MOISTURE TRANSFER RATES FOR GIN RUN COTTON SEED

G. L. Barker and J. W. Laird
Cotton Production and Processing Research Unit, USDA-ARS
Lubbock, TX

Abstract

The purpose of this study was to determine the effect of temperature on the drying rates of gin run cotton seed and to develop generalized relationships for drying cotton seed. Data showing moisture absorption and desorption rates for gin run cotton seed were collected. Absorption data was obtained for temperatures of 68 and 95°F and desorption values for temperatures ranging from 68 to 266°F. Generalized solutions were developed for the theoretical falling rate equation from the experimental data for the drying (desorption) data. The falling rate (exponential decay) function fit the data reasonably well, especially at temperatures above 212°F. The generalized solution of the falling rate equation was developed as a function of absolute temperature (°R), which should be suitable for engineering calculations. Results indicate that moisture absorption by cotton seed undergoes two absorption phases. The first absorption phase appears to be physical in nature and approximates the curves of other biological materials. The second phase, which shows an increased moisture absorption rate after a leveling off period, may indicate increased metabolic activity.

Introduction

Excessive moisture prior to and during harvesting results in fiber deterioration (especially color) and reduced yields (Barker et al., 1979 and Barker, 1982). 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).

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 86°F than at 50°F. Henain (1992) reported that 18 to 24 days were required to reach equilibrium at 86°F and 86.3% relative humidity under static conditions. Kradangnga (1994) determined the equilibrium moisture content of cotton seed at 50, 68, 77 and 86°F and showed that as temperature increased, the equilibrium moisture content decreased for relative humidity values less than 75%.

This experiment is a continuation of work to develop mathematical relationships describing moisture movement in machine harvested cotton and its components. These relationships will be used to model cotton processing and harvesting systems and to develop new dryer technology. The overall goal is to calculate the moisture content of a composite mass of harvested seed cotton, including the trash, from environmental conditions and exposure times.

The objective of this study was to determine the effect of temperature on moisture desorption rates for cotton seed under controlled temperature and humidity conditions at temperatures ranging from 68 to 266°F.

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. Three constant temperature water baths were used to control the temperature of the sample, the humidification tank and the dew point temperature of the humid air. A Cahn recording balance was used to continuously monitor the weight of the sample. 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 inserted into the sample chamber up and down stream from the sample to provide an indication of the air temperature surrounding the sample. A Hewlett Packard data logger (model 75000) was used to record the test information which included weight, temperature, dew point temperature, barometric pressure, velocity pressure and time.

Air entered the top of the sample chamber and then flowed around the sample before exiting to the atmosphere. A flow rate of 0.65 ft^3/min was used for the 68 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 the vibration and movement of the sample wire.

The study consisted of 7 different target temperatures (68, 95, 122, 167 and 212, 248, and 266 °F), using gin run (fuzzy) cotton seed. Three replicates (runs) were taken for each treatment. The sample size, 2 to 3g, (20-25 seed) for

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 2:1590-1593 (1997)
National Cotton Council, Memphis TN

this experiment was chosen to fit in a single layer on the (2 in diameter) balance platform.

The following protocol was used in this study for the 68 and 95°F runs: The equipment was allowed to stabilize at the desired temperature. A new sample, previously conditioned in dry air, was installed in the sample chamber. The data logger was initialized and humid air was allowed to enter the sample chamber. After several days, when the sample weight appeared to remain constant (equilibrium), the data was downloaded. Initial conditions were then obtained for the drying cycle, the data logger was reinitialized, and the sample was allowed to equilibrate with the dry air. After the sample and the air had reached equilibrium (stagnant sample weight) the temperature was increased to 212 °F 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 prior to use. The samples were then placed in the sample chamber and the above drying procedures were used. Rapid attainment of the higher sample conditioning air temperatures required the use of a small in-line heater and heat tapes applied to the glassware.

Results

The use of the additional heat sources for the higher temperature "drying" runs resulted in some over-shoot and/or under-shoot during the initial stages of the runs. Once a steady-state temperature condition was reached, the temperature profiles were stable (±1.0°F). Data points during the initial portion of the run for which the temperature around the sample deviated more than ±4°F from the average run temperature were deleted. No visible evidence of germination was present when the high moisture seeds were removed from the airtight container.

