

EFFECTS OF BRUISING ON TOBACCO CURABILITY¹

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INTRODUCTION

Since a tobacco leaf is a sensitive living system, harvesting and curing operations frequently damage the lamina by bruising. The final product, the cured leaf, then exhibits "scars" or visible indications of rough treatment.

Several factors have indicated the need for studies related to the physical and chemical responses of uncured tobacco tissue to bruising. (1) Research in tobacco harvesting and curing, directed toward reducing labor requirements in those operations, implies the substitution of mechanical devices for present hand operations. An understanding of leaf response to bruising would undoubtedly be pertinent to design and development engineers who are concerned with speed, efficiency, and timeliness of operation in the machines developed. (2) Tobacco researchers, and others in related fields, realize the importance of care in harvesting and curing but find inadequate their explanation of bruising effects. (3) Tobacco companies are interested in good quality tobacco having uniform color and minimum bruising.

In view of the above factors, two objectives were established for the experiment.

1. To determine the physical responses of uncured tobacco tissue to bruising.
2. To determine the chemical responses of uncured tobacco tissue to bruising.

Experimental work was performed at the Oxford Tobacco Research Station during 1954 and 1955, using tobacco leaves of mature Dixie Bright 101 for sample material. Comparisons of bruised laminae were made visually; and in addition, comparative chemical analyses were made by the Tobacco Chemistry Laboratory at N. C. State College.

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

PHYSICAL RESPONSES OF UNCURED TOBACCO TISSUE TO BRUISING

A common method of bruising or testing for rigidity and durability is impact loading. Tobacco tissue can be bruised, of course, by several means of force application; however, impact loading was selected since the force can be calibrated by varying the distance of fall for a given load. Figure 1 illustrates a variable impact tester designed for bruising tobacco tissue with calibrated forces. A 1-inch copper tube having a series of holes drilled one inch apart along its length was designed to allow a metal ball (weight-49 gm) to be dropped from various heights; the ball would strike a round impact plate of one square inch area resting on the tobacco leaf. The leaf rested on a steel plate during the bruising tests. Figure 2 illustrates the pattern of bruising given to the tobacco. Numbers on the circles indicate the heights in inches from which the weights were dropped. In addition to the range of 1 to 7 inches, ranges of 4 to 10 inches and 7 to 13 inches were applied to other leaf samples.

Since living tobacco tissue responds to bruising at any stage, the samples were bruised in both the green and yellow stages. Consideration of leaf response to bruising at two stages of the cure should characterize bruising as a function of the yellowing phase of tobacco -- important in view of mechanical handling of tobacco before or during the curing process. Samples, after bruising, were cured in laboratory curing cabinets for preservation.

Results and Discussion.

The photograph in figure 3 illustrates three ranges of bruising given to tobacco samples while in the green stage. The ranges of dropping distances for each leaf, from left to right respectively, are 1 to 7 inches, 4 to 10 inches, and 7 to 13 inches. The photograph shows that the leaf tissue was extremely sensitive to bruising. Effects of bruising appeared in the low range of 1 to 4 inches drop with tissue damage obviously increasing as the height of drop was increased. Small lateral veins were bruised first,

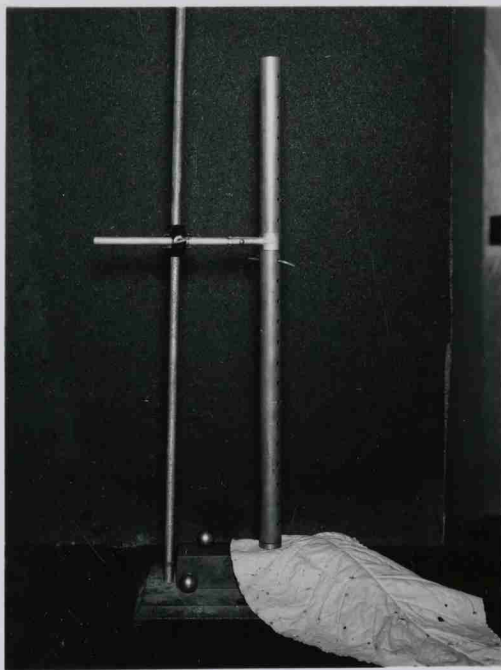


Figure 1. Impact device for bruising tobacco tissue
with calibrated forces.

