INFLUENCE OF DRYING RATE DURING CURING ON THE PHYSICAL PROPERTIES AND QUALITY OF SHADE-GROWN TOBACCO

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CONTENTS

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THE INFLUENCE OF DRYING RATE DURING CURING ON THE PHYSICAL PROPERTIES AND QUALITY OF SHADE-GROWN TOBACCO

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I. Introduction

During curing of tobacco leaves, two kinds of process go on. The leaf dries and at the same time a complex series of chemical changes occurs. Most of the loss in weight of leaves during curing results from the drying process, which is essentially a physical loss of water.

This bulletin reports a study of the influence of the rate at which leaves dry upon the physical properties and quality of shade-grown tobacco. Rate of water loss can be varied by raising the temperature during curing, lowering relative humidity, or possibly by increasing the flow of air past the drying leaf. Experiments were conducted so as to hold the rate of chemical reaction constant, while the rate of drying was varied. This was accomplished by curing leaves at a constant wet-bulb temperature[1] while dry-bulb temperature, relative humidity, and speed of air movement past the leaf were varied.

The progress of weight loss in leaves was followed, as also were the changes in leaf color during the curing process. After curing was completed, leaves were graded for color and uniformity of color, and these properties were related to rate of drying of leaves during curing. Other physical properties were also evaluated at this time. Finally, leaves were fermented according to current methods and sorted into commercial grades. The relation of drying rate to the commercial standards of quality was explored.

II. Review of Literature

An early study of the curing of Connecticut shade tobacco under controlled atmospheric conditions was conducted by Chapman in 1922 (2). He cured the third priming (13th to 16th leaves inclusive) of Cuban Shade in a small air-conditioned cabinet for the purpose of determining the atmospheric conditions which would increase the yield of light-colored leaves. The results of the experiment showed that conditions of 95° to 100° F. and 81 to 83 per cent relative humidity were not favorable to the production of good quality wrapper tobacco. It was concluded that lower temperatures and a longer curing period were necessary to attain more satisfactory results.

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[1]The dry-bulb temperature is that recorded by an ordinary thermometer. The wet-bulb temperature is obtained by enclosing a thermometer bulb in wet wicking and blowing air past it. The cooling caused by evaporation of water causes the wet-bulb temperature to be lower than the dry-bulb temperature. From the dry- and wet-bulb readings, relative humidity can be determined. A moist tobacco leaf behaves like a wet-bulb thermometer during early stages of curing because it is cooled as it loses water by evaporation. In this study it is assumed that the leaves are at the temperature of the wet-bulb thermometer during the period of their most rapid water loss.

Experiments on the curing of shade tobacco at controlled conditions of temperature and humidity were reported by Anderson, Swanback, and Street some 25 years ago (1). Samples of shade tobacco were cured under conditions of (a) low humidity (70 to 75 per cent), (b) high humidity (90 to 95 per cent) and (c) a 12-hour alternation of low and high humidities all with the temperature set at 90° F. The findings showed that the best quality tobacco was obtained at the low humidity. The leaf color was predominantly light brown, which is a desirable shade in cigar wrapper tobacco. High humidity caused trouble from pole rot and leaf color tended to be dark. Reddish shades of color resulted from curing at the high humidity. Subjecting the leaves to alternate low and high humidity produced better uniformity of color than did either of the constant conditions. Weight loss during curing was not determined in these experiments. These workers concluded that high temperatures should be used only in conjunction with fairly high humidities during curing. Low temperatures would result in good quality leaf only when the humidity was also kept low.

Vickery and Meiss (4) have made an extensive investigation of the chemical changes that occur during the normal curing and fermentation of Connecticut shade tobacco. They found that the major chemical changes took place during the first eight to 12 days of curing, in which time the tobacco lost 75 to 80 per cent of the original fresh weight. The most notable changes in chemical constituents were the conversion of protein to soluble nitrogenous compounds, decrease in malic acid and an increase in citric acid, the disappearance of starch and sugars, and loss of about one-half of the ether-soluble components, which included chlorophyll. Curing resulted in a total loss of some 16 per cent of the organic solids of the tobacco leaf.

No previous studies have been reported in which the rate of certain physical changes during curing, such as drying, have been followed and related in turn to the physical properties of the cured and fermented leaf of shade-grown tobacco.

III. Experimental Methods

Field Methods

Shade-grown tobacco of the Connecticut 49 variety was used in the experiment. Plants were grown in a large tent using conventional methods of tobacco production. Tobacco for curing was obtained as three single-leaf pickings, each leaf being harvested at a stage of technical ripeness. Counting upward from the base of the stalk the 6th, 12th, and 20th leaves were chosen. Prior to and between the sampling dates, the remaining leaves on the stalk were picked according to a normal schedule of harvest.

Preparation of Leaf Samples

A single leaf at the desired stalk position was removed from approximately 110 plants in a row. Healthy, uniform leaves were then dealt into 72 piles of one leaf each, the remainder being discarded. This procedure was repeated with leaves from the next row until each pile contained 20 leaves from as many rows. The variability in fresh weight of the 72 samples was estimated through the coefficient of variation which ranged from 2.9 to 5.7 for the three leaves harvested. Variability increased with higher leaf positions on the plant.

Management of the Samples

Each sample of 20 leaves was machine-sewn onto a lath. The 72 laths of tobacco thus prepared were evenly distributed among six air-conditioned cabinets and the curing operation begun immediately. The atmospheric conditions maintained during curing were attained before the laths of tobacco were hung. About four hours elapsed from the time picking started in the field until the laths of tobacco were placed in the cabinets to begin curing.

Curing Methods

The curing of the tobacco samples took place in wooden cabinets having inside dimensions of six feet by four feet by six feet high. The cabinets were arranged in two sets of three, each set being connected by a common duct to an air conditioner. Thus cabinets within a set were supplied with portions of the same air stream and were maintained essentially at the same temperature and relative humidity. The air velocity in each cabinet was regulated by a damper inserted in the branch duct leading into the individual cabinet. The air conditioning system permitted the dry- and wet-bulb temperatures to be controlled within $\pm$ 2° F. and relative humidity within about three per cent of the desired setting.

A constant wet-bulb temperature of 80° F. was selected to cure the tobacco in both sets of cabinets. To obtain a slow rate of drying in one set of cabinets the relative humidity was set at 77 per cent, which with a wet-bulb temperature of 80° F. fixed the dry-bulb temperature at 86° F. These constant conditions were employed for curing each of the three single-leaf pickings. For the curing of the 6th and 12th leaf positions the second set of cabinets were operated at constant conditions of 90° F. dry-bulb temperature and 65 per cent relative humidity. For curing the 20th leaf the conditions in the second set of cabinets were changed to 94° F. and 54 per cent.

Air velocities of 15, 25, and 35 feet per minute respectively were employed in the three individual cabinets in each set. Thus each air velocity was used with each combination of temperature and humidity.

IV. Results

Weight Loss During Curing

During the curing process three laths of leaves per cabinet were weighed daily. These weighings were used to obtain the daily weight loss.

Effect of air velocity. The drying rate of the tobacco was not influenced by air velocity within the range employed in these experiments, 15 to 35 feet per minute (Table 1). When leaves are freely exposed to air movement, a velocity of 15 feet per minute is apparently sufficient to carry off the water evaporated from leaves, and further increase in air velocity does not hasten the drying rate of leaves. In this respect, loss of water from harvested leaves differs from water loss by a porous clay bulb. In the latter case, increasing the velocity of air movement increases the rate of water loss. This result was confirmed for all pickings and under a variety of settings of temperature and relative humidity. Evidently the water in the tobacco leaf is not lost freely as from an open water surface. The structure of the leaf and the fact that the more water is lost, the more firmly what remains is held by the leaf, both tend to restrict water loss from the curing leaf.

