Airflow Resistance Modeling Through the White Garlic Pile

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Abstract
It is necessary for long term storage of garlic bulbs to reduce the moisture content from 64% to 56% and ventilation of bulbs during the storing time seems essential. Knowledge of garlic bulbs resistance to airflow is one of the basic parameters in designing drying and aeration systems and also for uniform distribution of air between the stored bulbs. In this research, the static pressure drop in Hamedan's white garlic was measured by a device consisting of an air compressor, a rotameter, a cylindrical bin, and a U-type manometer, and their regression relations with some parameters such as airflow velocity, percentage of impurity and moisture content of bulbs were defined in the form of Shedd's mathematical model . The results showed that in the fixed depth, by increasing air flow velocity from 0.085 to 0.53 m/s, the static pressure drop was increased 25 times with a decremental slope. By adding each 2% impurities to white garlic piles, the static pressure drop increased about 1.23 times. Reduction in moisture content of white garlic bulbs caused that static pressure drop to become 1.05 to 1.31 times. The least and most gradients in static pressure reduction occurred in 62% and 56% moisture content, respectively.
***Keywords*: Airflow Resistance, Garlic, Physical Properties, Pressure Drop.**

Introduction

Different studies have emphasized the early harvesting of garlic, drying process and then aeration during their storage time, but the uniformity of airflow distribution is not discussed in any of them (Hassah, 2002; Boettcher and Guenther, 1994; Iordachescu and Mihailescu, 1979). When air is forced through a bulk crop, it must pass through the existing narrow routes between individual small particles. The friction between the air and particles along the way causes a resistance to airflow. To predict the type of airflow distribution inside the aerated pile and to determine the required power of the ventilator to produce the necessary air pressure to overcome the existing resistance and friction, it is essential to know about the amount of airflow resistance. In addition to the air flow resistance, other parameters such as size, shape, moisture content of the seeds, and amount of impurities in the crop will influence the airflow distribution pattern within the crop. (Jayas and Muri, 1991).

Study of the resistance to airflow of various agricultural products has been started by Stirniman (1931) and followewded by other researchers (Jayas, 1988; Siebenmorgan and , Jindal, 1987; Segerlind, 1983; Neale and Messer, 1976; Shedd, 1953). For most of the tested products, the relationship between the air pressure drop per unit depth ($\Delta P/L$) and the velocity (V) was presented by Shedd's (1953) equation: $\Delta P / L = A (V)^{B}$ (1)

Where V is the airflow rate per unit area, (m3/s/m2), ΔP is the air pressure drop (Pa) and L is the depth of product (m). A and B are Experimental constants depending on the type of product and the test condition (Anonymous, 1998 and Shedd, 1953).

The first objective of this study was to experimentally measure the resistance to airflow in white garlic as affected by air velocity, the moisture content of garlic bulbs, and the amount of the soil mixed with garlic samples in a weight range common to storage in the west region of Iran. A second one was to develop empirical relationships to predict airflow resistance at different conditions based on the experimental data.

Materials And Methods

Garlic Samples

A bulk of white garlic (Allium sativum) consisted of 17% small bulbs (with a diameter lower than 4.51 cm), 57% medium bulbs (with a diameter between 4.51 to 5.9 cm) and 26% large bulbs (with a diameter higher than 5.9 cm) which is grown in Hamedan province was extensively used.

Physical Properties

For each test, the bulk and Particle density, average diameter, volume and weight, of garlic samples, were determined. The porosity of the pile calculated by the following equation too (Neale and Messer, 1976): Porosity = $(\rho_p - \rho_b)/\rho_p$ (2).

Airflow Resistance Apparatus

The apparatus used to measure static pressure drop is shown in fig.1(Goodarzi, 2004; Tabil and Marsall, 1999; Anonymous .1998; Irvine et al., 1993).

Experimental Procedure

Three replicates of each test condition were made. One replicate consisted of weighing the garlic, filling the bin, and measuring the static pressure under the different states and air velocities from 0.085 to 0.53 (m/s). The container was always filled so that the pressure drop was measured across the 100 cm depth of garlic for all experiments. Ambient temperature during the experiments was 25 $\pm$ 1 °C and its relative humidity was 23 %.

