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RESISTANCE OF COFFEE BEANS AND COFFEE CHERRIES TO AIR FLOW

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ABSTRACT

Experiments were conducted to obtain information on the effect of airflow rates and bed depths on the resistance of coffee cherries and coffee beans available locally (Coffea Liberica). The airflow used were in the range of 0.06 to 0.6 cu.m/s-sq.m. The moisture contents of the coffee cherries ranged from 10% to 50% (wet basis) and that of coffee beans ranged from 12% to 30% (wet basis). Two methods of filling were used i.e. loose fill and packed fill. Pressure drops across the material bed in a vertical column were measured at several depths using inclined manometer. The pressure drop increased directly with airflow rates as well as bed depths. The effects of air flowrates and moisture contents on the resistance in terms of pressure drop per unit bed depth were analysed. The pressure drop per unit depth across the material bed varied slightly due to different depth. The resistance to airflow decreased with the increase in moisture content for loose fill. However, the effect of moisture content is not apparent for packed fill.

INTRODUCTION

Most drying systems use air as a medium to transport heat to the material and to remove moisture from the material. In storage system, air is used to remove heat from bulk material so that temperature gradient within the material mass is reduced. Design of these drying and storage systems requires information on resistance of the material to airflow in order to select and use appropriate fan for the supply of air. The airflow resistance of the material is usually referred to and measured by the pressure drop across a bed of material. The pressure drop normally depends on air flowrate, bed depth, compaction, surface area and shape, moisture content, and the presence of foreign material. Even though the pressure drop depends on those factors mentioned, the pressure drop of most materials were reported in terms of airflow rates only; however, there are some information on the relationship of pressure drop with moisture content, in addition to airflow (Farmer et al,1981; Gunasekaran and Jackson, 1988; Hummeida and Ahmed, 1989; Steel, 1974; Wilheim et al, 1983).

MATERIALS AND METHOD

Apparatus

The apparatus used for conducting the experiments to determine the resistance of coffee beans and cherries to airflow is shown schematically in Fig. 1. The vertical test column, made of clear plastic cylinder was 190 mm in diameter and 1020 mm tall. The floor of the test column was made of wire mesh and the cylindrical plenum was made of PVC pipe.

Six pressure taps, each 4 mm internal diameter, were located at equal interval from each other around the perimeter of the test cylinder. This set of six pressure taps was located at each bed depth of 152, 304, 456, 608 mm and was connected to a common plastic tubing to form a piezometer ring which was connected to an inclined manometer. The pressure taps were inserted into the holes in the wall of the test column so that they were flushed with the inside wall surface.

The air was supplied from a centrifugal fan equipped with a 0.5 hp motor. The air supply duct was made of PVC pipe of 108 mm in diameter and about 3 meter in length. An orifice meter was mounted into the air supply duct, located at about 2.35 m from the fan outlet and 0.75 m from the bend to the plenum chamber.

Experimental Procedure

Experiments were conducted using coffee beans and coffee cherries separately. Coffee beans were beans in which the pericarp has been fully removed and were partially dried. Coffee cherries used were those that were partially dry, in which the pericarp was partly cracked and partially removed. Experiments were conducted for two filling conditions i.e. loose fill and packed fill. For loose fill, the test column was filled by freely pouring the bean into the column from the center of the top edge of the column. For packed filling, the bean was poured into the column which was then subjected to packing by a shaking machine for a period of about five minutes.

The total depth of the beans in the column was about 670 mm; pressure drop measurements were taken in the test column at bed depths of 152 mm, 304 mm, 456 mm and 608 mm from the bed floor. The pressure differentials at these bed depths were measured for each flowrate setting. Experiments were conducted on coffee beans with moisture contents ranging from 12% to 30% and on coffee cherries with moisture contents ranging from 10% to 50% (wet basis). Two runs were conducted for each test sample with a particular moisture content.