Table 1. Effect of air velocity during curing on the percentage of original fresh weight retained by leaves*

Days of curing	Percent of orginal fresh weight retained		
	15 ft./min.	25 ft./min.	35 ft./min.
0	100.0	100.0	100.0
1	82.8	82.1	81.4
2	73.7	72.2	71.5
3	65.5	64.1	63.2
4	58.4	56.7	55.9
5	50.6	48.8	48.1
6	41.9	40.5	40.3
7	33.4	32.7	33.1
8	25.5	25.6	26.4
9	19.1	19.8	20.5
10	16.2	16.8	18.0
11	13.0	13.5	14.8
12	10.6	11.4	12.3
13	10.1	10.7	11.6

*In this experiment, leaves were from position six on the plant. Curing was carried out at 90° F. dry-bulb temperature, 65 per cent relative humidity and 80° F. wet-bulb temperature.

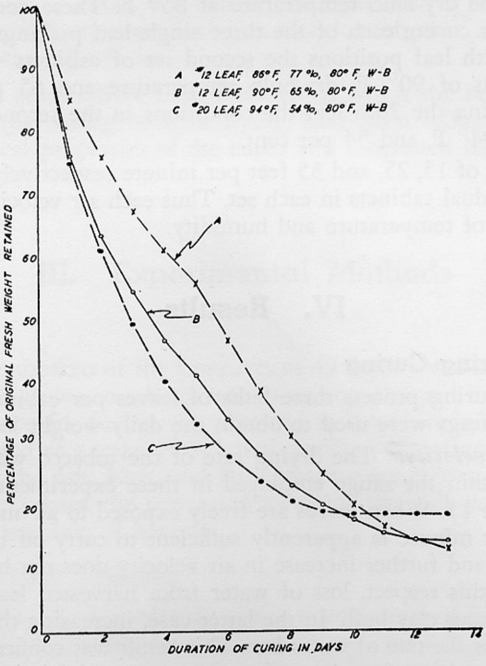

Figure 1. Loss of weight by leaves of shade-grown tobacco during curing in atmospheres favoring different rates of drying. Connecticut 49 variety, crop of 1953.

Moreover, the rate of color changes during curing, the color developed at the end of curing, the uniformity of color of cured leaves and the commercial grades of cured, fermented leaves showed no relationship to velocity of air movement during the curing process. Leaves from the different stalk positions passed from the green stage through yellow and into the brown stage at essentially the same rate whether the velocity was 15 or 35 feet per minute. Therefore, in the discussion to follow, when leaves were cured in varying air velocities, the effect of this can be ignored and differences can be ascribed to other causes.

Effect of temperature and relative humidity. Under conditions of rapid and slow drying during curing, leaves lost almost all of their moisture within 13 days, regardless of leaf position on the plant before picking (Figure 1). The drying curves for leaves from positions 6, 12, and 20 and cured at 86° and 77 per cent relative humidity were essentially the same, excepting that residual dry weight at the end of curing increased with leaf position (Table 2). The time required for leaves to lose 50 per cent of their initial weight is recorded in Table 2, together with the percentage of initial weight retained at the end of curing. Some shade-tobacco growers attempt to cure leaves so that they lose 50 per cent of their weight at harvest in from 90 to 100 hours. The rapidly drying leaves from positions 12 and 20 on the plants reached this stage somewhat more rapidly than in commercial curing whereas leaves from position six and all leaves subjected to slow drying reached this stage more slowly.

Table 2. Weight characteristics of leaves subjected to fast and slow drying at a wet-bulb temperature of 80° F.

Position of leaf on plant	Time (hours) for leaves to lose half their weight		Per cent of initial weight at end of curing	
	Fast Drying	Slow Drying	Fast Drying	Slow Drying
6	115*	140†	11.6	9.7
12	85*	132†	14.5	13.5
20	72‡	144†	18.7	15.5

*Leaves cured at dry-bulb temperature of 90° F. and relative humidity of 65 per cent.
†Leaves cured at dry-bulb temperature of 86° F. and relative humidity of 77 per cent.
‡Leaves cured at dry-bulb temperature of 94° F. and relative humidity of 54 per cent.

Regardless of leaf position, leaves undergoing slow drying lost more of their initial weight at the end of curing than corresponding leaves subjected to rapid drying (Table 2). Thus for position six, the difference in weight at the end of curing amounts to 1.9 per cent. This difference represents loss of organic solids that were oxidized and lost from leaves undergoing slower drying. Although this difference seems small on an initial fresh weight basis, it is rather high when expressed on the basis of dry weight, being approximately 16 per cent. The reason for the loss of the extra organic solids is that the major chemical reactions going on in the curing leaf require water and that when leaves dry to 25 to 30 per cent of their initial weight, these reactions cease (4). Thus, within limits, the longer leaves take to dry to this moisture content, the more organic matter is lost and the lower will be their final dry weight.

At the end of curing, the 12th leaf retained a higher percentage of its initial weight than did the 6th leaf. In turn the 20th leaf retained a still higher amount of its initial weight. Thus the leaves high on a plant have heavier body than the lower ones do.

Some growers of shade tobacco are of the opinion that leaves from tobacco plants grown under wet conditions lose weight more readily during curing than leaves from a dry weather crop. The results of the present experiments do not confirm this observation. Weather records for a 30-day period prior to the picking of the 6th leaf show the rainfall to have been 25 per cent heavier than normal and well distributed. Thus it might be termed a "wet-weather" crop. On the other hand, the rainfall for a month prior to picking the 12th leaf was nearly normal in amount and frequency. This crop would then be termed a "normal" crop as far as rainfall was concerned. Loss of weight occurred somewhat faster in the curing of the 12th leaf than for the 6th leaf (Table 2).

Changes in leaf color during curing. Each day a total of 40 leaves per cure were individually examined and classified into a color category which best described the relative distribution of green, yellow and brown. The scheme of color categories used in the experiment is outlined in Table 3.

Table 3. Color categories for describing changes in leaf color of shade-grown tobacco during curing

Category No.	Dominant color and description	Approximate ratios of green	yellow	brown
1	**Green.** Deep green color of the harvested leaf.	10	0	0
2	**Light Green.** Decidedly green but showing a slight yellow cast.	9	1	0
3	**Yellowish-Green.** Much green but small amount of yellow present.	8 - 7	2 - 3	0
4	**Yellow-Green.** More green than yellow. Slight amount of brown if any.	6 - 5	4	0 - 1
5	**Yellow.** More yellow than green. Small amount of brown if any.	4 - 3	6 - 5	0 - 2
6	**Brownish - Green - Yellow.** About equal yellow and green. Small amount of brown.	4 - 3	4	2 - 3
7	**Brown-Yellow.** Yellow in excess of brown. Some green persisting.	2	5 - 6	3 - 2
8	**Yellow-Brown.** About equal brown and yellow. Small amount of green.	2 - 1	4 - 3	4 - 5
9	**Yellowish - Brown.** Considerable brown. Some yellow and trace to slight amount of green.	1	3 - 2	6 - 8
10	**Brown.** Virtually all brown. Trace of yellow, green or both, if any.	0 - 1	1 - 0	9 - 10

From the color change data an index was calculated to characterize the color attained at each stage of curing. The index was computed for each day of curing by adding the products of number of leaves in a color category by the category number and dividing the sum by 40, the total number of leaves in a sample. These values for each leaf position are plotted against curing time in Figures 2, 3, and 4.

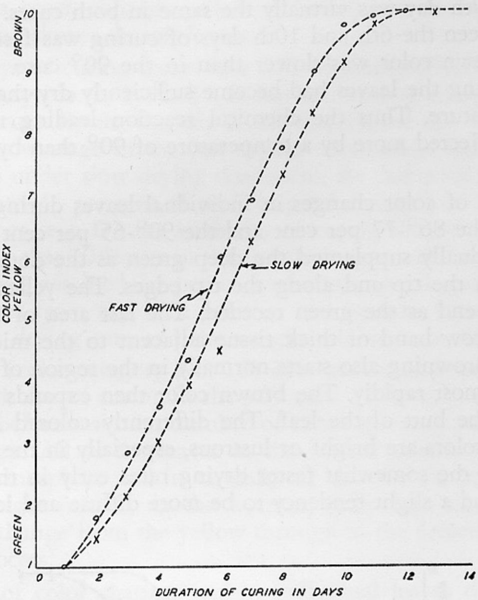

Figure 2. Changes in leaf color (expressed as a color index) in shade-grown tobacco as influenced by rate of drying during curing. Connecticut 49 variety, crop of 1953. See text for details.