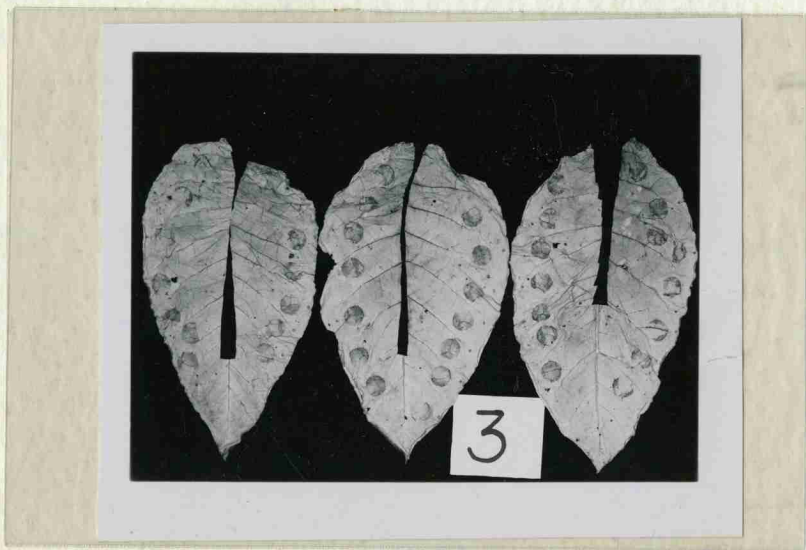


Figure 3. Leaves bruised while green by three ranges of bruising by impact: from left to right, 1 to 7 inches, 4 to 10 inches, and 7 to 13 inches.

since the impact plate rested essentially on them instead of uniform flat leaf surface; lateral veins are distinctly visible in damaged areas. A fairly uniform bruise occurred when the ball dropped 4 inches. Tobacco bruised in the green stage failed to yellow properly, exhibiting an undesirable greenish appearance in bruised areas in the cured leaf. This condition suggested a disruption in the normal chlorophyll-destruction processes that occur in tobacco leaves during the yellowing phase.

Tobacco samples which were yellowed before bruising responded to bruising by turning an undesirable brown. As with samples bruised in the green stage, bruised tissue appeared progressively darker as the height of drop was increased. Yellowed tobacco appeared to be more sensitive to bruising than green tobacco, since uniform bruises were perceptible with less impact force.

Figure 4 shows a photomicrograph of bruised and normal tobacco tissue. The tissue, having responded to bruising by swelling, is shown by the wide cross-section in the left portion; the normal tissue is shown by the narrow cross-section on the right.

CHEMICAL RESPONSES OF UNCURED TOBACCO TISSUE TO BRUISING

High percentages of total and reducing sugars are desirable in cured bright-leaf tobacco since they contribute to pleasing taste and smoking quality of cigarettes. Because of the importance of total and reducing sugars, analyses of these constituents were selected for making comparisons of the chemical response of tobacco tissue to bruising. As in the study of physical response to bruising, leaf samples were bruised in both the green and yellow stages of the cure. Samples were uniformly bruised by passing intact leaves between spring-loaded, rubber-covered rollers. Bruised and non-bruised samples were cured in laboratory curing cabinets and later chemically analyzed. Summaries of these analyses are shown in table 1 and 2.

