II. ON THE DETERIORATION OF COTTON ON WET STORAGE.

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(With Plate I.)

It is a well-known fact that exposure to damp renders cotton extremely brittle and short-fibred, and increases its alkali solubility. The extent of this damage is often very considerable, may in exceptional cases cause the complete destruction of the cotton affected, and will often entail the loss of from 10–15 % of the cotton in the form of exceptionally short fibres, the so-called “fly.”

In a preliminary report to the Admiralty, dated 19/3/19, an account was given of some experiments carried out in connection with the investigation of this deterioration on wet storage. The conclusion arrived at was, that cotton does not deteriorate on wet storage in the absence of micro-organisms, so that bacteria, in the wider sense of this word, must be considered responsible for the breakdown of the fibres. It was furthermore found that the activity of the bacteria can be brought to a standstill, and the deterioration prevented, if the moisture content of the cotton is reduced to below 9 %.

In view of the commercial importance of this breakdown of the cotton fibres, it was thought desirable to extend the investigation and to examine the types of micro-organisms responsible for the damage; secondly, to establish the source of the infection and the changes taking place in the structure of the fibres by the action of the bacteria, and finally, to determine to what extent this damage to the fibres is noticeable in the various types of cotton.

The present paper deals with some of the results obtained in the investigation of the changes caused by bacteria to the structure of the cotton fibre, and with the method worked out for the quantitative determination of this type of deterioration of cotton.

An investigation of the changes in structure of the attacked fibres was not found practicable by direct microscopical examination, as they were too minute to be examined carefully, even by the oil immersion lens. It was decided, therefore, to make use of Cross and Bevan's viscose process for the treatment of the fibres before the microscopic examination. The viscose process has already been used by Balls [1918] for the demonstration of the daily layers of growth in the cell wall of cotton hairs. When applied as suggested by this author, it causes the cotton fibre to swell to about five times its normal size.

The result of the application of the viscose process to the damaged cotton fibres proved most instructive. Some of the observations made will be outlined in the following pages.

The technique of the method, as applied for our purpose, was substantially the same as that used by Balls, except that, when using 15 % Na(OH), it was found possible to dispense with the application of alkali *in vacuo*.

In our investigation we proceeded as follows. From 0.1 to 0.3 gram of cotton of the sample to be examined was boiled for a short time in a 1 % Na(OH) solution, then washed in running water, dipped in a 1 % acetic acid solution, and again washed in water. After removal of most of the adhering water the cotton was transferred to a small stoppered glass bottle with a wide opening and 1.5 cc. of 15 % Na(OH) solution and 1.5 cc. of carbon disulphide were added. In this mixture the fibres were left for 15-45 minutes, then placed on an ordinary glass slide, covered with a cover slip, and a drop of tap water left to diffuse under the latter. The preparation was now ready for microscopic examination.

Fig. 1, Pl. I, shows the behaviour of normal fibres after the viscose treatment. The daily growth rings, described by Balls, are very marked. Particularly characteristic in most of the fibres is their prevalent beaded appearance. This, no doubt, is brought about by the cuticle giving way to the internal pressure created by the rapidly swelling cellulose. The cuticle can in many cases be seen rolled up between two individual beads as a narrow ring of high refractive power. In other fibres the cuticle seems to have burst longitudinally, and in this case forms a corkscrew band round the swollen cellulose.

If an attacked fibre is treated by the viscose process, quite a different effect is obtained, which varies with the type of micro-organism responsible for the deterioration.

Figs. 2 and 3 are from photographs taken from attacked fibres after treatment. In Fig. 2 a streptothrix was responsible for the action, while a cellulose-decomposing schizomycete caused the breakdown of the fibre in Fig. 3.

It will be noticed that in Fig. 2 the cuticle, and most of the cellulose, has been perforated in numerous places. The cuticle has apparently in this case lost its power of resistance, and the cellulose swells uniformly. No beads are observed.

The same can be said of the fibres in Fig. 3, where the swelling, as already mentioned, is due to a cellulose-decomposing schizomycete. The cuticle of the fibres in this specimen seems to have been eaten away over wide areas. It looks as if the destruction in this case was progressing uniformly from the surface toward the interior.

