starting from 09.00 AM. For day time experiment, the dryer was shaded with dark colour plastic.

In each experiment of the fifth series, fish was first dried by solar energy from 09.00 AM to 04.00 PM and by biomass energy from 04.00 PM on the same day until 02.00 AM on the next day. Three experiments were carried out on 15th to 16th September 6th to 7th October, and 7th to 8th October respectively. Data collection was performed using the same method as the fourth series of experiments.
The dried fish of all samples were taken to the laboratory for moisture content determination. An oven method using 150°C temperature for 20 hours prescribed by the Indonesian National Standardization Board was employed and the moisture content of fish was then calculated using the wet basis according to the following formula:

\[ M_c = \frac{W_w - W_d}{W_w} \times 100 \]  

Where  \( M_c \) is moisture content of sample (%),  \( W_w \) is wet weight of sample (kg), and  \( W_d \) is dry weight of sample (kg).

The drying parameters including temperature, relative humidity, and fish moisture content were analysed in the form of graphs in function of drying time. Temperature and relative humidity of the drying chamber were found by averaging readings from each story of trays while the moisture content of fish was also calculated by averaging the moisture content of fish from each story of tray. The values of temperature, relative humidity and the fish moisture content of each series of experiment were found by averaging the values of these parameters from three repetitions of the same series.

In analysis, the fish was justified to be dry when the moisture content of fish reached 20% wet basis (wb). The fuel needed to dry the fish was expressed in the form ratio of wet fish being dried to total fuel supply as follows.

\[ FFR = \frac{W_{fs}}{W_{fl}} \]  

Where  \( W_{fs} \) is weight of fish being dried (kg) and  \( W_{fl} \) is weight of total fuel supply (kg).

3. Results and Discussion

The experimental results are chronologically presented according to experimental sets up. Fig. 2 depicts the temperature and relative humidity plotted against observation time from the first series of experiments.

![Figure 2](image-url)  

**Figure 2** Temperature and relative humidity plotted against observation time when the dryer without load was solar energy operated

The data also revealed that the average temperature of drying chamber was 45.2°C whereas the average temperature of ambient air was 31.8°C, therefore the dryer was able to produce the drying air temperature of 13.4 °C higher than the ambient air temperature. This temperature gain was higher compared to the temperature gains for solar dryers reported by Olokor and Omojowo [6] for Kainji solar tent (12.1°C) and the Doe solar tent (6.2°C) observed in the dry season, and by Dasin et al. [33] for passive solar dryer (8°C) although the dryer tested here had a much higher holding capacity than those of three types of dryers. Averages relative humidity of the drying chamber and ambient air were 28.7% and 66.3%, respectively, in the other word, the dryer resulted the relative humidity of
drying air 37.6% lower than the relative humidity of ambient air. This relative humidity difference was also higher than those of the Kainji solar tent (14.3%) and Doe solar tent (7.2%).

Figure 3 indicates the temperature and relative humidity values from the second series of experiments.

![Figure 3](image1.png)

**Figure 3** Temperature and relative humidity plotted against drying time when the dryer without load was operated with biomass energy

Temperature of drying chamber increased from about the ambient temperature and stabilized at about 60°C after 3 hours producing very dry air with about zero % relative humidity. The temperature of drying chamber was in the interval of tolerable temperatures for fish drying described by Caprio [34] and it was the reason for utilizing 3 kgs fuel of the first supply and 1.5 kg of subsequent supplies per 20 minutes for operating the dryer loaded with fish in the fourth and fifth series of experiments.

The results of the third series of experiments are presented in Figure 4 and 5.

![Figure 4](image2.png)

**Figure 4** Temperature and relative humidity patterns when the dryer loaded with fish was solar energy operated
Figure 5 Fish moisture contents plotted against drying time when the dryer loaded with fish was solar energy operated.

The averages of temperature and relative humidity of the drying chamber were 42.8°C and 30.9% respectively whereas the average temperature and relative humidity of the ambient air were 31.3°C and 69.6% respectively.

