A QUANTITATIVE MICROSCOPIC AND PHYSICAL ANALYSIS OF DAMAGE CAUSED BY TRICHOPHYTON MENTAGROPHYTES ON A KNITTED WOOL-NYLON-COTTON FABRIC

by

TONDA HIGHLEY DIECKHOFF

B. S., Fort Hays Kansas State College, 1970

5248

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Clothing, Textiles and Interior Design

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1971

Approved by:

Jessie A. Warden
Major Professor

THIS BOOK CONTAINS NUMEROUS PAGES WITH THE ORIGINAL PRINTING BEING SKEWED DIFFERENTLY FROM THE TOP OF THE PAGE TO THE BOTTOM.

THIS IS AS RECEIVED FROM THE CUSTOMER.

ACKNOWLEDGEMENTS

The author would like to express her sincere appreciation to Dr. Jessie A. Warden, Head, Department of Clothing, Textiles, and Interior Design, for her assistance and guidance in directing this study; and to Dr. Shirley Friend, Assistant Professor, Clothing; and to Dr. Donald C. Kelley, Professor, Department of Infectious Diseases, for their cooperation and thoughtful suggestions while serving on the author's committee. Thanks is also given to Dr. A. Feyerherm, Professor, Department of Statistics; Mrs. Charissa Chou, Graduate Research Assistant, Department of Statistics; and Mr. Gary Plumburg, Laboratory Technician, Department of Infectious Diseases.

The research was sponsored by the THEMIS project of the Institute of Environmental Research of Kansas State University.

TABLE OF CONTENTS

PAGE

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

INTRODUCTION

Increased utilization of self-service public laundry facilities has created an urgent need for re-examination of the microbiology of home laundry. The American Public Health Association lists forty communicable diseases caused by bacteria, viruses, and fungi that are capable of being directly transmitted through textile articles (27). Likewise, Szathmary (31) reported that pathogenic microorganisms are possibly transmitted by articles of wearing apparel, towels, or surfaces contaminated by scales or hair from infected lesions. Thus, microorganisms may be transmitted by the wearing, handling or washing of infected textile articles. The dissemination of microorganisms by fabrics has been a public health problem for years (22). According to McNeil (22), the ability or inability of potentially harmful microorganisms to survive and multiply in textile materials could influence foot health and serviceability. Little information could be found on the prevalence of pathogenic fungi in textiles or their growth, survival and effect on textiles. Therefore, a member of the genus Trichophyton, *Trichophyton mentagrophytes*, was chosen for study in textiles used for footwear.

Dermatophytosis, bacterial pyodermas and candidiasis vie for being the most common disease of the skin, although each is predominate depending upon environmental factors (8). Blank and others (8) stated that the most prevalent infection in Vietnam is produced by *Trichophyton mentagrophytes*. In addition, Gray (16) reports that *Trichophyton mentagrophytes* is the most common cause of dermatophytosis of the foot.

This organism not only causes the common infection known as athlete's foot, but also produces tinea circinata, folicular infection of the scalp, ringworm of the smooth skin and other ringworm infections of the body. Dermatophytosis infections caused by T. mentagrophytes afflicts 50 to 70 percent of the male population in the United States (17). Cutaneous infections thrive in hot, humid climates (8).

An estimation of which textile fibers are most suitable for fungus colony growth is not completely known, because not only the quality but the method of manufacture, as well as treatments before and after construction, could influence fungi growth. However, it is known that microorganisms do damage textile fibers in a variety of ways. Manels and Reese (20) observed transverse cracks, helical cracks, x-shaped cracks, breaks, pits and different types of corrosion in their study on the microbial decomposition of cellulosic fabrics. Barnes (5) in the longitudinal study of fiber damage caused by Staphylococcus aureus on 60 percent nylon and 40 percent cotton sock material found little or no damage to nylon fibers. Damage to cotton fibers included transverse cracks, helical or spiral cracks, fissures, pits and some dissolution of the lumen. Hendrickson (17) found in the longitudinal study of fiber damage caused by Candida tropicalis on 60 percent nylon and 40 percent cotton sock material and 50 percent wool, 30 percent nylon and 20 percent cotton sock materials, that cotton fibers showed cracks and pits as major forms of damage, but internal corrosion, dissolution of the lumen and breaks were also observed. Damage to the wool fibers was primarily cracks, pits and loose and rough scales with small percentages of breaks, swelling, corrosion and absent scales.

Swelling, cracks and pits were observed in the nylon fibers. No reference was found in the literature regarding evaluating and recording fiber damage caused by fungi.

A second factor to consider is serviceability or wearing quality of a textile fiber. The length of wear life is of concern to all consumers whether they are private individuals, public concerns, or institutions. The term "wear" refers to the effects of many kinds of deteriorative actions on textiles, including abrasion, tensile stress, cuts, chemical damage, effect of sunlight and microbial attack. The major concern in this study will be how microbial attack changes the physical properties, strength and elongation, of the wool, nylon and cotton sock fabric.

Therefore, the objectives are the following: (1) to investigate methods for evaluating damage in a longitudinal microscopic study of textile fibers, (2) to analyze fiber damage results statistically for establishing sampling requirements for laundry and microorganism studies, and (3) to study the effect of Trichophyton mentagrophytes on the physical properties, strength and elongation, of the wool, nylon and cotton sock fabric.

Definitions of Terms:

Group - Indicates a group of swatches subjected to the same procedure.

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

Piece - Refers to an area within a swatch.

Procedure - Indicates a group of swatches that have been soiled-inoculated or unsoiled-inoculated, laundered one, seven or fourteen times in 0.0 percent or 0.2 percent detergent concentration.

Run - Refers to the completion of the test sequence.

Set - Refers to a collection of slides from one swatch.

Swatch - Fabric sample of wool, nylon and cotton knit sock fabric, 8 inches by 12 inches.

Test Sequence - Refers to the completion of four inoculations and holding periods.

Treatment - Indicates a group of swatches that has been soiled or that has not been soiled before inoculation.

View - Refers to one observation through a microscope.

REVIEW OF LITERATURE

The health of the feet is one of the major problems to the well being of man, particularly in tropical climates. In Vietnam, illness from skin diseases is often the major medical reason for disability of American troops. Dermatological infections, particularly foot skin diseases, are the most common cause for out patient visits in Vietnam. 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 (8). The degree of cutaneous disability is variable depending upon the weather, the terrain, and the nature of the military operation. The availability of clean, dry clothing is also regarded as important.

The importance of detecting damage to textile materials is necessary in the control of microbial disease and the elimination of microbial deterioration of fabrics. To understand the mechanism of degradation of textile materials by microorganisms, there must be a clear understanding of characteristics of fungi, dermatophytes, and the specific microorganism, *Trichophyton mentagrophytes*; the properties of textile fibers, wool, nylon and cotton; and the effects of fungi on textile fibers.

Characteristics of Fungi

Fungi. Fungi belong to the major division of the plant kingdom, *Thallophyta*, and to the subdivision, *Mycophyta* (32). Although some members of the division, *Thallophyta* possess chlorophyll, fungi do not. As a result, these microorganisms exist only as parasites or saprophytes. They depend, for their building materials and energy, on the organic compounds synthesized by other organisms. Accordingly, fungi possess varied, active and sometimes highly specialized enzyme systems which enable them to digest many types of organic materials. There are few organic substrates in man's environment which are free from attack by fungi. Vegetation, wood, lignin, keratin, chitin, bone, fats, oils, waxes and phenolic resins are susceptible to degradation by fungi (14).

Mycology is the science and study of fungi. An infection caused by these microorganisms is called a mycotic disease, a fungus disease or mycoses (24). There are a dozen important mycoses of man caused by more than fifty species of fungi plus another dozen of less severity and frequency. These diseases vary from the superficial skin infections such as dermatophytosis and cutaneous candidiasis to general mycoses such as coccidiodomycosis and histoplasmosis (14).

Dermatophytes. The dermatomycoses are a group of fungus infections of the skin caused by a definite group of fungi known as dermatophytes (7,14). These organisms invade the keratinized areas of the body such as the skin, hair and nails. However, these organisms are rarely found in the subcutaneous tissues or internal organs of the body.

Dermatophytes are the most common cause of widely distributed fungus diseases. The diseases they produce are known as ringworms or tineas. Beneke and Emmons (7,14) stated that these diseases are incited primarily by three genera: Microsporum, Epidermophyton and Trichophyton. Eighteen species are recognized as valid members of the dermatophyte group.

Most of the dermatophytes have been considered Deuteromycetes (*Fungi Imperfecti*); however, ascospores form in *Keratinomyces ajelloi* and *Microsporum gypseum*, as well as in others. This places the species with a perfect state in the class *Ascomycetes* (7).

Paldrok (25) stated that dermatophytes grow best over a range of 15° to 30° C. and that their growth is retarded at temperatures below 14° C., down to about 0° C., as well as over 40° C., up to 45° C., but did not necessarily kill the fungi. Dermatophytes grow at room temperature (25° C.) at a pH of 6.8-7.0. However, these fungi do tolerate variation in pH and temperature. Dermatophytes are able to utilize keratin, a substance found in the epidermal tissues, but they do not require it when growing in culture. Many keratinophilic fungi may be found in the soil that do not produce disease in animals or man (7).

Most of the dermatophytes produce two types of conidia. Both types are attached by a broad base to the conidiospore just below the base of the detached spore. Therefore, these spores are aleuriospores that are designated as two types, microconidia and macroconidia. The microconidia are unicellular; while the macroconidia are either unicellular or multicellular. Observeable in a few species has been the production of ascospores (14).

Trichophyton mentagrophytes. Many subspecies of *Trichophyton mentagrophytes* exist and as varieties are characterized by color or surface patterns of colonies. Because of these numerous known varieties, some refer to *Trichophyton mentagrophytes* as a group species (14).

The colonies of *T. mentagrophytes* vary from white, floccose colonies with a few clavate microconidia to cream-colored, yellowish or peach-colored, granular flat colonies which bear spores freely (14).

The two basic isolates of *T. mentagrophytes* are the white, downy type (human) and the granular type (animal). This fungus belongs to the class, *Fungi Imperfecti*. The usual form of reproduction is asexual; however, *Trichophyton mentagrophytes* has been established to have a sexual stage only in the granular form. *Trichophyton mentagrophytes* forms small spores even though Trichophytons as a group are of the large spore type. In addition, this fungus forms spores only on the surface of the hair; while other Trichophytons form spore chains inside and outside the hair (14).

Paldrok (25) reported that *Trichophyton mentagrophytes* grows at temperatures between 11° and 35° C., although at 11° C. development is slow. One strain of *Trichophyton mentagrophytes* has been found to grow fairly well even at 40° C.; while other strains were inhibited at this temperature. Rebell and Taplin (26) and Beneke (7) report no special nutritional requirements necessary for the development of *Trichophyton mentagrophytes*.

According to Beneke (7) *Trichophyton mentagrophytes* is reported as one of the four most prevalent dermatophytes found in the United States. *T. mentagrophytes*, like other dermatophytes, is listed as being a common cause of pathogenic fungus infections. *T. mentagrophytes* is the cause of a variety of inflammatory ringworm infections in man. They are Tinea capitis (ringworm of the scalp), Tinea barbae (ringworm of the beard), Tinea corporis (ringworm of the body), Tinea cruris (ringworm of the groin), Tinea Pedia (athlete's foot), and Tinea unguium (ringworm of the nail) (7,14,11). These infections occur throughout the world. Thus, this organism attacks chiefly the keratinized epidermis and keratinized epidermal appendages, such as the hair, hair sheaths and nails (11). Burrows (11) reported that the intravenous injection of Trichophyton mentagrophytes does not produce an infection of the internal organs of susceptible animals and man, but the micro-organism introduced tended to become localized in the skin and develop where it has been damaged as by scarification. In addition, this organism may cause ringworm in cattle, horses, dogs, cats, sheep, pigs, rabbits, squirrels, monkeys, chinchillas, silver foxes and laboratory rats and mice (14).

After the fungus has come in contact with man through contaminated clothing or other inanimate objects, separation of fiber structure, breaking off of hair and loss of hair occurs on man. Exudation from invaded epithelial layers, epithelial debris and fungal hyphae produce the dry crusts characteristic of the disease on skin. Growth of the fungus in skin and hair is more or less equal in all directions. Ringworm fungi are all strict aerobes and the fungi die out under the crust in the center of most lesions leaving only the periphery active. Thus, it is this mode of growth which produces the centrifugal progression and the characteristic ring form of the lesions. The lesions progress if suitable environmental conditions for mycelial growth exist, including a warm humid atmosphere and a slightly alkaline pH of the skin (9).

According to Blood and Henderson (9), the skin pH is significant in the development of ringworm. The susceptibility of humans to ringworm is much greater before puberty than afterwards when the skin pH falls from about 6.5 to about 4.0. This change is largely due to excretion of fatty acids in the sebrum which are often highly fungistatic.

The origin of human trichophytosis is unknown in spite of thorough investigations. Since trichophytosis continually occurs, two theories have been advanced to explain the origin. The theory is that inanimate objects are the cause of mycotic diseases in man. According to Szathmary (30), clothing that has been infected should be regarded as suspicious. Three examples of clinical cases were reported in support of the above suspicion. In one case, a woman was taken ill with trichophytosis on two spots, lying above her pubis. She had gone on an outing four or five days earlier into her vineyard. In another case, a twenty month old baby had an epidermophytosis localized on his buttocks, in the lower part of his abdomen and on the upper one-third of his thighs. Previous circumstances surrounding his case were that his underwear had been dried on the clothes line and had fallen on the soil. The same circumstances happened to a five year old child, whose shirt had fallen from the clothes line and after using it, a dermatosis began on the interscapular tract of the child (30).

In all these cases, the center of infections were lying in a line of friction from the clothing. According to this view, the sprinkling of pathogenic spores on the surface of human skin and clothing may be regarded as quite a natural process. Further investigation is needed to determine which cloth provides the most suitable conditions for adhering and whether the organism is able to live on it.

Other inanimate sources that may contain pathogenic fungi and may cause mycoses in man are carpets, bath mats, bathtubs, shoes, slippers, towels, socks and especially shower rooms and locker rooms. However, the mere isolation of fungi from these places can not be considered as unequivocal evidence of a dermatophyte's saprophytic existence in nature; it indicates only the presence of viable organisms. The main source of the pathogenic dermatophytes is probably the infected skin that is continually shedding the infecting fungus together with epithelial debris (10). Consequently, this theory proposes that fungi deposited in the external environment are indeed the cause of attacks of fungus diseases.

Baer and others (4) reported that the second theory proposes that the occurrence of clinically active fungus diseases, particularly of the feet, is principally due to fungi that people previously had been carrying on their feet in a latent "opportunistic" facultatively pathogenic state. In the presence of lowered resistance of the skin on the feet, fungi multiply and produce a disease. If this theory is correct, exogenous infections would play a minor role in the causation of attacks of dermatophytosis.

Effects of Fungi on Textile Fibers

Little is known about the mode of attack by fungi, or of the changes brought about in the fiber's structure. It is hard to estimate which fibers of textiles are most suitable for a fungus setting colonies on clothing, because not only the quality, but the method of manufacturing and the fabric's construction, are factors which have influence on the life of fungus growing on them. Most of the fungi growing on textiles affect not only materials constructed of vegetable (cotton fibers), but also animal (wool) fibers (31).

Wool. Wool fiber is an animal protein fiber. The wool fiber is composed of two layers--the epidermis or cuticle (outer) and the cortex (inner)--and a medulla. The epidermis is built of flat cells called scales, that give the fiber its characteristic surface appearance. The cortical layer under the scales is formed by spindle-shaped cells and represents the bulk of the fiber substance. The medulla is formed by thin walled cylindrical cells that are filled with air to a large extent (32). The cuticle acts as a protective sheath. However, it is protected by a covering called the epicuticle (19).

Keratin is the principle substance composing the wool fiber. It is a polypeptide composed of a wide variety of amino acids. In addition, a wool fiber consists of carbon, hydrogen, oxygen, nitrogen and sulphur (19).

Microorganisms are numerous in wool because of the excellent conditions for living and procreation. They find sufficient sustenance in organic compounds found in wool. Some varieties live simply on the wool cortex (13). The moisture content of wool is an important factor in the development of microorganisms in that the higher the content, the more numerous the microbes. Microorganisms enter wool through the intermediaries of soil, water and air (1,13).

From the time wool grows on the sheep on through the stages of manufacture and wear, the fiber is subject continually to contamination by microorganisms. Microorganic flora in wool may contain pathogenic organisms that cause wool fibers to deteriorate. Wool contains millions of these microorganisms per gram. Their number depends on the breed of sheep, country of origin, conditions of growth, maintenance of sheep, method of removal from the animal's skin, storing and on processing after shearing (13).

Microorganisms seem to attack wool most often after shearing, when the baled wool has been stored in conditions favoring their development, in a moist and badly ventilated room (13). Scouring causes an increase in the quantity of microorganisms in wool; while drying has a decreasing influence (32).

Under favorable conditions, development of microorganisms is rapid and abundant. Growth of microorganisms on wool leads to loss of strength, luster and color. Scientists, however, disagree as to the way in which microorganisms affect wool. Examination of damaged wool under a microscope revealed undamaged scales which either adhere to the fiber or are separated from it. No damage was observed to the spindle-shaped cells of the cortex; they retained their shape and size (13). Szathmary (31) reported that the consumption of animal keratin (hair, wool) was demonstrated by the signs of use caused by the filaments of fungus colonies growing on it. He also reported destructive changes caused by fungi are: (1) wide pitted hollows on the surface and (2) longitudinal channels in the middle. Zalinski (32) found that enzymes produced by fungi attack the fiber scales and penetrate into the cortical layer, causing decomposition of its outer cells and resulting in the scales falling off. Microorganisms do possess faculty for destruction of wool and wool textiles. However, it is not yet known how particular varieties of fungi affect wool.

Little information could be found on deterioration of woolen textiles in tropical climates because of its limited use in these areas. Agarwal and Puvathingal (1) reported that the breakdown of woolen fabric was brought about by actinomycetes, bacteria and fungi. A number of fungi, including Trichophyton mentagrophytes, have been found to cause discoloration and deterioration of wool (1).

Cotton. The cotton fiber is an unicellular seed hair. The three main parts of the fiber are the primary wall, the secondary wall and the lumen (29). The primary wall, externally covered with a cuticle, is exceedingly thin. The secondary wall, or the cell wall proper, is usually thicker. The secondary wall makes up the bulk of the cotton fiber. The lumen is generally filled with air, but it may also contain the remainders of dried protoplasm (32).

From the viewpoint of textile technology, the most important element of the fiber is the secondary wall which determines the character of the fiber. The significant function of the primary wall is to serve as a protective covering for the secondary wall.

Cotton contains constituents which serve as food for fungi development. The greatest part of the cotton fiber consists of cellulose (91-97%) (32); however, many other compounds are present. These include waxes, pectins, proteins, pigments and inorganic compounds. Most of the pectins occur in the primary wall. Pectins in cotton fibers are usually mixtures of calcium, magnesium and iron salts. In addition, the primary wall is comprised of waxes, fats, hemicelluloses and cellulose. Proteins occur primarily in the lumen. The secondary wall consists principally of cellulose (29,32).

After the boll has opened, cotton may be damaged at any point in its development. As the cotton dries in the boll, the cotton twists into helical ribbons and changes its shape. Its cross section that was formerly round, flattens. The directions of cotton convolutions are not uniform, changing constantly from Z to S. The places where fiber convolutions change their directions are the weakest; the fiber tends to break primarily in these places. Depolyerization of cellulose, cracking and external damages to the fiber surface can occur following exposure to sunlight in the open boll stage. This results in a drop in the tensile strength, total elongation and elasticity (32).

