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Peanut Drying Energy Consumption - A Simulation Analysis

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ABSTRACT

During the past few years the cost of conventional sources of energy has dramatically increased and future supplies are uncertain. Available energy sources must be used in the most efficient manner. However, with any changes in recommended peanut drying procedures, product quality must be maintained. An analysis of various factors affecting energy consumption and drying time of peanuts was performed, using a computer simulation model. The analysis included consideration of ambient conditions, dryer controls, and initial peanut moisture. The analysis indicated that the airflow rate used in many commercially available farm dryers is necessary to adequately dry high moisture peanuts, but that a lower airflow rate would be adequate for low-moisture peanuts. A lower airflow rate would reduce energy consumption. Increasing the temperature rise of the drying air would speed drying but would also lower milling quality. Energy consumption was lowest early in the drying season when ambient drying potential was high.

Key Words: Peanuts, Drying, Energy, Simulation

Conventional forms of energy are becoming scarce and their price is rapidly increasing. Peanut drying requires energy to heat the drying air and to operate the fan. Energy must be used efficiently to minimize peanut drying costs without reducing the quality of the final product.

The amount of water to be removed from the peanuts depends on the initial and final moistures. The rate of moisture removal from an individual peanut is proportional to the difference in vapor pressure between the interior of the peanut and the surrounding air. As the moisture content of the peanut decreases, the vapor pressure difference also decreases, thereby increasing the time required to remove a given amount of moisture. As heat energy is added to air flowing at a constant rate, the amount of heat energy used to remove a given amount of moisture from the peanut will also increase as the drying rate decreases.

Deep-bed drying can be considered as drying a succession of single layers of individual peanuts. Conditions of the air (temperature and humidity) for a given layer are modified as they pass through each layer. The relationship between the temperature and relative humidity of the air and the moisture content is given by an equilibrium-moisture curve (1). As the air moves through the bed, it picks up moisture from each layer of peanuts, thereby increasing its humidity and decreasing its temperature. At the same time, peanuts in each layer give up moisture as they approach equilibrium with the surrounding air. When the humidity of the air increases to a value in equilibrium with the peanuts, the peanuts can dry no further.

The amount of heat energy added to the incoming air to maintain a given temperature is dependent on the ambient temperature and the airflow rate. For an equilibrium moisture content of 10% (recommended for safe storage) the relative humidity of the air (from the equilibrium moisture relationship) must be below 75%. Extrememly low relative humidities will dry the peanuts too rapidly and result in an excessive percentage of split kernels. Maintaining the relative humidity in the range of 60 to 70% will provide sufficient drying potential without seriously lowering the milling quality (1). Research has also revealed that continuous application of drying temperatures above 35 C will result in off-flavor of the peanuts. Thus the drying air temperature must be limited to 35 C.

A study of the psychometric chart (Fig. 1) indicates that, if the temperature rise of the ambient air is limited to 8 C above the dewpoint, the relative humidity can be maintained in the range of 60 to 65%. A temperature rise of 15 C above the dewpoint decreases the relative humidity to 40 to 45%, thereby decreasing drying time but increasing the potential for split peanuts. A plot of some

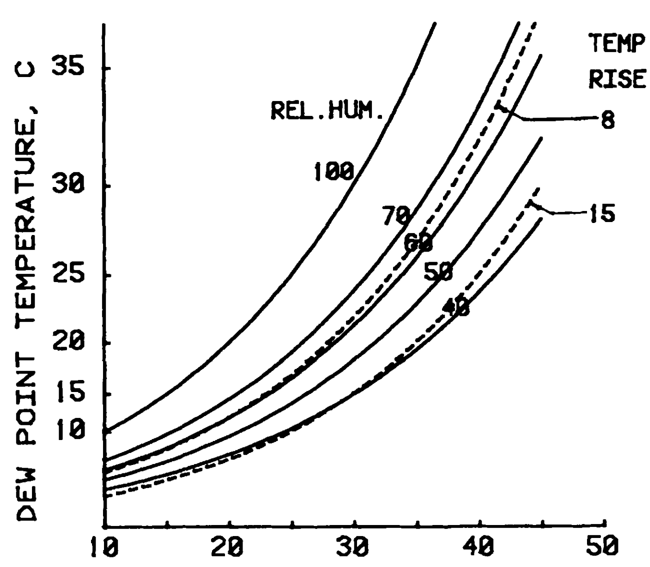

Fig. 1. Relative humidity vs. drying-air temperature rise on psychrometric chart.

