Philippine e-Journal for Applied Research and Development 7(2017), 1-11 ISSN 2449-3694 (Online)
http://pejard.slu.edu.ph/vol.7/2017.02.15.pdf

Design, Construction and Performance Evaluation of an Indirect Solar Dryer for Fermented Cacao Beans

Juanito D. Burguillos[1,*], Jessie C. Elauria[2], and Irene De Vera[3]

[1]Department of Mechanical Engineering, School of Engineering and Architecture, Saint Louis University, Baguio City; [2]University of the Philippines Los Baños; [3]Pangasinan State University
** Corresponding author (juanitoburguillos@outlook.com)*

Received, 15 June 2016; Accepted, 31 January 2017; Published, 15 February 2017

Abstract

A solar dryer adopting the structural arrangement of a direct-type and the heating mode of an indirect-type was constructed and tested for drying fermented cacao beans. The dryer consists of an integrated drying chamber and solar collector, DC fans in series to enhance moisture removal, air holes for airflow, and bicycle wheels for mobility. A black cotton cloth is also installed between the drying chamber and the solar collector to protect the drying product from the harmful effect of solar radiation. Fermented Cacao beans (*Theobroma cacao*) were dried from an initial moisture content of 55% to a final value of 7.5% wet basis at drying temperature between 40^{O}C to 70^{O}C. Results show improved quality of dried cacao beans. The titratable acidity and cut test scores ranged from 10.91 to 17.5 meq NaOH per 100 g and 550.67 to 589.33, with a maximum overall drying rate and efficiency values of 0.63 kg/hr and 77.4%; respectively. Moreover, it is noted that the dried beans produced have distinct chocolate flavor at a loading rate of 40.5 kg/m^2.

Keywords: solar dryer innovation; integrated solar collector and drying chamber; reflective-body; temperature profile; fermented cacao drying

Introduction

Cacao (*Theobroma cacao*) is a Philippine cash crop that has economic potentials for rural farmers but is otherwise beset with drying problems. Per traditional practice, the beans from the ripe cacao pods are immediately sun dried without undergoing any fermentation process. However, products made from this process do not manifest any chocolate flavor (Camu et al., 2008; Schwan and Wheals, 2004). The flavor precursors of cacao are developed initially during fermentation and continues in the drying process (Afoakwa, Peterson, Fowler and Ryan, 2008). Thus, the drying process must be done properly in order to facilitate the completion of the chemical reactions that were started during the fermentation process (Hii, Rahman, Jinap and Che Man, 2006).

Solar dryers improve the quality of cacao beans (Bonaparte, Alikhani, Madramootoo and Raghavan, 1998; Ajala and Ojewande, 2014; Hii et al., 2006). When weather conditions are not favorable, artificial drying method can be resorted to by using fan or blower to drive air across heating elements, raising the temperature and eventually reducing the moisture content of the cacao beans (Musa, 2012). Solar dryers are classified according to heating mode. In the direct-type, the drying chamber and the solar collector are integrated into one structural arrangement where the drying product is directly heated by solar radiation, which passes through the transparent cover and serves as solar heat absorber. The indirect-type comprises a separate solar collector and a drying chamber whereby the heated air from the solar collector dries up the product by means of natural or forced-convection process. When the drying product is heated directly by solar radiation and by the heated air from the solar collector, then it is a mix-mode type solar dryer. The direct-type has advantages, being simple and low-cost as compared to the indirect and mix-mode types that are complex in design and expensive to fabricate. However, the indirect type results in lesser nutritional degradation because exposure to direct ultraviolet rays from solar radiation is completely avoided (Madholopa, Jones and Kalenga, 2002; Pangavhane, Sawney and Sarsavadia, 2002).

The direct and indirect-mode solar dryers have been used to dry fermented cacao beans at loading rates of 13.5 kg/m^2, 26.9 kg/m^2 and 40.4 kg/m^2 (Bonaparte et al., 1998). Indirect drying method, at higher loading rate, has resulted in the lowest acetic acid but poor color for the dried beans; while at low loading rate, the color is good but high in acetic acid. The same results were achieved from using direct solar dryer at different loadings of 20, 30 and 60 kg (Hii et al., 2006) and mixed-mode solar dryer for a load of 50 kg (Fagunwa, Koya and Faborode, 2009). In the direct solar dryer, beans with good color but high acetic acid content were attained at lower loading. In the mixed mode solar dryer with a provision for controlling the rate of airflow, beans of good quality were obtained under free convective drying while acidic flavor were indicated with forced convective drying.

The challenge is to develop an innovative solar dryer that retains the good quality drying of indirect dyers while adopting the simple and low cost design of the direct-type dryers. This study aims to design and construct a new solar dryer with these features, and to test its drying rate and efficiency for fermented cacao beans. The quality of the dried beans will be assessed based on their moisture content, titratable acidity, and cut test score.

