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Research Article

MODELLING OF AIRFLOW RESISTANCE FOR POTATO TUBERS

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Abstract: Experiments were done to determine the air flow resistance of potato bulk of bed depth ranging from 0.1 to 0.6 m using air at a velocity range of 2 to 12 m/s. Potatoes of 3 different sizes namely small, mixed and were used in the study. The observed data was modelled to get the relationship of air flow to pressure drop and to determine the effect of bed depth and size of potato tubers on air flow resistance. Among the models tested, the cubic model showed best fit for air flow resistance with R2 value of 0.99 followed by quadratic and linear model with R2 value of 0.98 and 0.92 respectively. The depth of the bulk significantly altered the air flow resistance ($p<0.01$) which was maximum at a depth of 0.6 m. Smaller sized potatoes resulted in air flow resistance which was significantly different ($p<0.05$) from the rest.

Keywords: *Air flow resistance, Velocity, Pressure drop, Bed depth and potatoes*

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Introduction

India is a major producer of potato which ranks after China, Russia, Ukraine and Poland. In Tamil Nadu, potato is grown in an area of 6.44 thousand hectares with an annual production of 130.6 thousand metric tonnes and the productivity is 21.40 tonnes/ha. The harvested potatoes can be stored for four to five months and estimated that the annual loss during storage is approximately 10% [1]. Storage losses are due to transpiration, respiration, sprouting, changes in biochemical composition, damage by extreme temperatures and microbial growth [2]. To minimize the loss of quality and quantity during storage, good storage practices should be adopted. Ventilated storage is most suitable to the root crops to extend the shelf life with minimal losses. In ventilated storage, the heat developed due to respiration of potato tubers during storage, will be removed by supplying the fresh air. Harvested potatoes must be stored and properly ventilated for subsequent processing. Hot spots and other related damages will occur if the bulk piles of potatoes are not ventilated. It is necessary to distribute airflow for uniform heat transfer. Airflow resistance data is required to enable the prediction of airflow uniformity within ventilated potatoes and to determine the fan power requirements. Uniformity of airflow distribution in a bulk of potatoes may be influenced by the size and shape of tubers, variation in directional resistance determined by the duct shape and piling method and amount of soil and dirt adhering. The hot spots tend to develop at locations where airflow is restricted. The soil and foreign matter on the roots during storage is an important factor for the occurrence of hot spots[3].
Hence a study was conducted to determine the air flow resistance of potatoes as affected by size, bed depth and air velocity. The experimental data was fitted to models and the best model was identified. The effects of size of tuber and bed depth on air flow resistance were determined.

Materials and Method

Physical properties

Bulk density

It was determined by filling the potato tubers in a cubical container of a known volume and the content were weighed. The ratio between mass and volume was calculated as bulk density. The experiment was replicated three times by emptying and filling with new samples each time. The average value of bulk density was reported. The bulk density was calculated using following equation [4].

$$\rho_b = M/V \qquad (1)$$

where, ρ_b- Bulk density (kg/m3), M-Mass of the sample (kg), V-Volume of the container(m^3)

True density

It was determined by finding the individual volume of potato tubers using water displacement method and individual mass of the potato tubers was found using electronic weighing machine [4].

$$\rho_t = M/V \qquad (2)$$

where, ρ_t- true density (kg/m^3), M- mass of the sample (kg), V-individual volume of the potato, m^3

Porosity

Porosity is the percentage volume of voids or pore space to the total volume of bulk potato expressed in percent of whole mass. Porosity of a biological material can be calculated using the bulk and true density as given by [4].

$$\varepsilon = 1 - \rho_b/\rho_t \times 100 \qquad (3)$$

where, ε =Porosity, per cent, ρ_b= Bulk density, kg/m^3, ρ_t= True density, kg/m^3

Airflow Resistance Analysis

The Kurfi Jyoti potatoes were used to study the air flow resistance of potato bulk with different depths (0.10,0.20,0.30,0.40,0.50 &0.60 m) and with different air velocity (2,4,6,8,10,12 m/s). Potatoes of 3 different sizes namely small, mixed and big were taken for the experiment. The experiments were conducted in triplicate and analyzed using Analysis of Variance (ANOVA) followed by Least Significant Difference (LSD) Test using the AGRESS software version 7.01. The Factorial Completely Randomized Design (FCRD) was followed for the ANOVA estimation.

