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Drying Characteristics and Nutritive Analysis of Coffee Beans Under Different Drying Methods

Ayuni Nasrin Binti Mohd Sukiri[1], Adeline Shu Ting Tan[1], Chi Huey Ng[1], Arham Abdullah[2], Wan Ahmad Amir Zal Wan Ismail[3], Jidon Janaun[1#]

1 Industrial Dryer and Palm Oil Recovery Research Group, Chemical Engineering Program, Universiti Malaysia Sabah, Jalan UMS, 88400 Kota Kinabalu, Sabah, MALAYSIA.
2 Chancellery Office, Universiti Malaysia Kelantan, 16300 Bachok, Kelantan, MALAYSIA
3 Institute for Poverty Research and Management (InsPeK), Universiti Malaysia Kelantan, 16300 Bachok, Kelantan, MALAYSIA
#Corresponding author. E-Mail: jidon@ums.edu.my; Tel: +6088-320000; Fax: +6088-435324.

ABSTRACT Drying under certain conditions can result in degradation in terms of the nutritional value of dried products which then affects the consumer acceptability directly. In this study, the effects of three drying methods – open sun drying (OSD), solar dryer (SD), and solar-electrical hybrid dryer (S-EHD) for coffee beans were identified. Parameters observed include weight loss, drying rate, and nutritive value of dried coffee beans. Based on the data obtained, OSD with the highest temperature of 48 °C exhibits the highest moisture loss and drying rate throughout the drying period of 50 hours. Followed by S-EHD with drying temperature controlled at 45 °C and SD under natural convection. High drying temperature was expected to offer a rapid drying rate. The drying temperature attained in both S-EHD and SD does not exceed the acceptable limit for coffee bean drying. Based on the nutritive analysis, S-EHD dried coffee beans contain the highest protein value with the lowest fat content. Whereas, ash content obtained from different drying methods was insignificantly different.

KEYWORDS: Solar drying; solar-electrical hybrid dryer; coffee beans; drying characteristics; nutritive analysis
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Original Article

INTRODUCTION

Besides petroleum, coffee is the second-largest traded commodity with total global consumption of approximately greater than 9 million tons in 2015-2016, which give around US$21 billion (International Coffee Organization, 2017). The increases in the demand are attributed to the unique flavor and its quality (De Melo Pereira *et al*., 2019). Arabica coffee leads the world market around 70%-80% and it is the most preferred coffee type compared to others due to its outstanding sensory (Belitz *et al*., 2009).

The effect of climate and geographic location on the coffee quality is still not well defined although it plays an essential role in deciding the end product (De Melo Pereira *et al*., 2019). Moisture content in coffee need to be reduced below 12% to inhibit microbial growth to store it in a longer period and drying is an extensively used preservation method to achieve this (Dong *et al*., 2017; Flament, 2002). However, drying coffee at a temperature that exceeds 45 ℃ may degrade the quality of the coffee (Sfredo *et al*., 2005). Optimal heat and mass transfer are required to preserve the quality of the coffee. The drying process can cause nutrition changes and loss in value which directly affects the quality of end-products. This parameter varies according to the products and is damaged at a certain point of the drying process. However, a limited study was found in the literature regarding the solar drying of coffee beans. Hence, the objective of this study was to investigate the impact of drying methods on the nutritional quality of dried coffee beans and to gain well understanding in selecting a suitable drying condition to produce better quality dried coffee beans.

METHODOLOGY

Experimental Set-up

The coffee beans used in this study are green coffee beans collected from the Faculty of Science and Natural Resources in Universiti Malaysia Sabah (UMS). No pre-treatment process was performed before the drying process. The experiment was conducted from 8 AM to 5 PM daily between 16th to 19th November 2019. Samples were subjected to three different drying methods – open sun drying (OSD), solar dryer (SD), and solar-electrical hybrid dryer (S-EHD). During the process, ambient temperature, drying air temperature and relative humidity inside the drying chamber was measured using Mini Thermo-Anemometer (Extech). Weight measurements on samples were made every 2 to 4 hours by using Sartorious (TE2145) digital balance with ±0.001 g sensitivity and a maximum of 210 g. Figure 1 and Figure 2 show the complete view of UMS Eco-Solar dryer and UMS Eco-Solar House respectively to perform drying under complete solar mode and solar-hybrid mode respectively.

