EFFECT OF ENVIRONMENT DURING CURING ON THE QUALITY OF BURLEY TOBACCO: II. EFFECT OF HIGH HUMIDITY CURING ON SUPPORT PRICE[1]

By LINUS R. WALTON, WILEY H. HENSON, JR., and JOE M. BUNN
Agricultural Engineers, USDA, ARS, University of Kentucky and Associate Professor, Lexington, Ky., U.S.A.

An experiment was designed to determine the quality deterioration of burley tobacco due to low drying rate, i.e., excessive humidity during the cure. Support price was used as an indication of quality. The period of exposure to slow drying conditions varied in length and stage of application during the cure. Three temperatures (50, 65, 80°F), two humidities (80, 90%) and six periods of exposure (0, 48, 96, 144, 192, 240 hrs.) were applied during the initial stage and yellow stage of cure. When not exposed to an adverse environment, the tobacco was cured at near optimum conditions. A prediction equation was determined for each stage of application. The results showed that most of the decline in support price occurred at 90% RH. The decline in support price was as much as 9¢/lb at 50°, 90% during the initial stage of cure and 8¢/lb at 65°, 90% during the yellow stage.

INTRODUCTION

Three environmental factors largely determine the success or failure of the curing process: air velocity, air temperature, and relative humidity. The optimum temperature, relative humidity and air velocity needed to cure good quality burley tobacco (3,4) are:

Temperature = 60 to 90°F (mean daily)
Relative humidity = 65 to 70% (mean daily)
Air velocity = 15 $ft^3/min/ft^2$ empty chamber

The narrowness of the relative humidity range indicates that tobacco could easily dry at an undesirable rate.

The normal leaf changes color from green to yellow and then to brown during the cure. A buff tan is the most desirable color for the cured leaf. A relative humidity above 70% will cause the tobacco to dry too slowly. The tobacco may houseburn, a condition characterized by a darkened leaf.

Equipment necessary to maintain conditions in the desired ranges would be costly. A program of modifying only the more extreme environmental conditions that occur during the curing season appears to be more economical than complete environmental control. Hamon (2) estimated the damage to burley tobacco due to adverse weather conditions during the cure to be as high as 12%.

A measure of quality deterioration of burley tobacco because of adverse curing conditions is needed to develop a program for environmental modification. In particular, the time dependence of adverse environmental conditions needs to be determined, i. e., how long must an adverse environmental condition persist before leaf quality is lowered.

An experiment was run during the 1969 curing season to determine the effects of low drying (high humidity condition) on the quality of burley tobacco. The objective was to determine the quality deterioration of burley tobacco due to low drying rate at moderate temperatures as humidity increases above optimum and as exposure to a given adverse condition increases.

EXPERIMENTAL METHODS

The plan was to evaluate the support price of tobacco exposed to adverse conditions for varying periods of time and at various stages of the cure and then to determine a prediction equation from the data. The following levels of variables (5) were used:

Temperature	50°, 65°, 80°F
Relative Humidity	80, 90%
Air Velocity	15 $ft^3/min/ft^2$ empty chamber
Times of Exposure	0,48,96,144,192,240 hrs.
Stage of cure	Initial, yellow

The tobacco was cured at 70°F and 70% r.h. except when subjected to the listed conditions for the various exposure times. The zero hour time of exposure was, therefore, merely check tobacco cured at 70°F, 70% for the duration of the cure.

Environmental cabinets capable of controlling the dry bulb temperature and dewpoint temperature with ± 1°F were used to control the curing environment (1). Only three cabinets were available to provide the slow drying environments; therefore, tobacco was harvested on three different dates. The second harvest date provided tobacco for both the last initial stage test and the first yellow stage test.

