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AERODYNAMIC AND SOLIDS CIRCULATION RATES IN SPOUTED BED DRYING OF CARDAMOM (Part 1)

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Abstract: Two dimensional spouted bed units with flexible bed dimensions were used with draft tubes to study spouting pressure drop and minimum spouting velocity, solids circulation rate and average cycle time. The data were collected while varying slant angle, draft tube height, separation distance and height of bed using cardamom. The variables which affect the spouting pressure drop and airflow through the beds are discussed. Empirical correlations were developed following the principles of dimensional analysis and similitude. The developed correlations were in accordance with the collected data. The article has been divided into two parts where the first part includes the analysis for spouting pressure drop and minimum spouting velocity and the second parts includes the solids circulation rate and average cycle time.

Key words: *Spouting pressure drop, minimum spouting velocity, solids circulation rate, average cycle time, dimensional analysis, Elettaria cardamomum, Conical-Cylindrical Spouted Bed (CSB), curing chambers, rectangular orifices*

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INTRODUCTION

Drying is one of the most important processes as it affects the quality of the final product. Cardamom commonly known as the ‘queen of spices’ is a valuable spice obtained from the seeds of *Elettaria cardamomum*. It is grown in the coastal regions of India and several other countries. In order to preserve for longer period of time and also to enhance its aromatic flavor, fresh green cardamom is subjected to drying process. Several drying processes are used for this purpose, most commonly sun drying and cardamom curing chambers; however these traditional techniques have lower efficiency and also negatively affect the quality of the final product [1].

Spouted bed is a dynamic fluid-solid system which has a wide range of applications for processing of heat-sensitive coarse particles, such as grains and cereals [2]. Two-Dimensional Spouted Bed (2DSB) is a modified form of the Conical-Cylindrical Spouted Bed (CSB). It has a rectangular bed cross-section and vertical plane walls. The process of spouting in a 2DSB is the same as that in a conical-cylindrical spouted bed [3]. The spouting air enters the bed through a slot located at the center of the bottom of bed and runs parallel to the length of the bed. The insertion of draft tube above the air entry slot in the bed, parallel to the length, provides two independent down comers, one on each side of the spout. As the draft tube is fixed in the bed for a required separation distance, a rectangular orifice is formed on the side of spout in each down comer [4, 5].

The flow of grains through these orifices should be governed partially by bulk solids flows [6]. The air flowing through the entry slot has to pick the grains coming from the orifice, accelerate and convey them over the separation distance to the top of the bed and overcome air loss through grain voids via the rectangular orifices to the down comers for smooth operation of the bed. Since the spouting fluid has to overcome the forces of inertia, gravity, friction and fluid viscosity, spouting pressure drop occurs during the operation. A systematic cyclic pattern of solids movement are stabilized in a steady state operation [7].

Basically, spouting pressure drop, minimum spouting velocity are some of the major parameters which shape-up the systematic operation of a slotted 2DSB with draft tube and they are very important from the design and scaling point of view [8]. These parameters are being considered for the development of mathematic models based on dimensional analysis and similitude principles for a batch type slotted 2DSB with draft tube [9-11]. The addition of a draft tube has been proven to act as a beneficial constraint which helps in terms of a better definition of both the gas distribution and the solids motion pattern during various processes such as drying [12], coal gasification, combustion, [13, 14] pyrolysis of hydrocarbons [11] and production of pharmaceuticals [15, 16].

Draft tube installed above the air entry slot in a spouted bed leads to better grain circulation, reduced pressure drop, lower air velocity requirements and increased maximum spoutable bed height [17-19], Moreover, Law *et al.* (1986)[20] stated that spouting pressure drop was higher at the minimum superficial velocity than at superficial velocities greater than the minimum spouting velocity. When the draft tube is present in a bed of given dimensions, spouting pressure drop and airflow through the bed vary when either slant angle, spout diameter and separation distance is changed. This happens due to variation of normal distance. Barroso and Massarani (1984)[21] also developed spouting pressure drop and minimum spouting velocity equations for soybeans and rice as a function of separation distance. Since their equations do not fully account for the particle and spouting fluid properties and bed geometry, they cannot be applied with confidence to other bed geometries.

The objective of this research was to investigate the factors influencing the spouting characteristics of spouted bed with draft tube; taking into account grain particle parameters in order to provide a sound basis for the design of commercially viable units.

MATERIAL AND METHODS

Theory and model development: In a two-dimensional spouted bed with draft tube, the air passing through the bed has to accelerate as well as convey the grains coming from the rectangular orifices in the vertical direction for the stable operation of bed. In this situation, the total pressure drop at the bottom of the bed varies with the size of orifice, size of air inlet, height of draft tube, the ratio of solids to air, type of solids to be spouted, fluid properties and other bed geometry. For a given bed geometry, the spouting air flow through the bed varies with slant angle, draft tube height, normal distance, width of bed, length of bed, height of bed, particle properties and fluid properties.

