THE EFFECTS OF VARIOUS LAUNDRY TEMPERATURES, OBSERVATION POINTS, AND DETERGENT CONCENTRATIONS ON THE SURVIVAL OF TRICHOPHYTON MENTAGROPHYTES ON MILITARY SOCK FABRIC

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B. S., Kansas State University, 1970

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:

Major Professor

ACKNOWLEDGMENTS

The author wishes to recognize the members of her graduate committee for their assistance in planning, and carrying out the research. Sincere appreciation goes to Dr. Jessie Warden, major professor and head of the Department of Clothing, Textiles, and Interior Design; to Dr. Donald C. Kelley, professor in the Department of Infectious Diseases; and to Dr. Shirley E. Friend, Assistant professor in the Department of Clothing, Textiles, and Interior Design. A special thanks is also given to Mr. Gary Plumberg and Gary Fina for their suggestions and assistance in the bacteriological wark. This research was sponsored and funded by the T.H.E.M.I.S. project of the United States Air Force.

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INTRODUCTION

Disability from skin diseases among American troops in Vietnam engaged in combat in warm wet areas is often the greatest medical cause of non-effectiveness. The most common infection is produced by the dermatophyte Trichophyton mentagrophytes. This parasitic fungus produces the clinical conditions of tinea pedis, (athlete's foot), and ringworm (Blank et al., 1969).

Tinea pedis is not a problem in countries whose inhabitants are habitually barefooted, however hot and damp the climate or poverty-stricken the people. This fact is well attested in Southeast Asia. Only the combat troops who wear socks and boots are affected by the fungus. This disease is also a problem in the United States with its high living standards. The people of the United States and the combat soldiers in Southeast Asia bare their feet in swimming, showers, communal ablutions, or wade through swamps, pick up a fungal inoculum, and then carefully incubate the organism in the ideal environment provided by the shoes and socks they wear (English, 1969). Thus the purpose of this research is to study the effects of home laundry procedures on the growth and survival of Trichophyton mentagrophytes which has been inoculated on military sock material.

In the United States, there is a strong school of thought holding that almost everyone carries the causal fungi on symptom-free feet, and the clinical lesions only flare up when some change in the host's resistance allows the fungi to proliferate (Fosenthal et al., 1956). However, other American workers (George, 1960) support the view most commonly held in this country and elsewhere, that the disease is infectious and that, though a few people are carriers of the causal fungi, the vast majority are either free

of the organism or else have frank lesions of the skin or nails. The majority of published reports support the theory of exogenous infection (English, 1969).

Accepting that cross-infection is the most important cause of tinea pedis, means of reducing this cross-infection need to be studied. Since the most common source of infection appears to be fragments of skin or nails shed from an infected person, an uninfected person could become infected or reinfected by wearing socks which, because of improper laundry procedures, have become contaminated with the virulent organism Trichophyton mentagrophytes. It has been found by Blank et al. (1969) that much of the laundry in Vietnam is done by native girls in the local streams. The clothing itself may be heavily seeded with spores and may be a source of infection.

The importance of the laundry in disease transference is apparent from research previously done in this area. According to McNeil (1961), the ability or inability of a potentially harmful microorganism to survive and multiply in a textile material could influence foot health and serviceability of the fabric. Conversely, microbial survival could be dependent upon the textile fabric itself. Increasing use of household automatic clothes washers in self-service public installations, the use of cold water detergents in cold water, and shorter washing cycles have all focused the attention of many authorities on the possibility of the spread of diseases among families using these facilities. The American Public Health Association (1960) lists about forty communicable diseases caused by bacteria, viruses or fungi which are capable of being indirectly transmitted through articles freshly soiled be discharges from infected persons (Ridenour, 1950).

That dermatophytic infections are still a major military problem as well as a civilian problem in developed countries, points directions of research in the prevention of dermatophytic infections spread by inadequate

laundry.

Research has shown that viable microorganisms have been recovered and enumerated from test launderings under various conditions, but to this date, little specific investigation has been done on the viability during laundry and the specific state of activity of the dermatophyte Trichophyton mentagrophytes under known conditions.

It is obvious that acquisition of information on the subject is dependent on an effective method for recovering the viable organism from the fabric. Therefore the objectives of the present study are to: (1) experiment with efficient methods of recovery of the specific organism, (2) determine the effect of water temperature and soiling in a home laundry situation upon the specific organism, (3) determine the transference, if any, of the organism during the washing process, (4) and to study the interaction of detergent concentration, water temperature, and agitation time on the specific organism.