Many microorganisms attack cotton causing some degree of deterioration. Degradation is especially serious in tropical countries (21). Fungi attack cotton primarily as a result of disease and damages caused by insects. If the cotton is wetted by rain during its ripening period after the boll is opened, it also can be stricken by microorganisms (bacteria, fungi and mildew). Fibers attacked by microorganisms prior to ginning may be damaged only in their epidermis, which results in loss of luster and uneven dye penetration. Penetration of the wall and deterioration of tensile strength result in more serious cases. After ginning, microorganisms develop principally in the lumen that contains protein from the remaining protoplasm.

Mandels and Reese (20) stated that approximately half of all the fungi that they had tested were able to destroy cellulosic fabrics. The attack usually involved penetration of the fiber wall, growth of the hyphae within the lumen and digestion from within. Under favorable conditions of high humidity and warm temperature, the attack is rapid and the fabric looses its strength (20). Szathmary (31) reported that dermatophytes set colonies on dead vegetable materials. However, the attitude of fungi towards living and technically processed vegetable (cotton) material is not yet known.

As fungi grow on cotton, they secrete chemical substances called enzymes, which attack the cellulose by microbiological hydrolysis and convert it to soluble sugars that serve as food for the organisms (21). Although the mode of action is not known, the enzymes appear to attack amorphous cellulose more readily than crystalline. The action of these enzymes results in several structural changes. Mandels and Reese (20) reported that transverse cracks, breaks, pits, corrosion and complete or partial dissolution of the wall material resulted from microbe attack. Other structural changes reported by Basu and Ghose (18) were segmentation, holes, notches and diagonal or longitudinal splitting.

Little is known about the mode of attack by fungi in cotton. Normally, it would appear that the spores germinated externally and that this is followed by penetration. However, it has been hypothesized that fungi work from the inside outward, apparently having first entered the lumen through the cell wall. It has also been advanced that fungi grow in the cotton lumen by entry through the open end and not by penetration of the wall (6).

Nylon. According to general opinion, plastic materials are resistant to fungus attack. Although plastic fibers are more resistant to destruction by fungi as compared to vegetable and animal materials, some signs of destructive activity have been observed. These are not penetrating defects, but superficial ones. There are a few exceptional cases of erosion. It has not been concluded if a blend or combination of vegetable or animal fibers with plastic fibers plays a role in the development of fungus growth (31).

Microscopic Evaluation of Fiber Damage

The microscope plays an important and ever increasing role in textile testing and research. In addition to identifying fibers, yarns and fabrics, Heyn (18) reported that various types of damage to fibers caused either mechanically, chemically or by microorganisms during processing, storage and use can be observed and determined. The microscope is essential for the study of microbial damage to textile fibers as it is often invisible to the naked eye. The optical microscope has an advantage in the immediate availability in all research laboratories. When using an optical microscope, a high power of magnification is recommended for detecting fiber damage.

Photomicrography is the photography of objects of microscopic size (18). Photomicrographs can be taken of microscopic views by attaching a camera to the vertical tube of the trinocular body of the microscope. Photomicrographs can be used to record fiber damage permanently and to verify existing damage.

Little information could be found about the statistics of microscopical measurements of fiber damage for either the optical or electron microscope studies. Mr. L. R. Graybeal, manager of the Analytical and Testing Research Department, American Enka Corporation, stated that the scarcity of statistical treatment of microscopical results is largely attributable to widespread emphasis on qualitative rather than quantitative work in the field. Dr. Mary Rollins, Head of Microscopy Investigations that is concerned with cotton physical properties, United States Department of Agriculture, Southern Utilization Research and Development Division, replied in a letter that there is not a good paper giving statistical analysis of fiber phenomena. However, Dr. Rollins recommended that a study dealing with statistics of microscopical measurements of fiber damage and statistics of establishing sampling requirements would be a real contribution to the field.

Physical Analysis of Microbial Damage

The effect of *Trichophyton mentagrophytes* on the wool, nylon and cotton sock fabric was analyzed by the Constant Rate of Extension Tester for the physical properties, strength and elongation. The Scott Model E CRE Tensile Tester equipped with the ball burst attachment is used principally on fabrics that exhibit a high degree of elongation to measure their bursting or breaking strength. Tensile strength is defined as the strength shown by a specimen subjected to tension. Elongation is the increase in length of a specimen during a tensile test expressed in units of length (3).

A REVIEW OF FABRIC TREATMENTS AND PROCEDURES PRIOR TO MICROSCOPIC AND PHYSICAL ANALYSIS

Fabric Preparation

A black, 50 percent wool, 30 percent nylon and 20 percent cotton knit sock fabric, meeting military specification MIL S-486 for the foot or sole, was employed for this study. The United States Air Force sock fabric was received in the form of a knitted seamless tube, seven to eight inches in circumference and approximately twenty-four to thirty-six inches long. The tubes were split and cut into approximately twelve by eight inch swatches. The swatches randomly chosen were coded to indicate the procedure they were to be subjected to, see TABLE I, page 20. One inch squares were randomly marked on the 180 swatches for determining fungus growth and survival. Following preparation, the swatches were laundered for one, seven or fourteen times. The swatches were then sterilized with ethylene oxide to remove microorganisms before being inoculated with *Trichophyton mentagrophytes*.

Laundry Survey and Procedures

A preliminary survey of managers of the major supermarkets in Manhattan, Kansas was taken to determine the type of detergent purchased most often by local consumers and the type, if any, disinfectant purchased. From this preliminary survey, it was found that a high sudsing synthetic detergent containing phosphates, whitening agents and enzymatic reagents was purchased by the largest number of consumers. This finding agreed with the finding of a previous survey taken in the fall of 1969 (28). Although each supermarket carried several disinfectant products, a sodium hypochlorite disinfectant was reported to be

THIS BOOK CONTAINS NUMEROUS PAGES WITH DIAGRAMS THAT ARE CROOKED COMPARED TO THE REST OF THE INFORMATION ON THE PAGE.

THIS IS AS RECEIVED FROM CUSTOMER.

TABLE I

CODING CHART FOR FABRIC SWATCHES

Number of Laundries	
1	Red Coded Fabric (1" square)
7	Blue Coded Fabric (1" square)
14	Yellow Coded Fabric (1" square)
Detergent Concentration	
0.0%	Green Stitching (half circles)
0.2%	Orange Stitching (half circles)
Procedure	
P_1 (unsoiled-inoculated)	Red Stitching (1" from edge)
P_2 (soiled-inoculated)	Blue Stitching (1" from edge)
Run	
1	Green Stitching (rectangles)
2	Orange Stitching (rectangles)
3	White Stitching (rectangles)

purchased by the largest number of consumers and the only disinfectant purchased by many consumers. One supermarket manager indicated that aerosol Lysol disinfectants are becoming popular for household sanitation. No disinfectant, however, was used in this study during laundering as damage could be caused by a sodium hypochlorite disinfectant which would interfere with determining damage caused by the microorganism, Trichophyton mentagrophytes.

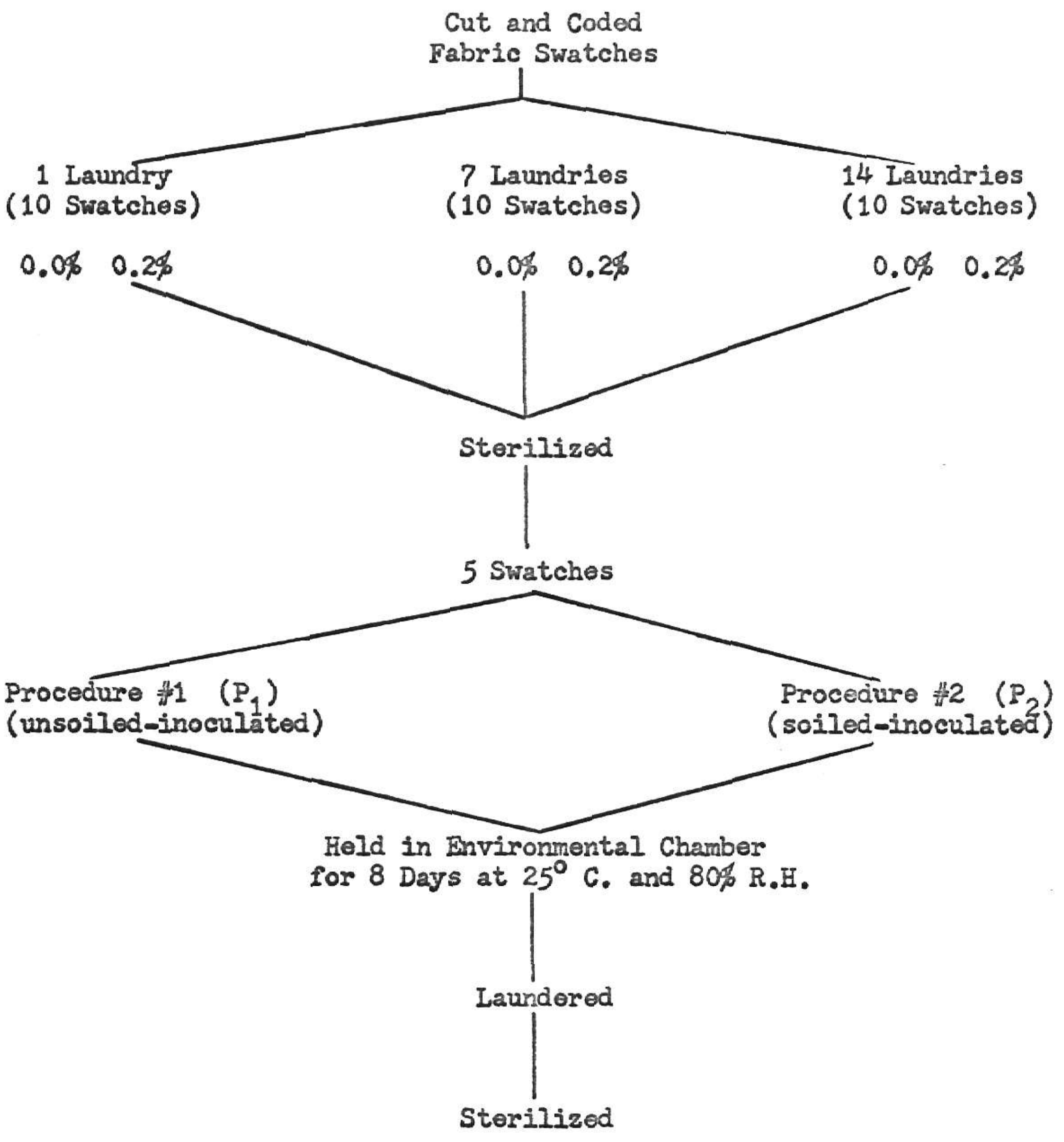
Laundering procedures were planned to simulate home washing and drying. A standard household automatic washer equipped with a mini basket was used and set on a normal wash and wear cycle. The washing loads were kept constant at two pounds. Water temperatures used were 140° F., first repetition of the test sequence; 120° F., second repetition; and 100° F., third repetition. The water temperature was regulated by the use of a small water heater which heated only the water for the laundry equipment, enabling it to be kept constant.

The electric dryer was regulated by an automatic electronic sensor and was set on a delicate setting which equals 126° F. $\pm 5^\circ$. The cycle lasts approximately thirty minutes. This setting is recommended for wool and synthetic fibers.

Following establishment of the laundry procedures, the prepared swatches were divided and used for the procedures in TABLE II, page 22. A group composed of five swatches per procedure was laundered and drawn after one, seven and fourteen launderings. The different number of laundries were done to determine if the mechanical agitation has any effect on the damage seen microscopically and in the physical analysis of the wool, nylon and cotton sock fabric. After laundering

TABLE II

FLOW CHART OF TEST PROCEDURES



these swatches were sterilized in a gas chamber with ethylene oxide to prevent contamination from outside sources before treatment and inoculation with Trichophyton mentagrophytes.

Treatment and Inoculation Procedures

One hundred and eighty swatches were utilized for treatment and inoculation. Ninety swatches were premoistened in a synthetic soil solution before inoculation to simulate the soiling of a fabric during a normal wearing period. The synthetic soil solution consisted of 15 grams of all purpose flour, 15 grams of cornstarch, 15 grams of cane sugar, 15 grams of powdered carbon, 15 milliliters of vegetable oil, 15 milliliters of mineral oil, 100 milliliters of milk and 250 milliliters of water (27). The ingredients for the synthetic soil solution were mixed in a Waring blender for two minutes to form a relatively stable emulsion. The remaining ninety swatches were premoistened in distilled water that contained a yeast extract. The yeast extract is a source of B vitamins and other growth promoting substances.

Following premoistening with either the synthetic soil solution or distilled water, the laundered and sterilized swatches were seeded with Trichophyton mentagrophytes. The human strain, described as the white, downy type, was utilized for this project and was isolated from a guinea pig under the auspices of the Infectious Diseases Department. The inoculation was accomplished by emersing the swatches in a microbial liquid solution. To enhance microbial growth, the swatches were covered with defated horse (Equus caballus) hair. Aseptic techniques were used when the swatches were placed in the Model E_4 Isco Environmental chamber at room temperature (25° C.) and

80 percent relative humidity for eight days. The humidity was kept constant by a pool of sterilized distilled water in the bottom of the chamber. The swatches were moistened with water throughout the holding period. The chamber had been fumigated with paraformaldehyde gas.

Following completion of the holding period, the inoculated swatches were laundered and sterilized. All inoculation and microbial work was completed by the personnel in the Department of Infectious Diseases, Kansas State University, Manhattan, Kansas. Laundry work was done by personnel in the Department of Clothing, Textiles and Interior Design, Kansas State University.

DEVELOPMENT OF PROCEDURES FOR AND STATISTICAL ANALYSIS OF A MICROSCOPIC STUDY OF FIBER DAMAGE

Procedures

Measurement of Fiber Length

Pilot work was done in order to find a method of measuring the exact length of a fiber with a microscope. This experimental work was attempted to see if fiber damage could be predicted as a number of flaws per specified length of fiber within a statistical sample.

Evaluation of Distribution of Fiber Damage

Experimental testing was done in order to gain information on the reliability of fiber damage results and to set limitation on the sample size. The testing was done to find out if there was variation in results from one swatch to another swatch, from one area to another area within a swatch and from one fiber to another fiber within an area in a swatch. An experimental design was set up by an statistician.

Three swatches were chosen from the first group of soiled-inoculated and unsoiled-inoculated swatches that showed visible growth of Trichophyton mentagrophytes. Each swatch was chosen to include a different area for microbial evaluation. Within each swatch, an area three by four inches was marked off and divided into twenty pieces in order to determine if the microbial damage to the fibers was different and if it varied throughout a given swatch, see Figure 1, page 26. From each piece, a small section of each yarn was withdrawn and separated into individual fibers. One fiber of each type was placed on a glass slide in the order, top to bottom, wool, cotton and nylon. The

Scale 1/2"=1"

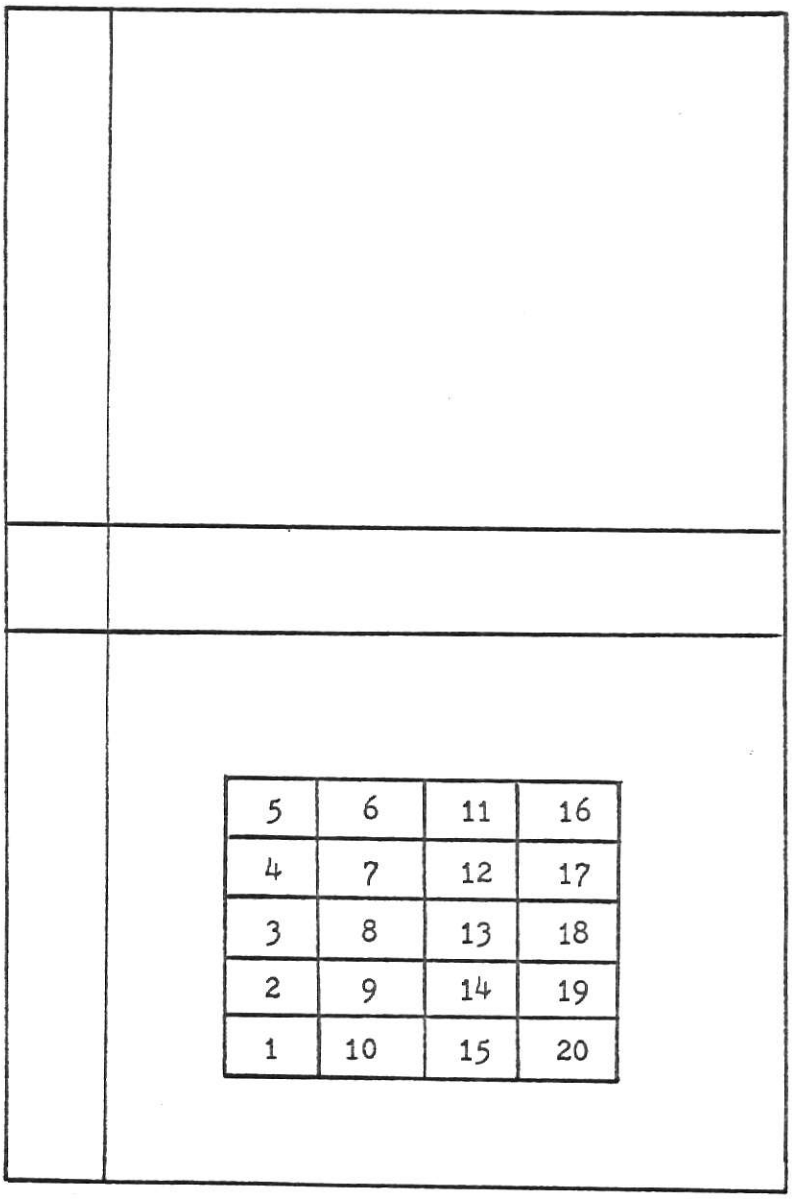


FIGURE I

DIVISION OF SWATCH FOR
MICROSCOPIC EVALUATION

fibers were approximately one-half inch to one inch long. These fibers were mounted on the slide with Permount, a permanent mounting media, and covered with a glass cover slip. Each slide was labeled as to treatment, number of laundries before inoculation, detergent concentration, run and slide set.

Three sets of twenty slides were prepared for microscopic evaluation of microbial damage. Two sets of the slides were made with fibers that had been subjected to soiling and inoculation. The third set of slides included fibers that had not been soiled, but had been inoculated. Three fields of view per fiber were chosen at random within each slide for observation. Each field of view was defined by an eyepiece equipped with a reticle which has framing marks.

The microscopic analysis was done with an American Optical Company Series Four Microstar Trinocular Microscope. The longitudinal sections were studied using a 43 power objective, 10 power eyepieces and substage illumination. A blue filter was used with the wool and nylon fibers but not with the cotton fibers.

The fiber damage classifications used to evaluate each fiber was different. The wool fibers were examined for cracks, loose and rough scales, absent scales, pits, swelling and corrosion. The cotton fibers were examined for fiber damage in the form of cracks, pits, internal corrosion and dissolution of the lumen. The nylon fibers were examined for cracks, pits and swelling. The presence of soil on the fibers also was noted. At the completion of examining each fiber group per slide set, the data of the type and quantity of damage was compiled for analysis by a statistician.

A photomicrograph was taken of one field of view per fiber from each slide. The field of view used for the photomicrograph was chosen at random and was designated by the framing marks on the special eyepiece. The photomicrographs were taken with a 35mm camera attached to the vertical tube of the trinocular body of the microscope. The magnification of the photomicrographs was 645 times when using the 43 power objective. The shutter speed of the camera was one tenth of a second and the setting of the light used was 7.5. The condenser was moved to vary the light intensity for the three types of fibers since darker wool and nylon fibers required more light than the cotton fibers. The variation in color value was caused by the fibers' dye absorption. The lower prism on the microscope was removed. The blue filter was used when photographing the wool and nylon fibers, but it was not used when photographing the cotton fibers. Kodak Plus X Pan, black and white, panchromatic film was used.

