Airflow Through Densely Packed Burley Tobacco Leaves

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Abstract

Curing of high density burley tobacco leaves is dependent on fan-forced air flow. Static pressure drop and airflow were measured through randomly oriented freshly harvested midstalk burley tobacco leaves in box containers with cross section of 30.5 × 61 cm (12 × 24 in.). Measurements were made for densities of 192, 224, and 256 kg/m^3 (12, 14, and 16 lb/ft^3) and bed depths of 0.91 and 1.22 m (3 and 4 ft). Air velocity as a function of pressure drop per unit bed depth was determined to be a straight line on a log-log plot ($r^2 > 0.80$) with slopes of 0.773, 0.694, and 0.907 at 192, 224, and 256 kg/m^3 (12, 14, and 16 lb/ft^3). Variation in velocity caused by density variation which results from inconsistent placement of leaves in the boxes should be a design consideration.

Introduction

High labor requirements, scarcity of labor, and the strenuous nature of the task of harvesting and housing burley tobacco are problems which have concerned burley producers for many years (Casada et al., 1971). Producers have expressed a desire for mechanization to alleviate these problems.

A leaf harvesting and curing system has been developed and is being used in the flue-cured tobacco production area (Splinter et al., 1968; Suggs, 1977). The question, naturally, arises as to the feasibility of adapting this operationally proven system to burley tobacco production (Duncan, 1976). Attempts have been made to use this equipment with little or no modification, but these efforts have met with mixed results and have not received general acceptance by the burley industry (Duncan, 1976).

A curing system for burley leaves using natural unheated air has been proposed (Walton et al., 1980; Walton et al., 1981). This system would utilize the mechanical leaf harvester which is commercially available and the natural environmental conditions so favorable to curing high quality burley tobacco.

In the development of such a natural air leaf curing system, allowable ranges of and relationships between loading density in the curing container, airflow rate, and length of airflow path required to cure high quality burley tobacco must be established. Characteristics of airflow in flue-cured tobacco systems has been studied by Suggs et al. (1984).

The objective of this study was to determine the airflow rate through randomly oriented, freshly harvested burley tobacco leaves as a function of static pressure and leaf density.

Materials and Methods

The burley variety used in this experiment was KY 14. Leaves from the middle stalk position were mechanically harvested with a Roanoke* harvester. Leaves were then placed by hand in box containers of 30.5 × 61 cm (12 × 24 in) in cross-section that were designed to simulate large box containers used for mechanical handling of flue cured tobacco (Suggs, 1977).

Two boxes were mounted one at a time on a plenum to which air was supplied by a 0.61 m (24 in.), 2.24 kW (3 hp) axial fan. The experiment consisted of three bulk densities of 192, 224, and 256 kg/m^3 (12, 14, and 16 lb/ft^3), two bed depths of 0.91, and 1.22 m (3 and 4 ft), two replications and a pressure drop range of 130 to 570 Pa (0.5 to 2.3 in. of water). There was no apparent effect of bed depth on pressure drop per meter of bed depth. Therefore, the two bed depths were also treated as replications for the purpose of data analysis giving a total of four replications.

Plenum static pressure was measured with a vertical micro manometer to the nearest 2.6 Pa (0.01 in. of water). Pressure drop was calculated by dividing plenum pressure by bed depth. Airflow was measured with a vane anemometer through a 15 × 15 cm (6 × 6 in) orifice placed over the air exit end of the boxes. Airflow was vertically upward.

Bed depth was chosen and quantities of freshly harvested leaves were weighed and placed into each of the two boxes corresponding to 192 kg/m^3 (12 lb/ft^3) for the selected bed depth. A side was removed from the boxes to facilitate loading the leaves into the boxes. Tips and butts of the leaves were randomly oriented, however, the major portion of leaf midribs were oriented parallel to airflow or within a 30° angle to parallel. No broken or folded leaves were used. Sides were replaced, rods were inserted to hold

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the leaves in place and both boxes were then connected to the air plenum. Air pressure in the plenum was adjusted by means of a damper on the fan inlet, from 130 Pa to 570 Pa (0.5 to 2.3 in. of water) in 63.3 Pa (0.25 in. of water) increments. Airflow readings were recorded for each increment of pressure throughout the pressure range. Boxes were then removed from the plenum, a side removed and a weighed quantity of leaves added to the leaves already present in the boxes to increase the density to 224 kg/m^3 (14 lb/ft^3) for the depth chosen. Airflow readings were again recorded for each increment of pressure throughout the pressure range. This procedure was repeated again after adding a quantity of leaves to the boxes which increased the bulk density to 256 kg/m^3 (16 lb/ft^3). This entire procedure was then repeated for the remaining bed depth.

Airflow rate was expressed as a superficial velocity by dividing the flow volume in m^3/s (ft^3/s) by the cross-sectional area of the box. Pressure was expressed as Pascals per unit of bed depth. The following equation was used to describe the data from each density:

$$V = a P^b \quad (1)$$

where
V = superficial velocity, m/s (ft/sec),
P = pressure gradient, pascals/m (in. of water/ft) and,
a,b = regression coefficients.

Constants a and b were determined by taking the log of both sides of equation 1 and using the method of least squares to fit the linearized form of the equation to the data.