In comparison to the result of the first experiment, the temperature and humidity gains did not seem to be influenced by fish loading. The fish moisture contents decreased exponentially for both the hybrid drying and the sun drying, and the hybrid drying’s fish moisture content decreased faster than that of the sun drying. These typical curves were also observed in the solar dryer for Sardines fish [35], greenhouse solar tunnel dryer for salted and unsalted Croaker fish, Anchovy fish and Ribbon fish [36]. Based on the above curves, the fish moisture contents of 20%(wb) was obtained in 20.47 hours by the hybrid dryer and 24.20 hours by the sun drying. The performance of this dryer was better than the dome dryer found by Sablani et al. [35] since this dryer consisted of five stories of rack, and completed the drying process faster than the sun drying, in contrast the dome dryer comprised only three stories and performed similar to the open rack drying they reported. Furthermore this dryer also performed better than the green house solar tunnel dryer reported by Swati and Chauhan [36] that operated with drying temperatures from 40°C to 45°C, and reduced moisture contents of unsalted fish from 226.95% - 296.05%(db) to 17.64% - 25% (db) in 24 to 32 hours, depending on the variety of fish and the initial moisture contents. Figure 6 and 7 demonstrate the result of the fourth series of experiments.
Figure 6. Temperature and relative humidity plotted against drying time when the dryer loaded with fish was biomass energy operated

After fuel combustion in the furnace was stabilized, the average temperature and relative humidity of the drying chamber were 58.55°C and 8.3%, respectively, while ambient air had an average temperature of 28°C and average relative humidity of 85.3%. The moisture content of fish decreased linearly with drying time. This typical curve was also observed by Sengar et al. [37] but for the prawn drying using the solar dryer operating with the temperature of 38.7°C to 57°C, and by Chavan et al. [38] for the mackerel fish dried by the solar-biomass hybrid cabinet dryer at the temperatures of 32.4°C - 57.7°C, the relative humidity of 23.9%-85.8% and the air flow rate of 0.20 m/s-0.6 m/s. The graph also indicated that the moisture content of fish reached 20% (wb) in 14.39 hours. Total fuel utilized to complete drying was 63.26 kg. Based on this evidence, the ratio of fuel consumption to dry fish was 0.633 kg coconut shell per kg wet fish.

Figure 7 Fish moisture contents plotted against drying time when the dryer loaded with fish was biomass energy operated
The results of the fifth series of experiments are presented in Figure 8 and 9.

![Figure 8](image1.png)

**Figure 8** Temperature and relative humidity plotted against drying time when the dryer loaded with fish was operated with solar and biomass energies

![Figure 9](image2.png)

**Figure 9**. Fish moisture content plotted against drying time when the dryer loaded with fish was operated with solar and biomass energies

In the course of drying, the temperature and relative humidity of the ambient air were 28.9°C and 79.5%, on the other hand the temperature and relative humidity of the drying chamber were 49.7°C and 21.3%. The fish moisture content decreased quadratically with the drying time and reached 20% (wb) in 15.43 hours with total fuel supplied of 43.5 kg. This typical curve has not been found in any fish drying with any mode of dryers but it was similar to the curve of the heat transfer coefficient functioned to the drying time for prawn simulated in the green house solar dryer by Das and Tiwari [39].
It is interesting to compare the performance of this dryer (Yuwana’s dryer) to the performance of the solar-biomass hybrid cabinet dryer described by Chavan et al. [40]. To do so, we first describe the important parameters of these dryers. Both dryers occupied 2 m x 2 m horizontal area of the drying chamber and used the similar principal gasifier but Yuwana’s dryer was built from the metal frame and the UV plastic cover. This dryer was also equipped with double heat collectors measured 1.5 m x 2 m each and the heat exchanger. On the other hand, Chavan’s dryer was constructed from bricks and mortar, and supported by pipes as the heat exchanger and an automatic temperature controller. Furthermore, Chavan’s dryer used the eucalyptus wood biomass whereas Yuwana’s dryer utilized the coconut shell biomass. Operating with 25 kg of the mackerel fish having 17.7±0.33 cm length, the solar and biomass energy sources, the drying air temperature of 32.39-57.69°C, the drying air relative humidity of 23.9-85.8%, the air flow rate of 0.20-0.60 m/s, the ambient temperature of 29.53-38.08°C, and the ambient relative humidity of 54.80-98.30% Chavan’s was able to reduce the fish moisture content from 72.5±0.44% to 16.7±0.52% within 24 hours. On the other hand, operating with the same mode and loaded with 100 kg, at the ambient air temperature of 28.9°C and the ambient relative humidity of 79.5%, Yuwana’s dryer produced the drying air temperature of 49.7°C and the drying relative humidity of 21.3%, and decreased the moisture content of Pepetak fish of 15 -18 cm length from 78.48% to 20% in 15.43 hours.