Material and Methods

Philosophy of the innovation

The mode of heating is based on the concept of the indirect solar dryer where the drying materials are not heated directly by solar radiation (Fig. 1). The solar collector is made of transparent glass as covering, and a black cotton cloth 100

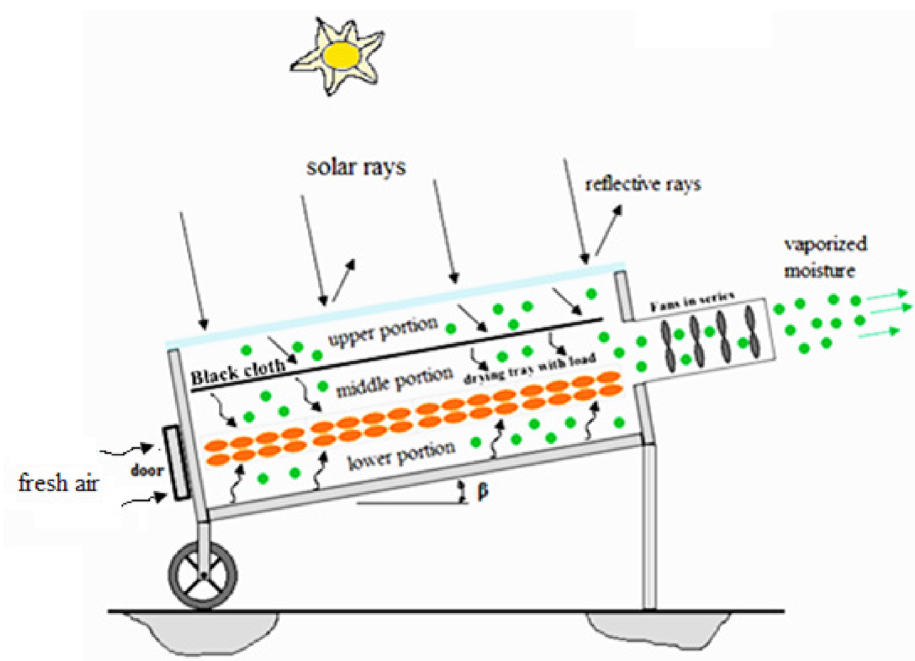

Figure 1. Mode of heating of the solar dryer.

mm below it. The transparent glass allows the short wavelength (high energy) solar radiation to penetrate while the black cotton cloth prevents it from reaching the drying materials. The black cotton cloth continuously absorbs heat from the solar radiation, and reradiates long wavelength (low energy) hitting the drying materials. The long wavelength radiation is trapped in the solar collector, causing the temperature to rise which is known as the "greenhouse effect."

Solar dryer

A new indirect solar dryer was constructed and installed in Mapandan, Pangasinan (latitude of 15.9167^{O}N and longitude of 120.333^{O}E and at sea level). The design of the new solar dryer adopted the structural arrangement of a direct solar dryer where the drying chamber and the solar collector are considered in one single unit (Fig. 2). The dryer is divided into three major sections: the upper, middle, and lower portions (Fig. 2A). The upper portion (UP) represents the solar collector, and the middle portion (MP) and lower portion (LP) represent the regions above and below the drying tray, respectively. The middle portion is where the drying product is located. A ¾-inch marine plywood was chosen in constructing the solar dryer enclosure because it is easy to handle, strong, and lightweight. The solar dryer comprising the solar collector and the dryer chamber has gross dimensions of 1930 mm long, 820 mm wide and 360 mm depth. Two 510 mm diameter bicycle wheels were mounted at the rear ends to make the dryer mobile. At the front ends, two 4" x 4" x 30" long wooden supports were installed, standing on removable steel supports with a height of 463 mm, thus, tilting the solar dryer to a position equal to the latitude of the drying location for maximum exposure to solar radiation (Onigbogi et al., 2012). A converging nozzle made of ¼ inch plywood was provided which served as an exit for vaporized moisture (Fig. 2B). Double layers of aluminum foil with 10 mm air gap in-between layer cover the inner surfaces of the solar box which serves as radiation shield and heat insulator (Fig. 2C).

The solar collector was covered with 90% transmissivity transparent glass, and a black cloth was provided at the bottom part which serves as heat absorber. The solar collector has a depth of 4 inches and covered with a ¼ inch thick transparent clear glass. The drying chamber and the solar collector were insulated with two layers of aluminum foil with a ¼-inch air gap to minimize heat loss. Aluminum foil has a high reflective property and air gap has a very low thermal conductivity, thus making this combination a good insulation. The capacity of the solar dryer was based on a heavy loading rate of 40.5 kg/m^2 (Bonaparte et al., 1998). The number of days needed to dry this amount was computed by estimating the amount of solar radiation that can be absorbed by the solar collector (Duffie and Beckman, 2006).

The drying chamber has a depth of 254 mm and housed an aluminum drying tray whose dimensions are 1900 mm long, 650 mm wide and a depth of 75 mm (Fig. 2D). The drying tray was made of 1" x 1" aluminum angular bar to form a rectangular shape. A 1½ inch aluminum flat bar was added on top of the angular bar all around the tray to form a total depth of 75 mm. The bottom part was provided with a fine aluminum screen as the top layer and a coarse one as support. The tray was subdivided into 10 compartments of equal sizes with numberings of 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10, respectively. These numberings represent the locations at the middle portion above the drying tray as follows: MP 1&2 and 9&10 at the extreme ends and MP 5&6 at midway. A black cotton cloth was provided in-between the solar collector and the drying chamber to protect drying product from direct rays of the sun coming from the solar collector and at the same time as heat absorber.

