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Deep bed peanut drying using Hukill's analysis

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ABSTRACT

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A simple model based on Hukill's Analysis was used in the simulation of deep bed drying of peanuts at various drying conditions. The model was first evaluated using published drying data and then actual drying experiments at different conditions. The results showed that the simulation model could adequately describe the deep bed drying of peanuts.

The effects of bed initial and final moisture contents, drying temperature, air humidity, airflow and bed depth on the drying time and moisture content of various layers within the bed of peanut pods were evaluated using the simulation model.

Drying temperature had the most significant effect on drying time followed by bed initial moisture content, bed final moisture content, air humidity, airflow and bed depth, respectively. As drying temperature, bed final moisture content and airflow increased, the drying time decreased. Conversely, as the bed initial moisture content, air humidity and bed depth increased, the drying time also increased.

The bed final moisture content had the greatest effect on the bottom, middle and top layer moisture of peanut pods among the factors studied. The lower the bed final moisture content, drying temperature, bed initial moisture content, bed depth and air humidity, the lower the moisture difference between the bottom and top layers. Conversely, the lower the airflow, the higher the moisture difference between the bottom and top layers.

Keywords: peanut, deep bed drying, Hukill's Analysis, simulation

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INTRODUCTION

Peanuts contain excess moisture when harvested and unless the pods are rapidly dried to a safe moisture level, seed deterioration through fungal growth and aflatoxin production rapidly occurs. A number of variables can affect deep bed drying of peanuts, which include the pod initial and final moisture contents, air humidity, drying temperature, airflow and bed depth. Drying time and moisture distribution within the bed of peanut pods are in turn affected by the variables mentioned.

A number of papers have been published on deep bed drying of peanuts but there are still some gaps in the available information especially on the effect of air humidity and bed final moisture content on the drying time and moisture distribution of the bed of peanut pods during deep bed drying. The effects of airflow and drying temperatures on the moisture distribution of the bed of peanut pods were also not accounted (Blankenship and Chew, 1979; Troeger, 1989; Parti and Young, 1992; Baker *et al.*, 1993; Chai and Young, 1995). In addition, all the published data mentioned were done in the United States which have different conditions in tropical countries like the Philippines.Conducting actual drying studies on the effects of the different variables mentioned earlier is a very expensive and impractical endeavor. Hence simulation analyses are useful in assessing the effect and importance of these variables in deep bed peanut drying.

Peanuts when freshly dug have moisture content of about 30 to 50% wb (42.8 to 100.0% db) and are allowed to partially dry in windrows to about 20 to 25% wb (25.0 to 33.3% db) (Woodroof, 1983; PCARRD/NAPHIRE, 1991; Sanders, 1995). The peanut pods are dried down to about 10 to 12% wb (11.1 to 13.6% db) to have better shelling quality and safe for storage (PCARRD/NAPHIRE, 1991; Sanders, 1995). In the Philippines, the average ambient conditions are about 86°F (30.0°C) dry bulb temperature, which could give an air humidity of 0.020 lb water/lb dry air (kg water/dry air). The temperature of 95°F (35.0°C) is the maximum recommended temperature for drying of peanuts for minimal shelling damage and better flavor (Baker *et al.*, 1952; Beasley and Dickens, 1963). However, PCARRD/NAPHIRE (1991) have shown that using drying temperatures of up 110°F (43.3°C) will still result in 100% germination and no wrinkling of kernels. Woodroof (1983) recommended that for drying of peanut pods, the airflow should be around 50 to 75 [ft^3/min]/ft^2 (0.25 to 0.38[m^3/s]/m^2).

For peanut drying, the most important part of the simulation procedure is a model for describing the bed drying of peanut pods. A number of models have been proposed to describe the deep bed drying of peanut pods. These include the models of Chinnan and Young (1978), Troeger and Butler(1979) and Parti and Young (1992). These models involve sophisticated computer methods and require considerable computer time. Hukill (1947) first proposed a simple approximate method of describing the deep bed drying grains which can be analyzed using hand-held calculators. By using appropriate data, this model can be used for the analysis of deep bed drying of peanut pods. This paper describes the use of Hukill's Analysis in the simulation of deep bed drying of peanut pods and the evaluation of its adequacy using published data and actual drying experiments at selected conditions.

Hukill's method made use of three dimensionless parameters, namely: a) moisture ratio; b) time factor; and c) depth factor which were derived using the English system (Hukill, 1974; Brooker *et al.*, 1974; Young and Dickens, 1975; Foster, 1982). The moisture ratio (MR) is defined as,

$$MR = \frac{(M-M_e)}{(M_i - M_e)} \qquad \text{-----------------------------(1)}$$

where: M = moisture content of grain at time, t (% wb)
M_e = equilibrium moisture content of grains (% wb)
M_i = initial moisture content of grain (% wb)

Before drying, MR = 1.0, and at equilibrium, MR = 0. The drying time can be expressed in terms of period half response; i.e. one period ($t_{1/2}$) is the time required for fully exposed grain to reach a MR = 0.5 under any given set of conditions. Hence the time factor (Y) can be calculated using,

$$Y = \frac{t_t}{t_{1/2}} \qquad \text{-----------------------------(2)}$$

where t_t = total drying time (h)

The unit depth factor can be defined as the depth which contains enough grain to make the heat requirement for evaporating its moisture, from an initial MR = 1.0 to a final MR = 0, equal to the sensible heat supplied by all air in one unit of time if its temperature is dropped from T_a to T_{wb}. At any level in the bin, the depth factor (D) can be determined using the following equations,

$$DM = \frac{AF \times 60 \times C_a \times (T_a - T_{wb}) \times t_{1/2}}{SV \times H_v ([M_i - M_e]/100)} \quad \text{-----------------(3)}$$

where: DM = amount of dry matter contained in one depth factor per unit area (lb/ft^2)
AF = airflow per unit area ([ft^3/min]/ft^2)
C_a = specific heat of air at T_a (BTU/[lb dry air.)^{0}F])
T_a = dry bulb temperature of drying air (^{0}F)
T_{wb} = wet bulb temperature of the drying air (^{0}F)
$t_{1/2}$ = time to bring the moisture ratio from 1.0 to 0.5 (h)
SV = specific volume of air (ft^3/lb dry air)
H_v = latent heat of vaporization of water at the mean temperature, T_m (BTU/lb water)
T_m = mean temperature of the air = $[T_a + T_{wb}]/2$

$$BD_{DM} = \frac{(100\ BD_{WG} - M_{wb} BD_{WG}}{100} \quad \text{-----------------(4)}$$

where: BD_{DM} = dry matter bulk density of the grain (lb/ft^3)
BD_{WG} = wet grain bulk density (lb/ft^3)
M_{WB} = moisture content of the grain (%wb)

$$D_{UNIT} = \frac{DM}{BD_{DM}} \quad \text{-----------------(5)}$$

$$D_{TOTAL} = \frac{DEPTH_{BED}}{D_{UNIT}} \quad \text{-----------------(6)}$$

where D_{UNIT} = unit depth factor (ft)
$DEPTH_{BED}$ = bed depth (ft)
D_{TOTAL} = total depth factor = 1, 2, 3, ... n

The three parameters can be related using,

$$MR = \frac{2^D}{(2^D + 2^Y - 1)} \quad \text{-----------------(7)}$$

Brooker *et al.* (1974) outlined the procedure using the Hukill's Analysis in obtaining the average moisture content, bed depth, air humidity, drying temperature, airflow and drying time.

In order to use Hukill's Analysis for deep bed drying of peanut pods, appropriate data are needed which include the thermophysical properties of air and water and a number of properties of peanut pods.

The psychrometric properties of air were calculated using the relationships from Brooker *et al.* (1974) and Singh and Heldman (1984). The specific heat of dry air was obtained from Raznjevic (1978) and the latent heat of vaporization of water was obtained from Keenan *et al.* (1969).

