MICROSCOPIC CROSS-SECTION EVALUATION OF FIBER DAMAGE CAUSED BY *CANDIDA TROPICALIS*

by 4589

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INTRODUCTION

Increasing use of household automatic clothes washers in self-service public laundry facilities has focused the attention of public health agencies on the possibility of the spread of disease among families using these establishments. The American Public Health Association lists forty communicable diseases caused by bacteria, virus, or fungi that are capable of being indirectly transmitted through articles freshly soiled by discharges from infected persons (14).

Marwin (12) stated that Candida albicans, the yeast-like fungus causing thrush, is probably the most familiar fungus to bacteriologists and to members of the medical profession. In the summer of 1953, in Japan, there was a large number of male military patients being treated for skin infections that were caused by C. albicans, yet civilian men infrequently were seen with evidence of similar eruptions. Reasons for the fungi infections may be the heavy summer clothing worn by male personnel of the Army and Air Force, prevented proper ventilation and the light weight clothing worn by civilians permitted adequate ventilation. The inadequate circulation of air resulted in an elevation of skin temperature, increased moisture and a fertile field for the propagation of pathogenic fungi (8).

Since little is known about the growth and survival of pathogenic fungi such as members of gensis candida in textiles used in footwear, Candida tropicalis a representative fungi was chosen for study. It is a non-pathogenic fungi and safe to use in the lab. According to McNeil (14), the ability or inability of a potentially harmful microorganism to

survive and multiply in a textile material could influence foot health and serviceability of the fabric. Microbial survival could be dependent upon the textile fabric itself or the environment.

Barnes (1), in the longitudinal study of fiber damage caused by staphylococci on a sixty percent nylon, forty percent cotton sock fabric, found no damage to nylon fibers and concluded that they probably possess a resistance to staphylococci. However, damage to cotton fibers included transverse cracking, helical or spiral cracking, fissures, surface etching and pitting, and in some cases, dissolution of the lumen. McNeil's study (15) of bacteria isolated from home laundering, had clothing that was reinoculated during family wear, but the fiber damage was not evaluated microscopically. No references were found in the literature reviewed where reinoculation of fabrics under controlled conditions with microorganisms was done. Reinoculation is a likely and realistic situation. Most studies of microorganism damage have been of longitudinal sections of fibers with few studies reporting the effects of microorganisms by the use of cross sections.

Therefore, the objectives of this study were the following:

1. To investigate a method of recording damage in cross-sections of textile fibers using a Microstar, Series Four, trinocular microscope.

2. To compare by microscopic examination of fiber cross-sections, the degree and type of damage on a fabric as influenced by the fungus, Candida tropicalis.

3. To record by use of photomicrographs of cross-sections, types of damage on a fabric as influenced by the fungus Candida tropicalis.

Definitions:

Treatment -- Indicates a group of swatches which have been uninoculated-unsoiled, uninoculated-soiled, inoculated-unsoiled, or inoculated-soiled.

Swatch -- Fabric sample of wool, nylon and cotton terry knit sock fabric 8" X 12".

Run -- Refers to the completion of a test procedure.

Laundered -- Refers to the washing and drying of swatches in a home automatic washer and dryer.

Evaluation -- Completed after various treatments as designated in Figure 1, page .

REVIEW OF LITERATURE

Human Factors in Microbial Development

Disability from skin diseases among American troops in Vietnam engaged in combat in warm wet areas is often the greatest medical cause of noneffectiveness. Infections are the leading cause of cutaneous diseases. Cutaneous infections thrive in hot humid climates. Dermatophytosis; bacterial, pyodemas, and candidiasis vie for the most common disease, although each is common and each may predominate, depending on local factors. The fighting strength of troops such as those in the MeKong delta region would be almost doubled by improving prevention and treatment of dermatological disorders (2).

Taplin et al. (20) studied microorganisms from men before, during and after a three month military exercise in a tropical jungle environment. Eighty percent of the men had suffered from moderate to severe microbial dermatitis in one or more body sites at some time during the study. C. albicans were found in the feet and groin areas of the body. Candidiasis of the groin area threatened to reach epidemic proportions and was found in men subject to the greatest heat stresses such as kitchen personnel and operators of vehicles with poorly ventilated driving compartments.

Fungus. Fungus is the general term encompassing such diverse forms as molds and yeasts. Molds, yeasts and bacteria having lost their chlorophyll become either parasitic or saprophytic, that is they no longer have the power, except in relatively few cases of manufacturing

their own food but most extract it from other forms of organic matter either living or dead. To enable them to do this they must possess highly efficient and varied enzyme systems and it is the possession of their extremely active enzymes which endows them with the economic importance they are now recognized as having. There are few organic substances in man's environment which are free from attack by fungi. Vegetation, wood, lignin, keratin, chitin, bone, fats, oils, waxes and phenolic resins to name a few are susceptible to degradation by one or many fungi.

Most of the fungi which cause deterioration of fabrics or spoiled food are unable to invade tissues of man. There are a dozen important mycoces of man however, caused by more than 50 species of fungi. These diseases vary from the superficial skin infections such as *dermtophytosis and sutaneous candidiasis* to generalized mycoses such as coccidioidomycosis and histoplasmosis (6).

Microorganisms: *Candida albicans* and *Candida tropicalis*

C. albicans. A pathogenic yeast-like fungus is an agent of lesions located in a wide variety of sites including mucous membranes of the mouth, throat, bronchi, lungs and vagina. It frequently attacks the skin especially the interdigital webs of the hands, feet and the axillae and the nails (12).

Dastidar *et al.* (3) reported there was little difference in the behavior of *C. albicans*, *C. tropicalis* and *C. kresei* as far as their

nutritional requirements. Candida grew at all pH values and most luxuriantly in the pH range 5-6. The formation of mycelial phase is more frequent under alkaline conditions with all the species. Ammonium compounds stimulated growth more than the nitrates. The amino acids, one of whose end products of metabolism is urea, stimulated luxurious growth of all candida, the yeast phase was seen more than the mycelial phase. All candida grew well on dextrin, while on starch, growth was moderate. The disaccharides stimulated growth better than the monosaccharides.

Textile Factors in Microbial Development

It is hard to estimate which textile fibers are most suitable for the fungi setting colonies on clothing because not only the quality but the method of manufacturing, the treatment before fabric construction as well as the further course of the ready fabric, will have an influence on the life of fungi growth on fibers. Environmental conditions such as hot humid climates as experienced in Viet Nam will also affect fungi growth on textiles. Most fungi growing on textiles may affect not only cotton but also wool materials (19).

Cotton. Cotton wetted by rain during the ripening period can be stricken by microorganisms, bacteria, fungi and mildew. Fibers attacked prior to ginning may be stricken only in the epidermis while microorganisms develop primarily in the lumen of cotton fibers already ginned (21).

All raw cotton contains constituents which serve as food for the

fungi and mineral substances which promote their growth. Capacity to support mildew is measured fairly closely by soluble reducing constituents, represented by the soluble copper number. The presence of nutrients such as starch also promotes mildew as well as atmospheres of high relative humidity, when moisture regains exceed eight to nine percent and the temperature reaches 80-90°F. As fungi and bacteria grow on cellulose, they secrete chemical substances called enzymes which attack it by microbiological hydrolysis and convert it to soluble sugars that serve as food for the organisms. Fungus damage to cellulose usually involves penetration of the fiber walls, such as pitting, cracking, fissures, and corrosion, growth of the hyphae within the lumen, and digestion from within. On short exposure transverse cracking is apparent but spiral fissures appear on more prolonged incubation. Under favorable conditions, attack is rapid by fungi and fabric loses its strength, pulls apart, or is punctured easily. Loss of functionality precedes extensive digestion (11, 13).

Wool. Wool contains many types of microorganisms invisible to the eye, many of these are harmless but there are those which cause diseases to animals, to humans, and damage wool as well. Microorganisms are so numerous in wool because they find excellent conditions for living and procreation. Sufficient sustenance in organic compounds are found in wool for microbial growth and microorganisms and many varieties live simply on the wool cortex (4). Various fungoid growths or mildew and bacteria develop in wool even during the period before it is shoren. Scouring causes an increase in quantity of microorganisms in wool, while

drying has a decreasing influence and acts similarly to pasteurization (21).

