CAVITOMA -- A MODERN ASSESSMENT

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Abstract

The historical origins of the term "cavitoma" are examined and the characteristics of this term are illustrated. Testing methods for "cavitoma" are reviewed.

Introduction

The term cavitoma is used to describe microbiologically damaged cotton. The condition was noted in the 1950s during some wet years in the Midsouth and Eastern growth areas and was generally associated with rank plant growth. Historically, the damage was attributed to lowered fiber strength that translated into processing and product quality deficiencies such as increased processing waste, higher end breakage in spinning, and lower yarn strength. The term, cavitoma, was coined by John Elting and Laura Hall of the Kendall Company during their work on microbiologically damaged cotton in the late 1940s and early 1950s [Elting, 1951; Hall, et al. 1951]. The word cavitoma now appears in the dictionary. Webster's Third New International Dictionary defines cavitoma as: "A series of changes in cotton fiber involving <u>loss of strength</u> and resulting from the activities of microorganisms". The key phrase is "loss of strength". In the absence of fiber strength loss the quality deficiencies are minimized and any quality problems stemming from excess microbiological activity are probably related to changes in fiber surface characteristics.

The qualitative test methods used to detect these damaged cottons are inadequate and at best offer only an indication that a cotton may be damaged. The term cavitoma is not well understood by the cotton trade and has been used too often in recent years as a catch-all term to describe perceived cotton quality deficiencies. The development of fast, precise methods, especially HVI, has now provided the technology to measure the properties of cotton that are important to quality, thus minimizing or negating the requirement for imprecise qualitative indicators of microbiological damage. All cottons contain microorganisms; but, under normal growing and storage conditions, their presence does not cause an adverse effect on quality. There are conditions under which cotton can suffer microbiological damage and we will examine these effects. However, for US cotton, the occasions are very rare where this damage is widespread or is intense enough to cause quality problems. In the following paragraphs, we will discuss several aspects of cavitoma in the context of a modern perspective.

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Cavitoma Characteristics

The factors usually associated with microbiologically damaged cotton include: (1) alkaline pH, (2) elevated bacterial and fungal levels, (3) low sugar content, (4) off color, (5) wasty, (6) rarely-shorter, weaker, (7) easily wet-out, and (8) lower color grade. These characteristics will be considered both in the context of developing test methods for detecting cavitoma and in predicting resulting processing and product quality.

Cavitoma Test Methods

The qualitative test methods historically employed to determine cavitoma are indicator tests only and generally cannot be related, with any significant level of confidence, to the fiber properties that actually affect cotton quality. The two qualitative tests that have been used most are: (1) acid-base indicators and (2) fluorescence under UV light. Several other tests using benzidine [Andrews, et al., 1962] and thiobarbituric acid [Pan, et al., 1959; Harrison, et al., 1961] have been proposed. These latter two have not been accepted or used to any extent because of a lack of understanding of the chemistry involved, no knowledge of interfering factors, and, in the case of benzidine, use of a dangerous chemical. They will not be considered further.

There are several microscopic methods for identifying microbiologically damaged cotton fibers. Most of these, even though effective in showing damaged fibers, cannot distinguish between microbiological and mechanical damage. One method that has been used extensively involves staining fibers with congo red in the presence of sodium hydroxide that swells the fibers. Congo red does not stain the primary wall of the cotton fiber, but does stain the secondary wall. Thus, damage involving rupture of the primary wall allows the congo red to visibly stain the secondary wall. The damaged fibers can be observed and counted using a microscope. However, trying to determine a degree of damage becomes a statistical nightmare, because hundreds of fibers must be examined to even begin to determine levels of damage. It must be remembered that <u>all</u> cottons contain some damaged fibers. Several years ago, Carolyn Simpson and her coworkers at USDA, ARS, CQRS, Clemson, SC, stained and examined a large number of cottons for damage [Simpson, 1993]. Even when examining several hundred fibers per sample, their conclusion was that accurate replication of results was very difficult. These microscopic methods are not useful on a practical basis for quantitative assessment of fiber damage, but may be useful for studying types of damage, etc.