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representative ambient temperatures (Fig. 2) indicates that the dewpoint can vary several degrees over a daily period. Current commercially available farm dryers limit the temperature rise above the ambient dry bulb temperature through orifice size and gas pressure adjustment. Thus proper relative humidity can be maintained when the dry bulb temperature approaches the dewpoint but relative humidity will be too low when dry bulb temperatures are high. Better control of the relative humidity at the plenum could be obtained by limiting the maximum plenum temperature to a fixed amount above the average dewpoint temperature.

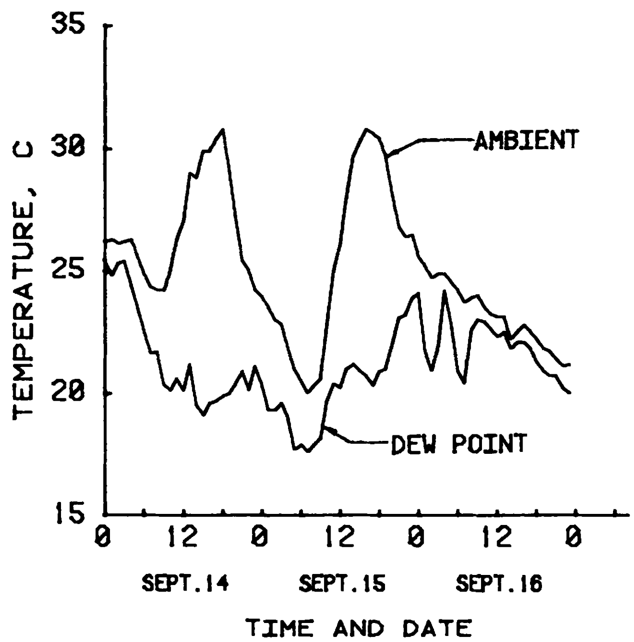

Fig. 2. Typical ambient dry-bulb and dew point temperatures.

Previous experimental research has indicated the effect of the initial peanut moisture content on the amount of energy used for drying (2, 3). This study used a computer simulation model to determine the effects of ambient conditions and dryer control settings as well as initial moisture contents, on energy consumption and on the time required to dry peanuts.

Materials and Methods

Since experimental tests covering a wide range of ambient conditions would take several years, a computer model developed for deep-bed peanut drying (5) was used to simulate the required conditions. Peanut volume was equivalent to that of a standard drying wagon (2.4-m by 4.3-m floor area, 1.4-m deep). Maximum air temperature entering the plenum was 35 C, the recommended temperature for drying peanuts.

The values of the independent variables included:

initial moisture (MO): 15, 20, 25, and 30% (wet basis),
minimum ambient temperature (TMIN): 5, 10, 15 and 20 C,
ambient temperature range (DTA): 5, 10, and 15 C,
dryer airflow rate (FLO): 3.05 and 4.72 m^3/s,
and temperature rise of the drying air (DTR): 8 and 15 C.

Analysis of ambient temperature records for the peanut drying season (September and October) at Tifton, GA showed that the daily range (DTA) between maximum and minimum ambient temperatures rarely exceeded 15 C. Maximum ambient temperature (TMAX) is the sum of TMIN and DTA. Daily ambient temperatures were varied between the maximum and minimum temperatures by the method outlined by Troeger and Butler (5). Dewpoint was held constant at 0.5 C below the minimum ambient temperature.

The low and high airflow rates represent respectively, the minimum recommended airflow rate and the maximum airflow rate found in many commercially available farm dryers. The low and high temperature rises of the drying air represent respectively, a rise that will result in an acceptable peanut quality and a rise that might be encountered if the dryer operator attempts to increase drying capacity by adding more heat.

In Georgia, peanuts are normally harvested in September and October. Maximum ambient temperatures during that period range from 20 to 35 C. Peanuts are dug at moisture contents of 40 to 50% and allowed to partially dry in the windrow to 20 to 25% moisture. They are usually combined in the afternoon so the vines can dry from overnight dew, thereby reducing harvest damage and losses. Drying of the harvested peanuts, under this procedure, would begin in the late afternoon. Drying in all simulations began at 6 P.M. Drying simulations continued until the moisture of the top layer of peanuts reached 10%.