The bulk density of peanut pods as a function of initial moisture content was derived from the data of Steele (1974). A generalized Henderson equation for predicting the equilibrium moisture content (EMC) of peanut pods was obtained from Beasley and Dickens (1963). The predictive equations for the period of half response for a given drying temperature and humidity were obtained from the thin-layer drying data for peanut pods of Whitaker and Young (1972).

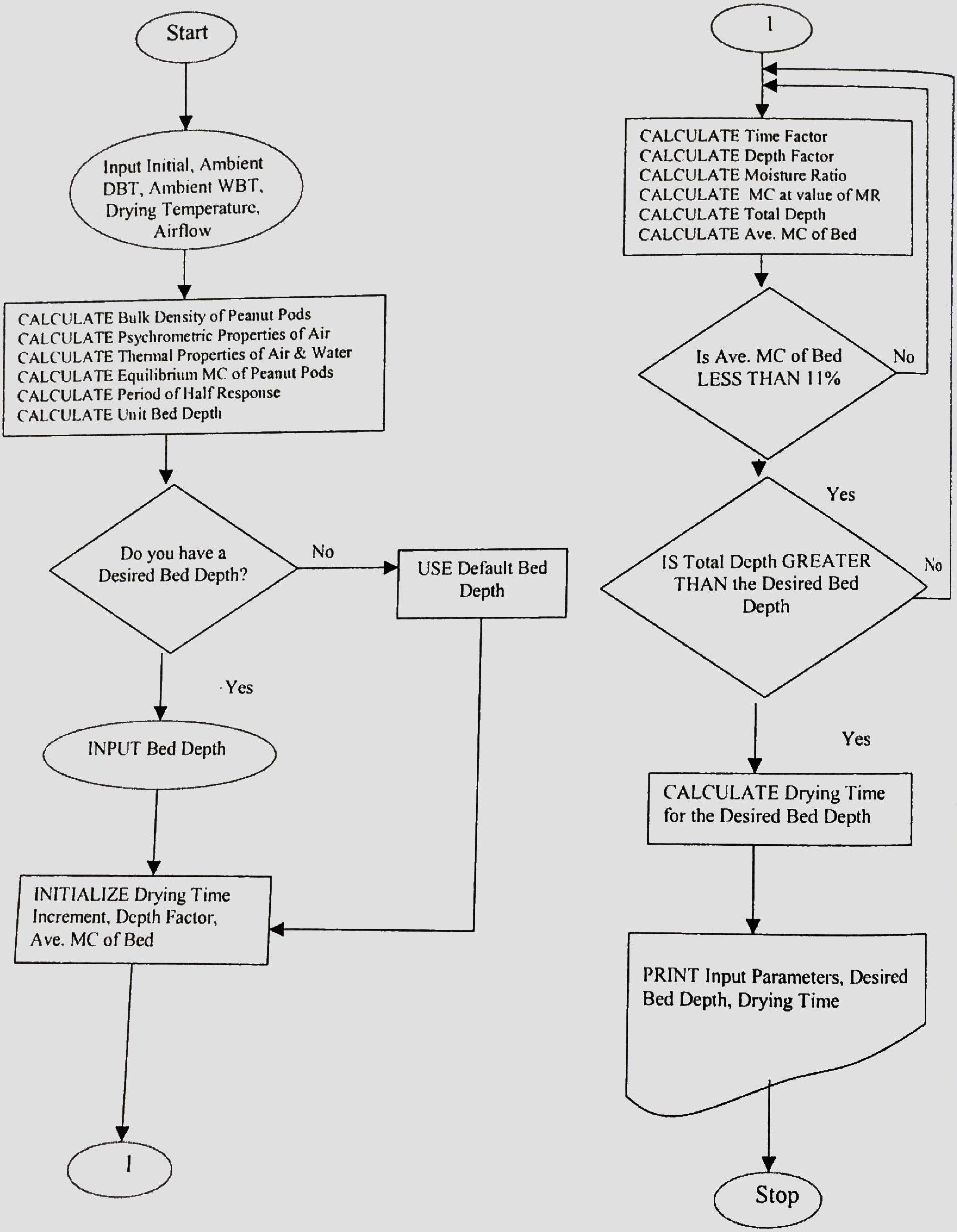
A simulation program for deep bed drying of peanut pods using Hukil's Analysis was written in Microsoft quickBASIC called PNUTDRY1 (Diamante, 1996). The algorithm of the computer program is shown in Figure 1.

MATERIALS AND METHODS

Evaluation of the peanut deep bed drying simulation program

The computer program PNUTDRY1 was used in the simulation analyses of the published deep bed drying data for peanut pos of Blakenship and Chew (1979) and Bulilan (1978). The drying data of Blakenship and Chew (1979) were obtained using a US standard peanut drying wagon whose dimensions are 4.6 x 8.0 x 14.0 ft (1.40 x 2.44 x 4.27 m). The peanut drying wagons have airflow of about 90 [ft^3/min]/ft^2 (0.45 [m^3/s]/m^2) for static load of 1 inch (0.0254 m) water. Simulation runs were done using approximate conditions used in the peanut drying studies of Blankenship and Chew (1979) showed the effects of the bed initial moisture content and the type of dryer (single and double trailers) on the total drying time. The data of Bulilan (1978) showed the effects of drying temperature, airflow, and bed depth on the total drying time of peanut pods. The ambient conditions for both studies were approximated from available data. In the case of Bulilan's data which did not report the initial moisture content of peanut pods, the initial moisture content was approximated using a weighted average of the moisture contents of the hull which constitute 25% and the kernel for the remaining 75%.

Actual drying of peanut pods was also conducted using a deep bed dryer at different conditions to evaluate the adequacy of the simulation program. The experimental drying time and the average moisture contents at various layers within the bed of peanut pods were compared to valuers predicted by the simulation program. The moisture content of the pods were determined in triplicate using the air oven method at 105°C for at least 15 hours (Diamante *et al.*, 2000).


Start
Input Initial, Ambient DBT, Ambient WBT, Drying Temperature, Airflow
CALCULATE Bulk Density of Peanut Pods
CALCULATE Psychrometric Properties of Air
CALCULATE Thermal Properties of Air & Water
CALCULATE Equilibrium MC of Peanut Pods
CALCULATE Period of Half Response
CALCULATE Unit Bed Depth
Do you have a Desired Bed Depth?
No
USE Default Bed Depth
Yes
INPUT Bed Depth
INITIALIZE Drying Time Increment, Depth Factor, Ave. MC of Bed
1
1
CALCULATE Time Factor
CALCULATE Depth Factor
CALCULATE Moisture Ratio
CALCULATE MC at value of MR
CALCULATE Total Depth
CALCULATE Ave. MC of Bed
Is Ave. MC of Bed LESS THAN 11%
No
Yes
IS Total Depth GREATER THAN the Desired Bed Depth
No
Yes
CALCULATE Drying Time for the Desired Bed Depth
PRINT Input Parameters, Desired Bed Depth, Drying Time
Stop

Simulation studies on deep bed drying of peanut pods

After the simulation program was to found adequately describe the published and actual peanut drying data, this was used to study the effects of several independent on drying time and bed moisture distribution in deep bed peanut drying. The independent variables used in the simulation studies were the following: a) bed initial moisture content, b) bed final moisture content, c) air humidity, d) drying temperature, e) airflow, and f) bed depth. The following standard conditions were used in the simulation studies: a) bed inital moisture content of 27% wb (37.0% db), b) bed final moisture content of 12% wb (13.6% db, c) air humidity of 0.020 lb water/lb dry air (kg water/kg dry air), d) drying temperature of 100°F (37.8°C), e) airflow of 60 [ft^3/min]/ft^2 (0.30 [m^3/s]/m^2), and f) bed depth of 3.0 ft (0.91 m). Simulation runs were also done by holding five of the variables constant and using 10% above and below the standard value of the selected factor to study the effect on the total drying time and moisture distribution within the bed of peanut pods. The 10% variation of the variables studied was limited by the maximum distribution of the bed of peanut pods were reported in terms of the moisture of layers of peanut pods at the bottom, middle and top of the bed. The bottom layer was obtained 0.6 ft (0.18 m) above the false bottom while the top layer was obtained 0.6 ft (0.18 m) below the topmost layer of the bed of peanut pods to minimize any boundary effects.

