



The effect of drying temperature on cup quality of coffee subjected to mechanical drying

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Abstract

The objective of the work was to study the effect of drying temperature on cup quality of the robusta coffee subjected to mechanical drying in comparison with conventional sun drying. The robusta coffee processed by wet (parchment coffee) and dry (cherry coffee) methods were subjected to drying at different temperature regimes (40°C, 50°C and 60°C) in a rotary mechanical dryer. The results of the study indicated that as the drying temperature increased, the time of drying reduced. Sun drying of parchment coffee took 48 hours (approximately seven days) to attain the desired moisture content of 11-12 per cent, while mechanical drying reduced the drying time to 16 to 24 hours. Similarly, cherry coffee subjected to sun drying took 88 hours (approximately 15 days), while mechanical drying reduced the drying time to 32 to 48 hours. The cup quality rating of coffee dried by different drying methods revealed that sun-dried robusta parchment coffee scored the highest cup rating. As the drying temperature increased, the cup quality ratings decreased. A similar cup quality rating was also observed with cherry coffee. These results indicate a considerable reduction of drying time when coffee beans are dried in a mechanical dryer. However, there is a need to regulate the drying temperature, which otherwise would negatively impact the quality of coffee. The drying temperature should not exceed 40°C for preserving the innate quality of robusta coffee because the high drying rates provoked by high temperatures can cause damage to the coffee quality due to the damage caused to the cell membranes. Overall, mechanical drying is more advantageous to sun drying in-terms of drying hours (indirectly reduces dependency on manpower) and preservation of innate quality of the coffee.

Keywords: Coffee, mechanical drying, quality evaluation, robusta

Introduction

Coffee is one of the most popular beverages consumed throughout the world. Arabica and robusta are the two types of coffee normally cultivated worldwide on a commercial basis. Arabica comes up well at higher elevation where cool-climate prevails during most of the year. In comparison, robusta comes up well at a lower elevation where hot and humid climate prevails. Arabica coffee is susceptible to many pest and diseases, while robusta is resistant to many pest and diseases affecting coffee. The quality of arabica is superior compared to robusta and fetches a higher price than robusta. Coffee growing areas in India can be classified as traditional coffee-growing areas mostly consisting of Western Ghats of Karnataka, Kerala and Tamil Nadu, the non-traditional area

consisting of Andhra Pradesh and Orissa and the North Eastern region consisting of all the northeastern states. The total area under coffee is about 4.59 lakh ha with a production of about 3,19,500MT; about 30 per cent of the production is Arabica coffee. Among different states, Karnataka produces about 68 per cent, followed by Kerala (22%), Tamil Nadu (5.5%), Andhra Pradesh and Orissa (3.5%) and the North-Eastern region (Database on coffee, 2020).

Coffee after harvesting at the estate is processed by two methods *viz.*, wet and dry method. Coffee processed by wet method is known as parchment coffee, and coffee processed by the dry method is known as cherry coffees. In the dry method, after harvest, coffee fruits are spread out on a clean cemented or tiled drying yard and dried for about

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12 to 15 days to bring down the safe moisture level of 11-12 per cent. Coffee obtained by dry processing is called cherry coffee. In the wet method, the harvested coffee cherries undergo a series of processing steps *viz*, pulping (removes the outer skin of the fruit) followed by fermentation and washing (to removes the pectinaceous mucilage adhering to the coffee bean), and sun drying for about 6 to 8 days. The coffee resulting from wet processing is known as parchment coffee. The cup quality of parchment coffee will be superior compared to cherry coffee. In India, most arabica coffee is processed by the wet method, while most robusta is processed by the dry method (Anonymous, 2014).