The data from the hydration of the gin run cotton seed at 68 and 95°F showed three distinct zones of moisture absorption (fig. 1). An early rapid increase in moisture for 68 and 95°F during the first hour followed by a slight leveling off, followed by a an increase in slope for the moisture absorption curves. Approximately 2% of the moisture gain during the first hour may be assigned to the lint remaining on the seed, assuming 10% lint on the "hand ginned" seed and a moisture gain of 20% for the lint (Barker and Laird, 1992). 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.

Plots of moisture content (dry basis) for the study show an exponential drop with time until the sample approaches equilibrium (figs. 2-4), which is analogous to a falling-rate drying process. Newman (1932) presented the following solution for a sphere for drying by diffusion:

$$\frac{M-M_E}{M_O-M_E}=0.7346\left(e^{-D\theta}+\frac{1}{4}e^{-4D\theta}+\frac{1}{9}e^{-9D\theta}...\right) \quad (1)$$

$$D=D_0 e^{-\frac{A}{T}} \quad (2)$$

Where:

- θ = Elapsed time, Hours
- **M** = Moisture content, % dry basis, after a period of time, θ
- $\mathbf{M_0}$ = Initial moisture content, % dry basis, at time zero
- $\mathbf{M_E}$ = Equilibrium moisture, % dry basis, moisture content when the air and the lint are in equilibrium (stagnant sample weight)
- **D** = Coefficient containing Diffusivity, hr^{-1}
- $\mathbf{D_0}$ = Coefficient D when $\mathbf{T}\simeq\infty$, hr^{-1}
- **A** = A constant
- **T** = Absolute Temperature, °R

Henderson and Perry (1979) showed that the term, D, containing diffusivity in equation 1 is a function of temperature, equation 2.

The SAS procedure, Proc SYSNLIN, (Freund et al., 1986) was used to predict the value of D for each individual data set (fig. 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 (Table 1). Values for M_0 and M_E used in equation 1 were determined from the individual data sets. The 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 (figs. 2-4). It was also observed that as the temperature increased the fit of the exponential function improved.

The individual values of D, in equation 1, determined for each run, showed an exponential increase in value when plotted against temperature (fig. 5). Predicted values for D_0 (28214.33) and A (6652.22), for equation 2, were determined using nonlinear regression. 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 with 10% moisture and above, during the early portion of the drying cycle.

Summary

Data were obtained defining the effects of temperature on the moisture absorption and desorption rates for gin run cotton seed. Temperatures of 68, 95, 122, 167, 212, 248, and 266°F were used for the desorption (drying) portion of the study. The desorption (drying) data were fit to the classical "falling rate" equations. The values of D were then fit to an exponential relationship providing a generalized solution for the desorption data. 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 (possibly metabolic) rate. The equations 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.

Disclaimer

Mention of a trade name, proprietary product or specific equipment does not constitute a guarantee or warranty by the USDA and does not imply approval of the product to the exclusion of others that may be available.

References

Barker, G. L. 1982. Equation for estimating cotton preharvest losses. TRANS. of the ASAE 25(2):271-276 & 282.

Barker, G. L. and J. W. Laird. 1992. Temperature effects on cotton lint moisture regain rates. TRANS. of the ASAE 35(2):435-441.

Barker, G. L., J. W. Laird, and B. J. Wieck. 1995. Moisture transfer rates for cotton trash components. TRANS. of the ASAE. 38(1):51-56.

Barker, G. L., R. W. McClendon, R. F. Colwick, and J. W. Jones. 1979. Relationship between cotton lint color and weather exposure. TRANS. of the ASAE 22(3)470-474.

Childers, R. E. and R. V. Baker. 1978. Effect of moisture conditioning on ginning performance and fiber quality of high plains cotton. TRANS. of the ASAE 21(2):379-384.

Freund, . J., R. C. Littell, and P. C. Spector. 1986. SAS System for Linear Models, 1986 edition. SAS Institute Inc., Cary N.C.