Four 12 volt DC axial fans in series were provided inside the converging nozzle at one end of the solar dryer to facilitate the strong suction effect for an easy and fast rate of vaporized moisture removal, simultaneously creating negative static pressure. A sun screen support made of ¼" diameter steel bar is provided as support for the black polyester cloth during high-intensity solar radiation, especially between 11 AM to 1 PM to prevent the drying temperature going beyond the recommended value. To monitor the temperatures at the different locations inside the solar dryer, the solar box is provided with resealable holes for glass thermometer and humidity probe (Fig. 2E). These resealables holes are also used to provide airflow to accelerate the evacuation of vaporized moisture.

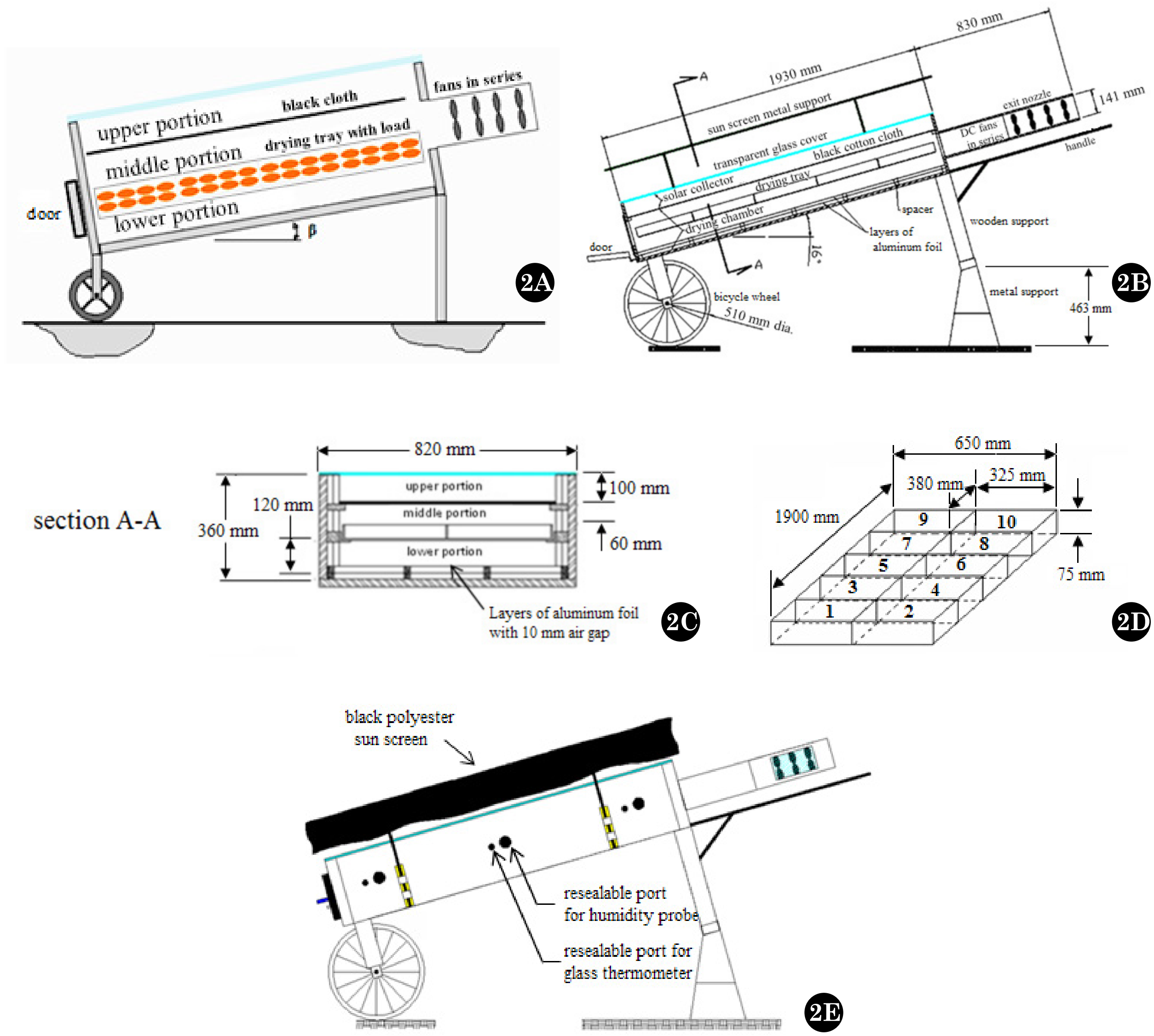

Figure 2. Schematic design of the solar dryer *(2A: Major sections of the solar dryer, 2B: Dimension of the solar dryer, 2C: Solar box, 2D: Drying tray, 2E: Resealable holes).*

Instruments and data collection

TENMARS mini pocket digital solar power meter model TM-750 with an accuracy of 10 W/m^2 was installed on a flat surface adjacent to the solar dryer to measure the hourly solar radiation flux incident on a horizontal surface. Lutron pocket type digital humidity meter model HT-305 measured the ambient temperature and relative humidity at an hourly interval. Distribution of temperatures inside the dryer chamber was determined by measuring the temperature at extreme ends and at the center of the drying tray using glass thermometer with a scale range of -10 to 100^{O}C for an hourly interval. A digital anemometer meter model AM-4206 measured the exit velocity of gas coming out from the converging nozzle.