Dependent variables obtained from the simulation included the drying time and the energy used. In addition, printouts of the peanut moisture (top, bottom, and average) and the air temperature (entering, exhaust, and ambient) were obtained at hourly intervals. The data in the simulation model were validated by comparison with results of experimental tests (6).

Results and Discussion

Two of the independent variables, airflow rate and the drying air temperature rise, are under direct operator control. Table 1 gives the average drying time and the heat energy used at each combination of these variables. The heat energy used for drying was calculated using the change in sensible heat of the air. Energy for running the fan is not considered. Drying time with the higher airflow rate (4.72 m^3/s) was 6% less than with the lower airflow rate (3.05 m^3/s,), but energy use was about 45% higher with the higher airflow rate than with the lower airflow rate. Figures 3 and 4 illustrate the effect of airflow rate on the drying time and energy use, respectively, for each level of initial moisture and for typical levels of the remaining independent variables.

Use of the 15 C temperature rise reduced drying time by 36% but increased energy consumption by 14% compared with use of an 8 C temperature rise. Figures 5 and 6 illustrate the effect of the drying-air temperature rise on the drying time and heat energy use, respectively, for

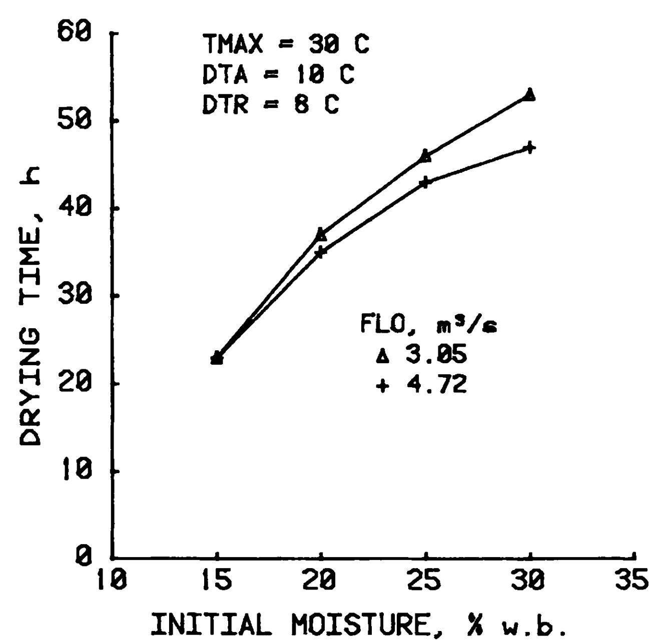

Fig. 3. Effect of airflow rate on drying time.

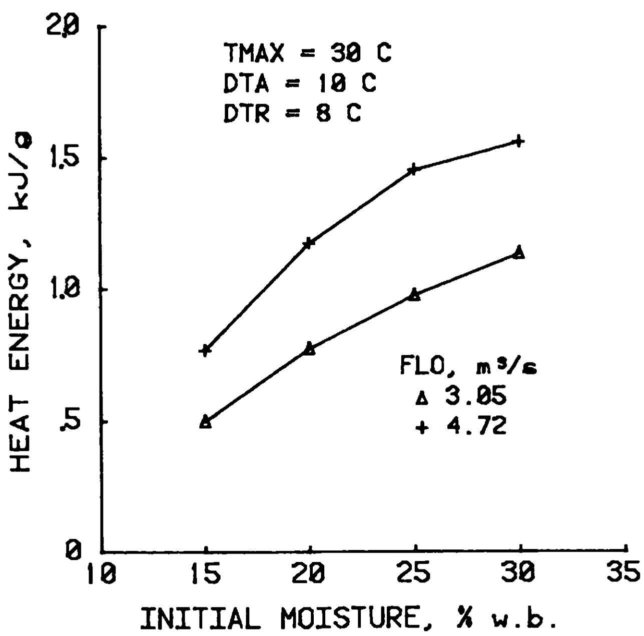

Fig. 4. Effect of airflow rate on energy use.

Table 1. Comparison of Drying Time, Energy Use, and Moisture Difference.