Among various factors, post-harvest processing plays a major role in preserving the innate quality of the coffee. Drying is the most important post-harvest operation from the energy consumption point of view and the preservation of the innate quality of the coffee cultivar being handled for processing. Both over-drying and under-drying lead to the formation of defective coffee beans with poor cup quality. Under-dried (>12% moisture content) coffee turns mouldy (fungal contamination) and get bleached during storage of coffee bean. At the same time, over-drying (<8% moisture content) of coffee samples results in woody off-taste in the cup (Menon, 2001).

Much of world coffees are sun-dried using solar energy, though sun drying is a labour-intensive operation. However, in countries like Brazil and Colombia, a major portion of coffee is dried using a mechanical dryer. In sun drying, the beans are heated by direct exposure to the sun by spreading

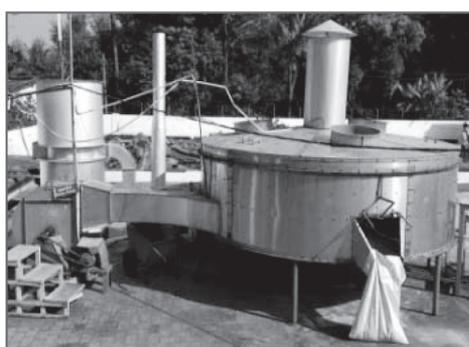
them on drying yards, while in mechanical drying, the coffee mass is exposed to hot air, which absorbs the moisture. In India, some of the coffee estates are equipped with mechanical dryers for drying coffee.

A survey was conducted to assess the performance of mechanical driers (Fig. 1.) installed in 17 estates of coffee growing areas of Chikkamagaluru and Hassan districts in Karnataka state during 2017-18. Information on the performance of the mechanical dryer was collected using a structured questionnaire.

It was observed that most of the dryers in estates are used during the peak harvest period (inclement weather conditions during harvest). The drying temperature varied from 40°C to 60°C. The temperature of the hot air in the drying chamber/drum was more than the recommended temperature limits to reduce the drying period and, in turn, to reduce the drying cost. Though coffee dryers have been in use for over a few decades, published reports on mechanical drying are mostly relating to drying kinetics (Varadharaju *et al.*, 2001; Izquierdo *et al.*, 2013; Valdiney *et al.*, 2016; Hameed *et al.*, 2018), biochemical (Farah *et al.*, 2006) and organoleptic quality of coffee (Brando, 2004; Farah *et al.*, 2006; Coradi *et al.*, 2007; Taveira *et al.*, 2015; Alves *et al.*, 2017; Hameed *et al.*, 2018; Mesfin and Won, 2020). Reports on the energy requirement of commercially employed mechanical coffee dryer and the economics of drying by various coffee drying systems are limited (Martin *et al.*, 2011). Given the lack of information on these aspects of coffee drying, a study was undertaken to generate information on



Static dryer



Static dryer with raker



Rotary dryer

Fig. 1. Different types of mechanical dryers employed in Indian coffee estates

energy requirements of commercially employed mechanical coffee dryer and economics of various coffee drying systems, as well as to gain further insights on drying period and cup quality of robusta coffee samples dried in a rotary mechanical dryer.

Materials and methods

The work was carried out at Central Coffee Research Institute farm located at 823-914 m above MSL with latitude: 13° 22' N and longitude: 75° 28' E. Coffee drying trials were carried out during the peak harvest season of robusta coffee during February to March 2019-2020.

Coffee harvesting and dry processing

The fully matured and ripe robusta (*Coffea canephora* Pierre ex Froehner) coffee fruits were harvested manually from the Central Coffee Research Institute farm. In dry processing, the harvested fresh cherries were pre-dried for two days under the sun to remove the free moisture by spreading them on a clean cemented drying surface and then loaded into a rotary mechanical dryer (Fig. 2) for further drying.