Drying experiment

Fresh cacao beans were collected with mixture of different varieties. The first trial was conducted in March 2014 and the 2^{nd} and 3^{rd} trials in January 2015. Prior to drying, the fresh beans were allowed to ferment for 6 days using the basket method. An average of 45 kilograms of fermented cacao beans with an initial moisture content of 55% wet basis were loaded into the drying tray for each drying test to satisfy the estimated high loading rate. High loading rates slow down the initial rate of drying in the bean mass and, therefore, allow a longer period for the loss of acids either enzymatically or physically (Liau, 1978; Jinap, Thien and Yap, 1994).

Weather conditions during the tests varied from fair to intermittent cloudy sky. Sometimes, rainshowers occurred in the late afternoon. Sun drying was also conducted to compare the performance of the solar dryer. Turning of beans was done during the drying, with increasing frequency in the 2^{nd} and 3^{rd} trials. Moisture reduction was determined by weighing the representative sample every hour. The drying test was stopped when the weight of the representative samples became constant.

Moisture content, titratable acidity and cut test scores

Final moisture content and titratable acidity were analyzed at the DOST laboratory using the oven method and AOAC method 920.92/Glass electrode, respectively. To assess the physical quality of the dried beans, Shamsuddin and Dimick's modified cut test score method (cited by Bonaparte et al., 1998) was followed. One hundred beans were cut lengthwise using sharp steel blade to expose maximum cotyledon surface, and the colors were assessed as fully brown, ¾ brown, half purple/half brown, 3/4 purple, fully purple, or slaty. Scores of 6, 5, 4, 3, 2 and 1 were assigned to each type of color from fully brown to slaty. The number of beans in each type was multiplied by the corresponding score to obtain the cut test score for the specific drying method. The cut test was done after every trial to indicate the level of browning and degree of fermentation. The beans were also checked for internal molding.

Drying efficiency and drying rate

Drying efficiency indicates the overall thermal performance of the system. This is essentially a measure of how effective the use of solar radiation is to the drying system. It is the ratio of energy required to evaporate the moisture from the product to the energy supplied to the solar dryer, which takes into account the energy consumed by the blower for forced convection solar dryers. It represents how much of the total heat energy absorbed by the solar collector was utilized to dehydrate the product to its final moisture content. The drying efficiency is approximated by the formula given by Brendorfer and Kennedy (1995):

$$Drying\ efficiency, \eta_d = \frac{(W\ \Delta H_L)}{\sum S_H\ A_C T + Q_b}$$

Where W is the moisture evaporated (kg) in time t, ΔH_L is the latent heat of vaporization of water at the final temperature of product in kJ/kg (Table 2), A_C is the area of collector in m^2 (Table 2), S_H is the hourly absorbed solar radiation by the solar collector in kJ/s-m^2, T is the total time in sec., and Q_b is the energy in kJ used by the exhaust fan for time, T.

The drying rate may be influenced by the size, shape, and moisture content of the drying product. However, the effect of relative humidity, dryer temperature, and airflow rate can contribute significantly. Daily drying rate is determined when the amount of moisture removed per hour is considered. The overall drying rate represents the total moisture removed for the duration of the drying time. The drying rate of solids, based on the moisture removed can be expressed as follows (Itodo, Obetta, and Satimehin, 2002),

$$Drying\ rate, \frac{dM}{dt} = \left[\frac{M_i - M_f}{t}\right] x100\%$$

Where $\frac{dM}{dt}$ is the drying rate in kg/hr, M_i is the initial moisture content in kg, M_f is the final moisture in kg, and t is the time interval in hr.

Statistical analysis of data

Influence of solar intensity on the ambient conditions (temperature and relative humidity) as well as on the dryer conditions (temperature and relative humidity) were examined using simple linear regression. Their relationships were analyzed using correlation analysis. Significant differences of temperatures (dependent variable) amongst the different locations (independent variable) specifically at the middle portion of the drying chamber (MP 1&2, 5&6, and 9&10) were analyzed by one-way ANOVA. Least Significant Difference revealed the locations. One-way ANOVA also determined the differences of the drying methods (dependent variables) based on the thermal performance and quality assessments (independent variables). Analyses of the statistical tools are at 95% ($p<0.05$) and 99% ($p<0.01$) confidence level using SPSS software.