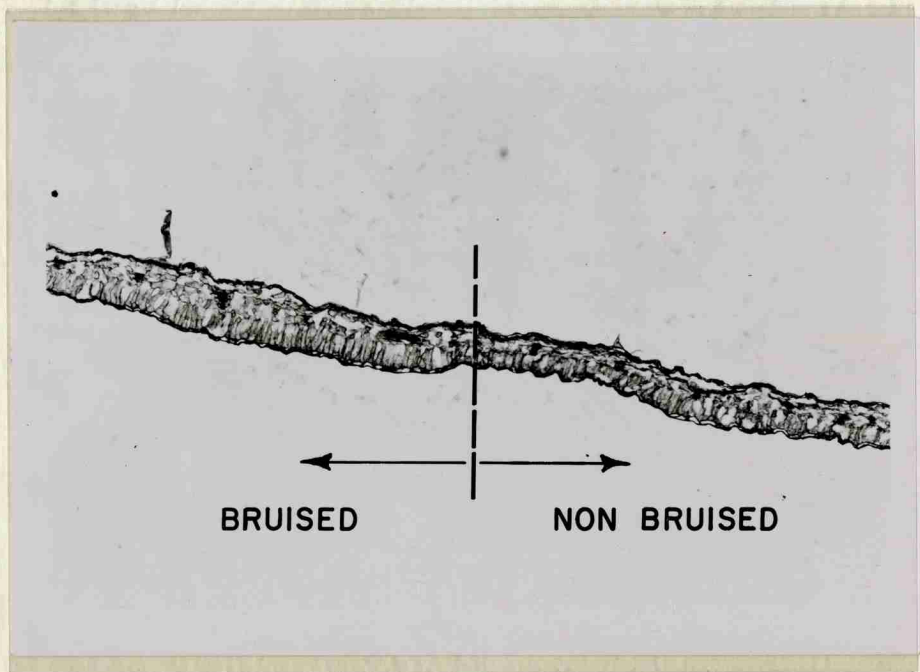


Figure 4. A microscopic comparison of bruised vs. normal tobacco tissue (66X). Enlarged area on the left illustrates leaf response to bruising. (Courtesy of Dr. Ernest Ball, N. C. State College, for photomicrograph technique).

Results and Discussion.

Table 1 gives the results of analyses of total and reducing sugars for non-bruised tobacco vs. tobacco bruised in the green stage. The mean sugar levels and the corresponding 99% confidence intervals are given. Tobacco bruised at the green showed a lack of increase in both total and reducing sugars. The means for non-bruised tobacco were 30.67 and 24.51 for total and reducing sugars, respectively, while the means for bruised tobacco were 17.34 and 12.50. These differences were significant at the 1 per cent level.

Table 2 gives the results of analyses of total and reducing sugars for non-bruised tobacco vs tobacco bruised in the yellow stage. The mean sugar levels and the corresponding 99% confidence intervals are given. Tobacco bruised at the yellow stage did not show similar differences in sugar content after curing. The means for non-bruised tobacco were 34.00 and 24.21 for total and reducing sugars, respectively, and likewise the means for bruised tobacco were 32.33 and 23.03. These differences were not significant at the 1 per cent level.

SUMMARY AND CONCLUSIONS

Visual observations indicated that bruising is detrimental to the appearance of tobacco tissue. Bruising of green tobacco tissue apparently disrupted important biochemical transformations which normally occur during the yellowing phase. Tissue bruised green did not yellow properly and exhibited a greenish, starchy appearance after curing. This appearance, which was proportional to the intensity of bruising, indicated that the rate of chlorophyll disintegration was reduced by bruising. Tobacco tissue bruised after yellowing turned a light brown color.

Chemical analyses of bruised and non-bruised tobacco tissue for total and reducing sugars indicated conclusively that bruising also affects the chemical values. Bruising of green tobacco tissue impeded the conversion of starches to sugars which normally occurs during yellowing. Sugar percentages for bruised and non-bruised

Table 1. Analyses of total and reducing sugars for non-bruised tobacco vs. tobacco bruised in green stage.

Sample	% Total Sugars		% Reducing Sugars	
	Non-bruised	Bruised	Non-bruised	Bruised
1	32.00	17.87	21.55	12.41
2	26.94	17.60	25.61	12.07
3	32.27	18.14	21.41	13.07
4	31.47	15.74	23.48	12.47
\bar{X} = Mean	30.67	17.34	21.51	12.50
W = Range	5.33	2.40	2.13	1.00
99% C. L.*	23.63-37.71	14.17-20.51	21.70-27.32	11.18-13.82

Confidence limits are given by: $\bar{X} - T_{1,W} < \mu < \bar{X} + T_{1,W}$, where $T_1(.01) = 1.32$. The statistic $T_d = \frac{\bar{X}_1 - \bar{X}_2}{\frac{W_1 + W_2}{2}}$ was used to test the

significance of differences in the means, with $T_d(.01) = .618$.