Since the system of spouting in this configuration is very complex in comparison to conventional CSBs, a dimensional analysis scheme was employed. The relevant variables for 2DSB dynamics (i.e., spouting pressure drop, minimum spouting velocity, solids circulation rate and average cycle time) are listed in Tab. 1 with the following assumptions:

- Bulk solids consist of particles which are small in comparison to the bed dimensions that they can be considered to be a continuous mass.
- Bulk solids have the same mechanical properties in any direction inside the bed.
- The rate of flow of grains through the orifice is independent of bed height because normal distance is always less than the bed height.
- Frictional forces between particles in down comers and the column walls are negligible compared to other forces.
- Grains are uniform in shape and free flowing.
- The void fraction in the down comer is uniform and is approximately equal to that of a loose packed bed.
- The particles move through the down comers in a plug flow manner.
- Grains are linearly distributed over the entrainment zone and are picked up by air uniformly.
- Solids velocity in the down comer is much lower than fluid velocity and may therefore be neglected.
- Air compressibility is neglected due to the relatively low pressures involved.
- Resistance to air flows through the down comers are higher than in the spout.
- The effects produced by broken seeds, foreign materials and bed shrinkage are not incorporated in the mathematical model.

It should be noted that all the variables in Tab. 1. constitute a unique set. They were chosen because they appeared convenient for the experimental and analytical phases of study.

Table 1. The pertinent variables for the mathematical modeling of fluid and particle dynamics in the 2DSB with draft tube

Symbol	Variable	Unit
P_s	Spouting pressure drop	Pa
U_f	Minimum spouting velocity	$m\cdot s^{-1}$
ρ_ϕ	Dry air density	$kg\cdot m^{-3}$
μ	Absolute viscosity	$kg\cdot m^{-1}s^{-1}$
g	Acceleration due to gravity	$m\cdot s^{-2}$
V_p	Average particle velocity	$m\cdot s^{-1}$
Q_p	Volumetric flow rate of grains	$m^3\cdot s^{-1}$
S_p	Solids circulation rate	$kg\cdot s^{-1}$
M_p	Mass of grains in the spouted bed	kg
t_c	Average cycle time	s
d_p	Geometric diameter of particle	m
ϕ	Sphericity	--
ρ_β	Bulk density of grains	$kg\cdot m^{-3}$
ρ_π	Particle density of grains	$kg\cdot m^{-3}$
E_v	Bed voidage	---
W_b	Width of spouted bed	m
W_d	Width of a down-comer of spouted bed	m
L_b	Length of spouted bed	m
H_b	Depth of grains in spouted bed	m
H_t	Height of draft tube	m
D_i	Diameter of air entry slot	m
θ_σ	Slant angle	--
D_s	Diameter of draft tube or spout	m
W_o	Normal distance	m

Table 2. Repeating variables for the mathematical models and variables representing mass, length and time

Symbol	P_s	U_f	S_p	t_c	
ρ_ϕ	-	+	+	-	
g	+	+	+	-	
S_p	-	-	-	+	
M_p	-	-	-	+	
d_p	-	+	-	+	
ρ_π	+	-	-	-	
H_t	+	-	-	-	
W_o	-	-	+	+	
	L	H_t	d_p	W_o	d_p
	M	$\rho_\pi H_\tau^3$	$\rho_\phi \delta_\pi^3$	$\rho_\phi \Omega o^3$	M_p
	T	$(H_t/g)^{1/2}$	$(d_p/g)^{1/2}$	$(W_o/g)^{1/2}$	S_p/M_p

+ = Variable in the theoretical model,
- = Variable not in the theoretical model

Buckingham (1914) [22] stated that if there is a dimensionally homogeneous equation relating '*n*' quantities defined in terms of '*r*' reference dimensions, then the equation may be reduced to a relationship between (*n*-*r*) independent Dimensionless

Products (DPs or PI) provided that the members of the reference set be themselves chosen so as to be independent of one another. Hence, the fundamental basis for Buckingham's PI theorem is that a valid physical equation must be dimensionless, or to reduce to like dimensions on both sides of the equality sign. Tab. 2 reveals that there can be three reference dimensions of MLT selected on the basis of ease of use, influence, independence from one another and literature data on spouted beds and granular flow through orifices. In view of this, the selected repeating variables for spouting pressure drop, minimum spouting velocity are given in Tab. 2 along with the variables representing the MLT reference dimensions.