KEY WORDS

Completed Wash Cycle - the completion of the washing, spray rinse, deep rinse, and spin drying

Run - the number of repetitions of the procedural sequence for the two detergent concentrations, the three variable preliminary launderings, and the four treatments

Survival of Organism - the presence of the specific test organism Trichophyton mentagrophytes on the culture plates

Swatch - the 12 by 8 inch rectangle of fabric cut from the original knitted tubes (and used for innoculation and laundering).

Samples - the one-inch squares, which are cut from the 12 by 8 inch swatch and are plated to determine growth of the specific organism

Treatment - the particular variable substances applied to the fabric swatches before innoculation or laundering

Observation Period - the point in the laundry sequence (after 2 minutes of agitation, after the completed wash cycle, or after drying) in which samples were cut and plated

REVIEW OF LITERATURE

Introduction

The fate of microorganisms in a laundering operation may depend upon a number of physical and chemical factors such as the nature of the water and the washing agents, the temperature and time schedule, and the concentration of the washing agents.

Trichophyton mentagrophytes

By far the most common type of fungus disease in man is dermatophytosis, a superficial infection of the keratinized epidermis and keratinized epidermal appendages, the severity of which is dependent for the most part upon the location of the lesion and the species of fungus involved (Burrows, 1968). Dermatophytes are the most frequently encountered among fungi parasitizing man. They produce predominantly superficial lesions, affecting skin and its appendages, hair and nails. Botanically the dermatophytes constitute a closely related group within the Fungi imperfecti. The spores formed are all asexual conidia (Paldrok, 1953). The majority of the organisms grow readily on laboratory mediums and also grow on such substrates as cereal grains, shed hairs, horn debris, and sterilized fragments of straw in moist tubes. If protected from dryness, they may live on the wooden floors of shower rooms, dressing rooms, and dressing cabins, and on mats for a considerable time. Furthermore, various dermatophytes have been isolated from soil and air, and it is probable that dermatophytes live a saprophytic existence, that was formerly unrecognized. Some dermatophyte species appear to be so closely adapted to man that they are unable to infect lower animals; human infection is transmitted by contact. But animals such as the cat and dog are natural hosts, and human infection may be acquired from them

(Burrows, 1968).

Trichophyton mentagrophytes forms small spores and occurs in chains inside or outside of hair. In general Trichophyton infections show a characteristic tendency to produce an inflammatory reaction with deep infiltration of the skin (Burrows, 1968). The culture of Trichophyton mentagrophytes varies from a powdery type to a cottony type. The powdery strains are considered to be the causative agents in deeper clinical processes, whereas the cottony strains are limited to more superficial lesions (Paldrok, 1953).

Trichophyton mentagrophytes does not produce an infection of the internal organs; rather the microorganisms introduced tend to become localized in the skin and to develop where it is damaged as by scarification. Growth of the fungus in the skin and hair is more or less equal in all directions, and the lesions produced tend to have a circular form. The clinical conditions produced are termed: tinea pedis (athlete's foot); tinea corporis (ringworm of the body); tinea capitis (ringworm of the scalp); tinea cruris (ringworm of the groin); tinea ungium (ringworm of the nail); and tinea imbricata (a special concentric ring form) (Burrows, 1968).

Skin Infections as a Military Problem

Skin infections among military personnel engaged in operations in tropical climates are an important cause of discomfort and disability. In spite of the advances in antibiotic theropy in recent years, dermatological casualties still represent a large proportion of cases seen on sick call by field medical officers. The drain on man power may exceed that caused by casualties due to enemy action (Taplin et al., 1964).

According to studies done by Blank et al. (1969), disability from skin diseases among American troops in Vietnam engaged in combat in warm wet

areas is often the greatest medical cause of noneffectiveness. Infections are the leading causes of cutaneous disease. The most common infection found to be produced was produced by Trichophyton mentagrophytes.

The statement by a military commander that "the fighting strength of troops, such as those in the Mekong delta region of Vietnam, would almost double by improving prevention and treatment of dermatological disorders" poses a real challenge to the military and to those concerned with dermatology (Blank et al., 1969).