Measurements

The air flowrates supplied by the fan were monitored using the orifice meter located in the air supply duct and the apparent air velocities entering the bean bed were then determined using continuity principle when the bed cross-sectional area is known. Air flow rate variations were obtained by adjusting the fan inlet opening as well as changing the rpm of the fan using a voltage regulator.

The moisture content of the beans as well as cherries was determined based on Malaysian Standard MS 293: 1984. Duplicate ground bean samples of about 10 gm each were placed in the oven set at 103° ± 2°C for a period of 16 ±1 hours. The moisture content on wet basis was taken calculated. The initial moisture content of the bean and the cherries were determined to be 30% and 50% respectively. In subsequent experiments, samples from the respective initial batches were used, which experienced reduction in moisture content by natural drying. Bulk density was determined for each test by taking the weight of the bean in the test column of known volume.

The pressure differential across the material bed depth was measured using inclined manometer. The ambient temperature and relative humidity were also measured.

RESULTS AND DISCUSSIONS

The results presented here are for coffee beans followed by coffee cherries under loose-fill and packed-fill conditions respectively.

(A) Coffee beans

Loose - fill condition

The resistance to airflow of coffee beans under loose fill condition is presented in Fig. 2 and Fig. 3. The pressure drop obtained for each bed depth (Fig. 2) at moisture content of 15.7% indicates the obvious increase with air flowrate and bed depths. Similar plots were obtained at other moisture content levels. The observed bulk densities ranged from 393 to 439 kg/cu.m. The plot of the pressure drop per unit bed depth for various velocities at three moisture content levels is given in Fig. 3. It can be seen that there is slight variation in the pressure drop per unit bed depth due to different bed depths. This is common for each moisture content. It is observed that there is a slight effect of moisture content on the resistance since generally the resistance tends to increase with a decrease in moisture content.

Packed - fill condition

The resistance to airflow of coffee beans under packed-fill condition is presented in Fig. 4 and Fig. 5. The pressure drop obtained for each bed depth (Fig. 5) at moisture content of 16.1% indicates obvious increase with air flowrates and bed depths. Similar plots were obtained at other moisture content levels. The bulk densities observed ranged from 341.2 to 469 kg/cu.m. The plot of the pressure drop per unit bed depth for various velocities at three moisture content levels is given in Fig. 5. It is again observed that there is slight variation in the pressure drop per unit bed depth due to different bed depths. The effect of moisture content on the resistance under packed fill condition is uncertain.

(B) Coffee cherries

Loose - fill condition

The resistance to airflow of coffee cherries (partly cracked and partially depulped) under loose fill condition is presented in Fig. 6 and Fig. 7. The pressure drop obtained for each bed depth (Fig. 6) at moisture content of 19.6% indicates the obvious increase with air flowrates and bed depths. Similar plot was obtained at moisture content of 49.5%. The observed bulk densities ranged from 349 to 497.5 kg/cu.m. The plot of the pressure drop per unit bed depth for various velocities at two moisture content levels is given in Fig. 7. It is also observed for coffee cherries that the pressure drop per unit bed depth varies slightly with bed depths. It is apparent that there is a slight effect of moisture content on the resistance whereby the resistance tends to increase with a decrease in moisture content.

Packed - fill condition

The resistance to airflow of coffee cherries (partly cracked and partially depulped) under packed-fill condition is presented in Fig. 8 and Fig. 9. The pressure drop obtained for each bed depth (Fig. 8) at moisture content of 10.8% indicates the obvious increase with air flowrates and bed depths. Similar plots were obtained at two other moisture content levels. The observed bulk densities ranged from 364 to 410 kg/cu.m. The plot of the pressure drop per unit bed depth for various velocities at three levels of moisture content is given in Fig. 9. Again there is slight variation in the pressure drop per unit bed depth due to different bed depths. The effect of moisture content on the resistance is unconvincing, eventhough there is a slight effect of moisture content especially at higher air flow rates.

CONCLUSIONS

The resistances to air flow have been obtained for coffee beans and coffee cherries at air flowrates ranging from 0.06 to 0.6 cu. m/s-sq.m. under loose fill and packed fill conditions at some limited values of moisture content.