Spouting pressure drop theory indicates that the airflow through the bed is not fixed constants but are functions of other variables. For a given bed geometry, the spouting air flow through the bed varies with slant angle, normal distance, width of bed, length of bed, height of bed, height of draft tube, particle properties and fluid properties. The variables that are important for the analysis of air and solids dynamics were selected. A list of variables for the mathematical modeling of 2DSBs with draft tube is given in Table 1. It should be noted that not all of these variables are necessarily important for each operational phase of spouted beds.

The normal distance (W_o) of the orifice was calculated from relationship of separation distance (H_E) and slant angle (θ_s): $W_o = H_E \cos\theta_s$

Spouting pressure drop: In the dimensional matrix, let the first variable be the dependent variable, let the second variable be that which is easiest to regulate experimentally [23]. Let the third variable be that which is next easiest to regulate experimentally and so on. In this way, the pertinent variables proposed in Tab. 1 for the modeling of spouting pressure drop were arranged and then reproduced.

$$F\,(P_s,\ U_f,\ \rho_f,\ \mu,\ g,\ Q_p,\ d_p,\ \rho_p,\ \phi,\ E_v,\ W_o, D_s,\ \theta_s,\ L_b,\ H_b,\ W_i,\ D_i,\ W_b,\ H_t)=0 \tag{1}$$

Taking the independent variables from Eq. 1 and using the repeating variables for the MLT reference dimensions given in Tab. 2, the following dimensionless *PI* numbers were generated for the *Ps* in Eq. 2:

$$\begin{gathered}F\,[P_s/g\rho_p H_t,\ U_f^2/gH_t,\ \mu^2/g\rho_f 2d_p^3, Q_p/Q_f,\ d_p/H_t,\ \rho_p\text{-}\rho_f/\rho_f, \phi,\ E_v,\ W_o/H_t,\ D_s/H_t,\\ \theta_s,\ L_b/H_t,\ H_b/H_t,,\ W_b/H_t,\ D_s/D_i]=0\end{gathered} \tag{2}$$

The dimensional numbers can be transformed in to some well known dimensionless numbers in order to simplify the relationship for spouting pressure drop. The number of dimensionless terms should however remain the same after transformation; otherwise, the new products do not form a complete set. The transformed numbers which were used in the analysis of data for establishing the following relation for spouting pressure drop are shown:

$$\begin{gathered}F[P_s/g\rho_p H_t, Fr, Ar, Q_p/Q_f,\ d_p/H_t,\ \rho_p\text{-}\rho_f/\rho_f,\ \phi,\ E_v,\ W_o/H_t,\ D_s/d_p,\ \theta_s,\ L_b/W_o,\\ H_b/H_t, W_b/W_o,\ D_s/D_i]=0\end{gathered} \tag{3}$$

where, *Fr* and *Ar* are Froude number and Archimedes number, respectively.

Minimum spouting velocity: However, this is not a unique set, since other groups of fifteen independent products could be formed from the *PI* numbers given in Eq. 3 by multiplication or division. It should be noted that this procedure of theoretical development of spouting pressure drop was also applied to the minimum spouting velocity regardless of number of pertinent variables and the following dimensionless numbers were obtained:

$$F\,[U_f^2/gd_p,\ \mu^2/g\rho_f^2 d_p^3,\ \rho_p\text{-}\rho_f/\rho_f,\phi,\ E_v,\ W_o/d_p,\ D_s/d_p,\ \theta_s,\ H_b/d_p,\ L_b/d_p,\ W_b/d_p,\ H_t/d_p]=0 \qquad (4)$$

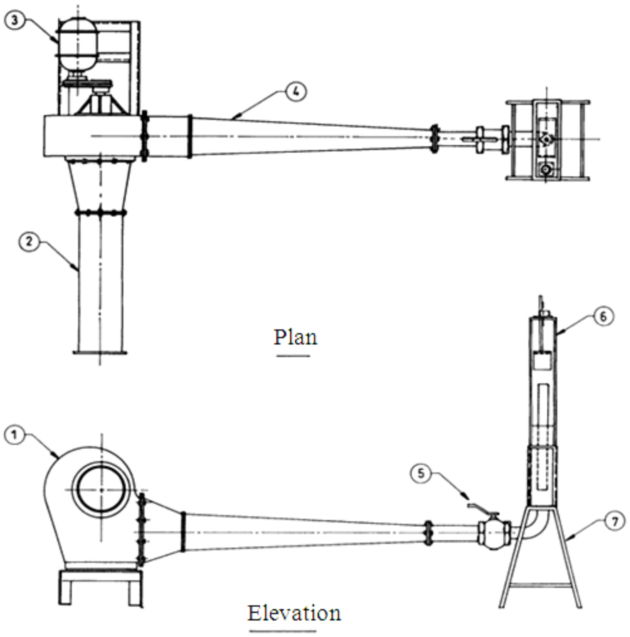
The dimensionless products of Eq. 4 were transformed into the following dimensionless products for establishing the relation for superficial spouting velocity through the spouted bed at the minimum spouting conditions:

$$F\,[Ar,\ \rho_p\text{-}\rho_f/\rho_f,\ \phi,\ E_v,\ W_o/L_b,\ D_s/W_o,\ \theta_s,\ W_b/H_t,\ d_p/W_i,\ W_b/W_o,\ H_t/H_b]=0 \qquad (5)$$

Experimental methods and procedures: The spouted bed drier used for the study (Fig. 1) consists of a motor-blower assembly, heating chamber, hot air delivery duct, temperature controller, plenum chamber and spouted bed chamber. The equipment was fitted with an energy meter. The motor-blower assembly is built-in type, run by three phase electric supply and has provision to adjust the airflow rate at suction side. The heater is connected to the suction side of the blower, which is made in cylindrical shape, with a heating coil of 2kW capacity connected in series. A temperature controller is provided to control the temperature of the inlet hot air. A ball valve is fitted in between the hot air delivery duct and spouted bed to keep the cardamom capsules at minimum spouting condition by adjusting the airflow rate.

The mechanical design of two-dimensional spouted bed was primarily aimed to permit variation of bed length, bed width, slant angles, air entry slots, separation distance and draft tube height. A rectangular frame with four support legs was made from angle iron and it was made in such a way to accommodate the spouted bed-drying chamber. The drying chamber was made of 0.01m thick plexiglass to visualize the material flow pattern. The sides of the bed were constructed using plexiglass and reinforced with screws at specified intervals. The width sides of the bed were rigidly fixed. The length sides of the unit can be clamped on the width sides of the bed. The unit can accommodate different slanting on the length sides. The unit was built with 0.50 m width, 0.15 m length and 1.2 m height. The unit can handle a maximum capacity of five kilogram of cardamom excluding the fountain portion.

The spout pressure measuring taps were positioned starting at 0.01 m and at intervals of 0.10 m from the bottom of the bed throughout the height. The spout pressure taps were fixed on one width side of the bed. The spouting pressure drop was measured using a U-tube manometer. The down comer pressure measuring taps were installed on the length side of the bed above the slanting base at an interval of 0.10 m. To eliminate potential stagnation zones, the slanting base plates were inclined at 45° and 60°. A parabolic deflector made of metal sheet was mounted above the draft tube to limit the spout height and aid the material circulation by directing the particles from the spout to the down comer. The circular air inlet nozzle was covered with wire mesh, which helped to distribute the air uniformly. Two guide ways were provided on either side of the down comer in order to maintain the cyclic movement of the material and also to obtain uniform dried product. A door-like structure was made on the width side of the bed to feed the material directly into the chamber. A shutter was provided on each side at the bottom of the bed in order to ease the discharge of the material.



1. Blower
2. Heater
3. Motor assembly
4. Got air duct
5. Air flow adjustment value
6. Spouted bed drying chamber
7. Stand

Figure 1. Schematic diagram of spouted bed dryer

The thermocouples were inserted at various points on one side of the bed to measure the down comer temperature. An energy meter was provided to measure the number of units of energy for each experiment. The two sided slanted base inclined at 45° and 60° to the side walls connected to a circular air entry slot which was covered with wire mesh to prevent the cardamom capsules going down. A draft tube was installed centrally above the air entry slot. Thermocouples for recording bed temperature were positioned centrally in both down comers and an additional thermocouple was embedded into the external and internal sides of a down comer wall along the plexiglass to monitor heat losses. Temperatures at all measuring points were recorded by a digital thermometer with an accuracy of ±0.1°C. Air velocity was monitored by a thermal anemometer accurate to ±3 %. Inlet and outlet air humidities were monitored continuously by a Humidity meter with the least count of ±0.1%.

RESULTS AND DISCUSSION

The data on grain aerodynamics from the experiments on slant angle, separation distance, draft tube height, variation of bed height of cardamom were pooled and then used to generate the *PI* terms in the models proposed for spouting pressure drop, minimum spouting velocity. The PI terms were then linearized by the natural logarithm transformation. The data were analyzed by full model regression using the M-STAT. A number of alternative models were created by multiplying or dividing *PI* terms, while maintaining both the independence of these terms and the total number of terms in each original formulation. The models were evaluated using the following criteria: the R^2 statistic, standard error, level of significance (α), residual characteristics and the number of terms in the model. The final selected models describing the dynamic phenomena of two-dimensional spouted bed with draft tube have been presented in the following sub-sections.