In case of wet processing, the wet parchment coffee samples obtained after complete removal of mucilage were pre-dried for one day under the sun

to remove the free moisture and then loaded into a rotary mechanical dryer for further drying. The coffee samples were dried at different temperature regimes (40°C/50°C/60°C) in a rotary mechanical dryer until the coffee samples attain the safe moisture levels (11-12%) for the safe storage of coffee samples. Parallely, wet parchment or fresh cherries from the same harvested lot was sun-dried (as a control treatment). During sun drying, the drying thicknesses of coffee samples were maintained at 4 cm for wet parchment coffee to prevent cracking of parchment skin and 8 cm for cherry coffee. Coffee samples were turned at regular intervals and dried until the coffee samples attain the prescribed moisture levels for the safe storage of coffee samples. The ambient temperature during sun drying ranged from 26.5°C to 32°C. Coffee samples from rotary mechanical dryer and control coffee lots (sun drying) were sampled at the periodical interval, and moisture content was determined by the International Organization Standardization (ISO) 6673 standard method (1983).

Energy utilization

The energy consumption in mechanical drying of parchment or cherry coffee is expressed in an equivalent energy unit per batch of drying. The

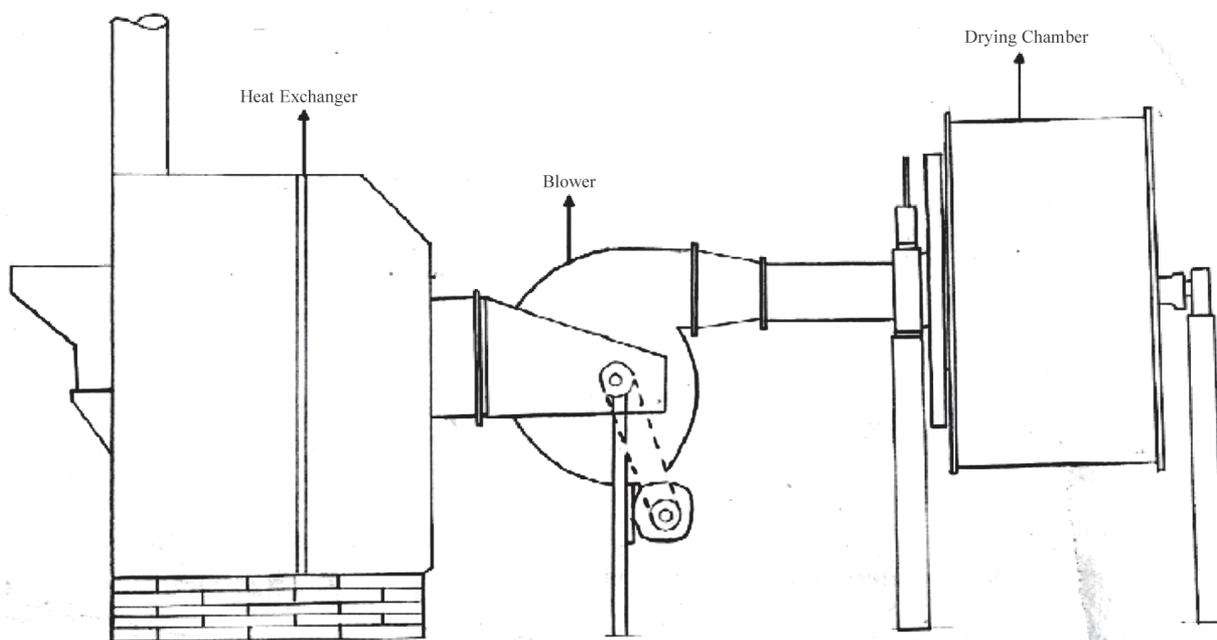


Fig. 2. Schematic diagram of mechanical rotary dryer used in the present study

energy input expressed in terms of electrical, thermal and human energy. The energy components are calculated based on one tonne of cherry/ parchment coffee, and energy component from each source was estimated using the following procedure (Jekayinfa and Bamgboye, 2006):

Electrical energy

The rated horsepower of each motor was multiplied by the corresponding hours of operation and summed to find the electrical energy usage by equipment. A motor efficiency of 80 per cent was assumed to compute the electrical inputs.