RESULTS AND DISCUSSION

Evaluation of the peanut deep bed drying simulation program

The peanut deep bed drying studies of Blakenship and Chew (1979) were done in a single trailer (ST) and a double trailer (DT) dryer. Airflows of 55 and 75 [ft^3/min]/ft^2)0.28 and 0.38 [m^3/s]/m^2) were selected to cover the range in the peanut dryer. The lower value used was the lowest airflow attainable by the vanexial fan used in the peanut dryers. The higher value used was the maximum recommended airflow for peanut dryers. The drying temperature over the drying period was estimated to vary between 87 and

95°F (30.6 and 35.0°C) since in the US the temperature controllers of the peanut drying wagons are set to a maximum temperature of 95°F (35.0°C). Ambient conditions were selected that would give the best and worst case for peanut drying in Georgia, USA and for the same months when the study were done (Akioka, 1988). The simulation analyses were carried out down to a average moisture content of 11% wb (12.4% db) which was about the same moisture levels that the peanuts were dried in the studies of Blankenship and Chew (1979) studies.

Figure 2 shows the effect of the average bed inital content on the total drying times ofpeanut dried with the ST and DT dryers. The drying times at two probable extreme conditions obtained using the simulation models are also plotted. The two conditions are: 1) ambient DBT of 74°F (23.3°C), air humidity of 0.0168 lb water/lb dry air (kg water/kg dry air), drying temperature of 95°F (35.0°C) and airflow 75[ft^3/min]/ft^2 (0.38[m^3/s]/m^2); and 2) ambient DBT of 77°F (25.0°C), air humidity of 0.0185 lb water/lb dry air (kg water/kg dry air), drying temperature of 87°F (30.6°C) and airflow of 55 [ft^3/min]/ft^2 (0.28[m^3/s]/m^2). The results show that the two sets of conditions almost encompassed all the data points of Blankenship and Chew (1979) except at moisture levels below 20% wb (25.0% db). The reason for these differences was the assumptions used in the simulation program, which used the latent heat of pure water in the calculation of the depth factor.Obviously, the latent heat of water inside the peanut pods at moisture levels below 20% wb (25.0% db) is much higher than that of pure water which leads to under estimation of drying time. In actual situations, the initial moisture content of peanut pods is about 20% wb (25.0% db) or higher even after partial drying in windrows (Woodroof, 1983; PCARRD/NAPHIRE, 1991; Saners, 1995). The results of the simulation model showed that it can adequately predict the drying times for deep bed peanut drying at a given bed initial moisture content and ambient conditions.

The data of Bulilan (1978) showed the effects of drying temperature, airflow and bed depth on the total drying time. The actual drying temperatures, airflows and bed depths, as well as air humidities used in the simulation analyses were approximated from the reported data.

Table 1 summarizes the experimental drying times for a given bed depth, drying temperature and airflow from the study of Bulilan (1978) and the predicted drying times using the simulation program. The results show that for a drying temperature range between 95 to 105°F (35.0 to 40.6°C), an airflow range between 40 to 50 [ft^3/min]/ft^2 (0.20 to 0.25 [m^3/s]/m^2) and a bed depth range between 3 to 6 ft (0.91 to 1.83 m) the simulation program was able to predict the drying times to within + 10% for more than half of the data. It must be noted that the experimental data of Bulilan (1978) was not replicated and therefore the variation for the same run cannot be quantified. In addition, the ambient conditions used in the simulation analyses was the same for each set of data, hence the variations due to air humidity fluctuations was not accounted for. Significant variations in the drying time due to changing air humidities were shown in the data of Blakenship and Chew (1979) (Figure 2). Hence, the results suggest that the simulation model can adequatley predict the drying times for deep bed peanut drying at a given drying temperature, airflow and bed depth.

Three experimental runs were carried out on deep bed drying of peanut pods at different conditions. Tables 2a and 2b present the experimental drying time and moisture content of various layers within the bed of peanut pods and the predicted values using the simulation program. The predicted drying times for the three drying runs were almost the same as the experimental values. While the predicted moisture contents of various layers within the bed of peanut pods were within the 95% confidence limits of the mean experimental values.

Hence, overall the results show that the simulation program was very satisfactory in predicting the drying time and moisture content of peanut pods.The results was not surprising since the use of Hukill's Analysis in describing the deep bed drying of grains abound in literatures (Hukill, 1974; Brooker *et al.*, 1974; Young and Dickens, 1975; Foster, 1982).

Effect of different factors on the drying time

Figure 3 shows the effect of bed initial moisture contents, drying temperature, air humidity, airflow and bed depth on the total drying time during deep bed peanut drying. Drying temperature had the most significant effect on drying time followed by bed initial moisture content, bed final moisture content, air humidity, airflow and bed depth, respectively. As drying temperature, bed final moisture content and airflow increased, the drying time decreased. Conversely, as bed initial moisture content, air humidity and bed depth