Whether leaves from the 6th position on the stalk dried rapidly or slowly, two days of curing were required to cause any appreciable alteration in the deep green color of the freshly harvested leaf (Figure 2). A loss of nearly 20 per cent in weight is apparently necessary in lower primings of shade tobacco before sufficient chlorophyll is decomposed to lighten the strong green color. At two days of curing 30 leaves had acquired noticeable amounts of yellow color in the tip region of the leaf in the 90° (fast drying) cure as compared to 16 in the 86° cure. At this time there were more than twice as many deep green leaves in the slower drying cure. This is a clear indication that the more rapid drying rate was accompanied by a more rapid loss of green color in the leaf.

By the 6th day of curing the fast drying sample contained six leaves that were rated as yellow-green, i.e. green color more extensive over leaf surface than yellow, as compared to 18 leaves in the 86°-77 per cent cure. At the same time nine leaves were rated as yellow brown or brown (40 per cent or more of leaf surface browned) in the fast-drying sample and only one leaf in the slow-drying sample. The percentage of weight retained was still somewhat lower in the former cabinet (40 per cent vs. 49 per cent). The leaves in the 90° cure were in a more advanced degree of yellowing and browning after the same duration of curing than those in the 86° cure.

After nine days of curing, one-half of the 40-leaf sample from the 6th position was cured in the 90°-65 per cent cure, while 13 leaves were regarded as cured or fully browned in the 86°-77 per cent cure. The percentage of weight retained on the 9th day was virtually the same in both cures. While the rate of weight loss between the 6th and 10th days of curing was faster in the 86°, the formation of brown color was slower than in the 90° cure. It is likely that at this stage of curing the leaves had become sufficiently dry that they were at the dry-bulb temperature. Thus the chemical reaction leading to brown pigment formation was affected more by a temperature of 90° than by a cooler temperature of 86°.

The pattern of color changes in individual leaves during curing was quite similar in both the 86°-77 per cent and the 90°-65 per cent cures. The yellow color, which gradually supplanted the deep green as the dominant color, began to appear first in the tip and along the tip edges. The yellow color progressed toward the butt end as the green receded. The last area of the leaf to remain green was a narrow band of thick tissue adjacent to the midrib near the butt end of the leaf. Browning also starts normally in the region of the tip, where the leaf tissue dries most rapidly. The brown color then expands behind the yellow and spreads to the butt of the leaf. The differently colored areas were sharply defined and the colors are bright or lustrous, especially in the cooler cure. It appeared that with the somewhat faster drying rates early in the cure in the 90° cure the colors had a slight tendency to be more diffuse and less sharply defined.

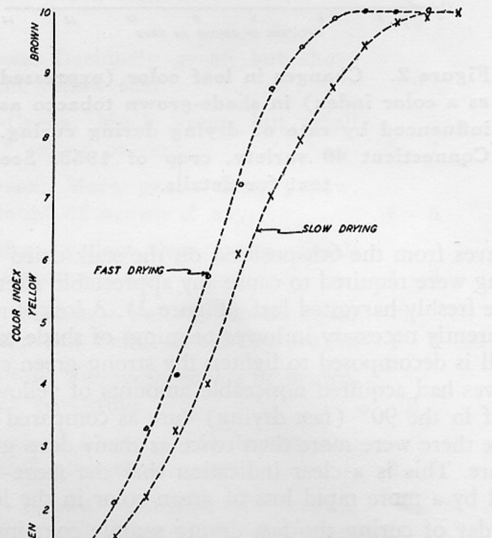

Figure 3. Changes in leaf color (expressed as a color index) in shade-grown tobacco as influenced by rate of drying during curing. Connecticut 49 variety, crop of 1953. See text for details.

As in the curing of the 6th leaf, the color changes in the 12th leaf were more rapid in the leaves dried at the faster rate (Figure 3). The procession of color change from green through yellow to brown was from one to two days ahead of that in the slower drying leaves.

After two days of curing there were still 19 leaves classified as deep green color (color category No. 1, Table 3) in the 86° cure as compared to only two leaves in the 90° cure. By the 4th day nearly one-half of the 40-leaf sample had advanced to a yellow stage in the fast drying cure, while only two leaves had attained this stage under slow drying conditions. At this point the leaves in the former cure retained 46 per cent of their original weight and those in the latter cure retained 61 per cent. On the sixth day of curing the color changes had advanced to the point that 20 leaves in the fast drying cure had become extensively browned. The leaves retained 34 per cent of the original weight. At the same time only six leaves from the 12th position had become browned to a similar extent in the slow drying cure and the weight retained was 46 per cent.

Cured leaves (color category No. 10) commenced to appear in appreciable numbers on the 7th day of curing in the 90° cure (Table 9). An additional day of curing elapsed before a similar number of cured leaves appeared in the cooler cure (slow drying). All of the leaves in the 40-leaf sample were cured in 11 days in the 90° atmosphere and in virtually 12 days in the 86° cure. Thus the greater loss of weight initially in the warmer, drier cure was accompanied by more rapid color change from the yellow through to the brown stage that marks the end of the process.

The pattern of color changes within individual leaves during curing was somewhat different in the two cures of the 12th leaf. In the slower drying cure color changes were sharp and well defined. Yellowing showed first in the tip region in sharply defined areas and progressed toward the butt end as the area of strong green color retreated. Browning also commenced generally in the tip and along leaf edges. The increased rate of drying in the 90° cure caused the yellow to appear mostly as a yellow cast over most of the leaf surface and diffused rather indefinitely into the green background. The yellow cast after becoming fairly intense, was gradually replaced by a brown cast that spread diffusely over the surface and at the same time there was relatively little decline in the amount of green color. As a result many of the leaves in the 90° cure attained a cured or dried state with a decided greenish cast accompanying the more dominant brown color.

For the 20th leaf the slow drying cure was maintained at 86° dry-bulb temperature, 77 per cent relative humidity and 80° wet-bulb temperature, the same conditions as were used for the slow drying cures of the 6th and 12th leaves. The conditions in the fast drying cure were changed to a higher temperature of 94° and lower humidity of 54 per cent, than was the case with the earlier pickings. In all fast drying cures the wet-bulb temperature was kept at 80° F. The contrast between drying rates was thus heightened for the curing of the uppermost leaf.

The pattern of the color changes in the 20th leaf was markedly different as a result of the wide differences in drying rates (Figure 4). In the cure operated at 86° and 77 per cent, the progress of color changes was similar to that observed in the earlier cures under these conditions. Yellowing commenced in the tip region of the leaf within two or three days of curing. The yellow areas were bright in color, sharply defined from the areas of rather deep green color, and they expanded toward the butt of the leaf as the green color retreated. Brown started to appear in noticeable amounts after about four or five days and replaced the yellow areas in the tip. The leaves passed through a strong yellow

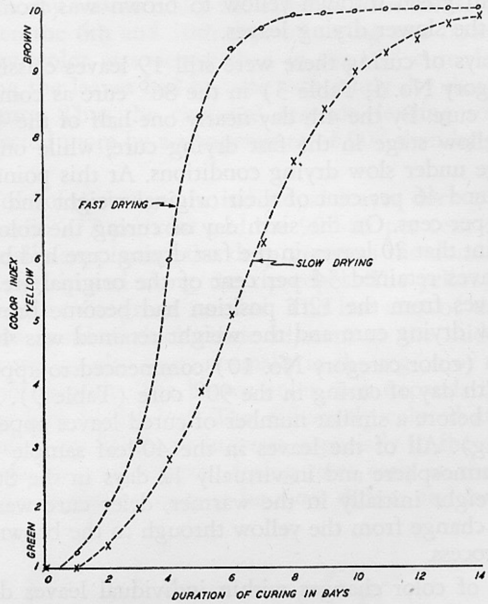

Figure 4. Changes in leaf color (expressed as a color index) in shade-grown tobacco as influenced by rate of drying during curing. Connecticut 49 variety, crop of 1953. See text for details.

stage during which time relatively small amounts of green and brown appeared in well-defined areas. The strong yellow stage was found to occur for all leaf positions cured at 86° when the percentage of weight retained was in the range of 50 to 60 per cent. Nearly all of the green color had disappeared by the time the leaves were approaching the completion of curing (browning) and the brown color became established in areas of the leaf lamina that had been yellow previously.

