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JOHNSON, W.H., "THE BULK CURING PROCESS FOR BRIGHT LEAF TOBACCO" ASAE PAPER # 63-125

In return, we would be pleased to add you to our mailing list for the completed bibliography if you so indicate.

Sincerely,

Larry M. Geno

Senior Author's Copy

MEMORANDUM

To: Director of Research

Date: January 21, 1957

From: G. W. Giles Head of: Department of Agricultural Engineering

Manuscript: For approval X (enclose 3 copies of text; 1 copy of photos and graphs)

For your information _____ (enclose 1 copy)

Title: Developments in Bulk Curing

Author(s) W. H. Johnson, W. H. Henson, Jr., F. J. Hassler, N. W. Weldon

Recommended for publication as follows:

Station Technical Bulletin _____ Number of copies recommended _____ (Ave. No. 5000)

Station Bulletin _____ Number of copies recommended _____ (Ave. No. 7000)

Journal Series article in "Tobacco Science" Section of Tobacco
(Name of Journal)

Note in _____
(Name of Journal)

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Contribution from Agricultural Engineering Department(s)

and U.S.D.A. X ; Other agencies: _____

It has been reviewed by a committee consisting of:

Co-Authors: Henson, Hassler and Weldon

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It has been approved by the following:

Departments: Agricultural Engineering

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Director

Manuscript: DEVELOPMENTS IN BULK CURING

William H. Johnson

2nd Carbon

DEVELOPMENTS IN BULK CURING

William H. Johnson, Agricultural Engineering Department, N. C. State College
Wiley H. Henson, Jr., Farm Electrification Section, U.S.D.A.
Francis J. Hassler, Agricultural Engineering Department, N. C. State College
N. W. Weldon, Agricultural Engineering Department, N. C. State College

Bulk curing, a new approach which offers many possibilities for simplifying tobacco harvesting and curing processes, is an outgrowth of research at N. C. State College in fundamental studies in tobacco curing. Basic information (Hassler, 1954) pertaining to leaf response to temperature-moisture conditions provided a foundation for new approaches in tobacco curing. Hassler and his associates observed that tobacco leaves could be yellowed to good color by placing them in piles to yellow. Although these observations were made on a small scale, they suggested possibilities of yellowing tobacco in a bulk to achieve good color, then arresting the color by some drying method. Studies in bulk yellowing (Henson, 1956) were made in which bulk yellowing was accomplished under a variety of conditions without significant degradation of leaf quality provided forced ventilation was employed to prevent temperature damage that otherwise resulted from heat of respiration. Studies ~~in~~ ON bruising and edge effects (Johnson, 1956) established conditions by which shredded tissue can by yellowed to good color while exhibiting negligible edge effects which result from premature arrestation of important biochemical reactions. Tobacco was first yellowed in piles in order to provide individual leaf samples having good color. However, the results of studies on leaf response to environmental conditions, bulk yellowing, and edge effects highly suggested that tobacco can be cured completely in the bulk, thereby accommodating biological transformations of yellowing followed by arrestation of color by desiccation.

Preliminary investigations in bulk curing by Hassler in 1955 gave encouraging results by showing that tobacco can be yellowed and cured in a bulk. First attempts in bulk-curing, in which leaves were placed horizontally in a bulk, were only partially successful because of the vertical density gradient of the bulk which encouraged uneven drying. Subsequent investigations, in which the leaves were oriented in a vertical position, provided a more uniform bulk density and gave better results.

Bulk curing tests were continued during 1956 to further evaluate this new approach to curing. A primary consideration in any curing system is to produce acceptable quality tobacco. Since conditions during curing are different for bulk tobacco as compared with barn tobacco, it would be expected that differences may exist in the cured products. In order to determine how well bulk-cured tobacco compares with conventionally-cured tobacco, the experiment was designed to provide representative samples for physical and chemical evaluations.

The objectives for the bulk-curing experiment are as follows:

1. To make chemical and physical evaluations of both bulk-cured tobacco (intact and shredded) and conventionally-cured tobacco.
2. To make measurements pertinent to bulk curing analyses and future design considerations.
3. To explore limits of operation in forcing air through bulk tobacco in curing operations.

This report is concerned primarily with the experimental methods in bulk curing, proposed analyses, and results available at this time.

Since principles and evaluations of bulk curing were of major importance, equipment for bulk- and conventionally-cured tobacco was designed to furnish relatively small quantities of tobacco for sample material. Two cabinets (figure 1),

each having a capacity for approximately 15 sticks of tobacco, were constructed to provide conventionally-cured (check) tobacco. Figure 2 shows one of three bulk-curing chambers designed for approximately 200 pounds of green tobacco. The chamber consists of a jet-type gas burner, a centrifugal (1/6 hp) fan, a conical section, a cylindrical section, and a louvered top. The burner was fired directly into the fan for convenience in design, and the temperature within the conical section was thermostatically controlled. A metal mesh screen located between the cylindrical and conical sections provided support for the tobacco. Air flow was controlled to some extent by the adjustable louvered top. A multiple-point temperature recorder shown in figure 2 recorded air inlet and pile temperatures. Pitot tubes positioned in the side of the chamber at locations directly above the fan, below the screen section, and near the top of the cylindrical section were used for measuring air volume and static pressures during the cure. Figure 3 shows a bulk-curing chamber designed for exploring limits of operation in bulk-curing. A centrifugal fan, powered by a 1 hp motor, drew heated air through the chamber from the top. Figure 4 shows the shredder in operation. Tobacco leaves, passing between two driven belts, were shredded to uniform widths by a reel-type blade.

In order to provide a significant number of samples for analyses, six tests or "primings" were used from a plot of Dixie Bright 244 tobacco. Each test was designed to provide two samples of conventionally-cured tobacco and three samples of bulk-cured tobacco (intact and shredded). Since three chambers were used for bulk-cured tobacco, two of the chambers were used for intact tobacco and one chamber for shredded tobacco for tests 1, 3, and 5. In tests 2, 4, and 6, two chambers were used for shredded tobacco.

Tobacco for each test was primed and randomized into five groups for the two check cabinets and three bulk-curing chambers. In loading intact tobacco the cham-

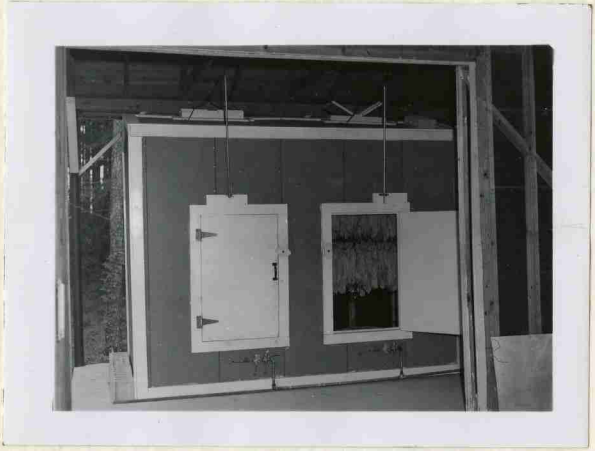

Figure 1. Check cabinets, each having a capacity for 15 sticks of tobacco, were used for conventional curing.

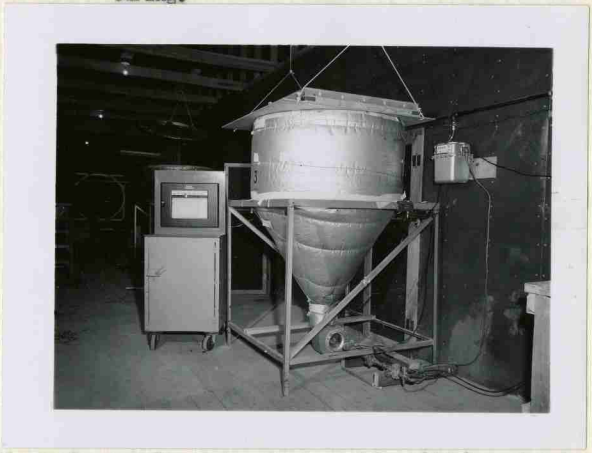

Figure 2. A bulk-curing chamber with multiple-point temperature recorder. Tobacco was placed in the cylindrical section for curing.

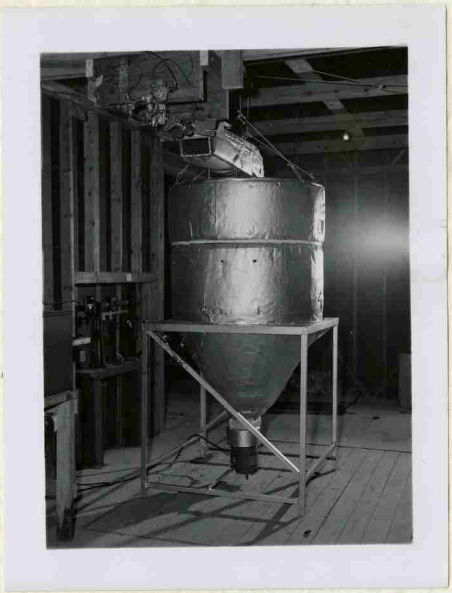

Figure 3. A bulk-curing chamber in which heated air was pulled down through the tobacco, thereby drying from the top of the bulk.

Figure 4. Tobacco leaves were shredded to uniform width by this electrically powered shredder using a reel-type blade.

bers were tilted and tobacco placed uniformly by the handful into the chambers, keeping the butts oriented in the same direction (figure 5). When a chamber was filled, 1/2 inch metal rods were pushed through the tobacco to help in supporting it. The filled chamber was then tilted upright and the louvered top lowered into position. For shredded tobacco, 1/2 inch shreds were placed uniformly to a depth of 15 - 17 inches above the screen. Figure 6 illustrates placement of shredded tobacco into a chamber for curing.

Schedules for bulk curing differed markedly from those of conventional curing. In conventional curing, yellowing was carried on in a 90-100 F. environment. After yellowing the temperature was increased gradually to 120-130 F. to "fix" the color and dry the leaf, then moved gradually to 170 F. to finish drying the leaf and midrib. With bulk curing, however, no external heat was used during yellowing. Exothermic reactions of respiration caused pile temperatures to gradually increase; therefore it was necessary to aerate the pile in order to maintain a pile temperature below 100 F.. This was accomplished by an on-off temperature control which opened and closed the fan circuit. After yellowing, two temperatures were used for drying the tobacco -- 130 F. for 8-15 hours and 170 F. until the leaf was completely dry.

During each test, measurements were made which are important in characterizing the bulk curing process. Measurements were made at regular 2 or 4-hour intervals during the cure with a zero hour selected as that time when tobacco was placed in the chambers or cabinets. The following temperatures were recorded: (1) ambient wet and dry bulb temperatures, (2) dry bulb temperature in chamber beneath tobacco, (3) several temperature points within the bulk tobacco, (4) wet and dry bulb temperatures above the bulk tobacco, and (5) wet and dry bulb temperatures in the check cabinets. Gas consumption in lbs/hr was read directly

Figure 5. Intact tobacco was placed by the handful into the bulk-curing chamber. After filling, the chamber was placed in its normal vertical position for the curing process.

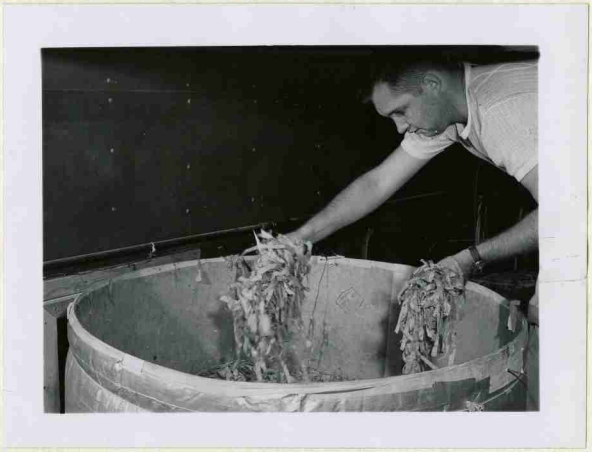

Figure 6. Shredded tobacco was placed uniformly in a layer to approximately 16 inches in depth.

from wall meters. Air volume through the bulk-curing chambers was measured indirectly by pitot tubes located in the chamber sides. In addition, pressure drop through various sections of each chamber and across the bulk tobacco were thereby measured. Weights of bulk tobacco were recorded before and after curing.

Several methods of analysis are planned for achieving the objectives:

1. chemical analyses. Samples of bulk and conventionally-cured tobacco were submitted to the Tobacco Laboratory, Williams Hall, N. C. State College for analyses of total sugar, reducing sugar, nicotine, calcium, total nitrogen, and soluble nitrogen. A statistical analysis of variance for the results will be used in comparing the chemical values for both methods of curing.

2. physical evaluations. Samples of bulk and conventionally-cured tobacco were evaluated by major tobacco companies at the annual display of Experiment Station tobacco (Mangum Warehouse, Durham, October 29-30, 1956). Appearance, color, testure, aroma, and U. S. Government grade were important characteristics evaluated.

3. smoking and aging tests. Samples from all experiments are available for conducting smoking and aging tests.

4. analysis of measurements. Analyses of time, temperature, air pressure, and fuel consumption will be used in evaluating the bulk curing process from an engineering standpoint. Information will be considered as it especially relates to curing schedules, efficiency of curing, and equipment design for future research investigations.

Results and Conclusions.