Analysis of Fiber Damage by Statistical Methods

The purpose of the preliminary experimental testing of the distribution of fiber damage caused by *Trichophyton mentagrophytes* was to gain information on the validity of fiber damage data and to establish criteria for sampling the entire population of inoculated wool, nylon and cotton knit sock fabric. The testing was done to determine if the variation in results occurred from swatch to swatch, from different portions within a swatch, or from different areas within individual fibers. In addition, the pieces within a swatch were divided into two sections for observation to determine if the fiber damage varied if samples were taken near the edge or from the center of the three by four inch area marked off in each swatch.

Statistical test of the mean of the three repetitions of the inoculation and laundry sequence of the swatches and pieces per swatch; a F test for variance of the variables of swatch and pieces per swatch; an unequal subclass analysis of variance of outside versus inside pieces within a swatch; and estimates of variation of compotents, swatches, pieces per swatch and views per piece, were calculated for the wool, nylon and cotton fibers according to each damage classification.

Effect of Swatch and Pieces per Swatch

Wool Fibers. The effect between swatches proved to be statistically significant by a F test of significant variance at the 95 percent level for the number of cracks, loose and rough scales and absent scales (TABLES III, V, VI, pp. 73,74). The effect of pieces per swatch was significant for two types of damage, cracks and pits. No statistically significant effects were found for swelling or corrosion (TABLES VII, VIII, pp. 74,75).

Cotton Fibers. The effect between swatches was found to be significant by a F test of variance in number of pits and corrosion but not in the number of cracks or dissolution of the lumen. For the number of cracks and pits, the pieces per swatch proved to be statistically significant at the 95 percent level. No significance was noted in the damage classification, swelling, for swatches of pieces per swatch (TABLES IX, X, XI, XIII, pp. 75-77).

Nylon Fibers. There were no significant differences at the 95 level for the effect of swatch or pieces per swatch for the number of cracks or swelling. The effect of swatch and pieces per swatch was found to be statistically significant by a F test of variance at the 95 percent level for the number of pits (TABLES XIII, XIV, XV, pp. 77, 78).

Effect of Treatment

The effect of treatment indicating whether the fiber damage varied from the edge to the center of a swatch was evaluated by an unequal subclass analysis of variance test according to each type of fiber damage for the wool, nylon and cotton fibers. The outside and inside pieces were designated as treatment one and treatment two. Tables XVI-XXVIII, pages 79-94, show that the inside pieces versus the outside pieces are not significantly different at the 95 percent level by a F test of variance. Thus, this factor was eliminated as a variable in the evaluation of fiber damage in the entire population of soiled and unsoiled swatches inoculated with *Trichophyton mentagrophytes*.

Effect of Variation

Estimates of variation for the compotents, swatches, pieces per swatch and views per piece, were calculated for each type of damage in the wool, nylon and cotton fibers. Analysis of the data revealed that the variation in fiber damage results increased as the area decreased. In the majority of fiber damage classification for each fiber, the greatest variation occurred in the microscopic views of the damage. The next source of variation was the pieces, or the areas in which the swatches were divided, with the variation from swatch to swatch contributing the least to the variation in fiber damage (TABLES XXIX, XXX, XXXI, pp. 86,87). Thus, on the basis of the above information, a ratio of 2 swatches: 4 pieces: 5 views was decided on for sampling the entire population of soiled and unsoiled swatches inoculated with <u>Trichophyton mentagrophytes</u>.

PROCEDURES FOR ANALYSIS OF MICROBIAL DAMAGE

Microscopic Analysis of Fiber Damage

Criteria for sampling the entire population of 180 inoculated swatches was determined from the findings of the experimental testing of the distribution of fiber damage using three swatches that showed visible growth. Since the pilot microscopic study revealed the source of variation increased as the size of the area decreased, swatches to views, an experimental design was set up on the basis of a ratio of 2 swatches: 4 pieces: 5 views. Statistically reliable data could have been collected using one swatch out of a group of five swatches, but it was felt that future researchers might question the validity of data based on such a small sampling. Therefore, two swatches with known microbe growth were chosen to be used for microscopic evaluation, leaving adequate space for a four by four inch specimen to be withdrawn for physical analysis. Twenty-four swatches were used for each repetition of the test sequence.

Within each swatch an area two by three inches was marked off and divided into four equal pieces in order to evaluate microbial damage from different areas of the swatch. Two pieces were included for evaluation from each swatch. From each piece within a swatch, small sections of wool, nylon and cotton yarns were withdrawn and separated into individual fibers. These fibers were approximately one inch long and were mounted on a glass slide with Permount. The fibers were covered with a glass cover slip. Each slide was labeled as to treatment, number of laundries before inoculation, detergent concentration and run.

Three sets of forty-eight slides were prepared for microscopic evaluation of microbial damage caused by Trichophyton mentagrophytes. Each set of slides included swatches from all twelve combinations of test procedures so that the interaction of the variables, soiling versus no soiling, one, seven or fourteen laundries before inoculation and 0.0 percent or 0.2 percent detergent concentration, could be analysed.

The microscopic analysis was done with the aid of an American Optical Company Series Four Microstar Trinocular Microscope. The longitudinal sections were studied using 43 power objective, 10 power eyepieces and substage illumination. One 10 power eyepiece contained a reticle which had framing marks to indicate the exact area to be observed for each field of view. A 35mm camera was attached to the microscope to take photomicrographs of representative types of fiber damage observed in each fiber. The fiber damage classification used to evaluate each fiber were the same as those used in the pilot microscopic study, page 27. The presence of soil was also noted.

Physical Analysis of Fabric Damage

Physical analysis of the inoculated soiled and unsoiled wool, nylon and cotton knit sock fabric, after a series of laundries, was done with the use of the Constant Rate of Extension Tester. The Scott Model E CRE Tensile Tester equipped with the ball burst attachment is used primarily on fabric that exhibit a high degree of elongation to measure their bursting or breaking strength. From preliminary experimentation, it was found that the CRE Tester produced consistent results on the knit sock fabric. However, results from experimental work using other textile testing instruments were inconsistant due to the high degree of stretch of the fabric and the irregularity of tension of the knitted fabric.

Total work force or load cell for operation of the CRE Tester was set for five hundred kilograms. After preliminary investigation, it was determined that only twenty percent of the capacity of the load cell was needed to burst a specimen. The range selector was set at .2, accordingly to produce a full deflection of the recorder. Speed of the crosshead was maintained at 12 inches per minute. The chart speed was set at 12 inches per minute.

Following Federal Specification Test Method 5120 (1966) (15), five specimens, four by four inches, were required. The specimens were withdrawn so that no specimens contained the same wales or courses. The specimens were taken within 1/10th of the width of the cloth sample on all sides. All specimens used for physical analysis were held at least twenty-four hours in the conditioning room at 70° F. $\pm$ 2° and 65% relative humidity $\pm$ 2% to obtain a moisture equilbrium.

Statistical Analysis of Fiber and Fabric Damage

Analysis of variance tests were performed to determine the effect of treatment (soiled or unsoiled), detergent concentration, number of laundries before inoculation and the interaction of these variables with three repetitions of the experimental sequence for their influence on the degradative action of *Trichophyton mentagrophytes* and for their effect on the damage in the fibers seen microscopically and in the bursting strength and elongation of the wool, nylon and cotton sock fabric.

The variables of swatches, pieces and views were also statistically analysed by a F test of variance to determine their influence on the variation found in fiber damage. The analysis of variance tests were done for the wool, nylon and cotton fibers according to each fiber damage classification and for bursting strength and elongation of the sock fabric. In addition, the effect of fiber and the interaction of this variable with treatments, detergent concentrations and the number of laundries before inoculation with three repetitions of the test sequence were analysed by a F test of variance for the two types of damage, cracks and pits, that occur in all three fibers. No type of statistical analysis could determine the type of damage that occurred in the greatest amount for each fiber since levels of damage are progressive.

RESULTS AND DISCUSSION

Microscopic Analysis of Fiber Damage

The amount of fiber damage caused by *Trichophyton mentagrophytes* in a military knit sock fabric composed of 50 percent wool, 30 percent nylon and 20 percent cotton was studied with an optical microscope. Types of damage seen in the fibers were recorded with black and white photomicrographs made with a 35mm camera attached to the vertical tube of the trinocular body of the microscope. The magnification of the photomicrographs was 645X.

Wool Fibers. The types of damage observed in the wool fibers were cracks, pits, loose and rough scales, absent scales, swelling and corrosion (Plate I).

The presence of soil on the wool fibers increased the difficulty of observing damage by covering up damage, particularly loose and rough scales and absent scales, and also, of giving the appearance of damage as cracks and pits. The wool fibers did not hold soil as readily as the cotton and nylon fibers. All wool fibers showed some evidence of soil due to the fact that the inoculated soiled and inoculated unsoiled sock swatches were laundered together at the end of the holding period in the environmental chamber (Plate I). This confirms the findings of Schmipf (28) that there was redeposition of soil in the washer. In addition, damage was difficult to evaluate when the fibers were darkly dyed. Some wool fibers exhibited a two toned color effect caused by the natural crimp of the wool fiber.

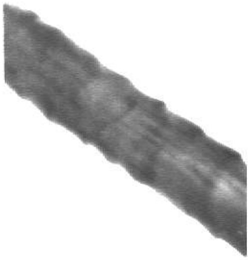


FIGURE 1

UNDAMAGED

FIGURE 2

SOILED

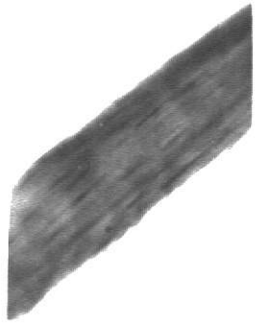


FIGURE 3

CRACKS

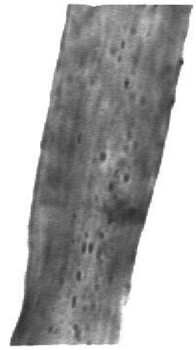


FIGURE 4

PITS

FIGURE 5

LOOSE AND
ROUGH SCALES

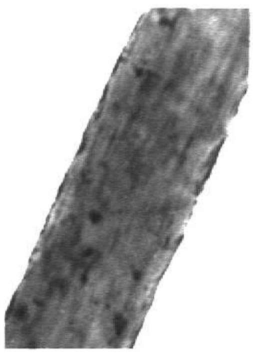


FIGURE 6

ABSENT
SCALES

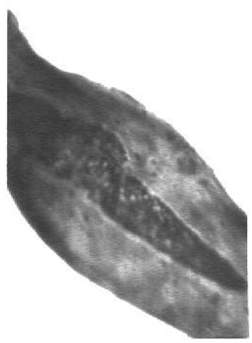


FIGURE 7

SWELLING AND
CORROSION

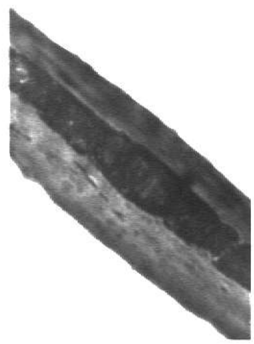


FIGURE 8

CORROSION

PLATE I

UNDAMAGED AND DAMAGED
WOOL FIBERS

The repetition of the experimental sequence was found to be statistically significant by a F test of variance at the 95 percent level for the number of cracks, loose and rough scales and swelling observed (TABLES XXXII, XXXIV, XXXVI, pp. 88,90, 92). There was no significant differences in the number of pits, absent scales and corrosion (TABLES XXXIII, XXXV, XXXVII, pp. 89, 91, 93). A least significant difference test at the 95 percent level resulted in significant differences between runs for the number of cracks, loose and rough scales and swelling observed (TABLES XLV, XLVI, XLVII, p.101). The first repetition (run) of the test sequence was found to be significantly different from the second and third repetitions in the number of cracks present in the wool fibers withdrawn from the sock fabric swatches utilized for each run. The number of loose and rough scales was significantly different in run one and two but not in run one and three and run two and three. All three runs were statistically different for the number of absent scales in the wool fibers.

A significant difference between repetitions may be the result of the temperature of the wash water. All swatches for each run were subjected to the same procedures except for the different water temperatures utilized in each run. All swatches used in the first repetition of the test sequence were laundered in 140° F. wash water. The second repetition employed 120° F. wash water, with the third repetition using 100° F. wash water.

The highest number of cracks, pits, loose and rough scales and corrosion occurred in the second repetition of the test sequence. The lowest number of cracks and loose and rough scales occurred in run one and the lowest number of pits was found in run three. The least number of absent scales was found in run one, with the most found in run two. Run two and three were equal in the highest occurrence of swelling in wool fibers (TABLE LXI, p. 107).

The twelve combinations of procedures were found to be significant by a F test at the 95 percent level for corrosion in wool fibers (TABLE XXXVII, p. 93). There was no significant differences for the combination effect of all procedures for the number of cracks, pits, loose and rough scales, absent scales and swelling (TABLES XXXII-XXXVI, pp. 88-92).

The effect of treatment (soiled or unsoiled) proved not to be statistically significant at the 95 percent level for the number of cracks, pits, loose and rough scales, absent scales and swelling viewed (TABLES XXXII, XXXIII, XXXIV, XXXV, XXXVI, pp. 88-92). A statistically significant difference at the 95 percent level was shown by a F test of variance for the amount of corrosion (TABLE XXXVII, p. 93). A least significant differences test showed significant differences between the amount of corrosion in the wool fibers withdrawn from the sock fabric that had been soiled and in the wool fibers withdrawn from the sock fabric that had not been soiled (TABLE XLIX, p.102).

The highest number of cracks occurred in the sock fabric that had not been soiled but inoculated. For pits, the highest number was shown in the wool fibers withdrawn from the sock fabric that had been soiled and inoculated. The unsoiled-inoculated knit fabric showed the highest number of loose and rough scales in wool fibers; while, the soiled-inoculated fabric exhibited the highest number of absent scales in wool fibers. The types of damage, swelling and corrosion, occurred in the largest numbers in the wool fibers taken from the soiled-inoculated sock fabric (TABLE LXI, p. 107).

There were no significant differences between 0.0 percent and 0.2 percent detergent concentrations by a F test of variance at the 95 percent level for all damage classifications in the wool fibers (TABLES XXXII-XXXVII, pp. 88-93). Schimpf (28) found in her study with Staphylococcus aureus a significant difference between 0.0 percent and 0.1, 0.2 and 0.4 percent detergent concentrations. No significant difference was found between 0.1, 0.2 and 0.4 percent detergent concentrations utilized for laundering Staphylococcus aureus inoculated knit sock fabric. The highest number of cracks, pits, absent scales and swelling was found in the wool fibers taken from the sock laundered in 0.0 percent detergent concentration. The sock fabric that was laundered in 0.2 percent detergent concentration showed the highest number of loose and rough scales and corrosion in wool fibers (TABLE LXI, p. 107).

The number of laundries before inoculation of the military knit sock fabric was found not to be statistically significant for the number of cracks, pits, loose and rough scales, swelling and corrosion (TABLES XXXII-XXXIV, XXXVI, XXXVII, pp. 88-90, 92, 93). A statistically significant difference at the 95 percent level by a F test of variance was shown for the number of absent scales observed in the wool fibers (TABLE XXXV, p. 91). A least significant differences test revealed significant differences between the wool fibers taken from fabric laundered one time, seven times and fourteen times before inoculation in the number of absent scales (TABLES XLVIII, p. 102). The highest number of absent scales occurred in the wool fibers taken from the knit fabric laundered fourteen times before inoculation and the lowest number from wool fibers taken from fabric laundered one time (TABLE LXI, p. 107).

The highest number of cracks occurred in wool fibers taken from the knit sock fabric laundered fourteen times before inoculation and the lowest number resulted in the fibers taken from the sock fabric that had been laundered one time. Pits were found in the largest number in wool fibers taken from sock fabric that had been laundered one time and the lowest from fibers taken from fabric that had been laundered fourteen times. After fourteen laundries, the wool fibers taken from the soiled and unsoiled inoculated sock fabric showed the highest number of loose and rough scales and corrosion and the lowest number of each type of damage after seven laundries. The occurrence of swelling was highest in wool fibers taken from fabric subjected to fourteen laundries before inoculation and was lowest in the wool fibers taken from fabric subjected to one laundry (TABLE LXI, p. 107).

The interaction between treatment and detergent concentration, interaction of treatment with number of laundries before inoculation, interaction of detergent concentration with number of laundries before inoculation and the interaction of all three variables was not statistically significant by a F test of variance at the 95 percent level for the number of cracks, pits, loose and rough scales, absent scales, swelling and corrosion (TABLES XXXII-XXXVII, pp. 88-93).

An analysis of variance test resulted in significant differences for the effect between swatches for the number of pits and absent scales

(TABLES XXXIII, XXV, pp. 90,83). The effect between swatches was not significant for the number of cracks, loose and rough scales, swelling and corrosion (TABLES XXXII, XXXIV, XXXVI, XXXVII, pp. 88, 90,92,93). The effect between pieces was shown to be statistically significant by a F test of variance at the 95 percent level for the number of cracks, pits and loose and rough scales (TABLES XXXII-XXXIV, pp. 88-90). No significant differences were noted for the number of absent scales, swelling and corrosion in wool fibers (TABLES XXXV-XXXVII, pp. 91-93).

Cotton Fibers. The cotton fibers were viewed for four types of damage. They were cracks, pits, corrosion and dissolution of the lumen (Plate II). The presence of soil was noted on all fibers whether they came from swatches that had been soiled or from those that had not been soiled before inoculation with Trichophyton mentagrophytes (Plate II). The occurrence of soil on all fibers resulted from the soiled and unsoiled inoculated swatches being laundered together when they were taken from the environmental chamber at the end of the eight day holding period for their final laundry. The presence of soil, the natural twist of the fibers, and in some cases, the dark dyeing of fibers made observation and evaluation of fiber damage difficult.

The repetition of the test sequence resulted in significant differences by a F test of variance at the 95 percent level for the number of cracks, pits and corrosion viewed (TABLES XXXVIII, XXXIX, XL, pp. 94,96). There was no statistically significant difference for the amount of dissolution of the lumen by a F test of variance (TABLE XLI, p. 97). A least significant differences test at the 95 percent level resulted in significant differences in the three repetitions of the

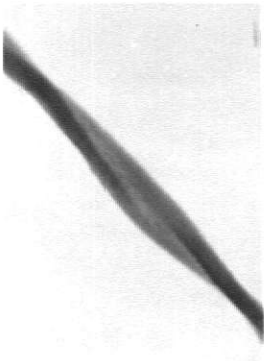


FIGURE 1

UNDAMAGED

FIGURE 2

SOILED

FIGURE 3

CRACKS

FIGURE 4

PITS

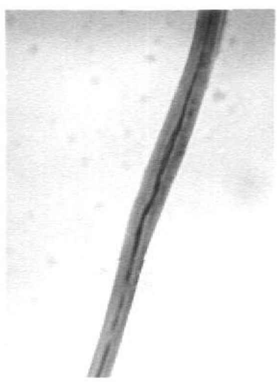


FIGURE 5

INTERNAL
CORROSION

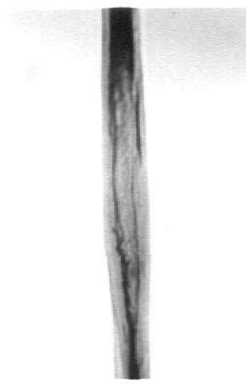


FIGURE 6

DISSOLUTION
OF LUMEN

PLATE II

UNDAMAGED AND DAMAGED
COTTON FIBERS

test sequence for the number of cracks, pits and corrosion in cotton fibers (TABLES L, LI, LIII, pp. 102-103). Run one, run two and run three were all significantly different for the number of cracks (TABLE L, p. 102). Run one was significantly different from run three for the number of pits in cotton fibers (TABLE LI, p. 103). Run three was significantly different from run one and two for the amount of corrosion in cotton fibers (TABLE LIII, p. 103).