Griffin, A. C., Jr. 1977. Cotton moisture control. In *Cotton Ginners Handbook*. Agricultural Handbook No. 503, U.S. Department of Agriculture, Washington, D.C., pp. 13-18.

Henain, E. S. 1992. Rates of absorption and desorption of hygroscopic moisture by gin run and acid delinted cotton seeds at 10° and 35°C. Msc. Thesis, Mississippi State University. Missisippi State, MS. 66pp.

Henderson, S. M., and R. L. Perry. 1979. Agricultural Process Engineering, third Edition, The AVI Publishing Co., Westport, Connecticut, USA.

Kradangnga, P. 1994. Storage parameters determination for cottonseed. Msc Thesis, Mississippi State University. Mississippi State, MS. 76pp.

Leonard, C. G., J. E. Ross and R. A. Mullikin. 1970. Moisture conditioning of seed cotton in ginning as related to fiber quality and spinning performance. U.S. Dep. Agric., Agr. Res. Serv. and Economic Res. Serv. Marketing Res. Report No. 859, 16pp.

Newman, A. B. 1932. The drying of porous solids: Diffusion calculations. TRANS. of American Inst. of Chem. Eng. 27:310-333.

Table 1. Average values of dry bulb temperature, initial moisture (M_o) and the equilibrium moisture (M_e) used with equation 2 to estimate the value of the coefficient D using three replications.

Dry bulb Temp.	Initial Moist.	Equil. Moist.	Coeff. "D"	R^2 Value
°F	%	%		
69.4	23.90	3.78	0.17124	.91
94.6	24.30	3.64	0.28670	.94
122.1	47.90	1.62	0.33216	.96
168.8	41.20	0.56	0.45958	.97
212.2	21.90	0.00	1.31337	.99
247.6	26.20	0.00	2.35422	.99
266.4	20.60	0.00	2.79619	.99

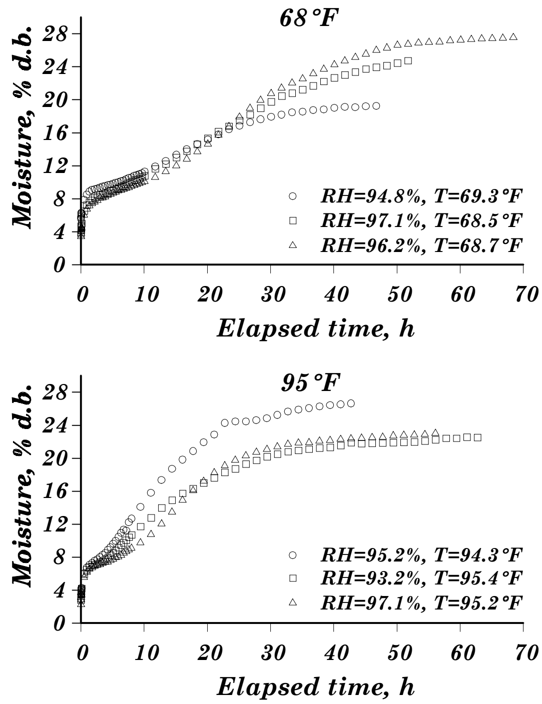

Figure 1. Moisture absorption rates for gin run cotton seed at 68 and 95 °F.

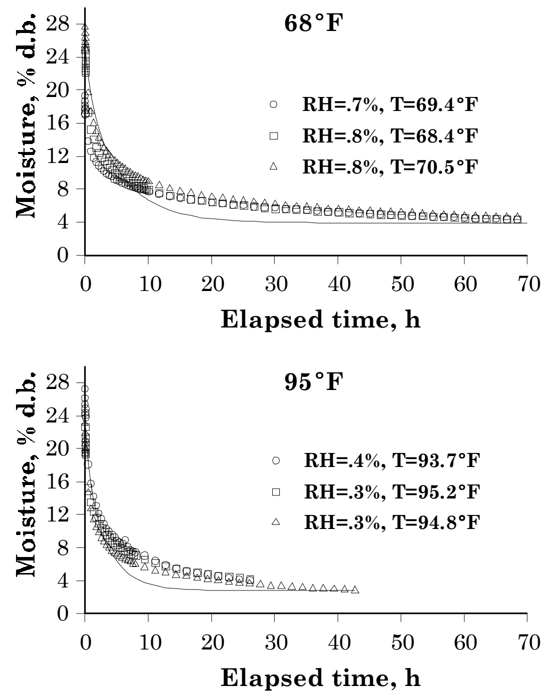

Figure 2. Drying rates of gin run cotton seed at 68 and 95ºF.

