ACID DELINTED COTTON SEEDDRYING RATES

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Abstract

Moisture is a dynamic component of cotton and affects the quality of the lint during the harvesting, storage, and processing phases. This report describes the thin layer drying rates for acid delinted cotton seed at temperatures ranging from 68°F to 266°F. Absorption values are shown for temperatures of 68°F and 95°F. The drying data were plotted against time and found to be exponential. Nonlinear regression analysis was used to fit the value of the coefficients in the theoretical falling rate equation to the experimental data. The drying data produced a good fit to the theoretical falling rate (exponential decay) function at temperatures above 200°F. Temperature significantly affected the coefficient containing the diffusivity parameter in the drying equations. A generalized solution using absolute temperatures was developed which should be suitable for engineering calculations.

Introduction

Moisture affects every aspect of cotton harvesting and processing. Excessive moisture results in grade losses, fiber deterioration, and decreased machine performance while low moisture can cause fiber breakage and results in operating difficulties. Although cleaning efficiency improves when the cotton is dried early (Leonard et al., 1970), excessively dry cotton is subject to fiber breakage and results in operating difficulties (static electricity) during the ginning process (Childers and Baker, 1978). Researchers report that the optimum lint moisture content for ginning is in the 6-8 percent range (Griffin, 1977).

Predicting cotton moisture content in gins requires basic knowledge of moisture relationships such as equilibrium moisture contents (Barker et al., 1990) and moisture transfer rates (Barker et al., 1991). Work by Barker and Laird (1992 and 1993) showed that temperatures between 5 and 90EC affected moisture absorption and desorption rates for cotton lint. Higher transfer rates occurred at higher temperatures. The data fit the theoretical falling rate equation.

Several authors have studied the effects of temperature and humidity on the equilibrium moisture content of cotton seed. Henain (1992) found that the equilibrium moisture content of cotton seeds increased linearly between 22 and 75% relative humidity and that the rates of absorption and desorption were more rapid at 30°C than at 10°C. Henain (1992) reported that 18 to 24 days were required to reach equilibrium at 30°C (when the relative humidity was 86.3% and 90.8%) under static conditions and that, at 90% relative humidity, the seed were destroyed by mold. Kradangnga (1994) determined the equilibrium moisture content of cotton seed at 10, 20, 25 and 30°C and showed that as temperature increased, the equilibrium moisture content decreased for relative humidity values less than 75%.

The objective of this study was to determine the effect of temperature on thin layer drying rates for acid delinted cotton seed under controlled temperature and humidity conditions at temperatures ranging from 68°F to 266EF and to compare low temperature absorption data to that shown in the literature for gin run cotton seed. These data will be useful to scientists developing models for ginning and harvesting systems and to engineers designing conditioning systems for the cotton processing industry.

Equipment and Test Procedure

The equipment assembled by Barker et al. (1995) was used, with minor alterations, to control temperature and humidity in this study. A Wilkerson compact heatless dryer was used to provide a continuous source of dry air. Saturated air was generated by bubbling air through a column of water and a mist created with a spray nozzle. Air, water, and seed temperature were controlled using three constant temperature water baths. The air passed through a series of valves and flow meters to achieve the desired air flow rates and allow rapid switching from a dry air environment to a humid environment. A Cahn recording balance (model C-1000), in an enclosed chamber, was used to continuously monitor the weight of the sample. A small heater was used to provide drying air at 122EF and above for the study.

The dew point temperature of the air was measured with a General Eastern Hygro M2 Dew point sensor located upstream of the sample chamber. Small thermocouples (type J, iron-constantan) and Platinum RTD sensors were used to monitor the air temperature surrounding the sample. Air entered the top of the sample chamber and then flowed around the sample before exiting to the atmosphere. An air flow rate of 0.65 ft^3/min was used for the 68°F and 95°F hydration and dehydration cycles. However, this flow rate was insufficient to maintain a constant temperature when using the small heater. Thus a flow rate of 1.5 ft^3/min was chosen for the remainder of the study. This flow rate (approximately 1-1.3 ft/s around the platform holding the seed) resulted in turbulence around the sample as was evidenced by vibration and movement of the hang down wire holding the sample.

The study consisted of 7 different target temperatures (68, 95, 122, 167, 212, 248, and 266 EF), using acid delinted cotton seed. Three replicates (runs) were taken for each target temperature. Approximately 3 g, (28-30 seed) were

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placed in a single layer on a 2 in diameter hang-down platform. A data logger was used to record all the test information which included weight, temperature, dew point temperature, barometric pressure, velocity pressure and time.

The 68 and 95°F runs used the following procedure: A new sample was installed in the sample chamber and conditioned in dry air. The data logger was initialized and the conditioning air was changed from dry to humid air (90-97% RH). After several days, when the sample weight appeared to remain constant (equilibrium), the data was downloaded and the air was changed from humid to dry. After the sample and the air had reached equilibrium (stagnant sample weight) an electric heater was used to generate air at or above 212 EF for 5 hours to determine dry weight. The samples for temperatures of 122°F and above were placed in an airtight container over distilled water for at least 3 days, at room temperature, prior to use. The samples were then placed in the sample chamber and dry air at the desired temperature.