According to Doberczak, Mauersberger and Zylinski (4, 13, 21), moldy wool is that which has been attacked by mildew. Mildew develops when wool is stored in improper conditions such as in moist rooms, which are warm and have no access to fresh air. Wool is damaged by microorganisms in these conditions. Musty wool tenderizes to such an extent that its strength is almost completely lost. The fibers literally fall apart under manual stress, lose their natural luster and other properties. When moldy wool is dried it is very brittle and under the microscope it is to be seen that scales of a fiber attacked by mildew of a variety called Ctenomyces becomes detached from the cortex and at some places fall off completely.

Scientists differ in opinion as to the way in which microorganisms affect wool. According to some opinions the cortex and scales of keratin are subject to hydrolytic deterioration, according to others a loosening and separation of cuticular cells and those of the cortex takes place due to destruction of intercellular substance by microorganisms. It seems that the latter opinion is more correct. A microscopic examination of wool damaged mainly by fungi reveals undamaged scales which adhere to the fiber or are separated from it. The spindle-shaped cells of the cortex also show no damage and retain their shape and size (4).

The epidermis or the scales have a low affinity to dyestuff and are rooted in the tissue of the cortex. On the outside they are covered

by a very fine membrane, which is referred to as the epicuticle and should form a continuous sheet on the surface of the fiber and is disrupted only by damage to the fiber during the manufacturing process. The epicuticle has low permeability to dyestuff which penetrates better into the fiber after the membrane has been disrupted (9, 10).

The examination of fungus damage on wool is sometimes made extremely difficult by the fact that during manufacturing the wool undergoes formal changes. From the surface the cortical outline, which is one of the characteristics of wool may disappear and the surface of the wool becomes smooth like that of plastic fibers. Changes due to fungus that have been noted on wool are wide pitted hollows on the surface, which sometimes spread deeply and in other cases are superficial and widespread. In the middle portion of the hair longitudinal channels are formed which seem to be perforation openings beginning in the inner part of the hair and spreading laterally. The channels are sometimes expanded to a degree that their walls are composed of the thin cortical fragments of the wool hair. If the imperfect perforation openings which are not passing through the hair substance, continue in the lateral branches and expand in the inner part of the wool hair, spherical cavities develop (19).

Nylon. According to general opinion, plastic materials are resistant to fungi. Undoubtedly the plastic fibers are more resistant against destructive activity of fungi as compared to vegetable and animal material, but on some plastic fibers such signs may nevertheless be observed. These are, however, not penetrating defects but superficial

ones in exceptional cases (erosion and indentations). It is not clear, if plastic fibers in textiles containing vegetable and animal material play a role in the development of fungus growths. At present it may be stated they do not have an important role (19).

Microscopic Evaluation of Fiber Damage

Most studies of fiber damage, where the damage has been quantitatively analyzed have been concerned with longitudinal fields of view of the fiber and not cross sections. The way in which the damaged was evaluated was to count the number of fibers in the field of view and then to count the number of damaged fibers and express the damaged number as a percentage. Little or no literature has been found on cross-sectional analysis of fungi damage to fibers (7, 9, 18).

PROCEDURES

Fabric Preparation and Treatments

Laundry procedures. Interviews were conducted in Manhattan, Kansas of military and non-military personnel to determine the laundry procedure for washing socks and other clothing most frequently used in that area. Also interviewed were managers of supermarkets as to the types of detergents and disinfectants used in the laundry (1). On this basis laundry procedures were established. A conventional automatic washing machine was used with the washer being set for a normal wash and wear cycle. The electric dryer, was regulated by an automatic electronic sensor, and set on delicate, the setting recommended for fabrics of man-made and wool fibers. A high sudsing synthetic detergent containing whitening agents and enzymes was used in the two percent concentration recommended by the manufacturer.

Fabric selection and sampling. A terry knit fabric of fifty percent wool, thirty percent nylon and twenty percent cotton meeting military specification MIL S-48G was used. The United States Air Force sock fabric was black and knitted in the form of seamless tubes seven to eight inches in circumference and approximately twenty-four to thirty-six inches long.

The tubes were split and cut into twelve-inch long swatches. Swatches were color coded by stitching to indicate the four treatments; uninoculated-unsoiled, uninoculated-soiled, inoculated-unsoiled, inoculated-soiled. The uninoculated fabrics were each run through one

set of treatments and the inoculated fabrics were each run through three sets of treatments. Each run was color coded by cloth tags. Five one inch squares were marked on each lengthwise side of the swatch for the purpose of microbial survival counts. All swatches were washed with detergent and dryed once to remove any finish remaining from the fabric construction and sterilized to remove any microorganisms present after coding and before subjected to the treatments. Five swatches were used for one treatment, with only four swatches being used for microscopic evaluation (Figure I, page 40).

Environmental conditions. All four treatments were subjected to the environmental conditions of one holding time, one temperature, and one humidity. The holding period of four days was used representing the average time between sock washings. The holding temperature of 37°C., body temperature and 100% relative humidity was used.

Soiling and inoculation. The ingredients for the synthetic soil were mixed in a standard commercial blender for five minutes to form a relatively stable emulsion. The pH of the prepared synthetic soil was 6.2. Ingredients for the synthetic soil are listed in Table I, page 13. The flour, cornstarch and carbon were sterilized in an ethylene oxide sterilizer and the sugar, powdered milk, vegetable oil and mineral oil were autoclaved in water to sterilize them. The soiled swatches were premoistened in the synthetic soil solution for one minute, unsoiled swatches were premoistened in sterilized distilled water for one minute.

The uninoculated-unsoiled swatches were then premoistened with sterilized distilled water, and held in the environmental chamber

TABLE I

SYNTHETIC SOIL SOLUTION (16)

INGREDIENTS	QUANTITY
All-purpose flour	15 g
Cornstarch	15 g
Powdered Carbon	1 g
Cane Sugar	15 g autoclaved in 50 ml water
Vegetable Oil	15 ml autoclaved in 100 ml water
Mineral Oil	15 ml autoclaved in 100 ml water
Powdered Milk	13.25 g autoclaved in 87.5 ml water

at 37°C., 100% R.H. for four days, removed, laundered and sterilized. The steps from premoistening in sterilized distilled water to the sterilization was repeated twice on the original swatches giving a total of three times for being held in the environmental chamber. A swatch was drawn after each sterilization for evaluation giving four evaluation periods for the uninoculated-unsoiled treatment (Figure I, page 40).

The uninoculated-soiled swatches were treated in the same manner except that they were premoistened with the sterilized soil. This gave a total of three times that the same swatches were soiled. In this treatment also a swatch was drawn after each sterilization for microscopic evaluation.

The inoculated-unsoiled swatches, were premoistened with sterilized distilled water and inoculated with an aerosal inoculation of the suspension of the microorganism C. tropicalis. After the swatches were inoculated, they were placed in the environmental chamber, and held at 37°C., and 100% R.H. for four days. The swatches were removed from the environmental chamber, laundered, and sterilized. The same swatches

were then premoistened with sterilized distilled water and reinoculated by aerosal inoculation and held under the same conditions as before, removed from the environmental chamber, laundered and sterilized. The reinoculation procedure was then repeated giving a total of three inoculations on the same swatches (Figure I, page 40).

The inoculated-soiled swatches, were premoistened with the soil and then inoculated with C. tropicalis in the same manner as the inoculated-unsoiled swatches. After the swatches were held in the environmental chamber at 37°C., 100% R.H. for four days, they were laundered and sterilized. The same swatches were then premoistened in the synthetic soil, reinoculated, held under the same conditions as before, removed from the environmental chamber, laundered and sterilized. This reinoculation procedure was then repeated giving a total of three inoculations and soilings on the same swatches (Figure I, page 40).

For all treatments, a swatch was drawn after each sterilization for evaluation (Figure I, page 40). Following completion of the test procedure, survival of C. tropicalis was assayed. Colonies of the microorganism were enumerated with the aid of the Quebec colony counter. All inoculation and microbial survival work was completed by personnel in the Department of Infectious Diseases.

Cross-Sectioning

Preparation of cross-sections. From all four treatments after each sterilization, one swatch was drawn giving four evaluation periods for each treatment for one run. Each swatch had three randomly chosen

areas from which specimens were cut to be embedded for cross-sectioning. The specimens were stapled to cardboard frames one and one-fourth by five-eighth inches with the terry side of the fabric next to the frame and the wale of the knit running the length of the frame. The coding of the specimens was put in pencil on the end of the frame that was permanently embedded. The code was written in pencil because pencil was not removed in the embedding process.