The resistances of both coffee beans and coffee cherries increase with the increase in air flowrates and bed depths. There is slight variation in the pressure drop per unit bed depth measured at different bed depths for all cases. This is probably due to the slight differences in density of fill at different depth. There is a slight indication that the resistance to air flow of coffee beans under loose fill condition tends to increase with the decrease in moisture contents. The effect of moisture content is not clear for packed fill condition. Similarly for coffee cherries under loose fill condition, there is some indication that there is a slight effect of moisture content on the resistance whereby the resistance tends to increase with moisture content decrease. Again, the moisture content does not matter much under packed fill condition.

There is a definite increase in resistance due to packing of coffee beans; however there is no apparent difference in resistance of coffee cherries between loose fill and packed fill.

The resistance to airflow is greater for coffee beans than that of coffee cherries under packed fill conditions. This is probably due to the fact that packing caused coffee beans to be more packed than coffee cherries. While for loose fill, there was no apparent difference between the resistance of coffee beans and cherries.

ACKNOWLEDGEMENTS

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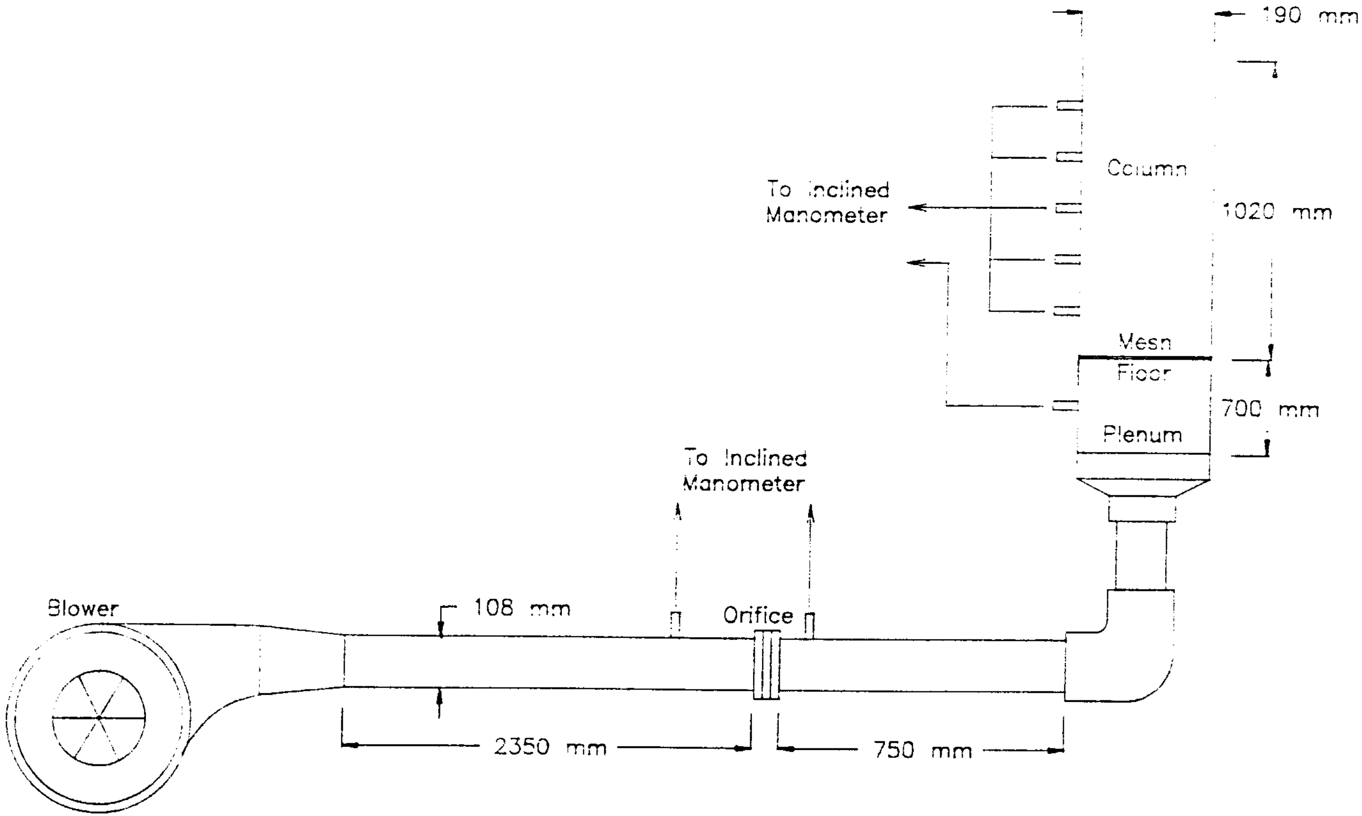