Results of the 1956 bulk-curing studies, although presently incomplete, are encouraging. Figure 7 shows a chamber of bulk-cured intact tobacco; the extended leaf illustrates good color achieved in the cure. Figure 8 illustrates uniform color of shredded tissue (1/2 inch shreds) cured in the bulk. Figure 9 shows a comparison of bulk-cured intact, bulk-cured shredded, and conventionally-

Figure 7. Bulk-cured intact tobacco shows good color after the cure. This chamber, filled to its capacity with uncured tobacco, now indicates "looseness" of bulk after curing.

Figure 8. Shredded tissue shows uniformity of color after curing. Tobacco was shredded in 1/2 inch strips while green, then yellowed and dried in the bulk.

Figure 9. This photograph shows bulk intact tobacco on left, shredded tobacco in center, and conventionally-cured tobacco on the right. Good color was characteristic of all three samples for this experiment.

cured intact tobacco (on stick). Good color was achieved with all methods of curing.

Bulk-cured intact and conventionally-cured samples were graded at the Durham display according to USDA Marketing Standards. Table 1 shows comparisons for seven tests or primings (~~one above the number of planned tests~~) of Dixie Bright 2L4 on the basis of government grade, auction average, and advance price (USDA Daily Tobacco Market Price Report - No. 29, Oct. 22, 1956). The mean prices for conventionally-cured and bulk-cured tobacco indicate greater acceptance and higher grades for conventionally-cured tobacco.

In conclusion the bulk curing process suggests possible advantages which can be achieved if bulk tobacco is accepted as "good" tobacco. Probably of greatest importance is the possibility of completely mechanizing the harvesting and curing phases of tobacco production. Bulk handling, by machinery, would be a major step away from the laborsome tasks required in individual leaf handling operations of conventional curing. Bulk curing suggests more compact curing structures, greater efficiency in curing, and completely automatic curing schedules. It is believed that greater uniformity of color can be achieved with bulk curing; this suggests less sorting or grading of leaves after curing. Shredding of green tobacco tissue could have even greater implications in mechanizing harvesting and curing operations. Leaf orientation, which appears necessary with bulk-cured intact tobacco, would no longer be a problem. Tobacco could be shredded in the field and mechanically handled until reaching the manufacturer.

Developments in bulk-curing research do not imply that conventional methods of curing will soon be obsolete. Bulk curing is now, at most, a new approach towards eliminating much of the hand-labor involved in harvesting and curing

tobacco. Before new curing systems can be recommended for tobacco producers, complete confidence must be established in the ability of the system to cure acceptable quality tobacco as well or better than conventional methods. Bulk curing, in itself, may not be a solution to the tobacco curing process; however, it does indicate that new horizons of investigation, not necessarily adhering to the conventional, may provide the answer.

Table 1. Price* and U. S. grade comparisons for bulk - cured vs conventionally - cured tobacco (1956)

Auction Bid Average and Advance Prices Per Hundred Pounds

Priming		Conventionally Cured			Conventionally Cured - High Moist. Yellowing			Bulk Cured Low Volume Air			Bulk Cured High Volume Air		
		U. S. Grade	Auc. Avg.	Adv. Price	U. S. Grade	Auc. Avg.	Adv. Price	U. S. Grade	Auc. Avg.	Adv. Price	U. S. Grade	Auc. Avg.	Adv. Price
1	g.1**	P3L	53	43	P3F	57	49	P4F	42	37			
	g.2				P4F	42	37						
2	g.1	P3F	57	49	C5L	63	62	P4F	42	37			
	g.2												
3	g.1	C4L	65	65	C5F	64	60	X4LL	45	50			
	g.2	X4KL	42	44	X4KF	45	45						
4	g.1	C5KL	50	49	C5KL	50	49	X4KL	42	44	X4KL	42	44
	g.2												
5	g.1	B4F	61	55	H4F	63	61	B4KL	44	43	B4KL	44	43
	g.2												
6	g.1	B5F	56	48	B5F	56	48	B5KF	45	40	B5KF	45	40
	g.2												
7	g.1	B5R	53	33	B4R	59	42				B5F	56	48
	g.2												
Mean Price			55	48		55	50		44	42		47	44

* Price based on USDA, Agri. Marketing Service, "Daily Tobacco Market Price Report - Type 11(b)", Middle Belt Flue-Cured, No. 29, Oct. 22, 1956.

** Grades 1 and 2.

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PROFESSIONAL RECORD

of

William H. Johnson
(First author of the paper)

"Bulk Curing Simplifies Tobacco Mechanization"

William H. Johnson received his B. S. degree in agricultural engineering at North Carolina State College in 1954. For his Master's program, he made his investigation in tobacco curing research, and received his M. S. degree in 1956, also at State College. At this time he was appointed Research Instructor, and since that date has continued research in studies on bulk curing. He is now working towards the Ph. D. in agricultural engineering at North Carolina State College.

SUMMARY
OF

BULK CURING SIMPLIFIES TOBACCO MECHANIZATION
(Paper No. 59-311)

by

William H. Johnson, Wiley H. Henson, Jr.
F. J. Hassler and Rupert W. Watkins

This paper describes the research and development of a curing operation which is more compatible with bright-leaf tobacco mechanization than conventional curing. The feasibility of bulk curing was well established by laboratory studies during 1955-1957. Chemical analyses and smoking evaluations performed by major tobacco companies and the North Carolina State College tobacco laboratory showed that intact bulk-cured leaf compared favorably with normally cured leaf.

During 1958 an applied study in bulk curing of intact leaf was conducted in which laboratory techniques and findings were extended to encompass a pilot operation, intermediate to laboratory and field operation. The curing system was designed for simplicity of loading and unloading racks of bulked tobacco, regulation of air flow and temperature schedules which enhance the quality of the cured product, and maximum operational efficiency. The system consisted essentially of a curing compartment for bulked tobacco, a thermostatically controlled heating furnace, and a dampered duct for regulating recirculated air. To simplify loading the compartment, the structure was designed for loading from the standing position. One of the essential features of this system is the forced air movement. Hot air, forced up through the racks of tobacco at rates up to 30 ft/min, promoted drying and prevented the tightly packed tobacco from scalding.

Results from the pilot bulk curing operation show bright possibilities for acceptance of the bulk-cured leaf by the tobacco industry. Chemical results showed

that both bulk and conventionally cured tobacco passed flavor tests as suitable for cigarettes. Representative samples of the bulk-cured leaf averaged $62 per hundred on the open market, with a high of $70 per hundred.

Bulk curing has many possibilities for achieving marked advantages over the conventional curing method. The potential for producing a more uniform leaf is offered through automatic control of temperature and drying conditions. It is estimated, because of the ease of loading the racks and placing them into the barn, that barning labor can be reduced by three-fourths, assuming conventional harvesting methods. The curing space is much smaller than that required by the conventional method since bulk tobacco requires only 1/6 the space required by conventional sticks of tobacco. The amount of tobacco cured on two tiers in the 10' x 12' x 6 1/2' compartment equalled that normally cured in a 16' x 16' x 20' conventional barn. Fire hazard is virtually eliminated since the heating plant is exterior to the curing compartment. The curing system, which lends itself to the use of a heat exchanger for recovering the heat normally lost through conventional barn ventilators, should easily surpass the conventional barn in efficiency.

The described engineering advancements in bulk curing are presently well adapted for conventional harvesting, but there is also the important possibility of integrating mechanical harvesting with bulk curing. Since many requirements for selectivity, orientation, and timing have been removed through bulk curing, tobacco mechanization through harvesting and processing now appears to be a near reality in the eastern United States.

Director's Copy

MEMORANDUM

To: Director of Research

Date: January 21, 1957

From: G. W. Giles Head of: Department of Agricultural Engineering

Manuscript: For approval X (enclose 3 copies of text; 1 copy of photos and graphs)

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Author(s) W. H. Johnson, W. H. Henson, Jr., F. J. Hassler, N. W. Weldon

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Co-Authors: Henson, Hassler and Weldon

_____ Chm.

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Departments: Agricultural Engineering

Other agencies: _____ Date: _____

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Signed: _____ Date: _____
Director

May 26, 1958

Mr. N. Ratten, General Manager
Australian Light & Power Co. Pty. Ltd.
161 William St.
Sydney, Australia

Dear Mr. Ratten:

We received your letter of May 15, 1958 and are pleased that you are interested in our curing research here at North Carolina State College. We are certainly in accord with you in realizing that the existing method of curing tobacco leaves much to be desired in labor efficiency, economy, and process control.

Presently we are not in position to publish an article describing the bulk curing methods. Our research work has been geared to finding the degree of acceptability of bulk cured tobacco compared with conventionally cured tobacco by the domestic companies. Results are encouraging; however, realizing that any new method of curing could involve radical changes in marketing and processing, we feel that we must have complete confidence in this curing method before any recommendations are released. Within the next year we may be able to report progress and further information on the bulk curing method. A report of this nature will, no doubt, appear first in Tobacco Magazine.

We apprecaite your interest and are sorry that we do not have available information on the process at this time.

Sincerely yours,

William H. Johnson
Research Instructor

WHJ:AS

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15th, May 1958.

The Principal,
North Carolina State College,
Raleigh, N.C.,
U.S.A.

Dear Sir,

We have read with considerable interest your article "Yellowing Flue-Cured Tobacco in the Bulk", which appeared in the Tobacco Science section of volume 146 number 11, March 14th. 1958 of "Tobacco". Also we read in a report in a previous issue of either "Tobacco" or "The Tobacco Leaf", that leaf cured in the manner apparently described in the article had been placed on the open market and sold for an average price of 10% less than conventionally cured tobacco leaf.

From the writer's recollection, the brief article in this particular issue, mentioned that the leaf had been coloured for a period of thirty hours approximately, then with ventilation in the box, taken to 130°F. and held for a period of 24 hrs. until the web of the leaf was dry, then lifted to 170°F. for stem drying.

As we supply at least 50% of the curing equipment for use in barns/kilns throughout Australia, and curing of tobacco leaf is of vital interest to us (not meant in any monetary sense) we are wondering whether you will be printing any reports on the method described in the Journals. If so, and provided it caused you no inconvenience, we would more than appreciate a copy of any further relevant information on this method.

For four years now it has been the Writer's contention that the existing method of curing tobacco leaf is antiquated and too costly because of the capital cost in erecting large, high barns/kilns, which in turn dry leaf unevenly, require manpower to load and unload and are wrongly designed for the necessary conditions of temperature and relative humidity. Years ago we introduced humidity control in curing and to some extent we have assisted the industry.

We realize you may not care to disclose information of any nature which may benefit tobacco curing in another country, but, as remarked before, our interest is not monetary. We are genuinly interested in improving our knowledge of curing leaf. Should any information on the methods described by your officers be available we should be most grateful to receive it.

Yours faithfully,
Australian Light & Power Co.Pty.Ltd.,

N.Ratten.

N.Ratten,
General Manager.

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July 20, 1960

Mr. William H. Johnson, Research Instructor
Agricultural Engineering Department
North Carolina State College
Box 5906
Raleigh, North Carolina

Dear Mr. Johnson:

Title: Bulk Curing of Bright Leaf Tobacco

The enclosed proofs of the above-titled article are being sent to you for final checking and approval prior to publication in AGRICULTURAL ENGINEERING. Please check the proofs carefully for typographical or other errors, and make any corrections previously overlooked. Also, add or delete such matter as you may care to. When you have done this, kindly sign your name in the space provided on the first proof sheet and mail in the return envelope enclosed.

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James Basselman

encls. JAMES BASSELMAN, Editor
Air Mail

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November 30, 1959

Mr. William H. Johnson
Research Instructor
Agricultural Engineering Dept.
North Carolina State College
Raleigh, North Carolina

Dear Mr. Johnson:

This is to acknowledge the receipt of and thank you for submitting for publication your paper entitled "Bulk Curing Simplifies Tobacco Mechanization".

Since other papers have been rated above this paper in our preliminary evaluation by members of the executive committee of each division, I doubt seriously that it can be published within the next eight or ten months. Therefore,we suggest that you submit the paper to "Tobacco Science", with the understanding that proper credit be given to ASAE and place of presentation. We often grant permission to other publications where little duplication of readership exists as a means of bringing the name of ASAE and the agricultural engineer before the public.

In the meantime we will process your paper in the usual manner by sending it to our critical readers and will appreciate hearing from them before making a final decision.

Sincerely,

James Basselman

JAMES BASSELMAN, Editor

vz

NORTH CAROLINA STATE COLLEGE

RALEIGH

DEPARTMENT OF
AGRICULTURAL ENGINEERING

November 23, 1959

Mr. James A. Basselman, Editor
Agricultural Engineering
420 Main Street
St. Joseph, Michigan

Dear Mr. Basselman:

The paper entitled "Bulk Curing Simplifies Tobacco Mechanization" by William H. Johnson; Wiley H. Henson, Jr.; F. J. Hassler; and Rupert W. Watkins was presented at the 1959 Annual Meeting of ASAE at Ithaca, N. Y., June 21-24, 1959. At the time the original manuscript was submitted prior to the meeting, it had not been approved by the North Carolina Agricultural Experiment Station and the USDA. Approved copies, however, were distributed at the meeting. I am enclosing two copies of the approved manuscript with photographs with the request for publication in "Agricultural Engineering" or in the "Transactions of the ASAE".

Because of the urgency for mechanizing tobacco harvesting and processing to reduce costs of production and to place the United States in a more favorable competitive position, the developments in bulk curing are of exceptional interest to the Southeastern United States. We are, therefore, very interested in having the paper published as soon as possible in order that these findings will be available to researchers and others interested in the tobacco industry. If the anticipated publishing date is on the order of eight or ten months or less from now, we would, of course, like for the paper to be published in "Agricultural Engineering" or in the "Transactions". However, if the anticipated publishing date is considerably later than this, please consider this letter as a request for permission to publish the paper in full in "Tobacco Science" section of Tobacco journal.