Results and Discussion

No trends in the slope b with density were evident (Table 1). The unity intercept "a" decreased with increasing density in English units but showed no trend in metric units. This came about because pressure drop was less than unity in English units and greater than unity in metric units. The most troublesome aspect shown in figure 1 is the variability in the data. There were two replications and two depths which when the pressure drop was divided by depth resulted in four replications. When equation 1 was fitted to each individual replication (Table 2), an r^2 of no less than 0.94 was found; however, the individual slope, b, varied between 0.656 and 1.043. The dashed lines in figure 1 show the range of velocity between which 95% of the data would be expected to fall. Apparently, packing of the leaves in the boxes was a task that cannot be performed with great consistency between replications. However, this inconsistency of packing should reflect what would occur in the field and is therefore an important design consideration. Much of the variation in the data may have been caused by shunting of the air along the edges of the bulk. A baffle has been shown by Suggs et al. (1989) to be an effective means of reducing shunting.

A comparison of our data (fig. 1) with the superficial velocity as a function of pressure gradient for flue-cured tobacco as given by Suggs et al. (1985) showed a slightly higher velocity for burley tobacco at 192 kg/m^3 (12 lb/ft^3) than for flue-cured tobacco at 183 kg/m^3 (11.4 lb/ft^3), figure 1. Since both studies showed that airflow decreased with increasing bulk density, reducing the bulk density of

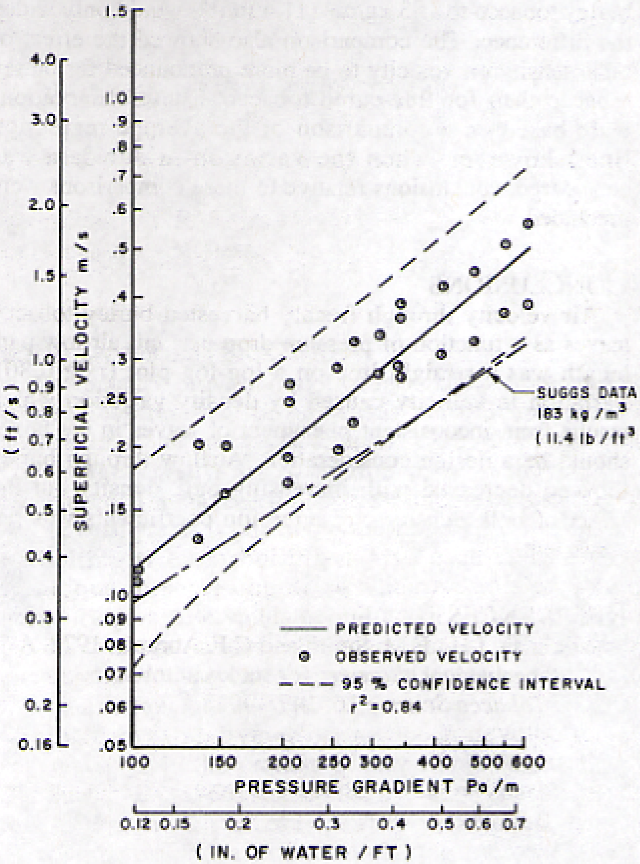

Figure 1–Observed and predicted velocity as a function of pressure gradient at 192 kg/m^3 (12 lb/ ft^3).

TABLE 1. Regression coefficient and r^2 values from equation 1 as a function of bulk density

Bulk density kg/m^3	(lb/ft^3)	Slope b	Unity intercept a m/s	(ft/s)	r^2
192	(12)	0.773	0.00345	(2.02)	0.84
224	(14)	0.694	0.00376	(1.29)	0.87
256	(16)	0.807	0.00149	(1.09)	0.80

TABLE 2. Regression coefficients and r^2 values from equation 1 for individual replications

Bulk density kg/m^3	(lb/ft^3)	Repli-cation	Slope b	Unity intercept a m/s	(ft/s)	r^2
192	(12)	1	0.824	0.00235	(1.93)	0.94
		2	0.973	0.00132	(2.95)	0.97
		3	0.748	0.00332	(1.64)	0.98
		4	0.656	0.00822	(2.19)	0.99
224	(14)	1	0.894	0.00123	(1.62)	0.99
		2	0.772	0.00308	(1.79)	1.00
		3	0.755	0.00263	(1.36)	0.99
		4	0.738	0.00258	(1.19)	0.95
256	(16)	1	1.043	0.00037	(1.32)	1.00
		2	0.799	0.00210	(1.46)	0.97
		3	0.892	0.00074	(0.96)	0.98
		4	0.852	0.00129	(1.28)	0.98

burley tobacco to 183 kg/m^3 (11.4 lb/ft^3) would only widen the difference. The comparison also showed the effect of bulk density on velocity to be more pronounced for burley tobacco than for flue-cured tobacco. These observations were based on a comparison of the average regression lines, however, when the variation in our data was considered, conclusions relative to these comparisons were precluded.

Conclusions

Air velocity through freshly harvested burley tobacco leaves as a function of pressure drop per unit airflow path length was a straight line on a log-log plot ($r^2 \geq 0.80$). Variation in velocity caused by density variation which results from inconsistent placement of leaves in the boxes should be a design consideration. Airflow through burley tobacco decreased with increasing bulk density but the effect of bulk density on regression coefficients was not consistent.

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