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Mechanical properties and stress relaxation characteristics of fresh and partially fermented coffee parchment

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The important commercial species of Coffee grown in India are arabica coffee (*Coffea arabica*), robusta coffee (*Coffea canephora*) and tree coffee (*Coffea liberica*). Arabica coffee is cultivated largely in the world since it produces the best quality coffee. Frictional properties of fresh and partially fermented arabica coffee parchment of Cauvery variety are important in development of washer mechanism for parchment at estate level processing of coffee. Mechanical behaviour of coffee parchment being time dependent must logically be studied by applying the principles of rheology and visco-elasticity. The stress relaxation function describes the behaviour of visco-elastic materials of coffee parchment. Hence stress relaxation behaviour of fresh and partially fermented arabica coffee parchment were studied. The result indicated that the stress decay last for 400, 1890, 1560 and 1740 seconds for fresh, 16, 20 and 24 hours fermented parchment, respectively. The stress relaxation behaviour indicated that the parchment have the tendency to break easily and hence care should be taken while handling / during washing of parchment.

Key Words : Arabica coffee parchment, Frictional properties, Stress relaxation behaviour

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INTRODUCTION

Coffee (*Coffea* spp.) an important commercial and high altitude crop is cultivated between tropic of cancer and tropic of capricon. The important commercial species grown in India are arabica coffee (*Coffea arabica*), robusta coffee (*Coffea canephora*) and tree coffee (*Coffea liberica*). Arabica coffee is cultivated largely in the world since it produces the best quality coffee. It was introduced in India sometime during 1670's by a muslim pilgrim, Bababudan who brought seven seeds from Yeman and raised seedlings on the hills near the town of Chikmagalur, Karnataka (Bheemiah, 1992). The arabica coffee grows well at an altitude of 800 to 1500 m above mean sea level. The annual rainfall, temperature and relative humidity required for coffee cultivation are 1750 to 2000 mm, 15 to 25°C and 70 to 80 per cent, respectively. In India, the commercial coffee producing states are Karnataka, Tamil Nadu, Andhra Pradesh, Orissa, Assam, West Bengal, Maharashtra, Nagaland, Tripura, Manipur, Himachal Pradesh and Andaman and Nicobar Islands.

Frictional properties of parchments are important especially in developing the washer mechanism used in estate level processing of coffee. Hence frictional properties of both fresh and partially fermented arabica parchment of Cauvery variety against various surfaces to parchment and stress relaxation behaviour were studied.

Shepherd and Bharadwaj (1986) determined the static co-efficients of friction of pigeon pea using an aluminium box (opened at bottom also) of dimensions 150 x 100 x 40 mm. The box was filled with grain and placed on the adjustable

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tilting surface. The structural surface with the box on its top was raised gradually with a screw device until the box just started to slide down and the angle of tilt was read from a graduated scale.

METHODOLOGY

Materials for measurements :

The freshly harvested arabica coffee berries were collected from the coffee Demonstration Farm, Coffee Board, Yercaud, Tamil Nadu, India.

Co-efficient of static friction :

The apparatus consisted of frictionless pulley fixed on a frame and a hollow sample holder connected to the weight pan through the frictionless pulley (Sreenarayanan *et al*., 1988). The parchment at different levels of fermentation *viz*., 0, 16, 20 and 24 hours were filled in the sample holder and weight was added to the loading pan until the sample holder just started moving, overcoming the friction on the surface. From the weights in the pan (W) and the weight of parchment with mucilage (P), the co-efficient of static friction (F) was calculated using the formula :

$$F = \frac{W}{P}$$

The experiment was repeated 5 times on each surface *viz*., mild steel, galvanised iron, aluminium and stainless steel and the average value was reported.

Stress-strain relationship of parchment:

Mechanical behaviour of coffee parchment being time dependent, must logically be studied by applying the principles of rheology and visco-elasticity. The stress relaxation function describes the behaviour of visco-elastic materials of many coffee parchment.

The stress relaxation behaviour, decay of stress with respect to time at constant strain was conducted. The relationship between the applied load and the indicator reading was established. The parchment were compressed by turning the load wheel to load just below its hardness and allowed to decay. The decay of stress was noted at 10 seconds interval from the load indicator till the stress attained equilibrium.

The compressive stress was plotted against the time in the semilog graph and the analysis was done by following the method of Successive Residual Analysis as explained by Mohsenin (1970).

OBSERVATIONS AND ASSESSMENT

The findings of the present study as well as relevant discussion have been presented under the following heads :

Co-efficient of static friction of parchment :

The average co-efficient of static friction of fresh, 16, 20, 24 hours of fermented and washed parchment were determined against various surfaces like aluminium, stainless steel, galvanized iron and mild steel.