The following abbreviations were used in establishing a code for identifying each specimen:

Uninoculated-unsoiled treatment	T_1
Uninoculated-soiled treatment	T_2
Inoculated-unsoiled treatment	T_3
Inoculated-soiled treatment	T_4
1st sterilization	A
2nd sterilization	B
3rd sterilization	C
4th sterilization	D
1st run	R_1
2nd run	R_2
3rd run	R_3
37°C., 100% R.H.	37

Use of the "$T_{3B}R_3 37$" code would indicate that this specimen came from fabric which had been inoculated-unsoiled, held four days at 37°C. and 100% R.H., laundered and sterilized and was the third repeat of the treatment.

After the specimens for embedding were stapled to the frame and labeled, each specimen was placed in a number eleven gelatin capsule, and dried in a drying oven for forty-five minutes at 45°C. A lucite

solution which forms a plastic substance, was used for embedding the fabrics. The solution was prepared by mixing together 300 ml. of methyl methacrylate (inhibitor removed), 170 ml. of di (n) butyl phthalate, and 2.5 g. of benzoyl peroxide. Because methyl methacrylate polymerizes rapidly with the evolution of heat, it is ordinarily stored and shipped only after the addition of a polymerization inhibitor. Hydroquinone is most commonly used for this purpose. The hydroquinone may be removed from the methyl methacrylate by washing three times with a 5% solution of sodium hydroxide, using a total amount of solution equal to 50% of the methyl methacrylate and then washing with distilled water and carefully dehydrating at 45°C., for two hours, in a drying oven to insure that no sodium hydroxide remained as any of the sodium hydroxide remaining would be damaging to the fabric (5).

The capsules containing the frames of fabric were filled to within one-eighth of an inch of the top with the lucite solution, tightly covered with the lids, and placed in the drying oven at 45°C., for forty-eight hours or until the solution hardened. The capsules were dissolved in warm running water leaving the embedded specimens in the lucite. A raised portion with vertical sides about one-fourth by one-eighth inch was shaped around the embedded fabric by using an exacto knife. Six cross-sections were cut from each specimen at a 45° angle with a thickness of eight to ten microns using an American Optical Company sliding microtome and mounted on a glass slide with Permamount and a cover glass.

Evaluation

Evaluation of microbial damage. Microscopic analysis of uninoculated-unsoiled, uninoculated-soiled, inoculated-unsoiled, and inoculated-soiled fibers was done with the use of an American Optical Company, Series Four Microstar, trinocular microscope after the slides had been blind coded. The cross-sections of the fibers were studied using the forty-three power objective, ten power eyepieces and substage illumination. The right hand eyepiece was equipped with a reticle, which had framing marks indicating the exact image area of the specimen to be evaluated and also the area of the specimen to be photographed.

Since it takes a very experienced person to get a good cross-section cut from the embedded specimens with the sliding microtome, six cuts were viewed for damage avoiding any areas that were apparently due to the knife blade of the microtome.

Three fields of view chosen at random were viewed of each cross-sectional cut giving a total of eighteen fields of view per slide and fifty-four fields of view for each evaluation for each treatment. As the field of view was observed, the number of each type of fiber was recorded as was the amount of soil. The number of fields of view showing the different levels of damage were recorded for each of the three fibers and types of damage. The levels of damage were as follows:

1 Damage in up to one-third of the fibers in the field of view.
2 Damage in one-third to two-thirds of the fibers in the field of view.
3 Damage in more than two-thirds of the fibers in the field of view.

After the number of fields of view showing the different levels of damage were recorded the percentage of the fields of view showing a particular type of damage, for a fiber, for each level was calculated and put into tables (Table II, page 41 and Table III, page 44).

Photomicrographs. Photomicrographs were made of representative types of damages of the fibers from the uninoculated-unsoiled, uninoculated-soiled, inoculated-unsoiled, and inoculated-soiled treatments. The photomicrographs were taken with a 35 mm camera attached to the vertical tube of the trinocular body of the microscope giving a magnification of 645X. Kodak Plus X Pan, Black and White, Panchromatic film was used. The light source setting was 7.5, a 1/10 shutter speed, no filter and the lower prism on the microscope was swung out.

RESULTS AND DISCUSSION

The amount of damage to fibers by C. tropicalis on a sock fabric of fifty percent wool, thirty percent nylon and twenty percent cotton was studied with an American Optical Series Four Microstar Microscope and then tabulated for three different levels of damage. Types of damages seen in the fibers were recorded with black and white photomicrographs made with a 35 mm camera attached to the vertical tube of the trinocular body of the microscope giving a magnification of 645X.

Photomicrographs at 645X

Photomicrographs appear fuzzy in places and sharp in others because of the variation in the thickness and uneveness of the cuts of the cross-sections from which the photomicrographs were made (Plate VI, Fig. 1). The fine adjustment on the microscope can cause the photomicrograph to be out of focus when the view in the microscope appears in focus.

Soiling appeared in fields of view of the microscope and in photomicrographs for inoculated-unsoiled treatments while fields of view from specimens inoculated-soiled showed no soil. This was due to the fact that the inoculated-unsoiled and the inoculated-soiled were washed together after being sterilized confirming the findings of Schimpf (17) that there is redeposition of soil in the washer. There was a pattern in the types of compounds of the soil that clung or remained around the fibers. Wool and nylon collected the carbon of the soil while the cotton seemed to attract the starches of the soil (Plate I, Fig. 1 and

Plate VI, Fig. 2).

Another general feature that showed in the photomicrographs was the apparent double image of a fiber as seen in Plate I, Fig. 1. However, this is the result of the fiber being pulled away from the mounting medium or the mounting medium being pulled away from the fibers. When the cross-sections are transferred from the microtome to the glass slide for mounting, it is difficult to get the slice spread even and to get the sections to lie flat thus causing the embedding medium to be pulled away from the fibers.

Wool. In observing the wool fiber damage through photomicrographs and the microscope, it was hard to distinguish between channels, fissures and serration. Plate II, Fig. 1 shows fissures in the wool which are surface cracks or marks on the fibers while channels are more etched into the fibers and appear as in Plate II, Fig. 2. Both photomicrographs, Plate III, Fig. 1 and Plate III, Fig. 2 show serration of wool which gives the appearance of complete separation of the sections of the fiber. Often rough edges were seen accompanying the serration as shown in Plate III, Fig. 1.

One of the highest recorded types of damage in wool fibers was serration but there was not a pattern of progression of damage due to different fabric treatments. For example, Plate III, Fig. 2 shows a lot of serration but this was taken of cross-sections from the second sterilization first run of the uninoculated-unsoiled treatment ($T_{1B}R_1$) while Plate I, Fig. 2 which shows no serration comes from the third sterilization third run of the inoculated-soiled treatment ($T_{4C}R_3$).

V-shaped corrosion shown in Plate IV, Fig. 1 is a usual type of damage but does not seem to show up well in the photomicrographs. Pitting of wool as seen under the microscope, many times, looked like the delustrant that has been added to nylon. If soil was present the pitting was harder to distinguish. The center of the cortex cells also made it hard to tell if there was actual pitting damage. Plate IV, Fig. 2 shows pitting damage that was felt to be actual damage and not soil or the center of cortex cells.

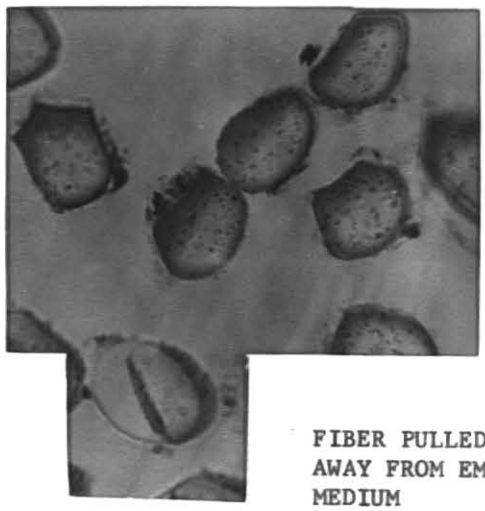
One example of unusual fiber damage of wool is shown in Plate I, Fig. 2 where the wool fiber has the center missing completely or maybe filled with some debris. The center seemed to be removed in a perfect circle and there were as many times that the center was vacant as there were times when the debris was present. Protruding scales seen in Plate IV, Figs. 3-4 showed up better in the photomicrographs than with the microscope.