Tobacco was cut in the morning, allowed to wilt during the day and brought into the laboratory in the afternoon. The variety Burley 21 was used in all tests. For the initial stage of cure tests the tobacco was randomly

[1] *The investigation reported in this paper (No. 72-2-49) is in connection with a joint project of the Agricultural Engineering Research Division, Agricultural Research Service, U. S. Department of Agriculture, and the Kentucky Agricultural Experiment Station, College of Agriculture, University of Kentucky, and is published with the approval of the Directors of the Division and the Station. Contribution received: June 27, 1972. Tob. Sci. XVII: 25-27; 1973.*

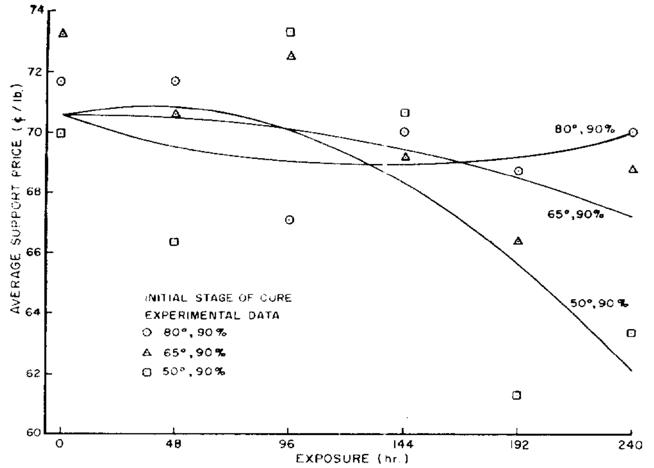

Figure 1. Predicted and actual support price as affected by temperature and time of exposure during the initial stage of cure.

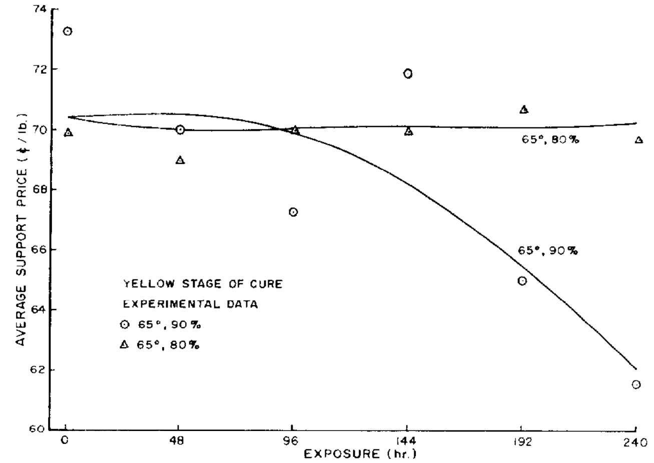

Figure 2. Predicted and actual support price as affected by humidity and time of exposure during the yellow stage of cure.

assigned to three batches, with the sample size for each treatment being one stick with six plants on each stick. One zero hour exposure was taken from each batch and placed directly in the 70°F, 70% environment. The five remaining sticks in each of the three batches were placed in three cabinets which provided three of the slow drying environments. Sticks were removed from the cabinets after 48-, 96-, 144-, 192- and 240-hour exposure periods to the adverse environments and placed in the 70°F, 70% environment. After transfer, the tobacco remained in the 70°, 70% environment until cured.

The tobacco for the yellow stage remained in the 70°, 70% environment until it reached the yellow stage (approximately 80 to 90% yellow leaf area as compared with green and brown) as judged by visual observation. Therefore, the initial stage of cure is defined as the 10 days of cure beginning immediately after field wilt. The yellow stage of cure is defined as beginning at the time when the tobacco reaches 90% yellow as compared to green and brown and proceeding for 10 days.

The effects of experimental treatments on the tobacco were assayed by subjective visual observations during the cure and by government grade at the end of the process. Farm-graded samples (X, C, B) were evaluated by government graders according to standard grades for Burley Type 31, 1969 crop.

RESULTS AND DISCUSSION

The average support price was determined for each sample by multiplying the support price for each grade by the weight of that grade, adding to determine the total value of the sample and dividing by the total weight of the sample. The treatments appeared to affect the three grades equally.

A separate mathematical model was sought for each of the two stages of cure. Both models were to be of the same general form with initial and boundary conditions as follows:

$$Y = f(E, \bar{T}, \bar{R}) \qquad (1)$$

$$Y = f(O, \bar{T}, \bar{R}) = \text{constant}$$

$$Y = f(E, O, O) = \text{constant}$$

where Y = average support price, ¢/lb,

E = Period of exposure to adverse environment, hrs,

$\bar{T}$ = (temperature − 70°), degrees Fahrenheit, and

$\bar{R}$ = (relative humidity − 70%).

