

Changes in physico-chemical characteristics of robusta coffee (*Coffea canephora*) during natural process using simple solar dryer

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Abstract. A simple solar drying technique was recently introduced for processing robusta coffee (*Coffea canephora*) in Indonesia. It is considered a modification of the natural process commonly found in Indonesia. The objective of this work is to evaluate changes in the characteristics of coffee beans during the drying process. The results show that a significant reduction of moisture content and A_w takes place in the first 7 days of drying, followed by a slight increase of total sugar and total acids. The next 14 days of drying occurred at a lower rate, and the above-mentioned parameters continued to decrease, but an increase in the pH and total phenols were observed. The yield of the process was 27.5%, and the moisture content of the green bean meets the Indonesian National Standard (SNI) of coffee. The water activity (A_w) of the green bean is considered low which could prevent growth of spoilage microorganism if stored properly. The levels of caffeine and chlorogenic acids in the green bean are considered low for robusta coffee.

1 Introduction

Coffee is a very popular drink in the ¹world. In Indonesia, the consumption of coffee and its products tends to increase [1] which is in line with the trend of coffee production. The KPPU, the Indonesian Business Competition Supervisory Commission, in 2020 revealed that 90% of the coffee production was of the type of robusta [2]. It was mostly processed into green beans or unroasted beans. The process involves a separation of the ripe coffee cherry tissues like exocarp, mesocarp, and endocarp tissues [3]. Based on the method of tissue separation, the process may be divided into two categories, namely the dry process and the wet process [4]. The wet process begins with de-pulping, i.e. separation of the exocarp tissue and parts of the mesocarp tissue. The mucilage covering the beans was then partially or totally removed by washing. The washed beans may be spontaneously fermented for a certain period of time. The fermented beans were dried and finally dehulled to get the green bean [5]. The wet method which removes a part of the mucilage is known as a semi-washed process, and the fully-washed process is the one carried out by washing

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off all the mucilage, followed by submerged fermentation in the water [6]. In addition, dry processing or the natural process is carried out by simply sun drying whole coffee cherries until the moisture content is considered low so as easier to conduct dehulling which separates non-bean tissues, eg. the husks, pulp, the outer skin).

The natural process found at a small-scale coffee processing unit “Wonosantri Abadi” located in Malang Regency is unique. Instead of applying direct sun-drying, the unit uses a single-layer plastic cover as a roof so that the cherries have no direct exposure to the sun’s rays. This type of processing may be considered a simple solar-drying method. The aim of this research is to examine changes in the physico-chemical characteristics of robusta coffee cherries processed using such simple solar drying.

2 Materials and method

The material used is ripe robusta coffee fruits (cherries) obtained from the Budugasu coffee plantation in the valley of Arjuno Mountain, East Java Province (ca 1,100 above sea level). The cherry was harvested in August, almost at the end of the harvesting season. Fruit sorting was carried out by soaking them in the water. The sound ones will sink and be used for the experiment after naturally draining for two hours. The weight of 100 sorted fresh fruits and the diameter were determined.

Processing coffee cherries in a natural way is done by spreading the fruit on a rack placed in the drying room of the simple solar dryer (Fig. 1). The thickness of the fruit bed is about 5 cm. Sampling for coffee fruit analysis was carried out on assorted fresh ones, after 7 days, 14 days, and 21 days of drying. The average temperature at the processing location is around 20°C. The equipment used includes a coffee pulper (RICHI K-15) and huller (ICCRI Tech, capacity 10kg/hour), a hygrometer for Aw measurement (Decagon PawKit), a portable LAB colorimeter (Konica Minolta, CR-10), desiccator (Nalgen, 5312), grinder (Klaz, CG9100), calipers (Mitutoyo), an electric stove (Maspion, S300), an electric oven (Memert WTC Binder, MIK-AL-006), a refrigerator (Sharp, MIK-AL-075), micropipettes (Socorex, Acura 825), analytical balances (Denver Instrument, M-310, and Mettler Toledo, MIK-AL-004), a pH meter (HANNA Instrument, HI-2002-02 edge pH), UV-Vis spectrophotometer (Shimadzu Corp, 03860 and Unico, UV-2100), a centrifuge (Hettich centrifuges, EBA 200), and a vortex (Heidolph, LQ1).