Experimental setup

The system designed to determine the pressure drop consists of components like blower, plenum chamber, reducer and bin [Fig-1]. The bin was made of a transparent acrylic cylinder of length 0.63m, internal diameter 0.192 m and thickness 4 mm. A stainless-steel plate with fine perforations was provided at the bottom of bin to support the potatoes and allows the air to pass through the potato tubers. To measure the pressure, drop, copper nozzle was provided at every 0.10 m interval, up to a height of 0.60 m. The nozzle was extended to 5 cm from the inside wall to avoid wall effect on pressure measurement. The pressure readings were measured by using a digital manometer (MODEL: EQUINOX, EQ8890A). The bed depth of 0.60 m was made sufficiently deep in order to give large pressure drops necessary for the determination of low airflow rate. Velocity was varied using the gate valve and measured using anemometer.

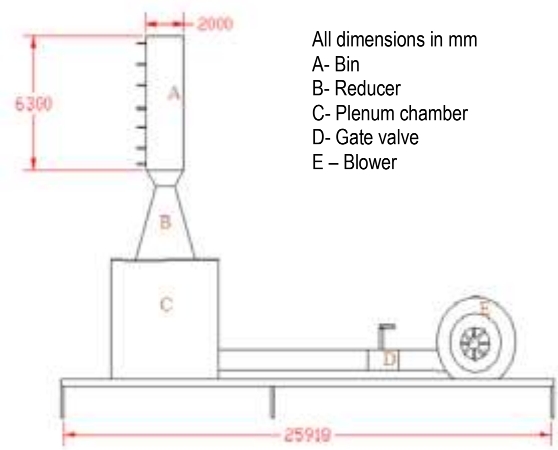

Fig-1 Schematic diagram of airflow resistance study

Results and Discussion

Physical Properties

The physical properties were found at a specific tuber moisture level (81.9%, w.b.) and the results were given in the [Table-1]. Similar results were reported by [5] regarding physical properties of potatoes namely bulk density, true density and porosity values as 680 kg/m^3, 1060 kg/m3 and 35.64 % respectively.

Table-1 *Physical Properties of Potato*

S	Physical properties	Minimum	Maximum	Mean	SD
1	Mass(g)	46	308.21	148.21	58.19
2	Bulk density(kg/m^3)	614	719	600	28
3	True density(kg/m^3)	1000	1090	1020	15
4	Porosity (%)	30	43	33.28	4.82

Modelling of air flow resistance analysis

Air flow resistance was determined with respect to pressure drop and velocity. The results were fitted to the model using SPSS software 15.0 version. The results are presented in [Table-2] and [Fig-2].

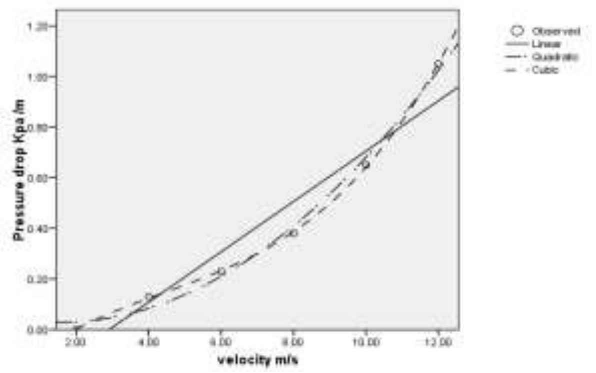

Fig-2 Modelling of air flow with respect to pressure drop

Table-2 *Modelling of Air flow Resistance*

S	Model	Equations	R^2	Adjusted R^2	ESE
1	Linear	$\Delta P/L= 0.99X-.289$	0.926	0.908	0.117
2	Quadratic	$\Delta P/L=0.027X+0.009X^2+0.49$	0.982	0.957	0.044
3	Cubic	$\Delta P/L= 0.121X-0.015 X^2+.001X^3$	0.992	0.996	0.01

Three models were fitted to the data among which cubic model showed best fit with higher R^2 value of 0.992. The other two models namely quadratic and linear had a R^2 value of 0.98 and 0.92 respectively. As the velocity increases the pressure drop also increases. Similar trends were reported by [6] for oranges, [7] for bulk piles of sweet potatoes, [8] for bell peppers and [9] for sugar beets respectively.