Results

The data from the humidification portion of the run for the acid delinted cotton seed at 68°F and 95°F showed three distinct zones of moisture absorption (figure 1) and was very similar to that for gin run seed (Barker and Laird, 1997). An early rapid increase in moisture (3 to 5% during the first hour) was followed by a leveling off, followed by a an increase in the moisture absorption rate. The data indicate that most of the samples were approaching equilibrium after 70 hours, which is consistent with the data of Henain (1992) for dynamic conditions.

The drying data for the acid delinted cotton seed exhibited an exponential drop with time until the sample approached equilibrium (figures 2-4), which is analogous to a falling-rate drying process. Newman (1932) presented solutions for this equation for drying by diffusion. All of the solutions presented were infinite series. A simplified version of the solution presented by Newman is:

Where:

$$\frac{M-M_E}{M_O-M_E}=\beta\left(\frac{1}{\alpha}e^{-\alpha D\theta}+\frac{1}{\gamma}e^{-\gamma D\theta}+\frac{1}{\eta}e^{-\eta D\theta}\ldots\right) \qquad \textbf{(1)}$$

M = Moisture content, % dry basis, after a period of time, θ
M_0 = Initial moisture content, % dry basis, at time zero
M_E = Equilibrium moisture, % dry basis, moisture content when the air and the lint are in equilibrium (stagnant sample weight)
D = Coefficient containing diffusivity, hr^{-1}
D_0 = Coefficient D when **T**$\approx\infty$, hr^{-1}
A = A constant
T = Absolute Temperature, °R
β = 0.7346 for the 3 term model.
α = 1 for the spherical solution.
γ = 4 for the spherical solution.
η = 9 for the spherical solution.

Henderson and Perry (1979) showed that the term, D, containing diffusivity in equation 1 is a function of temperature (equation 2). They stated that it can be related to the temperature of the drying air, although technically it should be the temperature of the drying object.

$$D=D_n e^{-\frac{A}{T}} \qquad (2)$$

The SAS procedure, Proc SYSNLIN, (Freund et al., 1986) was used to determine the value of D for each individual data set (figure 5). This procedure was also used to solve simultaneous equations for each individual replication within a treatment group and determine a value for D for the treatment. Values for **M_0** and **M_E** used in equation 1 were determined from the individual data sets. The drying data fit the exponential decay function relatively well, as is indicated by the R^2 values (Table 1) and by comparison of the experimental data with the regression curves (figures 2-4). It was also observed that as the temperature increased the fit of the exponential function improved. The exponential function (equation 1) can be used for the early portion of the dehydration curve, although it tends to reach the predicted equilibrium moisture content too quickly at the lower temperatures.

The individual values of the coefficient D, in equation 2, determined for each run, showed an exponential increase in value when plotted against temperature (figure 5). There was no noticeable differences in the data for the acid delinted cotton seed compared to similar data for gin run cotton seed (Barker and Laird, 1997). Thus, the data from both acid delinted and gin run cotton seed were combined and analyzed. This resulted in values of 81503.5 and 7422.4 for D_0 and A respectively in Equation 2. Equation 2 can be used to predict appropriate values for D which can in turn be used for prediction of the desorption (drying) rates of cotton seed.

Summary

Data were obtained defining the effects of temperature on thin layer drying rates for acid delinted cotton seed. Temperatures of 68, 95, 122, 167, 212, 248 and 266°F were used for the drying portion of the study. The drying data were plotted against time and found to exhibit the characteristics of an exponential relationship. Regression analysis was used to determine the value of the coefficient D (containing the diffusivity term) in the classical equations for a "falling rate" drying mechanism. The values of D (along with those for gin run cotton seed) were then plotted against temperature and found to fit the equation presented in the literature for the desorption data. The desorption data provided a good fit to the falling rate drying equations. Since it was desirable to maintain seed viability, absorption rates were obtained for only two temperatures (68° and 95°F) . The absorption data exhibited characteristics of a substance undergoing three phases. There was an early exponential rise, followed by the expected almost constant rate, followed by a period of increased rate. The equation and coefficients developed for the drying portion of the study can be used for modeling and for the design of cotton conditioning equipment such as dryers. There were no obvious differences in the rates of moisture absorption and/or desorption for the acid delinted cotton seed compared to gin run cotton seed data obtained from Barker and Laird (1997).

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Table 1. Average values of dry bulb temperature, initial moisture (M_o) and the equilibrium moisture (M_e) used with equation 1 to estimate the value of the coefficient D using three replications.

