DEEP-BIN DRYING CHARACTERISTICS OF UNSHELLED PEANUTS

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ABSTRACT

Unshelled peanuts were loaded in a deep-bin dryer at a maximum depth of 182.9 cm. The variations in the temperature and moisture content (M.C.) of unshelled peanuts dried at three drying air temperatures and two air flow rates were studied. Large temperature and M.C. gradients were observed between the upper and lower levels of peanuts in the bin during the first 20 hr of drying after which these gradients gradually decreased. The rate of moisture removal of unshelled peanuts was affected by drying air temperature and air velocity. The higher the drying temperature and the air velocity, the shorter was the drying time. Drying peanuts from 40 to 13% moisture (safe for storage) could be accomplished in at least 48 hr with an air temperature of about 43.3°C and an air flow rate of about 0.0052 cubic meter per second (cmps) per 0.028 cubic meter load. Under specific drying conditions, the rate of drying decreased with an increase in the height of the peanut column. Drying peanuts at a depth of 182.9 cm was found most economical (i.e., requires least energy) without much gradient in moisture at the end of the drying process.

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INTRODUCTION

Peanut producers have always been beset with problems in drying their products in windrows because of deterioration of peanut pods, discoloration of the nut shells, and off-flavor development in the nuts. Since peanuts are rich sources of protein and minerals, there is an urgent need to protect and maintain their quality during drying and storage.

Artificial drying may protect the quality of peanuts since they can be dried immediately after harvest to attain the recommended level of moisture content (Myklestad, 1965). Researches conducted in other countries aimed to maintain the quality of peanuts during drying and storage (Sorenson, 1948; Teter, 1954; Pickett, 1957; and Woodroff, 1966). These studies were however all done under conditions of temperature and relative humidity different from those in the Philippines.

MATERIALS AND METHODS

Experimental layout. — This study was conducted using a split-split-plot in randomized complete block design replicated two times. The main plots included the three drying air temperatures of 35°, 37.8° and 43.3°C. The subplots included the two air flow rates (0.0043 and 0.0052 cubic meter per second (cmps) per 0.028 cubic meter load). The sub-subplots included the six bin-depths of 30.48, 60.96, 91.44, 121.92, 152.40 and 182.88 cm above the "false floor" of the bin.

Drying. — To stimulate deep bins to hold fresh mature peanuts, wooden boxes of 20.3 cm x 20.3 cm opening x 243.8 cm high were constructed. Each box had one end open and the other end covered by a 0.035 cm diameter mesh screen which served as the false floor. The bins were placed vertically above a plenum chamber. To avoid heat losses, the bin wall was lined with 10.2 cm thick rice hull which served as insulator.

Blower and heaters. — A 0.47 cmps blower at a 30.4 mm H_2O per 30.48 cm of product maximum static pressure was used. The blower was connected to the drying bins through a canvass air duct placed in-between the blower and the bins to avoid vibration within the bins. Electric-regulated heaters (chrome-wire coil) were installed at the asbestos-lined plywood air duct.

Peanut preparation. — Newly-harvested mature peanuts with a moisture content (M.C.) ranging from 50 to 60% were thoroughly washed. The peanut samples were air-dried until the M.C. was approximately 40% before they were manually loaded in the drying bins. As the bins were completely filled, instruments for measuring air temperature and air velocity were set.

Drying-run. — Every drying set was made of bins filled with peanuts up to 182.88 cm deep, the two air velocities, and a required drying air temperature. Two drying sets for each drying air temperature were run. Since there were three drying air temperatures, there were six drying-runs in this experiment.

Drying air temperature. — Coil-type electric heaters were used to increase the drying air temperature. The temperature was measured with a glass-mercury-filled thermometer at the plenum chamber close to the bottom of the peanut column in each bin. The desired temperature was kept constant throughout the drying period.

Air-flow rate. — Air flow rates of 0.0043 and 0.0052 cmps per 0.028 cubic meter of peanuts were measured using the Dywer manometer and air velometer. Static pressures were maintained to get the desired air flow rates.

Peanut sampling and temperature measurement. — Peanut sampling was done by taking 5 g of peanuts using the time "interval pattern" until 13% M.C. of the kernel was obtained. The time "interval pattern" of 1 hr interval for 6 hr; 2 hr interval for 6 hr; 4 hr interval for 28 hr; and, 8 hr interval was used. The samples were dehulled and the kernels and hulls weighed separately before they were oven-dried.

Air temperature at different depths across the peanut column was also measured through the sampling holes using mercury in glass thermometers. The relative humidity of ambient air and of exhaust air was also taken.