Figure 1. UMS Eco-Solar Dryer for solar drying.

Figure 2. UMS Eco-Solar House for hybrid drying.

Drying Process

The experiments were performed in the Faculty of Engineering, UMS. For OSD, samples were distributed in a thin layer on a stainless-steel tray and dried under direct sunlight alongside the solar dryers with drying temperature between 27 ˚C to 48 ˚C until constant weight loss is achieved. This data is required to analyze the efficiency of the drying process of solar drying methods. For SD, samples were fully loaded in a 50 kg capacity indirect natural convectional solar dryer and distributed equally on 5 stainless-steel wire mesh drying trays. Drying was performed in updraft drying mode. The drying temperature attained in the SD ranged from 27.3 ˚C to 37.3 °C. As for S-EHD, the drying temperature in the 500 kg capacity drying chamber was controlled at 45 °C using the control panel system. Experiments were replicated five times at the different levels of trays (5 trays) and another five replicates were done for samples located at different locations on the drying tray.

Data Collection and Analysis

Parameters determined for nutritive analysis are protein, fat, and ash content using automated KJELTEC, SOXTEC 2050, and furnace respectively. All these analyses were conducted at Food Analysis Lab, Faculty of Food Science and Nutrition UMS according to standard procedure and done in triplicate.

RESULTS AND DISCUSSION

Analysis of Weight Loss Curve for OSD, SD and S-EHD

The equilibrium moisture content of coffee beans dried under three different drying methods was achieved within 48 hours drying time, with moisture loss ranged from 37 to 52%. Based on Figure 3, OSD exhibits the greatest percentage of weight reduction across the drying period, followed by S-EHD and SD. The moisture content of coffee beans dried under open sun decreases rapidly due to direct heating through solar radiation meanwhile both SD and S-EHD depend solely on pre-heated drying air from the solar heat collector and auxiliary heating element for hybrid mode through convective drying. During OSD, a significant drop of moisture loss was observed after 8 hours, which was around mid-noon of the second day. At this point, OSD attained the highest drying temperature (48 °C) among the drying methods employed, followed by S-EHD with a drying temperature of 41 °C, which was the second-fastest drying method for coffee beans. It can be observed that OSD temperature exceeds the acceptable limit recommended by Sfredo *et al*. (2005). Absent of an auxiliary fan and active heating system in complete solar drying mode results drying process in SD being slower or delayed due to poor air circulation and the intermittent characteristics of solar radiation. Although the highest moisture loss was expected in S-EHD, however, due to the temperature set in the dryer was lower than that of the temperature fluctuate in OSD, the drying efficiency of the hybrid solar dryer observed in this study was lower than that of OSD. Results obtained from this study were per Suherman *et al*. (2020) studying the drying characteristics of coffee beans. According to their study, moisture loss observed between OSD, SD and hybrid solar dryer with drying temperature set at 40 °C was insignificantly different. Rapid moisture loss in solar-hybrid drying was identified only at drying temperatures of 50 ˚C and 60 ˚C. Hence, it can then be inferred that the drying temperature set in S-EHD in this study was insufficient to surpass OSD.

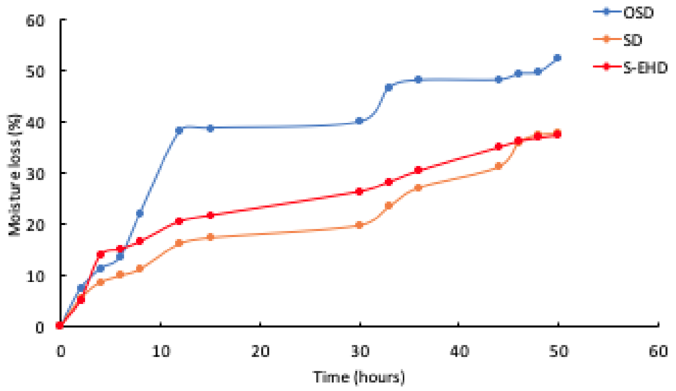

Figure 3. Percentage weight loss of coffee beans against time.