In run two, the highest number of cracks occurred, with the lowest number of cracks occurring in run one. For pits, the highest number appeared in run one and the lowest number was found in cotton fibers taken from sock swatches utilized in run three. The occurrence of corrosion was highest in run one and the lowest in run three. For dissolution of the lumen, the highest number was found in run three and the least was found in cotton fibers taken from sock fabric utilized in run one (TABLE LXII, p. 108).

The effect from all procedure combinations was found to be statistically significant by a F test in the fiber damage, corrosion and dissolution of the lumen, in cotton fibers (TABLES XL, XLI, pp. 96, 97). There was no significant differences for the number of cracks and pits at the 95 percent level in cotton fibers for the effect of all twelve combinations of procedures (TABLES XXXVIII, XXXIX, pp. 94, 95).

The effect of treatment (soil or no soil) was found to be significant in the fiber damage of the cotton fibers. Pits and corrosion were the types of damage resulting in statistically significant differences at the 95 percent level (TABLES XXXIX, XL, pp. 95, 96).

No significant differences were noted for the number of cracks and dissolution of the lumen by a F test of variance (TABLES XXXVIII, XLI, pp. 94,97). Statistically significant differences using the least significant differences test occurred between treatment one (soiled) and treatment two (unsoiled) for the number of pits and corrosion in cotton fibers (TABLES LII, LVI, pp. 103,104).

The number of pits, corrosion and dissolution of the lumen appeared the highest in cotton fiber taken from the soiled-inoculated knit sock fabric. The highest number of cracks occurred in the cotton fibers taken from the unsoiled-inoculated sock fabric (TABLE LXII, p. 108).

The detergent concentration was found not to be statistically significant in the four observed types of damage in cotton fibers withdrawn from the soiled and unsoiled inoculated sock fabric (TABLES XXXVIII-XLI, pp. 94-97). All types of damage observed in cotton fibers taken from the sock fabric laundered in 0.2 percent detergent concentration exhibited the highest number for each particular type of damage (TABLE LXI, p. 107).

The number of laundries before inoculation was statistically significant at the 95 percent level in the amount of corrosion and dissolution of the lumen in cotton fibers (TABLES XL, XLI, pp. 96, 97). A least significant difference test found significant differences between one, seven and fourteen laundries before inoculation in the occurrence of corrosion and dissolution of the lumen (TABLES LV, LVI, p. 104). There were no statistically significant differences noted for the number of cracks and pits from the effect of one, seven and fourteen laundries performed before treatment or inoculation (TABLES XXXVIII, XXXIX, pp. 94,95). Cracks, corrosion and dissolution of the lumen appeared in the highest numbers in the knit sock fabric after laundry fourteen. The highest number of pits occurred in the cotton fibers taken from the sock fabric that had been laundered one time before inoculation (TABLE LXII, p. 108).

The interaction of treatment with detergent concentration, interaction of treatment with number of laundries before inoculation, interaction of detergent concentration with number of laundries before inoculation, and the interaction of all three variables was not found statistically significant by a F test of variance for the number of cracks, pits, corrosion, and dissolution of the lumen in cotton fibers (TABLES XXXVIII-XLI, pp. 94-97).

The effect between swatches was found to be statistically significant for only one damage classification, corrosion, in cotton fibers (TABLE XL, p. 96). No significance was shown for cracks, pits or dissolution of the lumen for the effect between swatches (TABLES XXXVIII, XXXIX, XLI, pp. 94,95,97). The four types of damage observed in cotton fibers showed no statistically significant differences using an analysis of variance test for the effect of pieces within swatches (TABLES XXXVIII-XLI, pp. 94-97).

Nylon Fibers. The types of damage observed in the soiled and unsoiled inoculated nylon fibers were cracks, pits and swelling (Plate III). Nylon fibers were hard to evaluate with the microscope because the delustrant used in the nylon to reduce the shine is similar in appearance to pits. The darkness of the dyed fibers was another cause of difficulty in viewing the fibers.

FIGURE 1

UNDAMAGED

FIGURE 2

SOILED

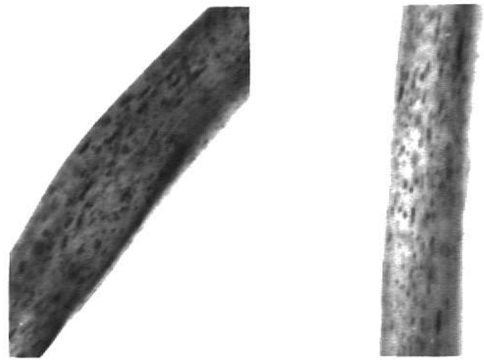


FIGURE 3

CRACKS

FIGURE 4

PITS

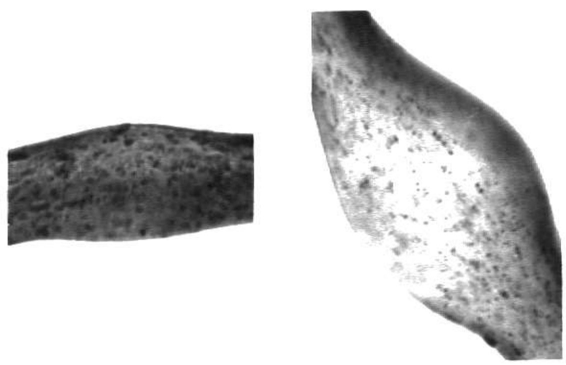


FIGURE 5

PROGRESSION OF SWELLING

PLATE III

UNDAMAGED AND DAMAGED NYLON FIBERS

Soil clung to the nylon fibers in the majority of microscopic views, even in the fibers that were subjected to the unsoiled treatment (Plate III). All of the soiled and unsoiled swatches of sock fabric were laundered together at the end of each holding period; therefore, the unsoiled fibers were soiled through redeposition of soil during the final laundry.

The repetition of the experimental sequence was found to be statistically significant at the 95 percent level by a F test of variance for the number of cracks and swelling (TABLES XLII, XLIV, pp. 98, 100). An analysis of variance test revealed no significant difference between runs for the number of pits in nylon fibers (TABLE XLIII, p. 99). A least significant differences test at the 95 percent level resulted in significant differences between run one and runs two and three for the number of cracks in nylon fibers (TABLE LVII, p. 105). Statistically significant differences using a least significant differences test occurred between run one, two and three for the amount of swelling (TABLE LX, p. 106). The highest number of cracks appeared in the nylon fibers taken from sock fabric utilized in run three with the lowest number occuring in fibers from run one. For pits, the highest number was exhibited in nylon fibers from run two and the lowest from fibers in run one. Swelling was noted in the highest number in run three and the lowest in run one (TABLE LXIII, p. 109).

The twelve combinations of procedures proved not to be statistically significant by a F test of variance at the 95 percent level for the number of cracks, pits and swelling in nylon fibers withdrawn from soiled and unsoiled inoculated knit sock fabric (TABLES XLII-XLIV, pp. 98-100).

The treatment of soiling and the treatment of not soiling of the wool, nylon and cotton swatches before inoculation with Trichophyton mentagrophytes was found not to be significant by a F test of variance at the 95 percent level (TABLES XLII-XLIV, pp.98-100). No evidence in the fiber damage classifications for the nylon fibers indicated a significant difference in the level of damage seen in fibers that had been soiled before inoculation versus those fibers withdrawn from unsoiled and inoculated sock fabric. For all three types of damage, the nylon fibers withdrawn from the unsoiled-inoculated fabric possessed the highest number for each type (TABLE LXIII, p. 109).

The detergent concentration was not significant at the 95 percent level by a F test for the number of cracks, pits and swelling observed (TABLES XLII-XLIV, pp.98-100). No influence was found with the use of no detergent (0.0%) versus a 0.2 percent concentration of synthetic detergent in the observable fiber damage in the nylon fibers. The highest number of pits and swelling resulted in the sock fabric that had been laundered in 0.0 percent detergent concentration. The sock fabric that had been laundered in 0.2 percent detergent concentration possessed the greatest number of cracks (TABLE LXIII, p. 109).

An analysis of variance test for the number of cracks and pits in nylon fibers showed a statistically significant differences at the 95 percent level for the number of laundries before inoculation (TABLES XLII, XLIII, pp. 98,99). A least significant difference test showed results were significantly different between one laundry and fourteen laundries performed before inoculation of the sock fabric for the number of cracks (TABLE LVIII, p. 105). No significant differences were noted between seven and fourteen laundries before inoculation for the number of cracks in nylon fibers. Statistically significant differences using a least significant differences test occurred between seven and fourteen laundries, but no significant differences were shown between one laundry and seven and fourteen laundries for the number of pits (TABLE LIX, p. 106).

After the fourteenth laundry, the nylon fibers from the unsoiled and soiled inoculated sock fabric exhibited the greatest amount of cracks, pits and swelling. The lowest number of cracks occurred in the fibers taken from the military sock fabric laundered one time before inoculation. Sock fabric that underwent seven laundries before inoculation exhibited the lowest number of pits in nylon fibers. Knit sock fabric laundered one and seven times showed the least amount of swelling found in nylon fibers in both cases (TABLE LXIII, p. 109).

Effect of Fiber. The effect of fiber proved to be statistically significant by a F test of variance at the 95 percent level in the number of cracks. The interaction of fiber with treatment, interaction of fiber with detergent concentration and the interaction of fiber with number of laundries before inoculation with *Trichophyton mentagrophytes* was not significant at the 95 percent level. The interaction of fiber with treatment and detergent concentration, interaction of fiber with treatment and number of laundries before inoculation, the interaction of fiber with detergent concentration and number of laundries before inoculation, and the interaction of fiber with treatment, detergent concentration and number of laundries before inoculation was not statistically significant by a F test of variance (TABLE LXIV, p. 110).

By an analysis of variance test, the fiber content of the knit sock fabric was found to be statistically significant by a F test at the 95 percent level in the number of pits. The interaction of fiber with soiled and unsoiled treatment proved to be significant. No significant differences were noted for the interaction between fiber and detergent concentration in the number of pits. A statistically significant difference using a F test of variance was found for the interaction between fiber and one, seven and fourteen laundries performed before inoculation with Trichophyton mentagrophytes.

The interaction of fiber with treatment and detergent concentration and the interaction of fiber with treatment and number of laundries before inoculation proved not to be statistically significant by a F test at the 95 percent level in the number of pits. The interaction of fiber with detergent concentration and number of laundries before inoculation was not significant. A statistically significant difference at the 95 percent level was noted for the interaction between fiber, treatment, detergent concentration and number of laundries before inoculation (TABLE LXV, p. 112).

Physical Analysis of Fabric Damage

The effect of Trichophyton mentagrophytes on the bursting strength and elongation of the 50 percent wool, 30 percent nylon and 20 percent cotton knit sock fabric was studied with a Constant Rate of Extension Tester.

Bursting Strength. The bursting strength for the soiled and unsoiled inoculated sock fabric ranged from 100 to 126 pounds. The highest bursting strength occurred in the first repetition of the test sequence in the unsoiled-inoculated sock fabric that had been laundered one time in 0.0 percent detergent concentration. The lowest bursting strength occurred in the second repetition in the soiled-inoculated sock fabric that had been laundered fourteen times in 0.0 percent detergent concentration.

The effect of treatment (soiled or unsoiled) proved to be statistically significant by a F test of variance at the 95 percent level in the bursting strength of the inoculated sock fabric (TABLE LXVI, p. 114). A least significant difference test at the 95 percent level resulted in significant differences between the soiled-inoculated and the unsoiled-inoculated knit sock fabrics (TABLE LXVIII, p. 116). The bursting strength of the unsoiled-inoculated sock fabric was lower than the bursting strength of the unsoiled-inoculated sock fabric (FIGURE 2).

There were no significant differences between 0.0 percent and 0.2 percent detergent concentration at the 95 percent level in the bursting strength of the sock fabric (TABLE LXVI, p. 114). Laundering fabrics in 0.0 percent detergent concentration resulted in a slightly higher bursting strength of 111.36 pounds over 110.17 pounds for sock fabric laundered in 0.2 percent detergent concentration (FIGURE 3). A small decrease in the bursting strength of the knit sock fabric that had been inoculated with <u>Trichophyton mentagrophytes</u> could be attributed to the use of detergent.

The number of laundries before inoculation of the knit fabric was found to be significant at the 95 percent level in the bursting strength (TABLE LXVI, p. 114). A least significant difference test revealed that there were no significant differences between sock

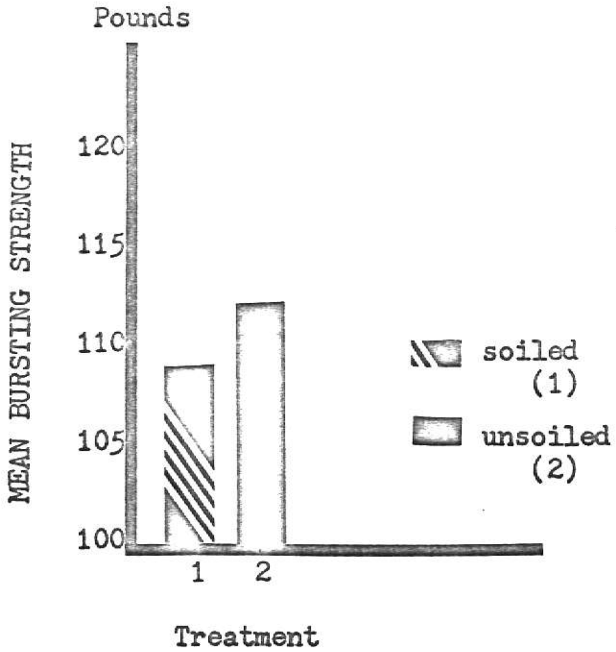


Figure 2. Mean bursting strength of inoculated fabric by soiled and unsoiled treatment. (Significant at the 95% level).

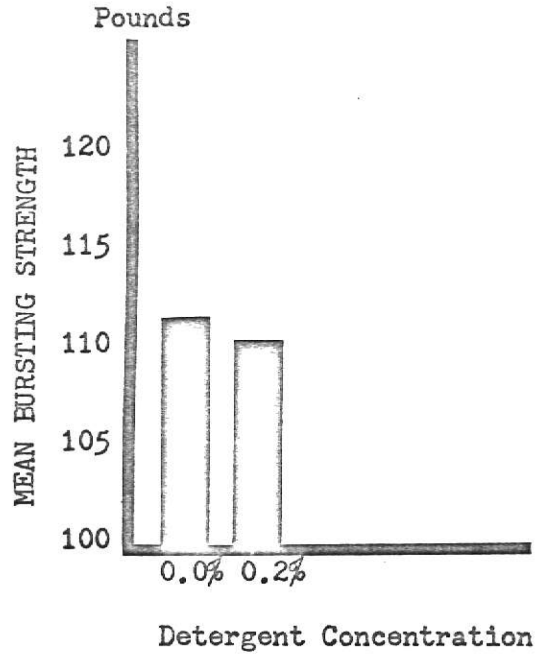


Figure 3. Mean bursting strength of inoculated fabrics laundered with two detergent concentrations.

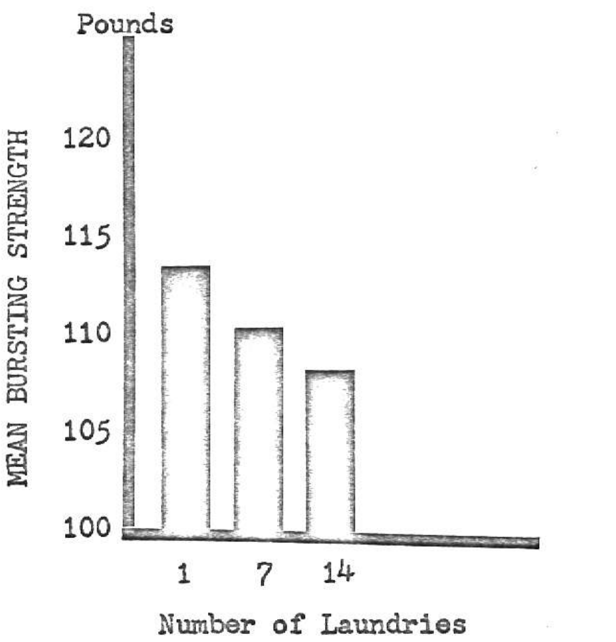


Figure 4. Mean bursting strength of soiled-inoculated and unsoiled-inoculated fabrics by number of laundries. (Significant at 95% level).

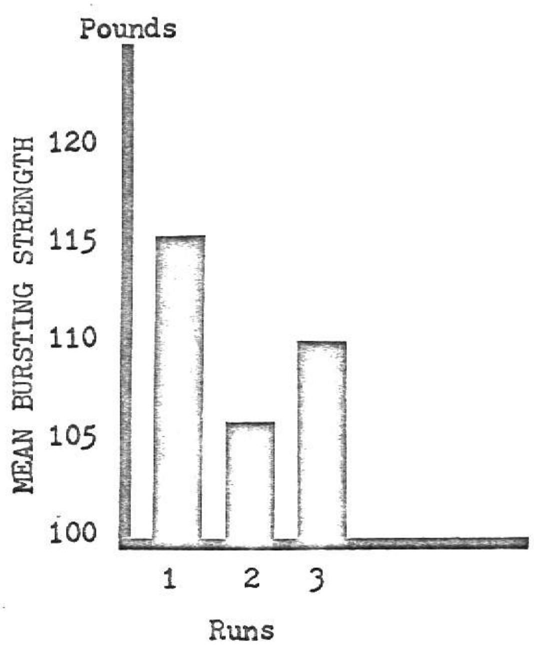


Figure 5. Mean bursting strength of soiled-inoculated and unsoiled-inoculated fabrics by each run. (Significant at 95% level).

fabric laundered seven times and sock fabric laundered fourteen times in the bursting strength (TABLE LXIX, p. 116). There were significant differences in the bursting strength between sock fabric laundered one, seven and fourteen times (TABLE LXIX, p. 116). The bursting strength was the highest after the first laundry and the lowest after the fourteenth laundry for the knit sock fabric (FIGURE 4).

The repetition of the experimental sequence was found to be statistically significant at the 95 percent level in the bursting strength of the soiled-inoculated and unsoiled-inoculated sock fabrics (TABLE LXVI, p. 114). The least significant difference test at the 95 percent level showed that there were significant differences between the bursting strength in run one and two, run one and three and run two and three (TABLE LXX, p. 116). The highest bursting strength occurred in the first repetition of the test sequence, with the lowest occurring in the second repetition (FIGURE 5).

There were no significant differences between the interaction of treatment and detergent concentration at the 95 percent level in the bursting strength of the sock fabric (TABLE LXVI, p. 114). The bursting strength of the unsoiled-inoculated sock fabric laundered in either the 0.0 percent or 0.2 percent detergent concentration was higher than the soiled-inoculated fabric laundered in either detergent concentration (FIGURE 6). The soiled-inoculated sock fabric laundered in 0.0 percent and 0.2 percent detergent concentration resulted in the same bursting strength (FIGURE 6).