The design of hybrid solar-biomass dryer presented here is unique compared to the dryers described in previous works [18], [19], [4]. The uniqueness is mainly relied on its structure and heat exchanger.

4. Conclusions
The hybrid solar-biomass dryer has been uniquely designed and tested. The dryer without load and operated by the solar energy was able to produce the dry air having temperature 13.4 °C higher than the ambient air temperature and the dry air relative humidity of 37.6% lower than the relative humidity of ambient air. Operated without load by the biomass energy of 3 kgs fuel for first supply and of 1.5 kg fuel for subsequent supplies per 20 minutes the dryer resulted averages drying chamber temperature and humidity 58.55°C and 8.3% respectively. The dryer completed the fish drying 20.47 hours when operated by the solar energy and shorter than that of the sun drying (24.20 hours), in 14.39 hours when operated with biomass energy, and in 15.43 hours when operated by the solar energy and the biomass energy subsequently. The ratio of fuel supply to dry fish was 0.633 kg coconut shell per kg wet fish.

Acknowledgment
Great acknowledgment is delivered to the Ministry of Research, Technology and Higher Education Republic of Indonesia for financial support of this research.

References
[1] Abur BT, Dan-Dakouta H and Egbo G 2014 Food security: Solar dryers and effective food preservation. Int. J. Adv. Engg. Res. Studies 3(2): 166-171.
[2] Prakash TB and Satyanayarana S 2014 Performance analysis of solar drying system for Guntur Chilli. IJLTET 4(2): 283-298.
[3] Panchal S, Solanki SK, Yadav S, Tilkar AK and Nagaich R 2013 Design, construction and Testing of solar dryer with roughened surface solar air heater. Int. J. Innov. Res. Eng. & Sci. 7(2): 7-17.
[4] Sontakkke MS and Salve SP 2015 Solar drying technologies: A review. IRJES. 4(4): 29-35.
[5] Kumar A, Singh R, Prakash O and Ashutosh 2014 Review on global solar drying status. CIGR Journal 16(4): 161-177.
[6] Olokore JO and Omejowo FM 2009 Adaptation and improvement of a simple solar tent dryer to enhance fish drying. Nature and Science 7(10): 18-24.
[7] Nandwani SS 2011 Design construction and study of direct indirect natural circulation solar dryer in Costa Rica. ISIESCO Sci. Tech. Vision 7(11): 43-47.
[8] Almuhanna EA 2012 Utilization of a solar greenhouse as a solar dryer for drying dates under the climatic conditions of the Eastern Province of Saudi Arabia. J. Agric. Sci. 4(3):237-246.
[9] Arun S, Ayyappan S and Sreenarayanan VV 2014 Experimental studies on drying characteristics of tomato in a solar tunnel greenhouse dryer. IJRTE.3(4):32-37.
[10] Banout J and Ehl P 2010 Using a double-pass solar drier for drying of bamboo shoots. J. Agr.& Rural Dev. Trop. Subtrop. 111(2):119-127.
[11] Sulaiman FN, Abdullah and Aliasak Z 2013 Solar drying system for drying empty bunches. J. Phys.Sci. 24(1): 75-93.
[12] Phadke PC, Walke PV and Kriplani VM 2015 A review on indirect solar dryers. ARPN J.Eng.Appl.Sci.10(8):3360-3371.
[13] Yuwana Y, Effransa F and Marmiza 2017 Observed Ysd-Unib Solar Drying curve and drying Time Prediction for White Pepper. American Journal of Engineering Research 6(12):380-387.
[14] Munir A, Sultan U and Iqbal M 2013 Development and performance evaluation of a locally fabricated portable solar tunnel dryer for drying of fruits, vegetables and medicinal plants. Pak. J. Agri. Sci. 50(3): 493-498.
[15] Ferreira AG, Charbel ALT, Pires RL, Silva JG and Maia CB 2007 Experimental analysis of a hybrid dryer. Eng Ter.6(2): 3-7.
[16] Rodriguez EC, Fiueroa IP and Mercado CAR 2013 Feasibility analysis of drying process habanero chili using a hybrid-solar-fluidized bed dryer in Yucatan Mexico. J. Energy Power Eng. 7:1898-1908.