Fig. 1. A simple solar dryer with a layer of clear plastic roof in which a natural convection air flow takes place.

Experimental parameters include moisture content, water activity (A_w), total sugar, total acid, and pH. On the 22nd day, the dried fruits were dehulled to get green beans. The sample of green beans sample was taken for analysis of total phenols, caffeine, chlorogenic acid, and colorimetric color (CIE). All chemicals were analytical grades unless otherwise stated. The experiment was conducted in triplicates. An appropriate statistical analysis (the ANOVA and LSD) was then performed.

3 Results and discussion

3.1 Characteristics of fresh robusta coffee cherries

The coffee cherries used in this study had a slightly lower average diameter, mass weight, water content, total sugar, pH, and total phenols than those reported in previous studies (Table 1). This difference is likely due to the planting location at an altitude more than 800 meters above sea level and being harvested at the end of the harvest season. Robusta coffee will grow better if planted at an altitude of 500-900 meters above sea level [7]. The peak development of weight and volume of Robusta coffee fruit occurs 42-49 weeks after the flowers bloom [8]. The sugar content will change in each part of the coffee over time of fruit ripening or time after flowering [9]. Rainfall can affect total phenols because coffee berries need water to carry out optimal metabolism and produce metabolites needed by coffee plants [10]. The coffee cherries used in this research were harvested from areas that experienced 2 months of rain outside the season.

Table 1. Characteristics of fresh robusta coffee cherries.

Parameters	Present study	Previous studies
Weight/100 cherries (g)	127.79	138.7-157.1 ^[8]
Cherry diameter (mm)	12.90	15.27-15.83 ^[8]
Moisture (%wb)	50.63	52.4-60 ^[11]
Water activity (A_w)	0.93	-
Total sugar (%wb)	0.82	2.4-12 ^[12]
Total acids (g NaOH/100g)	1.23	-
pH	5.22	5.58-5.74 ^[13]
Total Phenols (mg GAE/g)	4.80	5.24-35.67 ^[10]

3.2 Changes in characteristics of coffee during process using simple solar dryer

Moisture content and water activity were further decreased during the next 14 days but at a slower rate than at the beginning of the process. Moisture content decreased from 29% to 12%, whereas A_w decreased from 0.72 to 0.60. Dehulling did not affect moisture content, A_w , and total acids. The green beans obtained from the process using the simple solar dryer had a moisture content of 11.8%, which met the requirement of Indonesia's quality standard (SNI) for coffee beans [7]; these beans showed water activity (A_w) of 0,59. A significant decrease in moisture content and water activity (A_w) was observed within the first 7 days of drying as they decreased from 50.63% to 28.88% and from 0.93 to 0.72, respectively (Fig. 2).

Total sugars and the total acids slightly increased, which was accompanied by a decrease in pH after 7 days of drying (Fig. 3). In contrast, the next 14 days showed different trends in the physicochemical properties of dried coffee cherries. Total sugars decreased

significantly from 0.85% to 0.69%, whereas, the pH increased continuously. Dehulling had a significant impact on those three parameters. Table 2 shows changes in the observed parameters during the natural process using a simple solar dryer.