The color changes in the tobacco cured at 94° and 54 per cent followed an entirely different pattern. Within one day of curing the deep green color changed to a light yellowish green. A dull yellow cast was soon widespread and diffused over the leaf surface rather than being confined to the tip in sharply defined areas. The yellow cast did not become strong and it was difficult to classify the leaves into color categories. Brown started to appear as a dull, dirty spot or area in many leaves after about 72 hours of curing and quickly diffused over wider areas of the individual leaf. The brown cast seemed to replace the yellow, while the green color appeared to decline only slightly in intensity and extent of the leaf surface as the curing proceeded. Green remained the dominant background color in the tobacco as the dull brownish cast continued to spread over much of the leaf. Within a week of curing most of the leaves were quite dry and brittle and had a color best described as a brownish-green. When the curing terminated in 10 days the leaves were very dry and retained considerable green color mixed with about equal amounts of a dull, ill-defined brown cast. It is evident that the leaves lost moisture too rapidly to permit an extensive destruction of the chlorophyll and thus the cured leaves retained considerable green color. The rapid drying also caused early formation of the brown pigments and their rapid spread over the leaf surface. When leaves dry at relatively slow rates, it has been observed that the formation and spread of the brown color also proceeds slowly in individual leaves.

For the fast cure the leaves of position 20 on the stalk put into categories 7 through 10 do not exactly fit the description given for these categories in Table 5, although they represent a comparable degree of curing. Instead these categories represent leaves having considerable green color, a weak yellow cast, and increased amounts of brown going from category 7 to 10. The latter category included the cured leaves which were green-brown in color rather than the usual brown. The leaves in these categories were also dry, brittle, and difficult to handle without breaking or shattering. The leaves in the 86° cure which were classified into color categories 7 through 10 were distinctly yellow with increasing amounts of brown. Only minor amounts of green were present and the cured leaves (category 10) were distinctly brown.

The effect of rate of weight loss on the rate of yellowing was very marked in the curing of the 20th leaf. Yellowing or the disappearance of the deep green color of the freshly harvested leaf in the first few days of curing was accelerated by the much faster drying of the tobacco in the 94°-54 per cent atmosphere. Thus in the rapid drying cure only eight leaves out of 40 were classified in color category 1 (deep green) as compared to 26 in this color group after two days curing under slow drying conditions. Deep green leaves persisted in the 86° cure until the 5th day of curing, three days after they had disappeared in the drier cure. The appearance of cured leaves was two days earlier in the 94° cure and the number increased rapidly after five days of curing. In the 86° cure the number of cured leaves increased slowly after about seven days of curing.

The leaves in the 94° cure quickly passed from a yellow-green stage into brown-green stage as represented by color categories 7 through 10. The leaves, on the average, retained 28 per cent of their original weight at this point in the curing. On the whole, color changes in the 86° cure proceeded slowly. Midway during curing the leaves in the 40-leaf samples showed a wide variation in color. There were a few leaves in the sample that were only lightly yellowed and still very green in overall color while at the same time a similar number of leaves were classified as cured.

In agreement with results of the two earlier cures, it has been found that an acceleration of drying rate early in the curing is also accompanied by a faster rate of green color disappearance. This has occurred in present experiments, although between cures favoring different drying rates, the wet-bulb temperature of the atmosphere was the same. The subsequent color changes in the tobacco also take place sooner in the leaves that have dried faster in the initial stages of curing. This acceleration of the procession of color changes results in an earlier appearance of brown pigments and of cured leaves so that the curing process is completed in fewer days. The rate of weight loss in late primings can be so rapid that a considerable amount of chlorophyll remains undecomposed and the leaves, though cured sooner, retain a strong green color in addition to a certain amount of brown.

It is of interest to compare the color changes during the curing of the 12th and 20th leaf in the 86°, 77 per cent atmosphere, since the rates of weight loss were quite similar. Such a comparison would be indicative of the comparative behavior in the same curing environment of technically mature leaves from widely different stalk positions. Similar comparisons have been made earlier in the discussion with respect to loss of weight.

On the second day of curing 19 leaves of the 40-leaf sample of the 12th leaf were classified as deep green in color and the leaves retained 75 per cent of their original weight. After the same duration of curing the 20th leaf showed 26 leaves still deep green in color and 77 per cent retention of initial weight. Thus more yellowing took place in the same period of curing in the case of the lower leaf although loss of weight was similar. All deep green leaves disappeared after three days of curing in the cure of the 12th leaf, at which time the weight retained was near 65 per cent. On the other hand the deep green leaves disappeared slowly and were not eliminated until after the 20th leaf had been curing for five days and had lost about 45 per cent of their original weight. These

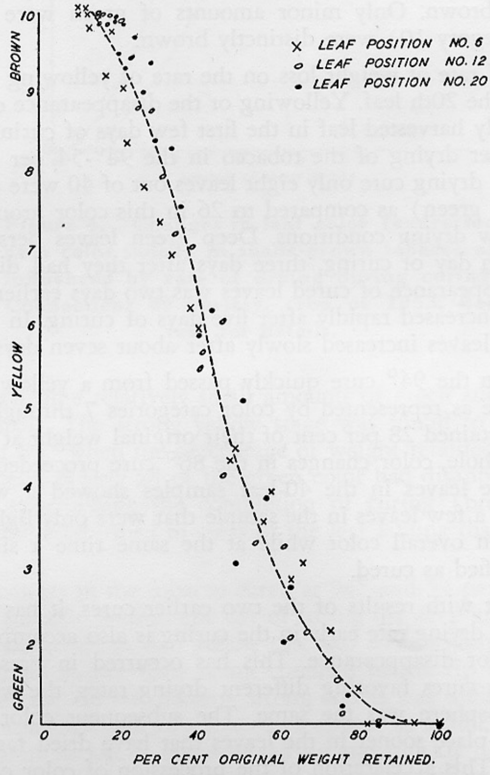

Figure 5. Relationship of leaf color (expressed as a color index) to per cent of original weight retained during curing. Leaves of shade-grown tobacco from different positions on the plant and cured at different rates of drying. Connecticut 49 variety, crop of 1953.

observations of slower yellowing in the case of the 20th leaf may be due to a higher concentration of chlorophyll in the harvested leaf and the requirement of a longer period of curing before the pigment is reduced to a level that gives the leaf a light green or yellow green appearance.

When the process of color change during curing is related to drying rate certain distinguishing features are revealed. These may be seen in Figure 5, where color change indexes for all curing conditions and leaf positions are plotted against percentage of original weight retained. Apparently there is a very close relation between these two factors, a relation good enough that one can predict the color index of a sample of leaves if he knows the percentage of original weight retained by the leaves. The relationship holds for all stages of curing, for fast or slow drying rates and for leaves from all three positions on the plant. It is also shown that color changes in slowly drying leaves followed one another in the same pattern as in leaves dried more rapidly.

Experience has shown that when drying is very rapid, cured leaves will have an undertone of green and that when it is slow there will be little green color in the cured leaf. Actually the shift in color involves two major processes: the loss of the green chlorophyll color and the appearance of the brown pigment. Because chlorophyll itself is not changed to a brown pigment on breakdown, these two reactions occur independently of each other. The color development described for leaf 20 when subjected to rapid drying is an example of the case where green color does not disappear as rapidly as when leaves dry slowly but where brown pigments are formed rapidly as the leaf dries.

Within the range of drying rates explored here, the development of color keeps pace with the loss of initial weight of the leaf. Brown pigments are formed as a result of enzyme reactions in the leaf and chlorophyll breakdown is also a chemical process. Chemical reactions go more rapidly at higher temperatures, but at a lower temperature, may go to the same end point, if they proceed longer. Thus two factors seemingly determine the stage of color development reached: the temperature and the time of reaction. Apparently, within the limits explored in these experiments the amount of moisture lost from the leaf is a good measure of the amount of reaction that has occurred affecting leaf color. At high temperature there is more weight loss and more rapid pigment change; at low temperature these processes take a longer time.