Spouting pressure drop: The variation of spouting pressure drop with change in variables is given in Figs. 2 and 3. From the figures it is clear that increased slant angles produced a positive effect on spouting pressure drop in all the spouting conditions. Spouting pressure drop increased from 117-333 Pa with an increase in slant angle from 45-60°. The spouting pressure drop was increased from 225-333 Pa while the slant angle changed from 45-60° under the spouting conditions of 40°C air temperature, 7.5 cm separation distance, 60 cm draft tube height with tempering period of 30 min. Possible cause for this trend may be due to the fact that higher air flow rates were required to keep the material in spouting conditions at 45° slant angle than at 60° slant angle and hence the air velocity at the fountain was also more at 45° than at 60° slant angle.

The effect of separation distance on the spouting drop associated with spouted bed drying of cardamom has been shown in Figs. 2 and 3. The data shows that the spouting pressure drop increased with separation distance and the similar effects were reported for small scale CSB's [19] for two dimensional spouted beds [2, 20]. This increase in spouting pressure may be attributed to the higher number of cardamom capsules entering the spout and at the same time spouting air pushing the grains towards the down comer sides to keep the spout open. In these experiments, the highest-pressure drop of 333 Pa was produced when the separation distance was increased from 5-7.5 cm.

The spouting pressure drop data collected in this study indicated that the spouting pressure drop increased as the draft tube height increased from 40-60 cm (Figs. 2 and 3). This increase in spouting pressure drop might be due to dissipation of energy from the air, which is more when the draft tube height is increased. It may be concluded that the spouting pressure drop at the minimum spouting conditions was most affected by separation distance followed by slant angle.

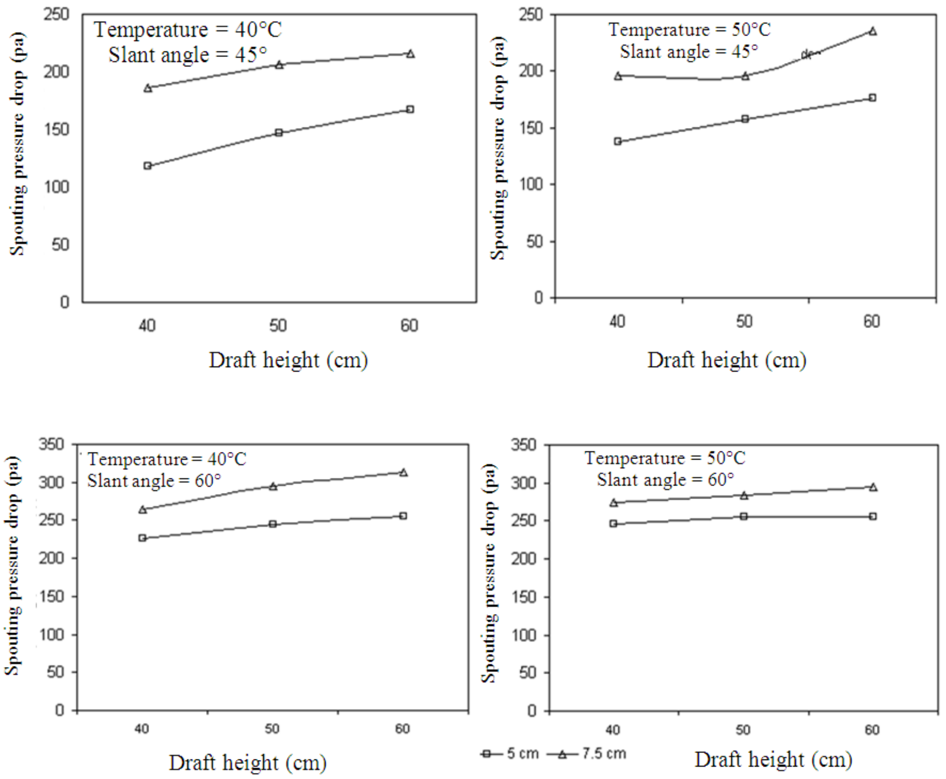
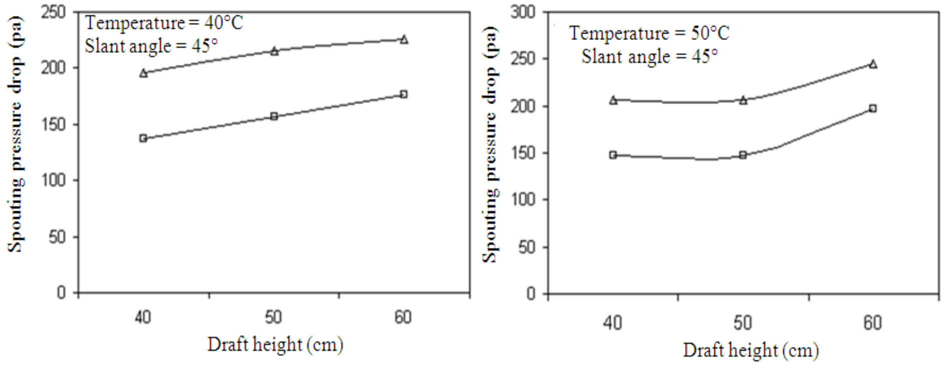