Fig. 1. Apparatus for determination of air flow resistance.

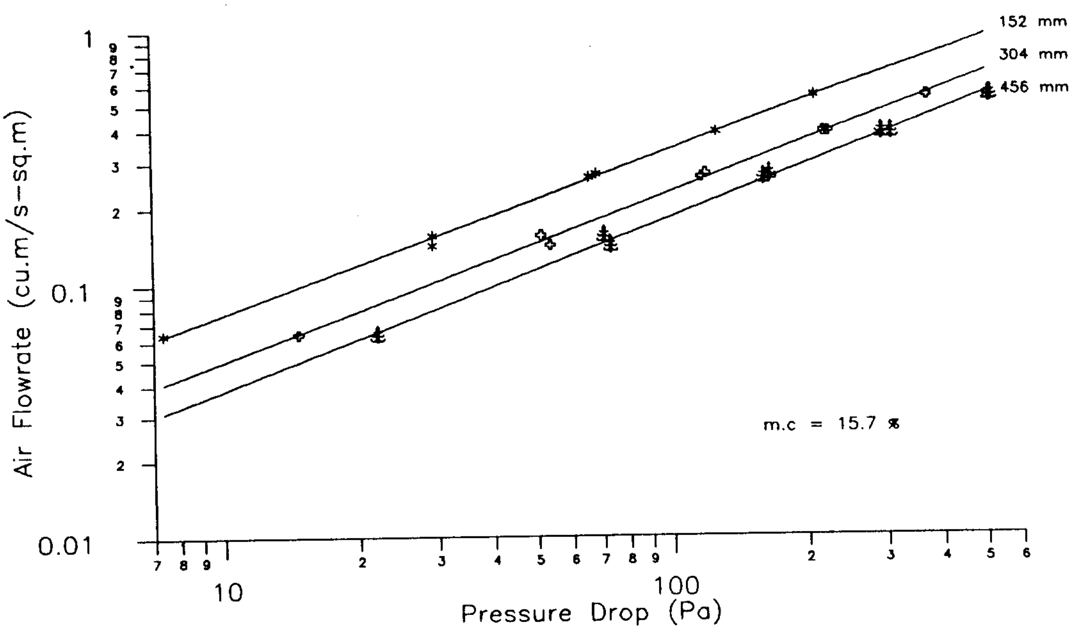

Fig. 2 Airflow resistance of coffee beans at various bed-depths (loose fill)