Cotton. Cotton fiber damage seen most with photomicrographs was swelling, fissures and breaks. Pitting was more visible with the microscope than with the photomicrographs. Plate V, Fig. 1 shows cotton close to normal and very little damage while Plate V, Fig. 2 shows cotton which was well swollen with the lumen being almost entirely collapsed because of the swelling.

Fissures and swelling can be seen in Plate VI, Fig. 1 as well as pitting but little fiber breakage was present. Plate VI, Fig. 2 shows cotton fiber breakage which seems to be in the outside walls. The fibers no longer seemed swollen but as if they had been blown up and

PLATE I

TYPES OF FIBER DAMAGE OBSERVED FROM DIFFERENT LABORATORY TREATMENTS



POLYGON NYLON FIBERS
SOIL CLINGING TO NYLON

Third sterilization, second run of the inoculated-soiled treatment ($T_{4C}R_3$)

Fig. 1

FIBER PULLED AWAY FROM EMBEDDING MEDIUM

CENTER WOOL MISSING WITH DEBRIS

Third sterilization, third run, from the inoculated-soiled treatment ($T_{4C}R_3$)

Fig. 2

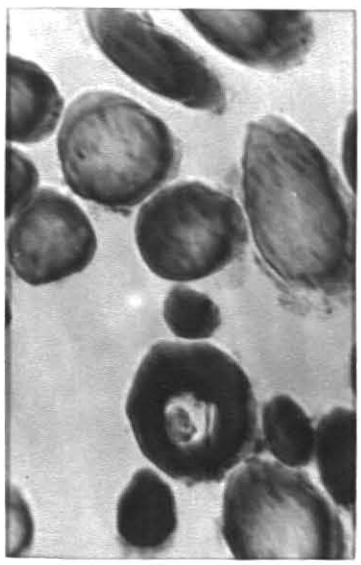


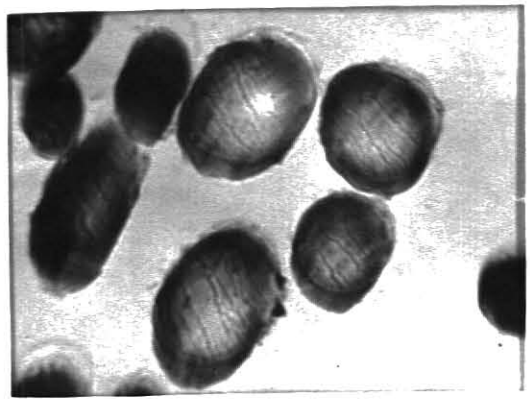
PLATE II

TYPES OF FIBER DAMAGE OBSERVED FROM DIFFERENT LABORATORY TREATMENTS

FISSURES

Third sterilization, first run from inoculated-soiled treatment ($T_{4C}R_1$)

Fig. 1



CHANNELS

Second sterilization, first run of the uninoculated-unsoiled treatment ($T_{1B}R_1$)

Fig. 2

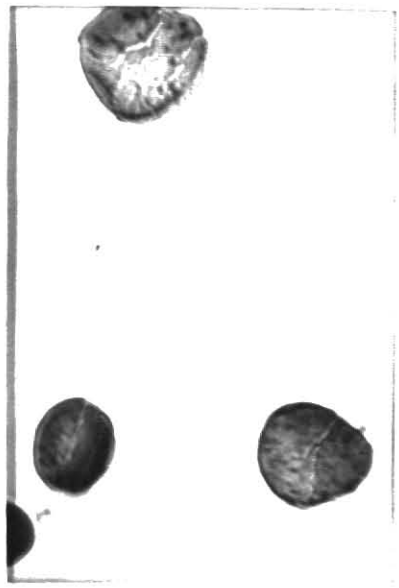


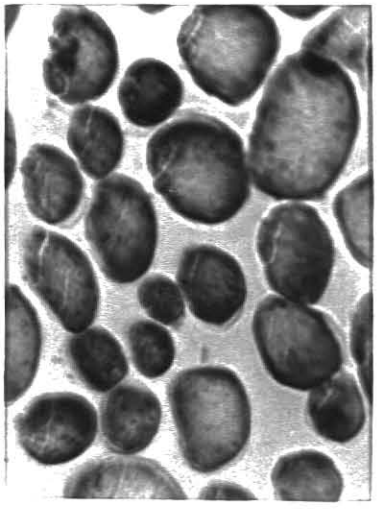
PLATE III

TYPES OF FIBER DAMAGE OBSERVED FROM DIFFERENT LABORATORY TREATMENTS

SERRATION AND ROUGH EDGES DUE TO KNIFE DAMAGE

Fourth sterilization, third run from the inoculated-soiled treatment ($T_{4D}R_3$)

Fig. 1



SERRATION

Second sterilization, first run from the uninoculated-unsoiled treatment ($T_{1B}R_1$)

Fig. 2

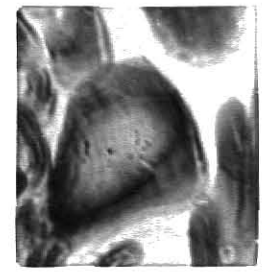
PLATE IV

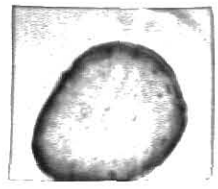
TYPES OF FIBER DAMAGE OBSERVED FROM
DIFFERENT LABORATORY TREATMENTS

V-SHAPED CORROSION

Second sterilization, second run from inoculated-soiled treatment ($T_{4B}R_2$)

Fig. 1





PITTING

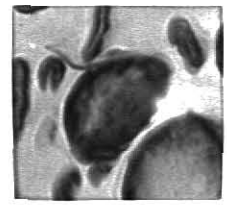
First sterilization, first run of inoculated-unsoiled treatment ($T_{3A}R_1$)

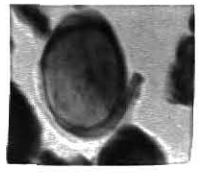
Fig. 2

PROTRUDING SCALES OF MEDIUM SIZED WOOL

Second sterilization, second run of the inoculated-soiled treatment ($T_{4B}R_2$)

Fig. 3





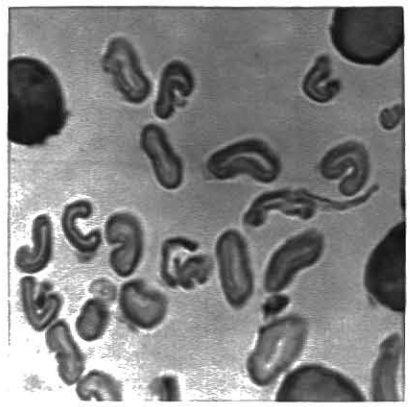
PROTRUDING SCALE

Second sterilization, second run, of the inoculated-unsoiled treatment ($T_{3B}R_2$)

Fig. 4

PLATE V

TYPES OF FIBER DAMAGE OBSERVED FROM DIFFERENT LABORATORY TREATMENTS



NORMAL COTTON FIBERS

Third sterilization, first run from the uninoculated-soiled treatment ($T_{2C}R_1$)

Fig. 1

SWELLING OF COTTON

First sterilization, first run of the inoculated-unsoiled treatment ($T_{3A}R_1$)

Fig. 2

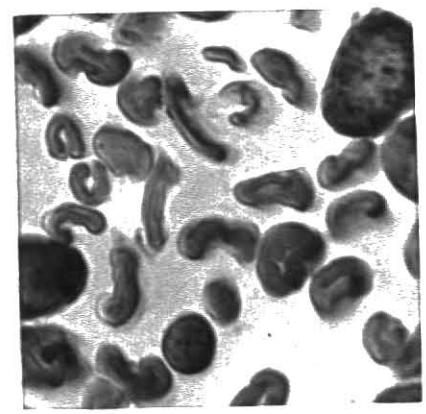
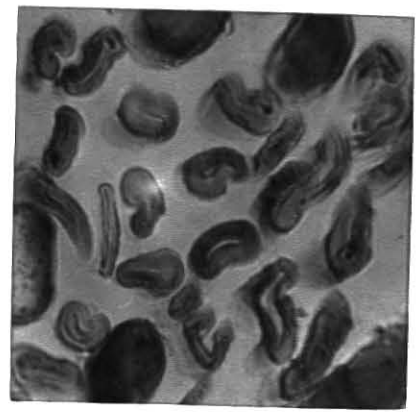