The interaction of treatment with the number of laundries before inoculation was not significant at the 95 percent level in the

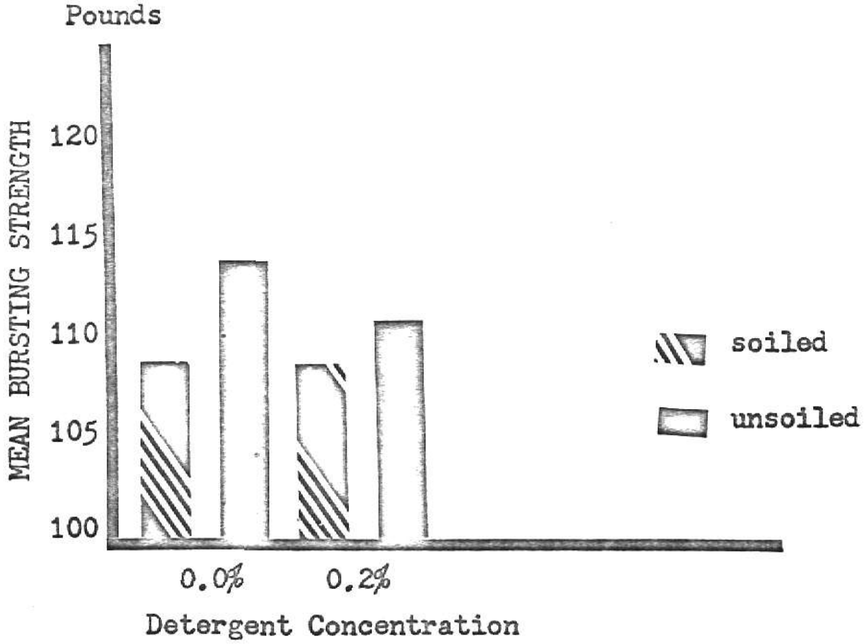


Figure 6. Mean bursting strength of soiled and unsoiled inoculated sock fabric after laundering with two detergent concentrations.

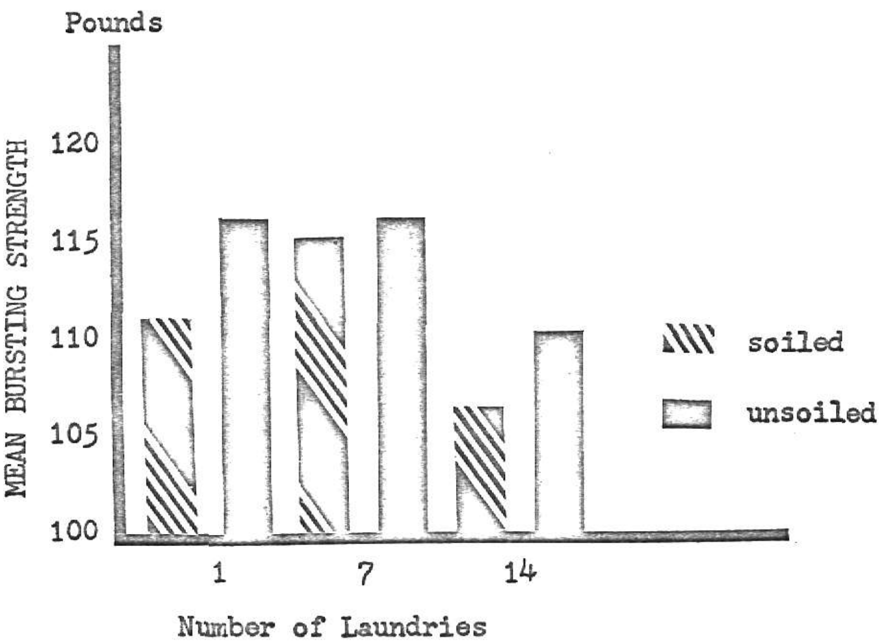


Figure 7. Mean bursting strength of inoculated fabric by soiled and unsoiled treatment and by number of laundries.

bursting strength of the inoculated fabrics (TABLE LXVI, p. 114). Figure 7 illustrates that the bursting strength for the soiled-and unsoiled-inoculated sock fabric was highest after seven laundries. After one and seven laundries, the unsoiled-inoculated sock fabric showed the same bursting strength. The bursting strength of the unsoiled-inoculated sock fabric was higher than the soiled-inoculated fabric for all three laundries (FIGURE 7).

The interaction between detergent concentration and the number of laundries before inoculation showed no significant differences in the bursting strength of the sock fabric (TABLE LXVI, p. 114). An increase in the number of laundries before inoculation led to a decrease in the pounds of force needed to burst an inoculated specimen that had been laundered in either 0.0 percent or 0.2 percent detergent concentration. The highest bursting strength occurred with the interaction of 0.0 percent detergent concentration and one laundry (FIGURE 8).

No significant differences were shown between the interaction of treatment, detergent concentration and number of laundries before inoculation at the 95 percent level in the bursting strength of the knit sock fabric (TABLE LXVI, p. 114). A decrease occurred in the bursting strength as the number of laundries increased for the unsoiled-inoculated fabric laundered in 0.0 percent detergent concentration and for the soiled-inoculated sock fabric laundered in 0.0 percent and 0.2 percent detergent concentration (FIGURE 9). An increase in bursting strength was shown after the fourteenth laundry for the unsoiled-inoculated knit fabric laundered in 0.2 percent detergent concentration (FIGURE 9).

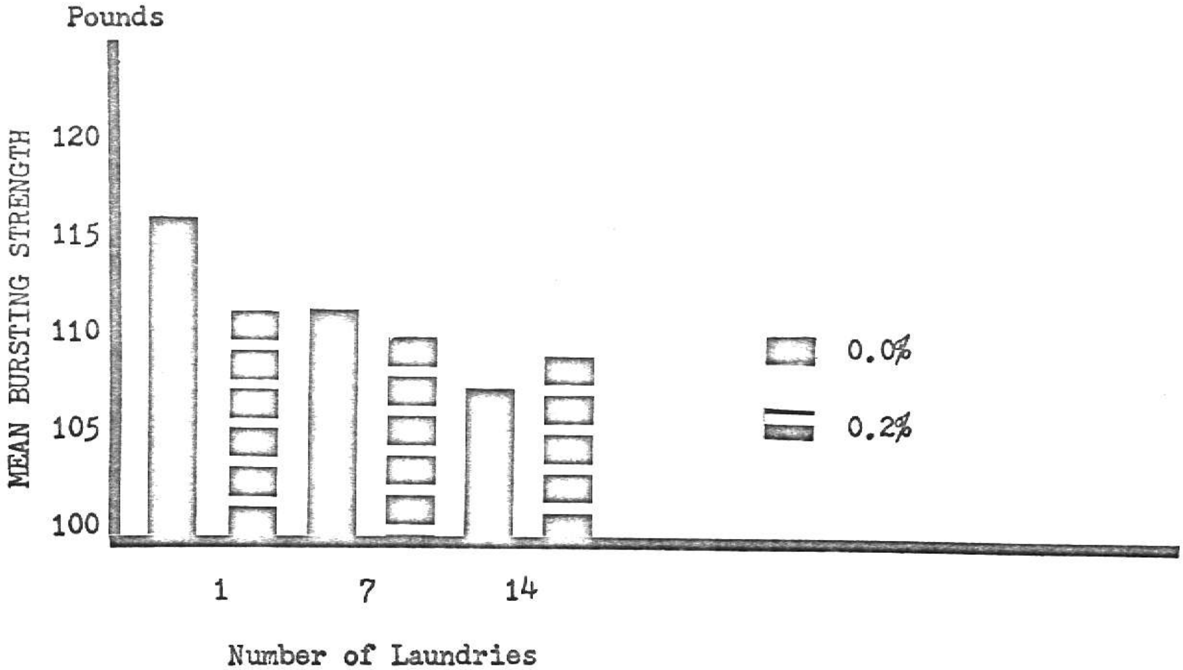


Figure 8. Mean bursting strength of inoculated fabrics laundered with two detergent concentration by number of laundries.

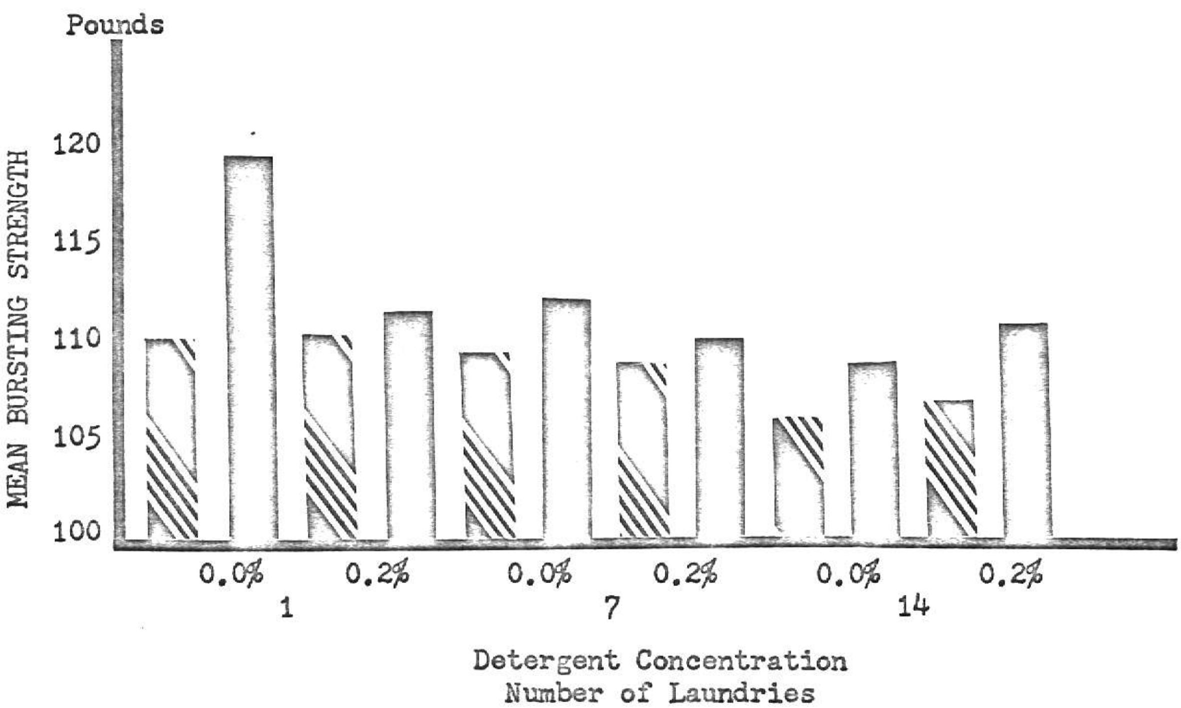


Figure 9. Mean bursting strength of soiled and unsoiled inoculated fabrics laundered in 0.0% or 0.2% detergent concentration one, seven or fourteen times.

Elongation. The percentage of elongation ranged from 90 percent to 114 percent in the soiled and unsoiled inoculated sock fabrics. The highest percentage of elongation occurred in the second repetition in the soiled-inoculated sock fabric laundered seven times in 0.2 percent detergent concentration. The lowest percentage of elongation occurred in the second repetition in the unsoiled-inoculated sock fabric that had been laundered one time in 0.2 percent detergent concentration and in the third repetition in the soiled-inoculated sock fabric that had been laundered fourteen times in 0.2 percent detergent concentration.

The treatment was found not to be a significant variable by a F test in the percentage of elongation of the knit sock fabric inoculated with Trichophyton mentagrophytes (TABLE LXVII, p. 115). With the soiling treatment, the inoculated sock fabric showed a lower percentage of elongation over the inoculated fabric that had not been soiled (FIGURE 10).

The detergent concentration was found not to be statistically significant at the 95 percent level in the percentage of elongation of the soiled- and unsoiled-inoculated wool, nylon and cotton sock fabric (TABLE LXVII, p. 115). When the soiled and unsoiled inoculated sock fabric was laundered in 0.2 percent detergent concentration, there was a decrease in the percentage of elongation (FIGURE 11).

The number of laundries before inoculation was found to be significant by a F test at the 95 percent level in the percentage of elongation (TABLE LXVII, p. 115). A least significant difference test resulted in significant differences between the number of laundries

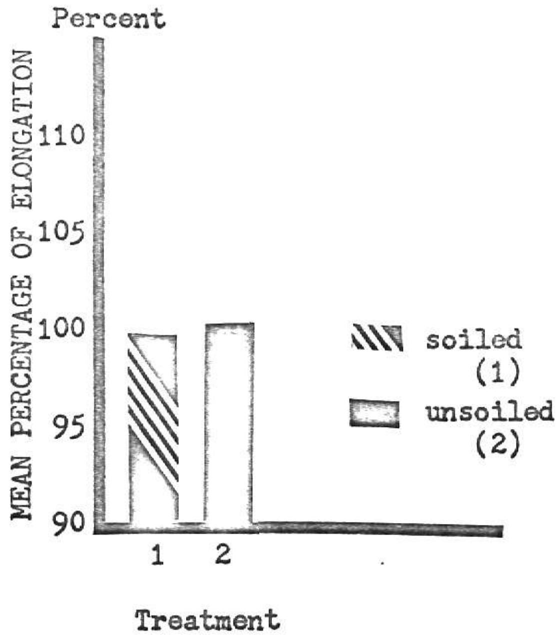


Figure 10. Mean percentage of elongation of inoculated fabric by soiled and unsoiled treatment.

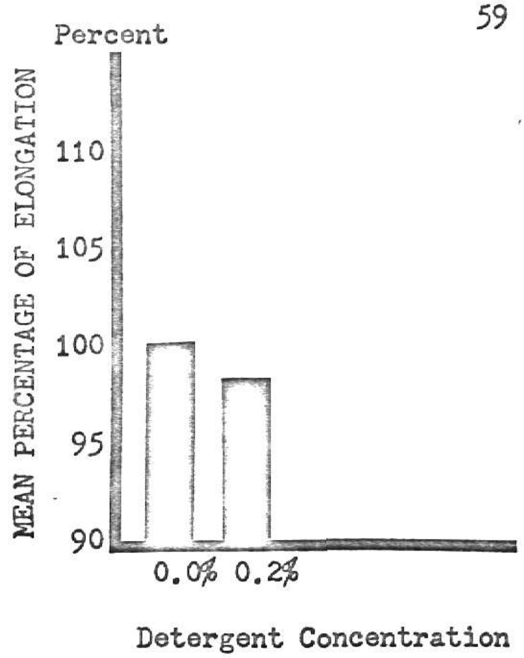


Figure 11. Mean percentage of elongation of inoculated fabrics laundered with two detergent concentrations.

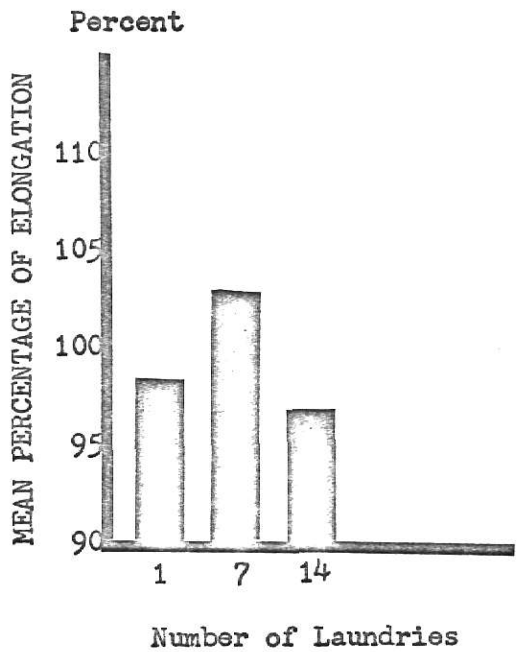


Figure 12. Mean percentage of elongation of soiled-inoculated and unsoiled-inoculated fabrics by number of laundries. (Significant at 95% level).

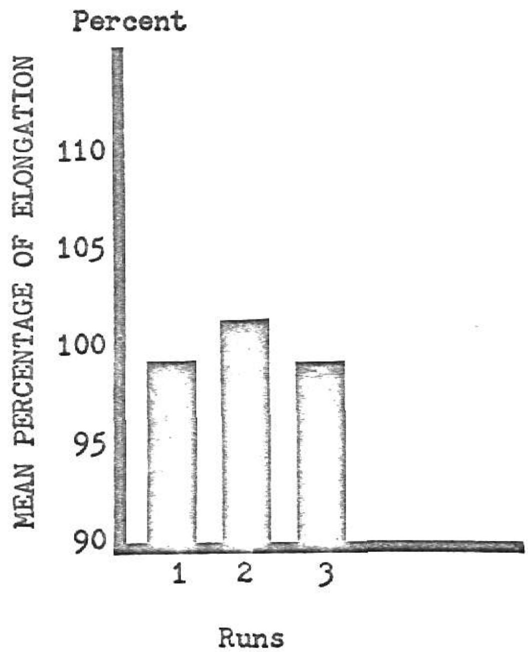


Figure 13. Mean percentage of elongation of soiled-inoculated and unsoiled-inoculated fabrics by each run.

performed on the fabric before inoculation (TABLE LXXI, p. 117). No significant differences between the number of laundries were shown for the soiled and unsoiled inoculated sock fabric laundered seven and fourteen times. The wool, nylon and cotton sock fabric laundered seven and fourteen times before inoculation. However, the highest percentage of elongation was found in the sock fabric that had been laundered seven times before inoculation (FIGURE 12).

The repetition of the test procedures was not a significant variable by a F test of variance at the 95 percent level in the percentage of elongation (TABLE LXVII, p. 115). The first and third repetitions of the test sequence resulted in the same percentage of elongation. The fabrics in the second run showed the highest percentage of elongation among the repetitions (FIGURE 13).

The interaction of treatment and detergent concentration showed no significant differences in the percentage of elongation of the inoculated sock fabric at the 95 percent level (TABLE LXVII, p.115). The soiled-inoculated sock fabric showed a lower percentage of elongation over the unsoiled-inoculated sock fabric with both the 0.0 percent and 0.2 percent detergent concentrations (FIGURE 14). The use of 0.2 percent detergent concentration with soiled and unsoiled fabric inoculated with Trichophyton mentagrophytes resulted in a decrease in the percentage of elongation (FIGURE 14).

There were no significant differences at the 95 percent level between the interaction of treatment and the number of laundries before inoculation in the percentage of elongation (TABLE LXVII, p. 115). Figure 15 illustrates that the percentage of elongation was highest

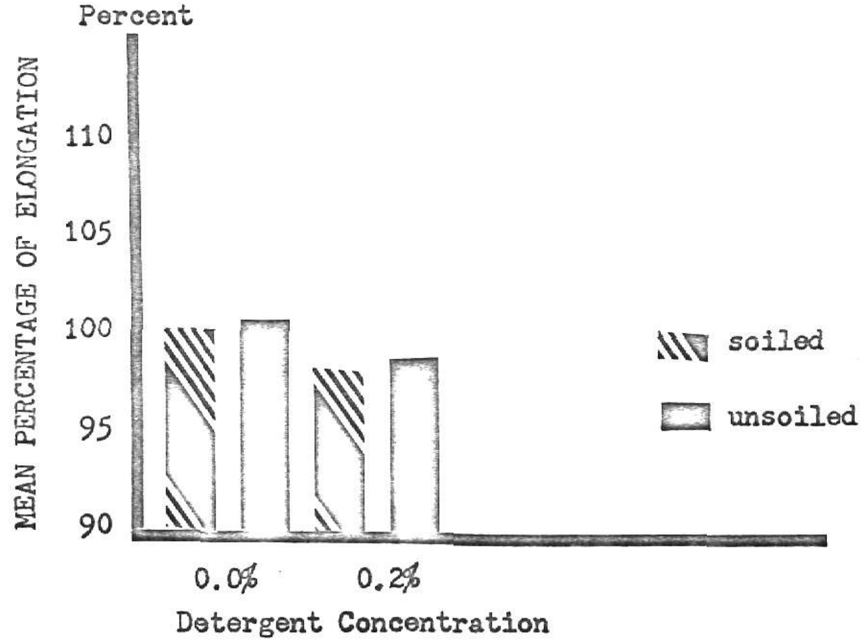


Figure 14. Mean percentage of elongation of soiled and unsoiled inoculated sock fabric after laundering with two detergent concentration.