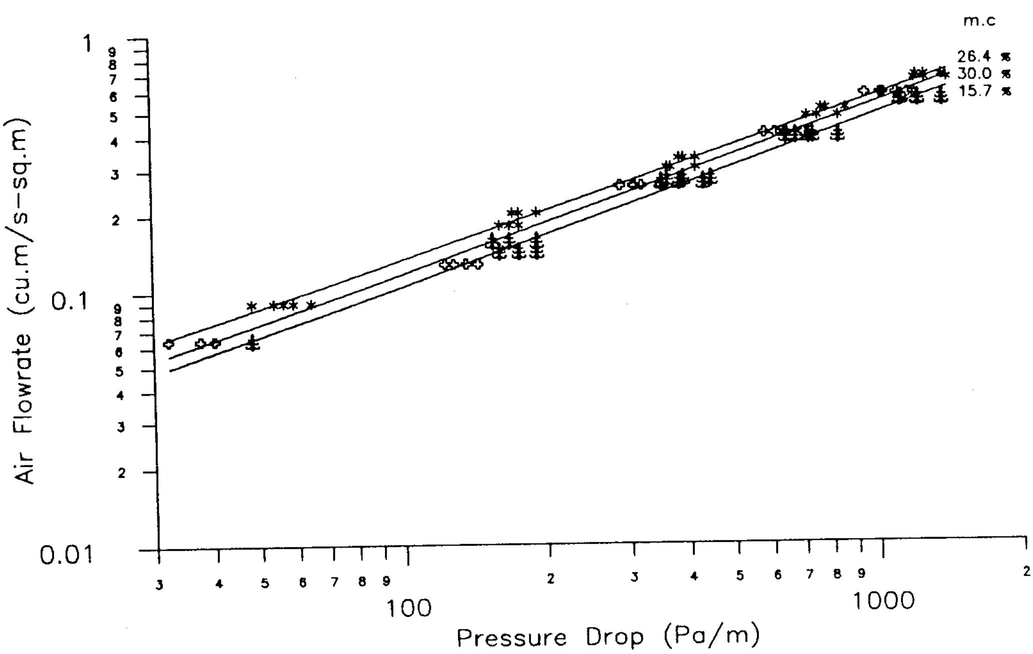

Fig. 3 Airflow resistance of coffee beans at various moisture contents (loose fill)

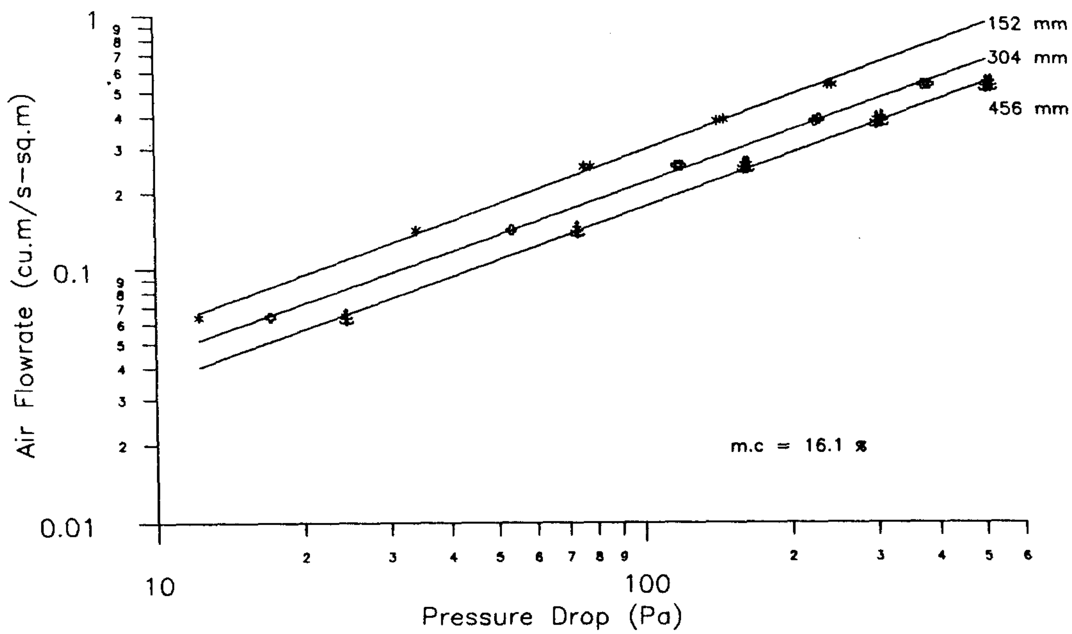

Fig. 4 Airflow resistance of coffee beans at various bed-depths (pack fill)