Fig. 2 explains the appearance of the large number of short fibres found in deteriorated cottons. They are produced by the action of a streptothrix, a form of micro-organism which is always found in large numbers in weathered cottons.

The damage of the true schizomycete is due, less to the formation of fly, than to a general weakening of the fibre.

The fibres, from which Figs. 2 and 3 were taken, had been exposed to the action of micro-organisms for a considerable time—over a month. It appeared of interest, therefore, to determine how soon after exposure to dampness, the action of the micro-organisms would be noticeable on the fibres. Samples of various grades of cotton were, therefore, wetted with tap water and left at ordinary room temperature. It was found, that a cotton waste sample with a bacterial content of about 1 million per gram, showed signs of extensive damage after five days' exposure. On the other hand, a carefully picked sample, taken direct from the bolls, and with only 20,000 micro-organisms per gram, could be left damp for twenty days before the fibres were visibly attacked. If, however, such samples were infected with the characteristic micro-organisms, the damage was considerably accelerated.

Fig. 4 shows a sample of ordinary cotton waste which has been exposed to dampness for five days. It will be noticed that very few of the fibres have any of their cuticle left intact.

Another point of interest is the difference between the ways in which the streptothrix and the true bacteria attack the fibres. The two types of damage are so markedly different, that it is almost possible by the microscopic examination to indicate where the fibres were damaged by a streptothrix, and where by bacteria.

These remarkable changes, found to occur in the structure of the cotton fibre after exposure to dampness, made it natural, on this basis, to attempt the elaboration of a method for the quantitative determination of damaged fibres in good cotton.

Most raw cottons, of American and Indian origin, have at one time or other been exposed to rain or excessive dampness, and others may have been deliberately wetted. In both cases the result is a damage to the fibres, which in its earlier stages, cannot at present, be detected. It is true, that where the moisture content of the cotton remains high—over 9 %—a determination of the amount of water present will be a useful indication of damage; but, in many cases, where the wetting occurred on the farms or after ginning, the cotton is likely to dry up when taken to other districts, for instance for transport to Europe. Moreover the determination of the moisture content can only be an indication, and not a quantitative method by which the cotton merchant is able to determine how far the fibres of a particular cotton have been damaged, and how much of it he is likely to lose during its subsequent treatment at the mills.

The alkali solubility test would, no doubt, in many cases of excessive damage, give good results; but where it is a case of detecting 10, or 5, or perhaps even 2 % of damaged fibres, this method is not sufficiently sensitive. In a later paper it is hoped to substantiate this assumption.

The method for the detection and quantitative determination of damaged fibres in cotton by microscopic examination, as worked out on the basis of the above observations has, so far as it has yet been tried, given very satis-

factory results. It may be of interest to give a few examples of the results obtained.

A sample of damaged cotton, in which all fibres were found to be attacked, was carefully mixed with various quantities of good cotton, picked direct from the boll, and containing normal fibres only. A sample of this mixture containing 30 % of damaged fibres was, on examination, found to have 29.6 %. A second determination of the same sample gave 29.5 %, a third 27.3 %. A mixture made up to contain 10 % was found to have 8.9 %; a 5 % sample 5.4 %, a 4 % sample 4.6 %, and a 2 % sample 2.0 % and 2.5 %.

The broad outlines of the method as now in use¹ are as follows. The sample to be examined is treated with the carbon disulphide and alkali mixture; the fibres are then spread out on a slide, as already described, and counted under the microscope. From each sample three preparations are made. The average of 10 counts from each preparation gives the required figure.

CONCLUSIONS.

In cotton which has been exposed to dampness the action of micro-organisms materially alters the structure of the fibres, giving rise to the formation of exceptionally short fibres, the so-called "fly."

The extent of this damage can be quantitatively determined by a method outlined in this paper.

REFERENCE.

Balls (1918). The existence of daily layers of growth in the cell wall of cotton hairs. Author's MS.

¹ The details of the technique will be published later.

Fig. 1. $\times 45$.

Fig. 2. $\times 45$.

Fig. 3. $\times 45$.

Fig. 4. $\times 45$.