Airflow Rate	Dryer Temperature Rise	Initial Moisture	Drying Time	Energy	Top-Bottom Moisture Difference
m^3/s	°C	%	h	KJ/g	%
3.05	8	15	34.7	.776	.448
		20	58.7	1.318	.749
		25	78.7	1.765	.885
		30	97.3	2.181	1.220
Mean			67.3	1.510	.826
	15	15	20.8	.836	.383
		20	39.8	1.565	.708
		25	50.2	1.995	.942
		30	60.8	2.400	1.224
Mean			42.9	1.699	.815
4.72	8	15	32.3	1.123	.249
		20	54.8	1.901	.446
		25	73.5	2.557	.523
		30	90.3	3.136	.668
Mean			62.8	2.179	.472
	15	15	19.7	1.233	.233
		20	38.3	2.323	.432
		25	48.0	2.948	.536
		30	57.2	3.524	.645
Mean			40.8	2.507	.461

each level of initial moisture and for typical levels of the remaining independent variables.

Since peanut quality cannot be measured in the simulation, the difference in moisture content between the top and bottom layers was used as an indicator of drying uniformity. Drying uniformity and time, when correlated

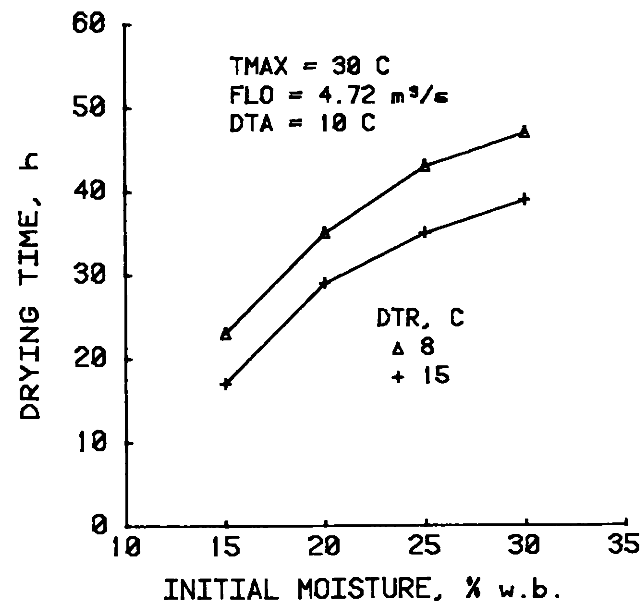

Fig. 5. Effect of drying-air temperature rise on drying time.

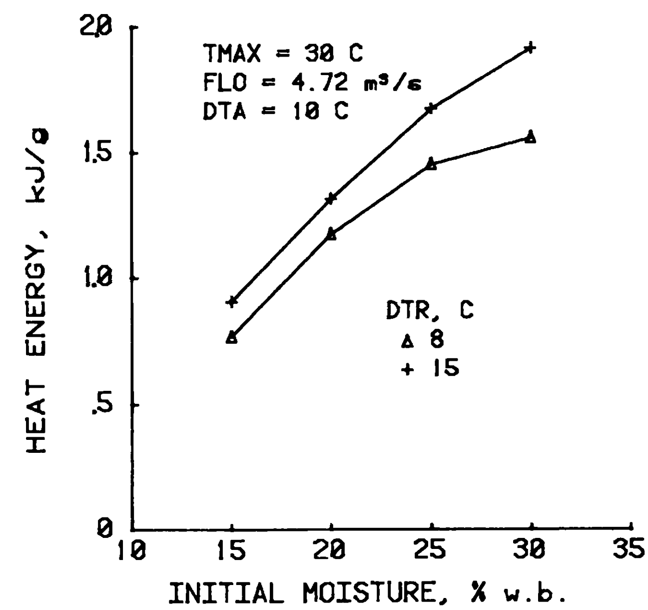

Fig. 6. Effect of drying-air temperature rise on energy use.

with experimental results, gave an indication of peanut quality. Use of a low airflow rate resulted in a greater difference in moisture content between the top and bottom of the dryer than use of a high airflow rate. At extremely low airflow, the bottom peanuts may dry completely before the top peanuts have begun to dry. The airflow rate must be high enough to ensure that all of the peanuts will dry before mold can grow. Table 1 gives the difference between the top and bottom moisture contents at the end of drying, for different airflow rates, dryer temperature rises, and initial moistures. The data indicate a 75% greater difference in top-bottom moistures when the lower airflow rate was used than when the higher airflow rate was used. The temperature rise of the drying air had little effect, an 8 C rise increased the top-bottom moisture difference only 5% more than did a 15 C rise. The initial moisture content can have a substantial effect on the top to bottom moisture difference. The data indicate that when drying high-moisture peanuts, a high airflow rate is needed to achieve the same moisture uniformity that would be attained with lower moisture peanuts and a lower airflow rate.