*Dixon, W. J. and F. J. Massey, Jr. Introduction to statistical analysis. McGraw-Hill Book Company, Inc., New York, 1951, pp. 241-243.

Table 2. Analyses of total and reducing sugars for non-bruised tobacco vs. tobacco bruised in yellow stage.

Sample	% Total Sugars		% Reducing Sugars	
	Non-bruised	Bruised	Non-bruised	Bruised
1	37.60	33.07	24.08	25.75
2	32.00	31.20	25.48	19.54
3	34.40	24.67	23.08	24.41
4	31.40	30.40	24.21	22.41
\bar{X} = Mean	34.60	32.33	24.21	23.03
W = Range	5.60	4.27	2.40	6.21
99% C.L.*	27.21-41.99	26.70-37.96	21.04-27.38	14.83-31.23

Confidence limits are given by: $\bar{X} - T_1 W < \mu < \bar{X} + T_1 W$, where $T_1 (.01) = 1.32$. The statistic $T_d = \frac{\bar{X}_1 - \bar{X}_2}{W_1 + W_2}$ was used to test the

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tissue differed significantly as much as 50 per cent. Since the majority of biochemical transformations in tobacco tissue have almost reached the desired endpoint at the end of yellowing, and since these transformations are arrested shortly after yellowing during the drying phase, bruising of yellowed tobacco tissue had no significant effect on the total and reducing sugars.

Regarding new approaches and techniques in mechanizing the harvesting and curing phases of tobacco processing, leaf bruising must be given careful consideration in the interest of good quality in the final product. Especially with green tobacco, handling with non-bruising methods will be essential in maintaining good quality and appearance. Possible handling of leaf tobacco or tissue during the curing process, and after yellowing, will involve considerations of appearance rather than chemical quality.

ACKNOWLEDGEMENTS

This study was conducted under joint cooperation of the N. C. Agricultural Experiment Station and the Farm Electrification Section, Agricultural Research Service, U.S.D.A.

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JOHNSON, W. H., F. J. HASSLER, and W. H. HENSON, JR. (N. C. State College,
Raleigh) Effects of bruising on tobacco curability. Tobacco, 115
(Tobacco Science, 1) 1957. Bruising of tobacco tissue in the green
state adversely affected both appearance and sugar levels. Tissue bruised
green exhibited a greenish appearance after curing, and chemical analyses
showed that there was less accumulation of total and reducing sugars than in
unbruised tobacco. Means for nonbruised tobacco were 30.67 and 24.51 per cent
total and reducing sugars, respectively, while the means for bruised tobacco
were 17.34 and 12.50. Tobacco tissue bruised after yellowing turned a light
brown color; however, bruising of yellowed tobacco tissue had no detectable
effect on the total and reducing sugars.--W. H. Johnson.

TOBACCO SCIENCE

Registration No. 43

Date June 19, 1957

AUTHORS William H. Johnson, Francis J. Hassler, Wiley H. Henson, Jr.

TITLE EFFECTS OF BRUISING ON TOBACCO CURABILITY

REVIEW COMPLETED RECOMMENDATION: APPROVE IN ITS

PRESENT FORM; NOT APPROVE (Give reasons below); APPROVE TENTATIVELY,

SUBJECT TO THE FOLLOWING SUGGESTED REVISIONS: (itemize below):