Your prompt consideration of this request will be greatly appreciated.

Very truly yours,

William H. Johnson
Research Instructor

CC: Wiley H. Henson, Jr.
F. J. Hassler
R. W. Watkins

Enclosures 2

OK 5/26/59
TEH

Paper No. 59-311

BULK CURING SIMPLIFIES TOBACCO MECHANIZATION

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For Presentation at the 1959 Annual Meeting
AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS
Ithaca, New York
June 21-24, 1959

BULK CURING SIMPLIFIES TOBACCO MECHANIZATION[1]

INTRODUCTION

A fundamental and age-old problem in tobacco production is the great amount of hand labor required in the conventional methods of production. Some mechanization has been achieved, particularly in cultural operations, but approximately 420 man-hours per acre are still necessary in tobacco production.[2] This is based on the average tobacco allotment of 4-5 acres and a yield of 1800 pounds per acre. Approximately three-fourths of the total labor is required in the harvesting and processing operations.

Present mechanical harvesters have not been successful in the solution of this problem. It is true that a measure of convenience has been introduced, such as conveying the field workers, and that the number of leaf handlings has been slightly reduced. According to Chumney and Toussaint (1)*, labor reduction in machine harvesting comes about largely through the elimination of a single harvesting operation -- handing. However all other essential operations (priming and looping) are retained. Progress notwithstanding, high labor requirements still exist. Furthermore, it is recognized that individual leaf handling operations essential for the conventional curing method, are the bottlenecks to the development of mechanical complements for eliminating hand labor in harvesting and processing. These operations, however, because of their complexity in terms

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1 Approved for publication as Paper No. 1049 of the Journal Series of the North Carolina Agricultural Experiment Station.

2 Private communication with Dr. W. D. Toussaint, Agricultural Economics Department, North Carolina State College, Raleigh.

* Numbers in parentheses refer to appended references.

of requirements for selectivity, orientation, and timing, present a real challenge to practical mechanization.

Systems engineering ~~in general~~, which is concerned with overall processes, involves application of new operational techniques which maximize efficiency. Since the inherent difficulties to advancing tobacco mechanization reside with the conventional curing method, past research at North Carolina State College has been directed towards the development of a curing operation which would be more compatible with overall mechanization. Results suggested the possibility of curing packed leaves, and by this approach eliminating the requirement for stringing leaves on a stick. Based on this conclusion, research and development have been initiated to test the feasibility of a curing method referred to as Bulk Curing.

REVIEW OF LITERATURE

The development of the bulk curing process, radically different from the conventional as described by Brown and Weldon (2), was a gradual evolution based upon accumulated observations and measurements of a fundamental nature. Studies by Hassler (3,4) provided limits for environmental control and information helpful to proper yellowing of leaf tissue. Using a thermocouple inserted between the layers of leaf tissue, he studied the phenomenon of color change as influenced by temperature, drying rate, and leaf moisture content. Concerning browning reaction he stated:

> "The rate of browning (sponging) was found imperceptible below 110°F, but the reaction speeds up with increasing temperature, becoming sufficiently rapid at 135°F to produce total discoloration within six minutes. Thermal killing of the enzyme system that produces the browning reaction was obtained within one second at 212°F."

These tests showed the necessity of maintaining leaf temperatures consistent with requisite biochemical changes and moisture content in order to produce a satisfactory cure. Drying of the leaf to 75-80 percent of its initial moisture content was also found desirable for hastening the green to yellow color change.

The impetus for curing in the bulk led to detailed studies on bulk yellowing by Henson et al (5) who investigated the conditions existing in ventilated and non-ventilated bulks of tobacco and evaluated the influence of these conditions on certain chemical and physical properties of the cured leaf. In the non-ventilated bulks, temperatures increased almost linearly with time for 35 to 51 hours after the leaves were bulked and reached peaks of 125° F. to 129° F. Almost two-thirds of the tobacco was damaged by these high bulk temperatures which resulted from heat of respiration. Ventilation of bulks with air velocities of 25 ft/min prevented temperature damage and resulted in yellowed tobacco having good color and physical appearance. Chemical analyses showed that bulk yellowing could be accomplished without appreciable reduction of total and reducing-sugar contents, provided forced air was employed to prevent temperature damage.

Johnson et al (6) studied the edge effects which resulted from shredding tobacco during the green stage. Results illustrated that edge effects from shredding green tissue were negligible when the tobacco was yellowed in a low-drying environment of 96 percent relative humidity. However, drying conditions of 82 percent relative humidity during yellowing amplified edge effects by producing premature arrestation of certain biochemical reactions along the cut edges. Under properly controlled temperature and humidity conditions, shredded tissue was predicted to

yellow to good color in a bulk with negligible edge effects.

A further study by Johnson et al (7) showed that bruising adversely affected both appearance and sugar levels of green tobacco tissue. Bruising of green tobacco tissue prevented normal chlorophyll disappearance and impeded the conversion of starches to sugars which normally occurs during yellowing. These results showed that, in order to maintain a quality product, non-bruising methods of handling must be used in the development of new approaches in mechanizing harvesting and curing operations.

EXPERIMENTAL

Laboratory Investigations — 1956

During 1956, laboratory studies were conducted to further evaluate the potentialities of bulk curing. Objectives for the experiment were:

1. To make chemical and physical evaluations of both intact and shredded bulk-cured tobacco in comparison with conventionally cured tobacco.

2. To make measurements pertinent to the design and construction of equipment for bulk curing.

Three bulk-curing chambers of the design shown in figure 1 were constructed for the initial tests of 1956. Each chamber consisted of a centrifugal fan, a conical section, and a cylindrical section. A metal mesh screen located between the cylindrical and conical sections provided support for approximately 200 pounds of uncured intact tobacco. This particular design was selected because it was considered that a circular chamber would provide uniform air distribution with simplicity of design. Heat was furnished by a jet-type gas burner which was fired directly into the fan. The temperature within the conical section was thermostatically controlled by an on-off valve in the gas line, actuated by a sensing

bulb located within the cone. A multiple-point temperature recorder registered the temperatures of thermocouples located in the air inlet and in the bulk. Air volume rate was measured with pitot tubes positioned beneath the tobacco.

Six tests were conducted throughout the harvesting season in which both intact leaves and leaf material shredded in 1/2-inch strips were cured in cylindrical chambers, while check samples were cured conventionally for comparison. In loading intact tobacco, the chambers were tilted and tobacco was placed uniformly by the handful into the chambers, keeping the butts oriented in the same direction. Shredded material was uniformly placed into the chambers by hand to a depth of 15-17 inches above the screen.

Schedules for the initial bulk-curing tests differed markedly from the conventional curing schedules. In conventional curing, yellowing was accomplished in a 90-100°F. environment. After yellowing, the temperatures were increased gradually to 130-140°F. to "set" the color and to dry the leaf, then ~~moved~~ raised gradually to 170°F. to finish drying the leaf and midrib. With bulk curing, however, no external heat was used during yellowing. Exothermic reactions of respiration caused bulk temperatures to gradually increase; therefore it was necessary to aerate the bulks in order to maintain bulk temperatures below 100°F. Aeration was accomplished by using a liquid-filled sensing bulb which actuated an on-off microswitch in the fan circuit whenever the bulk temperature exceeded 100°F. After yellowing, two temperatures were used for drying the tobacco -- 130°F. for 8-15 hours and 170°F. until the leaf was completely dry.

Observations during the initial tests showed many aspects of bulk curing that needed improvement. Both intact and shredded leaf compared favorably in color with conventionally cured tobacco; however, the bulk intact tobacco

exhibited a flat, "unnatural" appearance while shredded tobacco had an abnormal and undesirable aroma. It was believed that the bulk-curing conditions were not as favorable as the conventional curing conditions, thus causing these noted differences. For example, the irregular air flow and temperature schedules during bulk yellowing gave a non-uniform yellowing environment; also the rapid temperature increases appeared to produce discoloration. Observations also suggested that a limited amount of drying during yellowing would be desirable for preventing surface-moisture accumulation which occurred in the tightly bulked tobacco and also for promoting more desirable yellowing conditions. More uniform air distribution was obtained when the leaves were supported with the butts upward and with air flow from the tip end to the butt end. Furthermore, this gave the advantage of drying in the same direction as yellowing, i.e., from tips to butts. Non-uniform air distribution, which resulted in uneven drying and lowered quality, was ~~an imposing~~ found to be a major problem to the advancement of bulk curing. Since uniformity of air distribution depends directly on bulk uniformity, the non-uniform loading method employed caused air channeling through less dense sections of the bulk. The tightly packed sections, which dried last, were damaged by high bulk temperatures. Comparisons of energy efficiencies showed that bulk curing using forced convection was less efficient than conventional curing, since a large amount of sensible heat was discharged from the bulk chambers.

Laboratory Investigations — 1957

From the above observations, two additional objectives were added to the following 1957 experiment:

1. To make improvements in the loading techniques and equipment which would simplify the process and contribute to curing a more acceptable and higher quality product.

2. To improve the curing schedule and develop techniques of recirculation for improving process efficiency.

Six climatic chambers of the type shown in figure 2 were used to provide a controlled environment and to accommodate an improved loading technique. Electronic temperature controls maintained conditions within one degree F, while air-flow and recirculation dampers allowed any desired air movement. A steam supply to the chambers provided a positive method for maintaining high humidities during yellowing as well as for conditioning the tobacco after curing.

An improved loading method contributed to faster, easier bulking, and allowed much greater uniformity in packing of tobacco within racks. The loading rack consisted of two wooden members constructed of 2" x 4" x 48" material. One member had a series of 3/8-inch metal rods spaced at 6-inch intervals along the rack to provide support for the tobacco. In principle, a side member of the loading rack, without the rods, was placed in the bottom of a loading form which was similar to a box with an open top and front. After tobacco had been placed to a given height in the form (by the armful or handful), a second side member of the loading rack was connected to the first side member, thereby clamping the tobacco in a rectangular shape, 16" x 48", and at the same time piercing the tobacco with the rods. A filled rack of tobacco is shown in the chamber of figure 2. Each chamber held two racks of intact tobacco (160 lbs) or one metal basket of shredded tobacco (100 lbs).

Six tests were conducted throughout the harvesting season in which bulk tobacco was cured with three replications in climatic chambers, while check samples were cured conventionally for comparison. Temperature schedules for bulk curing followed closely those for conventional curing. Air-flow and recirculation schedules for bulk curing were designed to improve the efficiency.

As a result of these modifications in equipment and improvements in the controls, noticeable improvements were recognized in the quality of cured intact tobacco. Visual observations showed no apparent color differences between tobacco cured

in the bulk and that cured conventionally. The appearance of tobacco cured in the bulk was greatly improved over that cured in 1956, and much of the objectionable flat appearance was overcome by adequately conditioning the tobacco after curing. Shredded tobacco, however, still continued to exhibit an undesirable aroma. As a consequence of the improved loading technique, uniform air distribution and even drying resulted, thus maintaining quality by proper drying. In addition to upgrading quality, fuel efficiencies for bulk curing surpassed conventional curing as a result of proper recirculation of air.

Results of sugar and nicotine assays by the North Carolina State College Tobacco Laboratory on representative samples of tobacco from the 1956 and 1957 tests are shown in table 1. In every case, shredded tobacco had lower contents of sugar and nicotine while intact, bulk-cured leaf compared favorably with normally cured leaf. Chemical evaluations by several tobacco companies agreed closely with the results of table 1. Moreover, shredded tobacco had significantly smaller contents of total alkaloid and petroleum ether extract but larger ash content and specific volume. Although everything is not known concerning the role played by each chemical component, it was considered that significant departures from the conventional analyses were undesirable.

Smoking tests on samples from both seasons were completed by several tobacco companies. Results were essentially the same for both seasons with company evaluations agreeing closely. Bulk-cured leaf was similar in smoking characteristics to that cured by the conventional method; however, the shredded tobacco produced an undesirable smoke which lacked flavor and had an acrid aroma.

Because of the highly favorable results obtained in bulk curing of intact leaf, from both standpoints of operation and quality of cure, development towards

a practical curing system was initiated. On the other hand, negative results in bulk curing of shredded tobacco suggested more fundamental research to find ways of improving its curability.

Pilot Operation -- 1958

An applied study in bulk curing of intact leaf was conducted in which laboratory findings and techniques were extended to encompass a pilot operation, intermediate between laboratory and field operations. The design and operation of this curing system were concerned with simplifying the loading and unloading of racks of tobacco, adopting air-flow and temperature schedules which enhance the quality of the cured product, and obtaining maximum operational efficiencies.

Figure 3 shows a schematic drawing of the curing system. It consisted essentially of a curing compartment for bulked tobacco, a thermostatically controlled heating furnace (indirectly gas-fired), and a dampered duct for regulating the amount of air to be recirculated. To simplify the operation of loading the racks of bulked tobacco into the barn, the structure was designed so that two men standing on the floor of the barn could lift the racks of tobacco onto the tiers. An essential feature of this system is the forced air movement. Hot air, forced up through the compartment floor and through the racks of tobacco at rates from 15 to 30 ft/min, promoted drying and prevented "scalding" of the tightly packed tobacco.

The loading technique ~~as~~ used in the preceding laboratory tests was improved to allow more rapid clamping of tobacco into racks. As shown in figure 4, tobacco was placed uniformly into the loading form by the handful. By having the form balanced on two pivot points, it was possible to place an approximately equal

amount of tobacco in each rack — the right amount indicated by a slight tilting of the form. Each rack, ~~six~~ 6 feet in length and 16 inches wide, held approximately 120 lbs of uncured tobacco. Twenty-eight racks of tobacco, required for filling the 10' x 12' x 6 1/2' compartment (figure 5), equalled that normally required for filling a 16' x 16' x 20' conventional barn.