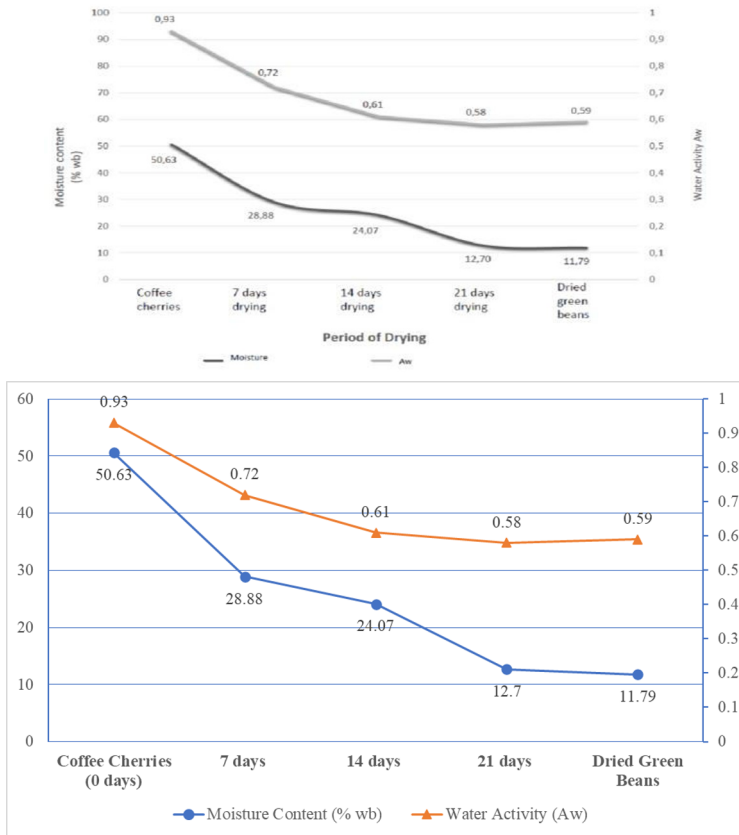
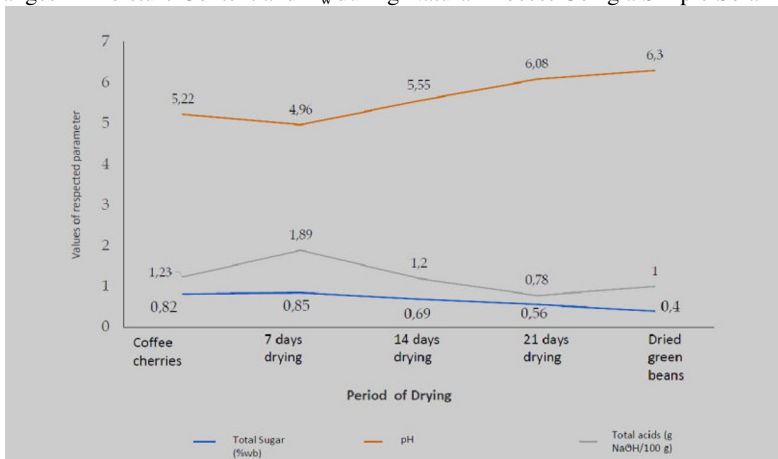


Fig. 2. Changes in Moisture Content and A_w during Natural Process Using a Simple Solar Dryer



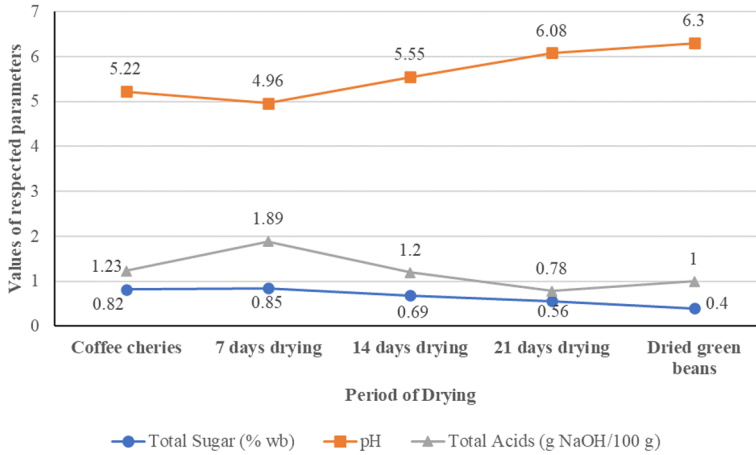


Fig. 3. Changes in total sugars, total acids, and pH during natural process using a simple solar dryer.

Significant decreases in moisture content and water activity (A_w) observed in the first 7 days of drying may be attributed to abundant free water in coffee cherries at the beginning of the process. The lower rate of drying in the next 7 days and 14 days indicated the water is mostly bound by polysaccharides and mucilage matrix [14]. The drying process during those periods occurred slowly. Green beans produced by natural process had a moisture content of 11.79% and water activity (A_w) of 0.59, thus reasonably low and therefore suitable for storage and packed in tight containers.

Table 2. Changes in coffee cherries during the natural process to produce green beans.