The most universally used indicator methods are based on changes in pH of the fiber surface. Essentially all of the "cavitoma indicator sprays" are combinations of acid-base indicators. The cotton fiber surface is normally slightly acidic or neutral (pH range about 6.3 - 7.0). Conditions of mild weathering (light to moderate rain) or excess microbiological activity during extensive field weathering cause loss of organic compounds, such as malic and citric acid, causing the pH to increase due to the presence of residual alkaline earth metals -- potassium, magnesium, sodium, etc. The alkaline pH may range from 7.1 to above 9.0. However, the increase in pH is, at the very best, only an indication that a cotton may be microbiologically damaged. Mild to even moderate rainfall on open cotton will cause an increase in fiber pH without causing damage to fiber quality. In fact, some rain on open cotton may actually improve quality by removing unwanted components such as sugars. Even the early researchers recognized the serious problems of using pH as an indicator of microbiological damage. Consider the quotations which follow: (1) "no strength loss was found even for cottons that had shown the greatest change in pH" [Nickerson, et al., 1958], (2) "....the pH change in fiber due to microbiological action is very sensitive and may occur before measurable alterations in any of several other properties" - [March, et al.,1951], and (3) "while there is a trend toward higher pH as biological damage increases, no degree of damage could be determined by the pH method for samples in a pH range of 7.5-9.0. Microscopic examination also revealed no correlation between biological damage and pH in this range" [Andrews, et al., 1962]. It is our conclusion, based on reported research and our observations over the years, that fiber pH, standing alone, is not an effective or accurate indicator of microbiological damage in cotton.

In recent years, parties in the cotton trade have attempted to relate variations in cotton fluorescence under UV light (black light) to microbiological damage. Particular attention has been directed toward the intense greenish-yellow fluorescent spots, sometimes called cat-eye, that appear in cotton at times. This fluorescence is specifically characteristic of infection by Aspergillus flavus fungus. The fluorescence results from kojic acid produced by the fungus and its reaction products that develop at the time of boll cracking and before the fibers in the open bolls dry. The fungus requires high temperature (about 35°c) and high moisture for development. These conditions are usually met only at time of boll opening. Thus, fungal development ceases a few hours after boll opening. The fungus does not grow under any reasonable conditions of cotton storage. Of more importance is the fact that Aspergillus flavus fungus does not produce a cellulase complex that is capable of degrading cotton fiber [Cotty, 1996]. Thus, the presence of this fluorescence in cotton is in itself not an indicator of damage. If the fluorescence, including greenish-yellow cat-eye, is widespread and intense throughout a cotton sample, it could indicate a quality problem. However, a few random spots of greenish-yellow fluorescence in a classer=s sample should be of little consequence. There is no documentation in the literature that this type fluorescence causes or is related to any problems in either spinning or wet processing.

There is one qualitative test that gives some valid information about the surface characteristics of the fiber that may be related to processing quality [Perkins, 1988]. This test, used properly in conjunction with quantitative fiber property tests, could be useful in defining subtle surface deficiencies in cotton. The test consists of taking a 1-gram sample of cotton, rolling it lightly into a ball, and dropping it onto the surface of a solution composed of 43% ethanol and 57% water. The time for the fiber to sink is recorded. Normally, the cotton will float for at least several minutes. If the fiber sinks immediately or in less than about 1 minute, the implication is that the surface characteristics of the fibers have been altered relative to surface tension properties, perhaps because of disruption of the wax layer or other factors. The fact remains that the surface is altered, and this could be related to processability of the cotton.

There are direct methods that can be used to detect excessive microbiological activity on cotton [Roberts, et al., 1978]. If obviously damaged bolls, including microbial tightlock and insect damaged bolls, are harvested by hand from field weathered cotton, a change in the composition of water extractable components can be observed by analysis using gas chromatography and high performance liquid chromatography. If microbiological activity has been excessive, the levels of normal constituents such as glucose, fructose, and malic acid are much lower than normal, and compounds such as arabitol and mannitol, not normally found to any extent on cotton, become the dominant components of the water extract. Even under severe conditions of weathering, these types of bolls are usually not harvested to a great extent by mechanical harvesters. The cotton does not fluff enough to be harvested by the finger picker. For stripper harvested cotton , these type bolls are removed by the green boll extractor and the burr and stick machines and do not enter the ginned cotton. These analytical methods are useful as research tools, but are not practical for general testing of cotton.

