AEU-93

COOPERATIVE EXTENSION SERVICE
UNIVERSITY OF KENTUCKY — COLLEGE OF AGRICULTURE

BURLEY CURING TECHNOLOGY[1]

Curing is the sum-total of the physical and biochemical processes that convert burley tobacco from the yellowish-green high moisture leaf at harvest to the brown aromatic low moisture leaf packaged for market. The most obvious physical and biochemical processes are drying and color changes, respectively. Drying is simply the transfer of moisture from the leaf to the ambient environment. The color change is indicative of the myriad enzymatic reactions taking place within the leaf. The drying and enzymatic reaction rates must be compatible for good curing. If the enzymatic reactions are slow, drying must be slow; if enzymatic reactions are rapid, drying must be rapid. Johnson and Ogden (1931) described the importance of curing on the quality of the cured product: "The production of a desirable quality of tobacco depends upon the curing process as it does upon field development. The potential quality of the crop may be developed to its highest point, or the crop may be badly damaged, during the curing process; the success of the cure depending upon the air conditions maintained during this period."

Chemical Conversions

Burley leaves respond to the curing conditions imposed upon them by undergoing substantial chemical conversions with concurred changes of their color and texture and with losses of dry matter, ranging up to 20%. Frankenburg (1956) divides the chemical reactions into a first phase of a few days that cover the change from the yellowish-green at harvest to yellow (with some browning of the bottom leaves) and a second phase that covers the remainder of the cure. He summarized the most conspicuous chemical conversions as follows:

A. The first phase (summarized in Figure 1) is dominated by activities of the hydrolytic enzymes and the initiation of some of the oxidative activities. The hydrolytic enzymes convert the poly- and disaccharides to simple sugars; hydrolyze 50 to 70% of the leaf proteins to individual amino acids and break the pectins into lower molecular weight compounds. During this phase, which takes 4 to 5 days, the chlorophyll disappears and there is very little loss of dry matter.

Disaccharides and Polysaccharides--→	Simple Sugars
Proteins -------------------------------- →	Amino Acids
Amino Acids -------------------------- →	Slow Start of Oxidative Deamination
Pectins and Pentosans ---------------- →	Partial Hydrolysis to Pectic Acid, Uronic Acid and Methyl Alcohol
Chlorophyll ---------------------------- →	Conversion to Unknown Substances
Loss of Dry Weight ------------------ →	None to 1%

Figure 1: Curing First Phase (2 to 5 days) Used for All Tobacco Types (Frankenburg, 1956).

B. The second phase (summarized in Figure 2), which occurs only in air cured tobacco, is dominated by oxidative reactions. These oxidative reactions oxidize the simple sugars to acids, CO2 and water, deaminate amino acids; and oxidize and polymerize phenols to brown products. An appreciable loss of dry matter occurs during this second phase of curing.

[1] by Dr. Linus R. Walton, Professor, Agricultural Engineering Dept., U. Ky. College of Agriculture, mid-1980s, reviewed and reprinted 2-2004 by L. Walton, Prof. & G. Duncan, Ext. Prof., Biosystems & Agric. Engr. Dept., Coll. of Agr., U. Ky.

Simple Sugars	→	Oxidation to Acids and to CO2 1H20
Amino Acids	→	Increased Oxidation deamination, Formation of Ammonia and of Amides, Particularly Asparagine
Organic Acids	→	Conversion of Malic into Citric Acid: Decarboxylations
Phenols	→	Oxidation and Polymerization to Brown Products
Alkaloids	→	Disappearances to a Small Extent (5% Decrease)
Loss of Dry Weight	→	From 5% (Air-cured Cigarette Tobaccos) Up to 25% (Cigar Tobaccos Cured "On the Stalk")

Figure 2: Curing – Second Phase (5 to 10 Weeks) Used for Air-cured Tobacco Only (Frankenburg, 1956).

The most obvious result of the chemical conversions is the color change of the leaves. Chlorophyll disappears almost completely during the first phase of curing, and with it, the green color of the leaves. Since the yellow leaf pigments, carotene and xanthophylls, are degraded at a considerably slower rate than chlorophyll, the leaves assume a bright yellow color toward the end of this first phase of curing. The brown color of tobacco is caused by the oxidation of polyphenols and the polymerization to brown products.

Many of the chemical changes that occur in the early stage of curing, before dehydration becomes a factor, are the continued processes of leaf sensecense which starts as the leaves mature before harvest.