PLATE VI

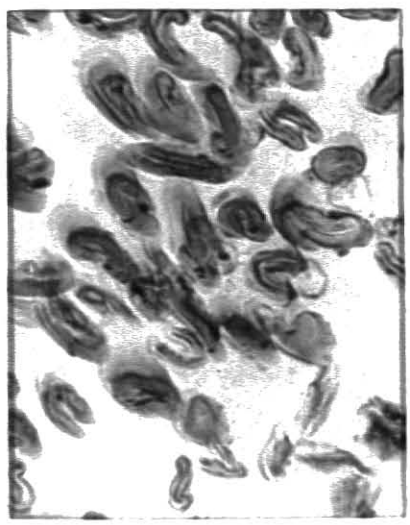
TYPES OF FIBER DAMAGE OBSERVED FROM DIFFERENT LABORATORY TREATMENTS



FISSURES AND PITTING OF COTTON

Third sterilization, first run from inoculated-soiled treatment ($T_{4C}R_1$)

Fig. 1



PITTING
BREAKING OF CELL WALL
FISSURES

Fourth sterilization, first run of the inoculated-soiled treatment ($T_{4D}R_1$)

Fig. 2

burst. The dark spots on the cotton seen in Plate VI, Fig. 2 are not all actual pitting but are pieces of carbon from the soil clinging to the fibers.

Visibly, there did seem to be an increase in swelling of cotton fibers as seen in the photomicrographs from the uninoculated-unsoiled specimens to the inoculated-soiled specimens. However, more photomicrographs were needed before drawing conclusions. The advantages of the photomicrographs are that they can be referred back to and they are easier on the eyes and easier to compare than slides.

Nylon. The nylon fiber when studied by photomicrographs were polygon shapes and showed that the carbon from the soil seemed to cling to the nylon while the starches didn't. As with the microscope, no damage was noted in the nylon by photomicrographs (Plate I, Fig. 1).

Microscopic Analysis by Tabulation

The tabulation of the types of damages that were seen for the three fibers, wool, cotton and nylon was recorded by studying a field of view and rating the type of damage as one of three levels of damage. The levels of damage indicate the number of the fibers in a field of view that were damaged by a specific type of damage such as serration. The levels that were established were; 1) indicating that up to one-third of the fibers in the field of view were damaged, 2) that from one-third to two-thirds of the fibers in the field of view were damaged, and 3) more than two-thirds of the fibers in the field of view showed damage. After this was done for each field of view for each type of

damage of each fiber for each evaluation period, then the results were calculated to percentage of fields of view showing a type of damage for a fiber for each level (Table II, page 41, and Table III page 44).

Nylon. The nylon when viewed under the microscope had a dark outer edge, a light pinkish yellow center and delustrant spread throughout. The fibers were approximately all the same diameter but there were a variety of shapes including five sided, round, three sided, bean shaped and a combination of curves and straight sides. Cross-sections from specimens that had been subjected to soiling as part of their treatments showed that often the carbon from the soil collected around the nylon while only very small amounts of starches clung to the fibers (Plate I, Fig. 1). There were times when the soil did not show up and the amount of soil clinging to the fibers varied indicating that there was not consistent removal of the soil in laundering.

Wool. The wool fibers appeared under the microscope in a variety of diameters and the shapes varied from round to oval with some being elongated. The fibers varied also in color from very light to dark. Most of the fibers had a blue-black color probably due to the black dye used on the knitted sock material. Once in a while a wool fiber would appear that was a yellowish brown color.

The types of damage that were observed in the wool fibers using the microscope were protruding scales, serration, V-shaped corrosion, missing chunks, smooth fibers, channels, rough edges, pitting and fissures. The two types of damage that showed up the least were channels and smooth fibers. Only two fields of view in the entire experiment

showed smooth fibers and both fields of view were from the evaluation of the first sterilization, first run, of the inoculated-unsoiled treatment ($T_{3A}R_1$). Channels were observed in wool fibers for each of the four treatments but not at all evaluations. The evaluations that did show channels present showed also that very few of the fields of view were affected by channels (Table II, page 41).

Fissures were seen on wool fibers for all evaluations at the first level of damage except for the third sterilization, first run of the uninoculated-unsoiled treatment ($T_{1C}R_1$) while two-thirds of the evaluations showed fissures at the second level of damage. No fissures showed up at the third level of damage on the wool fibers analyzed.

Wool fibers in all but three evaluations, the third sterilization first run of uninoculated-unsoiled treatment ($T_{1C}R_1$), the fourth sterilization first run of the uninoculated-soiled treatment ($T_{2D}R_1$) and the fourth sterilization first run of the inoculated-soiled treatment ($T_{4D}R_1$) showed pitting at the first level of damage. Nine of the evaluation periods showed second level pitting damage to wool (Table II, page 41).

Rough edges appeared on wool fibers at the first level of damage at all evaluation periods except for the third sterilization second run of the inoculated-soiled treatment ($T_{4C}R_2$). All but four of the evaluations, the fourth sterilization first run of the uninoculated-soiled treatment ($T_{2D}R_1$), the first sterilization first run of the inoculated-unsoiled treatment ($T_{3A}R_1$) and the fourth sterilization first run of the inoculated-unsoiled treatment ($T_{3D}R_1$) and the second sterilization first

run of the inoculated-soiled treatment ($T_{4B}R_1$) contained wool fibers which showed rough edges at the second level of damage. In almost half of the evaluations wool fibers showed rough edges at the third level of damage. There did not seem to be a progressive pattern to the rough edge damage viewed. For example, at the first level of damage, uninoculated-unsoiled treatment showed 14.3%, 4.3%, 14.2% and 4.3% of the fields of view showing the first level of rough edges in wool fibers while the inoculated-soiled treatment showed 9.8%, 15.2%, 26.1% and 20.0% of the fields of view showing first level of rough edges in wool fibers (Table II, page 41).

Missing chunks were seen on wool fibers for both first and second levels of damage. Four evaluation periods showed that a small percentage of the fields of view showed chunks missing at the second level of damage. In two-thirds of the evaluations, no missing chunks in the cross sections of the fibers were seen at the first level of damage.

All but one evaluation, the third sterilization, second run of the inoculated-unsoiled treatment ($T_{3C}R_2$) showed V-shaped corrosion to wool fibers at the first level of damage. A higher percentage of the fields of view showed V-shaped corrosion on wool fibers at the first level of damage than the second level of damage. Wool fibers from the uninoculated-unsoiled treatment showed V-shaped corrosion of wool only at the first level of damage while wool fibers from the uninoculated-soiled, inoculated-unsoiled, and the inoculated-soiled treatments showed V-shaped corrosion at the first and second level of damage (Table II,

page 41).

The two types of damage that showed up most according to the tabulations were the protruding scales and serration. Serration of the wool cross-sections was seen at all three levels (Table II, page 41). The range from 13.9% to 41.3% of the fields of view showed serration at the first level of damage to the wool fibers. Both of these were from the inoculated-soiled treatments with 13.9% being from the fourth sterilization third run ($T_{4D}R_3$) and 41.3% from the third sterilization first run ($T_{4C}R_1$). At the second level of serration of wool fibers, the range was from 6.4% at the second sterilization first run from inoculated-unsoiled treatment ($T_{3B}R_1$) and 31.8% at the fourth sterilization second run of the inoculated-soiled treatment ($T_{4D}R_2$).

Cross-sections of wool fibers from all evaluations showed protruding scales at the first level of damage. Two-thirds of the evaluations showed fields of view which had wool protruding scales at the second level of damage (Table II, page 41). In only two evaluations, first sterilization first run of the inoculated-unsoiled treatment ($T_{3A}R_1$) and third sterilization first run of the inoculated-soiled treatment ($T_{4C}R_1$) did wool fibers show protruding scales at the third level of damage.

Cotton. The types of cotton fiber damages observed with use of the microscope were swelling, pitting, breaking and fissures. Of all the types of damage the breaking of the fibers was viewed less often than any other damage.

Swelling of the cotton fibers was noticed at all three levels

for all four treatments. All evaluations showed fields of view that had swollen cotton at the first and second level of damage. One-half of the evaluations showed cross sections that had swollen cotton at the third level of damage.