Skin problems are reported as the fourth most common cause of hospitalization in the army. Hospital admission rates alone however, are an inadequate measure of the dermatologic problems because many of the men, although unfit for field duty, are not hospitalized. The following examples of units under prolonged cutaneous stress indicates how prominate the problems can become in the front line combat man. One army combat unit of 450 men had 106 of the men incapacitated for field duty by skin problems in one week in September of 1967, in the Mekong delta region of South Vietnam. In August of 1967, one infantry brigade reported that of 209 men requiring hospitalization, 77 per cent were for "foot infections." In the northern part of the country, around Da Nang, the United State's Marines noted that in August of 1967, of 2800 hospitalizations for all causes, 1150 were for skin diseases. In other months the proportions were one half to one third of this figure. In the Air Force at Cam Rahn Bay, skin diseases also were common, with fungous infections as the most common outpatient complaint (Blank et al., 1969).

The degree of cutaneous disability was found to be variable depending upon the weather, the terrain, and the nature of the military operation. Also important were the availability of clean, dry clothing, facilities for good personal hygiene, and a dry place to sleep at night

(Blank et al., 1969).

The most common form of dermatophytosis was Trichophyton mentagrophytes infection which often extended over much of the body surface. In a mycologic study in the Mekong delta region of Vietnam, of 58 men whose skin was often wet for prolonged periods, fungi were demonstrated in 65 of 91 skin lesions studied. The area of the body involved in 142 examined cases definitely pointed to the feet and lower leg. Sixty-nine of the men showed recognizable fungous infection on the ankles and lower legs, 63 involved the dorsa of the feet and 23 involved between the toes and the soles of the feet (Blank et al., 1969).

Blank et al. (1969) stated that dermatophytic infections are still a major military problem in spite of the antibiotic Griseofulvin, which has been used as the drug of choice in treatment. Unfortunately there has been a serious lag in studies of the epidemiology and prevention of these conditions. Almost no specific measures to prevent the mycologic disease and disability have been applied to this problem. In spite of greater knowledge and better drugs, Trichophyton mentagrophytes continues to account for much of the extremely high rate of disease among combat troops.

Clothing as a Means of Transference

Investigations made by Szathmary (1968) further the findings of Ajello (1956) that the soil is a natural reservoir for human pathogenic fungi. Szathmary (1968a) stated that the dust which settles on clothes renders the clothes spore-bearing as well. The origin of human trichophytosis, in spite of thorough investigation, is not yet completely known. Since trichophytosis continually occurs, the origin of which cannot be otherwise explained, the infection of the clothing as a means of transference of the

organism has to be regarded as suspicious. Szathmary (1968) cited the following cases of infection. A five year old child became infected with dermatosis on her interscapular tract 8 to 10 days after her shirt had fallen on the ground from the clothes line. Most frequently cited are the cases which occur in which the disease was restricted to the neck area. The centers of infection lay in the line of friction caused by the collar of the clothing. Cultures taken from these lesions were often accompanied by organisms found in the soil.

Clinical observations also verify the assumption that fabric may be a reservoir for pathogenic fungi. In the case cited, a six year old boy who used to sumersault on an old carpet, was taken ill with trichophytosis on the top of the head eight days later. The carpet had been used constantly and had been exposed to soiling by dirt (Szathmary, 1968).

It is hard to estimate which fibers of textiles are most suitable for the fungi, setting colonies on clothing, because not only the quality, but the method of manufacturing, the treatment before weaving, as well as the further course of the ready fabric, especially staining, are factors which have an influence on the life of fungi growing on them (Szathmary, 1968b).

Ajello and Getz (1954b) studied 100 pairs of shoes that had been in storage for periods of one to four weeks in a prison storeroom. Scrapings were made of the inner soles of these shoes and plated with agar. Fifteen of the 100 pairs of shoes examined were found to yield cultures of dermatophytes. Trichophyton rubrum was recovered from one pair of shoes, and Trichophyton mentagrophytes was obtained from 14 sets of these shoes. In addition, Trichophyton mentagrophytes was isolated from the tile flooring of shower stalls in the prison.

Although tinea pedis is a minor disease, nevertheless it

frequently is a cause of severe discomfort and disability. The economic burden caused by this disease is considerable as trade figures in the United States reveal. In the United States alone $10,000,000 are expended annually for prescribed medicine to combat tinea pedis. In addition to the above figure, many more millions of dollars that are spent for proprietary and patented medications (Ajello, 1954).