Moisture content determination. — The M.C. of the peanuts was determined using the oven-dried method. The wet basis formula was used in computing the M.C. of the peanut kernels and shells.

Drying curves for deep-bin. — For each treatment combination of drying air temperature and air velocity, a family of curves was obtained by plotting, with M.C. as ordinate and drying time as abscissa. Six families of curves were made for the six treatment combinations of drying air temperature and air flow rates.

RESULTS AND DISCUSSION

Temperature and Moisture Variation.

At the early stages of drying, large differences in temperature across the peanut column were observed. These differences, however, gradually decreased with time (Fig. 1). Statistical analysis shows that drying temperature varied significantly along the axis of the deep-bin dryer after 20 hr of drying (Table 1). Furthermore, the temperature gradient across the peanut column was significantly affected by drying air temperature and air flow rate (Table 1).

There was significant moisture variation within the column of peanuts during the early stages of drying (Table 2), but such variation tended to be insignificant at the end of the drying process (Fig. 2). For instance, moisture differences of about 13% at 35°C drying air temperature with an air flow rate of 0.0043 cmps (9 cfm), 16% at 35°C with 0.0052 cmps (11 cfm), 17% at 37.8°C with 0.0043 cmps, 17% at 37.8°C with 0.0052 cmps, 15% at 43.3°C with 0.0043 cmps and 14% at 43.3°C with 0.0052 cmps were noted between the upper and the lower positions after 20 hr of drying. Basing from the drying time for each drying treatments, these differences