Six cures were conducted throughout the harvesting season of 1958 ~~in order~~ for comparing ~~to compare~~ bulk curing with conventional curing. ~~Environmental conditions during bulk curing were more easily controlled than in the conventional method.~~ During yellowing, the temperature was held between 90° and 100°F. with complete recirculation of the air. A temperature schedule similar to the conventional schedule was then followed (figure 6). Color was "set" during a gradual temperature rise to 130-140°F, then the temperature was advanced to 170°F. for stem drying. Relative humidities ranged from 80 to 90 percent during yellowing and as low as 10 to 20 percent during leaf and stem drying. The damper setting for air recirculation was varied manually to obtain a drying environment consistent with the stage of curing.

Although a curing system may be operationally successful, it is recognized that acceptability of the cured product must precede the introduction of the system for practical application. Results from the pilot operation of bulk curing of bulk-cured tobacco show good possibility for acceptance by the tobacco industry. Chemical and smoking evaluations performed by a cooperating tobacco company are shown in table 2. Percentages of nicotine, nornicotine, reducing sugar, and total nitrogen agreed closely for bulk and conventional curing. Smoking evaluations rated bulk-cured tobacco as having low flavor (mild) and conventionally cured tobacco as having low to medium flavor; both passed the flavor test as suitable for cigarettes.

Table 3 gives the results of a sale of bulk-cured tobacco on the open market. Representative samples averaged $62 per cwt, with a high of $70 per cwt. Samples of bulk-cured and conventionally cured leaves from the entire season were also graded according to USDA Marketing Standards. Average prices based on government grades were $58.70 per cwt for bulk-cured tobacco and $56.15 per cwt for conventionally cured tobacco -- indicating slightly better acceptance for bulk-cured tobacco.

Indications are that the bulking method saved both time and labor in the barning operations. It is estimated, because of the rapidity and ease of filling the racks and placing them into the curing compartment, that barning labor (after cropping) was reduced by three fourths, as compared with conventional methods. This figure was arrived at by comparing the total labor for stringing, handing, and loading a conventional barn with that required for bulking and loading an equivalent amount of tobacco for bulk curing.

DISCUSSION

Bulk curing has many possibilities for achieving marked advantages over the conventional curing method. The potential for producing a more uniform leaf is offered through automatic control of temperature and drying conditions. In addition to saving labor during barning, ease of unloading tobacco from racks speeds up the preparation for marketing. ~~The curing space is much smaller than that required by the conventional method since~~ bulk tobacco requires only 1/6 the curing space required by conventionally strung sticks. This suggests cost savings for basic curing structures, as well as the possibility of designing curing systems to accommodate the individual farmer's acreage. Fire hazard is virtually

eliminated since the heating plant is exterior to the curing compartment. During 1958, fuel efficiencies were equivalent to conventional curing, although the damper for recirculating air was manually controlled. Therefore, a compact system for bulk curing, well insulated and automatically controlled, would easily surpass the conventional barn in efficiency. The curing system also lends itself to the use of a heat exchanger for recovering the heat normally lost through conventional barn ventilators.

The results of the developments to date show that there is high probability that bulk-cured leaf will be acceptable to the trade. However, before appropriate curing systems can be developed for farm application, this principle must be evaluated on a farm-scale operation. The described engineering advancements in bulk curing are presently well adapted for conventional harvesting, but there is also the important possibility of integrating mechanical harvesting with bulk curing. The introduction of these or other methods will serve to advance the engineering of operational practices in tobacco harvesting and curing.

SUMMARY

This paper describes the research and development of a curing operation which is more compatible with mechanization of bright-leaf tobacco than conventional curing. The feasibility of bulk curing was well established by laboratory studies during 1955-1957. Chemical analyses and smoking evaluations performed by major tobacco companies and the North Carolina State College Tobacco Laboratory showed that intact bulk-cured leaf compared favorably with normally cured leaf.

During 1958 an applied study in bulk curing of intact leaf was conducted in which laboratory techniques and findings were extended to encompass a pilot

operation, intermediate between laboratory and field operations. The curing system was designed for simplicity of loading and unloading racks of bulked tobacco, regulation of air flow and temperature schedules which enhance the quality of the cured product, and maximum operational efficiency.

Results of curing in the pilot operation show good possibility for acceptance of bulk-cured tobacco by the tobacco industry. Chemical results showed that both bulk and conventionally cured tobacco passed flavor tests as suitable for cigarettes. Representative samples of the bulk-cured leaf averaged $62 per cwt on the open market, with a high of $70 per cwt. Possibilities for achieving marked advantages over the conventional curing method are discussed.

The described engineering advancements in bulk curing are presently well adapted for conventional harvesting, but there is also the important possibility of integrating mechanical harvesting with bulk curing. Since many requirements for selectivity, orientation, and timing in the barning operations have been removed through bulk curing, tobacco mechanization through harvesting and processing now appears to be a near reality.

ACKNOWLEDGMENTS

This study was conducted under joint cooperation of the North Carolina Agricultural Experiment Station and the Farm Electrification Research Branch, Agricultural Research Service, U.S.D.A.

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Table 1

Results of Chemical Analyses For Laboratory Bulk Curing 1956-57*

	1956	1957
Total Sugar Percentage		
Conventionally Cured	32.24	28.77
Intact Bulk Cured	31.88	28.45
Shredded Bulk Cured	29.04**	24.44**
Reducing Sugar Percentage		
Conventionally Cured	27.30	23.53
Intact Bulk Cured	27.23	23.30
Shredded Bulk Cured	21.85**	18.84**
Nicotine Percentage		
Conventionally Cured	2.04	3.43
Intact Bulk Cured	1.93	3.55
Shredded Bulk Cured	1.70**	2.84**

* Analyses performed by North Carolina State College Tobacco Laboratory
1956 analyses - average of 12 samples
1957 analyses - average of 18 samples

** Significantly lower at the .01 level

Table 2

Company "A" Evaluation of Bulk and Conventionally Cured Tobacco (1958)

	Intact Bulk Cured (Primings 2-6)	Conventionally Cured (Primings 2-6)
% Nicotine	2.65	2.59
% Nornicotine	.10	.14
% Reducing Sugar	15.15	15.62
% Total Nitrogen	2.26	2.12
Smoking Evaluation	Low Flavor (mild)*	Low to medium Flavor*

* Pass flavor test as suitable for cigarettes.

Table 3

Sale of Bulk-Cured Tobacco (1958)

Grade*	Pounds	Price Received	Amount	Auction Av.	Support
X 4 KF	178	$.62	$110.36	$.62	$.50
X 4 KF	72	.62	44.64	.62	.50
X 3 L	160	.69	110.40	.70	.69
B 5 FV	216	.50	108.00	.55	.50
B 5 FV	134	.50	67.00	.55	.50
B 5 F	106	.66	69.96	.60	.55
B 4 F	176	.70	123.20	.64	.61
B 4 F	186	.69	128.34	.64	.61
	1,228		$761.90		

Average price per pound - $.62

* Representative samples from cures 1, 3, 4, 5 and 6

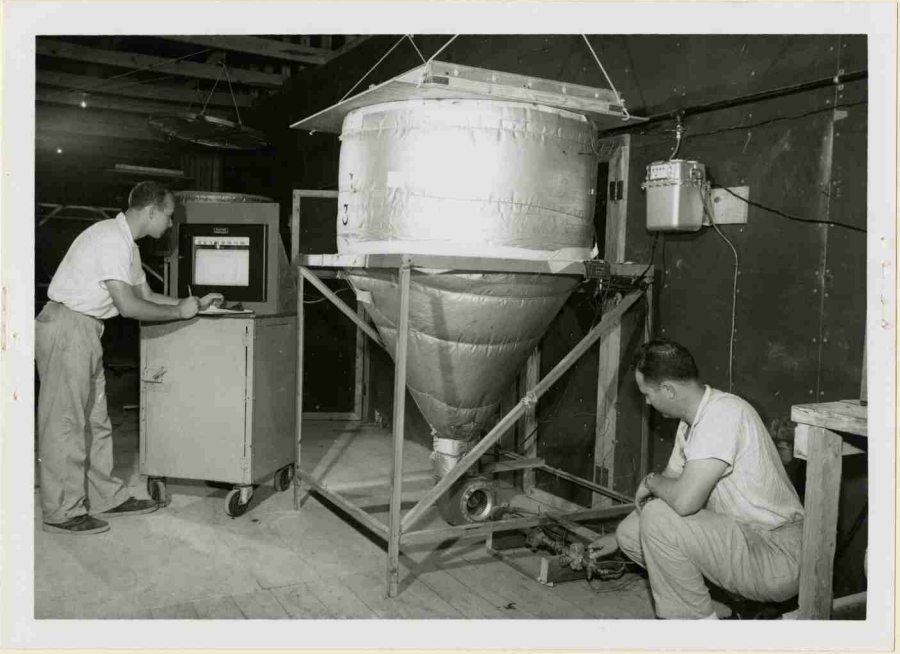

Figure 1. Cylindrical chambers were used in the initial experimentation on bulk curing.

Figure 2. Climatic chambers of this type, having sensitive electronic temperature controls and air recirculation dampers, improved the quality of cure.

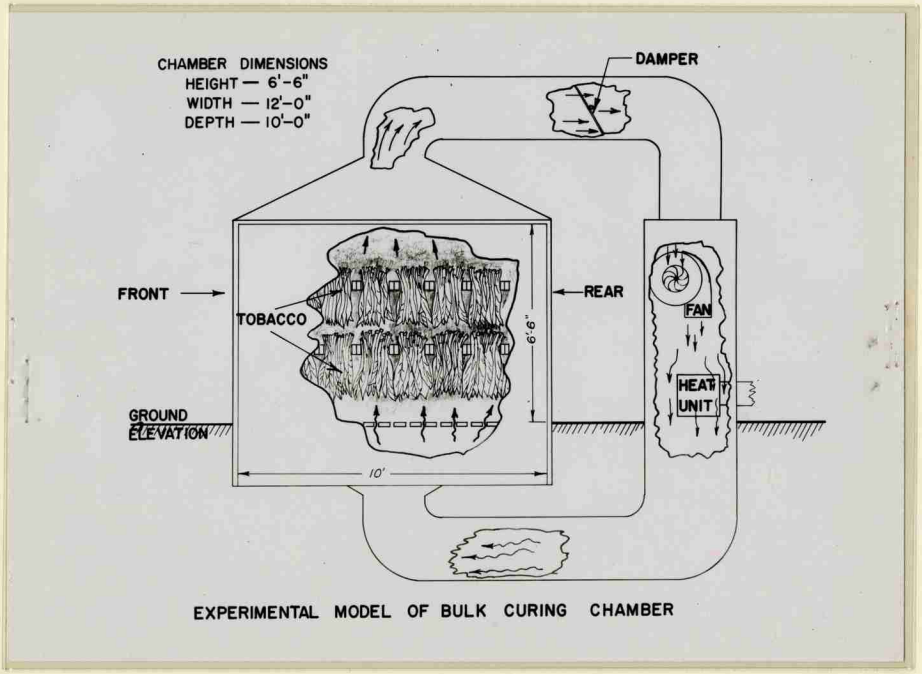

Figure 3. On the basis of laboratory investigations, this experimental model was developed and tested.

Figure 4. This method of bulking leaves eliminated many individual leaf-handling operations.

Figure 5. Bulk tobacco, easily loaded into this compartment, required only 1/6 the space of conventionally strung tobacco.

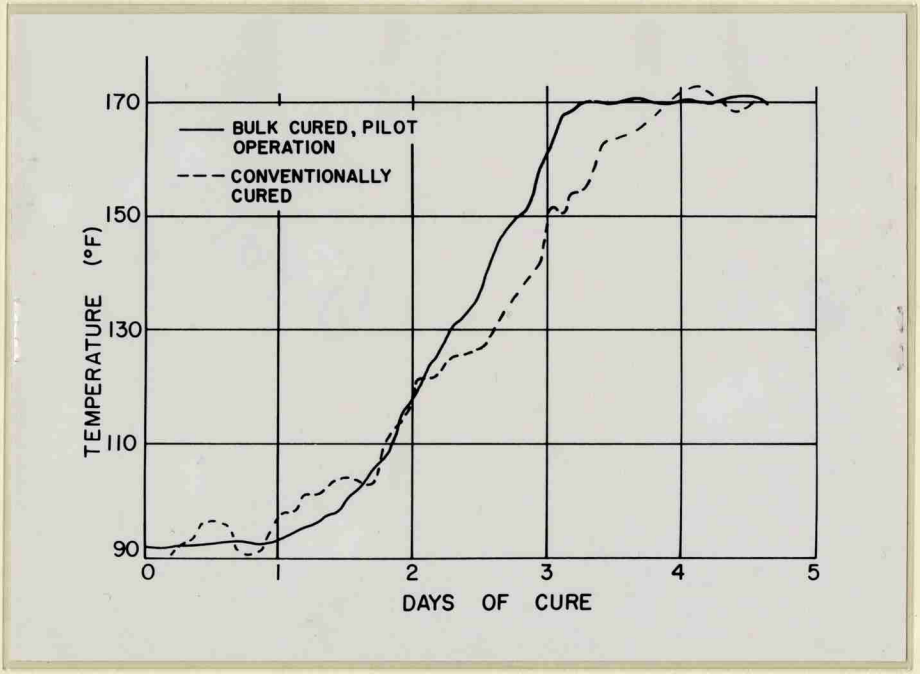

Figure 6. Comparison of temperature-time schedules for bulk and conventionally cured tobacco (1958).