With the demonstration that dermatophytes have been isolated from the environment, it is apparent that any treatment directed solely at the feet is inadequate to control the disease. Topical agents are often impractical for widespread body areas, the required repeated applications may not be feasible, especially under combat conditions in Vietnam because the agents are often quickly washed off under wet conditions (Blank et al., 1969). Dermatophytes may be resistant to the treatment of choice, Criseofulvin by mouth. The problems of obtaining pills under combat conditions, of keeping them dry, and of remembering to take them daily is significant (Blank et al., 1969).

Ajello (1954) stated that effective control measures of Trichophyton mentagrophytes must go beyond the body and must also include eradication of the organism in shoes, clothing, and other inanimate reservoirs in the environment to prevent reinfection.

Importance of Laundry in Disease Transference

There are many different types of organisms of both the saprophytic and pathogenic variety that can be incorporated into clothing. Potentially, many kinds of diseases may be transmitted through the medium of clothing. The viability and state of activity of such organisms are dependent upon a variety of factors. Some of the organisms, adapted to living

in or on the human body, may readily succumb once they leave the body; others may survive and multiply slowly, if at all; still others may adapt themselves completely; some may lie dormant in the spore state also (Ridenour, 1950).

Soil removal is achieved in a washing machine by: (1) mechanical and detergent action which dislodge soil from the fabric, and (2) by flushing and dilution which reduces the concentration of soil in the wash solution. The removal of microorganisms occurs in the same way. Microorganisms attached to soil are lifted from the fabric and are suspended in the wash solution (Marmo, 1969a).

To efficiently remove bacteria from cloth or to prevent redeposition of bacteria on cloth, the organism must be removed by the physidal means of dilution or by chemical treatment of the water resulting in chemical desorption followed by dilution (Marmo, 1969a). This, in effect, is the principle around which a clothes washer is constructed, namely chemical desorption by means of detergents in the wash cycle and additional desorption by dilution in the following rinse cycles. But complete bacteria removal cannot be achieved through detergency and dilution alone. Ridenour (1950) concluded that the task of completely destroying bacteria was the job of heat and chemical additives.

It is true that the destruction of bacteria can be achieved entirely with chemicals rather than with high heat, but there are compelling reasons which favor the latter method: (1) It is less expensive to use heat. Hot water is already available because it is necessary for proper soil removal. (2) It is easy to control the amount of heat. Water temperature can readily be maintained within five degrees Fahrenheit of the desired temperature. (3) Careful supervision is required to insure addition of the proper amount of chemicals. A mistake of twice the desired amount, or one

half, can easily occur. (4) An excess of heat, except for a few special fabrics, will not harm the fabrics. (5) An excess of chemicals can often create undesirable and irreversible changes in the fabric. (6) It is absolutely necessary to neutralize or rinse out certain chemicals which may be potentially harmful to the user (Marmo, 1969c).

In 1969, random samples were taken from 40 home or coin-operated washing machines in the San Fernando Valley, California area. The tests showed that bacteria was never completely eliminated from the washing machines and contaminated succeeding washes. The design of the machines and the use of low water temperatures in short washing cycles were blamed for the problem (The Kansas City Times, 1969).

Ruppert (1950) conducted a limited investigation of clothes washer bacteriology in the field. These studies were confined to gross qualitative analysis of wash water samples. Of forty-six samples examined, the organisms found most often were micrococci. Fungi were noted in seventeen of the samples.

Gilson and Bartfeld (1948) studied the public health aspects of self-service clothes washers. They found that at the relatively low temperatures of hot water used, soap wash and repeated rinsing did not disinfect the clothing; and removal of the wash left the washer bacterially contaminated for the next user. Likewise where higher temperatures were maintained in automatic clothes washers, bacterial flora was equally decreased.

The fact that articles of transmission such as socks, towels, sheets, and other items of wearing apparel are handled by more than one member of the family and are washed with other uncontaminated items in the laundry, reveals the tremendous importance laundry can play in the role of public health. For example, The American Public Health Association stated

that ringworm was possibly transmitted indirectly by articles of wearing apparel or towels or by surfaces contaminated with scales or hair from such lesion (Ridenour, 1950). Examples of bacterial and fungal contamination of clothes and bedding from skin lesions was also cited by McNeil (1961).