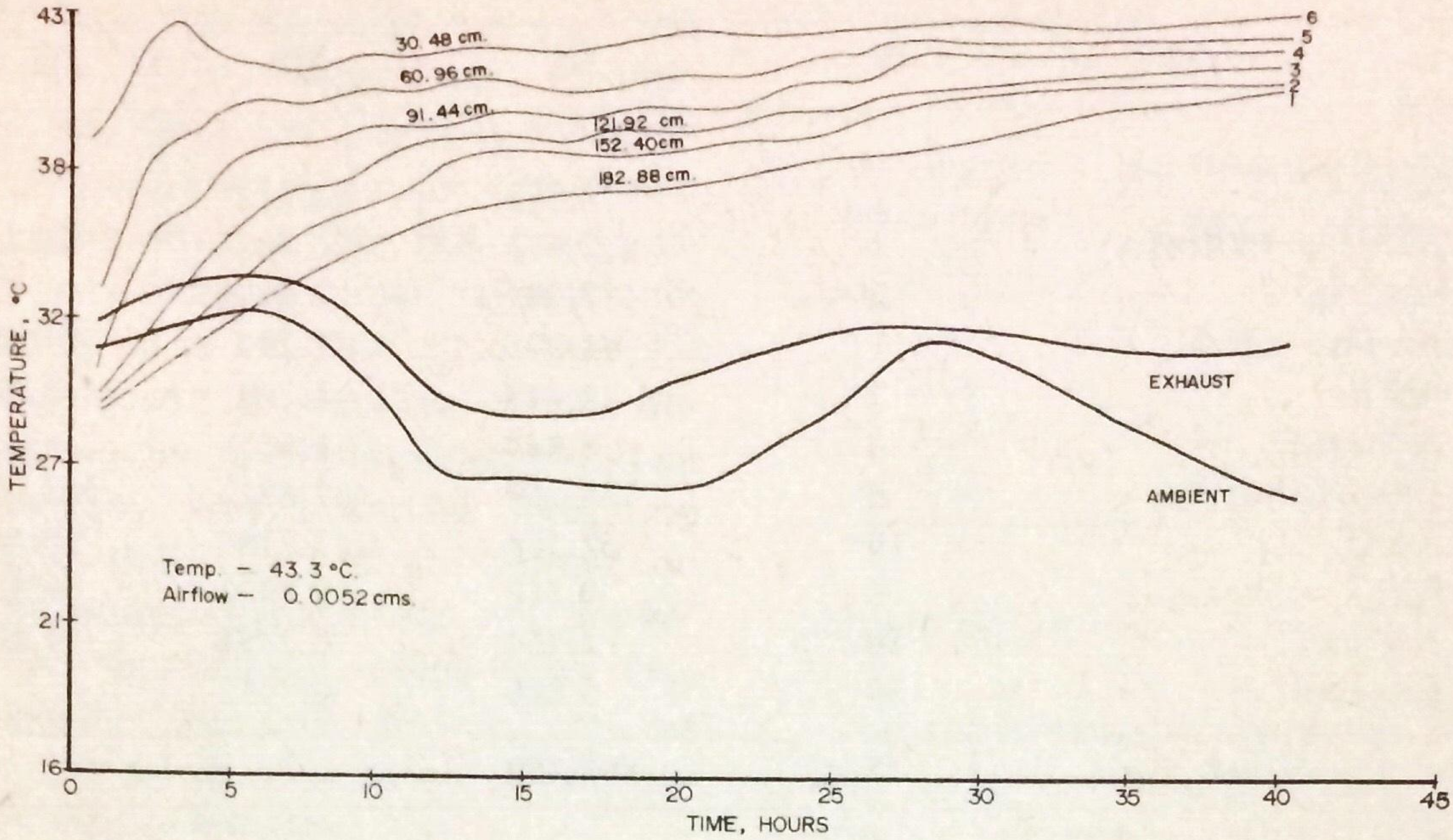

Fig. 1. Temperature at various depths as affected by drying time.

Table 1. Analysis of variance, split-split-plot design for temperature variation after 20 hr of drying.

SV	df	SS	MS	F
Block	1	2.31	2.31	
Air temperature (A)	2	2439.77	1219.885	34.4*
Error (a)	2	71.00	35.500	
Air flow rate (B)	1	331.12	331.120	40.1*
A x B	2	168.57	84.285	10.2
Error (b)	3	24.79	8.260	
Depth in bin (C)	5	2612.70	55.540	213.6**
A x C	10	67.23	6.723	25.9*
B x C	5	220.43	44.083	169.6**
A x B x C	10	351.15	35.115	135.1**
Error (c)	30	7.73	0.26	
Total	**71**	**6296.80**		

CV(a) = 19.8% CV(b) = 9.527% CV(c) = 1.69%

* Significant

** Highly significant

Table 2. Analysis of variance, split-split-plot design for moisture variation after 20 hr of drying.

SV	df	SS	MS	F
Block	1	14.311	14.311	
Air temperature (A)	2	612.612	306.306	86.40*
Error (a)	2	7.091	3.5455	
Air flow rate (B)	1	51.276	51.276	31.70*
A x B	2	12.418	6.209	3.84
Error (b)	3	4.848	1.616	
Depth in bin (C)	5	158.360	31.672	163.00**
A x C	10	32.168	3.2168	16.50**
B x C	5	0.516	0.1032	0.53
A x B x C	10	2.754	0.2754	1.42
Error (c)	30	5.826	0.1942	
Total	71	902.180		