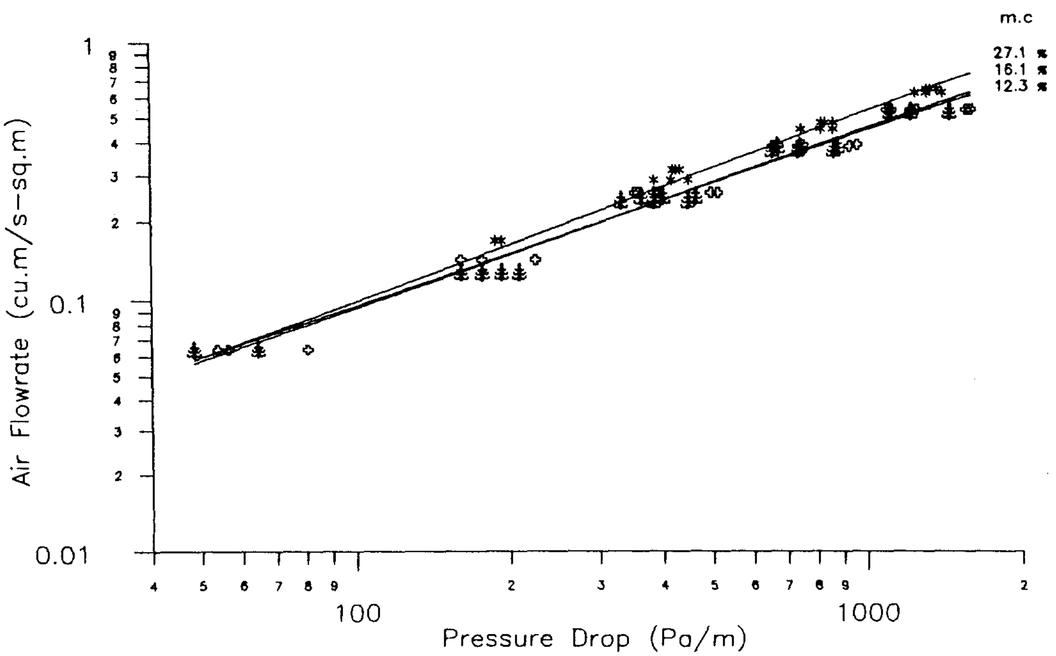

Fig. 5 Airflow resistance of coffee beans at various moisture contents (pack fill)