The only terms that can satisfy the initial and boundary condition are product terms that include E and either $\bar{T}$ and $\bar{R}$ or both. A regression equation with 17 terms was used:

$$Y = a_0 + a_1 \bar{T} E + a_2 \bar{R} E + a_3 \bar{T} \bar{R} E + a_4 \bar{T} E^2 + a_5 \bar{T}^2 E + a_6 \bar{T}^2 E^2 + a_7 \bar{R} E^2 + a_8 \bar{R}^2 E + a_9 \bar{R}^2 E^2 + a_{10} \bar{T} \bar{R} E^2 + a_{11} \bar{T} \bar{R}^2 E + a_{12} \bar{T} \bar{R} E + a_{13} \bar{T} \bar{R}^2 E^2 + a_{14} \bar{T}^2 \bar{R} E^2 + a_{15} \bar{T}^2 \bar{R}^2 E + a_{16} \bar{T}^2 \bar{R}^2 E^2 \qquad (2)$$

The coefficients in equation 2 were determined by multiple regression techniques. After all coefficients were determined, terms were systematically eliminated until the standard error was minimized. The resulting equation for tobacco exposed to a slow drying environment during the initial stage of cure was:

$$Y = 70.66 + 2.1684\,(10^{-3})\,\bar{T} E + 4.6217\,(10^{-4})\,\bar{R} E - 1.3930\,(10^{-5})\,\bar{T} E^2 - 2.3022\,(10^{-5})\,\bar{T}^2 E - 4.5899\,(10^{-5})\,\bar{R}^2 E - 9.3137\,(10^{-6})\,\bar{T} \bar{R}^2 E + 6.0141\,(10^{-8})\,\bar{T} \bar{R}^2 E^2 \qquad (3)$$

The R square was 0.4220, the standard error of Y was 2.30 ¢/lb (28 d.f.), and the standard deviation was 2.71¢/lb (35 d.f.).

The regression equation for tobacco exposed to the slow drying environment during the yellow stage of cure was:

$$Y = 70.68 + 5.7218\,(10^{-3})\,\bar{T} E - 2.8280\,(10^{-5})\,\bar{T} E^2 + 2.6698\,(10^{-4})\,\bar{T}^2 E - 1.3617\,(10^{-6})\,\bar{T}^2 E^2 - 3.5974\,(10^{-7})\,\bar{R}^2 E^2 - 2.2427\,(10^{-5})\,\bar{T} \bar{R}^2 E + 1.1175\,(10^{-7})\,\bar{T} \bar{R}^2 E^2 - 1.2920\,(10^{-6})\,\bar{T}^2 \bar{R}^2 E + 7.1435\,(10^{-9})\,\bar{T}^2 \bar{R}^2 E^2 \qquad (4)$$

The R square was 0.6575, the standard error of Y was 1.77¢/lb (26 d.f.), and the standard deviation was 2.61¢/lb (35 d.f.).

Equations 3 and 4 show the effect of damage during both stages of cure for several temperature humidity conditions. The effect of temperature was different within each stage of cure. The effect of temperature during the initial stage of cure was for damage to increase as temperature decreased. The damage was due to the presence of green in the cured leaf, especially at 50°F. Apparently, a lengthy cold spell during the initial stage of cure will result in green tobacco, regardless of humidity. The loss was not as great as at a lower humidity, but did result in an 8¢/lb or 11% loss. The period of exposure necessary to cause this damage was 8 days at 50°, 90% compared with 12 hours at 50°, 30% (6). An example of the effect of temperature and period of exposure

Tobacco Science, 1973, 17-10, p. 25-27, ISSN.0082-4523.pdf

during the initial stage of cure is shown in **Figure 1**.

Effect of temperature during the yellow stage of cure differed greatly from that during the initial stage. For 50°F during the yellow stage, damage was slight. Both 65°F and 80°F showed significant damage at 90% relative humidity, with the 65°F showing more damage after 240 hours exposure. The damage was due mainly to a darkening of the leaf.

The effect of humidity was about the same for the two stages of cure. That is, 90% relative humidity caused the bulk of the damage as compared to the 80% r.h., regardless of the stage of cure when exposure was made. An example of the effect of relative humidity and period of exposure during the yellow stage of cure is shown in **Figure 2**. The 80% relative humidity caused damage at only 80°F for each stage of cure.

A summary of the damage after 240 hours for the various treatments is shown in **Table 1**.