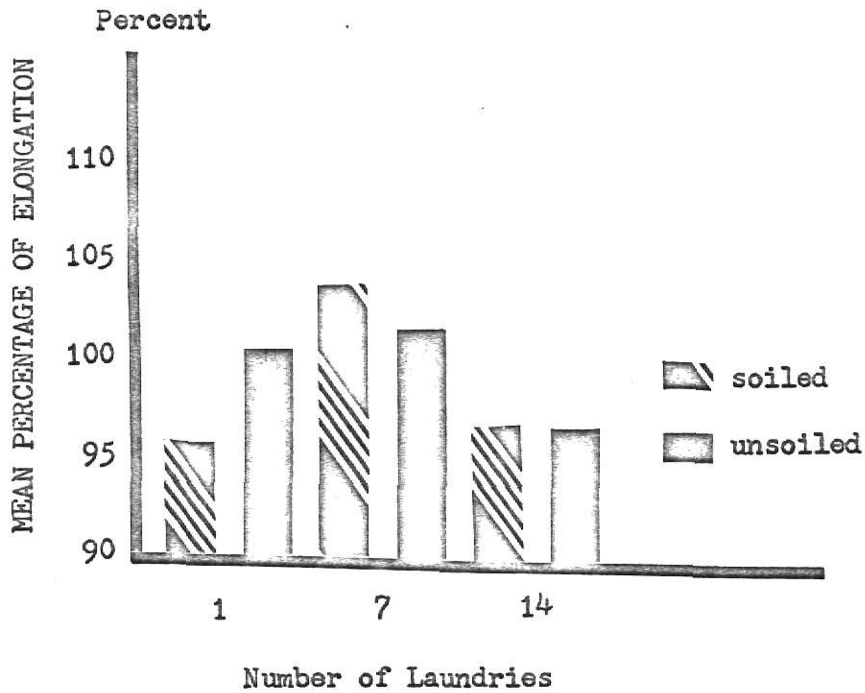


Figure 15. Mean percentage of elongation of inoculated fabric by soiled and unsoiled treatment and by number of laundries.

for the soiled and unsoiled fabric laundered seven times before inoculation. The percentage of elongation increased in the soiled and unsoiled inoculated sock fabrics with seven laundries before inoculation (FIGURE 15).

The interaction between detergent concentration and the number of laundries before inoculation was not significant by a F test of variance in the percentage of elongation of the soiled and unsoiled inoculated sock fabric (TABLE LXVII, p. 115). Figure 16 illustrates that the soiled and unsoiled sock fabric inoculated with Trichophyton mentagrophytes and laundered one, seven and fourteen times with 0.0 percent detergent concentration resulted in a higher percentage of elongation in each case. The percentage of elongation increased with the sock fabric laundered seven times before inoculation, decreasing to a slightly lower percentage of elongation with fabric laundered fourteen times before inoculation (FIGURE 16). The highest percentage of elongation with the use of 0.2 percent detergent concentration resulted with fabric laundered seven times before inoculation.

There were no significant differences between the interaction of treatment, detergent concentration and the number of laundries before inoculation at the 95 percent level in the percentage of elongation of the inoculated sock fabric (TABLE LXVII, p. 115). The percentage of elongation of the soiled-inoculated sock fabric laundered in 0.0 percent detergent concentration was low with one laundry before inoculation and highest with seven laundries before inoculation (FIGURE 17). The unsoiled-inoculated sock fabric laundered in 0.0 percent detergent concentration showed the highest percentage of elongation with one

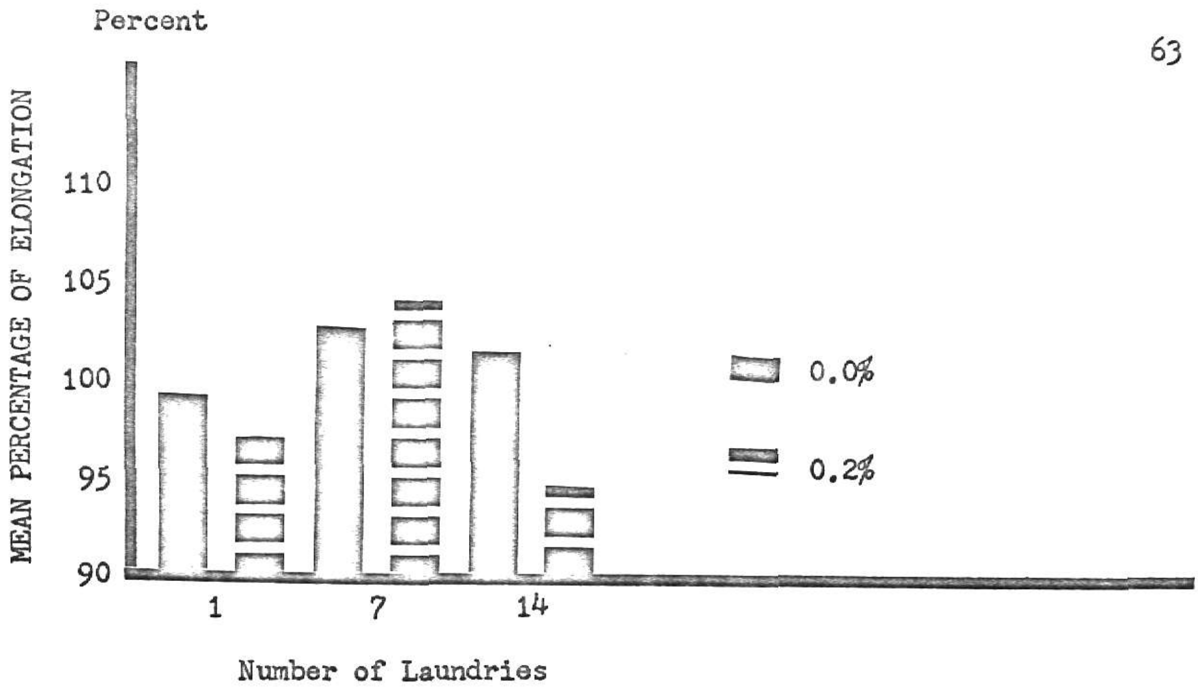


Figure 16. Mean percentage of elongation of inoculated fabrics laundered with two detergent concentrations by number of laundries.

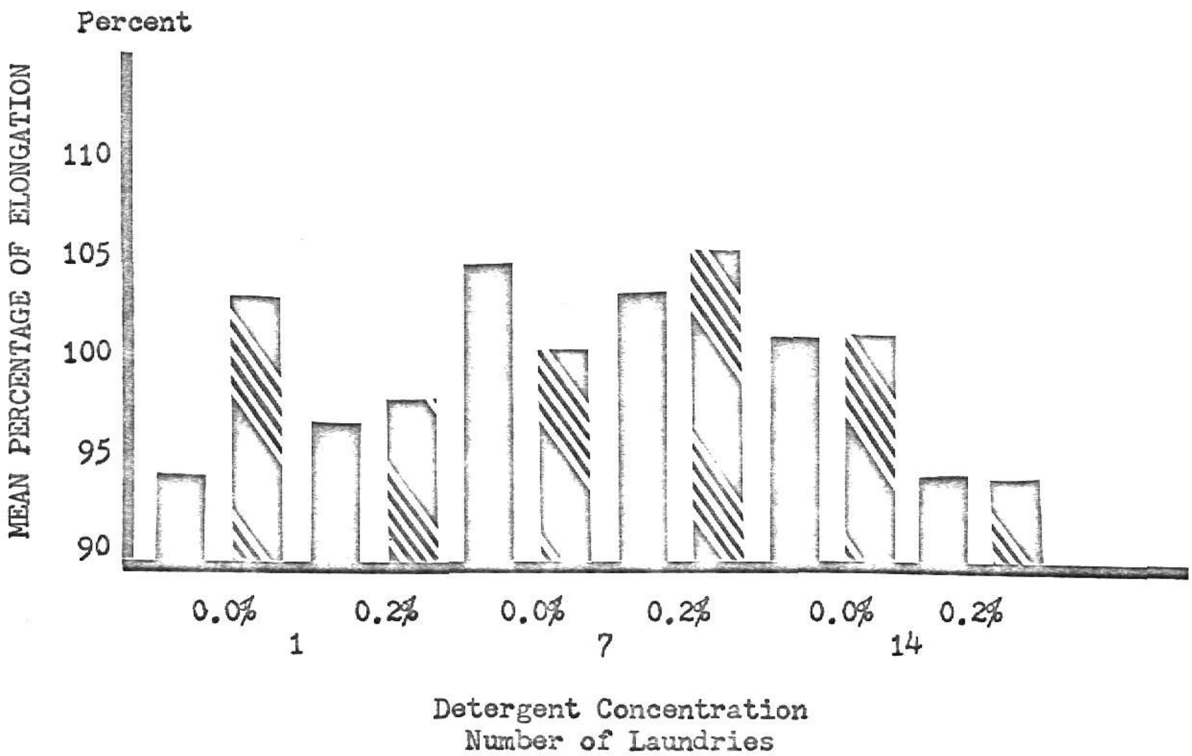


Figure 17. Mean percentage of elongation of soiled and unsoiled inoculated fabrics laundered in 0.0% or 0.2% detergent concentration one, seven or fourteen times.

laundry before inoculation and the lowest with seven laundries before inoculation (FIGURE 17). When the soiled and unsoiled inoculated sock fabric was laundered in 0.2 percent detergent concentration, the percentage of elongation was highest with seven laundries before inoculation. The highest percentage of elongation for the unsoiled-inoculated sock fabric was with the fabric laundered seven times with 0.2 percent detergent concentration (FIGURE 17). The highest percentage of elongation for the soiled-inoculated sock fabric was with the fabric laundered seven times with 0.0 percent detergent concentration (FIGURE 17).

The raw data for bursting strength and elongation tests with the Constant Rate of Extension Tester on the 50 percent wool, 30 percent nylon and 20 percent cotton knit sock fabric can be found in Tables LXXII and LXXIII, p. 118,119).

CONCLUSIONS AND RECOMMENDATIONS

This investigation was designed to evaluate damage to fibers of a military knit footwear fabric composed of 50 percent wool, 30 percent nylon, and 20 percent cotton and to analyse the bursting strength and elongation of the sock fabric after exposure to *Trichophyton mentagrophytes* at room temperature (25 C.) and 80 percent relative humidity for a eight day holding period. The specific factors studied were the effects of: (1) treatment (soil or no soil), (2) detergent concentration, (3) number of laundries before inoculation, and (4) type of fiber on two types of damage, cracks and pits, with three repetitions of the test sequence.

A preliminary microscopic study was performed to provide criteria for sampling requirements for the entire population of *Trichophyton mentagrophytes* inoculated sock fabric. Statistical analysis of fiber damage data collected from three inoculated swatches showed that the variation in fiber damage was within microscopic views of fibers. An unequal subclass analysis of variance test showed that fiber damage in the inside pieces within a swatch was not significantly different from the damage seen in fibers from the outside pieces. All outside pieces were inch from the edge of the eight by twelve inch fabric swatch. Thus, the theory that damage varied from the outside to the inside of a swatch was not accepted.

The damage of fibers in the knit sock fabrics that had been soiled before inoculation was not significantly different from the fiber damage of the unsoiled-inoculated sock fabrics in nylon and wool fibers, except for the amount of corrosion in wool. However, there were significant differences noted for the number of pits and the corrosion between the cotton fibers withdrawn from the soiled-inoculated sock fabric and the unsoiled-inoculated sock fabric. In addition, the effect of soil versus no soil on the inoculated sock fabric was statistically significant in the bursting strength but not in the percentage of elongation.

The detergent concentration was not significant for all observed types of damage in the wool, cotton and nylon fibers. No difference in bursting strength or percentage of elongation was found between the sock fabric laundered in no detergent and the sock fabric laundered in 0.2 percent concentration of high sudsing synthetic detergent. Thus, the effect of detergent on prevention of damage was minimal.

The number of laundries before inoculation with Trichophyton mentagrophytes of a military knit sock fabric was found to be significant in fiber damage for all three fibers, in the bursting strength and percentage of elongation. The fiber damage, absent scales, was significantly different in the wool fibers withdrawn from the sock fabrics laundered one, seven and fourteen times. In the cotton fibers, the amount of corrosion and dissolution of the lumen was significantly different in the three series of laundries. The number of cracks in nylon fibers withdrawn from sock fabric laundered one time before inoculation was significantly different from fabric laundered fourteen times. The number of pits in the nylon fibers withdrawn from the sock fabric laundered fourteen times before inoculation was significantly different from the nylon fibers taken from sock fabric laundered seven times before inoculation.

The sock fabric subjected to one laundry before inoculation was significantly different from the sock fabric laundered seven and fourteen times in the bursting strength and percentage of elongation. The indication was that the damage to the fibers and to physical properties increased as the number of laundries increased.

Statistical analysis of the effect of the repetition of the experimental sequence revealed that the variance in fiber damage was significant for the wool, nylon and cotton fibers. For the number of cracks in wool fibers, run one or the completion of laundry, treatment and inoculation procedures one time, was found to be significantly different from run two and three. A significant difference was noted between run one and two for the number of loose and rough scales; the number of cracks and pits in cotton fibers and the amount of swelling in nylon fibers were significantly different in all three runs.

The repetition of the experimental sequence was significant for all three runs in the bursting strength of the sock fabric. The effect from the different repetitions was not significant for the percentage of elongation of the sock fabric.

The above fiber damage was analysed statistically according to each individual fiber damage classification and fiber. This analysis of variance combined the data for the types of damage, cracks and pits, for the wool, nylon and cotton fibers to determine the effect of fiber on occurring damage. The effect of fiber proved to be statistically significant in the number of cracks and pits. Thus, the type of fiber has an effect on the amount of damage observed.

Although the results of the fiber analysis did show damage in the unsoiled and soiled inoculated fibers, the damage caused by Trichophyton mentagrophytes can not be evaluated accurately until analysis of unsoiled and soiled uninoculated sock fabric has been completed. This further study is recommended so a comparison of the uninoculated with inoculated sock fabric can be made for the fiber and fabric damage.

Several other suggestions for future research are made. A suggestion would be to use fabric of 100 percent wool, cotton and nylon to determine if the fungus prefers protein fibers to cellulose and synthetic fibers and would attack the wool fibers before other types of fibers.

It would also be interesting to see the effect Trichophyton mentagrophytes would have on wool, nylon and cotton fabrics if the fabric was inoculated, held one day, laundered with various water temperatures and detergent concentrations and held again for a specified growth period. This study would give results on how effective different combinations of water temperatures and detergent concentrations were on the removal of the test organism and reveal if remaining organisms after laundry multiply and cause damage to fibers and fabric.

Another suggestion for future research would be to microscopically analyse sterilized swatches that had been laundered with inoculated swatches to determine if the fibers or the fabric had been damaged or weakened through redeposition of the microorganism.

LITERATURE CITED

1. Agarwal, P. N. and J. M. Puvathingal, "Microbiological Deterioration of Woolen Materials," Textile Research Journal, 39:38-42, January, 1969.

2. Ajello, L. and Shu-Lan Cheng, "The Perfect State of Trichophyton Mentagrophytes," Sabouraudia, 5:230-234, February, 1967.

3. A.S.T.M. Standards on Textile Materials, Committee D-13, Philadelphia. American Society for Testing Materials, Part 24, 1969.

4. Baer, Rudolf L., Stanley A. Litt, Z. Jerome and Hymen Rogashifsky, "Experimental Investigations on Mechanism Producing Acute Dermatophytosis of Feet," Journal of the American Medical Association, 160:184-190, January 21, 1956.

5. Barnes, Carolyn J. "Microscopic Evaluation of Damage by Staphylococcus Aureus on a Knitted Nylon-Cotton Fabric Before and After Laundering, Unpublished Masters Thesis, Kansas State University, 1969.

6. Basu, S. N. and Rekha Ghose, "A Microscopical Study on the Degradation of Jute Fiber by Micro-organisms," Textile Research Journal, 32:677-693, August, 1962.

7. Beneke, E. S. Medical Mycology Laboratory Manual. Minneapolis: Burgess Publishing Co., 1966, pp. 1, 59-64, 82-85.

8. Blank, Harvey, David Taplin and Nardo Zaias, "Cutaneous Trichophyton Mentagrophytes Infections in Vietnam," Archives of Dermatology.

9. Blood, D. C. and J. A. Henderson. Veterinary Medicine. Baltimore: The Williams and Wilkins Co., 1968, pp. 555-556.

10. Bocobo, F. C., L. J. Miedler, G. A. Eadie, "Further Isolations of Trichophyton Mentagrophytes from Inanimate Sources," Sabourandia, 3:178-179, February, 1964.

11. Burrows, William. Textbook of Microbiology. Philadelphia: W. B. Saunders Company, 1968, pp. 704-710.

12. Deakin, Malcolm J. and Sister Regis Mary Dunne, "Granulomatous Lesion Due to Trichophyton Mentagrophytes," Aust. Journal of Dermatology, 9:221-225, 1968.

13. Doberczak, A., St. Dowgielewica, and W. Zurek. Cotton, Bast, and Wool Fibers. Translated from Polish, Published for the Department of Agriculture and the National Science Foundation, Washington, D.C. by Central Institute for Scientific, Technical and Economic Information, 1964.

14. Emmons, Chester W., H. Chapman, and John P. Utz (Ed.) Medical Mycology. Philadelphia: Lea and Febiger, 1963, pp. 11-29, 86-119.

15. "Federal Specifications Textile Test Methods," CCCT-191b, Washington 25, D.C., General Services Administration, 1966.

16. Gary, William D. The Relation of Fungus to Human Affairs. New York: Henry Holt and Co., Inc., 1959, pp. 451, 476-477.

17. Hendrickson, Delores. "Microscopic Longitudinal Evaluation of Fiber Damage Caused by Candida Tropicallis," Unpublished Masters Thesis, Kansas State University, 1970.

18. Heyn, A. N. J. Fiber Microscopy. New York: Interscience Publishers, Inc., 1954.

19. Kehren, M., "The Wool Fibers," Ciba Review, February, 1956, pp. 4102-4138.

20. Mendels, Mary and E. T. Reese, "Fungal Celluloses and the Microbial Decomposition of Cellulosic Fabric," Developments in Industrial Microbiology, 5:5-20, 1964.

21. Mauerberger, Herbert R. Matthew's Textile Fibers. New York: John Wiley and Sons, 1954, pp. 248-250.

22. McNeil, Ethel, "Dissemination of Microorganisms by Fabrics and Leather," Developments in Industrial Microbiology, 5:30-35, 1964.

23. Munoz, Frank F. The Microscope and Its Use. Brooklyn: Chemical Publishing Co., Inc., 1943, pp. 243-252.

24. Neter, Erwin. Medical Microbiology. Philadelphia: F. A. Davis Company, 1966, pp. 362-363.

25. Paldrok, Heiti, "The Effect of Temperature on the Growth and Development of Dermatophytes," Acta Dermato-Venereologica, 35:1-29, 1955.

26. Rebell, Gerbert and David Taplin, "Dermatophytes: Their Recognization and Identification," University of Miami Press, Coral Gables, Florida.

27. Ridenour, G. M., "A Bacteriology Study of Automatic Clothes Washing," The National Science Foundation, Ann Arbor, Michigan, 1952.