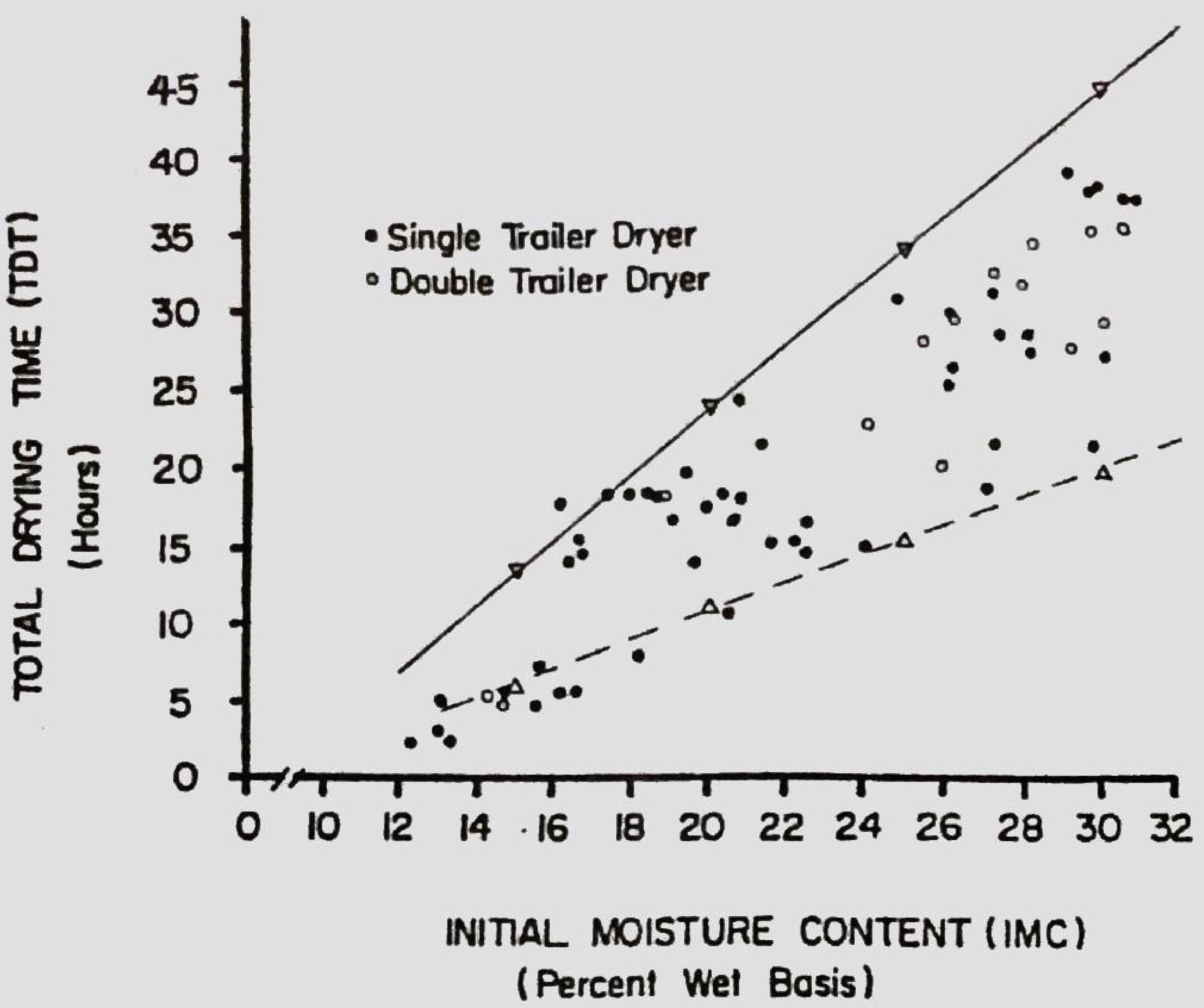


Figure 2. The effect of intial moisture content on total drying times of peanuts dried using the single trailer and double trailer dryers (Blankenship and Chew, 1979) and the results of the simulations at two probable conditions. Set of Conditions A: (△) ambient dry bulb temperature = 74°F, humidity = 0.0168 lb water/lb dry air, drying temperature = 95°F and airflow = 75 [ft³/min]/ft²; Set of conditions B: (▽) ambient dry bulb temperature = 77°F, humidity = 0.0185 lb water/lb dry air, drying temperature = 87°F and airflow = 55 [ft³/min]/ft².

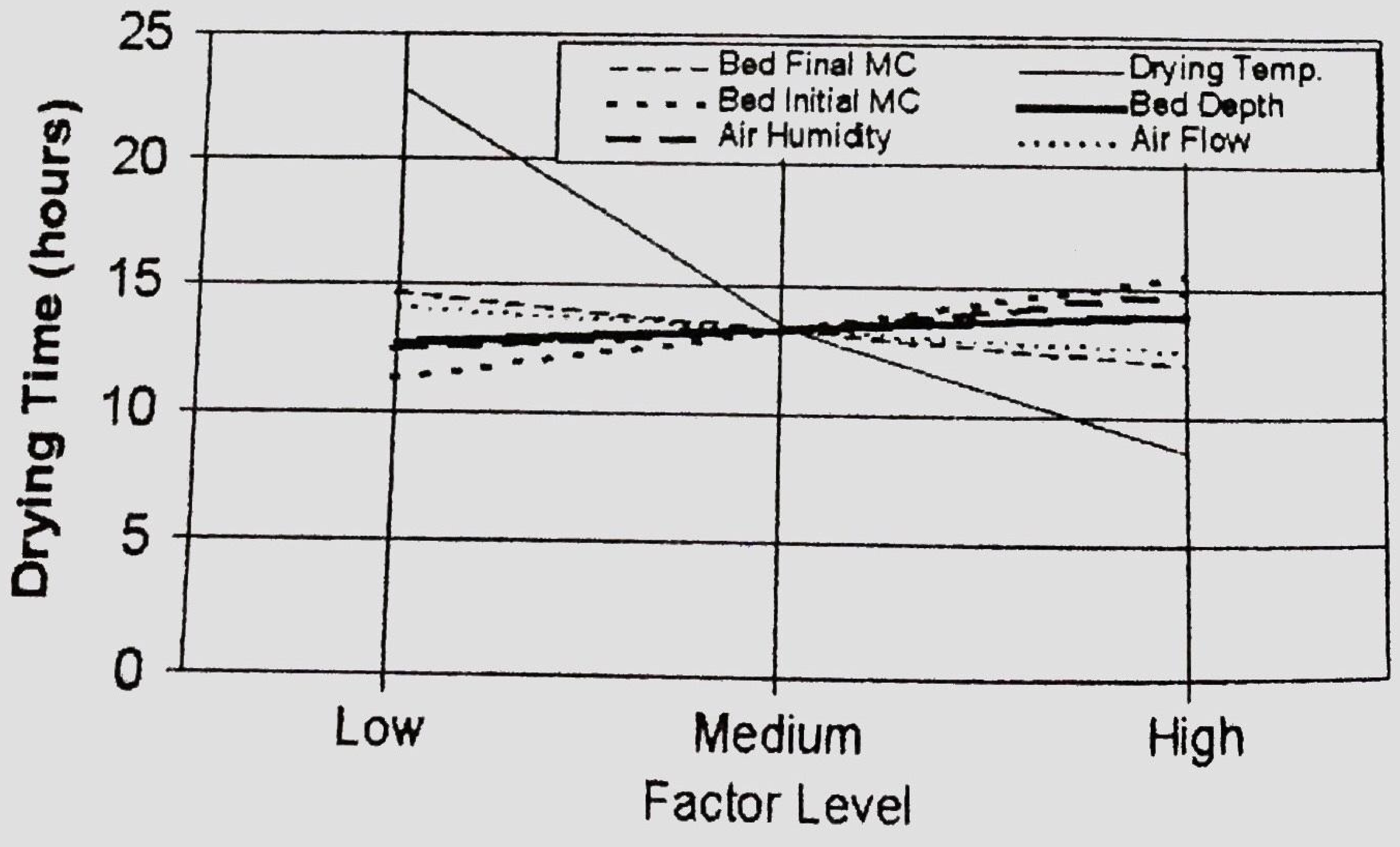


Figure 3. Effect of different factors on the total drying time during deep bed drying of peanut pods

Table 1. Comparison of drying times of a bed of peanut pods at different drying temperatures airflow and bed depth from the data of Bulilan (1978) (Experimental) and from the simulation analyses (Predicted)

Drying Temp. (°F)/(°C)	Airflow ([ft³/min]/ft²)/ ([m³/s]/m²)	Bed Depth (ft)/(m)	Drying Time (h) Experimental	Percentage	Percentage Difference
105/40.6	50/0.25	3/0.91	35	28	20
105/40.6	50/0.25	4/1.22	38	36	5.2
105/40.6	50/0.25	5/1.52	45	44	2.2
105/40.6	50/0.25	6/1.83	48	52	8
105/40.6	40/0.20	3/0.91	35	32	9
105/40.6	40/0.20	4/0.91	42	41	2
105/40.6	40/0.20	5/1.52	48	51	6
105/40.6	40/0.20	6/1.83	50	60	21
99/37.2	50/0.25	3/0.91	38	30	21
99/37.2	50/0.25	4/1.22	41	38	7
99/37.2	50/0.25	5/1.52	45	46	2
99/37.2	50/0.25	6/1.83	51	54	7
99/37.2	40/0.20	3/0.91	47	36	23
99/37.2	40/0.20	4/1.22	50	46	8
99/37.2	40/0.20	5/1.52	52	56	9
99/37.2	40/0.20	6/1.83	54	67	24
95/35.0	50/0.25	3/0.91	47	35	25
95/35.0	50/0.25	4/1.22	49	45	9
95/35.0	50/0.25	5/1.52	50	54	8
95/35.0	50/0.25	6/1.83	54	64	18
95/35.0	40/0.20	3/0.91	50	39	22
95/35.0	40/0.20	4/1.22	52	50	4
95/35.0	40/0.20	5/1.52	57	61	7
95/35.0	40/0.20	6/1.83	59	72	23

Table 2a. Comparison of drying times of a bed of peanut pods at different conditions (Experimental) and from the simulation analyses (Predicted)

Conditions	Drying Times (h) Experimental	Predicted
Initial MC = 25.3% wb (33.78% db) Ambient DBT = 87°F (30.6°C) Ambient WBT = 82°F (27.8°C) Air humidity = 0.0225 lb water/lb dry air (kg water/kg dry air) Drying temp. = 97.5°F (36.4°C) Airflow = 50 [ft^3/min]/ft^2 (0.25[m^3/s]/m^2) Final MC = 17% wb (20.62% db) Bed depth = 0.5 ft (0.15 m)	5.00	4.98
Initial MC = 14.4% wb (16.81% db) Ambient DBT = 87°F (30.6°C) Ambient WBT = 82°F (27.8°C) Air humidity = 0.0225 lb water/lb dry air (kg water/kg dry air) Drying temp. = 89°F (31.7°C) Airflow = 50 [ft^3/min]/ft^2 (0.25[m^3/s]/m^2) Final MC = 11.8% wb (13.34% db) Bed depth = 1.5 ft (0.46 m)	9.58	9.53
Initial MC = 26.0% wb (35.06% db) Ambient DBT = 87°F (30.6°C) Ambient WBT = 82°F (27.8°C) Air humidity = 0.0225 lb water/lb dry air (kg water/kg dry air) Drying temp. = 100°F 937.8°C) Airflow = 50 [ft^3/min]/ft^2 (0.25[m^3/s]/m^2) Final MC = 12.0% wb (13.64% db) Bed depth = 2.0 ft (0.61 m)	13.00	12.97