$$E_p = sPt \quad (1)$$

Where,

- E_p electrical energy consumed, kWh
- P rated horsepower of motor, kW
- t hours of operation, h
- s power factor (assumed to be 0.8)

Thermal energy

The total quantity of energy consumed from firewood was converted to a common energy unit (J) by multiplying the quantity of fuel consumed by the corresponding calorific value (lower heating value) of the fuel used.

$$E_f = C_f W \quad (2)$$

Where,

- E_f thermal energy consumed, J
- C_f calorific value of the fuel used, J kg⁻¹
- W quantity of fuel used, kg

Human energy

To determine the human energy input for a given operation, the time spent by the worker on each operation was recorded. This included the intermittent resting periods. For any unit operation, the manual energy expenditure, E_m , was determined by:

$$E_m = 0.075NT_a \quad (\text{kWh}) \quad (3)$$

Where,

- 0.075 the average power of normal human labour in kW
- N number of persons involved in an operation
- T_a useful time spent to accomplish a given task (operation) in an hour

Before the commencement of the experiments, a known quantity of firewood was weighed. The initial reading of the electric power reading meter was recorded. After completing the drying of one tonne of coffee, the quantity of the firewood left, and the final reading of the electric meter were taken. The differences in these readings represented the quantity of firewood used (in kg) and the electric power consumed (in kWh), respectively. The number of persons involved was noted. Based on these values, the cost of drying for one tonne of cherry and parchment coffee was calculated.

Sensory analysis

Sensory analysis was performed with a cup test using the UCDA method (2010) at Coffee Quality Division, Coffee Board, Bangalore by the experts. Parameters of cup test were fragrance/aroma, flavour, aftertaste, saltiness/acidity, bitterness/sweetness, mouth feel/body, balance, overall, uniform cup and clean cup.

Results and discussion

The total drying period (pre-drying and mechanical drying) of robusta cherry was found to be 48, 40 and 32 hours at 40°C, 50°C and 60°C, respectively, over 88 hours by sun drying. Similarly, robusta parchment recorded 24, 16 and 16 hours at 40°C, 50°C and 60°C, respectively, over 48 hours by sun-drying, as shown in Figure 3. As drying temperatures increased, the moisture percentage and drying time decreased. Moisture percentage decreased faster at a higher temperature than at a low temperature. At 40°C, the decrease in moisture percentage was relatively slow.

Accordingly, the total energy utilized and the operation cost for drying robusta cherry and parchment by using a rotary dryer compared with sun drying is illustrated in Tables 1 and 2, respectively.

The results indicated that the energy required was found to be 2.7 MJ and 484 MJ, 279 and 199 MJ for sun drying and rotary dryer at 40, 50, and 60°C, respectively, for drying cherry. Similarly, the sun drying and rotary dryer at 40, 50, and 60°C recorded 1.3 MJ and 261 MJ, 134 and 135 MJ for drying parchment. When total energy was separated into different forms of energy, it was observed that