December 7, 1959

Dr. J. A. Weybrew
Chairman Editorial Board
407 Williams Hall, Tobacco Laboratory
North Carolina State College
Raleigh, North Carolina

Dear Dr. Weybrew:

I am transmitting herewith two copies of the manuscript entitled "Bulk Curing Simplifies Tobacco Mechanization" by W. H. Johnson, W. H. Henson, Jr., F. J. Hassler, and R. W. Watkins. The manuscript has been approved for publication as Paper No. 1049 of the Journal Series of the North Carolina Agricultural Experiment Station and reviewed and approved by the Farm Electrification Research Branch of the U.S.D.A.

We would like to submit the manuscript for publication in Tobacco, New York. You may note that the paper was presented at the 1959 Annual Meeting of the American Society of Agricultural Engineers; consequently the paper is considered the property of the Society. Permission to publish the paper in full in "Tobacco Science" section of Tobacco has been granted by James Basselman, Editor of the Agricultural Engineering journal. Mr. Basselman pointed out that proper credit must be given to ASAE and place of presentation when published in Tobacco.

Sincerely,

William H. Johnson
Research Instructor

WHJ/ml
cc: W. H. Henson, Jr.
F. J. Hassler
R. W. Watkins
encl.

JOHNSON, W. H., W. H. HENSON, JR., F. J. HASSLER, and R. W. WATKINS (N. C. State College, Raleigh). Bulk Curing of Bright-Leaf Tobacco. Tobacco Science 4: _____. 1960 - - Development of a new curing method for bright-leaf tobacco was contingent upon accumulated observations on response of tobacco tissue to curing conditions. Shredding of tobacco leaves prior to curing resulted in significant reductions of sugar, nicotine, total alkaloid, and petroleum ether extract but larger ash content and specific volume. Smoking evaluations rated shredded tobacco as undesirable because of its low flavor and acrid aroma. Bulk curing of intact leaves to an acceptable quality depended upon proper conditioning of air at flow rates above 15 cfm per ft^2 curing area. Laboratory findings led to the development of a practical bulk curing method for intact leaves which is more compatible with tobacco mechanization than the conventional curing method. Possibilities for achieving marked advantage over the conventional curing method are discussed.

TOBACCO SCIENCE

EDITORIAL OFFICE
J. A. WEYBREW, CHAIRMAN
409 WILLIAMS HALL
N. C. STATE COLLEGE
RALEIGH, N. C.

December 28, 1959

Mr. William H. Johnson
Agricultural Engineering
110 Ag. Engineering Building
Campus

Registration No. 142

Dear Mr. Johnson:

I am returning one copy of your manuscript, **BULK CURING SIMPLIFIES TOBACCO MECHANIZATION,**

with the reviewers' recommendations to ( ) not approve; (X) approve after revision; ( ) approve in its present form. Copies of their critiques are enclosed. Please give careful consideration to each suggestion made by the reviewers. If you do not choose to make a particular change suggested in the review, then give a rebuttal to that comment in your letter of transmittal.

Resubmit your revised manuscript in duplicate with at least one set of figures suitable for reproduction (glossy photographs or inked drawings). Accompany this with an abstract of your paper on the BIOLOGICAL ABSTRACTS forms enclosed (include three extra carbons of the abstract on plain paper).

Acceptance of your revised paper will be acknowledged. At the time the printer sends you the galley-proof of your paper, he will furnish you with the prices of reprints in lots of 250 copies. Your reprint order should accompany the return of the galley.

We appreciate having had the opportunity to consider your manuscript for TOBACCO SCIENCE.

Sincerely yours,

J. A. Weybrew/pp

J. A. Weybrew
Chairman, Editorial Board

pp

Enclosures

Manuscript Review Form

TOBACCO SCIENCE

Registration No. 142 Date December 12, 1959

AUTHORS William H. Johnson, Wiley H. Henson, Jr., F. J. Hassler, Rupert Watkins

TITLE BULK CURING SIMPLIFIES TOBACCO MECHANIZATION

REVIEW COMPLETED December 23, 1959 RECOMMENDATION: ___APPROVE IN ITS PRESENT FORM; ___NOT APPROVE (Give reasons below); X APPROVE TENTATIVELY, SUBJECT TO THE FOLLOWING SUGGESTED REVISIONS: (itemize below):

1. The title is ambiguous and the tone of the manuscript is somewhat lacking in objectivity. We suggest revision to eliminate promotional tone. Throughout the manuscript there are many statements without supporting data. Claims for process are disproportionate to data presented.

2. We have the following specific comments:

   a. Page 1, Paragraph 1, Line 5 - We are under the impression that the average flue-cured allotment is around 3½ acres and that the average acre yield is somewhat lower than 1800 pounds. We suggest that the term "average" be eliminated.

   b. Page 5, Paragraph 2, Line 3 - "compared favorably" is a rather loose term. This entire paragraph is poorly worded, also paragraph 3.

   c. Page 6, Paragraph 3 - Statement that higher government grades means better acceptance is subject to question. The sale price of check samples cured in the conventional manner would be of interest.

   d. Page 7 - Discussion - Automatic control of temperature and relative humidity and outside heat source can be provided for conventional curing barns. The loading capacity of conventional barns can be increased through carefully controlled heating and ventilation.

NOTE—Execute in triplicate using additional sheets if more space is required. Retain the third copy for your file. Return the original (signed) and the first carbon (*unsigned*) along with the manuscript to this office. The unsigned copy and the manuscript will be returned to the author for his consideration.

e. Page 7 - Summary and Table 2 - The statement that the bulk-cured tobacco passed flavor tests as suitable for cigarettes appears to be inconsistent with the classification "low flavor". It would seem that some explanation should be added to the effect that such tobacco would be suitable for cigarettes if blended with full-flavored tobaccos.

f. Table 3 - The purpose of the last two columns is not obvious, nor is the meaning clear. One might suppose that the "auction average" is the season average of this particular government grade, but this would be a guess. Since the support price agrees with the price received in three instances, does it follow that three out of seven piles went into the Flue-Cured Stabilization Corporation?

g. The choice of words is not the best in many cases; for example:

Page 1, Line 1 - What is a fundamental problem?

Page 3, Line 17 - "volume rates" or "velocity"?

Page 7, Paragraph 5, Line 2 - What chemical tests were used for flavor evaluation?

We feel that the present research represents a noteworthy scientific achievement and that the results should be published in TOBACCO SCIENCE with proper emphasis on the technical aspects of the work.

TOBACCO SCIENCE

EDITORIAL OFFICE
J. A. WEYBREW, CHAIRMAN
409 WILLIAMS HALL
N. C. STATE COLLEGE
RALEIGH, N. C.

December 12, 1959

Mr. C. M. Sprinkle
Research Department
R. J. Reynolds Tobacco Company
Winston-Salem, North Carolina

Dear Mr. Sprinkle:

This is to request that you serve as a reviewer on the enclosed manuscript, Registration No. 142 :

Title: BULK CURING SIMPLIFIES TOBACCO MECHANIZATION

Authors: W. H. Johnson, W. H. Henson, Jr., F. J. Hassler, R. W. Watkins

Review forms are enclosed for your convenience. We would appreciate your recommendations as to the suitability of this paper for publication in TOBACCO SCIENCE. The authors will welcome your constructive criticisms.

We recognize that you are busy with other things, but please be as prompt as possible.

Sincerely yours,

J. A. Weybrew/pp

J. A. Weybrew
Chairman, Editorial Board

pp

Enclosures

Dec 16, 1959

Dear Joe: To save time, I'll just write this. This is an excellent paper, and publishing same in Tobacco Science will get this idea before a great many people who can help it along if they become interested — Regards — Charlie

Manuscript Review Form

TOBACCO SCIENCE

Registration No. 142 Date December 12, 1959

AUTHORS W. H. Johnson, W. H. Henson, Jr., F. J. Hassler, R. W. Watkins

TITLE BULK CURING SIMPLIFIES TOBACCO MECHANIZATION

REVIEW COMPLETED Dec 16, 1959 RECOMMENDATION: ✓ APPROVE IN ITS PRESENT FORM; ____ NOT APPROVE (Give reasons below); ____ APPROVE TENTATIVELY, SUBJECT TO THE FOLLOWING SUGGESTED REVISIONS: (itemize below):

NOTE—Execute in triplicate using additional sheets if more space is required. Retain the third copy for your file. Return the original (signed) and the first carbon (*unsigned*) along with the manuscript to this office. The unsigned copy and the manuscript will be returned to the author for his consideration.

C. W. Sprinkle

ELECTRICITY
ON THE Farm Magazine
466 Lexington Ave., New York 17, N. Y. ORegon 9-4000

March 10, 1960

Mr. William H. Johnston
Research Instructor
Agricultural Engineering Department
North Carolina State College
Raleigh, North Carolina

Dear Mr. Johnston:

Al Morris, our Southeast Editor, has sent in the article on "Bulk Curing of Tobacco" which is based on some research work done by you and your colleagues at N. C. State. This is a very interesting report indeed and I am sure it will be most useful to our readers in the Southeastern States.

Al tells me you gave him considerable help in the preparation of this article. He also informs me that you have offered to check the final copy for accuracy before it is printed. We will be looking forward to receiving your ok'd copy in the near future.

As a small token of appreciation for your efforts in working with Al on this article I've instructed our Accounting Department to mail you a check directly. You should be receiving it within the next couple of weeks. In behalf of Al we certainly want to thank you for your fine assistance in making this the best possible report on the subject.

Sincerely,

H. J. Hansen
Editor

HJH:RW

TOBACCO SCIENCE

February 2, 1959

Dear Mr. Johnson

This is to advise you that your manuscript (No. 142) has been approved for publication. with Priority No. 12 about 3/18
If you desire reprints of your article, write **immediately** to "Tobacco Science," Lockwood Trade Journal Co., 15 West 47th St., New York 36, N. Y. and state the quantity desired. They will inform you of the cost of reprints with or without covers.

Order reprints when you return galley

Sincerely yours,

J. A. Weybrew, Chairman
Editorial Board
Williams Hall, N. C. State College

NORTH CAROLINA STATE COLLEGE
RALEIGH

DEPARTMENT OF
AGRICULTURAL ENGINEERING

March 10, 1960

Mr. Albert Morris, Jr.
Associate Editor
Electricity On The Farm
Magazine
2535 Layton Drive
Lithonia, Georgia

Dear Mr. Morris:

Thank you for the article on "Bulk Curing Tobacco". I have reviewed this article with the authors and have made two corrections on the second page. For your convenience, this page has been retyped.

I shall be looking forward to seeing this article in print and will be glad to assist you in future articles whenever results become available.

Sincerely yours,

William H. Johnson
Instructor

WHJ:mac

Enclosure

ELECTRICITY ON THE FARM
Southeast Edition
North Carolina State College

BULK CURING OF TOBACCO

May Be Just Around the Corner

This New Process Would Cut Sharply into Labor Costs

Scientists at North Carolina State College are ready for on-the-farm testing of a new bulk-curing process for tobacco. They estimate that it will eliminate up to three-fourths of the labor now needed for barning after the leaves have been cropped, and it will save still more labor when racks are being unloaded for market.

The product of years of curing research, the new bulk process hits hard at the prime cost factor in tobacco production. Approximately 420 man-hours per acre are necessary for growing this crop with present day methods. Bulk curing combined with mechanical harvesting may practically eliminate hand labor in these two operations.

More Efficient Curing Barn

Pilot studies by the scientists -- W. H. Johnson, W. H. Henson Jr., F. J. Hassler and Rupert W. Watkins -- also indicate that the bulk process will produce a more uniform leaf because there is closer control of curing and drying conditions. And the compact bulk curing chamber, well-insulated and equipped with automatic controls, is expected to prove a more efficient user of fuel than conventional barns.

The experimental bulk curing chamber is 10 x 12 x 6½ feet. It will hold as much tobacco as a conventional barn that is six times larger. It consists of a curing compartment, a thermostatically controlled heating furnace, and a dampered duct for regulating the amount of air to be recirculated.

(MORE)

Forced Air Movement Is Essential

In the curing chamber, the tobacco is held on 28 racks, each one 6 feet long and 16 inches wide. Leaves are loaded into these racks by the hand- or armful. One man can load what amounts to 12 sticks of tobacco into a rack in less than 5 minutes. Two men standing on the floor lift the loaded racks onto the barn tiers for curing.

Forced air movement is essential in this bulk process. Temperatures are almost the same as for conventional curing. Hot air is forced up through the compartment floor and through the racks of tobacco at rates from 15 to 30 feet per minute. It promotes drying and prevents "scalding" of the tightly packed leaves.

Price Comparison Is Favorable

Indications are that the tobacco industry will accept the bulk-cured product. Chemical and smoking evaluations have been made, and these show little difference between tobacco cured conventionally and that cured by the new bulk process.

Average prices based on government grades indicate that the grower might get a slightly higher price for his tobacco by bulk curing. This is another evidence of acceptability. Sold on the open market, samples of the bulk-cured leaf averaged $62 per hundred, with a high of $70.

Other Uses for Special Curing Barn

While the bulk curing process would require a special barn, the scientists estimate that it would not cost appreciably more than present barns. It would be smaller and might be sized to fit the tobacco allotment. And they believe it might be used for curing other farm crops like sweet potatoes, peanuts and grain.

This study is conducted jointly by the North Carolina Agricultural Experiment Station and the Farm Electrification Research Branch, Agricultural Research Service, USDA.

#

ELECTRICITY ON THE FARM
Southeast Edition
Bulk Curing of Tobacco - Cutlines

1) Experimental model of bulk curing chamber.