Effect of Water Temperature

The temperature of the washing medium in the home depends upon the thermostat setting and capacity of the water heater, and how much hot water has been used for other purposes in the home. Very few homemakers have any conception of what temperature is adequate for cleaning clothes. Although much emphasis in advertising has been put on detergents and washing machines, they cannot do the job alone. Water is the basic ingredient for washing.

Washing temperature is still an important factor in determining the amount of soil removed by detergents, even those sold as cold water agents. Schimpf (1969) reported that water temperature was found to be the most significant variable in bacterial removal and redeposition of microorganisms during the laundry process. Arnold (1938) reported after a year's study of commercial laundries that there appeared to be few sanitary problems connected with laundry practices which utilize high temperatures of 165° to 175°F. He pointed out that low temperature operations of about 100°F. might present bacterial problems. Bacteria grew in deposits within the machine and subsequent washings were contaminated. Galbraith (1960) reported that on most fibers, washing at either 120° or 140°F. would remove more soil than would washing at 100°F. which, in turn removed more soil than washing at 70°F.

Certain changes in our way of life indicate a re-examination of bacteriology and the water temperature used in home laundry. Many home

washing machines now have a "cold," "warm," and a "hot" water wash temperature. This is largely a result of recommendations by manufacturers that certain fabrics will maintain a better appearance if washed in warm or cool water. The United States Department of Agriculture (1967) found that such water temperatures range from 57° to 100°F. Their survey also indicates that water temperatures at the "hot" water setting in home washers generally range from 125° to 135°F., and the average water temperature of coin-operated machines was only 128°F. McNeil (1961) states that unless water temperature is very high, large numbers of microorganisms are introduced and may remain in the tub. Schimpf (1969) found that even the use of 140°F. hot water left traces of the organism Staphyloccus aureus on test fabric and resulted in the redeposition of the organism to other fabric during laundry.

Cold water detergents have been found to be as dependent on temperature for their cleaning ability as were the conventional laundry detergents (Galbraith, 1960), and on July 8, 1969, the United States Department of Agriculture prohibited the labeling of cold water detergents as being "germproof" (Anon., 1969).

Because of the lack of data available on the effect of washing temperature on the organism Trichophyton mentagrophytes, or for that matter on fungus in general, the following laboratory studies are presented.

Laboratory Studies of the Effect of Temperature on Trichophyton mentagrophytes

Sabouraud stated that dermatophytes grew best over a range of 15° to 30°C. (59°-86°F.), and that their growth was retarded at 12°C. (52°F.) (Paldrok, 1955). Trichophyton mentagrophytes has been reported to grow at temperatures between 11 and 35°C. (52°-95°F.). One strain of Trichophyton mentagrophytes has been found to grow fairly well even at 40°C., whereas

the growth of strains of the type persicolor of the same fungus was inhibited at this temperature. It was also found that the resistance of the cultures, on the whole, depended on the degree of their development, the more developed ones being more resistant. Trichophyton mentagrophytes has been found to grow most rapidly at 35°C. (95°F.). The optimum temperature for growth and sporulation was reported to be 25° to 30°C. (77° to 86°F.) (Paldrok, 1955). Paldrok (1955) listed the cardinal points of temperature for vegetative growth of the organism to be 6°C. (43°F.) minimum, 31°C. (88°F.) optimum, and 44°C. (111°F.) maximum.

Exposure to high temperatures has been found to injure the conidia. The germination of Trichophyton tonsirans spores exposed within water for 10 minutes, resulted in increasing retardation as the temperature increased from 40 to 46°C. Gabrielson (1960) found that conidia were less resistant than mycelia. Paldrok (1955) also reported that the optimum temperature for sporulation seems to lie some degrees centigrade below the optimum for the vegetative growth.

Laboratory data on the thermal destruction of microorganisms can sometimes be misleading. Under these conditions, the microorganism is distributed evenly in solution, and are directly affected by heat. But in practical situations, the microorganism is present in soil and cannot be attacked directly. This can greatly increase the temperature required to kill (Marmo, 1967b). Thus it is extremely important to take into consideration the factor of soil and a more practical research situation such as actual laundry conditions.

Effect of Detergents and Detergent Concentration

Manufacturers have produced such an array of synthetic detergents

and soaps that homemakers have a difficult decision as to which product they will use. Most often this decision depends on advertisements, testimonies by other homemakers, and sales for obtaining products at reduced costs (Anderson, 1965). The homemaker has need for a better basis for choosing the supplies used in washing. The homemaker usually merely adds detergent to wash water until enough suds appear to please her. Although some manufacturers give directions for using a specific amount, few homemakers have measuring devices available near the laundry center. Even if she does measure the detergent, she does not know whether or not she is getting the best cleaning from the most economical use of the detergent.