Physical Properties of the Cured Leaf

Uniformity of Color. The cured leaves were graded for uniformity of color, which is an important property in judging the quality of cigar wrapper tobacco. In grading for uniformity attention was paid to (1) the extent of leaf surface covered by the dominant color and (2) the occurrence and extent of one or more secondary colors. Consideration was not given to the shade of dominant color and its relationship to the commercial value of the leaf. Dark and light colored leaves were graded equally so long as the same criteria of color uniformity were satisfied. The criteria used to grade color uniformity in the cured leaves are given in Table 4.

Each degree of uniformity was given an arbitrary rating ranging over a scale of 1 to 10, in order that an index of uniformity could be calculated for each lot of tobacco. The index is a single number related to the distribution of leaves in the several degrees of uniformity and increases in value as the distribution favors the higher degrees. The index is computed by multiplying the number of leaves in each degree of uniformity by the corresponding rating and adding the

Table 4. Degrees of color uniformity in cured leaves of shade-grown tobacco with an arbitrary scale (1 to 10) of rating

Degree	Description	Rating
Very good	Approximately 95 to 100 per cent of surface one color. Very small spots or areas, if any, of a different color	10
Good	Approximately 85 to 95 per cent of surface one color. Small spots or areas of a different color	9
Fair	Approximately 75 to 85 per cent of surface one color. Sizeable spots or areas of a different color	7
Non-uniform	Approximately 55 to 75 per cent of surface one color. Large spots or areas of a secondary color. Small amounts (up to 10 per cent) of a third color allowed	5
Mixed colors	Approximately 50:50 distribution of two different colors or a 50:25:25 distribution of three colors	4
Variable colors	Three distinct colors about evenly distributed. No single color dominant	2
Mottled colors	Intermingling spots or areas of several different colors giving the leaf a dappled appearance. No one or two colors dominant	1

products. The sum of the products is then divided by the total number of leaves in the lot or sample of tobacco to yield the index.

The distribution of cured leaves according to the degree of color uniformity is tabulated in Table 5 for each of the three stalk positions. In the case of the 6th leaf the uniformity of color in the leaves cured at 90° and 65 per cent was not appreciably different from that of leaves cured at 86° and 77 per cent. The grading data in Table 5 indicate an average uniformity index of 5.6 for the warmer, drier cure as compared to 5.3 for the 86° cure. Such a small difference is not significant from the standpoint of leaf quality. The average distribution of leaves, however, shows a slight trend in favor of more leaves in the higher grades of uniformity in the 90° cure.

The cured tobacco from position six on the plant was of poor commercial quality from the standpoint of uniformity of color. This was true of both the fast and slow drying rates. In general the leaves were characterized by reddish shades of color in the tip half and a brown to greenish brown color in the butt.

Uniformity of color in the leaves from stalk positions 12 and 20 was noticeably improved by the fast drying rate during curing. In the case of the 12th leaf the faster rate of drying yielded three times as many leaves with good to very good color uniformity and only half as many leaves with variable or mottled colors in comparison to the slow drying rate. As a result the uniformity index was almost a unit higher for the tobacco dried at the fast rate.

For the leaf from the 20th position the very rapid rate of drying resulted in 22 per cent of the sample having good to very good color uniformity as compared to 12 per cent at the slow drying rate. A greater percentage of leaves

Table 5. Uniformity of color of cured, unfermented leaves of shade-grown tobacco as influenced by slow and fast rates of drying and a wet-bulb temperature of 80° F. Data expressed as percentage of sample (total of 720 leaves). Connecticut 49 variety, crop of 1953

		Degree of color uniformity and rating							
Leaf position	Drying Rate*	Very good 10	Good 9	Fair 7	Non-uniform 5	Mixed colors 4	Variable colors 2	Mottled colors 1	Uniformity Index
6	8.9†	0	6	22	44	20	8	0	5.3
	10.8‡	0	11	24	41	18	6	0	5.6
12	10.3†	0	4	20	49	17	9	1	5.1
	13.3‡	1	12	30	42	10	5	0	5.9
20	9.2†	1	11	33	42	11	2	0	6.0
	14.5§	3	19	44	27	7	0	0	6.7

*Drying rate expressed as the average percentage of original fresh weight lost daily during the first 96 hours of curing.
†Slow drying at 86° F. dry-bulb temperature and 77 per cent RH.
‡Fast drying at 90° F. dry-bulb temperature and 65 per cent RH.
§Fast drying at 94° F. dry-bulb temperature and 54 per cent RH.

having variable colors resulted from drying the tobacco at the slow rate during curing.

Of the three leaf positions cured at 86° and 77 per cent, the cured tobacco from the 20th position was superior in uniformity of color.

The cured tobacco from the middle stalk position showed a mottling of yellowish or reddish colors over the leaf surface, especially in the tobacco dried at the slow rate. There was no tendency at either drying rate for the colors in the leaf tips to be notably non-uniform from those in the butt. Similar mottling of colors was noted in the 20th leaf at the slow drying rate but the degree was less than in the 12th leaf. The upper leaf cured at 95° and 54 per cent was not mottled but rather showed a harmonious blend of green and brown shades of color. The slow drying rate caused darker colors in the tip end of the leaf than in the butt end.

The results of curing shade-grown leaves from three different stalk positions have indicated that uniformity of color tends to be improved with increased rates of drying during curing. To test this relationship, color uniformity indexes for all curing conditions and all leaf positions have been plotted against the corresponding drying rate in Figure 6. From the graph it can be seen that an increase of drying rate favors more uniform colors in the cured leaf.

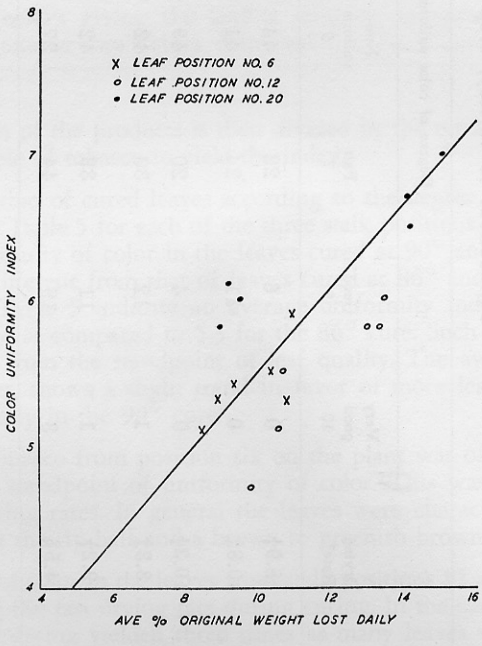

Figure 6. Relationship of uniformity of color (expressed as an index) to average per cent of original weight lost daily during the initial 96 hours of curing. Shade-grown tobacco, Connecticut 49 variety, crop of 1953.

Table 6. A preliminary schedule of color classes or grades for cured, unfermented leaves of shade-grown tobacco

Color Class No.	Description	Approximate Munsell No.
1	Dark to very dark green or blackish green.	10Y3/3 to 10Y4/4
2	Moderately dark green or brownish green (green dominant over brown).	7.5Y3/3 to 7.5Y4/4
3	Light to medium green or yellowish green (green dominant over brown).	7.5Y4/6 to 7.5Y5/6 and 5Y5/6
4	Dark to very dark green brown or dark olive (equally green and brown).	5Y3/3 to 5Y4/4
5	Medium to moderately dark green brown or olive.	5Y4/5 to 5Y5/4
6	Light to medium brown or greenish brown (brown dominant over green).	2.5Y4/6 to 2.5Y5/6
7	Moderately dark to dark brown or greenish brown (brown dominant over green).	2.5Y3/4 to 2.5Y4/4
8	Light to medium brown or yellowish brown. Possibly a slight reddish cast.	10YR4/6 to 10YR5/6
9	Medium to moderately dark brown. Occasionally a slight reddish cast.	10YR4/4 to 10YR5/4
10	Dark to very dark brown or reddish brown (brown dominant over red).	10YR3/3 to 10YR4/3
11	Medium red brown (equally brown and red).	7.5YR4/4 to 7.5YR5/6
12	Dark red brown (equally red and brown).	7.5YR3/3 to 7.5YR3/4

Color of the Cured Leaf

After curing was completed, leaves were graded for the dominant color, a property much influenced by curing. To establish standard color grades, a number of cured leaves, covering a wide range of color, were separated into piles of very similar color. It was found that the leaves could be grouped efficiently into 12 color grades, each grade being easily distinguishable from the others. The major or dominant color of the grade was described and representative leaves from each grade were compared with color standards in the Munsell system[2] until the nearest match was obtained. The color notation of the matching

[2]Munsell Color Company, Inc. Baltimore, Maryland

standard was then taken as the color equivalent for this color grade. Since all of the leaves in a color grade were not strictly identical in color, a narrow range in the Munsell system was adopted to define the limit of the grade.