Having divided the biochemical reactions into two phases, it is interesting to note some of the major differences between the flue cured tobacco which goes through the first phase only and burley tobacco which goes through both phases. The flue cured leaf is prevented from entering the second phase of curing by exposing the leaves to temperatures above 105°F which deactivates the enzymes. Thus, flue-cured tobacco is higher in sugars, amino acids, malic acid, and polyphenols than is burley tobacco. Flue-cured tobacco has a lower dry weight loss and a lower citric acid content than does burley tobacco. Since oxidation of polyphenols is prevented, flue-cured tobacco retains the yellow color that it possesses at the end of the first phase of curing.

The primary variable that determines the rate of chemical conversions in burley curing is temperature. A frequently quoted approximation, known as the van't Hoff rule, states that the reaction rate doubles for each 10°C (18°F) rise in temperature. Since oxidation reactions are important, the availability of oxygen is important; however, in air-curing of burley, adequate oxygen is always available. Secondary variables are drying rate and sunlight. Chemical reaction rate goes up or down with drying rate but only to a slight extent as compared to temperature. Sunlight enhances curing as opposed to darkness.

Drying

Tobacco is a hygroscopic material which has considerable intercellular pore space. Tobacco exchanges moisture with the ambient air until the moisture content of the leaf is in equilibrium with the relative humidity of the ambient air. The intercellular space plays an important part in the moisture transfer process. During curing, the interior cells give up moisture to the air in the intercellular pore space which then moves out of the leaf through the epidermal cells and stomata due to the moisture content gradient between the leaf and the ambient environment. This process continues until the relative humidity within the intercellular pore space is equal to the relative humidity of the ambient air.

Equilibrium moisture content of burley tobacco is shown as a function of temperature and relative humidity in Figure 3. Some definitions are necessary for the proper use of this figure:

Moisture Content (dry basis) = ratio of weight of moisture to dry weight

$$M.C.\ (dry\ basis) = (W_W - W_D)/W_D * 100,\ (\%)$$

Where

W_W = wet weight of tobacco, and
W_D = dry weight of tobacco.

Moisture Content (wet basis) = ratio of weight of moisture to wet weight

$$M.C.\ (wet\ basis) = (W_W - W_D)/W_W * 100,\ (\%)$$

Relative Humidity = ratio of moisture (lb H_20/lb dry air) in air to the maximum amount of moisture that the air can hold at the same temperature.

As long as the moisture content of the tobacco leaf is different than the equilibrium moisture content of the air, moisture will diffuse from the higher to the lower moisture content. Freshly cut tobacco is about 85% (wet basis) moisture and will dry to about 15% (wet basis) moisture.

These environmental factors affect the drying of burley tobacco; temperature, relative humidity, and air flow. Jeffrey (1940) gave the range of these variables that produce good quality burley tobacco are:

Temperature ----------------------- 65 - 90°F (mean daily)
Relative Humidity ---------------- 65 to 70% (mean daily)
Air Velocity ----------------------- 15 ft/min (minimum)

The narrowness of the relative humidity range makes it the most critical variable (the most likely to deviate outside the norm). The mean daily temperature and relative humidity is the average of the high and low temperature and relative humidity for a given day. For example, if the minimum and maximum temperature temperatures on a given day are 55 and 75°F respectively, the mean daily temperature is 65°F. If the minimum and maximum relative humidity are 60 and 80% respectively, the mean daily relative humidity is 70%. Therefore, the temperature and relative humidity are proper for good curing even though the extremes are well outside the accepted range. Of course, the airflow is also provided by the naturally occurring weather conditions by placing the curing barn broadside to the prevailing wind, by providing one-third of the wall area in ventilators, and by providing proper spacing on the tier rail.

Our only control of the curing process is control of the drying rate. This is done primarily by opening the ventilators to promote drying and closing the ventilators to retard drying. The leaf characteristics that result from improper curing conditions are as follows:

a. Low temperature results in green regardless of the relative humidity and air flow. The chemical conversions are too slow because of the low temperature. However, the drying rate does determine the degree of green cast in the leaf. The higher the drying rate, the greener the cured leaf.
b. Low humidity, moderate temperature results in greenish or mottled leaf.
c. Low humidity, high temperature (75°F and above) causes pie-bald (yellow) leaf.
d. High humidity, moderate to high temperature is "houseburning" weather. Houseburn results in a dark leaf with excessive loss in dry weight. The excessive weight loss is primarily caused by the action of microorganisms that cause soft rot.

Temperature determines the undesirable colors that prevail in the cured leaf during improper curing; however it is the relative humidity (if airflow is adequate) that determines the degree of damage incurred. Walton et al. (1971, 1973) showed that the greater the departure from the optimum relative humidity range, the greater the damage to the quality of the tobacco.