Results and Discussion

Temperature and relative humidity profile of the solar dryer

The solar dryer performed well throughout the drying tests in terms of solar intensity, temperature, and relative humidity (Fig. 3). Weather conditions fluctuated from fair to an

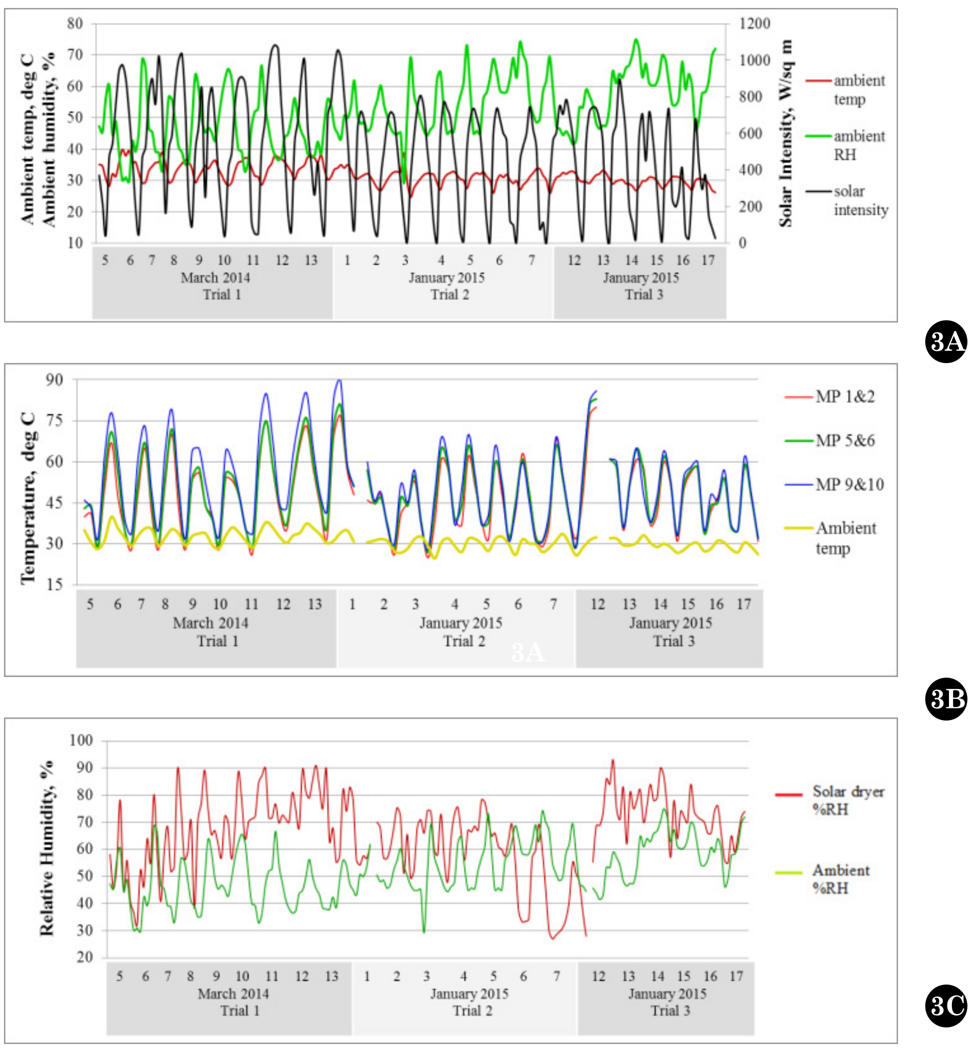

Figure 3. Performance of the solar dryer for the three trials *(3A: Solar intensity, 3B: Temperature, 3C: Relative humidity of the solar dyer).*

intermittent cloudy sky, and there were times of continuous sunshine the whole day. The ranges of solar intensities recorded during the experimental runs are 100-1084 W/m^2 for the 1st run, and 100-808 and 100-894 W/m^2 for the 2nd and 3rd runs, respectively (Fig. 3A). The variation of measured solar intensities may be accounted for by the variation of weather conditions depending on the time of the day when the data were collected. This variation may affect the drying process because the amount of necessary heat to dry the product depends on the magnitude of absorbed solar radiation by the solar collector. The drying time can lengthen during intermittent cloudy sky or shorten during continuous clear sky condition. If the weather condition is bad, the solar dryer needs to be provided with back-up heater. The corresponding ranges of ambient temperatures are 29-39, 27-38 and 26-33^{O}C consecutively for the 3 trials. The relationship between the solar intensity radiation and ambient condition could not be established exactly because significant correlation was not observed consistently for the three runs. If there was, it is weak because Pearson coefficient is less than 0.5 at p-value<0.01. But the ambient temperature and relative humidity are negatively correlated at a significant value of $p<0.01$ with high Pearson coefficient of greater than 0.5. This finding can be supported by the concept of thermodynamics that when a gas is heated it expands, thus increasing its moisture holding capacity.

The minimum and maximum values at MP locations for ambient temperature were 24.7^{O}C and 39.9^{O}C, respectively (Fig. 3B). The solar dryer temperatures are considerably higher than the ambient temperatures throughout the drying tests. Intermittent cloudy sky was frequently experienced during the 2nd and 3rd trials that caused the ranges of solar intensities to drop, thus slightly decreasing the ranges of dryer temperatures. The ranges of dryer temperatures in consecutive order from 1st to 3rd trials were 29-89, 26-83, and 32-66^{O}C with maximum average dryer temperature of 76.7^{O}C, which is higher than the solar dryer design with mirror booster in drying red chili (Paul and Singh, 2013). The variations of dryer temperatures can be associated with the fluctuations of solar intensity and ambient temperature. Regression analysis confirms that the solar intensity significantly influenced the ambient temperature as well as the solar dryers' temperature at p-value of 0.05. The ambient temperature also influenced the dryer temperature at p-value = 0.05. According to the principle of heat transfer (Cengel, 2008), at high ambient temperature the heat loss from the dryer is low because the temperature gradient between the dryer and the ambient is small. However, at low ambient temperature, the heat loss is high due to large temperature gradient.