A schedule of color classes or grades to be used with cured leaves of shade tobacco is presented in Table 6, with the corresponding designations in the Munsell system. The color grades or classes range from a very dark green color at one end of the scale to a very dark red brown at the other end. The classes are arranged in the order of decreasing amounts of green color and increasing proportions of brown through class 9. Classes 10, 11, and 12 comprise leaves showing a definite red cast. This arrangement presumes that very rapid drying during curing leads to leaves of predominantly green color, while very slow drying favors reddish shades.

The distribution of the cured leaves according to color class is presented in Table 7 for each of the three stalk positions.

In the case of the 6th leaf, the distribution of leaves according to color was found to be quite similar for both drying rates. Most of the leaves were graded as light to medium greenish brown (class 6) in both cures. In the slower drying cure 30 per cent of the leaf graded as light to medium red brown (class 11) as compared to 22 per cent in the faster drying cure. The third most prevalent color grade in both cures was a moderately dark brown, being found to the extent of 18 and 20 per cent in the slow and fast drying rates, respectively.

However, some differences in leaf color due to drying rate should be noted. The faster drying cure yielded a somewhat higher percentage of leaves having a dominant greenish brown color (classes 6 and 7, Table 6). In this cure 39 per cent of the leaf had a light to medium greenish brown color and another 14 per cent was a dark greenish brown color, making a total of 53 per cent in these color classes. At the slower drying rate the respective percentages were 34 and 9 for a total of 43 per cent.

The more noticeable differences between drying rates occurred in the yield of leaf having a red-brown coloration (classes 11 and 12). On the average the cooler temperatures and slower drying resulted in 30 per cent of the leaf in the light to medium red-brown class and 6 per cent in the dark red-brown class for a total of 36 per cent in this general color. The 90° cure resulted in 22 per cent in class 11 and no tobacco in the dark red-brown colors.

These data clearly show that curing the early primings of shade tobacco under conditions of cool temperatures (86°) and slow drying favors the production of red colors in the cured leaf. A small increase in curing temperature and in the rate of drying results in a quite noticeable decrease of reddish-colored tobacco. At the same time an increase in drying rate is reflected by a small increase in the amount of green color in the cured leaf. It has, therefore, been shown that the rate of drying during curing has an observable effect on leaf color. As the drying rate is increased the leaf presumably dries out before some of the chlorophyll is decomposed thus giving the leaf an increasingly green color. Relatively slow drying allows sufficient time for the green pigment to disappear. At the same time oxidation processes go on to a considerable extent and produce the dark brown pigments and possibly other substances that are responsible for the red colors.

For the 12th leaf, curing at 86° and 77 per cent relative humidity resulted in markedly different color grades than did curing at 90° and 65 per cent relative humidity (Table 7). For the cooler cure 10 per cent of the leaves fell into

Table 7. Color grading and color indexes of cured, unfermented leaves of shade-grown tobacco as influenced by varying drying rates during curing, Connecticut 49 variety, crop of 1953

Leaf position	Drying rate†	Percentage of sample* in color grade number: Green 2	Green 3	Green-brown 4	Green-brown 5	6	7	Brown 8	Brown 9	10	Red-brown 11	Red-brown 12	Color index
6	8.9‡	—	—	—	—	34	9	—	18	3	30	6	8.6
	10.8§	—	—	—	—	39	14	—	20	5	22	—	8.0
12	10.3‡	—	—	1	—	10	24	—	34	21	10	—	8.6
	13.3§	—	—	1	13	42	4	29	—	11	—	—	6.9
20	9.2‡	—	—	—	—	20	17	—	32	27	4	—	8.4
	14.5‖	5	—	54	19	13	9	—	—	—	—	—	4.6

*Total sample contains 720 leaves.
†Drying rate is expressed as the average percentage of original fresh weight lost daily during the first 96 hours of curing.
‡Slow drying rate at 86° F. dry-bulb temperature, 77 per cent relative humidity, and 80° F. wet-bulb temperature.
§Fast drying rate of 90° F. dry-bulb temperature, 65 per cent relative humidity, and 80° F. wet-bulb temperature.
‖Fast drying rate at 94° F. dry-bulb temperature, 54 per cent relative humidity, and 80° F. wet-bulb temperature.

the red-brown color category and 55 per cent of the leaves were graded as moderately dark to very dark brown (classes 9 and 10). In the warmer cure much more tobacco was produced in classes 4, 5, 6 and 8 which cover the color ranges from green-brown to medium brown. No red-brown leaves resulted at the fast drying rate.

Thus an increase in drying rate reduced the amount of red color and increased the amount of green in the cured leaf. The faster drying rate also resulted in generally lighter colors. The increase in green color with increased rate of drying early in the cure is evidently due to certain parts of the leaf becoming desiccated before the breakdown of chlorophyll is completed. The drying rate at 90° F. was not so rapid as to yield cured leaves with a strong green color (classes 1, 2, or 3) but yet it was sufficiently fast for some chlorophyll to remain and give the tobacco a mild green cast. A slow rate of drying as in the 86° cure permits a more complete destruction of chlorophyll while at the same time the dark brown colors and possibly the red pigments form as a result of oxidative reactions before the leaf becomes too dry for further enzymatic activity. A slow rate of drying allows browning to take place for a relatively long time, with the result that the cured leaves are predominantly dark in color. A fast rate of drying, on the other hand, stops the oxidative reactions before the brown pigments becomes too dark and a more light-colored leaf results.

From the standpoint of potential commercial quality, the cured tobacco from the faster drying cure was superior to that dried more slowly at 86° F.

These data suggest that the 12th leaf (fourth priming) of Connecticut 49 shade tobacco can be cured so as to avoid dark and reddish colors in the cured leaf if it loses weight at the rate of 13 per cent of initial value daily during the initial firing of approximately 96 hours. This rate appears to result in better colors and better uniformity of color.

The wide difference in drying rates of the 20th leaf obtained during curing resulted in striking differences in color of the cured leaves (Table 6). The tobacco cured at 94° F. was predominantly of a moderately to dark green brown color. On the other hand the tobacco cured at 86° was mostly a deep brown color with a slight reddish cast. There was only a slight greenish cast to some of the leaves from this cure.

For the 20th leaf the effect of drying rate on color is apparent in Table 7. At the higher drying rate 54 per cent of the tobacco was moderately dark green to very dark green-brown color (classes 2 and 4) and 19 per cent was moderately dark green brown (class 5), making a total of 73 per cent in this general color. In addition, 5 per cent of the tobacco was graded a dark brownish green (class 2) color. The amount of green color in these leaves, which lost nearly 24 per cent of their original weight in the first 24 hours of curing, shows that the leaves dried too fast for chlorophyll breakdown to be substantial. On the other hand, the tobacco in the slow-drying cure yielded no tobacco in this green brown and brownish green color classes.

A few leaves, less than 0.5 per cent, of the tobacco in the 94° cure was dark red-brown in color, quite different from the rest of the leaves. Thus, in a sample of leaves which in the main react similarly to the curing environment, there are rare leaves that behave in a totally different manner.