2) Costly hand labor in the tobacco barning process is reduced sharply. Tobacco leaves are handled in bulk, placed evenly in form, and clamped between two sides of rack. One man loads equivalent of 12 sticks of tobacco in less than 5 minutes.

3) Frames holding bulk tobacco are easily lifted onto barn tiers by two men. Experimental curing chamber holds 28 racks. In bulk, tobacco requires 1/6 space needed in conventional barn.

4) Comparison of temperature-time schedules for bulk and conventional curing shows temperatures under two systems were about the same.

March 7, 1960

Mr. James Basselman, Editor
AGRICULTURAL ENGINEERING
420 Main Street
St. Joseph, Michigan

Subject: Paper entitled "Bulk Curing Simplifies Tobacco Mechanization" by W. H. Johnson, W. H. Henson, Jr., F. J. Hassler and R. W. Watkins

Dear Mr. Basselman:

In reply to your letter of February 15, 1960, the authors have considered the suggestions of your Critical Readers and have made several improvements as follows:

1. A footnote to Table 1 has been changed from "** Significantly lower at the 0.01 level" to read "** F-test exceeds the tabular F at the 1% level of significance"

2. Table 3 and its text reference have been omitted

3. The last paragraph in "Discussion" has been omitted

In addition to these changes, the authors have made several revisions in accordance with suggestions from a review committee from Tobacco Science (the manuscript will appear in March 18th issue of Tobacco magazine), and with the Editor's permission we would like to include these revisions. These revisions are primarily concerned with rewording at several places to eliminate promotional tone and to add objectivity to the manuscript. For example, the title was changed to read "Bulk Curing of Bright Leaf Tobacco", figure captions were improved, and several words such as highly favorable, good possibility, etc. were deleted.

I am enclosing a copy of the revised manuscript, less photographs for your approval. Captions for the photographs are included with the manuscript.

Sincerely yours,

William H. Johnson
Research Instructor

WHJ/ml
Encl.

March 7, 1960

Mr. James Basselman, Editor
AGRICULTURAL ENGINEERING
420 Main Street
St. Joseph, Michigan

Subject: Paper entitled "Bulk Curing Simplifies Tobacco Mechanization" by W. H. Johnson, W. H. Henson, Jr., F. J. Hassler and R. W. Watkins

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Sincerely yours,

William H. Johnson
Research Instructor

WHJ/ml
Encl.

AGRICULTURAL
ENGINEERING
and
Agricultural Engineers Yearbook

420 Main Street, St. Joseph, Michigan
Telephone: YUkon 3-2700

February 15, 1960

Mr. William H. Johnson
Research Instructor
Agricultural Engineering Dept.
North Carolina State College
Raleigh, North Carolina

Dear Mr. Johnson:

Subject: Paper entitled "Bulk Curing Simplifies Tobacco Mechanization"
by W. H. Johnson, W. H. Henson, Jr., F. J. Hassler and R. W. Watkins

In order to make it possible for you to receive comments of our Critical Readers regarding your paper without further delay because of the large number of manuscripts to be processed, we are making use of the following form. The comments we receive are offered as constructive criticism.

Please let us know (1) if you agree with the Critical Readers and (2) if you care to make any revisions in the paper before it is published. Since readers often disagree on recommendations, their comments are not considered binding, but rather contain the type of information they, themselves, would like to receive concerning their own papers.

Comments of Readers:

"Introduction, review of literature, and the 1956 Lab. test should be shortened. Instead of first two sections -- an introductory paragraph and a statement of the fundamental ideas of related research (without discussion) would be in order. Section 3, the 1956 study, could be cut by eliminating or briefing paragraphs 2 and 3 on page 3."

"**Significantly lower at the 0.01 level -- Table 1; what does it mean? Points offered for condensation: Condense review of literature and include under introduction; page 6 -- omit reference to Table 3; omit table 3. This adds very little to such a technical publication. This information would be available from the author. Table is summarized in text -- pages 7 and 8. Summary and discussion have considerable duplication. Suggest combining as a summary only."

We trust that the above mentioned comments will be helpful to you and we lookforward to receiving a reply to the readers' suggestions.

Sincerely,

James Basselman

JAMES BASSELMAN, Editor

vz

April 26, 1960

Mr. William G. Reddan, Editor
Tobacco Industry and Science Weekly
49 West 45th Street
New York 36, New York

Dear Mr. Reddan:

I am writing in reference to purchase order No. A-10391 for 500 Photo-Offset reprints without cover of the manuscript "Bulk Curing of Bright-leaf Tobacco" by W. H. Johnson, W. H. Henson, Jr., F. J. Hassler, and R. W. Watkins.

Would you please check on the status of this order and let me know as soon as possible when we may expect to receive the reprints? Numerous requests for this paper are now being received.

With kindest regards.

Sincerely,

William H. Johnson
Research Instructor

WHJ/ml

March 2, 1960

AIR MAIL

Mr. William G. Reddan
TOBACCO Magazine
49 West 45th Street
New York 36, New York

Dear Mr. Reddan:

Enclosed are the proofs of the manuscript "Bulk Curing of Bright-Leaf Tobacco" which is to be published in "Tobacco Science" section of TOBACCO. The authors have reviewed the proofs and made two minor corrections as indicated on the proofs.

I am placing a purchase order through the college channels for 500 copies of photo-offset reprints without cover. You should receive this order within two or three weeks.

Sincerely yours,

William H. Johnson
Research Instructor

WHJ/ml
Encl.

TOBACCO

INDUSTRY & SCIENCE WEEKLY

ESTABLISHED 1886

PUBLISHED EVERY FRIDAY

49 WEST 45th STREET, NEW YORK 36, N. Y.

PLAZA 7-2370

February 25, 1960

Dr. William H. Johnson
Agricultural Engineering Department
North Carolina State College
Raleigh, N.C.

Dear Dr. Johnson:

Enclosed are the proofs of the manuscript

"Bulk Curing of Bright Leaf Tobacco"

which you submitted to "Tobacco Science". The manuscript will be published in the "Tobacco Science" section of TOBACCO, issue of

March 18, 1960

It is essential that the proofs be returned to us by March 8 marked with any corrections that you may desire to be made in the manuscript prior to publication. It will be appreciated if you will make corrections only for errors of fact or typesetting, as any material changes will necessitate the return of the manuscript to the Editorial Board for further processing. If the proofs are not returned to this office by March 8 we will assume that no corrections are desired and that the manuscript in galley form meets your approval for publication.

Attached is a schedule of prices for reprints of your article. Should you desire reprints to be made by us, kindly enclose your order, specifying kind and quantity, at the time you return the proofs. A bill for reprints will follow their delivery.

Thank you for your support of "Tobacco Science".

With kindest regards,

Sincerely,

William G. Reddan

William G. Reddan
Editor

WGR/s
Encls

T.S. 12

Prices for reprints of your manuscript which is to be published in "Tobacco Science" are as follows: F.O.B., East Stroudsburg, Pa. 600

For Printed Reprints:	
250 copies without cover	$60.00
each additional 250 cys	11.75
250 copies with cover	72.00
each additional 250 cys	12.00
For Photo-Offset Reprints:	
250 copies without cover	61.00
each additional 250 cys	6.00
250 copies with cover	61.00
each additional 250 cys	11.00

If you desire reprints of your manuscript, kindly submit your order when you return the galleys of your article. Reprint requests received after an article has been published will cause an additional charge for taking the pages out of storage (unwrapping and wrapping charges).

TOBACCO SCIENCE

December 8, 1959

Dear Mr. Johnson

This will acknowledge receipt of your manuscript entitled,

BULK CURING SIMPLIFIES TOBACCO MECHANIZATION

This manuscript has been assigned the Registration No. 142
which will identify it in any future correspondence.

Sincerely yours,

J. A. Weybrew, Chairman
Editorial Board
Williams Hall, N. C. State College

September 18, 1957

Dr. J. A. Weybrew
Chairman Editorial Board
409 Williams Hall
North Carolina State College
Raleigh, North Carolina

Dear Dr. Weybrew:

I am transmitting herewith two copies of the manuscript entitled "Some Determinations Pertinent to Removal of Midrib from Bright-Leaf Tobacco During Curing Operations" by W. H. Johnson, F. J. Hassler, and W. H. Henson, Jr. This manuscript, having Registration No. 45, has been revised after consideration of each suggestion made by the reviewers.

I have a rebuttal to one question: "Is it a case of translocation entirely or is it in part due to the conversion of starches into sugars?" I would interpret from the reviewers comment that this question is made with reference to possible greater drying of the leaf as a result of midrib removal which in turn would inhibit starch conversion. The nature of the data, however, does not support this proposal. Assume that no translocation occurred, i.e. that the reduction or increase of sugars in midrib or lamina was attributed to accelerated drying due to midrib removal. Then the sugar concentration in the lamina and midrib should be lower for midrib removal at an early stage. However, the data shows that the lamina sugar percentage was greater for early midrib removal. The sugar percentages for lamina decreased for late midrib removal, whereas the midrib sugars increased. In answer to the question, the data would seem to indicate that the differences in sugar percentages for midrib and lamina are due entirely to translocation.

Sincerely yours,

William H. Johnson
Research Instructor

WHJ:AS

encl.

JOHNSON, W. H., F. J. HASSLER, and W. H. HENSON, JR. (N. C. State College, Raleigh) Some determinations pertinent to removal of midrib from bright-leaf tobacco during curing operations. Tobacco,145 (Tobacco Science,1)1957. Edge effects from midrib removal by cutting and stripping were negligible when the tobacco was yellowed under a 96% relative humidity. A high drying condition of 82% relative humidity amplified edge effects by producing premature arrestation of important biochemical reactions. An analysis of translocation showed that 7.5% of reducing sugar was translocated from the lamina to the midrib during cabinet yellowing of tobacco, however no significant translocation occurred with pile yellowed tobacco. Force requirements for separating 3-inch sections of midribs from laminae by tearing, which were slightly higher for pile yellowed than for cabinet yellowed tobacco, increased from 3.5 lb. at the beginning of yellowing to 6.0 lb. after yellowing. The implications of these findings as related to tobacco curing are discussed. ------- W. H. Johnson.

February 1, 1960

Dr. J. A. Weybrew
Chairman Editorial Board
409 Williams Hall
North Carolina State College
Raleigh, North Carolina

Dear Dr. Weybrew:

I am transmitting herewith two copies of the manuscript entitled "Bulk Curing of Bright Leaf Tobacco" by W. H. Johnson, W. H. Henson, Jr., F. J. Hassler, and R. W. Watkins. This manuscript, having Registration No. 142, has been revised after consideration of each suggestion made by the reviewers.

I have a rebuttal to one comment "The statement that the bulk-cured tobacco passed flavor tests as suitable for cigarettes appears to be inconsistent with the classification 'low flavor'. It would seem that some explanation should be added to the effect that such tobacco would be suitable for cigarettes if blended with full-flavored tobaccos." The authors feel that this explanation is not necessary since the tests were primarily concerned with comparing bulk tobacco with that conventionally cured - not with the general level of flavor classification for the particular variety tested. All varieties now in production are normally recognized to have different levels of flavor classification.

Sincerely yours,

William H. Johnson
Research Instructor

WHJ/ml
Encl.

Please reply to: Albert Morris, Jr., Associate Editor, 2535 Layton Drive, Lithonia, Georgia, HUdson 2-6101
305 East 45th Street, New York 17, New York · ORegon 9-4000
W. J. RIDOUT, JR. GENERAL MANAGER EDITORIAL DIRECTOR • KARL H. GORHAM BUSINESS MANAGER ADVERTISING MANAGER • HUGH J. HANSEN EDITOR • RUTH GAFFNEY HOME EDITOR

ELECTRICITY
ON THE Farm Magazine

2535 Layton Drive
Lithonia, Georgia
March 8, 1960

Mr. William H. Johnson
Research Instructor
Agricultural Engineering Department
North Carolina State College
Raleigh, North Carolina

Dear Mr. Johnson:

Enclosed are two copies of the article that I have written about the work you and your associates have done on bulk curing tobacco. This, of course, is based upon the papers you provided me several weeks ago. Except for minor editorial changes that may become necessary to fit space, we propose to use the story in this form. I wonder if you will be kind enough to review it, note on one of the copies such changes as you find desirable, and return this to me at your early convenience.

Also enclosed are two of the photographs which you sent me. I am forwarding the other four illustrations with the story in the hope that we shall be able to use all of these.

We shall look forward to hearing about further results of your work. May I thank you again for your kindness and your helpfulness.

Sincerely yours,

Albert Morris
Southeast Editor

while the bulk curing process will require a special barn,

the cost of the barn will vary depending
on its size and design for other uses.
The barn can be sized to fit a tobacco allotment
and perhaps designed for the curing & drying of
other farm crops such as sweet pot. peanut, and grain.

Forced Air Movement Is Essential

In the curing chamber, the tobacco is held on 28 racks, each one 6 feet long and 16 inches wide. Leaves are loaded into these racks by the hand- or armful. One man can load what amounts to 12 sticks of tobacco into a rack in less than 5 minutes. Two men standing on the floor lift the loaded racks onto the barn tiers for curing.

Forced air movement is essential in this bulk process. Temperatures are almost the same as for conventional curing. Hot air is forced up through the compartment floor and through the racks of tobacco at rates from 15 to 30 feet per minute. It promotes drying and prevents "scalding" of the tightly packed leaves.

Price Comparison Is Favorable

Indications are that the tobacco industry will accept the bulk-cured product. Chemical and smoking evaluations have been made, and these show little difference between tobacco cured conventionally and that cured by the new bulk process. Sales results also indicate that tobacco cured by this method will be acceptable to the trade. Average prices based on government grades indicate that the grower might get a slightly higher price for his tobacco by bulk-curing. This is another evidence of acceptability. Sold on the open market, samples of the bulk-cured leaf averaged $62 per hundred, with a high of $70.