Relative humidity, airflow, and temperature interact to affect drying of tobacco. The effect of each on drying is as follows:

a. Drying increases as airflow increases for a constant relative humidity and temperature.
b. Drying increases as relative humidity decreases for a constant temperature and airflow rate.
c. Drying increases as temperatures increases for a constant relative humidity and airflow.

Of these three environmental factors, airflow is the easiest for us to control. The major managerial variables other than barn management is to harvest the crop at optimum maturity, stagger spacing to avoid green tips in contact with drier flyings of rail below, and to provide proper spacing on the tier rail (9 to 12 inches in older barns with 3 ½ to 4 feet vertical spacing between tiers and 7 to 8 inches for the 3-tier barns with 4 ½ to 5 feet vertical tier spacing. (Duncan & Walton, 1986) Never hang freshly harvested tobacco under partially cured tobacco. Assuming that we've hung our tobacco properly, we will now turn our attention to how to apply what we've learned when threatened by adverse curing conditions.

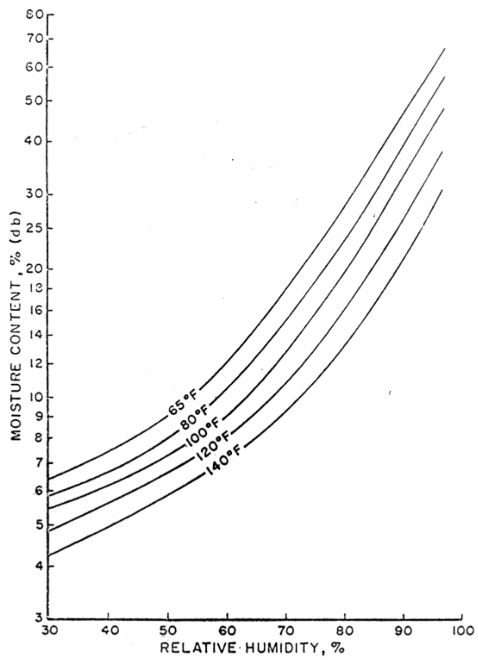

Fig. 3. Equilibrium moisture content as a function of temperature and relative humidity from combined data of Jeffrey (1940) and Locklair, et. al. (1957).

When our tobacco is drying too fast, we need to retard the drying rate. If our temperature is within the acceptable range, we should be able to improve the curing by reducing the ventilation. Probably the most difficult condition we have to face is low temperature during the first week of curing. For low temperatures (low to mid 50's°F mean daily), our only recourse is to close ventilators to retard drying and stall for warmer weather.

When we're confronted with humid, houseburning weather, we want our tobacco to dry as much as possible. Therefore, we should keep our ventilators open to enhance drying. Moving humid air does far more good than allowing air to stagnate. That is why using fans is advised as a means of reducing houseburn (Duncan, 1992). Since there is no evidence that we can get too much airflow when the temperature and relative humidity are normal (within optimum range), we can conclude that for normal and humid weather, we should leave the ventilators open at all times during the first three weeks of the cure. Prudence, of course, dictates, that we must close the ventilators to protect against blowing rain.

Heat can also be added to alleviate houseburn. The heat raises the temperature of the air entering the tobacco from below which greatly increases the moisture holding capacity of the air which in turn lowers the relative humidity. It is the lowering of the relative humidity that alleviates the houseburn.

A question that often arises is how do we know what curing conditions we have. We must not lose sight of the fact that it is the tobacco we're interested in and our interest in the weather is its effect on the tobacco.

Experience often permits the farmer to evaluate the progress of his cure. However, it is of benefit to us to study how the temperature and relative humidity varies inside and outside of a burley curing barn as shown in Figures 4 and 5. The conditions inside the barn do follow the same general pattern as the conditions outside the barn. We can expect the average temperature inside the barn to be slightly lower than outside because of evaporative cooling during drying and the average relative humidity inside to be higher than outside. It is the air entering the barn (outside air) that we need to monitor for good curing conditions. We generally know when the weather is too humid or too cool. We can calculate the mean daily temperature and relative humidity by averaging the high and low for the day. We can also note that on normal days (no fronts passing through), the mean temperatures and relative humidity are encountered about 6 hours after the peak temperature. Therefore a thermometer and a simple dial humidity indicator, or combination of the two called a hygrometer, can be used to determine the mean temperature and relative humidity. Another method is to use the feel (case) of the flyings as a rough indicator of relative humidity inside the barn as shown in Table 1. When flyings feel "dry to low case", the humidity is about right for good curing (O'Bannon, 1947).

REFERENCES

1. Duncan, G. A. 1992. Using fans in Conventional Burley Barns. AEN-69. Coop. Extension Service, Coll. of Agric., Univ. of Ky., Lexington.