Table 2b. Comparison of moisture contents of various layers within the bed of peanut pods at different conditions (Experimental) and from the simulation analyses (Predicted)

Conditions	Layers	Drying Times (h) Experimental	Predicted
Initial MC = 25.3% wb (33.78% db) Ambient DBT = 87°F (30.6°C) Ambient WBT = 82°F (27.8°C) Air humidity = 0.0225 lb water/lb dry air (kg water/kg dry air) Drying temp. = 97.5°F (36.4°C) Airflow = 50 [ft³/min]/ft² (0.25[m³/s]/m²) Final MC = 17% wb (20.62% db) Bed depth = 0.5 ft (0.15 m)	Middle	20.62 ± 0.66	20.47
Initial MC = 14.4% wb (16.81% db) Ambient DBT = 87°F (30.6°C) Ambient WBT = 82°F (27.8°C) Air humidity = 0.0225 lb water/lb dry air (kg water/kg dry air) Drying temp. = 89°F (31.7°C) Airflow = 50 [ft³/min]/ft² (0.25[m³/s]/m²) Final MC = 11.8% wb (13.34% db) Bed depth = 1.5 ft (0.46 m)	Bottom Middle Top	12.90 ± 0.91 13.40 ± 0.76 13.96 ± 0.87	12.70 12.96 13.35
Initial MC = 26.0% wb (35.06% db) Ambient DBT = 87°F (30.6°C) Ambient WBT = 82°F (27.8°C) Air humidity = 0.0225 lb water/lb dry air (kg water/kg dry air) Drying temp. = 100°F 937.8°C) Airflow = 50 [ft³/min]/ft² (0.25[m³/s]/m²) Final MC = 12.0% wb (13.64% db) Bed depth = 2.0 ft (0.61 m)	Bottom Middle Top	10.00 ± 0.74 12.78 ± 1.95 17.96 ± 2.63	9.83 11.99 15.84

increased, the drying time also increased.

The same effect of drying temperature on drying time of peanut were also observed by Blankenship and Chew (1979), Bulilan (1978) amd Butt and Kummer (1951).Drying temperature greatly influenced the EMC and the drying rate of peanut pods as well as the properties of moist air which all affect the bulk drying of peanuts. The rate of drying of peanut pods increases with increasing drying temperature due to greater driving force resulting in shorter drying time.

The drying time increases with increasing initial moisture content similar to previous studies for deep bed drying of peanuts (Blankenship and Chew, 1979; Troeger and Butler, 1980; Baket *et al.*, 1993). The drying time increased with initial moisture content due to the greater amount of water that needs to be evaporated.

As the bed final moisture content increases the drying time decreases since the total amount of moisture to be evaporated was lesser resulting in shorter drying time.

The drying time increases with increasing air humidity since the drying air will have less capacity to absorb moisture resulting in longer drying time. The wide spread of the drying time for the same bed initial moisture content in the data of Blankenship and Chew (1979) could be partly attributed to the changing air humidity during the course of the drying study which lasted for several months. The air humidity changes from month to month due to the changing season.

The drying time decreases with increasing airflow. The same effect of airflow on drying time of peanuts is also reported in the literature (Blankenship and Chew 1979; Troeger, 1982; Young, 1984; Baker *et al.*, 1991; Baker *et al.*, 1993; Chai and Young, 1995). The rate of drying of peanuts increases with increasing airflow due to greater driving force in evaporating the moisture resulting in shorter drying time.

As bed depth increases, the drying time also increases similar to the results of Bulilan (1978). With deeper bed, the distance traveled by moisture increases resulting in longer drying time.

Effect of different factors on bed moisture distribution

Figure 4 shows the effect of the average bed moisture content on the moisture content of various layers within the bed of peanut pods.Among the different factors affecting deep bed drying,the average bed final moisture content had the greatest effect on the bottom, middle and top layer moisture of peanut pods. As the bed final moisture content increased the bottom, middle and top layer moisture also increased with the effect being greatest on the top layer moisture. The lower the bed final moisture content, the lower the moisture content difference between the bottom and top layers. The results obtained are as expected since the lower bed final moisture content of peanut pods within the bed will also be lower resulting in a narrower moisture difference.

The effect of drying temperature on the moisture content of various layers within the bed of peanut pods is shown in Figure 5. Drying temperature is also a major factor that affects the moisture contents of various layers of peanut pods. As the drying temperature decreased, the top layer moisture also decreased while the bottom and middle layer moisture increased. There was also wider moisture difference for the different temperature at the bottom layer than at the top layer. The same effect of drying temperature on the bottom and top layer moisture was also observed byBrooker *et al.* (1974) in their deep bed drying simulation of corn. The lower the drying temperature the lower the moisture difference between the bottom and top layers. with lower drying temperature, the resulting equilibrium moisture content (EMC) of peanut pods will be higher and nearer to the average final moisture content which will therefore narrow down the moisture difference between the bottom and top layers. With lower drying temperature, the resulting equilibrium moisture content (EMC) of peanut pods will be higher and nearer to the average final moisture content which will therefore narrow down the moisture difference between the bottom and top layers.

Figure 6 shows the effect of the average bed inital moisture content on the moisture content of various layers within the bed of peanut pods. The effect of bed initial moisture content on the various layers was similar to that of drying temperature except that the variations were not as great. The moisture difference at the different bed initial moisture contents for the bottom and top layers were almost the same. The higher the bed initial moisture content, the