To determine a prediction equation for the drying time, regression analyses were performed on the simulation data to determine the parameters that would give the best fit. The equation chosen was:
best fit. The equation chosen was:

$$TIME = a_o + a_1(MO) + (MO)^2 + a_3(TPLN) + a_4(TPLN)^2 + a_5(MO)(TPLN) + a_6 (MO)/(FLO) + a_7 /(DTR)^2 \quad (1)$$

where TIME = drying time, h
MO = initial moisture, % wet basis
TPLN = plenum temperature, K
FLO = airflow rate, m^3/s
DTR = air temperature rise, C

and a_o = 17610.
a_1 = 96.763
a_2 = -0.072083
a_3 = -121.024
a_4 = 0.20699
a_5 = -0.30079
a_6 = 1.32814
a_7 = 231.22

Plenum temperature was estimated by adding DTR to the mean of the maximum and minimum ambient temperature with a limit of 35 C.

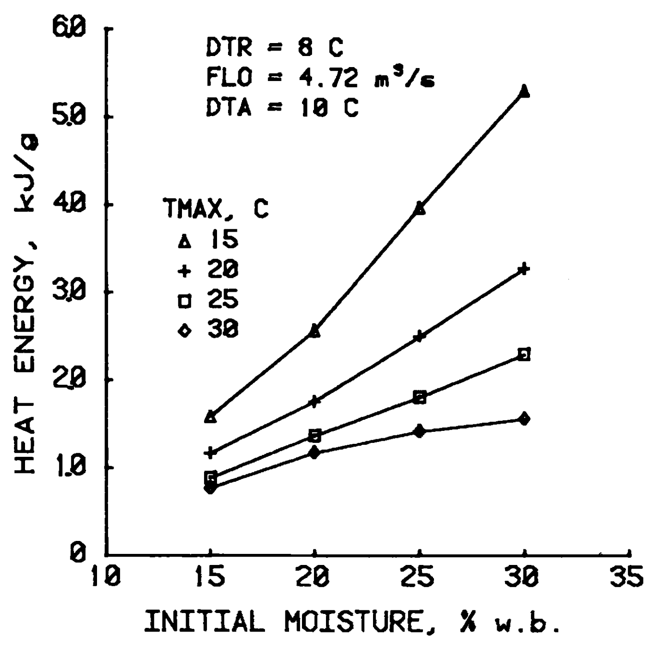

Fig. 7. Effect of maximum ambient temperature on energy use.

Heat energy used for drying will depend on the air flow rate, temperature rise and the drying time. A regression analysis on the simulation data produced the following equation:

$$E = b_o(FLO)^{b_1} \ (TIME)^{b_2} \ (DTR)^{b_3} \quad (2)$$

where E = heat energy, kJ/g dry peanuts
b_o = 0.84808E-3 b_2 = 1.05657
b_1 = 1.01436 b_3 = 0.91409

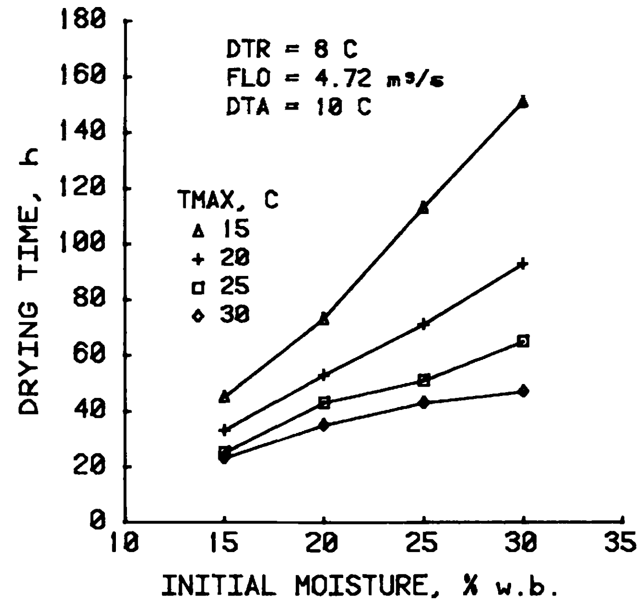

Fig. 8. Effect of maximum ambient temperature on drying time.