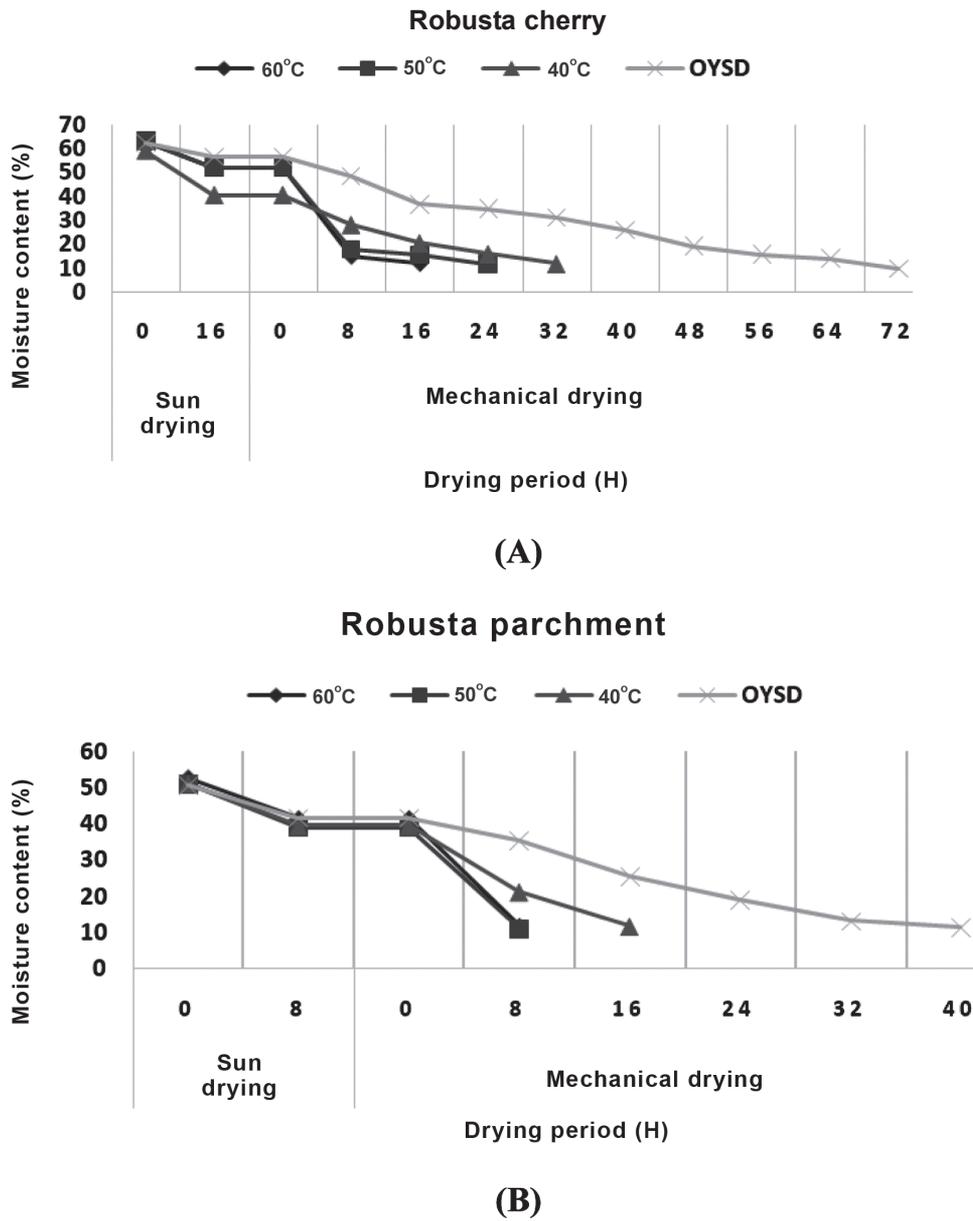


Fig 3. Effect of drying temperature on drying period of robusta cherry (A) and parchment (B)

Table 1. The total energy required for drying 1 tonne of cherry and wet parchment

Temperature (°C)	Energy requirement (MJ T ⁻¹)							
	Robusta cherry				Robusta parchment			
	Electrical	Thermal	Human	Total	Electrical	Thermal	Human	Total
60°C	192.78	5.06	1.08	198.92	129.42	5.06	0.54	135.02
50°C	271.98	5.94	1.08	279.00	129.42	4.07	0.54	134.03
40°C	477.90	5.06	1.62	484.58	256.14	3.96	0.81	260.91
Sun-dried	-	-	2.70	2.70	-	-	1.35	1.35

Table 2. The total drying cost required for drying 1 tonne of cherry and wet parchment