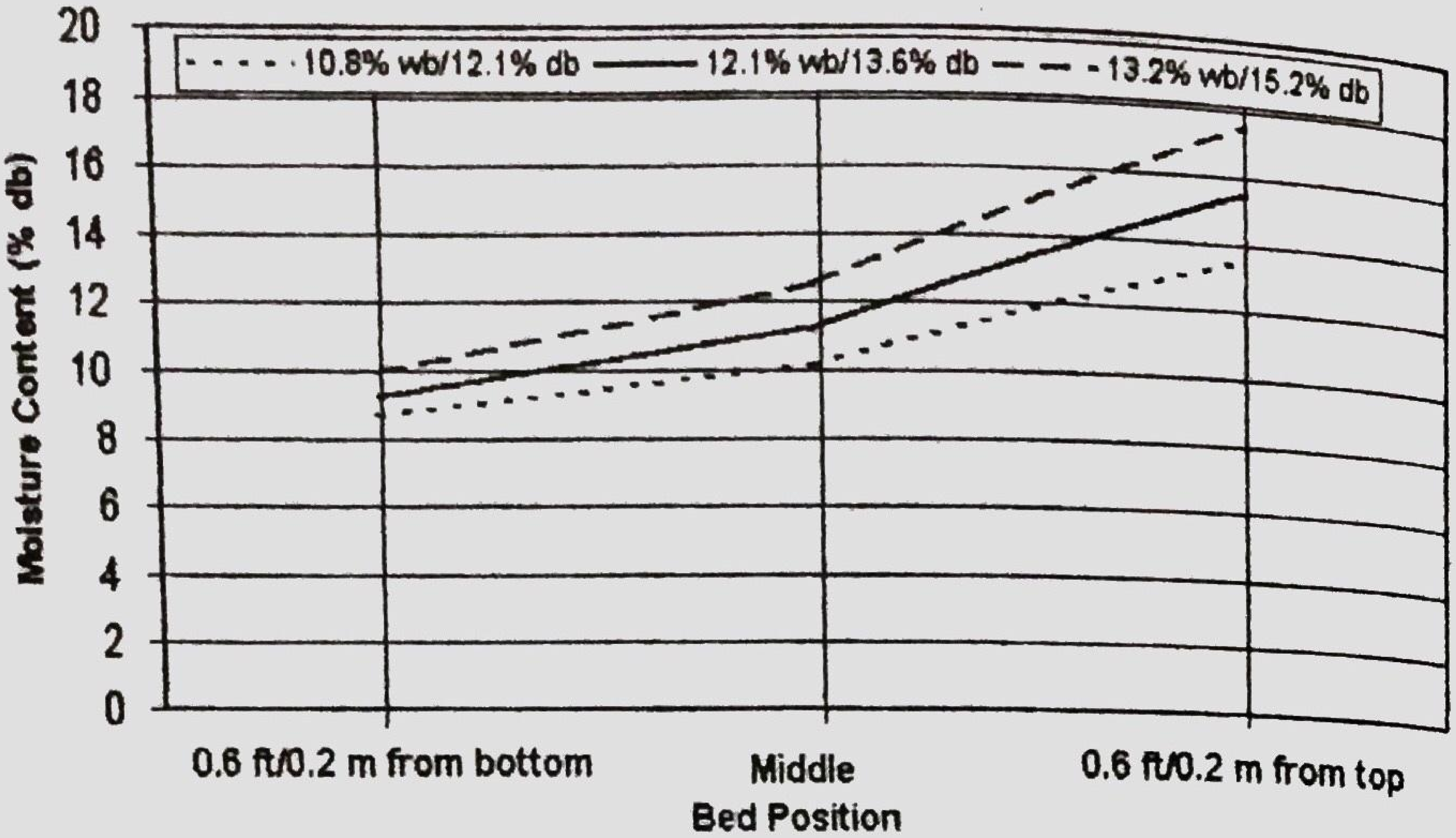


Figure 4. Moisture contents of bottom, middle and top layers within bed of peanut pods at standard conditions but with different bed final moisture content

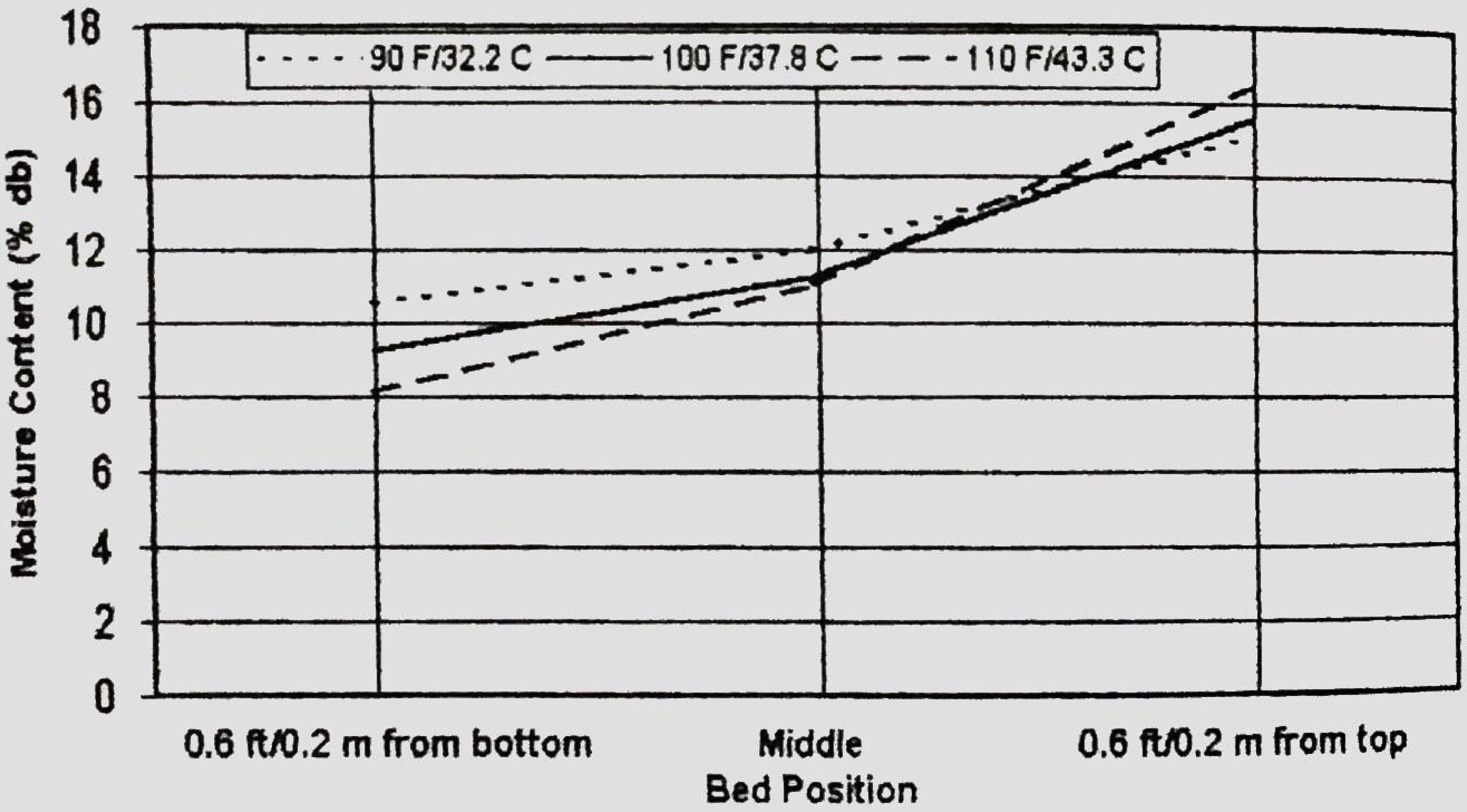


Figure 5. Moisture contents of bottom, middle and top layers within bed of peanut pods at standard conditions but with different drying temperaturesFigure 4. Moisture contents of bottom, middle and top layers within bed of peanut pods at standard conditions but with different bed final moisture content