An important side effect showed up during the tests. Leaf midribs were off color and brittle at the point of attachment to the stalk. This condition was most prevalent during the yellow stage of cure, at high temperatures and high humidities. A noticeable increase in leaves breaking from the stalk during handling was observed. At humidities above 90%, the midribs may rot sufficiently for the leaves to fall off the stalk.

Table 1. Decline in Support Price after 240 hours exposure as predicted by equations 3 and 4

Temp.	INITIAL STAGE 80% RH	INITIAL STAGE 90% RH	YELLOW STAGE 80% RH	YELLOW STAGE 90% RH
		¢/lb		
50°	0	9	1	1
65°	0	3	1	8
80°	2	1	4	4

SUMMARY AND CONCLUSIONS

The objective was to determine the damage to the quality of burley tobacco due to low drying rate at moderate temperatures as humidity increases above optimum and exposure to a given adverse condition increases. Support price was used as an indication of quality. Three temperatures (50°, 65°, 80°F), two humidities (80, 90%), and six periods of exposure (0, 48, 96, 144, 192, 240 hrs.) were investigated. The tobacco was exposed during both the initial and yellow stage of cure.

A prediction equation for value (¢/lb) as a function of temperature, humidity and period of exposure was determined by multiple regression techniques for each stage of cure. The results showed damage from low drying rate during both stages of cure. A maximum damage of 8¢/lb occurred at 50°, 90% during the initial stage of cure and 65°, 90% during the yellow stage of cure. A noticeable increase in leaves breaking from the stalk during handling after exposure to high humidities was attributed to brittleness accompanied by off color observed in the midrib at the point of attachment to the stalk.

CONCLUSIONS

1. Quality deterioriation due to slow drying rate increases as relative humidity increases above optimum and as period of exposure increases at moderate temperature.
2. Temperatures as low as 50°F during the initial stage of cure will cause green in the cured leaf after 240 hrs. at humidities as high as 90%.
3. The general effect of high humidity on burley tobacco is a darkening of the leaf.
4. The adverse effect of high humidity on the midrib indicates that tobacco midrib may decay sufficiently to cause leaves to fall off the stalk at humidities and exposures greater than those studied.

ACKNOWLEDGMENTS

The work reported was conducted jointly by the United States Department of Agriculture, Agricultural Research Service, Agricultural Engineering Research Division and the University of Kentucky, Department of Agricultural Engineering. The assistance of the many individuals who provided services and tobacco samples is gratefully acknowledged.

1. Messrs. Gerald Schlatter, Larry Wells and Carl King, USDA, University of Kentucky, and Terry Collett, University of Kentucky, for their services during conduction of field work and collection and reduction of data.
2. USDA Tobacco Grading Service, Lexington, Ky., for providing three official graders to evaluate the test samples.

LITERATURE CITED

1. Bunn, J. M. and W. H. Henson, Jr., "Environmental Control Facilities at the Agricultural Engineering Department, University of Kentucky." Humidity and Moisture, Vol. II, Chapt. 31, Reinhold Publishing Company, New York, 1965.
2. Hamon, W. Russell, "Weather and Burley Tobacco Curing." Mimeographed Report, U. S. Department of Commerce, Weather Bureau, Washington, D. C. 1954, 28 pages.
3. Jeffrey, R. N., "The Effects of Temperature and Relative Humidity During and After Curing upon the Quality of White Burley Tobacco." Bulletin No. 407, Ky. Agric. Exp. Station, Lexington, Ky., July, 1940.
4. Jeffrey, R. N., "The Relation of Curing Conditions to Quality in Burley Tobacco." Bulletin 496, Kentucky Agricultural Experiment Station, University of Kentucky, Lexington, Kentucky 40506, December, 1946.
5. Walton, L. R. and W. H. Henson, Jr., 1969 Annual Research Report on Harvesting and Curing Burley Tobacco. Unpublished report, Department of Agricultural Engineering, University of Kentucky, Lexington, Kentucky. March 1970.
6. Walton, L. R. and W. H. Henson, Jr., "Effect of Environment During Curing on the Quality of Burley Tobacco: I. Effect of Low Humidity Curing on Support Price." Tobacco Science 15: 51-57. Tobacco, New York 152(10): 43-46, May 14, 1971.