CV (a) = 10.88% **CV (b) = 7.35%** **CV (c) = 2.55%**

* Significant
** Highly significant

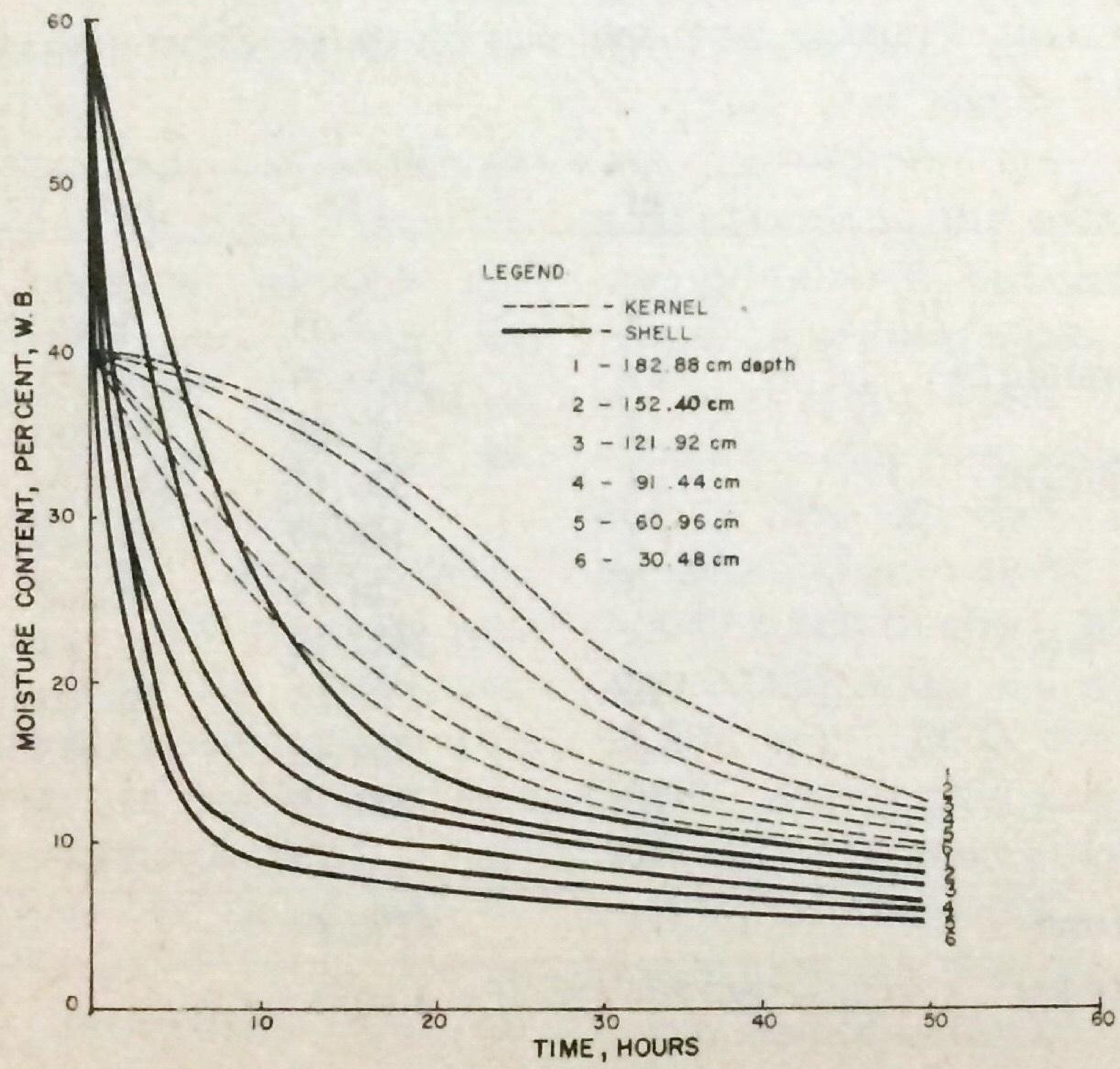

Fig. 2. Drying curves under conditions of 43.3°C drying temperature and 0.0052 cmps air flow rate.

were reduced to 4% after 36 hr, 4% after 34 hr, 5% after 33 hr, 4% after 31 hr, 5% after 32 hr and 3% after 28 hr, respectively. Furthermore, Table 2 shows that drying air temperature and air velocity significantly affected the moisture variation of peanuts across the bin depth after 20 hr of drying. However, no significant interaction effect between drying air temperature and air velocity was observed indicating that the effect of the former on moisture variation was not dependent on the latter or vice-versa. This implies that the finding can be applied in a wide range of environmental conditions.

Drying Time.

Drying at 43.3°C and 0.0052 cmps reduced the M.C. of peanuts from 40 to 13% after 48 hr (Table 3). A reduction in air velocity to 0.0043 cmps prolonged the drying time to 52 hr while a period of 53 hr was needed when temperature was reduced to 37.8°C. A comparison of the conditions in the various locations of the bin showed that test position 1 (30.48 cm depth above the false floor of the dryer) had the lowest M.C. since it is always in contact with the driest air. At this position, the rate of moisture loss was much higher during the first 10 hr of drying than in the top location. This was because the nuts placed at 182.88 cm above the false floor were in contact with the wettest air, a condition which has the opposite influence on the rate of drying.

Table 3. Drying time (hr) as affected by drying temperature and air velocity.

Drying air temperature (°C)	Air flow rate (cmps)	
	0.0043	0.0052
35.0	56	54
37.8	53	51
43.3	52	48

Optimum Depth.

The most economical depth in drying under conditions of 43.3°C drying air temperature and 0.0052 cmps air flow rate was determined considering the following factors: (a) the number of kilowatt-hour consumed in drying (using heaters and electric motor); (b) the relative humidity (RH) at each depth in the bin; and (c) the presence of mold.

The optimum depth for drying peanuts was 182.88 cm (Table 4). This was followed by 152.40 cm (0.52 kilowatt-hour per unit depth) and 121.92 cm (0.57 kilowatt-hour per unit depth).

During the early stages of drying, the RH measured at the exhaust of the dryer was lower than the RH at 182.88 cm deep (Fig. 3) which may be due mainly to the lower vapor concentration of the ambient air recorded during the early stages of drying. However, the situation was reversed after 20 hr until the drying process ended suggesting that water removal from peanuts still occurred at 182.88 cm depth.

Table 4. Drying time and energy consumption in drying peanuts to the desired moisture content with various bin depths at 43.3°C air temperature and 0.0052 cmps air velocity per 0.028 cubic meter load.

Depth (cm)	Drying time (hr)	Energy consumption (kw-hr)	K-value (kw-hr per unit depth)
30.48	25	52.0	1.71
60.96	32	32.9	1.06
91.44	35	66.6	1.00
121.92	38	70.0	0.57
152.40	45	79.7	0.52
182.88	48	79.2	0.43

No mold formation was observed in each of the sampling layers of the peanuts in the bin.