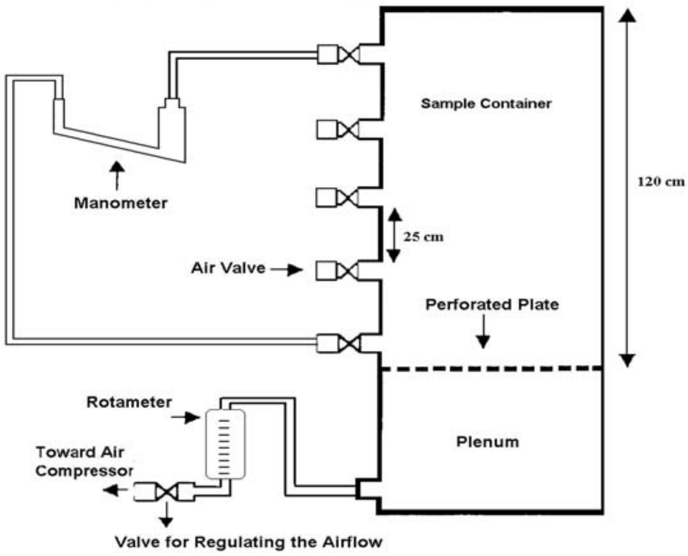

Fig 1. Schema of apparatus used for airflow resistance measurement.

To study the effect of moisture on the air pressure drop, the garlic samples were dried out in a cabinet dryer at 45 °C to reduce their moisture content from 64% (at the harvest time) to required moistures (62, 60 , 58 , or % 56) base on wet basis. It is worthy to mention that the garlic moisture content was reduced to % 56 after keeping in the warehouse for six months. Samples were dried in a cabinet dryer at 100 °C for 24 hours to measure moisture content (Madamba and Buckle, 1993).

External materials including soil, root, and stem of the bulbs were added to the clean garlic samples with the relation of 2, 4, and 6% (w/w) and in ten equal portions. These materials filled in the bin evenly over each 10 cm layer of garlic bulbs.

To study the effect of the product moisture content on the static pressure drop in the air, several experiments on the clean garlic with the moisture of 56 to 64 percent (with % 4 intervals) and with airflow velocities of 0.1225, 0.2449, 0.3674 and 0.4899 m/s were carried out. For processing data, a third order equation was used for defining the relation between percentage of moisture content of the bulbs and the amount of static pressure drop.

Analysis

Base on Segerlind (1983) recommendations, the Shedd's (1953) equation was used to analyze data in this study. The equation 1 was fitted in nonlinear regression procedure of SPSS (Release 11.0.0, Copyright SPSS Inc., 1989-2001) to estimate the A and B constants.

Results And Discussion

The physical properties and resistance to airflow of the white garlic samples are given in table 1 along with constants A and B of equation 1. The appropriate R^2 which is achieved for equation 1 indicates suitable fitness of data and is also acceptable for the result of the equation.

Table 1 - Physical properties of white garlic pile

Bulk Density	Porosity	Soil Content	Equation	$\Delta P/L = A(V)^B$		$\Delta P/L(pa/m)$
kg/m3	%	% weight	A	B	R^2	$V = 0.5m^3/s.m^2$
425	50.2	0	442.33	1.7100	0.994	135.199
436	48.8	2	543.23	1.7002	0.998	167.175
445	47.66	4	653.95	1.6830	0.997	203.663
453	46.73	6	770.64	1.6720	0.995	241.857

(Average Diameter = 4.93 cm, Average Moisture Content (wb) = % 64)

The constant B in the equation 1 was determined as equal to 1.68-1.71. Similar results have been conducted on some other vegetable root, sugar beet, and potato by Neale and Messer(1976), Tabil, (1999) and Irvine (1993).

According to the Fig.2, by increasing the airflow velocity from 0.08 to 0.56 (m/s), the static pressure drop of clean garlic samples was increased up to 25.1 times with a descending gradient. At a low rate of air velocity, the air passes through the routes between the garlic bulbs easily and with no strict thumps, then loses less energy but, at higher velocities, there are more severe strikes between the air bits and bulbs, so that the air losses more energy (and then more static pressure) than the preceding one(goodarzi, 2004).

Effect of Soil and Impurity

By adding each 2% (w/w) impurities to garlic samples, the air pressure drop increased about 1.23 times (Fig 2). Similar results have been reported by other researchers(Misener, 1986; Friesen, 1982; Neals and Messer, 1976). The external materials added to the garlic bulbs are more likely to fill the voids between the bulbs and block the airflow paths between them; however, these results may be resulted from the mixed particle sizes changing direction and causing higher winding rather than simply plummeting the porosity and plugging up the flow paths.

