Drying of Empty Fruit Bunches using a Solar Drying System

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Abstract: In this paper, the drying characteristic of Empty Fruit Bunches (EFB) of oil palm is presented. The EFB, a waste of oil palm processing was used as the test sample and dried using a solar drying system that was built. The system used was comprised of six double-pass solar collectors with porous media in the second channel which were connected in a series of three collectors in two banks and a drying chamber. Two conditions of the EFB sample were considered in the drying test; treated and untreated. A simple water washing treatment was used to treat the first sample to reduce its ash content whereas the second sample was untreated in its original condition. The EFB samples were dried until equilibrium moisture content below 10 mf wt% was reached, a condition required to achieve a number of purposes in energy applications and storage of biomass material. From the results obtained, it was found that the samples were successfully dried from an initial moisture content of 170.68 mf wt% to a final moisture content of 3.85 mf wt% for the untreated sample and from 376.14 mf wt% to 4.36mf wt% for the treated sample in 66 hours of solar drying.

Keywords: *Solar Drying, EFB, Moisture content, Ash content*

1. Introduction

Malaysia is the largest producer of palm oil industry in the world and has around 4.3 million hectares of oil palm plantation. Malaysia also produces an average of 81.5 million tonnes of fresh fruit bunches. Among other contributors, palm oil industry represents the highest contributor and generates more residues during the harvesting, replanting and milling processes. The residues that come from the milling processes are fruit fibers, shell and empty fruit bunches (EFB) which have great potential as energy resources. Other residues which include trunks and fronds are also available at the plantation area [1]. These wastes are currently left on the ground or burned which are causing many environmental problems.

Biomass is an organic matter which can be converted into useful energy. There are plenty of processes available for converting biomass waste into valuable fuels such as fuel oil, fuel gas or higher value products for chemical and bio-technology industry. The waste can be converted into useful energy by direct combustion, pyrolysis, liquefaction or gasification [2,3,4]. However, before the waste can be used effectively in these processes, some pre-treatment processes should be applied to the sample such as size reduction, drying treatment and washing treatment.

Biomass products are dried to achieve standard value of moisture content to avoid damage from infestation and also to increase the yield of the products. However, if the products are over dried, it will cause a decrease in its value [5]. Biomass with moisture content of less than 10 mf wt% is required to avoid microorganism attack which affects the end-product quality and to achieve a number of purposes in energy applications and storage of biomass material. At this rate, the enzymes inside the products become inactive [6,7].

Solar drying system has three types of drying modes: direct, indirect and mixed-mode. In the direct mode dryer, the product is directly exposed to solar radiation. This type of dryer mainly consists of a drying chamber that has a transparent glass or plastic cover. Biomass product is placed on a perforated tray that allows the air to flow through it [8]. In the indirect mode, the product is not directly exposed to direct solar radiation. The dryer basically consists of a solar collector and a drying chamber. The performance of the indirect mode dryer depends on the efficiency of the collector. Biomass product is placed in an opaque drying chamber which is heated by the air from the collector connected to it. This type of dryer is more efficient than the direct mode dryer or open sun drying and was reported that it could produce higher operating temperature [9]. However, the performance of the mixed-mode solar dryer was found to be most effective and particularly promising in tropical humid areas where climatic conditions favor direct sun drying for agricultural products. This type of dryer basically consists of a cabinet-type solar dryer with a transparent top cover and connected to a solar collector. Normally, natural convection works the best for the mixed-mode dryer since it utilizes heat from direct solar radiation as well as the convective energy of the heated air from the collector. This type of dryer is a combination of the direct and indirect modes [10].

The performance of the solar drying system is highly influenced by the performance of the collector. Therefore, several researches have been conducted in order to improve the performance of the solar collector, such as in [11,12,13,14]. In order to produce better quality end-product, several researches have been conducted on the drying of biomass products which include a solar assisted dryer for oil palm fronds [15], solar dryer for pineapple [16], solar drying characteristics of strawberry [17], drying of copra in a forced convection solar drier [18] and mixed-mode natural convection solar crop dryers [19].

The purpose of this study was to dry the EFB, a waste from palm oil industry in a double-pass solar drying system until a moisture content of below 10 mf wt% is reached. The results from this study are presented and discussed below.

2. Experimental set up and procedure

A solar drying system has been designed and constructed in Universiti Sains Malaysia, in the northern region of Peninsular Malaysia. The system consisted of a drying chamber and six solar collectors of double-pass type with porous media in the second pass of the collector.