2. Duncan, G. A. and L. R. Walton. 1986. Curing Burley Tobacco. AEN-59. Cooperative Extension Service, Coll. of Agric., Univ. of Ky., Lexington

3. Frankenburg, W.G. 1956. Chemical conversions in harvested tobacco leaves. Tobacco 14:10-14.

4. Jeffrey, R.N. 1940. The effect of temperature and relative humidity during and after curing upon the quality of white burley tobacco. Bulletin No. 407, Ky. Agricultural Experiment Station, Univ. of Ky., Lexington.

5. Jeffrey, R.N. 1946. The relation of curing conditions to quality in burley tobacco. Bulletin No. 496, Ky. Agricultural Experiment Station, Univ. of Ky., Lexington.

6. Johnson, J. and W. B. Ogden. 1931. The relation of air conditions to tobacco curing. Research Bulletin 110, Agricultural Experiment Station, Univ. of Wisconsin, Madison.

7. Locklair, E. G., L. G. Veasey and M. Samfield. 1957. Equilibrium desorption of water vapor on tobacco. Agricultural and Food Chemistry 5:294-298

8. Massie, I.E. and J.H. Smiley. 1974. Harvesting and curing burley tobacco. AGR-14, Coop. Ext. Service, Coll. of Agr., Univ. of Ky., Lexington.

9. O'Bannon, L. S. 1974. Principles of burley tobacco barn operation. Bulletin 501, Ky. Agric. Experiment Station, Univ. of Ky., Lexington.

10. Walton, L.R. and W.H. Henson, Jr. 1971. Effect of environment during curing on the quality of burley tobacco. I. Effect of low humidity curing on support price. Tobacco Science 15:54-57.

11. Walton, L.R., W.H. Henson, Jr., and J.M. Bunn. 1973. Effect of environment during curing on the quality of burley tobacco. II. Effect of high humidity curing on support price. Tobacco Science 17:25-27.

12. Walton, L.R. 1974. Moisture diffusion in the cured burley tobacco leaf. Unpublished Dissertation, University of Tennessee, Knoxville, TN. 112 p.

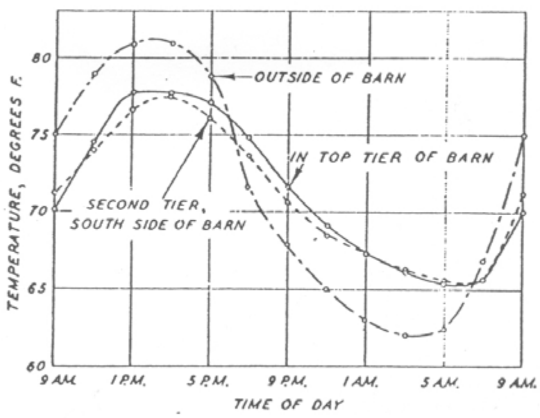

Figure 4. Average temperature outside and inside a full burley tobacco barn during good curing weather at Lexington (Jeffrey, 1946).

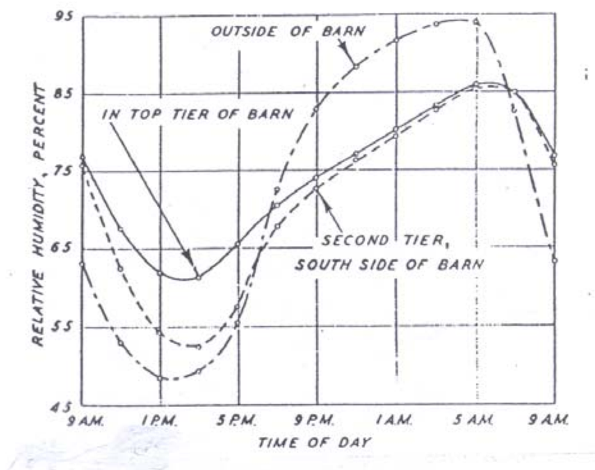

Figure 5: Average relative humidity outside and inside a full Burley tobacco barn during good curing weather at Lexington (Jeffrey, 1946).

Table 1: Feel of Cured Tobacco Flyings in Relation to Relative Humidity.

Feel of Cured Leaf	Relative Humidity (Per cent)
High Case	90 to 100
Medium to high case	85 to 90
Medium case	80 to 85
Low to medium case	75 to 80
Low case	70 to 75
Dry to low case	65 to 70
Dry	60 to 65
Dry to brittle	55 to 60
Brittle	50 to 55
Fragile	0 to 50

a. From Kentucky Agricultural Experiment Station Bulletin 501 “Principles of Burley Tobacco Barn Operation.”