Drying Curves.

The drying curves obtained under all drying conditions at various depths were similar to those illustrated by Myklestad (1965). However, only the curves for 43.3°C and 0.0052 cmps were presented in this paper (Fig. 2). The rate of moisture removal from the shell followed Hall's typical drying curves for all crops which showed a constant rate of drying (Hall, 1967).

On the other hand, the kernel drying curves for 121.92 to 182.88 cm depths were far from those for lower depths. This observation indicates that the rate of drying was lower at the upper levels of the peanut column especially during early stages of drying (Fig. 2).

At the end of the drying process, it appeared that the shell has much lower M.C. than the kernel and that some of the moisture in the kernel were taken up by the shell. Further-

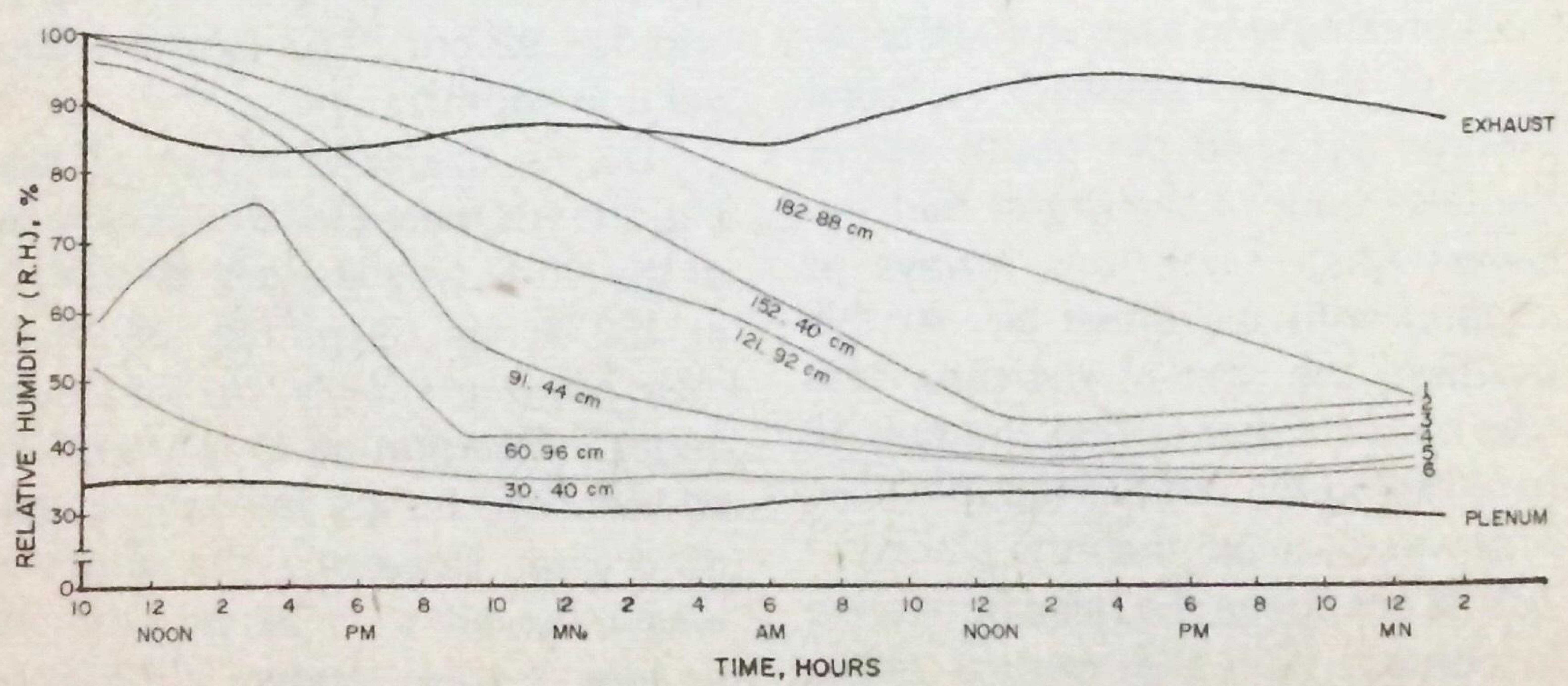

Fig. 3. Relative humidity versus drying time under conditions of 43.3°C drying temperature and 0.0052 cmps air flow rate.

more, slippage was noticed only at 30.48 cm above the false floor. At this depth, peanuts cannot be used for seeds but can be utilized for further processing into food products.

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