AIRFLOW RESISTANCE DUE TO SOIL ON BULK POTATOES

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The resistance to airflow through bulk potatoes was determined with clean potatoes and with potatoes that had small percentages of soil mixed with them. The addition of loose soil offered significantly higher resistance to airflow than did clean potatoes. An equation was developed for the prediction of pressure drop through bulk potatoes as a function of airflow for various levels of loose soil mixed with the product.

INTRODUCTION

The relationship between pressure drop and the rate of the airflow through agricultural products is important in the design of drying or cooling systems. Airflow resistance of agricultural products has been found to be affected by moisture content, presence of foreign material, and the degree of packing in the bed. Woodruff et al. (1983) suggest that soil which may adhere to the surfaces of potatoes during storage can account for 3% of the tuber weight. This soil tends to loosen from the tuber surfaces and partially fill the voids between the tubers which increases the resistance to airflow through the voids.

Field conditions are the major factors affecting the efficiency for soil-tuber separation on potato harvesters (Thornton et al. 1973). In Eastern Canada, harvesting is often done under unfavorable weather conditions. Often under these conditions, soil is transported to storage with the potatoes. Vibration of the main conveyor chain on the harvester is used to improve soil-tuber separation. However, the method used to produce such vibration causes a significant amount of damage to the tubers (Chaudhry et al. 1978).

Several researchers have measured the resistance of clean potatoes to airflow. Agreement on pressure drop and airflow rate has been indicated by Staley and Watson (1961) and Wager et al. (1952). More recently Neale and Messer (1976) have investigated the effect of sprouts and foreign material mixed with the potatoes for the varieties Majestic and Maris Piper. The purpose of this project was to determine the effect of loose soil mixed with potatoes on the airflow resistance of the bulk product.

EQUIPMENT AND PROCEDURE

Samples of the material leaving the bin loading conveyor at four bulk storages were collected during the fall of 1981. The samples were taken over a 2-wk period during the potato harvesting season. Potatoes were harvested with harvesters equipped with potato-stone separators and transported in bulk to the storages. Samples weighing 15 kg were randomly taken from the material leaving the bin-loading conveyor. The tubers were separated from the soil and debris and then cleaned thoroughly in order to determine the amount of soil and debris being loaded with the tubers into the bulk storage.

For the pressure-airflow study, the test column consisted of a cylindrical bin of 600-mm diameter with a perforated floor placed over a plenum chamber. In order to compensate for the wall effect, the walls of the test column were lined with 25.4-mm-thick foam sheets. These sheets provided baffling at the periphery of the column which reduced air losses up the sides of the column. Straighteners were used in the approach sections to the test column to assure uniform airflow. Figure 1 shows the schematic arrangement of the experimental apparatus.

A variable speed fan was used to deliver air, the airflow rates were measured in the inlet duct using a Thermo-Systems Incorporated, Model 1610-4 hot wire anemometer. Velocity profiles were obtained across the inlet duct and the average velocity determined for each test. Static pressure was measured by connecting four

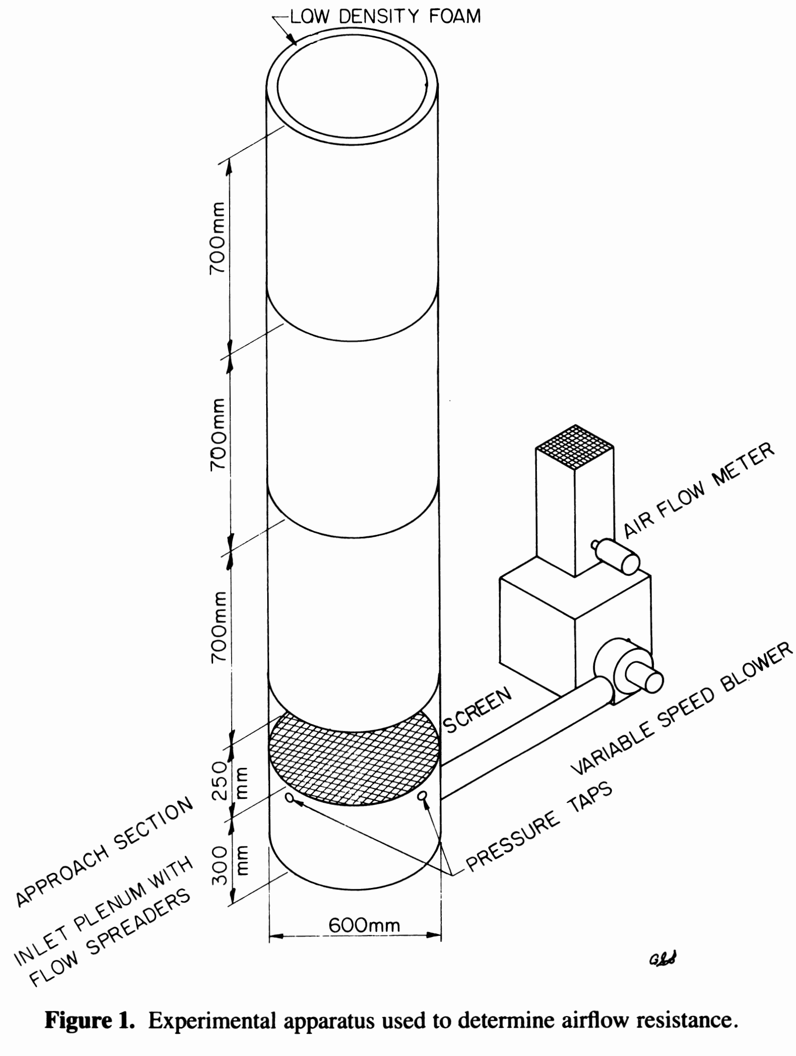

Figure 1. Experimental apparatus used to determine airflow resistance.

pitot static tubes located in the plenum to an inclined micromanometer. Pressure drop due to the apparatus with a layer of potatoes 0.25 m deep was determined over a range of air velocities. These values were subtracted from the total resistances measured during the tests when the column was filled with potatoes to obtain the resistance of the potatoes alone.