Effects of beds depth on airflow resistance

Effect of bed depth on air flow resistance was found and presented in [Fig-3]. At a depth of 0.3m, the pressure drop was 0.04kPa at an air velocity of4m/s whereas for the same velocity at 0.5m bed depth, the pressure drop was found to be 0.08 kPa. It can be concluded that the pressure drops increased significantly ($p<0.01$) with increase of bed depth. Similar results were reported by [10] for potatoes, [11] for sesame seeds and [12] for canola.

Effects of potato size on airflow resistance

Size of the potato had a greater influence in air flow resistance as shown in the [Fig-4]. Pressure drop significantly increased ($p<0.05$) for the small sized potatoes when compared to mixed (both small and big size tubers) and big tubers at a constant airflow rate. The pressure drop at a depth of 0.6 m for an airflow rate of 12 m/s was highest at 0.76 kPa/m for small potatoes and the pressure drop was measured to be 0.61 and 0.46 kPa/m for mixed and big size potatoes respectively. This was due to the high density of small potatoes compared to other sizes. It is also evident from the values of bulk density and porosity. Higher density and consequently lower porosity contributed to higher pressure drop for small potatoes. Similar results were reported [13], [10] for potatoes and [9] for sugar beets.

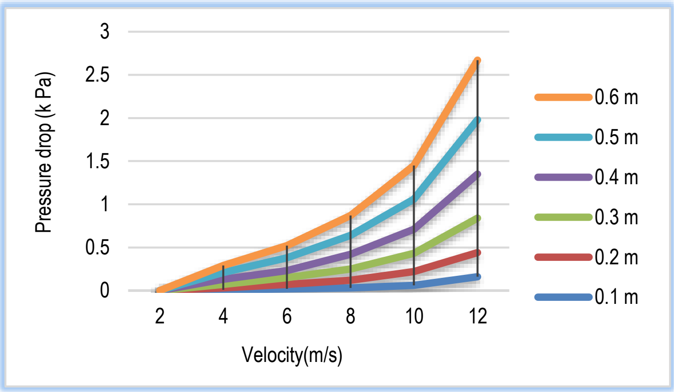

Fig-3 Effect of potato bed depth on air flow resistance

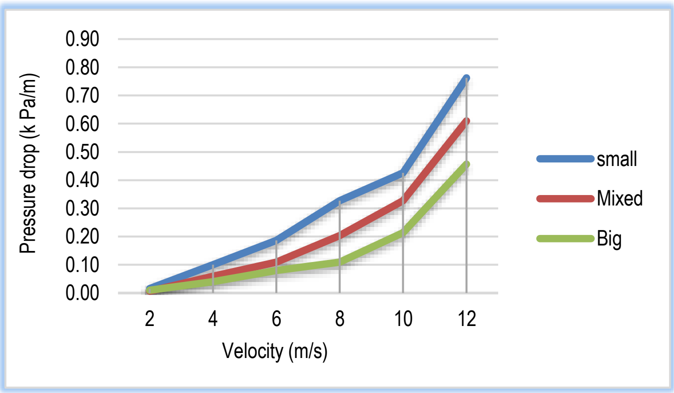

Fig-4 Effect of potato size on pressure drop

Conclusion

From the study it was concluded that the cubic model ($\Delta P/L= 0.121X-0.015 X^2+.001X^3$) was found to give the best fit with R2 value of 0.99 with respect to the relationship between air flow and pressure drop. The air flow resistance was found to be higher (0.76 kPa/m) for larger (0.6 m) bed depth of potato. Small size potatoes showed 1.2 times higher airflow resistance than big size potato, whereas big size potatoes showed lower air flow resistance.

Application of research: Air flow resistance is an important factor in ventilated storage and it also decides the blower power requirement. Hence the study helps to understand the relationship between the pressure drop and velocity.

Research Category: Food Process Engineering

Abbreviations: kg/m^3 -Kilogram per cubic meter, m/s- meter per second, w.b.- wet basis, kPa/m- kilo Pascal per meter, g- gram, %- Percentage.

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Study area / Sample Collection: Local farmers, Ooty

Variety name: Kufri Jyoti

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

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