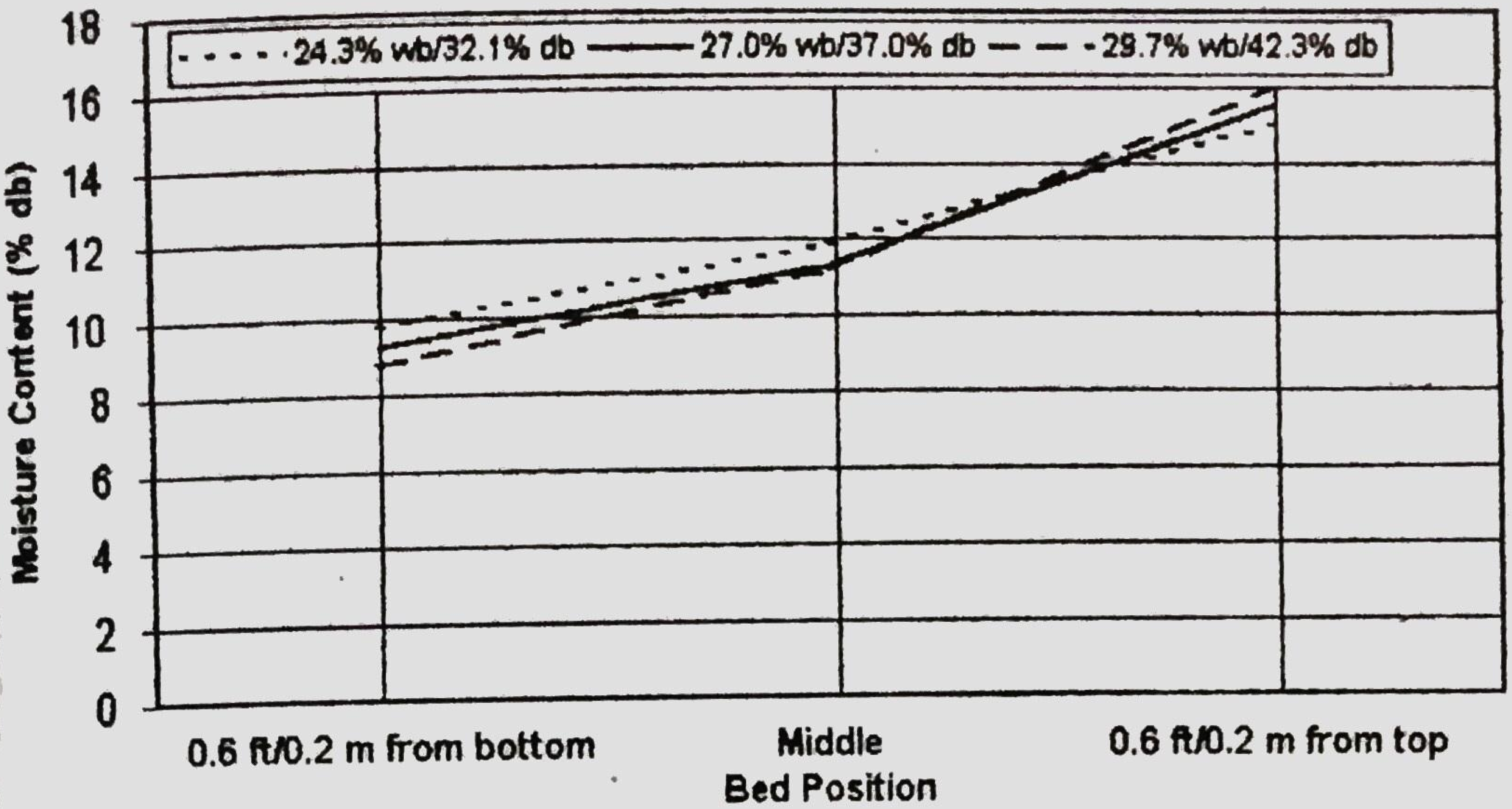


Figure 6. Moisture contents of bottom, middle and top layers within bed of peanut pods at standard conditions but with different bed initial moisture content

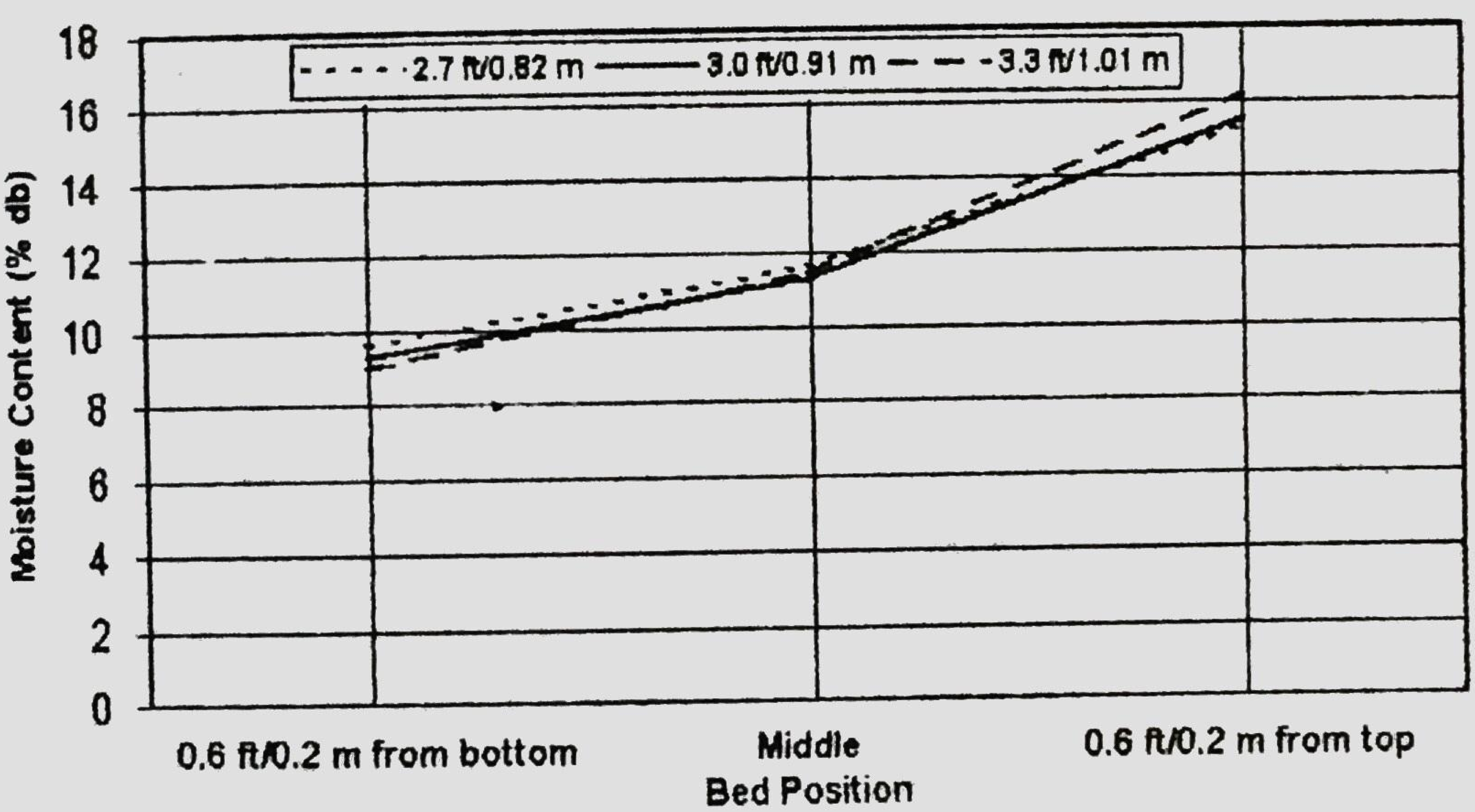


Figure 7. Moisture contents of bottom, middle and top layers within bed of peanut pods at standard conditions but with different bed depth