1. Page 2, Paragraph 2. Second sentence is not clear in meaning. Suggest substitute sentence similar to following. "The former simulates possible injury from mechanical handling of tobacco during harvesting and the latter simulates injury during curing."
- ✓ 2. Page 6, Paragraph 3. Did the bruised tissue swell beyond the normal green leaf thickness or did it show less collapse than the unbruised tissue as the leaf dried?
3. Page 8, Paragraph 1. Sentence 3 is correct with the figures if the reader understands that a mean of 34.60 for non-bruised tobacco represents a normal increase during curing over some unmentioned lower level in the green leaf. It would seem more clear to say "Tobacco bruised in the green stage showed less accumulation of both total and reducing sugars than did the unbruised tobacco."
4. Page 11, First 5 lines. To make the paragraph parallel it would seem desirable to turn the sentence around. e.g. "Bruising of yellowed tobacco tissue had no detectable effect on the total and reducing sugars. This is not surprising since the majority etc."
5. Final paragraph could be strengthened by rearrangement of emphasis. e.g.,
Bruising in the yellow phase adversely affects the appearance. Bruising in the green phase adversely affects both appearance and sugar levels. These results clearly show that bruising must be given careful consideration in the development of new approaches and techniques in mechanizing the harvesting and curing phases of tobacco processing. Especially with

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.

green tobacco, handling with non-bruising methods will be essential in maintaining good quality and appearance.

Manuscript Review Form

TOBACCO SCIENCE

Registration No. 43

Date June 19, 1957

AUTHORS William H. Johnson, Francis J. Hassler, and Wiley H. Henson, Jr.

TITLE Effects of Bruising on Tobacco Curability

REVIEW COMPLETED 6/25/57 RECOMMENDATION: APPROVE IN ITS
PRESENT FORM; NOT APPROVE (Give reasons below); APPROVE TENTATIVELY,

SUBJECT TO THE FOLLOWING SUGGESTED REVISIONS: (itemize below):

- ✓ 1. Could "curing" substitute for the cumbersome "curability" in the title?
2. The statement that bruising inhibits starch degradation should be based on actual starch analyses. The failure of sugars to increase during the curing of bruised leaves could result from an increase in sugar metabolism on bruising rather than from an inhibition of starch breakdown. In this connection, initial sugar values of leaves before curing might be of some interest if put in table 1.
3. Could a few words be added to describe the physical effects of bruising by spring-loaded rollers? That is, are there any striking differences between this type of bruising and that produced by the dropping ball method?

p 8 - In the 10% level of significance really intended here rather than the more common 5%?

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.

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T. E. Stanton

Giles

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(Name of Journal)

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Since living tobacco tissue responds to bruising at any stage, the samples were bruised in both the green and yellow stages. ~~Consideration of leaf response to bruising at two stages of the cure should characterize bruising as a function of the yellowing phase of tobacco — important in view of mechanical handling of tobacco before or during the curing process.~~ *The former simulates possible injury from mechanical handling of tobacco during harvesting and the latter simulates injury during curing.* Samples, after bruising, were cured in laboratory curing cabinets for preservation.

Results and Discussion.

The photograph in figure 3 illustrates three ranges of bruising given to tobacco samples while in the green stage. The ranges of dropping distances for each leaf, from left to right respectively, are ~~7~~ to ~~7~~ inches, ^{one seven} ~~4~~ to ~~10~~ inches, and ^{four ten} ~~7~~ to ~~13~~ inches. The photograph shows that the leaf tissue was extremely sensitive to bruising. Effects of bruising appeared in the low range of ~~7~~ to ~~4~~ inches ^{one four} drop with tissue damage increasing as the height of drop was increased. Small lateral veins were bruised first,

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Tobacco samples which were yellowed before bruising responded to bruising by turning an undesirable brown. As with samples bruised in the green stage, bruised tissue appeared progressively darker as the height of drop was increased. Yellowed tobacco appeared to be more sensitive to bruising than green tobacco, since uniform bruises were perceptible with less impact force.

Figure 4 shows a photomicrograph of bruised and normal tobacco tissue. The tissue, having responded to bruising by swelling, is shown by the wide cross-section in the left portion; the normal tissue is shown by the narrow cross-section on the right.