Figure 2. Effect of draft height (H_d) on spouting pressure drop at indicated separation distances for cardamom



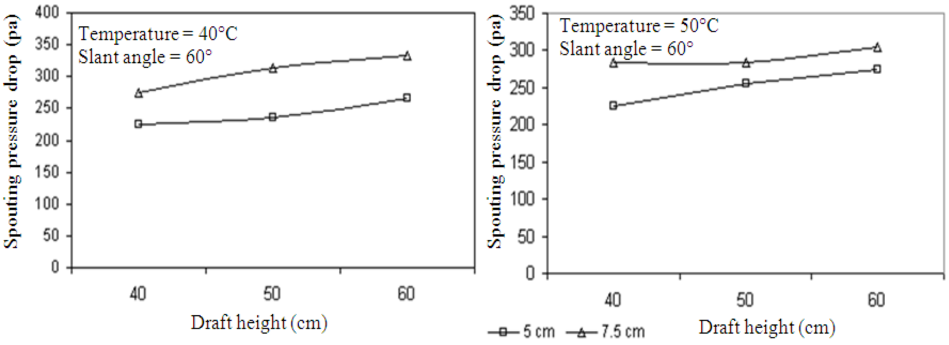


Figure 3. Effect of draft height (H_t) on spouting pressure drop at indicated separation distances with tempering period for 30 min for cardamom

The model developed for the spouting pressure drop is Eq. 6:

$$P_{s} / g P_p H_t = (U_f^2/g H_t)^{-0.4512} (d_p/H_t)^{0.1595} (W_o/H_t)^{0.501} (H_b W_b/H_t W_o)^{0.0019} (\theta_s)^{1.56} \tag{6}$$

The model has $R^2 = 93.44\%$, standard error of estimate =0.0274, $\alpha = 0.0001$. The residuals exhibited a random distribution when plotted against predicted values of spouting pressure drop (Fig. 4b). A plot of observed versus predicted values for the selected model of spouting pressure drop has been shown in Fig. 4a. The estimates from the model deviated, on average, by ±2% from the collected data.

Minimum spouting velocity: The airflow monitored in the air supply conduit during the studies was divided by the cross-sectional area of the spouted bed to get the superficial velocity. Some superficial velocity data through two-dimensional spouted bed have been presented in Fig. 5 and 6. From these data, it could be inferred that the superficial velocity through beds increased as the separation distance increased from 5-7.5 cm. Similar results have been reported by Buchanan and Wilson (1965)[17] and Claflin and Fane (2009)[19] for Conical-cylindrical spouted beds and Law *et al.* (1986)[20] for small scale two dimensional spouted beds and Kalwar and Raghavan (1993)[24] for pilot scale two dimensional spouted beds. This increase of superficial velocity might be due to the combined effects of:

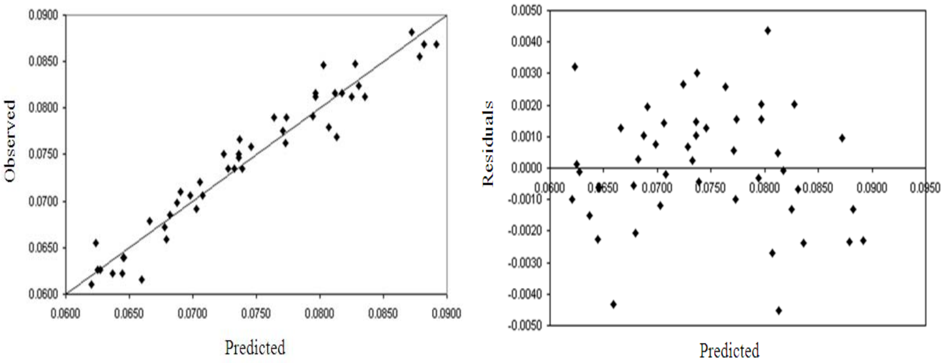
1. large number of grains entering the spout,
2. more jet air being dispersed into the down comer at larger separation distances, and
3. physical characteristics of grains leading to higher air flow rates through the spouted beds.