28. Schimpf, Cheryl A. "The Survival of Staphylococcus Aureus on Military Sock Fabrics Laundered at Various Water Temperatures and Detergent Concentrations," Unpublished Masters Thesis, Kansas State University, 1969.

29. Sui, R. G. H. Microbial Decomposition of Cellulose. New York: Reinhold Publishing Corporation, 1951.

30. Szathmary, Sebastian, "The Latent Trichophytosis of Human Clothes, Part I," Mycopathologia, 32:26-36, June 13, 1967.

31. Szathmary, Sebastian, "The Latent Trichophytosis of Human Clothes, Part IV," Mycopathologia, 36:199-208, November 13, 1968.

32. Zalinski, Tadeusz. Fiber Science. Translated from Polish, Published for the Department of Agriculture by the Scientific Publications Foreign Cooperation Center of the Central Institute for Scientific, Technical and Economic Information, 1964, pp. 455-510, 649-650.

APPENDIX

TABLE III

NESTED ANALYSIS OF VARIANCE
OF CRACKS IN WOOL FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Swatch	2	280.632	141.316	35.281*
Pieces/swatch	57	473.649	8.309	2.074
Error	120	480.650	4.005	
Total	179	1236.932		

TABLE IV

NESTED ANALYSIS OF VARIANCE
OF PITS IN WOOL FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Swatch	2	54.670	27.350	4.508
Pieces/swatch	57	1058.094	18.563	3.060*
Error	120	727.983	6.066	
Total	179	1840.777		

* Significant at 95% level.

TABLE V

NESTED ANALYSIS OF VARIANCE OF LOOSE AND ROUGH SCALES IN COTTON FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Swatch	2	6.299	3.149	3.514*
Error	57	51.099	0.896	
Total	59	57.399		

TABLE VI

NESTED ANALYSIS OF VARIANCE OF ABSENT SCALES IN WOOL FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Swatch	2	25.600	12.800	21.459*
Error	57	33.999	0.596	
Total	59	59.999		

TABLE VII

NESTED ANALYSIS OF VARIANCE OF SWELLING IN WOOL FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Swatch	2	0.633	0.317	0.775
Error	57	23.280	0.409	
Total	59	23.933		

* Significant at 95% level.

TABLE VIII

NESTED ANALYSIS OF VARIANCE OF
CORROSION IN WOOL FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Swatch	2	2.133	1.067	2.528
Error	57	24.049	0.422	
Total	59	26.183		

TABLE IX

NESTED ANALYSIS OF VARIANCE OF
CRACKS IN COTTON FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Swatch	2	29.478	14.739	3.619
Pieces/swatch	57	427.382	7.498	1.841*
Error	59	488.654	4.072	
Total	179	945.515		

* Significant at 95% level.

TABLE X

NESTED ANALYSIS OF VARIANCE OF
PITS IN COTTON FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Swatch	2	128.177	64.089	21.246*
Pieces/swatch	57	258.149	4.529	1.501*
Error	120	361.987	3.016	
Total	179	748.313		

TABLE XI

NESTED ANALYSIS OF VARIANCE OF DISSOLUTION
OF THE LUMEN IN COTTON FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Swatch	2	1.033	0.517	0.985
Error	57	29.899	0.524	
Total	59	30.933		

* Significant at 95% level.

TABLE XII

NESTED ANALYSIS OF VARIANCE OF
CORROSION IN COTTON FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Swatch	2	1.599	0.799	3.406*
Error	57	13.6500	0.239	
Total	59	15.250		

TABLE XIII

NESTED ANALYSIS OF VARIANCE OF
CRACKS IN NYLON FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Swatch	2	2.411	1.205	0.977
Pieces/swatch	57	70.699	1.240	1.006
Error	120	147.999	1.233	
Total	179	221.110		

* Significant at 95% level.

TABLE XIV

NESTED ANALYSIS OF VARIANCE OF
PITS IN NYLON FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Swatch	2	96.099	48.049	28.831*
Pieces/swatch	57	155.098	2.721	1.633*
Error	120	199.992	1.666	
Total	179	451.190		

TABLE XV

NESTED ANALYSIS OF VARIANCE OF
SWELLING IN NYLON FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Swatch	2	0.433	0.217	0.436
Error	57	28.299	0.496	
Total	59	28.733		

* Significant at 95% level.

TABLE XVI

UNEQUAL SUBCLASS ANALYSIS OF VARIANCE
OF CRACKS IN WOOL FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Swatch	2	708.1531	354.0764	13.964*
Treatment	1	50.0008	50.0008	1.972
Swatch x Treatment	2	1.6872	0.8436	0.033
Pieces/swatch x Treatment	54	1369.2629	25.3567	6.331*
Error	120	480.6503	4.0054	
Total	179	2609.7204		

TABLE XVII

UNEQUAL SUBCLASS ANALYSIS OF VARIANCE
OF PITS IN WOOL FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Swatch	2	113.0330	56.5165	1.019
Treatment	1	132.1142	132.1141	2.381
Swatch x Treatment	2	46.2332	23.1166	0.417
Pieces/swatch x Treatment	54	2995.9528	55.4806	9.145*
Error	120	727.9833	6.0665	
Total	179	4015.3165		

* Significant at 95% level.

TABLE XVIII

UNEQUAL SUBCLASS ANALYSIS OF VARIANCE OF LOOSE AND ROUGH SCALES IN WOOL FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Swatch	2	4.862	2.421	2.775
Treatment	1	0.178	0.178	0.204
Swatch x Treatment	2	0.462	0.231	0.264
Error	54	47.309	0.876	
Total	59	54.583		

TABLE XIX

UNEQUAL SUBCLASS ANALYSIS OF VARIANCE OF ABSENT SCALES IN WOOL FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Swatch	2	23.339	11.670	18.798*
Treatment	1	0.203	0.203	0.327
Swatch x Treatment	2	0.237	0.136	0.220
Error	54	33.524	0.621	
Total	59	59.599		

* Significant at 95% level.

TABLE XX

UNEQUAL SUBCLASS ANALYSIS OF VARIANCE
OF SWELLING IN WOOL FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Swatch	2	0.7047	0.3523	0.832
Treatment	1	0.0642	0.0642	0.152
Swatch x Treatment	2	0.3047	0.1523	0.360
Error	54	22.8809	0.4237	
Total	59	24.1833		

TABLE XXI

UNEQUAL SUBCLASS ANALYSIS OF VARIANCE
OF CORROSION OF WOOL FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Swatch	2	2.1762	1.0881	1.885
Treatment	1	0.0071	0.0071	0.012
Swatch x Treatment	2	1.1762	0.5880	1.019
Error	54	31.1667	0.5772	
Total	59	33.6450		

* Significant at 95% level.

TABLE XXII

UNEQUAL SUBCLASS ANALYSIS OF VARIANCE
OF CRACKS IN COTTON FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Swatch	2	64.2395	32.119	1.382
Treatment	1	22.667	22.667	0.976
Swatch x Treatment	2	7.440	3.720	0.160
Pieces/swatch x Treat.	54	1254.6430	23.234	5.706*
Error	120	488.654	4.072	
Total	179	1837.644		

TABLE XXIII

UNEQUAL SUBCLASS ANALYSIS OF VARIANCE
OF PITS IN COTTON FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Swatch	2	316.692	158.346	10.906*
Treatment	1	7.467	7.467	0.514
Swatch x Treatment	2	28.959	14.479	0.997
Pieces/swatch x Treat.	54	784.025	14.519	4.813*
Error	120	361.987	3.016	
Total	179	1238.983		

* Significant at 95% level.

TABLE XXIV

UNEQUAL SUBCLASS ANALYSIS OF VARIANCE
OF CORROSION IN COTTON FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Swatch	2	1.9301	0.9650	3.958*
Treatment	1	0.0198	0.0198	0.081
Swatch x Treatment	2	0.4634	0.2317	0.950
Error	54	13.1666	0.2438	
Total	59	15.2500		

TABLE XXV

UNEQUAL SUBCLASS ANALYSIS OF VARIANCE
DISSOLUTION OF LUMEN IN COTTON FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Swatch	2	0.3920	0.1960	0.379
Treatment	1	0.5365	0.5365	1.038
Swatch x Treatment	2	1.4587	0.7293	1.411
Error	54	27.9047	0.5167	
Total	59	30.9333		

* Significant at 95% level.

TABLE XXVI

UNEQUAL SUBCLASS ANALYSIS OF VARIANCE
OF CRACKS IN NYLON FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Swatch	2	5.8301	2.9150	0.830
Treatment	1	3.8888	3.8888	1.107
Swatch x Treatment	2	18.4968	9.2484	2.632
Pieces/swatch x Treatment	54	189.7145	3.5132	2.849*
Error	120	147.9997	1.2333	
Total	179	555.7444		

TABLE XXVII

UNEQUAL SUBCLASS ANALYSIS OF VARIANCE
OF PITS IN NYLON FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Swatch	2	254.3472	127.1736	11.387*
Treatment	1	0.2571	0.2571	0.023
Swatch x Treatment	2	10.7476	5.3738	0.481
Pieces/swatch x Treatment	54	603.0988	11.1684	6.701*
Error	120	199.9917	1.6665	
Total	179	1068.4424		

* Significant at 95% level.

TABLE XXVIII

UNEQUAL SUBCLASS ANALYSIS OF VARIANCE OF SWELLING IN NYLON FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Swatch	2	0.9539	0.4769	0.962
Treatment	1	0.3841	0.3841	0.775
Swatch x Treatment	2	1.1539	0.5769	1.164
Error	54	26.7619	0.4955	
Total	59	28.7333		

* Significant at 95% level.

TABLE XXIX

ESTIMATES OF VARIATION OF COMPOTENTS IN WOOL FIBERS ACCORDING TO TYPE OF DAMAGE

Compotent	Estimates					
	Types of Damage					
	Cracks	Pits	Loose and Rough Scales	Absent Scales	Corrosion	Swelling
Views	4.005	6.067				
Pieces	1.435	4.165	0.896	0.596	0.422	0.409
Swatches	2.217	0.146	0.113	0.610	0.032	0.000

TABLE XXX

ESTIMATES OF VARIATION OF COMPOTENTS IN COTTON FIBERS ACCORDING TO TYPE OF DAMAGE

Compotent	Estimates			
	Types of Damage			
	Cracks	Pits	Corrosion	Dissolution of the Lumen
Views	4.072	3.017		
Pieces	1.142	0.504	0.542	0.239
Swatches	0.121	0.993	0.000	0.028

TABLE XXXI

ESTIMATES OF VARIATION OF COMPOTENTS IN NYLON FIBERS ACCORDING TO TYPE OF DAMAGE

Compotent	Estimates		
	Types of Damage		
	Cracks	Pits	Swelling
Views	1.233	1.667	
Pieces	0.000	0.000	0.496
Swatches	0.000	0.755	0.000

TABLE XXXII

ANALYSIS OF VARIANCE OF
CRACKS IN WOOL FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Runs	2	487.606	243.803	6.106*
Procedures	11	389.606	35.427	.888
Treatment	1	0.112	0.112	.003
Detergent concentration	1	42.535	42.535	1.064
Number of Laundries	2	173.008	86.504	2.166
Treat. x Det. Conc.	1	7.812	7.812	0.196
Treat. x No. of Laundries	2	14.658	7.329	0.183
Det. Conc. x No. of Laundries	2	131.752	65.876	1.650
Treat. x Det. Conc. x No. of Laundries	2	19.825	9.912	0.248
Runs x Procedures	22	878.423	39.928	
Swatches	36	1225.744	34.048	1.507
Pieces/swatch	72	1626.681	22.593	3.539*
Error	576	3677.241	6.384	
Total	719	8285.418		

* Significant at 95% level.

TABLE XXXIII

ANALYSIS OF VARIANCE OF
PITS IN WOOL FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Runs	2	201.558	100.789	1.625
Procedures	11	298.403	27.127	0.437
Treatment	1	1.335	1.335	0.210
Detergent Concentration	1	23.835	23.835	0.384
Number of Laundries	2	4.658	2.329	0.037
Treat. x Det. Conc.	1	50.668	50.668	0.817
Treat. x No. of Laundries	2	30.469	15.235	0.245
Det. Conc. x No. of Laundries	2	180.302	90.151	1.453
Treat. x Det. Conc. x No. of Laundries	2	7.136	3.568	0.057
Runs x Procedures	22	1364.569	62.026	
Swatches	36	2066.445	57.401	1.734*
Pieces/swatch	72	2382.860	33.095	3.004*
Error	576	6345.558		
Total	719	12659.433		

* Significant at 95% level.

TABLE XXXIV

ANALYSIS OF VARIANCE OF LOOSE AND ROUGH SCALES IN WOOL FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Runs	2	56.764	28.382	9.150*
Procedures	11	55.242	5.022	1.619
Treatment	1	0.562	0.562	0.181
Detergent Concentration	1	3.062	3.062	0.987
Number of Laundries	2	18.597	9.299	2.998
Treat. x Det. Conc.	1	0.007	0.007	0.002
Treat. x No. of Laundries	2	11.625	5.812	1.874
Det. Conc. x No. of Laundries	2	9.875	4.937	1.592
Treat. x Det. Conc. x No. of Laundries	2	11.514	5.757	1.857
Runs x Procedures	22	68.235	3.102	
Swatches	36	80.250	2.229	
Error	72	97.494	1.354	
Total	143	357.987		

* Significant at 95% level.

TABLE XXXV

ANALYSIS OF VARIANCE OF ABSENT SCALES IN WOOL FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Runs	2	5.680	2.840	1.994
Procedures	11	19.076	1.734	1.218
Treatment	1	2.007	2.007	1.409
Detergent Concentration	1	0.174	0.174	0.122
Number of Laundries	2	12.930	6.465	4.544*
Treat. x Det. Conc.	1	0.062	0.062	0.043
Treat. x No. of Laundries	2	1.264	0.632	0.444
Det. Conc. x No. of Laundries	2	2.347	1.174	0.824
Treat. x Det. Conc. x No. of Laundries	2	0.292	0.146	0.102
Runs x Procedures	22	31.319	1.424	
Swatches	36	61.250	1.704	2.059*
Error	72	59.499	0.826	
Total	143	176.825		

* Significant at 95% level.

TABLE XXXVI

ANALYSIS OF VARIANCE OF SWELLING
IN WOOL FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Runs	2	21.125	10.562	4.675*
Procedures	11	14.416	1.310	0.580
Treatment	1	2.778	2.778	1.230
Detergent Concentration	1	1.778	1.778	0.787
Number of Laundries	2	1.542	0.771	0.341
Treat. x Det. Conc.	1	0.694	0.694	0.307
Treat. x No. of Laundries	2	1.930	0.965	0.373
Det. Conc. x No. of Laundries	2	3.180	1.590	0.704
Treat. x Det. Conc. x No. of Laundries	2	2.514	1.257	0.556
Runs x Procedures	22	49.707	2.259	
Swatches	36	73.500	2.042	1.324
Error	72	110.998	1.542	
Total	143	269.748		

* Significant at 95% level.

TABLE XXXVII

ANALYSIS OF VARIANCE OF
CORROSION IN WOOL FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Runs	2	1.055	0.528	0.626
Procedures	11	19.243	1.749	2.271
Treatment	1	4.340	4.340	5.636*
Detergent Concentration	1	0.062	0.062	0.080
Number of Laundries	2	4.847	2.424	3.148
Treat. x Det. Conc.	1	1.174	1.174	2.252
Treat. x No. of Laundries	2	1.264	0.632	0.821
Det. Conc. x No. of Laundries	2	2.792	1.396	1.813
Treat. x Det. Conc. x No. of Laundries	2	4.764	2.382	3.093
Runs x Procedures	22	16.944	0.770	
Swatches	36	38.250	1.062	
Error	72	44.500	0.618	
Total	143	119.992		

* Significant at 95% level.

TABLE XXXVIII

ANALYSIS OF VARIANCE OF CRACKS IN COTTON FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Runs	2	159.886	79.943	5.999*
Procedures	11	135.061	12.278	0.921
Treatment	1	32.939	32.939	2.472
Detergent Concentration	1	47.022	47.022	3.529
Number of Laundries	2	0.953	0.474	0.036
Treat. x Det. Conc.	1	8.889	8.889	0.667
Treat. x No. of Laundries	2	0.086	0.043	0.003
Det. Conc. x No. of Laundries	2	4.786	2.393	0.180
Treat. x Det. Conc. x No. of Laundries	2	40.386	20.193	1.515
Runs x Procedures	22	293.179	13.326	
Swatches	36	202.999	5.639	0.462
Pieces/swatch	72	878.995	12.208	1.587
Error	576	4431.461	7.693	
Total	719	6101.609		

* Significant at 95% level.

TABLE XXXIX

ANALYSIS OF VARIANCE OF PITS IN COTTON FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Runs	2	192.675	96.337	5.266*
Procedures	11	294.569	26.779	1.464
Treatment	1	148.512	148.512	8.118*
Detergent Concentration	1	0.001	0.001	0.000
Number of Laundries	2	102.558	51.279	2.803
Treat. x Det. Conc.	1	10.512	10.512	0.575
Treat. x No. of Laundries	2	13.225	6.612	0.361
Det. Conc. x No. of Laundries	2	17.603	8.801	0.481
Treat. x Det. Conc. x No. of Laundries	2	2.158	1.079	0.059
Runs x Procedures	11	402.489	18.295	
Swatches	36	294.047	8.168	0.796
Pieces/swatch	72	738.695	10.260	1.076
Error	576	5491.058	9.534	
Total	719	7414.058		

* Significant at 95% level.

TABLE XL

ANALYSIS OF VARIANCE OF CORROSION IN COTTON FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Runs	2	51.847	25.924	11.486*
Procedures	11	110.220	10.020	4.439*
Treatment	1	44.444	44.444	19.692*
Detergent Concentration	1	3.361	3.361	1.489
Number of Laundries	2	47.680	23.840	10.563*
Treat. x Det. Conc.	1	8.028	8.028	3.557
Treat. x No. of Laundries	2	1.430	0.715	0.317
Det. Conc. x No. of Laundries	2	1.097	0.549	0.243
Treat. x Det. Conc. x No. of Laundries	2	4.180	2.090	0.926
Runs x Procedures	22	49.653	2.257	
Swatches	36	71.500	1.986	1.589*
Error	72	89.992	1.507	
Total	143	373.214		

* Significant at 95% level.

TABLE XLI

ANALYSIS OF VARIANCE OF DISSOLUTION OF THE LUMEN IN COTTON FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Runs	2	3.014	1.507	1.192
Procedures	11	37.022	3.366	2.663*
Treatment	1	2.250	2.250	1.780
Detergent Concentration	1	0.078	0.078	0.062
Number of Laundries	2	32.722	16.361	12.944*
Treat. x Det. Conc.	1	0.028	0.028	0.022
Treat. x No. of Laundries	2	1.167	1.167	0.923
Det. Conc. x No. of Laundries	2	0.055	0.028	0.022
Treat. x Det. Conc. x No. of Laundries	2	0.722	0.361	0.286
Runs x Procedures	22	27.818	1.264	
Swatches	36	38.500	1.069	1.262
Error	72	60.999	0.847	
Total	143	167.305		

* Significant at 95% level.

TABLE XLII

ANALYSIS OF VARIANCE OF CRACKS IN NYLON FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Runs	2	179.969	89.984	7.063*
Procedures	11	144.142	13.104	1.029
Treatment	1	21.355	21.355	1.676
Detergent Concentration	1	1.422	1.422	0.112
Number of Laundries	2	89.519	44.760	3.513*
Treat. x Det. Conc.	1	12.800	12.800	1.005
Treat. x No. of Laundries	2	0.469	0.235	0.018
Det. Conc. x No. of Laundries	2	17.969	8.985	0.705
Treat. x Det. Conc. x No. of Laundries	2	0.608	0.304	0.024
Runs x Procedures	22	280.294	12.741	
Swatches	36	178.299	4.953	1.438
Pieces/swatch	72	516.796	7.178	2.084*
Error	576	1984.306	3.445	
Total	719	3283.814		

* Significant at 95% level.