The length of each collector was 240cm and the width was 120cm. To produce the highest outlet temperature, an absorber plate made of aluminum sheet was placed between the upper and bottom channel of each collector with height at H_1=1.0cm on the top pass and H_2=10.0cm on the bottom pass as shown in Fig. 1 [20]. The plate was painted matt black to increase the absorber's absorption value. The collector's frame is made of plywood also painted black and a single sheet of glass was used as top cover. The bottom and sides of the collector are insulated with polystyrene to minimize heat losses.

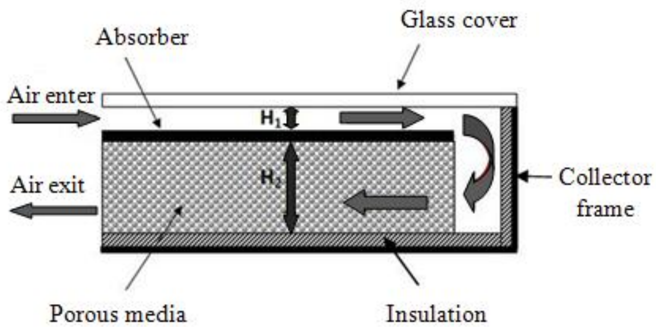

Fig. 1. The side view of the solar collector

The dimensions of the drying chamber were 120cm x 120cm x 240cm as shown in Fig. 2. The external walls were made of plywood which was painted black while the internal walls were made of zinc and insulated with polystyrene of thickness 5cm. The heat absorbed by the interior walls was greatly influenced by the direct solar radiation through the top glass cover besides the heated air from the collectors. There were three different levels of wire mesh trays inside the chamber where the samples were dried. The moisture picked up from the EFB samples during the drying process finally exits the dryer through the exhaust outlet on the upper side of the drying chamber.

The layout of the solar drying system is as shown in Fig. 3. There are two sets of three collectors that are connected in series where air enters the two inlets of the upper channel of the first collector for each set. Solar radiation through the transparent glass cover of the collectors is readily absorbed by the absorber and heats the air inside the first pass of the collector before flowing to the second pass. The porous media acts as a good thermal storage and assists in maintaining high temperatures in the later part of the afternoon. Finally, the hot air from the two banks of the collectors is directed to the drying chamber.