The frictional values of 0.22, 0.51, 0.51, 0.51 and 0.55 against aluminium surface, 0.20, 0.38, 0.39, 0.45 and 0.46 against stainless steel surface, 0.21, 0.43, 0.49, 0.53 and 0.54 against galvanized iron surface and 0.31, 0.52, 0.56, 0.56 and 0.58 against mild steel surface were observed for fresh, 16, 20, 24 hours fermented and washed parchment, respectively.

On aluminium surface, the maximum friction of 0.55 was obtained with washed parchment and minimum friction of 0.22 was obtained with the fresh parchment. Similarly the maximum value of 0.46 and minimum of 0.20 were obtained with washed and fresh parchment, respectively on stainless steel surface. In the case of galvanized iron, the maximum value was 0.54 with washed parchment and the minimum

Table 1 : Co-efficient of static friction of parchment

Sr. No.	Treatment	Material			
		Aluminium	Stainless Steel	Galvanized iron	Mild steel
1.	Fresh	0.22	0.20	0.21	0.31
2.	16 h fermented	0.51	0.38	0.43	0.52
3.	20 h fermented	0.51	0.39	0.49	0.56
4.	24 h fermented	0.51	0.45	0.53	0.56
5.	Washed	0.55	0.46	0.54	0.58

Table 2 : Adhering strength of mucilage with parchment

Sr. No.	Treatment	Average adhering strength of mucilage (N)
1.	Fresh	0.00132
2.	16 h fermented	0.00120
3.	20 h fermented	0.00099
4.	24 h fermented	0.00095

value of 0.21 was obtained with fresh parchment. But the maximum frictional value of 0.58 was obtained with washed parchment and the minimum frictional value of 0.31 was obtained with fresh parchment on mild steel surface.

From the table, it is further seen that in all surfaces studied, the fresh parchment recorded the minimum co-efficient of static friction. This is due to the presence of fresh mucilage with its oil like characteristic which provides smooth lubricating effect for the parchment to move on the surfaces. Washed parchment recorded the maximum co-efficient of static friction of 0.46 on stainless steel surface (*i.e.* on smooth surface) and the maximum value of 0.58 on mild steel surface (rough surface). This is in accordance with the nature. As the washed parchment have rough seed coat when compared to the parchment with mucilage, it recorded the maximum frictional values in all the surfaces studied. As the duration of fermentation increased, the co-efficient of static friction also increased in all the surfaces studied.

Crushing strength of parchment :

The crushing strength of parchment was determined using the instrumental set up developed for this purpose. The incremental load cracked the parchment and the minimum load required to crush or make a crack on the parchment. The crushing strength was measured along the two axes of parchment *viz*., major and minor. Each experiment was replicated thrice and the average value was reported. The mean value of crushing strength of 0.81 N was obtained while measuring along major axis and the mean value of 2.34 N was obtained along minor axis.

Adhering strength of mucilage with parchment :

The adhering strength of mucilage with parchment was determined for fresh, 16, 20 and 24 hours fermented parchment.

It can be seen from the table that the average adhering strength of mucilage with fresh, 16, 20 and 24 hours fermented parchment were 0.00132, 0.00120, 0.00099 and 0.00095 N, respectively. The results clearly indicate that as the duration of fermentation increased, the mucilage was loosened more and hence recorded lower force to remove the same.

Moisture content :

The moisture content of washed parchment was recorded as 161.8 per cent (d.b).

Stress relaxation behaviour of coffee parchment :

The stress relaxation behaviour of coffee parchment was studied at different fermentation levels *viz*., 0, 16, 20 and 24 hours. The experiment was conducted at the loading rate of 10 cm/min, as the constant deformation rate tests allow simultaneous determination of failure and relaxation properties (Waanen and Okos, 1992). The data of decay of stress was recorded at an interval of 10 seconds and analysed by successive residual method (Mohsenin,1970).

Based on this experiment following four equations were obtained to represent the stress relaxation behaviour of fresh,16, 20 and 24 hours fermented parchment, respectively.

$$\sigma(t) = 0.63\, e^{-t/81.3} + 1538.46$$

$$\sigma(t) = 0.43\, e^{-t/1111.11} + 0.24 e^{-t/173.91} + 15000$$

$$\sigma(t) = 0.42\, e^{-t/166.66} + 5357.1$$

$$\sigma(t) = 0.44\, e^{-t/1296.29} + 0.28 e^{-t/1320} + 10625$$

The stress decay last for 400, 1890, 1560 and 1740 seconds for fresh, 16, 20 and 24 hours fermented parchment, respectively. The stress relaxation behaviour indicated that the parchment have the tendency to break easily and hence care should be taken while handling / during washing of parchment. Similar findings were observed by Chandrasekar and Viswanathan (1999), Lodder and Kreger-van (1967), Masoud *et al.* (2004) and Mburu (1997).

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