Other Uses for Special Curing Barn

While the bulk curing process would require a special barn, the scientists estimate that it would not cost appreciably more than present barns. It would be smaller and might be sized to fit the tobacco allotment. And they believe it might be used for curing other farm crops like sweet potatoes, peanuts and grain.

This study is conducted jointly by the North Carolina Agricultural Experiment Station and the Farm Electrification Research Branch, Agricultural Research Service, USDA.

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This study is conducted jointly by the North Carolina Agricultural Experiment Station and the Farm Electrification Research Branch, Agricultural Research Service, USDA.

#

BULK CURING OF BRIGHT-LEAF TOBACCO

By

William H. Johnson

Basic studies indicated the possibility of curing packed leaves whereby the requirement for stringing leaves on sticks could be eliminated. During 1955-1959, development proceeded from laboratory bulk curing to a pilot stage operation, intermediate between the laboratory scale and a farm-scale operation. This new method of curing offers the potential for marked advantages over conventional curing in labor and other economics, simplicity of operation, and safety. The development of the new bulk curing method from laboratory investigations to its present status is discussed, along with implications for practical application.

NORTH CAROLINA STATE COLLEGE

RALEIGH

DEPARTMENT OF
AGRICULTURAL ENGINEERING

May 22, 1959

Dr. T. E. Heinton
Farm Electrification Section
U.S.D.A., A.E.R.B., A.R.S.
North Building, Plant Industry Station
Beltsville, Maryland

Dear Dr. Heinton:

I am enclosing three copies of a manuscript entitled "Bulk Curing Simplifies Tobacco Mechanization", by W. H. Johnson, W. H. Henson, F. J. Hassler and R. W. Watkins.

This manuscript has been reviewed by the Agricultural Experiment Station at N. C. State College, a journal series number assigned and approved by Dr. R. L. Lovvorn. We are submitting it to you for review and approval by A.R.S.

I believe Wiley Henson transmitted to you a preliminary copy earlier. The authors would like to get approval as quickly as possible so that copies can be duplicated in time for handing out in conjunction with the Cornell meeting. It is William Johnson's intention to present this at the Cornell meeting. It is my understanding that the copies must be duplicated and in the mail from this point by June 14th. I suspect, however, that arrangements could be made to have them duplicated at a later date if arrangements were made in advance. Your fine cooperation in moving this forward as rapidly as possible, would be greatly appreciated.

Yours very truly,

G. W. Giles, Head
Agricultural Engineering
Department

al
encl.
cc: W. H. Johnson
W. H. Henson

Editor's Copy

MEMORANDUM

To: Director of Research Date: May 23, 1959

From: G. W. Giles Head of: Department of Agricultural Engineering

Manuscript: For approval X (enclose 3 copies of text; 1 copy of photos and graphs)

For your information _____ (enclose 1 copy)

Title: "Bulk Curing Simplifies Tobacco Mechanization"

Author(s) W. H. Johnson, W. H. Henson, F. J. Hassler, R. W. Watkins

Recommended for publication as follows:

Station Technical Bulletin _____ Number of copies recommended _____ (Ave. No. 5000)

Station Bulletin _____ Number of copies recommended _____ (Ave. No. 7000)

Journal Series article in Agricultural Engineering
(Name of Journal)

Note in _____
(Name of Journal)

Other _____

Contribution from Agricultural Engineering Department(s)
and U.S.D.A. X ; Other agencies: _____

It has been reviewed by a committee consisting of:

W. G. Woltz J. A. Weybrew

W. E. Splinter Chm.

It has been approved by the following:

Departments: Agricultural Engineering

Other agencies: _____ Date: _____

_____ Date: _____

If you approve of its publication please: Assign Journal Series No. and return X .

Transmit to Publications Office _____. Initial and return _____.

Other remarks Will be transmitted to U.S.D.A. after approval and assignment of Journal article.

Action taken by Director:

(1) Approved as: Tech. Bull. No. _____, Sta. Bull. No. _____, No. Copies: _____.

(2) Approved as Paper No. _____ of the Journal Series.

(3) Manuscript returned to: _____

Comments: _____

Signed: _____ Date: _____
Director

AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS
SAINT JOSEPH, MICHIGAN

March 24, 1959

Mr William H Johnson
Agricultural Engineering Dept
North Carolina State College
Raleigh, N C

Dear Mr Johnson:

Please permit me to welcome you as a scheduled speaker for our 52nd Annual Meeting at Cornell University, Ithaca, New York, this June 21-24. A copy of the printed program and further details regarding hotel reservations will be sent to you in May.

We are enclosing a mimeographed sheet entitled "Information for Speakers on ASAE Meeting Programs." Will you please give this information your careful attention so that our Committee on Public Relations and our editorial staff for AGRICULTURAL ENGINEERING can make the most effective use of the information you present?

May we call to your immediate attention paragraphs 5, 6, 9, 11 and 13 of the enclosed information. These sections refer to deadline dates and other data requiring prompt attention. Information that should be submitted to ASAE headquarters as soon as possible, but no later than May 4, includes:

1 Two copies of your manuscript. If you want ASAE to prepare additional copies, please get them to us as soon as possible. If you prepare copies for distribution, they should reach Ithaca and ASAE headquarters by June 12 (labels enclosed). In either case, send two copies for publicity purposes to ASAE by May 4. See instruction 5.
2 Two copies of summary. See instructions 6, 7 and 8.
3 Two copies of professional record. See instruction 9.
4 Two copies of projection equipment requirements. See instructions 10 and 11.
5 For reference purposes, and for your information if you reproduce your own paper (see instruction 5b), your manuscript has been designated paper number 59-311.

I am sure your contribution to our meeting will be an outstanding one. We wish to welcome you and offer our assistance in any way that would tend to make your presentation more effective.

Yours very truly

J. L. Butt

J L BUTT
Executive Secretary

of
Enc

AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS
Saint Joseph, Michigan

INFORMATION FOR SPEAKERS ON ASAE MEETING PROGRAMS

Speakers on ASAE meeting programs are asked to note carefully the following paragraphs containing certain requests and instructions, compliance with which, insofar as practicable, will be appreciated by the Society.

Program Time

1 Each speaker is ordinarily allotted a specified amount of time (noted on the program). The purpose of this is three-fold: (a) To have it definitely understood in advance how much program time each speaker is to have, (b) To insure sufficient time for questions and discussion from the floor, and (c) generally to keep the program on schedule.

2 The Society suggests that the length of paper a speaker prepares be governed by the material available and essential to a proper presentation of his subject. But if the paper is too long to present in full within the allotted program time, the speaker is asked to condense his oral presentation accordingly. However, the complete paper should be submitted for possible publication or other distribution by the Society.

3 Speakers are especially requested not to use program time for long, detailed descriptions of methods, equipment, etc, used in performing experimental or other work, or for developing involved mathematical formulas. ASAE audiences prefer that a minimum of time be devoted to history, procedure, etc, and that the speaker confine himself mainly to presenting results achieved.

Copies of Papers for Distribution at and Following Meeting

4 Speakers usually find an active demand for copies of their papers at and following the session at which their presentation is made. Past experience has indicated the desirability of distribution after the session from a central location operated under the supervision of the Local Arrangements Group and/or the Society as described in paragraph 5.

5 The preparation and distribution of papers for the 1959 Annual Meeting will be handled in the following manner:

(a) As a service to speakers, and upon request, ASAE will reproduce (by mimeograph) all papers submitted in duplicate so as to reach ASAE headquarters by or before May 4. Photographs, formulas using characters not on standard typewriters, and complex graphs or drawings cannot be reproduced with existing facilities; therefore, authors are requested to develop their papers accordingly, or to provide lettered stencils when this type of presentation is essential to the paper. If stencils are provided, follow single-space format comparable to this instruction sheet. Stencils prepared by ASAE will be proof read by typists but not by the ASAE professional staff. If author elects to utilize this service, ASAE will prepare all copies for subsequent distribution and will mail

25 copies to the author. Authors may obtain additional copies for personal use at the rate of $1.00 per page, per 100 copies (example: 200 copies of a 6-page paper - $12.00), provided order is placed when manuscript is submitted.

(b) For speakers with facilities for reproducing their own papers, 300 copies are requested. Fifty copies should be mailed directly to ASAE, St Joseph, Michigan; and 250 copies should be mailed to ASAE Paper Distribution, c/o Orval C French, Agricultural Engineering Department, Riley-Robb Hall, Cornell University, Ithaca, New York, so as to arrive there by June 12 (labels enclosed). Speakers supplying their own papers are requested to set up a title sheet similar to the one shown as Appendix A attached. This will provide a uniformity of style and will aid in indexing and ordering papers.

(c) To help assure maximum and equitable distribution of papers at the meeting, a punch card system of rationing copies to registrants will be employed. Each registrant will be entitled to a given number of papers upon payment of his registration fee. If he wants more papers than are allocated on his card (for example, to place in a department library), additional cards will be available at the registration desk at a nominal charge to help defray handling costs. If the supply of a particular paper is exhausted, cards will be provided to registrants, and the paper will be mailed to them by ASAE following the meeting.

6 Mail to ASAE headquarters, as soon as possible, but not later than May 4, two copies each of your paper and a thorough summary of your presentation (1) for use by our committee in preparing advance publicity, and (2) for possible publication in AGRICULTURAL ENGINEERING. Publishing of a summary or synopsis will bring the contents of your paper to the attention of all ASAE members rather than only the 15 or 20 percent who normally attend our meetings. It assures the author of an audience of at least 7500 persons.

7 It is the desire of the Society that speakers on ASAE meeting programs derive maximum possible publicity for themselves, their employers, and the subject matter they present. To that end the cooperation of each speaker is requested in regard to paragraphs 5 and 6 above. This allows time for the preparation of news releases under the supervision of the Society's Committee on Public Relations.

8 The preparation of news releases by a central agency from the complete manuscript has been found more effective than when preparation is attempted by the individual speaker or his agent. A certain uniformity of style is obtained which facilitates the use of the material by news distributing agencies. If for some reason, however, the complete manuscript cannot be supplied as requested above, a summary, abstract, or a prepared news release supplied as far in advance of the meeting as possible is urgently requested.

Professional Record of Speakers

9 Speakers are requested to furnish two copies of a brief typewritten statement (not to exceed 100 words) of positions they have held and of their professional training and accomplishments for use of the presiding chairman in introducing them. These statements should be submitted to the Secretary of the Society by May 4.

Illustrative Material

10 The Society encourages the use of illustrative material intended for more effective presentation of papers. It is important, however, that charts or other illustrations shall, when shown, be sufficiently large and clear that they may be easily read the full length of a large meeting room. Speakers are urged to prepare illustrations with special care to meet this requirement. ASAE can provide on request copies of a pamphlet giving helpful suggestions regarding the preparation of slides and charts.

11 The Society will ordinarily provide projection equipment, including screens, for 3½x4 and 2x2 slides, film strips, and 16-mm silent and sound motion pictures. Speakers who desire to show illustrative material should notify the Secretary, ASAE, by May 4 as to their requirements. This applies to the above conventional sizes and types of illustrations as well as any special requirements which the speaker may have.

Publication Information

12 It should be understood that papers presented before ASAE meetings are considered to be the property of the Society, and speakers are asked to refer requests for copies to the Secretary of the Society. In general, the Society reserves the right of first publication of such papers, in complete form, in its Journal, AGRICULTURAL ENGINEERING or in TRANSACTIONS OF THE ASAE; however, it has no objection to publication, in abstract form, in other publications prior to use in the Society's publications.

13 Space is critical in the Society's Journal, AGRICULTURAL ENGINEERING. All papers should be condensed as much as possible and still contain the essential information. Shorter papers are usually given preference for publication in AGRICULTURAL ENGINEERING, to provide a greater variety of subject matter in the available space.

General

14 The Society does not pay honorariums or traveling expenses to speakers appearing on its meeting programs.

15 Further information desired by speakers on ASAE meeting programs will be furnished gladly on request to: Secretary, ASAE, Saint Joseph, Michigan.

Paper No. 59-123

(TITLE OF YOUR PAPER IN CAPITAL LETTERS)

By

(John W. Doe)
(Title)
(Your Department or Company)
(Your address, city and state)

For Presentation at the 1959 Annual Meeting
AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS
Ithaca, New York
June 21-24, 1959

(Appendix A)

NORTH CAROLINA STATE COLLEGE

RALEIGH

DEPARTMENT OF
AGRICULTURAL ENGINEERING

May 5, 1959

Mr. G. W. Giles, Head
Agricultural Engineering Department
North Carolina State College
Raleigh, North Carolina

Dear Mr. Giles:

Enclosed are four copies of the manuscript entitled "Bulk Curing Simplifies Tobacco Mechanization". These copies are submitted for approval as a publication of the Journal Series of the North Carolina Agricultural Experiment Station, and for approval by the USDA.

The paper will be presented at the Summer Meeting of ASAE at Ithaca, New York, June 21-24, and then, we would hope, published in AGRICULTURAL ENGINEERING.

I would recommend Bill Splinter, Charles Suggs, and Dr. J. A. Weybrew as review committee for this manuscript.