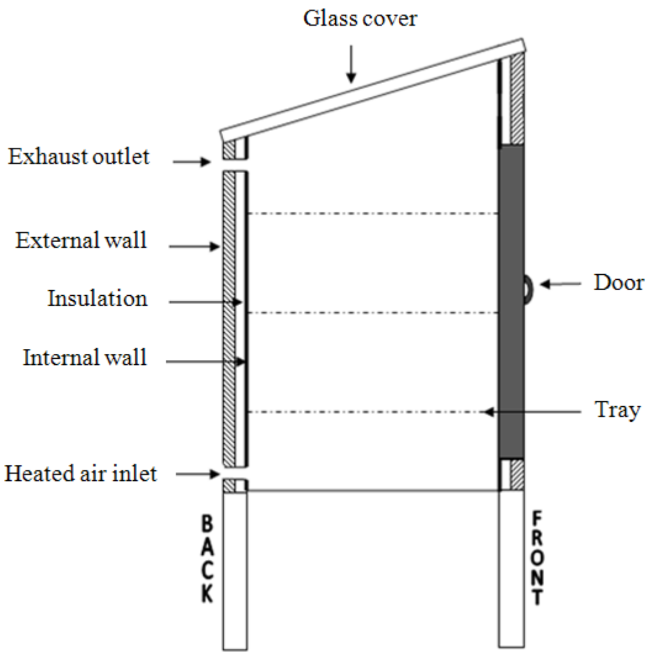

Fig. 2. The side view of the drying chamber

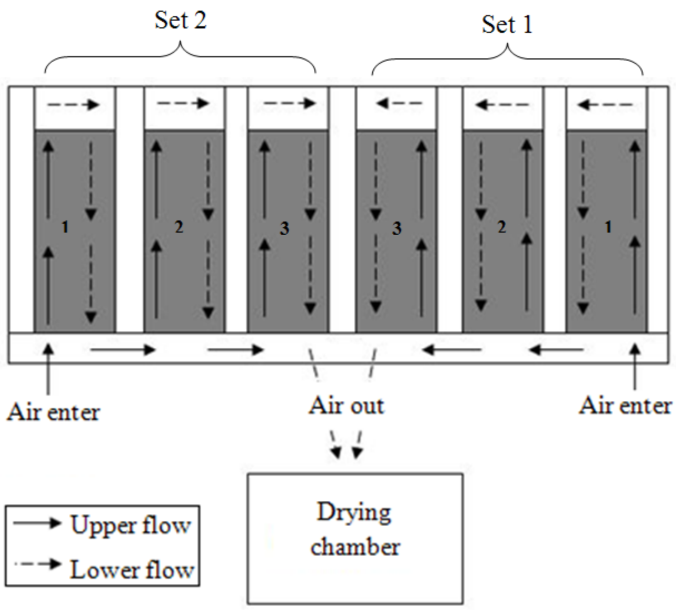

Fig. 3. The configuration of the solar drying system

For the drying test, EFB samples were taken fresh from a local oil palm industry in a whole bunch form which had gone through the sterilization process and was very wet. Two conditions were considered in this study which is treated and untreated. The samples were cut into smaller size ranging around 2-3cm and divided into two. Sample 1 was treated using water washing treatment to reduce the ash content by soaking into tap water for about 20-30 minutes. For every 100g of sample, 5ℓ tap water was used [21]. After undergoing the water washing treatment, the sample was drained for 30 minutes. On the other hand, no treatment was applied on the other sample, labeled as Sample 2.

Then both samples were placed on the same tray level inside the drying chamber next to each other. The weight of the samples before and after the drying process on each day was measured and the moisture and ash contents were also determined. The samples were dried until equilibrium moisture content of below than 10 mf wt% was reached.

3. Results and discussion

The drying experiment to investigate the weight loss and moisture content of the EFB samples was carried out for 9 days continuously (66 hours) at which the average solar radiation ranged between 293-733 Wm^{-2}. It was recorded that the average drying chamber temperature for the period of drying varied between 36-45^{o}C at ambient temperature of 23-28^{o}C. Most of the days were cloudy and a bit sunny in the mornings which are the typical weather in Malaysia. It was noted that it had rained on the eighth day.

From the results obtained as in Fig. 4, it can be seen that the weight for both the treated and untreated samples decreased drastically on the first three days even though the average solar radiation intensity at that time was between 450-570 Wm^{-2}. This happened when the surface of the samples reached the hygroscopic threshold and entered the deceleration zone where the evaporation inside the sample began. At this time, water (in liquid form) do not exist anymore but instead appeared in dependent and vapor form. It was hence noted that the weight of both samples decreased very slowly in the next six days of drying even though the average solar radiation intensity was higher than the first three days except when it was raining. At the end of the experiment, the untreated sample was found to be heavier than the treated sample even though the treated sample was much heavier initially. This is due to the washing treatment that was applied which has removed some of the dirt, ash and oil on the sample.