In the slower drying, 86° cure, 32 per cent of the tobacco was found to have a moderately dark brown color and 27 per cent was very dark brown. A small quantity of leaf showed enough reddish color to be classed as a light red-brown color. There was no tobacco of these three color classes in the 94° cure, which further indicates the great difference in leaf color resulting from the two drying rates. The color of the cured leaf is greatly influenced by drying rate in the early stages of curing. As the rate of moisture loss is increased, the cured leaves exhibit an increase in the amount of green color. A decrease in drying rate, on the other hand, decreases the green coloration of the leaf and seems to increase the darkness of the brown pigments and the amount of reddish cast. This relationship has prevailed in the present experiments, even though the rate of chemical reaction was presumably constant because of the constant wet-bulb temperature. Because reactions could proceed longer at slower drying rates, the changes in the slow-drying leaves went further before lack of water in the leaf limited these reactions.

Observations of color changes during curing have suggested that chlorophyll breakdown is influenced by the amount of moisture left in the leaf at any given stage of curing (Figure 5). However, at rapid drying rates chlorophyll does not break down completely and the leaves retain a green background of color at the end of curing. Thus with a daily loss of 9 per cent of the original weight, there was some tobacco with a noticeable green cast (classes 6 and 7), (Table 7). When the drying rate is of the order of 13 per cent or greater, the cured leaves show a considerable amount of green color, although the green color disappears more rapidly early in the cure, as indicated by the rate of yellowing.

Relation of color of the cured leaf to rate of drying. A color index was computed from the distribution of leaves in a given sample. To obtain the color index, the percentage of sample falling in a color class was multiplied by the class number (Table 5), and the sum of these products over all classes was computed. This number, divided by 100, is the color index. Color indexes for all 18 lots of tobacco cured in these experiments are plotted against the average drying rate during the first 96 hours of curing in Figure 7.

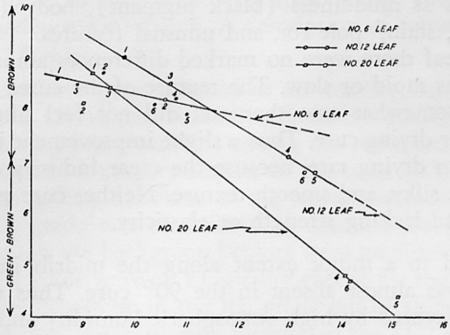

Figure 7. Relationship of rate of weight loss to color in cured, unfermented leaves of shade tobacco. Connecticut 49 variety, crop of 1953. Color expressed as an index and rate of weight loss as the average percentage of original fresh weight lost daily during the first 96 hours of curing.

In the case of the sixth leaf it appears that a unit increase in rate of drying affects the color of the cured leaf only to a small degree. A drying rate of over 15 per cent seems to be necessary for the color index to lie in the greenish-color classes. The data in the graph suggest that the early primings of shade tobacco can withstand a high rate of drying without becoming "hayed-down" or excessively green. Tobacco having a color index of six or seven apparently results in the best commercial grading after fermentation. Therefore, the drying rates obtained in the present curing experiments were too slow for leaves of the sixth position. A drying rate of 18.5 per cent per day appears necessary to obtain a color index of about 6.5. The curing of first or second priming of Connecticut 49 tobacco probably requires a "hard" firing in the shed during the initial stages of curing.

In contrast to the 6th leaf, the color of the cured leaf from the 20th position seems to be strongly influenced by drying rate in the early stages of curing. A unit increase in drying rate results in a marked decrease in color index or a shift in color toward increasing amounts of green. The behavior of the 12th leaf from the middle portion of the stalk was found to be intermediate but resembling the upper leaf more than the 6th leaf. A drying rate of 15 per cent appears to be too rapid for the 20th leaf as it resulted in strongly green tobacco, which for the most part darkened during fermentation. Satisfactory colors result from a drying rate of about 12 per cent to 13 per cent or the late primings of Connecticut 49, 13 per cent to 14 per cent for the mid-season primings, and 16 to 18 per cent for the early primings.

The data in the graph show that a drying rate of eight per cent to 11 per cent results in predominantly brown to red-brown tobacco regardless of stalk position. The indicated effect of a drying rate of 15 per cent on the color of the cured leaf shows a striking difference between leaves from the upper and lower positions on the stalk.

Miscellaneous properties of the cured leaf. Leaves were examined for such physical properties as muddiness (black pigment), body (thickness), texture (feel and stretch), stain,[3] pole rot, and unusual features.

For the 6th leaf there were no marked differences among these properties, whether drying was rapid or slow. The texture of the cured leaves in the faster drying cure was somewhat smoother and did not feel like sandpaper as did leaves in the slower drying cure. Thus a slight improvement in feel was obtained from an increase in drying rate, because the cigar industry desires a cured leaf having a very soft. silky, and smooth texture. Neither cure produced leaves that were stiff, tight, and lacking strength or elasticity.

Stain occurred to a minor extent along the midrib in the cooler, slower drying cure and was almost absent in the 90° cure. Thus the development of stain seems to be favored by high atmospheric humidity and can be reduced by increasing the temperature and lowering the humidity. The conditions in the leaf that lead to stain during curing may well have their basis during the growing of the crop but under certain conditions of curing the appearance of stain is favored.

[3]Stain or bleeding stem is defined as the occurrence of a narrow strip of discolored tissue along the midrib or a spot of similar appearance well out in the blade or web of the leaf. The discoloration appears translucent and resembles a water- or oil-soaked spot. Sometimes it is dark greenish color and in other cases the spot is reddish-brown color. In either case the occurrence of stain lowers the value of a leaf to the cigar industry. The cause of stain is not known but it occurs principally in the early primings of shade tobacco.

There was no pole rot for either the rapid or slow drying cure. A relative humidity of 77 per cent is considered much too high for successful curing in a regular barn because of the resulting high incidence of pole rot. The absence of pole rot at this high humidity is probably due to presence of a steady air movement and free ventilation around individual leaves. In a regular barn tobacco is packed close together and there are many spots within the barn where air is almost quiet.

For the 12th leaf, muddiness was the only notable difference among the physical properties examined that was influenced by the rate of drying. Muddiness was appreciably greater in the slow drying cure in that most leaves had black pigment spread over 10 to 25 per cent of the leaf surface and a few leaves were more than 25 per cent muddy. An occasional leaf showed only slight muddiness.

The tobacco from the fast drying cures was much cleaner and in general was rated as clean to slightly muddy. Very few leaves exhibited any more than a very small amount of dark pigment. The colors were bright in the fast drying cure but were dull in the slow drying one. No pole rot was observed in either cure.

For the 20th leaf the only difference between the slow and rapid drying cures lay in the body or thickness of the leaves. Tobacco from the fast drying cure seemed thicker, probably owing to less loss of dry matter during curing than in the slower cure. These leaves were generally of poor quality and expectedly so because the leaves were picked at the uppermost limit of the last commercial picking. The upper leaves on a shade-grown plant normally tend to be thick, of small size and are called "toppy" by growers. Curing cannot be expected to alter these properties to any great extent.

Commercial grading of the fermented leaf. After the cured leaves had been graded, they were fermented according to the normal procedure. All of the tobacco was placed in the same bulk and kept together during the entire process. The fermented leaves from each cure were then graded into recognized commercial grades of shade grown tobacco. A description of commercial grades may be found elsewhere (3, 4).

Numerical values have been assigned to the commercial grades that reflect the value of the grade (Footnote, Table 8). From the distribution of leaves of a lot of tobacco receiving one treatment among the commercial grades, one can compute a grade index in a manner similar to the color index used previously. The grade index then reflects the value of the fermented tobacco. In the case of the 20th leaf, an RL grade was established to describe leaves having a rather strong red cast, although the background colors were medium light to moderately dark. Leaves in this grade were of YL quality except for the red cast. The RL2 grade contained leaves otherwise in the RL grade but of slightly poorer quality. The LC3 grade comprises leaves slightly inferior to the LC2 grade but not having large patches of off-color as in the YL grade.

For the 6th leaf the tobacco cured at 90° (fast drying rate) graded similarly to that of the tobacco cured at 86° (slower drying rate) (Table 8). The average grade index for the 90° cure was slightly higher but not significantly so. The tobacco from both of these cures was of poor commercial quality. An index value of at least 14 should be attained in order to rate the overall quality as good.