Temperature (°C)	Cost of drying (₹ per tonne)							
	Robusta cherry				Robusta parchment			
	Electrical	Thermal	Human	Total	Electrical	Thermal	Human	Total
60°C	1966	575	1296	3837	1320	575	648	2543
50°C	2774	675	1296	4745	1320	463	648	2431
40°C	4875	575	1944	7394	2613	450	972	4035
Sun-dried	-	-	3240	3240	-	-	1620	1620

human energy requirement was highest with sun drying in both cherry (2.7 MJ) and parchment (1.3 MJ) drying, when compared to mechanical drying by rotary dryer for cherry (1.08-1.62 MJ) and parchment (0.54-0.81 MJ). The cost of drying cherry and parchment coffee with different types of drying indicates that mechanical drying considerably increases the cost when compared to sun drying (Table 2).

Sensory analysis

The cup quality rating of robusta coffee dried by different drying methods revealed that sun-dried robusta parchment coffee scored the highest cup rating (79.5 points out of 100), followed by 78.5, 62 and 50.3 points for those coffees dried at 40°C, 50°C and 60°C, respectively in a mechanical dryer.

Regarding cherry coffee, sun-dried robusta cherry coffee scored 62.5 points. In contrast, the robusta cherry dried at 40°C in mechanical dryer scored the highest cup rating of 70.3, followed by

56.8 and 49.3 points for the coffees dried at 50°C and 60°C, respectively (Table 3). The higher drying rates caused by high temperatures deteriorate coffee quality due to damage to cell membranes (Marques *et al.*, 2008; Borem *et al.*, 2008b). Borem *et al.* (2008a) verified, through ultrastructural scanning electron microscopy, that natural and pulped caffeine endosperm, during drying at 40°C and in the yard, maintained the integrity of the cell membranes and that these membranes were damaged only between moisture contents of 30 per cent and 20 per cent (w.b.), when natural and pulped coffee was dried at a temperature of 60°C.

Conclusion

These results indicated a considerable reduction of drying time when coffees are dried in a mechanical dryer (50% to 66.6% and 45% to 63% reduction of drying time for parchment and cherry coffees, respectively). Further, the cup quality rating of robusta coffee dried at 40°C in a mechanical dryer

Table 3. Influence of drying temperature on cup quality of coffee

Characteristic	Robusta parchment				Robusta cherry			
	40°C	50°C	60°C	Sun drying	40°C	50°C	60°C	Sun drying
Fragrance/aroma	7.3	6.5	5.8	7.5	6.5	6.3	6.5	6.5
Flavour	7.0	6.0	2.0	7.5	6.0	5.5	5.8	5.5
After taste	7.0	5.0	4.0	7.5	6.3	4.5	5.0	5.0
Salt/acid	7.5	5.5	4.0	7.3	6.3	5.5	5.0	5.5
Bitter/sweet	7.5	4.5	4.5	7.3	6.0	5.0	4.0	5.0
Mouth feel	7.5	4.5	3.0	7.5	6.3	4.5	5.0	5.0
Balance	7.3	5.0	3.5	7.5	6.5	5.0	5.0	5.0
Uniformity	10.0	10.0	10.0	10.0	10.0	10.0	6.0	10.0
Clean cup	10.0	10.0	10.0	10.0	10.0	8.0	6.0	10.0
Overall	7.5	5.0	3.5	7.5	6.5	4.5	5.0	5.0
Defects (Deduction)	0.0	0.0	0.0	0.0	0.0	2.0	4.0	0.0
Total	78.5	62.0	50.3	79.5	70.3	56.8	49.3	62.5

scored equal or higher quality points than sun-dried coffees, indicating that the drying temperature should not exceed more than 40°C for preserving the innate quality of robusta coffee. Overall, mechanical drying is more advantageous to sun drying in-terms of drying hours (indirectly reduces dependency on manpower) and preservation of innate quality of the coffee.

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