Very truly yours,

William H. Johnson
Research Instructor

WHJ
encl. (4)

Paper No. 59-311

Bulk Curing Simplifies Tobacco Mechanization

~~BULK CURING OF TOBACCO~~
~~AN ADVANCEMENT FOR ENGINEERING~~ HARVESTING
~~-~~ AND PROCESSING OPERATIONS

By

William H. Johnson, Research Instructor

Wiley H. Henson, Jr., Agricultural Engineer
Farm Electrification Research Branch (AERD,ARS)

F. J. Hassler, Professor

Rupert W. Watkins, Research Instructor

Agricultural Engineering Department
North Carolina State College
Raleigh, North Carolina

For Presentation at the 1959 Annual Meeting
AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS
Ithaca, New York
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BULK CURING OF TOBACCO
AN ADVANCEMENT FOR ENGINEERING HARVESTING AND PROCESSING OPERATIONS

A fundamental and age-old problem in tobacco production is the great amount of hand labor required by inherent in the conventional methods. ~~of harvesting and processing.~~ ~~With partial~~ Some mechanization, has been achieved, particularly in cultural operations, 390 man-hours are required to produce one acre, ~~with approximately~~ At least 73 percent of the total labor is still required in the harvesting and processing operations (1). Approximately 33 percent of the total labor is required in the operations of cropping, handing, stringing, and placing tobacco into the curing barn.

The development and introduction of so called mechanical harvesters have not been successful in the solution of this problem. It is true that a measure of convenience has been introduced, such as ~~riding~~ conveying the field workers, ~~or also eliminating~~ with some reduction in the number of leaf handlings. Progress not withstanding the handing operation; ~~however~~, high labor requirements still exist, since the operations, complex in terms of selectivity, orientation and timing, have defied complete mechanization. Furthermore, It is recognized, ~~therefore,~~ that individual leaf handling operations, as required by the conventional curing method, ~~have presented~~ are the bottleneck to the development of mechanical complements for eliminating hand labor in harvesting and processing. these operations, because of their complexity in terms of requirements for selectivity, orientation and timing, present a real challenge to practical mechanization.

Systems engineering in general, which is concerned with overall processes, involves application of new operational techniques which maximize efficiency. Since ~~underlying~~ the inherent difficulties to ~~advancing~~ tobacco mechanization ~~were imposed by~~ made with the conventional curing method, research for several years at North Carolina State College has been directed towards a curing operation which would be more compatible with overall mechanization. Results ~~were~~ have been obtained that suggested the possibility of curing packed leaves, and by this approach eliminating the requirement for stringing leaves on a stick. On this conclusion research and development ~~were~~ has been initiated to test the feasibility of ~~what has come to be called~~ a curing method referred to as Bulk-curing.

Fundamental Studies

The development of the bulk curing process, radically different from the conventional, was a gradual evolution based upon accumulated observations and measurements of a fundamental nature. Basic information established by Hassler (2) pertaining to leaf response to temperature-moisture conditions provided a foundation for this new curing approach. Color change phenomena as influenced by temperature, drying rate, and leaf moisture content was studied on an individual leaf basis. Figure 1 shows the curing apparatus which allowed simultaneous measurement of leaf weight and leaf temperature. This coupled with time-lapse photography permitted the correlation of color change with environmental variables. Results of these studies provided limits for environmental control and information helpful to proper yellowing of leaf tissue. For example, it was found that at 135° F leaf tissue temperature (thermocouple inserted between layers of leaf tissue), a browning reaction occurred which, within five minutes, completely degraded leaf quality. Initial drying was also found desirable for hastening the green to yellow color change.

The impetus for curing in the bulk led to detailed studies on bulk yellowing by Henson (3), who investigated the conditions existing in ventilated and non-ventilated bulks of tobacco and evaluated the influence of these conditions on certain chemical and physical properties of the cured leaf. Figure 2 illustrates some of the typical results of forced aeration in bulk yellowing tests. In the non-ventilated bulks, temperatures increased almost linearly with time with peak temperatures ranging from 125° F to 129° F and occurring 35 to 51 hours after the leaves were bulked. Almost two-thirds of this tobacco was damaged by high bulk temperatures due to exothermic heat of respiration. Ventilation of bulks with air velocities up to 25 ft/min prevented temperature damage and resulted in yellowed tobacco having

good color and physical appearance. Chemical analyses showed that bulk yellowing was accomplished without appreciable reduction of total and reducing-sugar contents, provided forced air was employed to prevent temperature damage.

Studies on bruising and edge effects by Johnson (4-5) established conditions by which shredded tobacco can be yellowed to good color without significant edge effects which otherwise result from premature arrestation of important biochemical reactions. These findings were important because of the potential advantages suggested by the possibility of bulk curing shredded material. It also pointed out that, in order to maintain a quality product, non-bruising methods of handling must be used in the development of new approaches in mechanizing harvesting and curing operations.

Laboratory Bulk Curing Investigations

During 1956 and 1957, laboratory studies were conducted to further evaluate the potentialities of bulk curing. Objectives for the experiments were:

1. To make chemical and physical evaluations of both intact and shredded bulk-cured tobacco in comparison with conventionally cured tobacco.
2. To make measurements pertinent to bulk curing analysis and design.

Three bulk curing chambers of the design shown in figure 3 were constructed for the initial tests of 1956. Each chamber consisted of a 1/6 hp centrifugal fan, a conical section, and a cylindrical section. A metal mesh screen located between the cylindrical and conical sections provided support for approximately 200 pounds of uncured intact tobacco. This particular design was selected because it was considered that a circular chamber would provide uniform air distribution with simplicity of design. Heat was furnished by a jet-type gas burner which was fired directly into the fan. The temperature within the conical section was thermostatically controlled by an on-off valve in the gas line, actuated by a sensing

bulk located within the cone. A multiple-point temperature recorder ~~recorded~~ measured air inlet and bulk temperatures. Air volume rate was measured with pilot tubes positioned beneath the tobacco.

Replicated tests were conducted in which both intact and 1/2" shredded leaf material were cured in the cylindrical chamber, while check samples for comparison were conventionally cured.

Observations during the initial tests were important in advancing laboratory bulk curing studies. Of primary importance was the fact that tobacco had been yellowed and cured in the bulk. Both intact and shredded leaf compared favorably in color with conventional tobacco; however the bulk intact tobacco exhibited a flat, "unnatural" appearance while shredded tobacco had an undesirable aroma. It was believed that the bulk curing conditions were not as favorable as the conventional curing conditions, thus causing these noted differences. Leaf orientation with butts upward proved most satisfactory for uniform air distribution; however, this orientation presented the additional requirement of vertical support for the leaves. Leaf drying was found most desirable when air was forced upward from the tips to the butts. Observations also suggested that a limited amount of drying during yellowing was desirable for preventing surface-moisture accumulation in tightly bulked tobacco and for promoting yellowing. One of the most important problems encountered was non-uniform air distribution which resulted in uneven drying. Since uniformity of air distribution depends directly on bulk uniformity, the non-uniform loading method employed caused air channeling through less dense sections of the bulk. Comparisons of energy efficiencies showed that bulk curing using forced convection was less efficient then conventional curing.

From the above observations, two additional objectives were added to the following 1957 experiment:

1. To make improvements in the loading techniques and equipment for bulk curing which would simplify the process and contribute to curing a more acceptable and higher quality product.

2. To improve the curing schedule and adopt techniques of recirculation for improving process efficiency.

Six climactic chambers of the type shown in figure 4 were selected and modified for achieving both a controlled environment and an improved loading technique.

Sensitive electronic temperature controls maintained conditions within one degree F., while air flow and recirculation dampers allowed any desired air movement. A special loading form was developed which allowed rapid loading and clamping of tobacco into racks. Each chamber held 2 racks of bulk tobacco or ~~a sheet~~ one metal basket with shredded tobacco. Another modification in equipment was the use of steam for conditioning tobacco after curing.

As a result of improving the equipment and control, marked improvements were recognized in the quality of cured intact tobacco. Visual observations showed no apparent color differences in tobacco cured by the two methods. Leaf appearance was greatly improved over that cured in 1956, and much of the objectionable flat appearance was overcome by adequately conditioning the bulk tobacco after curing. Shredded tobacco, however, still continued to exhibit an "undesirable" aroma. The improved loading technique contributed to faster, easier bulking and allowed much greater uniformity of tobacco within the racks. As a consequence, uniform air distribution and even drying resulted, thus maintaining quality by proper drying. In addition to quality upgrading, fuel efficiencies for intact bulk curing surpassed conventional curing as a result of proper air ~~flow~~ recirculation.

Results of Laboratory Bulk Curing

~~Perhaps most~~ an important contribution to the development of bulk curing were the physical and chemical assays of tobacco samples by several major tobacco companies and the State College Tobacco Laboratory. Visual inspection by tobacco leaf and research men showed that intact bulk-cured leaf was gaining greater acceptance. Smoking tests completed by several tobacco companies agreed closely, and essentially the same results were obtained for both 1956 and 1957 tests. Bulk-cured leaf was similar in smoking characteristics to conventionally cured leaf, however shredded tobacco produced an undesirable smoke which lacked flavor and aroma.

Chemical evaluations by tobacco companies also agreed closely, thereby giving further substantiation for the differences noted in shredded tobacco. In general, their results showed that intact bulk-cured tobacco closely resembled that conventionally cured; however, shredded tobacco had significantly smaller contents of total alkaloid, nicotine, sugar and petroleum ether extract but larger ash content and specific volume. More detailed statistical analyses of sugar and nicotine percentages were made from results of the State College Tobacco Laboratory. Table 1 shows, that in every case, shredded tobacco had lower contents of sugar and nicotine, significant at the .01 level, while intact bulk-cured leaf compared favorably with normally cured leaf.

Because of the highly favorable results ~~achieved~~ obtained in bulk curing intact leaf, from both standpoints of operation and quality of cure, ~~continued~~ development towards a practical curing system was initiated. On the other hand, negative results in bulk curing shredded tobacco suggested more fundamental research to find ways of improving its curability.

Bulk Curing Pilot Operation

During 1958 an applied study in bulk curing of intact leaf was conducted in

which laboratory findings and techniques were extended to encompass a pilot operation, intermediate to laboratory and field operation. Figure 5 shows a schematic of the curing system. It consisted essentially of a curing compartment for bulked tobacco, a thermostatically controlled heating furnace, and a dampered duct for regulating recirculated air. To simplify loading the ~~barn~~ compartment, the structure was designed for loading from the standing position. One of the essential features of this system is the forced air movement. Hot air, forced up through the barn floor and through the racks of tobacco at rates up to 30 ft/min, promoted drying and prevented the tightly packed tobacco from scalding. ~~On~~ The amount of tobacco cured in two tiers in the 10' x 12' x 6½' ~~structure, 6 1/2' high, approximately 3/4 of an 18'~~ compartment equalled that normally cured in a 16'x16'x20' conventional barn ~~of tobacco was cured.~~

A bulking method for the pilot operation was developed which proved to save time and labor (figure 6). Rather than handle leaves individually, handfuls or armfuls of tobacco were placed uniformly into a form, then clamped between two members of a rack. Metal rods, which pierced the leaves, provided vertical support and held the tobacco securely for curing. It is estimated, because of the ease of loading the racks and placing them into the barn, that barning labor can be reduced by three-fourths, assuming conventional harvesting methods. This figure was arrived at by considering the total labor required for stringing, handing, and loading the barn by the two methods. Filling 28 racks for the barn was equivalent to stringing 340 conventional sticks (figure 7).

Environmental curing conditions in bulk curing were more easily controlled than in the conventional method. During yellowing, the temperature was held between 90 and 100° F with complete recirculation of the ~~moving~~ air. A temperature schedule similar to the conventional was then followed. Color was set during a gradual temperature rise to 140-150° F, then the temperature was advanced to 170° F for stem drying. ~~During the leaf drying phase,~~

manual control of the air recirculating damper increased the drying potential; during stem drying, the damper was again closed.

Six complete cures were made, thereby covering the entire harvesting season of 1958.

Results and Possibilities

It is recognized that acceptability of the product to the trade is paramount to the introduction of a new curing method. Results from the pilot bulk curing operation show bright possibilities for acceptance. Chemical and smoking evaluations performed by a cooperating tobacco company are shown in table 2. Chemical results agreed closely for both methods of cure, and highly encouraging was the fact that smoking evaluations for both bulk and conventionally cured tobacco passed the flavor test as suitable for cigarettes. Another important indication of acceptability was the results of selling bulk-cured tobacco on the open market (Table 3). Representative samples averaged $62. per hundred, with a high of $70 per hundred. Samples of bulk-cured and conventionally cured leaves from the entire season were also graded according to USDA Marketing Standards. Higher grades and average prices indicated slightly better acceptance of bulk-cured tobacco.

Bulk curing has many possibilities for achieving marked advantages over the conventional curing method. More precise control of curing and drying conditions provided in this forced air, thermostatically controlled system, gives the potential for producing a more uniform leaf. In addition to saving labor during barning, ease of unloading tobacco from racks speeds up the preparation for marketing. The barn size is much smaller than the conventional since bulk tobacco requires only 1/6 the

space required by conventional sticks of tobacco. Fire hazard is virtually eliminated since the heating plant is exterior to the curing compartment. During 1958 fuel efficiencies were equivalent to conventional curing; however the compact system, well insulated and automatically controlled, could easily surpass the conventional barn in efficiency. The curing system lends itself to the use of a heat exchanger for recovering the heat normally lost through conv. barn ventilation.

The results of the developments to date show that there is high probability that bulk-cured leaf will become acceptable to the trade. However, before appropriate curing systems can be developed for farm application, this principle must be evaluated on a farm-scale operation. The described engineering advancements in bulk curing are presently well adapted for conventional harvesting, but there is also the important possibility of integrating mechanical harvesting with bulk-curing. The introduction of these or other methods for advancing the operational practices in tobacco harvesting and curing will serve to reduce human labor, improve economic efficiencies, and engender social improvements - our real mission in agriculture.

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