Clean, freshly harvested Russet Burbank potatoes were added to the bin in 0.25-m-deep layers. After the placement of each layer, the static pressure and velocity readings were recorded over a range of airflow. The hot wire anemometer probe was inserted into the inlet duct and the airflow was adjusted until the desired level was obtained. Airflow to the column of potatoes was varied to cover an approach velocity range of 0.03–0.3 m/s by adjusting the output of the voltage regulator which controlled the speed of the fan. This procedure was repeated up to a height of 1.75 m of potatoes at 0.25-m intervals. Exact duplication of the procedure was undertaken in successive tests. The series of tests was repeated with the addition of soil to the potatoes in order to determine the effect of loose soil on the resistance to airflow. Measured weight of soil was alternately sprinkled over single layers of potatoes up to the 0.25-m depth interval and then measurements of static pressure and air velocity were taken. This procedure was again repeated in duplication up to a column height of 1.75 m at 0.25-m intervals. The series of tests included soil mixed with the potatoes at ratios of 2, 4, and 6% by weight.

RESULTS AND DISCUSSION

The on-farm survey of measuring soil mixed with potatoes in storage yielded the data which is summarized in Table 1. It is apparent that field soil moisture affects the amount of soil that the harvesters are unable to separate from the potatoes. A marked increase in soil content can be noted with the higher field soil moisture.

The relationship between static pressure drop and airflow has been experimentally determined for many agricultural products and reported by Shedd (1953). The resultant log-log plots of airflow rate versus pressure drop per unit depth of product have been adopted as Standard D272 by the American Society of Agricultural Engineers (ASAE Yearbook 1983–1984).

Data were fitted to Shedd's model using the regression analysis procedure given by Smillie (1969). A term was added to the equation to account for the addition of loose soil. The following equation was

TABLE I. SOIL ACCUMULATED WITH POTATOES COLLECTED FROM BIN CONVEYOR AT STORAGE

Location	Soil texture	Soil/ potatoes(%)	Field soil moisture % (dry basis)
1	Gravely loam	1.3	25.1
2	Silt loam	3.4	30.9
3	Gravely sandy loam	0.8	11.9
4	Gravely sandy loam	1.3	18.2

selected which yielded a coefficient of determination of 0.82:

$$P = 140Q^{1.5}(1 + m)^{0.8} \qquad (1)$$

where P = pressure drop per unit depth of product (Pa/m); Q = airflow, volume/time – cross-sectioned area (m^3/s.m^2); and m = soil content (% weight)

The effect of soil mixed with potatoes on static pressure drop as determined by Eq. 1 is shown by the curves presented in Fig. 2. The soil appears to have a dramatic affect on the airflow-pressure drop relationship. The pressure drop of airflow through a soil/potato mixture of 2% was more than double that through clean potatoes at any given airflow. This increased pressure drop is amplified with the higher soil content mixed with the potatoes as also indicated by Neale and Messer (1976). The results of this study stress the importance of pre-cleaning the potatoes before storage to minimize the amount of soil in storage in order that proper airflow can be maintained through the bulk product.

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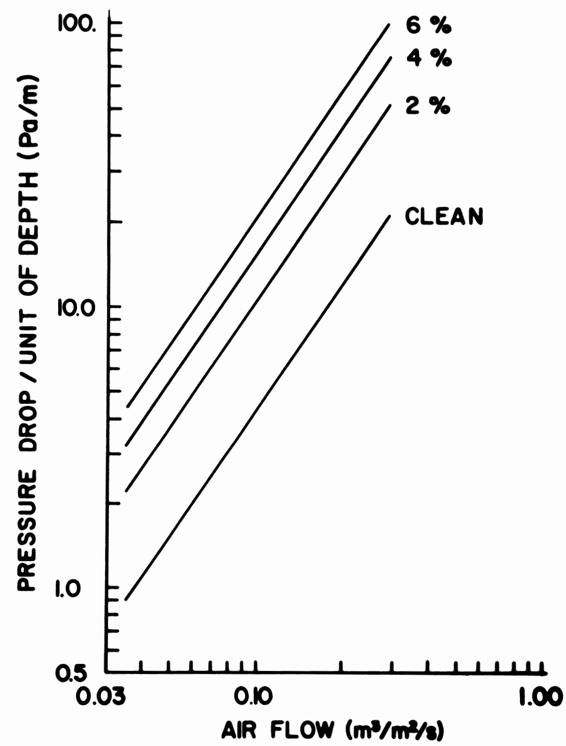

Figure 2. Airflow versus static pressure drop for potatoes with various soil content.