With regards to the temperature distribution inside the solar dryers, ANOVA analysis showed significant difference existed at p-value = 0.05 between the extreme ends of the drying chamber particularly at MP 1&2 and MP 9&10 during the 1st trial. However, no significant differences existed when four 10 mm holes, evenly spaced, were provided at the rear end of the dryer to increase airflow. The air holes may have induced air turbulence producing uniform heat distribution inside the solar dryer.

The relative humidity in the dryer is relatively high at the start and followed a decreasing pattern. Its magnitude is higher than ambient throughout the experiment, except on the last day when the drying product has reached the desired moisture content (Fig. 3C). The higher reading was due to the rapid vaporization of free moisture from the surface of the drying product, and the rate of vaporized moisture removal by the exhaust fan is relatively lower than the rate of vaporization of moisture from the product. As the drying process continues, the relative humidity inside the dryer decreases slowly as the concentration of free moisture from the surface of the product slowly declines, and eventually it becomes equal or lower than the ambient relative humidity.

Drying rate and drying system efficiency

Moisture loss was slow in the first and second trials, but great improvement was observed in the third trial, showing a steep curve (Fig. 4A). This behavior was also observed in the daily drying rate (Fig. 4B) and the system efficiency curves of the solar dryer (Fig. 4C). It is apparent that the pattern of the drying rate and the system drying efficiency are generally high for the first few days during the first and second trials, and then declined abruptly on the last day. The third

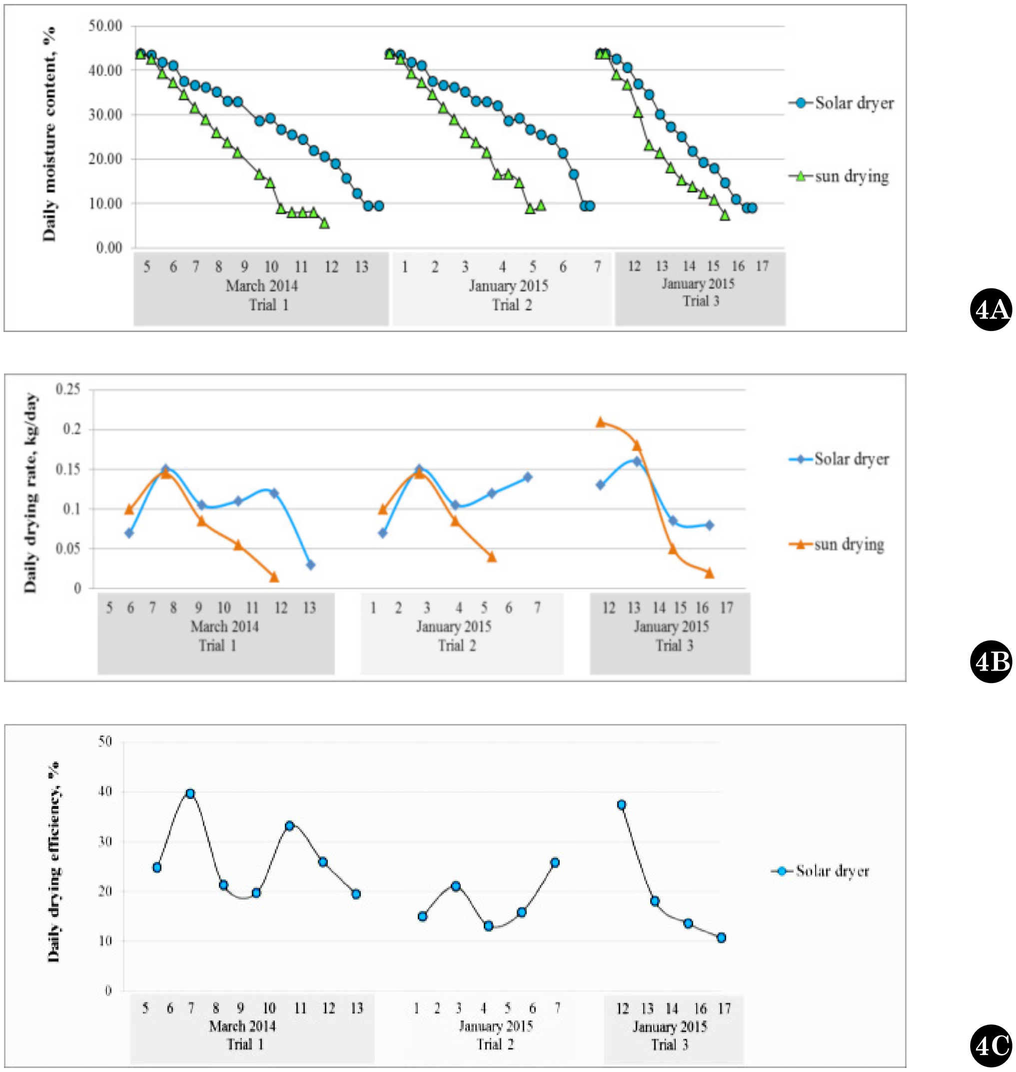

Figure 4. Daily drying rate and system efficiency curves of the solar dryer.