The total percentage of fields of view that showed swelling damage of cotton fibers for all evaluations did not vary much from one evaluation to another. The range in total percentage was only from 86.2% to 100% for all evaluations except one, the third sterilization first run from the uninoculated-soiled treatment ($T_{2C}R_1$) which was 62.6%. Six of the evaluations showed 100% of the fields of view indicating swollen cotton (Table III, page 44).

Pitting of cotton fibers was seen at all evaluations. At the first level of damage all evaluations were represented by pitting while the second level of damage was represented by pitting for all but one evaluation, the third sterilization first run of the uninoculated-unsoiled treatment ($T_{1C}R_1$). However, the third level of damage showed pitting in the cotton cross-sections in only eight of the evaluations (Table III, page 44).

Breaking the least type of damage seen in the cotton fibers, showed up in all evaluations except for the second sterilization third run of the inoculated-unsoiled treatment ($T_{3B}R_3$) which showed no breaks at any of the levels of damage in the fields of view observed. Almost half of the evaluations showed breaking of cotton fibers in the fields of view as being at the second level of damage. Breaks in the cotton fibers at the third level of damage was observed in two evaluations, the

third sterilization third run of the inoculated-soiled treatment ($T_{4C}R_3$) and the first sterilization first run of uninoculated-soiled treatment ($T_{2A}R_1$). The percentage of fields of view affected by breaking of cotton fibers was low for all evaluations (Table III, page 44).

Fissures were seen in cotton fibers from all evaluations with most of the fissures being seen at the first level of damage. The second level of damage of fissures in the cotton cross-sections, was noted at all evaluations except three (Table III, page 44). Three evaluations showed fissures in cotton fibers at the third level of damage with these being very small percentages of the total fields of view (Table III, page 44).

When the total number of fields of view showing damage for a cotton, wool, or nylon fiber for each treatment were compared to the number of fields of view which had a particular fiber present, the resulting percentage of damage fields of view did not show a difference from the results obtained through tabulation of the types of damage for three levels at which evaluations of the treatments were made (Table IV, page 47).

RECOMMENDATIONS FOR FURTHER STUDY

The method of tabulating the fiber damage of cross-sections did not indicate a progressive increase in the amount or types of damage due to laundering, soiling or inoculating with C. tropicalis (Table II, page 41 and Table III, page 44). By one other method investigated (Table IV, page 47) there was still not a progressive trend. However, the tabulating methods did show which types of damage were more prevalent than others. The types of cotton damage most often observed were swelling, fissures and pitting while the protruding scales and serration were seen most when viewing the wool. If only damage or no damage were indicated from analysis of the fields of view instead of the three levels of damage, results may be as relevant as to breaking the damage down into levels. The latter method was time consuming and the accuracy of estimations of levels of damage was inadequate. Channels, fissures and serration on wool fibers might be tabulated into one category because of the difficulty in distinguishing between these types of damage.

Opportunity for error may be greater for microscopic fiber analysis when cross-sections are studied rather than longitudinal sections since the sample is more minute. Thus much work in this area needs to be done before conclusions can be drawn.

Emmons (6) reported there are few organic substances that are free from attack by fungi. Thus it was not surprising to find that the uninoculated-unsoiled swatches showed a large amount of damaged natural fibers. The protein and vegetable fibers can be attacked by microorganisms at many stages of development and production. Thus considerable

microscopic fiber analysis needs to be completed before any laboratory treatment because of the minute samples.

Further study needs to be made on the effect of ethylene oxide sterilization may have on textile fibers. Preliminary study of ethylene oxide for sterilization resulted in the belief that the textiles would not be harmed but researchers now question this theory.

Dastidar et al. (3) stated, all candida growth was stimulated by amino acids which gave an indication that wool might show more damage than cotton. Since our results showed slightly more damage on cotton than wool, it is wondered if a larger sample would indicate some of the cotton damage was due to fiber irregularity.

More details were seen in the photomicrographs, in photographing the fibers due to the increased magnification. Damage as a result of the treatments to the swatches of sock fabric could be more easily analyzed if more photomicrographs were taken. It is recommended a comparison of a tabulation of damage of slides and photomicrographs be made.

Because of the difficulty with cutting the cross-sections, other methods of preparation should be investigated to give more reliable cuts and therefore more reliable information by whatever method is used to analyze the cross-sections.

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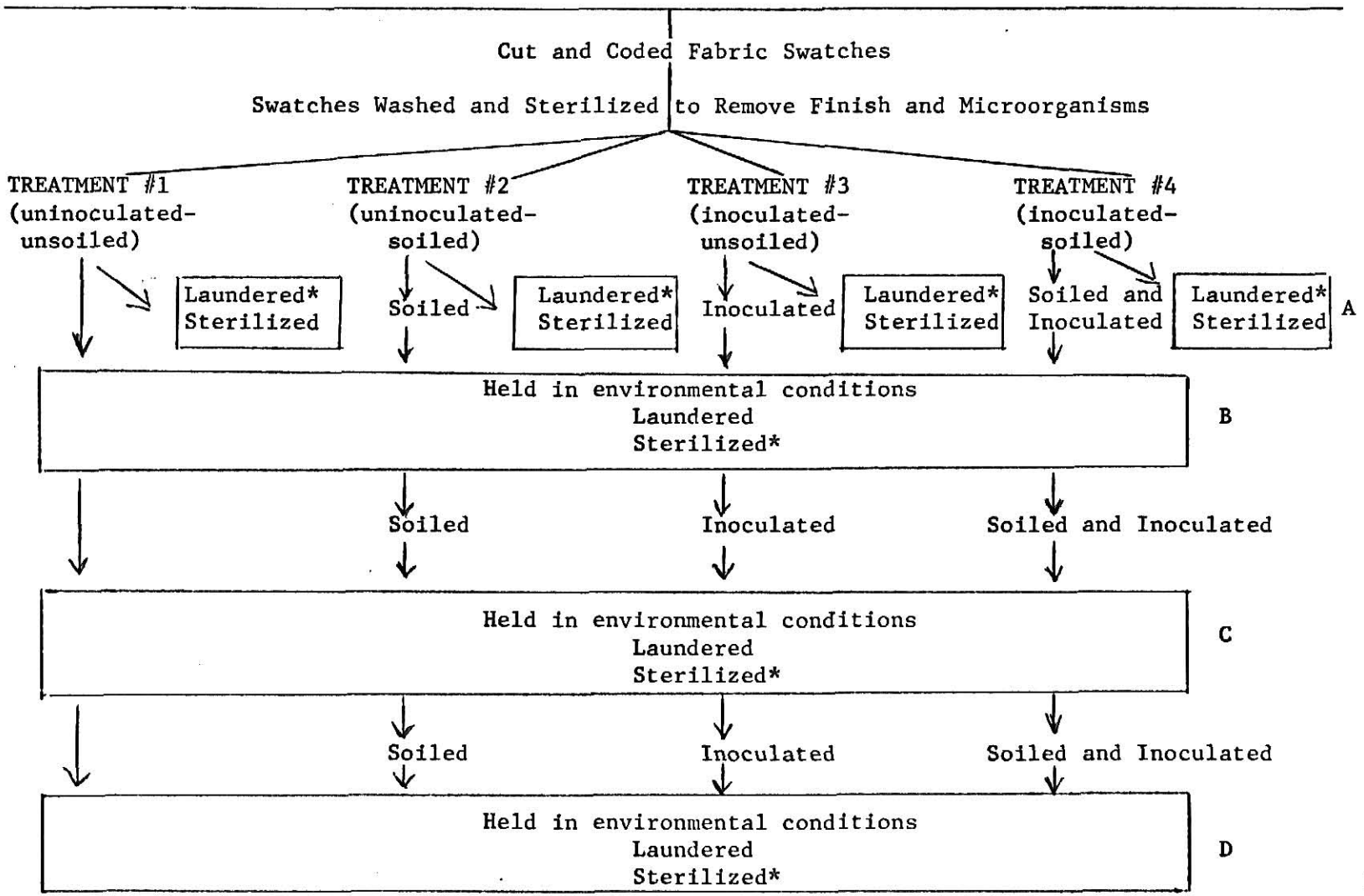
APPENDIX

FIGURE I

FLOW CHART OF TEST PROCEDURES



*A swatch will be drawn for evaluation after each sterilization for each treatment.