Both cures yielded a high percentage of tobacco in the YL grade, which is indicative of poor uniformity of colors. The uniformity of colors in the cured

Table 8. Distribution of fermented leaves of shade-grown tobacco among commercial grades as influenced by stalk position and drying rate during curing: each sample contains 720 leaves, Connecticut 49 variety, crop of 1953

Leaf position	Drying rate*	Percentage of sample in commercial grades												Grade Index†
		LL	LC	LC2	LC3	YL	YL2	RL	RL2	LV	LV2	V	V2	
6	8.9	—	—	3	16	52	13	—	—	—	2	12	1	9.44
	10.8	—	1	5	19	46	9	—	—	—	3	14	3	9.80
12	10.3	—	5	20	37	21	2	—	—	2	6	6	1	11.92
	10.3	3	13	32	30	12	1	—	—	2	3	—	—	13.39
20	9.2	—	—	—	6	18	19	32	17	—	4	8	—	7.38
	14.5	—	2	4	6	14	9	—	—	5	17	32	11	9.43

†The grade index is calculated from the following values assigned to each commercial grade.
*Drying rate is expressed as the average percentage of orginal fresh weight lost daily during the first 96 hours of curing.

Grade	Value	Grade	Value	Grade	Value
LL	20	LV2	13	RL2	4
LC	18	YL	10	V	8
LC2	14	YL2	5	V2	3
LC3	12	RL	8	KV	1
LV	17				

leaves was rather poor in the two cures and fermentation did not result in any improvement in this respect.

The amount of tobacco sorting into the better grades of shade tobacco such as LL and LC, was so small in either cure than any difference favoring the faster drying cure is not significant. The distribution of leaves into the darker grades, LV, V, etc., showed no appreciable difference between cures as about 15 to 20 per cent of the sample fell into these grades, irrespective of curing treatment.

The commercial quality of the 12th leaf cured at a fast drying rate was superior to that cured at a slow drying rate. Thus the average grade index was 13.4 for the tobacco cured at 90° as compared to an average of 11.9 in the 86° cure (Table 7). This difference is important practically because it is equivalent to a boost upward of one grade on the commercial scale.

The yield of the better grades of light-colored leaf (LL, LC and LC2) was considerably higher in the faster drying cure. Thus 48 per cent of this cure was in these top grades as compared with 25 per cent in the 86° cure. The slower drying cure resulted in nearly twice as much tobacco in the YL grades, which includes light-colored leaves that are mottled or non-uniform in color. The amount of tobacco graded into the dark grades (the LV and V grades) was rather small in both cures. Thus both curing conditions favored the production of light-colored leaf. The cool, slow-drying cure produced slightly more dark colored tobacco.

The commercial quality of the 12th leaf was better than that of the 6th leaf cured under the same atmospheric conditions. The drying rates of the 6th leaf in the 90° cure and the 12th leaf in the 86° cure were comparable but the quality and grade index of the latter was definitely better in this case (Table 7). This suggests that the rate of drying for the 12th leaf was nearer an optimum than it was for the lower leaf position. Apparently the drying rates employed for the curing of the second priming (6th leaf) were too slow for the attainment of good quality wrapper tobacco. The drying rates obtained with the 12th leaf seem to have been more in line with what is needed to attain good quality.

The relatively large difference in drying rate between the 86° and 95° cures of the 20th leaf is reflected in the results of the commercial grading. Sixty-five per cent of the tobacco cured at the faster drying rate graded into the dark commercial grades (LV, V, etc.,) as compared to only eight per cent in the slower drying cure. The latter cure yielded principally light colored leaf of poor color uniformity and with a rather strong reddish cast (RL and RL2 grades). There was no tobacco in the 95° cure which showed any appreciable red cast but approximately 25 per cent graded into the light, off-colored grades, YL and YL2. A small percentage (six per cent) of good quality light colored tobacco (LC, LC2 grades) resulted in the fast drying cure as well as 22 per cent in the top grades (LV and LV2) of the dark colored leaves. No tobacco of similar good quality resulted in the 86° cure.

A high percentage of tobacco in the fast drying cure was dark green brown in color (Table 6). The fermentation of these strongly green leaves resulted in a darkening of the color as well as the retention of considerable green cast. These leaves were graded into the V and V2 grades, which comprised nearly 50 per cent of the total sample. Thus cured leaves having a strong green cast will not be improved by the bulking process but rather they will tend to darken and fall into the poorer grades.

The average grade index of the tobacco from the faster drying cure was found to be 9.4 as compared to 7.4 in the slower drying cure. This shows that the overall quality was somewhat better in the case of the tobacco cured under conditions that favored a rapid loss of moisture.

It would appear from these data and similar results from the earlier cures that there are factors or physical properties of the leaf which play an important role in the commercial grading but which are not consistently affected by the drying rate during curing. These factors would include size and shape of leaf. Leaf body (thickness) and texture also are considered in commercial grading. It was found in the present experiments that different drying rates did not result in any detectable differences in these latter properties.

V. Summary

Mature leaves of the Connecticut 49 variety of shade-grown tobacco were cured in atmospheres of controlled dry- and wet-bulb temperatures, relative humidity and air velocity. The curing of each of three single-leaf pickings (position numbers 6, 12, and 20 counting upward) was operated to attain two different rates of drying, while presumably keeping the rate of chemical change the same by uniform wet-bulb temperature. Loss of total weight and visible color changes were followed during curing. The cured leaves were graded or examined for each of several physical properties which are associated with quality in cigar wrapper tobacco. After normal fermentation the tobacco was sorted into commercial grades and the overall quality assessed.

An air velocity of 15 feet per minute was found to be adequate for the removal of moisture evaporated from the tobacco. Under conditions of the experiment no significant increase in drying rate resulted with an increase in velocity to 35 feet per minute. Rate of color change during curing, physical properties of the cured leaf, and the commercial quality of the fermented leaf showed no relationship to air velocity maintained during curing.

The drier the atmosphere the faster the rate of weight loss during the first four or five days of curing. The greatest daily loss of weight occurred in the first day of curing. A secondary maximum of daily loss took place in all but rapidly dried leaves on about the seventh day of curing. Under conditions of both fast and slow drying the leaves lost almost all of their moisture within 13 days, regardless of leaf position. The percentage of original weight retained in the cured leaf was greater for all leaf positions at the faster drying rate. The higher the leaf position on the stalk the greater was the percentage of weight retained.

The process of yellowing or disappearance of green color in leaves of similar stalk position was accelerated by increasing the rate of drying. Brown pigments and cured leaves also appeared earlier when loss of moisture was accelerated. When leaves are dried slowly, the color changes are sharply defined and proceed from the tip end toward the butt end of the leaf. On the other hand rapid drying resulted in diffuse, dull, and widespread color changes over the leaf surface with the yellow stage being weakly expressed compared to that in a slow drying cure.

The color of a leaf appears to be closely related to its moisture content under normal curing conditions. The deep green color remains until about 20 per cent of the original weight is lost, the yellow stage is at maximum with a

loss of 35 to 55 per cent, and brown pigments in considerable amount do not show until the weight has diminished to 30 to 40 per cent of the original.

Uniformity of color in the cured leaf was found to be influenced by drying rate in that an increase in drying resulted generally in more uniform color.

The color of the cured leaf was strongly influenced by rate of drying. As the rate is increased, greater amounts of green color appear, while decreasing the rate favors darker shades of brown and increased amounts of red color. Lighter shades of color were found to be favored in each of the three leaf positions by increasing the rate of drying. The higher the position of the leaf on the stalk, the greater is the effect of drying rate on color. Early maturing leaves seem to withstand a rapid rate of drying without becoming excessively green. However, late maturing leaves tend to develop green colors readily when cured at a rapid drying rate.

In these studies different drying rates did not influence leaf thickness, texture, muddiness (black pigment), stain and pole rot.

For each leaf position commercial quality and grade distribution were superior with the faster rate of drying. Tobacco of high quality was not obtained in any of the cures.

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