Dry bulb Temperature °C	Initial Moisture %	Equilib. Moisture %	Coefficient "D"	R^2 Value
68.4	41.6	3.99	0.18438	.97
95.0	36.2	3.72	0.22577	.95
124.2	30.5	1.70	0.26570	.97
167.7	29.7	0.50	0.50927	.98
212.7	30.3	0.00	1.15845	.99
248.4	25.7	0.00	2.29208	.99
267.1	18.0	0.00	2.91468	.99

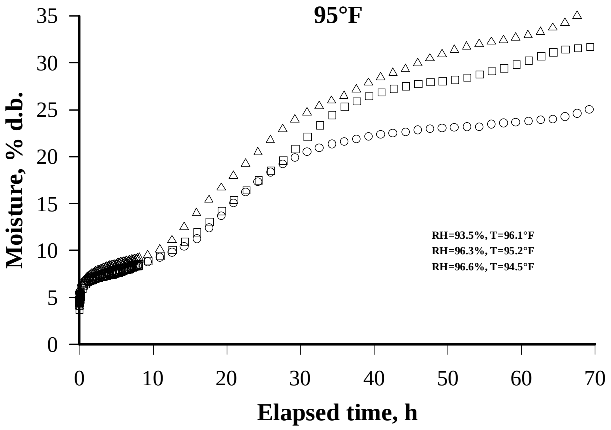

Figure 1. Moisture absorption curves for acid delinted cotton seed at 95° F.

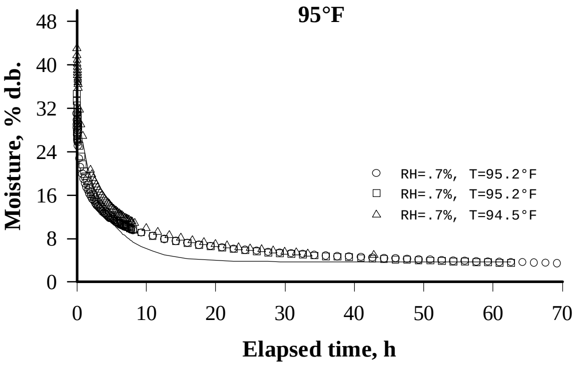

Figure 2. Drying rate curves for acid delinted cotton seed at 95° F. Solid line indicates predicted regression curve using the appropriate coefficients from table 1.

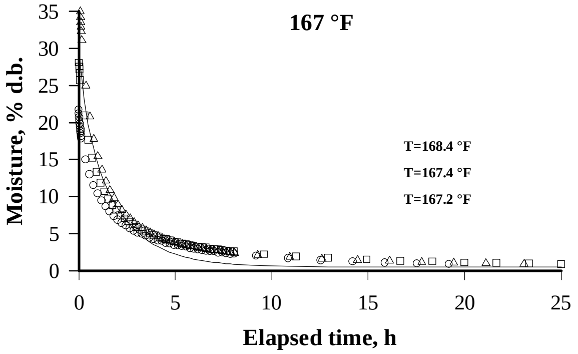

Figure 3. Drying rate curves for acid delinted cotton seed at 167° F. Solid line indicates predicted regression curve using the appropriate coefficients from table 1.

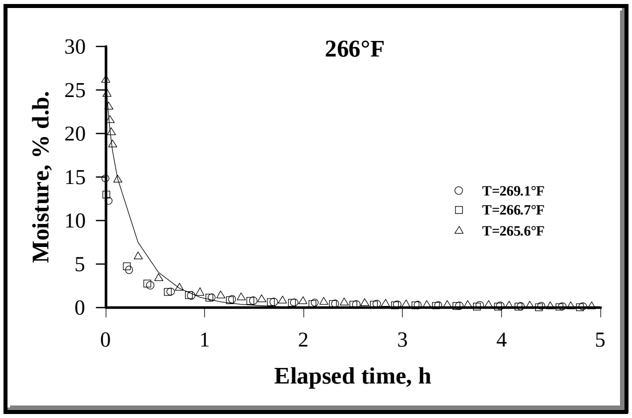

Figure 4. Drying rate curves for acid delinted cotton seed at 266 °F. Solid line indicates predicted regression curve using the appropriate coefficients from table 1.

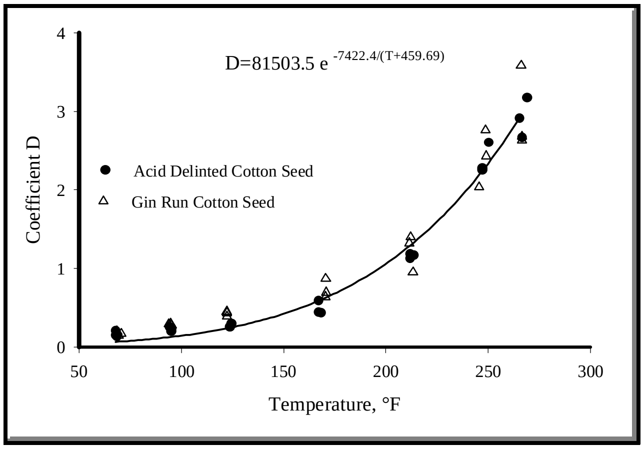

Figure 5. Effects of temperature on the coefficient D in equation 1. The solution to equation 2, shown in the figure in equation form and as the solid line, includes both gin run and acid delinted cotton.