trial, however, showed a decreasing pattern from the start, and this may be accounted to the shorter drying time. Sun drying behavior is consistently with steeper slope during the first few days, showing a fast drying behavior and declining slowly on the remaining days. The first few days of drying fermented cacao beans are crucial because formation of molds will most likely occur if moisture removal was not sufficient (Bonaparte et al., 1998). However, case hardening may happen during fast drying, causing the inefficient removal of acetic acid from the beans (Barel, 1998 as cited by Zahouli, Guehi, Monke Fae, Ban-koffi, and Nemlin, 2010). Although, the moisture removal was faster in sun drying method throughout the test runs, ANOVA analysis showed no significant differences in the drying rate of the two methods at a significance level of $p<0.05$. Over-all drying rate and system efficiency are shown in Figures 4. Maximum overall drying rate and efficiency was attained in the third trial with values of 0.63 kg/hr and 77.4%, respectively. The increase in magnitude was due to the increase in frequency of beans' turning from 3 to 6 times a day, and airflow velocity from 0.8 to 1.4 m/s.

Titratable acidity and cut test scores

The titratable acidity (acetic acid) and cut test scores of the dried beans are shown in Figure 5. The average value of titratable acidity before drying is 25.75 meq NaoH per 100g as determined from similar study (Hii et al., 2006). The graph shows a decrease in titratable acidity in the beans in the second and third trials from the solar dryer with minimum values of 12.53 and 10.91 meq NaOH per 100g, respectively (Fig. 5A). Result from the sun drying method did not show any improvement for the three trials, hence, it is not capable of reducing the acetic acid due to faster drying rate and, thus, causing the beans surface to case harden. The lowest value observed from the solar dryer was slightly better than those reported from similar studies (Bonaparte et al., 1998; Hii et al., 2006) at similar loading rates with values of 13.3 and 12.6 meq NaOH. Slow initial drying rate may happen at high loading rates, allowing a longer period for the loss of acids either enzymatically (Liau, 1978) or physically (Jinap et al., 1994) as mentioned from a similar study (Bonaparte et al., 1998). Therefore, the new solar design is capable of producing low acidic dried beans.

Average cut-test scores ranged from 550.67 to 589.33 (Fig. 5B). These scores indicate a high proportion of fully brown beans in the samples from the solar drying method. No statistical differences were observed between solar and sun drying methods. However, the solar drying revealed the highest score while sun drying the lowest.

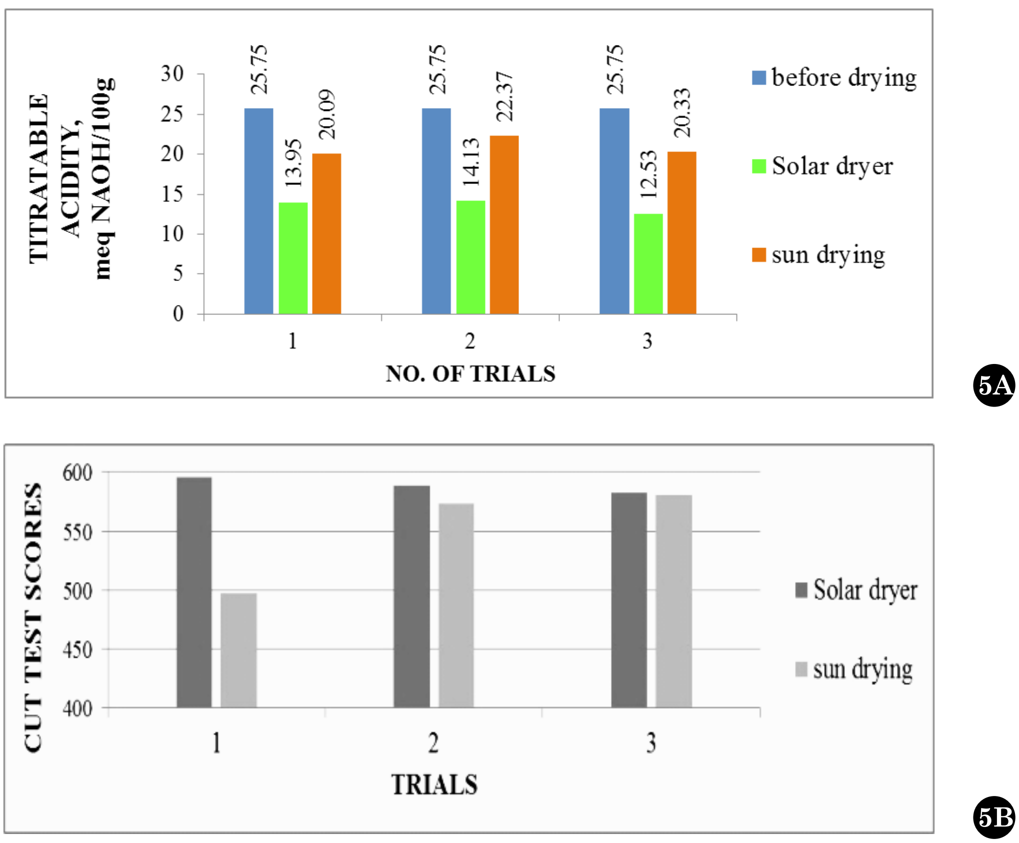

Figure 5. Titratable acidity and cut test scores of dried fermented cacao beans for the solar dryer and sun drying methods.