Analysis of Drying Rate Curve in OSD, SD and S-EHD

The final moisture content of coffee beans dried under OSD, SD, and S-EHD was in the range of 6.47%-8.83%, 14.98%-16.23%, and 10.60-13.61% (w.b) respectively. The drying curve of coffee at different drying methods is shown in Figure 4. As shown, the drying method employed significantly affects the drying rate of coffee. This finding is in agreement with Pochont *et al*. (2020). The drying time required to achieve a certain level of moisture content depends on the temperature range attributed to each drying method. As temperature increases, the drying rate will increase (Vega-Galvez *et al*., 2012). At the beginning of the drying process, S-EHD with an auxiliary heating system demonstrates the highest drying rate of 0.655 g/h, followed by 0.176 g/h and 0.161 g/h in OSD and SD respectively. Along the drying period, OSD eventually attained a drying temperature higher than that of temperature controlled in S-EHD. This explained the increasing pattern of OSD drying rate at the later stage. Based on the results obtained, both S-EHD and SD offer uniform drying throughout the process as drying conditions in the solar dryer can be easily controlled. Hence, by regulating the temperature in the drying chamber, the drying rate can then be enhanced.

Based on the drying curve, no constant rate period was observed. The drying process of coffee beans undergoes completely in falling-rate period throughout the process. An unsteady-state period was observed in OSD due to fluctuation of temperature, particularly when approaching an off-sunshine period where the temperature difference of the surrounding from the sunshine period tonight was significant. Hence, resulting in a sudden drop in drying rate when approaching to off-sunshine period. In contrast, drying in both SD and S-EHD exhibits a steady pattern. This exhibits the ability of solar dryers to store heat energy in an enclosed environment even after the sunshine period. However, a lower drying rate was observed in SD compared to S-EHD with additional heating elements. Similar drying characteristics were reported by (Sekyere *et al*., 2016).

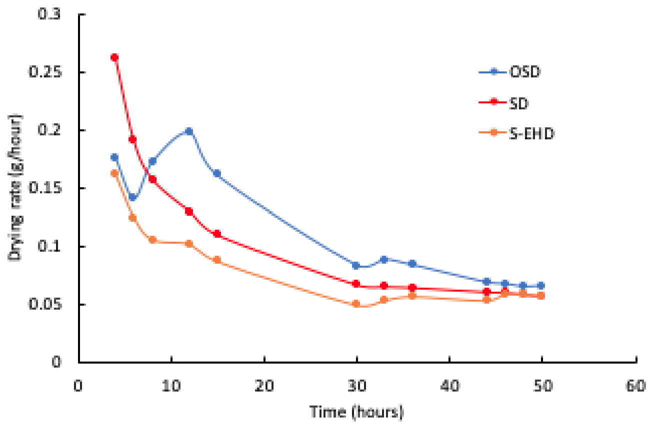

Figure 4. Drying rate of coffee beans against time.

Nutritive Analysis

Table 1 summarizes the mean value of protein, fats, and ash content of dried coffee beans for OSD, SD, and S-EHD. The protein value varies at different drying methods. OSD and S-EHD were found to have the lowest and highest protein value respectively. As for fat content, OSD exhibits the highest value among the others. This can be inferred from a study conducted by Rodríguez *et al*. (2014) that observed a lower loss of total phenolic content (TPC) at high drying temperature. Coffee dried by solar drying remained as the lowest value of fat content as long drying time associated with low process temperature may promote a decrease of nutritional value. No significant difference was observed for the ash content.

Table 1. Summarization of results from nutritive analysis.

	Protein content (%)	Fat content (%)	Ash content (%)
Open sun drying	9.82	0.30	2.88
Solar drying	10.27	0.04	2.89
Solar-electrical hybrid drying	11.30	0.07	-

CONCLUSION

In this study, the drying experiment of coffee beans using three different drying methods of OSD, SD, and S-EHD was performed. Coffee beans were dried to equilibrium moisture content of 6.47%-8.83%, 14.98%-16.23% and 10.60-13.61% (w.b) respectively. OSD gives the fastest moisture reduction due to the higher drying temperature was attained in the products. The drying process of coffee beans was completely under the falling-rate period. Based on the results of nutritive analysis, open sun-dried coffee beans consist lowest protein content and the highest fat content. The difference in ash content was not significant.

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