TABLE II

PERCENTAGE OF MICROSCOPIC FIELDS OF VIEW SHOWING WOOL DAMAGE BY QUANTITY OF FIBERS PRESENT AT THREE LEVELS

TREATMENT AND CODING	Level of Damage*	TYPES OF DAMAGE: Protruding Scales	Serration	V-Shaped Corrosion	Missing Chunks	Scales Absent	Channels	Rough Edges	Pitting	Fissures
UNINOCULATED-UNSOILED										
$T_{1A}R_1$	1	40.8	18.4	10.2	10.2			14.3	4.1	8.2
	2	16.3	16.3		6.1			6.1	2.0	
	3		4.1							
		57.1	38.8	10.2	16.3			20.4	6.1	8.2
$T_{1B}R_1$	1	32.6	28.3	17.4	4.3			4.3	4.3	6.5
	2		15.1				2.2	2.2		2.2
	3		2.2					2.2		
		32.6	45.6	17.4	4.3		2.2	8.7	4.3	8.7
$T_{1C}R_1$	1	30.4	28.3	4.3				15.2		
	2	4.3	17.4					2.2		
	3		2.2							
		34.7	47.9	4.3				17.4		
$T_{1D}R_1$	1	41.3	19.6	2.2	2.2			4.3	6.5	2.2
	2		10.8					4.3		6.5
	3									
		41.3	30.4	2.2	2.2			8.6	6.5	8.7
UNINOCULATED-SOILED										
$T_{2A}R_1$	1	38.3	40.4	17.0	6.4		2.1	17.0	4.3	14.9
	2		17.0	6.4				8.5		4.3
	3									
		38.3	57.4	23.4	6.4		2.1	25.5	4.3	19.2
$T_{2B}R_1$	1	13.0	21.7	19.6	4.3			8.7	15.2	8.7
	2		21.7					2.2		
	3		4.3							
		13.0	47.7	19.6	4.3			10.9	15.2	8.7
$T_{2C}R_1$	1	36.7	18.4	2.0	2.0			2.0	2.0	16.3
	2		16.3					4.1		2.0
	3		4.1							
		36.7	38.8	2.0	2.0			6.1	2.0	18.3
$T_{2D}R_1$	1	34.8	36.9	32.6	6.5			23.9		8.7
	2	4.3	15.2						2.2	
	3		4.3							
		39.1	56.4	32.6	6.5			23.9	2.2	8.7

*1) Damage in up to one-third of the fibers in the field of view.
2) Damage in one-third to two-thirds of the fibers in the field of view.
3) Damage in more than two-thirds of the fibers in the field of view.

TABLE II (continued)

TREATMENT AND CODING	Levels of Damage	TYPES OF DAMAGE: Protruding Scales	Serration	V-shaped Corrosion	Missing Chunks	Scales Absent	Channels	Rough Edges	Pitting	Fissures
INOCULATED-UNSOILED										
$T_{3A}R_1$	1	40.9	25.0	18.2	9.1	2.3	13.6	27.3	15.9	2.3
	2		20.5	4.5					4.5	
	3	2.3	2.3					2.3		
		43.2	47.8	22.7	9.1	2.3	13.6	29.6	20.4	2.3
$T_{3B}R_1$	1	25.5	29.8	23.4	12.8		2.1	10.6	12.8	6.4
	2	6.4	6.4	6.4	4.3			2.1	2.1	2.1
	3		6.4							
		31.9	42.6	29.8	17.1		2.1	12.7	14.9	8.5
$T_{3C}R_1$	1	10.9	19.6	6.5	8.7			8.7	10.9	6.5
	2		19.6					4.3		4.3
	3		4.3					2.2		
		10.9	43.5	6.5	8.7			15.2	10.9	10.8
$T_{3D}R_1$	1	8.7	32.6	6.5	4.3			13.0	8.7	23.9
	2	2.2	13.0							6.5
	3		2.2					2.2		
		10.9	47.8	6.5	4.3			15.2	8.7	30.4
$T_{3B}R_2$	1	32.6	41.3	15.2	2.2		2.2	17.4	6.5	2.2
	2	2.2	8.7		4.3			4.3	2.2	
	3		4.3					2.2		
		34.8	54.3	15.2	6.5		2.2	23.9	8.7	2.2
$T_{3C}R_2$	1	14.9	27.6					8.5	10.7	19.1
	2	2.1	17.0					2.1		
	3									
		17.0	44.6					10.6	10.7	19.1
$T_{3D}R_2$	1	22.2	31.1	17.8	4.4			13.3	2.2	4.4
	2		17.8	2.2			2.2	4.4		2.2
	3		2.2							
		22.2	50.1	20.0	4.4		2.2	17.7	2.2	6.6
$T_{3B}R_3$	1	46.9	16.3	8.2				10.2	6.1	6.1
	2	2.0	10.2	2.0				8.2		
	3		4.1					2.0		
		48.9	30.6	10.2				20.4	6.1	6.1
$T_{3C}R_3$	1	29.2	16.7	16.7	4.2		2.1	8.3	6.3	4.2
	2	8.3	10.4					4.2	2.1	
	3		6.3							
		37.5	33.4	16.7	4.2		2.1	12.5	8.4	4.2
$T_{3D}R_3$	1	29.5	15.9	4.5				11.4	4.5	2.3
	2	6.8	20.5	2.3				18.2		2.3
	3		13.6					4.5		
		36.3	49.0	6.8				34.1	4.5	4.6

TABLE II (continued)

TREATMENT AND CODING	Level of Damage	TYPES OF DAMAGE: Protruding Scales	Serration	V-Shaped Corrosion	Missing Chunks	Scales Absent	Channels	Rough Edges	Pitting	Fissures
INOCULATED-SOILED										
$T_{4A}R_1$	1	36.6	17.1	7.3	2.4			9.8	17.1	7.3
	2	4.9	21.9	4.9				4.8	2.4	4.9
	3		2.4					2.4		
		41.5	41.4	12.2	2.4			17.0	19.5	12.2
$T_{4B}R_1$	1	23.9	30.4	29.3			6.5	15.2	4.3	8.7
	2	2.2	8.7	2.2						
	3		4.3							
		26.1	43.4	30.5			6.5	15.2	4.3	8.7
$T_{4C}R_1$	1	47.8	41.3	21.7	15.4		2.2	26.1	10.8	2.2
	2	2.2	13.0	4.3				15.2		2.2
	3	2.2	6.5					2.2	2.2	
		52.2	60.8	26.0	15.4		2.2	43.5	13.0	4.4
$T_{4D}R_1$	1	28.9	20.0	4.4	2.2			20.0		15.6
	2	2.2	20.0					4.4		4.4
	3		8.9					2.2		
		31.1	48.9	4.4	2.2			26.6		20.0
$T_{4B}R_2$	1	29.5	27.3	15.9	4.5			15.9	6.8	13.6
	2	4.5	9.1	2.3				2.3		
	3		2.3							
		34.0	38.7	18.2	4.5			18.2	6.8	13.6
$T_{4C}R_2$	1	25.0	20.4	4.5					4.5	6.8
	2	4.5	13.6					2.3		2.3
	3									
		29.5	34.0	4.5				2.3	4.5	9.1
$T_{4D}R_2$	1	27.3	20.5	2.3	2.3			4.5	4.5	4.5
	2	4.5	31.8				2.3	4.5	6.8	2.3
	3		2.3							
		31.8	54.6	2.3	2.3		2.3	9.0	11.3	6.8
$T_{4B}R_3$	1	45.1	25.5	17.6	1.9		1.9	9.8	11.8	15.7
	2	3.9	27.5	1.9				15.7	1.9	7.8
	3		1.9						1.9	
		49.0	54.9	19.5	1.9		1.9	25.5	15.6	23.5
$T_{4C}R_3$	1	40.4	21.3	6.4	8.5			6.4	4.3	2.1
	2	2.1	19.1	6.4	2.1			8.5		
	3		6.4							
		42.5	44.7	12.8	10.6			14.9	4.3	2.1
$T_{4D}R_3$	1	16.3	13.9	18.6			2.3	4.7	9.3	13.9
	2	6.9	27.9					4.7	2.3	
	3							6.9		
		23.2	41.8	18.6			2.3	16.3	11.6	13.9