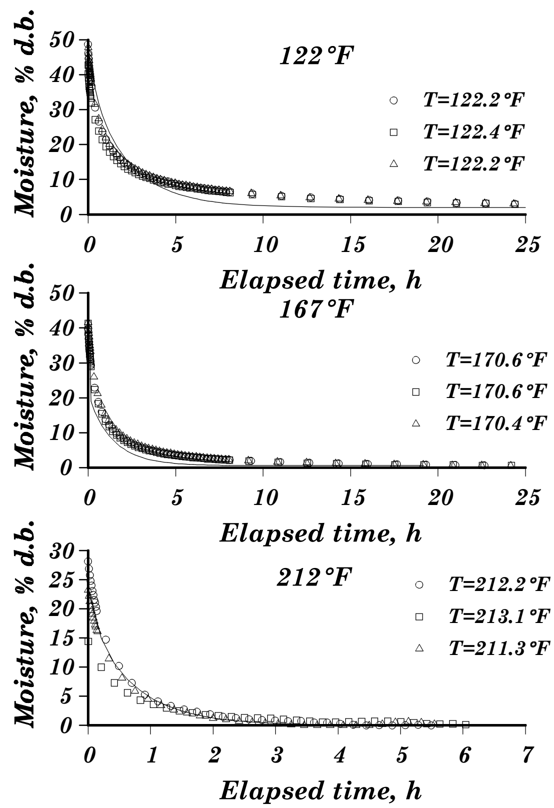

Figure 3. Drying rates for gin run cotton seed for temperatures between 120 and 212 °F. represent a regression curve using solutions to equation 1.

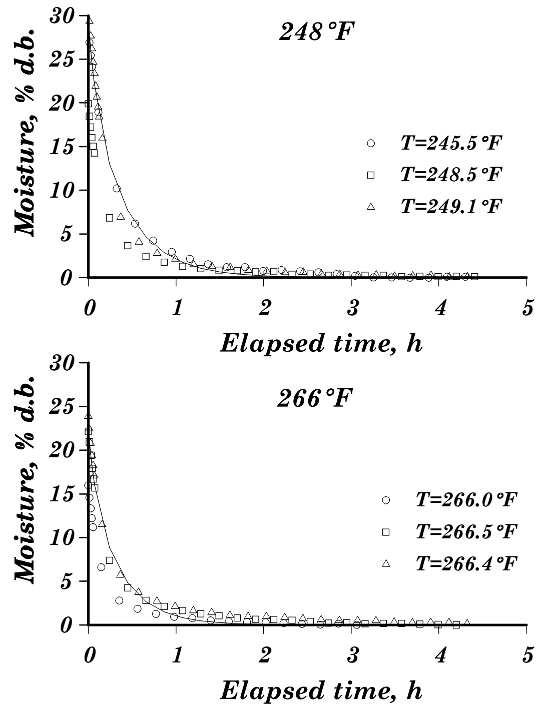

Figure 4. Drying rates for gin run cotton seed at 248 and 266 °F. Lines represent regres
equation 1.

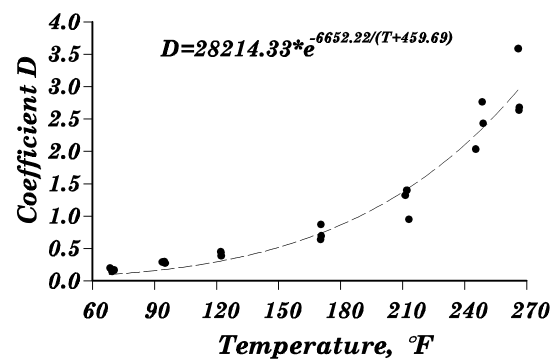

Figure 5. Effect of temperature on the coefficient D from Equation 1.