TABLE XLIII

ANALYSIS OF VARIANCE OF
PITS IN NYLON FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Runs	2	143.168	71.584	2.213
Procedures	11	457.091	41.554	1.285
Treatment	1	19.338	19.338	0.598
Detergent Concentration	1	3.755	3.755	0.116
Number of Laundries	2	224.169	112.084	3.465*
Treat. x Det. Conc.	1	0.200	0.200	0.006
Treat. x No. of Laundries	2	0.869	0.435	0.013
Det. Conc. x No. of Laundries	2	115.086	57.543	1.779
Treat. x Det. Conc. x No. of Laundries	2	93.674	46.837	1.426
Runs x Procedures	22	711.494	32.341	
Swatches	36	220.297	6.119	1.171
Pieces/swatch	72	376.196	5.225	1.317*
Error	576	2284.717		
Total	719	4192.973		

* Significant at 95% level.

TABLE XLIV

ANALYSIS OF VARIANCE OF
SWELLING IN NYLON FIBERS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Runs	2	28.847	14.423	6.390*
Procedures	11	12.056	1.096	0.486
Treatment	1	0.028	0.028	0.011
Detergent Concentration	1	1.778	1.778	0.788
Number of Laundries	2	1.389	0.694	0.308
Treat. x Det. Conc.	1	0.028	0.028	0.012
Treat. x No. of Laundries	2	2.055	2.055	0.910
Det. Conc. x No. of Laundries	2	4.389	4.389	1.945
Treat. x Det. Conc. x No. of Laundries	2	2.389	1.194	1.058
Runs x Procedures	22	49.652	2.257	
Swatches	36	80.000	2.222	1.468
Error	72	108.997	1.514	
Total	143	279.553		

* Significant at 95% level.

TABLE XLV

MEAN NUMBER OF CRACKS IN WOOL FIBERS BY EACH RUN

Runs	Mean	LSD*
3	6.625	1.155
2	6.067	
1	4.596	

TABLE XLVI

MEAN NUMBER OF LOOSE AND ROUGH SCALES IN WOOL FIBERS BY EACH RUN

Runs	Mean	LSD*
2	2.125	1.056
3	1.750	
1	0.646	

TABLE XLVII

MEAN NUMBER OF SWELLING IN WOOL FIBERS BY EACH RUN

Runs	Mean	LSD*
3	1.812	0.286
2	1.812	
1	0.999	

* Significant at 95% level.

TABLE XLVIII

MEAN NUMBER OF ABSENT SCALES IN WOOL FIBERS BY NUMBER OF LAUNDRIES

Number of Laundries	Mean	LSD*
14	0.979	0.226
7	0.541	
1	0.250	

TABLE XLIX

MEAN NUMBER OF CORROSION IN INOCULATED WOOL FIBERS BY SOILED AND UNSOILED TREATMENT

Treatment	Mean	LSD*
1 (soiled)	0.680	0.131
2 (unsoiled)	0.333	

TABLE L

MEAN NUMBER OF CRACKS IN COTTON FIBERS BY EACH RUN

Runs	Mean	LSD*
2	2.592	0.230
3	2.029	
1	1.437	

* Significant at 95% level.

TABLE LI

MEAN NUMBER OF PITS IN COTTON FIBERS BY EACH RUN

Runs	Mean	LSD*
1	4.546	0.809
2	4.008	
3	3.283	

TABLE LII

MEAN NUMBER OF PITS IN COTTON FIBERS BY SOILED AND UNSOILED TREATMENT

Treatment	Mean	LSD*
1 (soiled)	4.340	0.662
2 (unsoiled)	3.492	

TABLE LIII

MEAN NUMBER OF CORROSION IN COTTON FIBERS BY EACH RUN

Runs	Mean	LSD*
3	3.208	0.378
1	1.979	
2	1.896	

* Significant at 95% level.

TABLE LIV

MEAN NUMBER OF CORROSION IN COTTON FIBERS
BY SOILED AND UNSOILED TREATMENT

Treatment	Mean	LSD*
1 (soiled)	2.917	0.562
2 (unsoiled)	1.805	

TABLE LV

MEAN NUMBER OF CORROSION IN COTTON
FIBERS BY NUMBER OF LAUNDRIES

Number of Laundries	Mean	LSD*
14	2.896	0.286
7	2.652	
1	1.562	

TABLE LVI

MEAN NUMBER OF DISSOLUTION OF THE LUMEN
IN COTTON FIBERS BY NUMBER OF LAUNDRIES

Number of Laundries	Mean	LSD*
14	1.500	0.207
7	0.958	
1	0.333	

* Significant at 95% level.

TABLE LVII

MEAN NUMBER OF CRACKS IN NYLON FIBERS BY EACH RUN

Runs	Mean	LSD*
3	2.075	0.890
2	2.054	
1	1.004	

TABLE LVIII

MEAN NUMBER OF CRACKS IN NYLON FIBERS BY NUMBER OF LAUNDRIES

Number of Laundries	Mean	LSD*
14	2.129	0.674
7	1.737	
1	1.267	

TABLE LIX

MEAN NUMBER OF PITS IN NYLON FIBERS BY NUMBER OF LAUNDRIES

Number of Laundries	Mean	LSD*
14	6.267	1.076
7	5.429	
1	4.912	

* Significant at 95% level.

TABLE LX

MEAN NUMBER OF SWELLING IN NYLON
FIBERS BY EACH RUN

Runs	Mean	LSD*
3	2.437	0.286
2	2.042	
1	1.354	

* Significant at 95% level.

TABLE LXI

MEANS FOR FIBER DAMAGE CLASSIFICATIONS IN WOOL FIBERS ACCORDING TO PROCEDURES

Procedure	Types of Damage					
	Cracks	Pits	Loose and Rough Scales	Absent Scales	Swelling	Corrosion
1 (soiled)	5.742	2.864	1.444	0.708	1.680	0.680
2 (unsoiled)	5.717	2.778	1.569	0.472	1.403	0.333
0.0% Det. Conc.	5.972	3.003	1.361	0.625	1.653	0.486
0.2% Det. Conc.	5.486	2.639	1.653	0.555	1.430	0.528
1 Laundry	5.162	2.892	1.042	0.250	1.479	0.250
7 Laundries	5.667	2.862	1.562	0.542	1.458	0.604
14 Laundries	6.358	2.708	1.917	0.979	1.687	0.667
Run 1	4.596	3.142	0.646	0.854	0.999	0.396
Run 2	6.525	3.246	2.125	0.375	1.812	0.604
Run 3	6.067	2.075	1.750	0.542	1.812	0.521

Underlined number indicates the highest mean value for that specific fiber damage classification according to procedure.

TABLE LXII

MEANS FOR FIBER DAMAGE CLASSIFICATIONS IN COTTON FIBERS ACCORDING TO PROCEDURES

Procedure	Types of Damage			
	Cracks	Pits	Corrosion	Dissolution of the Lumen
1 (soiled)	1.805	4.340	2.917	1.055
2 (unsoiled)	2.233	3.492	1.805	0.905
0.0% Det. Conc.	1.764	3.944	2.514	0.917
0.2% Det. Conc.	2.275	3.947	2.208	0.944
1 Laundry	1.996	4.471	1.562	0.333
7 Laundries	1.992	3.767	2.625	0.958
14 Laundries	2.071	3.600	2.896	1.500
Run 1	1.437	4.546	1.979	0.749
Run 2	2.592	4.008	1.896	0.937
Run 3	2.029	3.283	3.208	1.104

Underlined number indicates the highest mean value for that specific fiber damage classification according to procedure.

TABLE LXIII

MEANS FOR FIBER DAMAGE CLASSIFICATIONS IN NYLON FIBERS ACCORDING TO PROCEDURES

Procedure	Types of Damage		
	Cracks	Pits	Swelling
1 (soiled)	1.805	4.340	1.055
2 (unsoiled)	1.883	5.699	1.958
0.0% Det. Conc.	1.667	5.608	2.055
0.2% Det. Conc.	1.755	5.464	1.833
1 Laundry	1.267	5.429	1.875
7 Laundries	1.737	4.912	1.875
14 Laundries	2.129	6.267	2.083
Run 1	1.004	5.104	1.354
Run 2	2.054	6.150	2.042
Run 3	2.075	5.354	2.437

Underlined number indicates the highest mean value for that specific fiber damage classification according to procedure.

TABLE LXIV

ANALYSIS OF VARIANCE OF
CRACKS BY FIBER CONTENT

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Fiber	2	7200.433	3600.217	207.865*
Treatment	1	33.500	4.670	4.669
Detergent Concentration	1	0.778	0.778	0.108
Number of Laundries	2	182.534	91.267	12.722
Runs	2	744.058	372.029	51.860
Fiber x Treat.	2	20.906	10.453	0.603
Fiber x Det. Conc.	2	90.200	45.100	2.604
Fiber x No. of Laundries	4	80.946	20.236	0.163
Treat. x Det. Conc.	1	29.167	29.167	4.066
Treat. x No. of Laundries	2	3.340	1.670	0.233
Det. Conc. x No. of Laundries	2	56.412	28.206	3.932
Fiber x Treat. x Det. Conc.	2	0.334	0.167	0.009
Fiber x Treat. x No. of Laundries	4	98.096	24.524	1.416
Fiber x Det. Conc. x No. of Laundries	4	11.874	2.968	0.171
Fiber x Trest. x Det. Conc. x No. of Laundries	4	58.457	14.614	0.844
Treat. x Det. Conc. x No. of Laundries	2	2.362	1.181	0.165
Fiber x Run	4	83.404	20.851	2.906
Treat. x Run	2	20.548	10.274	1.432

TABLE LXIV (Continued)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Det. Conc. x Run	2	18.915	9.457	1.318
No. of Laundries x Run	4	155.030	38.757	5.403
Fiber x Treat. x Run	4	43.832	10.985	1.527
Fiber x Det. Conc. x Run	4	270.142	67.535	9.414
Fiber x No. of Laundries x Run	8	239.764	29.970	4.178
Treat. x Det. Conc. x Run	2	19.248	9.624	1.341
Treat. x No. of Laundries x Run	4	5.391	1.348	0.188
Det. Conc. x No. of Laundries x Run	4	100.107	25.027	3.489
Fiber x Treat. x Det. Conc. x Run	4	73.404	18.351	2.558
Fiber x Treat. x No. of Laundries x Run	8	116.819	14.602	2.035
Fiber x Det. Conc. x No. of Laundries x Run	8	201.258	25.157	3.507
Treat. x Det. Conc. x No. of Laundries x Run	4	48.902	12.225	1.704
Fiber x Treat. x Det. Conc. x No. of Laundries x Run[1]	8	138.536	17.317	2.414
Error	2052	14720.492	7.174	
Total	2159	24869.250		

[1] Error term used to figure F value for fiber and the interactions of fiber with detergent concentration, treatment, number of laundries and run.

TABLE LXV

ANALYSIS OF VARIANCE OF
PITS BY FIBER CONTENT

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Fiber	2	2680.155	1340.077	136.547*
Treatment	1	26.667	26.667	2.709
Detergent Concentration	1	15.335	15.335	1.558
Number of Laundries	2	71.392	35.696	3.626
Runs	2	318.484	159.242	16.178
Fiber x Treat.	2	142.519	71.260	7.261*
Fiber x Det. Conc.	2	12.257	6.128	0.624
Fiber x No. of Laundries	4	259.993	64.998	6.623*
Treat. x Det. Conc.	1	3.918	3.918	0.398
Treat. x No. of Laundries	2	25.433	12.717	1.292
Det. Conc. x No. of Laundries	2	56.781	28.391	2.884
Fiber x Treat. x Det. Conc.	2	57.462	28.730	2.927
Fiber x Treat. x No. of Laundries	4	19.130	4.783	0.487
Fiber x Det. Conc. x No. of Laundries	4	256.209	64.052	6.527*
Fiber x Treat. x Det. Conc. x No. of Laundries	4	67.232	16.808	1.713
Treat. x Det. Conc. x No. of Laundries	2	35.737	17.868	1.815
Fiber x Run	4	218.917	54.729	5.560
Treat. x Run	2	2.969	1.484	0.151

TABLE LXV (Continued)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Det. Conc. x Run	2	19.795	9.897	1.005
No. of Laundries x Run	4	154.196	38.549	3.916
Fiber x Treat. x Run	4	129.777	32.444	3.296
Fiber x Det. Conc. x Run	4	204.712	51.178	5.199
Fiber x No. of Laundries x Run	8	377.300	47.162	4.791
Treat. x Det. Conc. x Run	2	334.300	167.370	17.004
Treat. x No. of Laundries x Run	4	108.072	27.018	2.745
Det. Conc. x No. of Laundries x Run	4	79.879	19.969	2.028
Fiber x Treat. x Det. Conc. x Run	4	305.179	76.294	7.751
Fiber x Treat. x No. of Laundries x Run	8	374.629	46.829	4.757
Fiber x Det. Conc. x No. of Laundries x Run	8	220.128	27.516	2.795
Treat. x Det. Conc. x No. of Laundries x Run	4	88.662	22.166	2.252
Fiber x Treat. x Det. Conc. x No. of Laundries x Run[1]	8	78.517	9.814	0.997
Error	2052	20197.906	9.843	
Total	2159	26944.141		

[1] Error term used to figure F value for fiber and the interactions of fiber with detergent concentration, treatment, number of laundries and run.

TABLE LXVI

ANALYSIS OF VARIANCE FOR BURSTING STRENGTH

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Treatment	1	112.997	112.997	6.228*
Detergent Concentration	1	12.840	12.840	0.708
Number of Laundries	2	166.823	83.412	4.597*
Runs	2	462.111	231.056	12.735*
Treat. x Det. Conc.	1	12.840	12.840	0.708
Treat. x No. of Laundries	2	27.687	13.843	0.763
Det. Conc. x No. of Laundries	2	53.792	26.897	1.482
Treat. x Det. Conc. x No. of Laundries	2	17.083	8.541	0.470
Error	22	399.153	18.143	
Total	35	1265.329		

* Significant at 95% level.

TABLE LXVII

ANALYSIS OF VARIANCE FOR PERCENTAGE OF ELONGATION

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Test for Significance
Treatment	1	5.444	5.444	0.155
Detergent Concentration	1	48.999	48.999	1.397
Number of Laundries	2	242.889	121.444	3.462*
Runs	2	17.556	8.778	0.250
Treat. x Det. Conc.	1	0.111	0.111	0.003
Treat. x No. of Laundries	2	62.889	31.444	0.896
Det. Conc. x No. of Laundries	2	97.999	48.999	1.398
Treat. x Det. Conc. x No.of Laundries	2	73.555	36.778	1.048
Error	22	771.774	35.081	
Total	35	1321.219		

* Significant at 95% level.

TABLE LXVIII

MEAN BURSTING STRENGTH OF INOCULATED FABRICS
BY SOILED AND UNSOILED TREATMENT

Treatment	Mean[1] (pounds)	LSD*
Soiled	108.998	2.442
Unsoiled	112.541	

TABLE LXIX

MEAN BURSTING STRENGTH OF SOILED-INOCULATED AND UNSOILED-INOCULATED FABRICS BY NUMBER OF LAUNDRIES

No. of Laundries	Mean[1] (pounds)	LSD*
14	108.267	2.992
7	110.518	
1	113.522	

TABLE LXX

MEAN BURSTING STRENGTH OF SOILED-INOCULATED AND
UNSOILED-INOCULATED FABRICS BY EACH RUN

Run	Mean[1] (pounds)	LSD*
2	106.364	2.992
3	110.804	
1	115.140	

[1] Ranked in descending order.

* Least significant difference at the 95% level.

TABLE LXXI

MEAN PERCENTAGE OF ELONGATION OF SOILED-INOCULATED AND UNSOILED-INOCULATED FABRICS BY NUMBER OF LAUNDRIES

No. of Laundries	Mean[1] (pounds)	LSD*
14	97.333	4.197
1	98.499	
7	103.333	

[1] Ranked in descending order.

* Least significant difference at the 95% level.

TABLE LXXII

BURSTING STRENGTH OF SOILED-INOCULATED AND UNSOILED-INOCULATED FABRICS ACCORDING TO DETERGENT CONCENTRATION, NUMBER OF LAUNDRIES AND RUN

		Fabric Treatments					
Det. Conc.	No. of Laundries	Soiled-Inoculated			Unsoiled-Inoculated		
		Pounds			Pounds		
		Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
0.0%	1	116.81	104.91	112.62	126.95	112.40	120.56
	7	115.05	102.04	112.62	119.90	106.10	106.67
	14	106.89	100.28	109.76	115.27	106.10	106.67
0.2%	1	113.28	105.13	111.96	122.10	106.23	109.23
	7	115.05	102.04	112.62	116.81	108.00	106.23
	14	102.27	111.52	107.11	111.30	111.71	110.42

TABLE LXXIII

PERCENTAGE OF ELONGATION OF SOILED-INOCULATED AND UNSOILED-INOCULATED FABRICS ACCORDING TO DETERGENT CONCENTRATION, NUMBER OF LAUNDRIES AND RUN

		Fabric Treatments					
Det. Conc.	No. of Laundries	Soiled-Inoculated			Unsoiled-Inoculated		
		Percent			Percent		
		Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
0.0%	1	92	94	100	106	96	108
	7	96	114	106	100	102	98
	14	106	100	96	102	108	92
0.2%	1	96	96	100	104	90	100
	7	100	110	100	98	112	104
	14	98	94	90	96	92	94

A QUANTITATIVE MICROSCOPIC AND PHYSICAL ANALYSIS OF DAMAGE CAUSED BY *TRICHOPHYTON MENTAGROPHYTES* ON A KNITTED WOOL-NYLON-COTTON FABRIC

by

TONDA HIGHLEY DIECKHOFF

B. S., Fort Hays Kansas State College, 1970

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Clothing, Textiles and Interior Design

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1971

This study was designed to examine damage of fibers by microanalysis, and analyze bursting strength and elongation of a knit footwear fabric after exposure to Trichophyton mentagrophytes. The fabric composed of 50% wool, 30% nylon and 20% cotton was laundered one, seven and fourteen times before inoculation to determine the susceptibility of the footwear fabric to microbial attack after progressive laundering. After treatment with soil or no soil and inoculation with Trichophyton mentagrophytes, the fabric was held in an environmental chamber for eight days at 25° C. and 80% relative humidity, laundered and sterilized. Two swatches were drawn from a group of five for observation. Swatches were divided into four pieces; fibers were withdrawn and mounted permanently on slides for observation. Five fields of view were randomly chosen for each fiber per slide and representative types of damage were photographed. Physical analysis was made on a Constant Rate of Extension Tester.

Preliminary microscopic study revealed that variation in fiber damage increased as the size of the area studied decreased and that fiber damage does not vary from the outside to the inside of a fabric swatch.

Effect of soil versus no soil on the inoculated fabric was statistically significant in the number of pits and corrosion in cotton fibers and in the bursting strength. Detergent concentration was not significant for all observed types of damage in any of the textile fibers or for loss of strength and elongation in the fabric. Number of laundries before inoculation was significant in damage for all fibers and for loss in bursting strength and percentage of elongation.

Repetition of the experimental sequence was significant in damage of wool, nylon and cotton fibers and in loss of bursting strength. Type of fiber proved to be significant in the occurrence of cracks and pits.