TABLE III

PERCENTAGE OF MICROSCOPIC FIELDS OF VIEW SHOWING COTTON DAMAGE BY QUANTITY OF FIBERS PRESENT AT THREE LEVELS

TREATMENT AND CODING	Level of Damage*	TYPES OF DAMAGE			
		Swelling	Pitting	Breaking	Fissures
UNINOCULATED-UNSOILED					
$T_{1A}R_1$	1	62.5	33.3	12.5	54.2
	2	25.0	45.8		16.7
	3		4.2		
		87.5	83.3	12.5	70.9
$T_{1B}R_1$	1	37.5	66.7	20.8	70.8
	2	54.2	25.0	4.2	16.7
	3				
		91.7	91.7	25.0	87.5
$T_{1C}R_1$	1	82.6	73.9	13.0	56.5
	2	13.0			4.3
	3				
		95.6	73.9	13.0	60.8
$T_{1D}R_1$	1	71.4	64.3	21.4	60.7
	2	21.4	28.6		17.9
	3	3.6			
		96.4	92.9	21.4	78.6
UNINOCULATED-SOILED					
$T_{2A}R_1$	1	73.1	60.0	32.0	80.0
	2	26.9	24.0	20.0	4.0
	3			4.0	
		100.0	84.0	56.0	84.0
$T_{2B}R_1$	1	50.0	87.5	29.2	50.0
	2	45.8	8.3		4.2
	3	4.2			
		100.0	95.8	29.2	54.2
$T_{2C}R_1$	1	43.8	59.4	25.0	65.6
	2	18.8	15.6		6.3
	3				
		62.6	75.0	25.0	71.9
$T_{2D}R_1$	1	51.9	77.8	29.6	48.1
	2	44.5	22.2		
	3				
		96.4	100.0	29.6	48.1

*1) Damage in up to one-third of the fibers in the field of view.
2) Damage in one-third to two-thirds of the fibers in the field of view.
3) Damage in more than two-thirds of the fibers in the field of view.

TABLE III (continued)

TREATMENT AND CODING	Level of Damage	TYPES OF DAMAGE			
		Swelling	Pitting	Breaking	Fissures
INOCULATED-UNSOILED					
$T_{3A}R_1$	1	62.5	79.2	25.0	50.0
	2	33.3	12.5		8.3
	3	4.2	4.2		
		100.0	95.9	25.0	58.3
$T_{3B}R_1$	1	85.1	61.5	3.8	57.7
	2	11.1	25.0	3.8	7.7
	3	3.7	3.8		
		99.9	90.3	7.6	65.4
$T_{3C}R_1$	1	37.5	66.7	20.8	62.5
	2	54.2	29.2	4.2	12.5
	3	8.3			
		100.0	95.9	25.0	75.0
$T_{3D}R_1$	1	66.6	55.6	11.1	77.8
	2	20.8	40.7	3.7	11.1
	3				
		87.4	96.3	14.8	88.9
$T_{3B}R_2$	1	69.2	57.7	15.4	61.5
	2	26.9	34.6	7.7	3.8
	3	3.8			
		99.9	92.3	23.1	65.3
$T_{3C}R_2$	1	69.2	42.3	11.5	50.0
	2	26.9	46.2		7.7
	3				
		95.1	88.5	11.5	57.7
$T_{3D}R_2$	1	24.1	62.1	24.1	62.1
	2	58.6	27.6	6.9	17.2
	3	10.3			
		93.0	89.7	31.0	79.3
$T_{3B}R_3$	1	62.1	44.9		48.3
	2	24.1	24.1		3.4
	3				
		86.2	69.0		51.7
$T_{3C}R_3$	1	51.9	44.4	25.9	66.7
	2	25.9	48.1		18.5
	3	1.4			
		79.2	92.5	25.9	85.2
$T_{3D}R_3$	1	27.6	34.5	48.3	58.6
	2	55.2	55.2	3.4	41.4
	3	17.2	6.9		
		100.0	96.6	51.7	100.0

TABLE III (continued)

TREATMENT AND CODING	Level of Damage	TYPES OF DAMAGE			
		Swelling	Pitting	Breaking	Fissures
INOCULATED-SOILED					
$T_{4A}R_1$	1	82.8	55.2	17.2	58.6
	2	13.8	27.6	3.4	13.8
	3		3.4		3.4
		96.6	86.2	20.6	75.8
$T_{4B}R_1$	1	75.9	93.1	17.2	58.6
	2	20.7	3.4		
	3				
		96.6	96.5	17.2	58.6
$T_{4C}R_1$	1	28.0	40.0	44.0	40.0
	2	48.0	40.0	20.0	12.0
	3	16.0	8.0		4.0
		92.0	88.0	64.0	56.0
$T_{4D}R_1$	1	11.5	55.6	55.6	25.9
	2	73.0	37.0	37.0	
	3	15.3			
		99.8	92.6	92.6	25.9
$T_{4B}R_2$	1	60.0	52.0	48.0	68.0
	2	32.0	24.0		8.0
	3				
		92.0	76.0	48.0	76.0
$T_{4C}R_2$	1	70.8	75.0	37.5	70.8
	2	20.8	20.8		20.8
	3	8.3			
		99.9	95.8	37.5	91.6
$T_{4D}R_2$	1	24.0	36.0	20.0	52.0
	2	48.0	36.0		16.0
	3	12.0			4.0
		84.0	72.0	20.0	72.0
$T_{4B}R_3$	1	57.7	30.8	34.6	38.5
	2	23.1	65.4		46.5
	3				
		80.8	96.2	34.6	85.0
$T_{4C}R_3$	1	26.9	42.3	26.9	65.4
	2	61.5	23.1	3.8	19.2
	3	1.5	3.8	3.8	
		89.9	69.2	34.5	84.6
$T_{4D}R_3$	1	50.0	38.5	38.5	80.8
	2	50.0	50.0	3.8	1.5
	3		3.8		
		100.0	92.3	42.3	82.3

TABLE IV

PERCENTAGE OF MICROSCOPIC FIELDS OF VIEW SHOWING DAMAGE FOR UNINOCULATED-UNSOILED, UNINOCULATED-SOILED, INOCULATED-UNSOILED, AND INOCULATED-SOILED OF WOOL AND COTTON FIBERS

TREATMENT	COTTON	WOOL
Uninoculated-Unsoiled, first run (T_1R_1)	70.4	24.4
Uninoculated-Soiled, first run (T_2R_1)	68.3	26.4
Inoculated-Unsoiled, first run (T_3R_1)	70.0	27.1
Inoculated-Unsoiled, second run (T_3R_2)	69.1	25.0
Inoculated-Unsoiled, third run (T_3R_3)	70.3	27.0
Inoculated-Soiled, first run (T_4R_1)	71.4	27.9
Inoculated-Soiled, second run (T_4R_2)	71.9	24.5
Inoculated-Soiled, third run (T_4R_3)	78.6	28.5

MICROSCOPIC CROSS-SECTION EVALUATION OF FIBER DAMAGE CAUSED BY CANDIDA TROPICALIS

by

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This study was designed to examine the type and the extent of damage to fibers of a knitted wool, nylon and cotton sock fabric caused by Candida tropicalis. The extent of the damage was evaluated by micro-analysis and the types of damage were recorded by photomicrographs.

The sock fabric composed of fifty percent wool, thirty percent nylon and twenty percent cotton was uninoculated-unsoiled, uninoculated-soiled, inoculated-unsoiled or inoculated-soiled. The fabric after being subjected to one of the above treatments was held in an environmental chamber for four days at 37°C. and 100% relative humidity, then laundered and sterilized before being subjected to the same treatment two additional times. A sample was drawn after each sterilization for evaluation. From each of the samples, specimens were embedded in lucite for cross-sectioning with a sliding microtome. The cross-sections were mounted permanently on slides and coded for microscopic evaluation.

The number of each fiber, amount of soil, the amount of different types of damages to the different fibers were recorded in each of fifty-four fields of view per evaluation period. Photomicrographs were made of representative types of damages seen.

Swelling and fissures were found in cotton more often than pitting and breaking. These types of damages were found after each treatment but damage did not appear to be progressive. Little damage was found on nylon fibers. Serration and protruding scales on wool fibers were abundant at all treatment levels. There was little difference in type or level of damage due to laundrying, soiling or inoculation with C. tropicalis for both cotton and wool fibers.