The final moisture contents of the dried fermented cacao beans from both drying methods were within the desired value of 7-8%. No statistical difference existed between the solar drying and sun drying methods.

Conclusion

The new indirect solar dryer design was capable of reducing the acetic acid of fermented beans. The ability of the dryer to remove moisture slowly allowed the acetic acid to vaporize from the beans efficiently. Increasing the frequency of beans turning and the airflow velocity has also reduced significantly the drying time. Shortening the drying time did not lessen the efficiency of acetic acid removal but rather improved the appearance of the dried beans. Finally, high cut test score revealed that the dried beans from the solar dryer can result in products with the distinctive chocolate flavor.

Acknowledgements

We acknowledge research funding provided by PCIEERD-DOST given on May 1, 2014.

References

Afoakwa, E.O., Peterson, A., Fowler, M. and A. Ryan. Flavor formation and character in cocoa and chocolate: a critical review. *Critical Reviews in Food Science and Nutrition*, 48, 840–57.

Ajala, A.S., and Ojewande, K.O. (2014). Study on drying of fermented cocoa beans (Theobroma cacao). *International Journal of Innovation and Applied Studies*, *6*(2), 931-936.

Barel, M. (1998). The first transformation of cocoa. *Cahiers des Ingenueurs Agronomes*, *448*, 14-15.

Bonaparte, A., Alikhani, Z., Madramootoo, C.A. and Raghavan,V. (1998). Some quality characteristics of solar-dried cocoa beans in St. Lucia. *Journal of the Science of Food and Agriculture*, *76*, 553-558.

Camu, N., De Winter, T., Addo, S.K., Takrama, J.S., Bernaert, H. and De Vuyst, L. (2008). Fermentation of cocoa beans; Influence of microbial activities and polyphenol concentrations on the flavor of chocolate. *Journal of the Science of Food and Agriculture*, *88*, 2288-2297.

Cengel, Y. A. (2008). *Thermodynamics an Engineering Approach*. New York: McGraw Hill.

Duffie, J.A. and Beckman, W.A. (2006). *Solar Engineering of Thermal Processes*. New York: John Wiley and Sons.

Fagunwa, A.O., Koya, O. A., and Faborode, M.O. (2009). Development of an intermittent solar dryer for cocoa beans. *Agricultural Engineering International: the CIGR Ejournal*, *11*, 1-4.

Hii, C.L., Rahman, R.A., Jinap, S. and Che Man, Y.B. (2006). Quality of cocoa beans dried using a direct solar dryer at different loadings. *Journal of the Science of Food and Agriculture*, *86*, 1237–1243.

Itodo, I.N., Obetta, S.E., and Satimehin, A.A. (2002). Evaluation of a solar crop dryer for rural applications in Nigeria. *Botswana Journal of Technology*, *11*, 58-62.

Jinap, S., Thien, J. and Yap, T.N. (1994). Effect of drying on acidity and volatile fatty acids content of cocoa beans. *Journal of the Science of Food and Agriculture*, *65*, 67-75.

Liau. H.T.L. (1978). "The criteria and mechanism for the removal of cocoa bean acidity." In *Proceedings of the international conference on cocoa and coconuts, Kuala Lumpur*. Retrieved from: agris.fao.org/agrissearch/search.do?recordID=MY19790379831

Musa, N.A. (2012). Drying characteristics of cocoa beans using an artificial dryer. *Journal of Engineering and Applied Sciences*, *7*(2), 194-197.

Onigbogi I.O, Sobowale, S. S and Ezekoma, O.S (2012). Design, Construction and Evaluation of a Small Scale Solar Dryer. *Journal of Engineering and Applied Science, 4*(2), 8-21.

Pangavhane, D. R., Sawhney, R. L., and Sarsavadia, P. N. (2002). Design, development and performance testing of a new natural convection solar dryer. *Energy, 27*, 579-590.

Paul, B. and Singh, S.P. (2013). Design, development, and performance evaluation of solar dryer with mirror booster for red chili

(Capsicum Annum). *International Journal of Engineering Trends and Technology, 5*(1), 25-31.

Schwan, R.F. and Wheals, A.E. (2004). The microbiology of cocoa fermentation and its role in chocolate quality. *Critical Reviews in Food Science and Nutrition*, *44*, 1-17.

Zahouli, B.G., Guehi, T.S., Monké Fae, A., Ban-Koffi, L., and Nemlin, G.J. (2010). Effect of Drying Methods on the Chemical Quality Traits of Cocoa Raw Material. *Advance Journal of Food Science and Technology*, 2, 184-190.