To determine the validity of these equations, data from experimental tests conducted using conventional drying wagons over two seasons were evaluated. Fig. 9 shows predicted energy versus experimental energy and 95% confidence limits. A similar plot for drying times is shown in Fig. 10.

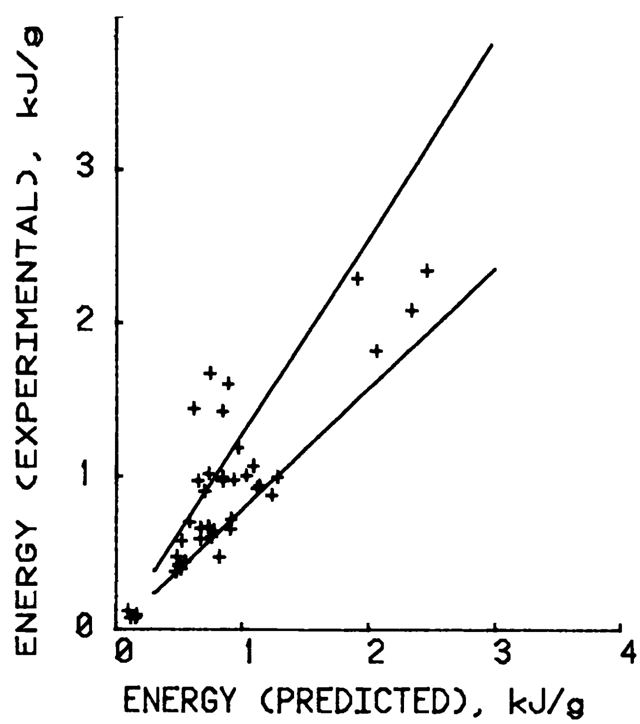

Fig. 9. Comparison of energy predictions with experimental results with 95% confidence intervals.

Conclusions

Conventional fuel sources are becoming scarce and

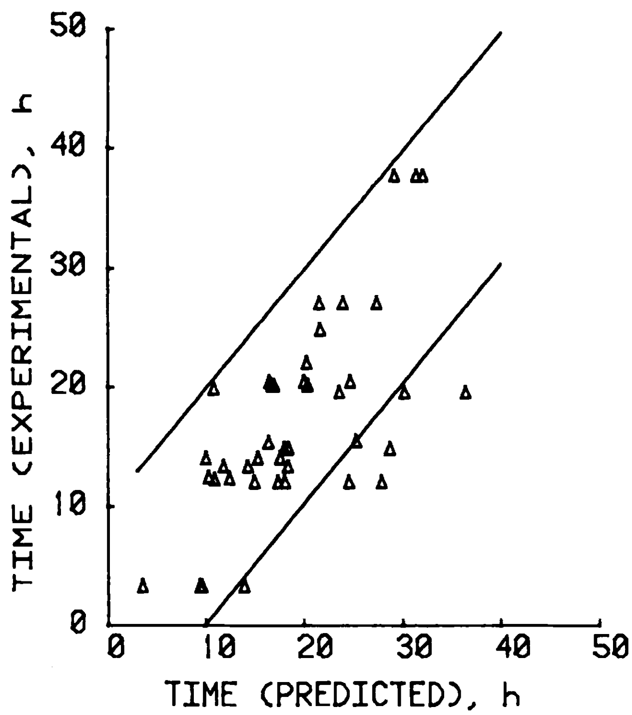

Fig. 10. Comparison of time predictions with experimental results with 95% confidence intervals.

more expensive so more efficient use of energy is becoming important. This paper considers the effects of various peanut drying parameters on energy use. The higher airflow rate (4.72 m^3/s) increased heat energy use by 45% while cutting the drying time by only 6% when compared with the lower drying rate of 3.05 m^3/s. The higher air flow is needed for high moisture peanuts but the lower air flow is sufficient if lower moisture peanuts are being dried.

A higher temperature rise of the drying air (15 C) will reduce drying time by 36% and increase energy consumption by 14% compared with a temperature rise of 8 C. This practice, however, reduces the relative humidity below the optimum range for maintaining acceptable milling quality and may impair flavor.

Energy can be saved by partially drying the peanuts in the windrow. The amount of moisture that can be removed with windrow drying is dependent on weather conditions during the harvest period. Harvesting early in the season will allow the producer to take advantage of higher ambient temperatures, thereby reducing the amount of heat that must be added to the air during forced air drying.

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