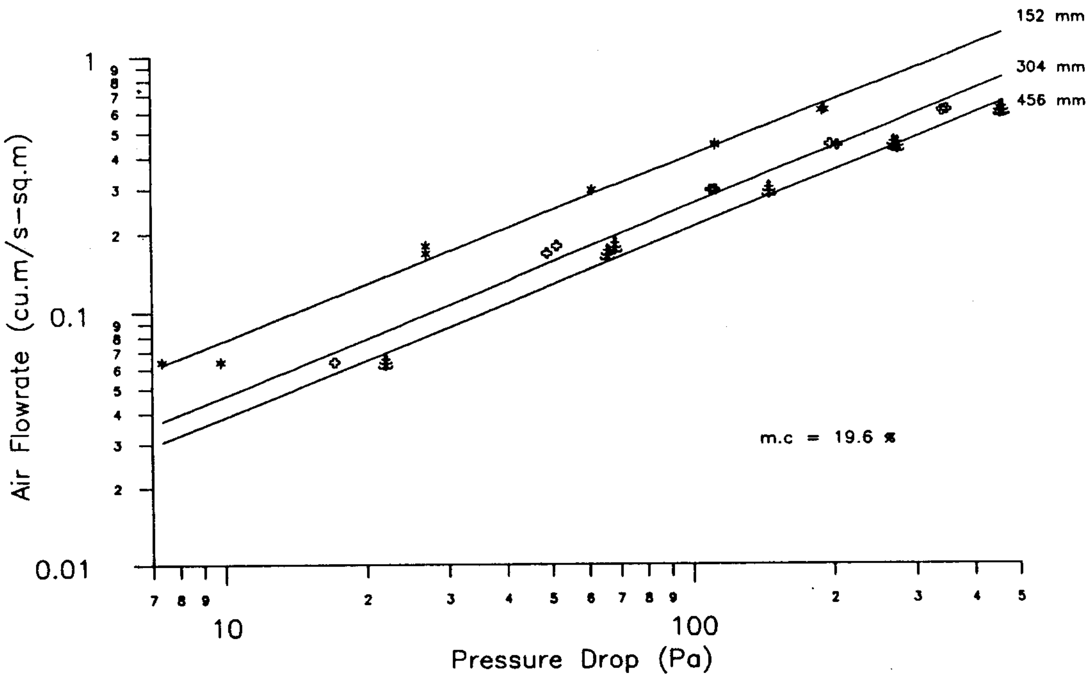

Fig. 6 Airflow resistance of coffee cherries at various bed-depths (loose fill)

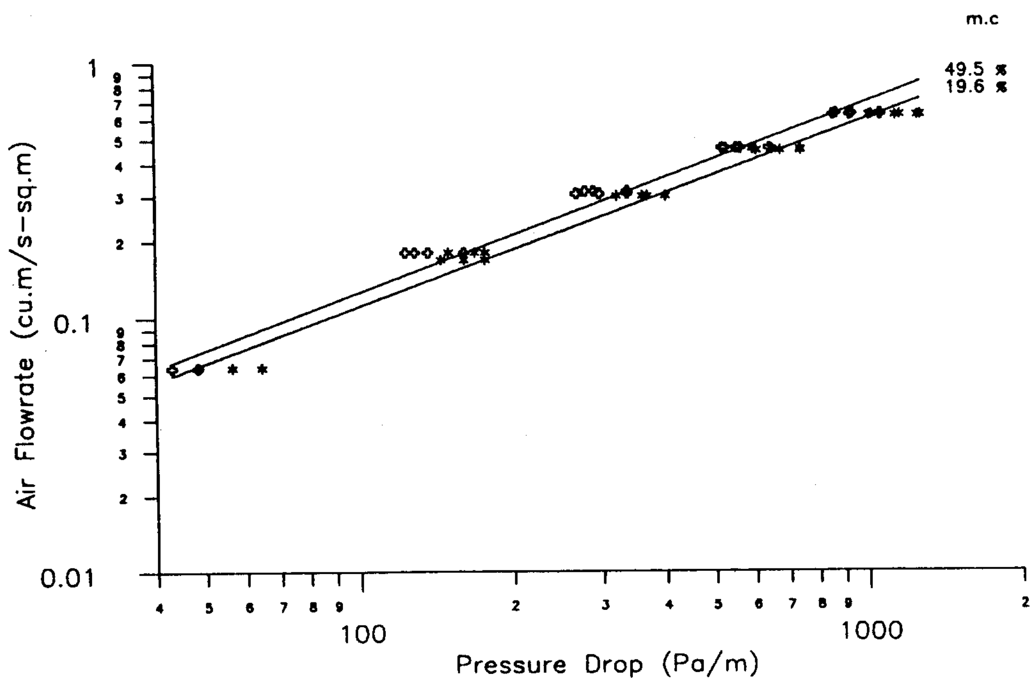

Fig. 7 Airflow resistance of coffee cherries at various moisture contents (loose fill)