Parameters	Drying period				
	Fresh coffee cherries	7 days of drying	14 days of drying	21 days of drying	The Final product of Green beans
Moisture content (% wb)	50.63 ± 0.60 a	28.88 ± 1.73 b	24.07 ± 0.94 c	12.7 ± 0.30 d	11.79 ± 0.10 d
Water activity, A_w	0.93 ± 0.10 a	0.72 ± 0.01 b	0.61 ± 0.01 c	0.58 ± 0.00 d	0.59 ± 0.00 d
Total sugars (% wb)	0.82 ± 0.08 a	0.85 ± 0.19 a	0.69 ± 0.06 ab	0.56 ± 0.16 bc	0.40 ± 0.07 c
Total acids (g NaOH/ 100 g samples)	1.23 ± 0.21 b	1.89 ± 0.12 a	1.20 ± 0.20 b	0.78 ± 0.20 c	1.00 ± 0.20 bc
pH	5.22 ± 0.00 d	4.96 ± 0.02 e	5.55 ± 0.03 c	6.08 ± 0.15 b	6.30 ± 0.14 a
Total phenolic content (mg GAE/g materials)	4.79 ± 2.11 b	-	-	-	14.27 ± 2.13 a

The degradation of cell wall components like pectins [15] resulted in a non-significant increase in the levels of total sugars after 7 days of drying. Some sugars were used during respiration. It was reported that glycolysis predominantly took place in the pericarp [16]. That process continues as long as the water is available. The drying process in the next 7 and 14 days resulted in a decrease in water activity leading to a decrease in respiration rate.

The increased pH was observed when reaching the end period of the drying process and may be attributed to the evaporation of some organic acids during the drying process. It indicates that some acids evaporate during drying. Similar results were reported in previous research [17]. In addition, stress due to the drying process stimulated the formation of GABA (γ -aminobutyric acid) [18].

The process resulted in increases in the total phenolic content from 4.79 mg GAE/g in coffee cherries to 14.27 mg GAE/g in green beans. Phenolic compounds may be mobilized during respiration, especially when the beans are not exposed to oxygen. Respiration is hypothesized to decrease the cohesiveness of the tissues that compose the pulp, mainly containing polysaccharides such as cellulose and pectin. This process may result in the evaporation of water after the first 7 days of drying, leading to lower moisture content outside part of the seed endosperm compared to inside one. On the other hand, the endosperm matrix of coffee seeds may become porous due to respiration. This condition promotes diffusion and osmosis of soluble components including phenolic compounds from the epicarp and pulp (mesocarp) into the seed (endocarp). This process may contribute to the increase in total phenolic compounds in green beans.



Fig. 4. Real color of coffee green bean.

The colour of the green bean obtained from the natural process was quite appealing indicated by L^* , a^* dan b^* values of 46.73; +2.07, and +13.07 respectively. The real color of green bean shown in Fig. 4. The lightness (L^*) of the green beans obtained from this process using a simple type of solar dryer was low. The brown appearance occurred is probably due to the enzymatic oxidation of phenolic compounds, as stated by Sa'diyah (2019) [19]. Enzymatic oxidation decreased in the second and third periods of each 7-day drying process continued by non-enzymatic oxidation of polyphenolic compounds, phenols, and chlorogenic acids. Disintegration of the mesocarp tissue components due to respiration may facilitate the observed enzymatic oxidation, thus promoting phenolic diffusion into the seed. The appearance of green beans obtained from the natural process using a simple type of solar dryer was comparable with the results of the previous studies using similar techniques. The moisture content of green beans obtained from the natural process in the present study met the requirement of Indonesia's quality standard SNI [7]. The low water activity of the green beans provided safe storage if packed properly.

4 Conclusions

Natural processing of coffee cherries using a simple type of solar dryer at ambient temperature significantly decreased moisture content and water activity A_w , slightly increased total sugars and total acids accompanied by decreased pH after the first 7 days of drying. Further drying in the next 14 days continued the process at a more slowly rate but pH and phenolic content increased in the final products of green beans. The yield of green

beans obtained from this kind of natural process was 27.5% with moisture content met the requirement of Indonesian national standard (SNI) of coffee quality. In addition, the water activity (A_w) of the beans was low inhibiting microbial growth. The caffeine and chlorogenic acid contents of green beans were relatively low for Robusta coffee. It is necessary to measure the levels of sucrose, fructose, and glucose so that the decrease in total reducing sugar can be known specifically whether it occurs due to the formation of sucrose or by the degradation of fructose and glucose.

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