Effect of Moisture Content

Resistance to airflow through the clean white garlic piles at different levels of moisture content (64 to 56%) and the air velocity are shown in table 2, along with coefficients(A, B, C and D) of polynomial equation 3 which used to set the data. In this equation, X stands for percentage of the moisture content of samples.

$$\Delta P/L = A(x)^3 + B(x)^2 + C(x) + D \quad (3)$$

According to the results, with decreasing the moisture content of garlic, the static pressure is increased inconsistently. On the other hand , the most upsurges in pressure drop occurred by reducing the moisture from 58 to 56 % (around 1.31 times) and 62 to 60 % (roughly 1.25 times); but, the least increase in resistance to airflow happened when the moisture changed from 64 to 62% (about 1.05 times).

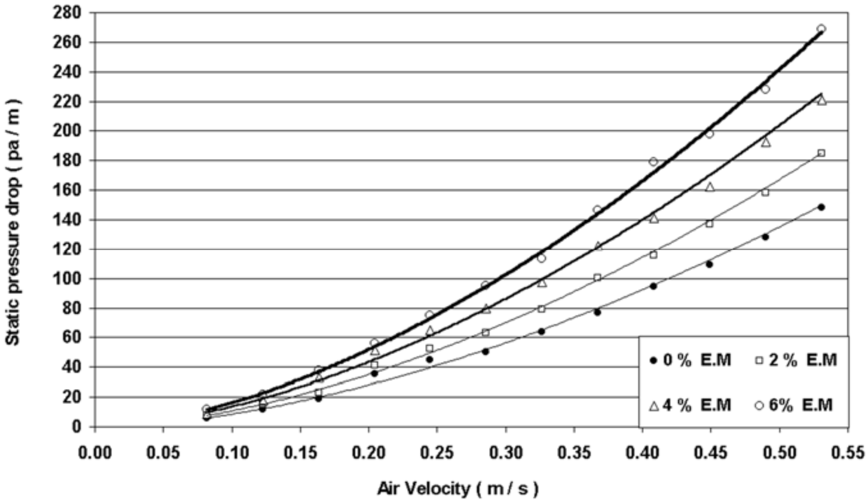

Fig 2.Air flow resistance through the White garlic pile Mixed with different percents of external materials (E.M).

An acceptable theory for interpreting the results is that when garlic has a higher moisture content, its external shell has a smoother surface which is less shrinkage because of filling the tiny pores of the shell with water. By declining the moisture of bulbs, the external shells start shrinking limitedly, but with more reduction in moisture (about 60% and 56%); the external shell dries out harshly and the stability of the shell structure would be broken up. Therefore, severe shrinkage took place. In this situation, the crushed shells cause the airflow path to block out and act somehow as impurity inside the pile(goodarzi, 2004). This causes an abnormal increase in the air pressure drop. Similar results have been reported by Friessen and Huminicki (1982), SokhanSanj (1990) and Rajabipour (2001).

Table 2. Pressure drop (pa/m) in clean white garlic pile at different Levels of Moisture content of bulbs and air velocities.

Air Velocity	Mean of $\Delta P/L$ (pa / m)					Coefficients of Equation :				
	Moisture content (wb)					Ax^3+Bx^2+Cx+D				
(m / s)	0.56	0.58	0.6	0.62	0.64	A	B	C	D	R^2
0.122	23.00	17.50	15.60	12.40	11.62	-12292	23579	15142	3266.7	0.987
0.245	88.00	67.25	59.50	47.50	44.60	-40625	78741	-51092	11140	0.989
0.368	151.30	116.00	103.00	82.65	76.60	-83333	159134	-101761	21867	0.989
0.49	253.80	193.80	172.00	136.55	128.00	-117708	227812	-147634	32157	0.988

Conclusion

The following conclusions were drawn from the present study:

1-Resistance to airflow of white garlic increased by raising the air velocity.

2-By adding each 2% soil and other impurities to the garlic pile, the resistance to airflow through the sample was increased by 1.23 times.

3-When the moisture content of the bulbs is reduced, the pressure drop increased in different rates between 1.05 to 1.31 times.

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