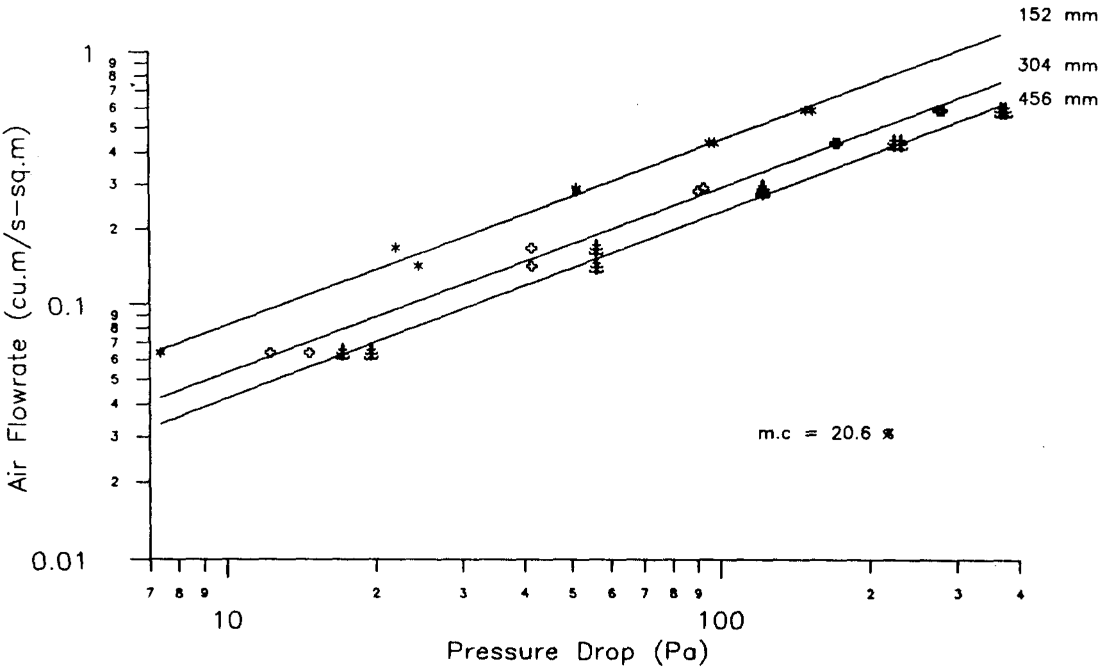

Fig. 8 Airflow resistance of coffee cherries at various bed-depths (pack fill)

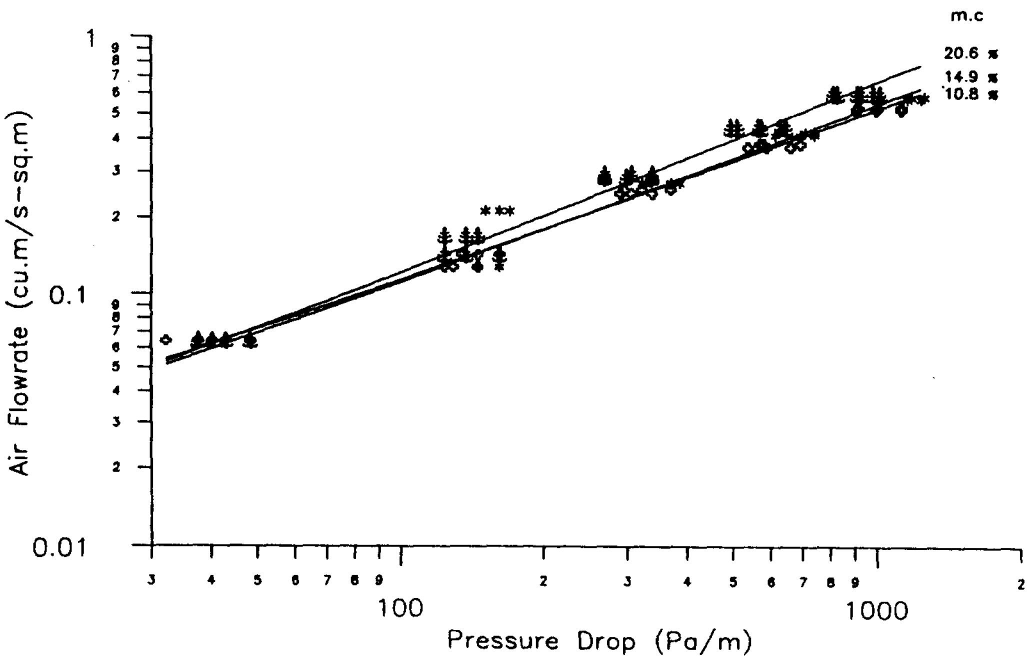

Fig. 9 Airflow resistance of coffee cherries at various moisture contents (pack fill)