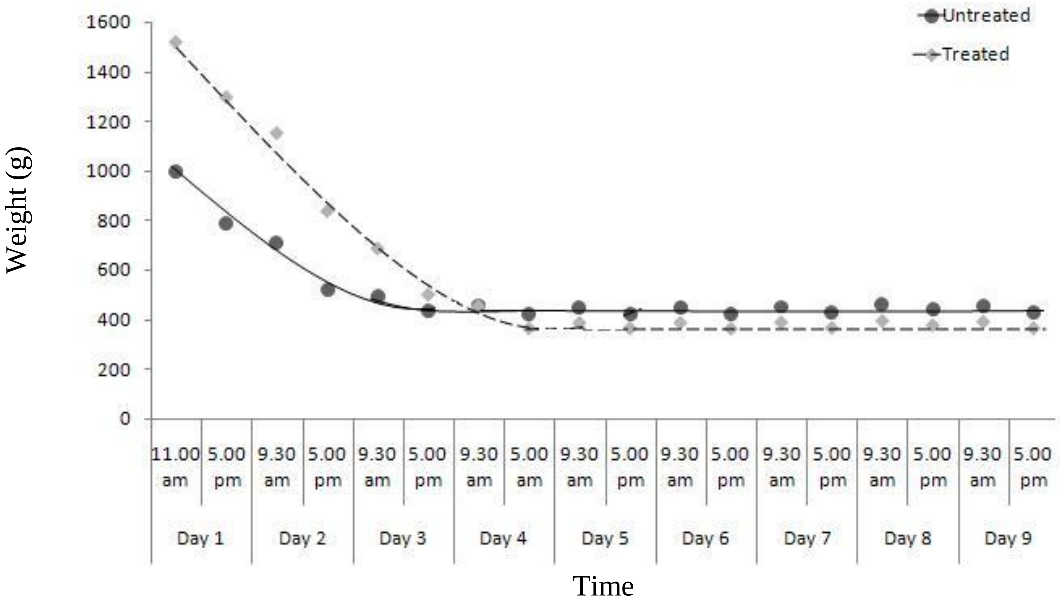

Fig. 4. Weight of sample for each drying day

At the beginning of the experiment, the initial moisture contents for both treated and untreated samples were 376.14 mfwt% and 170.68 mfwt%, respectively. Referring to Fig. 5, after nine days of drying, the moisture content of the treated sample reached 4.36 mf wt% while the untreated sample 3.85 mf wt%. Moisture content of below 10 mf wt% was reached in only two days (13.5 drying hours) for the untreated sample and three days (21 drying hours) for the treated sample.

After the drying process was done, the ash content for both samples was determined. It was found that the ash content of treated sample was lower than the untreated sample as expected. It was found that the ash content of the untreated sample was at 4.98 mf wt% which is higher than the treated sample which was at 2.86 mf wt%. This result indicated that the treated sample which achieved ash content of below 3 mf wt% had met the condition required for the purpose of other energy applications such as pyrolysis process to derived high yield of bio-oil.

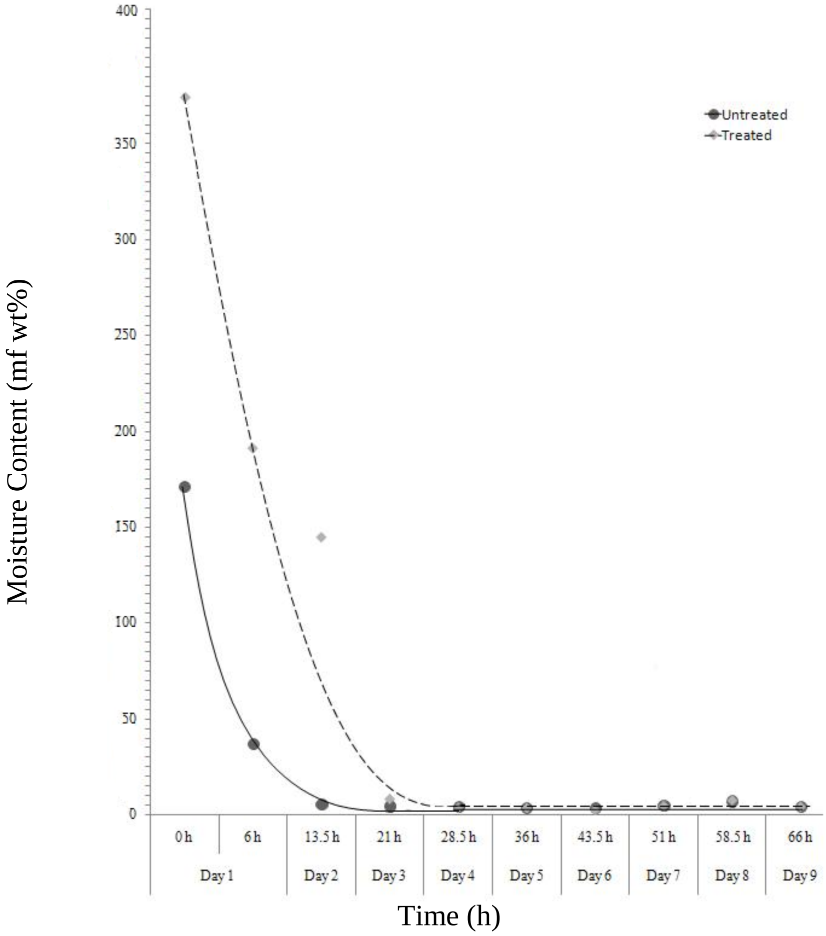

Fig. 5. Moisture content of sample for each drying day

4. Conclusion

From the results obtained, it can be concluded that the solar drying system designed and used in this study was successful in drying EFB that has very high moisture content exceeding 170 mf wt% for which one of the samples was treated with washing treatment. It was observed that the moisture content was successfully reduced to below 10 mf wt% in 13.5 hours for the untreated sample and 21 hours for the treated sample, thus encouraging the use of solar drying. The ash content of the treated sample of less than 3 mf wt% was achieved.

Acknowledgements

The authors would like to acknowledge the short term research grant provided by Universiti Sains Malaysia that has made this research possible.

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