Quantitative Test Methods

The original definition of cavitoma is very concise and straightforward emphasizing that loss of fiber strength due to microbiological activity is the key factor. The cotton and textile trades have, in many cases, now expanded that definition to a catch-all term to explain instances of perceived quality deficiencies including random fluorescent spots. This extension of the definition has brought about a revival of widespread use of questionable qualitative tests to indicate cavitoma. This is to the detriment of all segments of the cotton industry and the cotton textile industry. The HVI measurements of cotton properties available to the cotton industry and that are the basis of the US cotton classification system provide the information needed to define cotton quality independent of unreliable, qualitative indicators that are of limited value at best and at worst may actually give completely erroneous indications of quality.

The fiber properties readily available from HVI systems include length, length uniformity, strength, micronaire fineness, color (grade, Rd, and +b), and trash. An analysis of these properties along with a knowledge of the type of cotton under consideration provide the necessary information to effectively determine the ultimate quality of the cotton including any effects of cavitoma. An example of this is shown from results of testing and processing cottons from the 1984 Mississippi Delta crop. After initial harvest of some unweathered cottons, the remainder of that crop received extensive weathering due to extended rainfall over a period of many weeks. Thus, the after-rain cottons were subjected to intense microbiological activity and would be generally regarded as having cavitoma. The grade and fiber properties of the cottons are shown in Table 1. For length, strength, and micronaire, there were no differences between the before-and after-rain cottons. However, there were differences in composite grade, reflectance (Rd), pH, and sinking time in alcohol/water solution. The cotton harvested before rain as compared to the cotton harvested after rain had a higher composite grade, had a better reflectance value, had a lower pH value, and a longer (better) alcohol/water sinking time. Thus, the overall quality of the before rain cotton was better than that of the after rain cotton. Some processing and yarn qualities are shown in Table 2. The cotton harvested before rain, as compared to the cotton harvested after rain, had lower levels of processing waste and card generated dust, had fewer end breaks in spinning, and produced stronger yarn. Thus, the overall processing and product qualities were better for the before rain cotton. The important factor is that the processing and product qualities were predicted accurately by the cotton grade and fiber properties.

Conclusion

The occurrences of cavitoma in US cottons are infrequent and are limited in severity and in geographical distribution. However, on rare occasions some damage may occur. The best indicators of microbiologically damaged cottons are low fiber strength and low reflectance (Rd) values. These must be interpreted in the context of what is typical for the type of cotton being considered. For example, if the color grade and accompanying reflectance values are poorer than is typical for the area of growth or cotton type, then cavitoma may be a factor. The same is true of fiber strength. If the strength is lower than would be typically expected, then these cottons may be damaged. The information on fiber damage gained from examination of cotton grade and quantitative fiber properties is far superior to information gained from indirect, qualitative tests, particularly those relying on fiber pH or fiber fluorescence. The alcohol/water sinking test may supply useful information to supplement results of quantitative fiber tests.

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Table 1. Mississippi Delta, 1984 Cottons, Fiber Quality

Property	Before Rain	After Rain
Composite Grade	41	52
Length (mm)	28.7	29.0
Strength (g/tex)	22.8	23.1
Micronaire	4.4	4.4
Rd (%)	76.7	71.0
pH	6.5	7.2
Sinking Time A/W (sec)	270	45

Table 2. Mississippi Delta, 1984 Cottons, Processing Quality

Property Rain	Before Rain	After Rain
Shirley Analyzer Waste (%)	1.83	2.88
Processing Waste (%)	4.5	5.6
Card Generated Dust (mg/m^3)	2.86	3.83
EDMSHo	11	22
Yarn Strength (BF)[2]	1989	1936

[1]EDMSH - Ends down per 1000 spindle hours.
[2]BF - Break factor.