The superficial velocity of air through the beds also increased as the draft tube height increased from 40-60 cm for all the spouting conditions. This increase was due to higher cross-sectional area of the spout causing higher airflow requirements for transporting an increased number of capsules through the spout and to preserve stable dynamic conditions. This trend was supported by Law *et al.* (1986)[20] for small scale two dimensional spouted beds with flat bottoms, for rice beds with a slant angle of 45° by Khoe and Brakel (1983) [8] and for wheat beds with a slant angle of 60° in a conical-cylindrical spouted beds geometry by Claflin and Fane (2009)[19].

Figures 5 and 6 show the differences in superficial velocity due to slant angles. The required airflow rates were higher at a slant angle of 45° than at 60° under the same separation distance and draft tube height. The result was supported by the findings of Thorley *et al*. (1959) [25] for Conical-cylindrical spouted beds when slant angle was changed from 45-60°. It was concluded that the superficial velocity through two-dimensional spouted beds increased with separation distance and draft tube height. However, the superficial velocity decreased when the slant angle was shifted from 45°-60° for cardamom used in this study.

The mathematical model obtained from the superficial air velocity through the bed has been given below:

$$U_f/(gH_t)^{0.5} = (P_s/g\rho_p H_t)^{-0.2339} (d_p/H_t)^{0.3606} (W_o/H_t)^{0.0821} (H_b W_b/H_t W_o)^{0.0641} (Q_p/Q_f)^{-0.604} (\Theta_s)^{-0.4802} \quad (7)$$



(a) (b)

Figure 4. (a) Comparison of measured spouting pressure drop with predicted spouting pressure drop by Eq. 6 (b) Residual plot for spouting pressure drop model Eq. 6

The model has R^2 =95.63%, *SE* = 0.0197 and α = 0.0001. The plot of residuals against the predicted values of superficial velocity showed randomness of residuals (Fig. 7a and 7b). Hence, the developed model accounted for most of the variation found in the collected data. Using Eq. 7, the predicted values of superficial velocity were generated and compared with the entire observed values of superficial velocity. This comparison indicated that the Eq. 7 predicted with an average error of ±1.5% from the observed values.