CHEMICAL RESPONSES OF UNCURED TOBACCO TISSUE TO BRUISING

High percentages of total and reducing sugars are desirable in cured bright-leaf tobacco since they are generally accepted as contributing to the pleasing taste and smoking quality of cigarettes. Because of the importance of total and reducing sugars, analyses of these constituents were selected for making comparisons of the chemical response of tobacco tissue to bruising. As in the study of physical response to bruising, leaf samples were bruised in both the green and yellow stages of the cure. Samples were uniformly bruised by passing intact leaves between spring-loaded, rubber-covered rollers. Bruised and nonbruised samples were cured in laboratory curing cabinets and later chemically analyzed. Summaries of these analyses are shown in table 1 and 2.

There were no appreciable differences in the physical effects of bruising by spring-loaded rollers and by the dropping of balls.

Figure 4. A microscopic comparison of bruised vs. normal tobacco tissue (66X). Enlarged area on the left illustrates leaf response to bruising. (Courtesy of Dr. Ernest Ball, N. C. State College, for photomicrograph technique).

Insert: ~~10/26/68~~

The failure of
sugars to increase
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leaves could result from
an increase in sugar
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Results and Discussion.

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Table 2 gives the results of analyses of total and reducing sugars for non-bruised tobacco ^{as compared to} vs tobacco bruised in the yellow stage. The mean sugar levels and the corresponding 99% confidence intervals are given. Tobacco bruised at the yellow stage did not show similar differences in sugar content after curing. The means for non-bruised tobacco were 34.60 and 24.21 for total and reducing sugars, respectively, and likewise the means for bruised tobacco were 32.33 and 23.03. These differences (2.27% Total, 1.18% Reducing) tested "not significant" ^{even} at the ^{ten} per cent level.

SUMMARY AND CONCLUSIONS

Visual observations indicated that bruising is detrimental to the appearance of tobacco tissue. Bruising of green tobacco tissue apparently disrupted important biochemical transformations which normally occur during the yellowing phase. Tissue bruised green did not yellow properly and exhibited a greenish appearance after curing. This appearance, which was proportional to the intensity of bruising, indicated that the rate of chlorophyll disintegration was reduced by bruising. Tobacco tissue bruised after yellowing turned a light brown color.

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2	26.94	17.60	25.61	12.07
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\bar{X} = Mean	30.67	17.34	24.51	12.50
W = Range	5.33	2.40	2.13	1.00
99% C. L.*	23.63-37.71	14.17-20.51	21.70-27.32	11.18-13.82

*Confidence limits are given (Dixon, 1951) by: $\bar{X} - T_1 W \leq \mu \leq \bar{X} + T_1 W$,
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Sample	% Total Sugars		% Reducing Sugars	
	Nonbruised	Bruised	Nonbruised	Bruised
1	37.60	33.07	24.08	25.75
2	32.00	31.20	25.48	19.54
3	34.40	34.67	23.08	24.41
4	34.40	30.40	24.21	22.41
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INSERT: ~~2~~

Bruising of yellowed tobacco tissue had no detectable effect on the total and reducing sugars. This is not surprising since the majority of biochemical transformations in tobacco tissue have almost reached the desired endpoint at the end of yellowing, and since these transformations are arrested shortly after yellowing during the drying phase.

*Insert
here.*

sugars which normally occurs during yellowing. ~~Since the majority of biochemical transformations in tobacco tissue have almost reached the desired endpoint at the end of yellowing, and since these transformations are arrested shortly after yellowing during the drying phase, bruising of yellowed tobacco tissue had no detectable effect on the total and reducing sugars.~~

omit
Regarding new approaches and techniques in mechanizing the harvesting and curing phases of tobacco processing, leaf bruising must be given careful consideration in the interest of good quality in the final product. Especially with green tobacco, handling with non-bruising methods will be essential in maintaining good quality and appearance. On the basis of the results obtained in this investigation, the possible handling of leaf tobacco or tissue during the curing process and after yellowing involves more consideration to appearance than to the percentages of total and reducing sugars.

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INSERT:

Bruising in the yellow phase adversely affects the appearance. Bruising in the green phase adversely affects both appearance and sugar levels. These results clearly show that bruising must be given careful consideration in the development of new approaches and techniques in mechanizing the harvesting and curing phases of tobacco processing. Especially with green tobacco, handling with non-bruising methods will be essential in maintaining good quality and appearance.

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