[17] Reyes A, Mahn A and Cares V 2015 Analysis of dried onions in a hybrid solar dryer, freeze dryer and tunnel dryer. Chem. Eng. Trans.43
[18] Yuwana Y and Sidebang B 2017 Performative improvement of Solar-Biomass Hybrid Dryer for Fish drying. IJASEIT 7(6): 2251-2257.
[19] Gunasekarakan K, Shanmugam V and Suresh P 2012 Modeling and analytical experimental study of hybrid solar dryer integrated with biomass dryer for drying coleus forskohlii stems. IPSSIT. 28: 28-32.
[20] Saravanand D, Wilson VH and KumaraSamy S 2014 Design and thermal performance of the solar biomass hybrid dryer for cashew drying. Mech. Eng. 12(3): 277-288.
[21] Aukah J, Muvengei M, Ndiritu H and Onyango C 2015 Simulation of drying uniformity inside hybrid solar biomass dryer using ANSYS CFX. Proc. SRI Conference: 336-344.
[22] Dhanushkodi S,Wilson WH and Sudhakar K 2015 Simulation of solar biomass hybrid dryer for drying cashew kernel. Adv. Appl. Sci. Res.6(8):148-154.
[23] Delgado E, Peralta J, Arboleda I and Aguera AL 2012 Design and analysis of a hybrid drying using renewable technologies. Proc. ICREPQ 12.
[24] Maia CB, Ferreira AG, Caberles-Gomez L, Hanriot SM and Martin TO 2012 Simulation of the airflow inside a hybrid dryer. IJRRAS. 10(3): 382-389.
[25] Sajith KG and Muraleedharan C 2013 A study on drying of amla using a hybrid dryer. IJJSET. 2(1): 794-799.
[26] Mortezapour H, Ghabadian B, Khoshtagaza MH and Minaei S 2014 Drying kinetics and quality characteristics of saffron dried with a heat pump assisted hybrid photovoltaic-thermal solar dryer. J.Agric. Sci. Tech.16: 33-45.
[27] Sajith KG and Muraleedharan C 2014 Economic analysis of hybrid photo voltaic/thermal dryer for drying amla. IJERT. 3(8): 907-910.
[28] Mastekeyev YA, Bhatta CP, Leon MA and Kumar S 1999 Experimental studies on a hybrid dryer. Paper presented at the ISES 99 Solar World Congresss.
[29] Amer BMA, Hossain MA and Gottschalk K 2009 Design and performance evaluation of a new hybrid solar dryer for banana. Energy conservation and Management.
[30] Ali SA and Bahnasawy AH 2011 Development of a simulation model for the hybrid solar dryers as alternative sustainable drying system for herbal and medicinal plants. Proc. 6th CIGR, Nantes France: 1-6.
[31] Dhanuskodi S, Sukumaran R and Wilson H 2013 Investigation of solar biomass hybrid system for drying cashew. Int. J. Chem. Tech. Res. 5(2):1076-1082.
[32] Reyes A, Cubillos F, Mahn A and Vasques J 2014 Dehydration of agro products in a hybrid solar dryer controlled through a fuzzy logic system. Int. J. Mod. Nonlinear Theory and Appl. 3:66-70.
[33] Dasin DY, Godi NY and Kingsley OC 2015 Experimental investigations of the performance of passive solar food dryer tested in Yola-Nigeria. Int. J. Energy. Engng. 5(1): 9-15.
[34] Carpio EV 1982 Drying fish in the Philippines. In « Food Drying » Proceeding of a Workshop held at Edmonton, Alberta, 6-9 July 1981.
[35] Sablani SS, Rahman MS, Haffar I, Mahgoub O, Al-Marzouki AS. Al-Ruzeiqi MH, Al-Habshi NH and Al-Belushi RH 2003 Drying rates and quality parameters of fish sardines processed using solar dryers. Agricultural and Marine Sciences 8(2):79-86.
[36] Swati MN and Chauhan PM 2015 Development of greenhouse solar tunnel dryer for industrial fish drying of selected species from the western coastal region of India. Res. J. Engng. Sci. 4(10):1-9.
[37] Sengar SH, Khandetod YP and Mohod AG 2009 Low cost solar dryer for fish. African J. Environnl. Sci. Tech. 3(9): 265-271.
[38] Chavan BR, Yakupitiyage A, Kumar S and Rakshit SK 2008 Experimental investigation on biochemical, microbial and sensory properties of mackerel (Rastrilliger kanagurta) dried by solar-biomass hybrid cabinet dryer. J.Food, Agr.& Envrmtnt. 6(3&4):167-171.
[39] Das T and Tiwari DN 2008 Heat and mass transfer of greenhouse fish drying under forced convection mode. Int. J. Agric. Res. 3(1): 69-76.