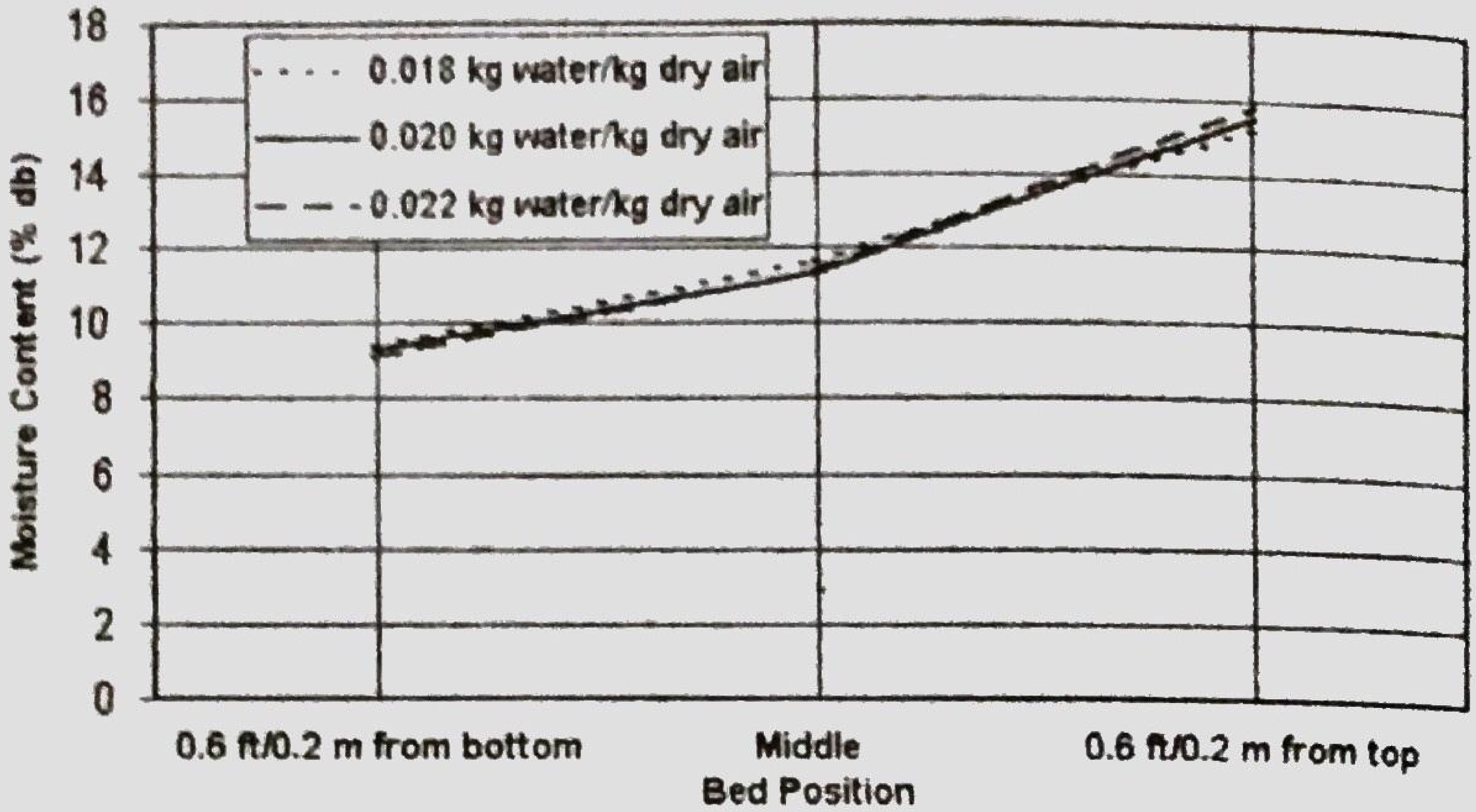


Figure 8. Moisture contents of bottom, middle and top layers within bed of peanut pods at standard conditions but with different air humidity

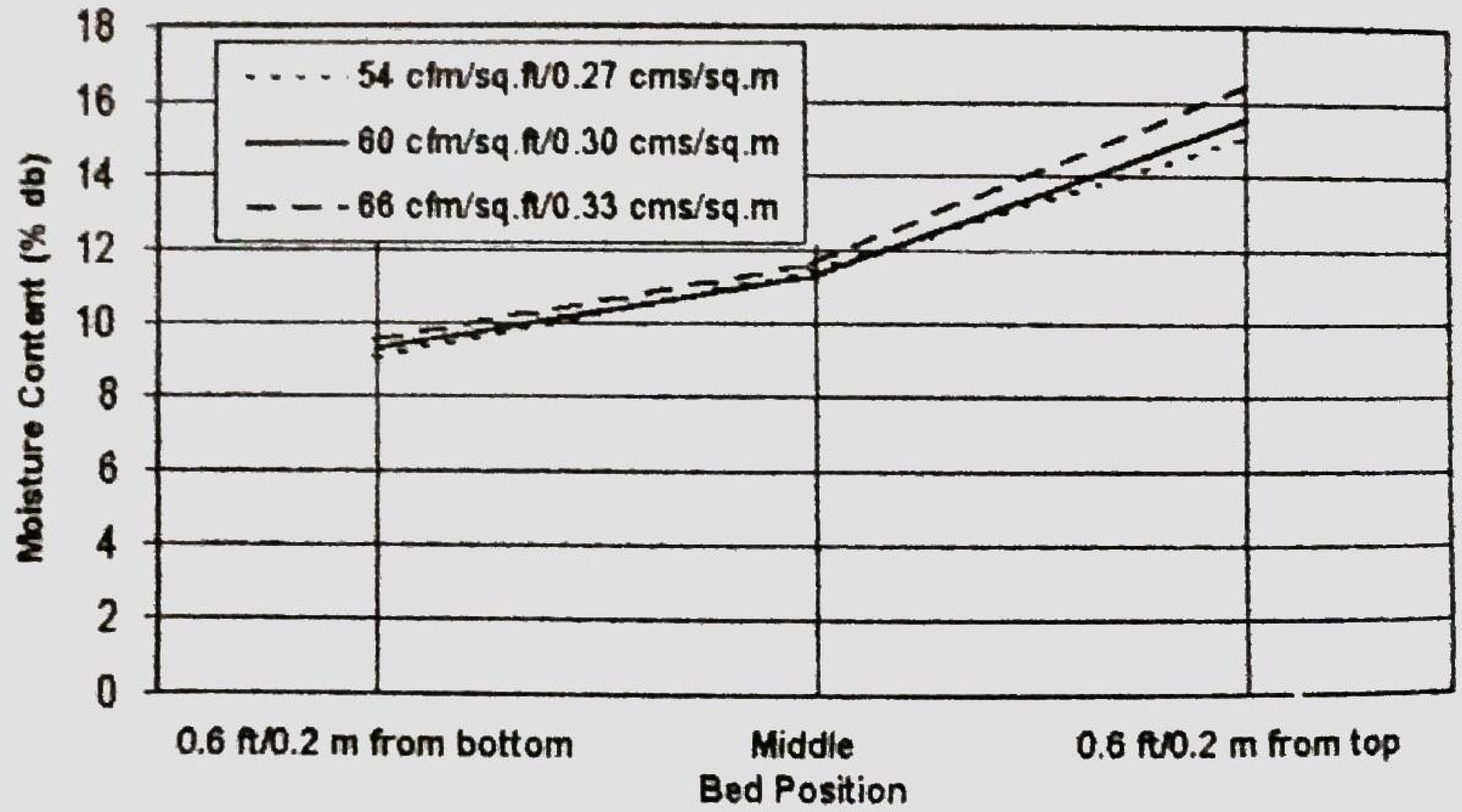


Figure 9. Moisture contents of bottom, middle and top layers within bed of peanut pods at standard conditions but with different airflow

higher the moisture range between the bottom ad top layers. Troeger (1982) also found in his peanut drying simulation that the bed bottom and top moisture difference increased with increasing initial moisture content. With higher initial moisture content, the amount of moisture to be evaporated will be much higher which probably resulted in a wider difference between the bottom and top layers.

The effect of bed depth on the moisture content of various layers within the bed of peanut pods is shown in Figure 7. The bed depth has similar effect on the moisture content of various layers as those of drying temperature and bed initial content. The moisture differences at the different bed depths for the bottom and top layers were also almost the same. The lower the bed depth, the lower the moisture difference between the bottom and top layers. When the bed depth decreased, the gradient for moisture evaporation also decreased which reduced the moisture difference between the bottom and top layers.

Figure 8 shows the effect of air humidity on the moisture content if various layers within the bed of peanut pods. The effect of air humidity on the various layers were very minimal. This is probably due to the narrow difference between the lower and higher air humidity values used in the simulation.

The effect of airflow on the moisture content of various layers within the bed of peanut pods is shown in Figure 9. The effect of airflow on the various layers opposite to those of earlier factors mentioned. As the airflow decreased, the top layer moisture decreased in Figure 9 while the bottom layer moisture decreased. There was also a wider moisture difference at the different airflows at the top layer than at the bottom layer. The same effect of airflow on the bottom and top layer moisture was also observed by Brooker *et al.*(1974) in their bed drying simulation of corn.The lower the airflow, the higher the moisture difference between the bottom and top layers. When airflow is decreased, the resistance to moisture evaporation increases widening the moisture difference between the bottom and top layers.

CONCLUSION

The simulation model based on Hukill's Analysis has shown that it can adequately describe the deep bed drying of peanut pods using published and actual drying data.

Drying temperature had the most significant effecton drying time followed by bed initial moisture content, bed final moisture content and airflow increased, the drying time decreased. Conversely, as the bed initial moisture content, air humidity and bed depth increased the drying time also increased.

The bed final moisture content had the greatest effect on the bottom, middle and top layer moisture of peanut pods among the factors studied. The lower the bed final moisture content, drying temperature, bed initial moisture content, bed depth and air humidity, the lower the moisture content difference between the bottom and top layers. Conversely, the lower the airflow, the higher the moisture difference between the bottom and top layers.

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