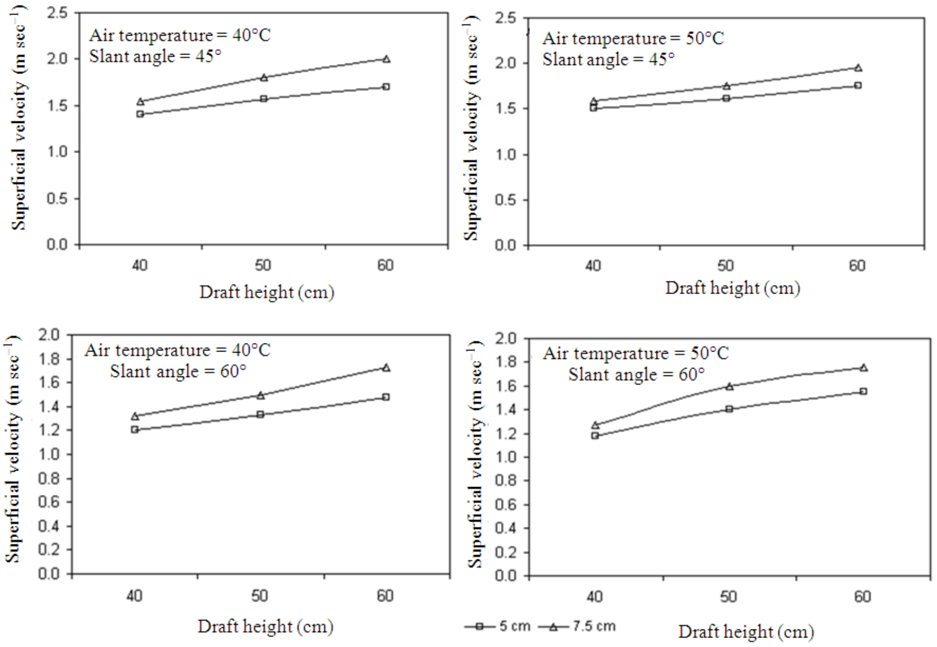


Figure 5. Effect of draft height (H_t) on superficial velocity for cardamom

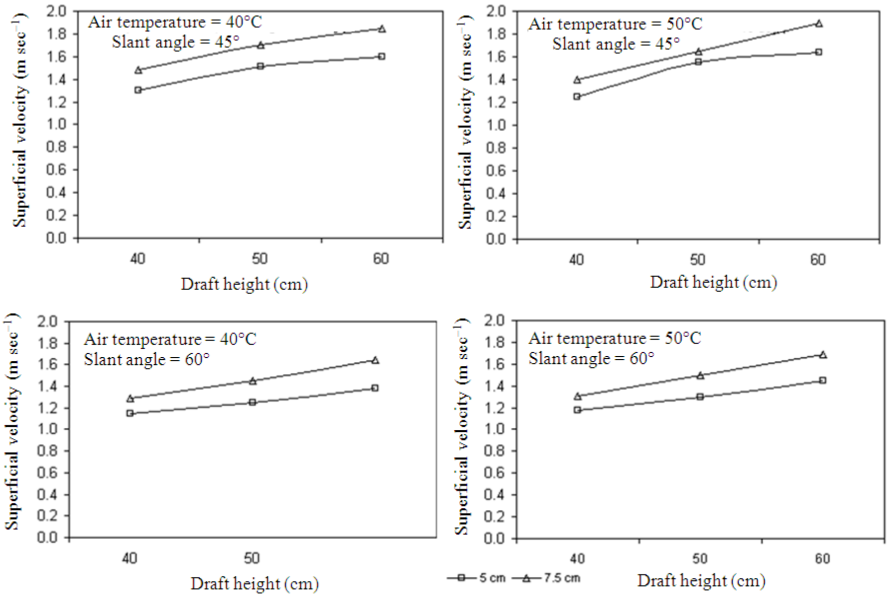
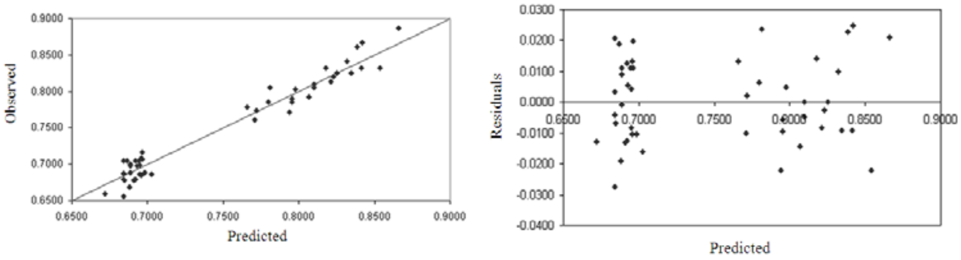


Figure 6. Effect of draft height (H_t) on superficial velocity
with tempering for 30 min for cardamom



(a) (b)

Figure 7. (a) Comparison of measured minimum spouting velocity with predicted minimum spouting velocity by Eq. 7 (b) Residual plot for minimum spouting velocity model, Eq. 7

CONCLUSIONS

Spouting pressure drop increases as the separation distance and slant angle increase. It also increases as the draft tube height increases. Minimum spouting velocity increases as the separation distance and draft tube height increase and as the slant angle decreases. The insertion of draft tube to form a tube in two-dimensional spouted bed proved very effective in controlling pressure drop, air flow and to operate in plug flow manner. Hence, the two-dimensional spouted bed with draft tube can satisfy drying requirements in practice. Empirical correlations are presented for spouting pressure drop and minimum spouting velocity. The comparison of these developed models with the experimental data indicated quite close agreement.

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STEPENI AERODINAMIKE I PROTOKA ČVRSTE MATERIJE U ODVODNIM KANALIMA ZA SUŠENJE KARDAMOMA (1. deo)

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Sažetak: Za proučavanje pada pritiska u odvodnom kanalu, minimalne brzine odvođenja materijala, stepena cirkulacije čvrstog materijala i prosečnog vremena ciklusa korišćene su dvodimenzionalne jedinice odvodnih kanala sa fleksibilnim dimenzijama. Podaci su prikupljani variranjem ugla nagiba, visine pripremnog kanala, rastojanja pri separaciji i visine kanala. Analizirane su veličine koje utiču na pad pritiska u odvodnom kanalu i protok kroz kanal. Razvijene su empirijske zavisnosti korišćenjem simulacije i dimenzione analize. Razvijene zavisnosti su bile u skladu sa prikupljenim podacima. Rad je podeljen u dva dela pri čemu se prvi deo bavi analizom pada pritiska u odvodnom kanalu i minimalnom brzinom odvođenja a drugi deo stepenom protoka čvrste materije i prosečnim vremenom ciklusa.

Ključne reči: *Pad pritiska pri odvodjenju materijala, minimalna brzina odvodjenja, stepen protoka čvrste materije, prosečno vreme ciklusa, dimenziona analiza, Elettaria cardamomum, konično-cilindrični kanal za odvodjenje (CSB), komore za konzervaciju, pravougaoni otvori*

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