A good home laundering detergent is a substance which is capable of removing many types of soil from fabrics of highly varied fiber content and which can then hold the removed soil and bacteria in emulsion or suspension in the washing water during the remainder of the laundry time. Private market research surveys have shown that housewives tend to under-use detergents. It was found that heavy duty detergents were superior in removal of soil followed by the low or controlled suds, the built liquids, the unbuilt solid, and finally by cold water detergents. Results indicated that increasing the detergent concentration from 0.1% to 0.2% increased the percentage of soil removal, but a further increase in concentration to 0.3% did not produce an equal increase in soil removal except in the case of wool. This finding is in agreement with Kohler's (1954) findings that an increase of the soap concentration over and above that required for the dispersion of dirt did not appreciably improve the detergent effect.

Schimpf (1969) found that as the detergent concentration increased, there was a decrease in bacterial survival on fabric at the end of the wash cycle, drying period, and also a decrease in bacterial redeposition.

Davis (1963) reported that with each of the detergent systems he studied, soil removal increased dramatically with detergent concentration up to about 0.5%. Beyond that point, there was a slow increase for the high foaming system. The reason for this decrease was found to be the excess sudsing which either reduced mechanical action or depleted the wash solution by foam factionation.

It has long been known that washing in hard water, especially with soap, produced inferior results. This generalization is still valid even though the addition of large amounts of polyphosphates to modern built detergents increases the efficiency of detergents in hard water. The use of synthetic surfactants in place of soap also contributes to this increased efficiency (Anderson, 1964).

During the past 15 to 20 years, built synthetic laundry detergents have developed into complex mixtures of antiredeposition agents, brightners, builders, softners, enzymes, and an array of surface active ingredients.

Phosphates are of critical importance in modern laundry detergents because, in combination with other detergent ingredients, they perform a number of unique functions. Phosphates increase the efficiency of dirt removal, keep the dirt suspended, maintain the proper alkaline balance for efficient cleaning, make oil and grease removal easier, soften water, and reduce the level of germs in fabric and greatly reduce the risk of infection from fabric (FMC Corporation, 1979).

The enzymes in detergents are biologically active catalysts which break down soils and stains into less complex forms. The hydrolysis reaction by which enzymes work is very specific. Enzymes react only with protein or starchy material, and therefore will not damage fabrics. Enzymes are destroyed above 180^{o}F. and require at least 30 minutes to reach their full

effectiveness. Therefore, in a ten minute wash cycle, enzymes do not reach maximum effectiveness. The two most important types of enzymes in detergents are protease enzymes, which break down protein, and amylase enzymes which attack starch (Colgate Polmolive Company, 1969).

Laboratory Studies of the Effect of Detergent Concentration on Trichophyton mentagrophytes

Few investigations appear to have been made regarding the effect of detergents on dermatophytes. Pfister (1952) reported that several washing powders had no fungicidal effect on Trichophyton rubrum. He used detergent concentrations of up to 0.10%. Gip (1964) examined the anti-mycotic effect in vitro and found that detergent concentrations of 1/100 or .01% had a fungistatic effect on both Trichophyton mentagrophytes and Trichophyton rubrum. However, the study found that the fungicidal effect of the detergent was little, and a concentration of detergent higher than 0.10% was needed to extinguish the tested dermatophytic strains within one hour.

Effects of Agitation Time

Results of data show that soil removal proceeds very rapidly occuring mostly during the first five minutes of washing (Davis, 1963). This observation is in good agreement with results reported in the 1954 intersectional contest paper at the Washington Section American Association of Textile Chemists and Colorists. The authors of the above paper showed soil removal equal to about 87% during the first four minutes of washing. Kohler (1954) also reported that a prolongation of the time at maximum temperature, other factors being equal, resulted in a general increase in detergent action. This increase was found to be practically proportional to the time if the latter was prolonged from 2 to 30 minutes.

Ridenour (1950) found that if heavily contaminated material was washed in the same load with lightly contaminated material, an equilibrium was approached for all material in the load due to redeposition. This amount of redeposition was found to depend upon the length of the wash cycle.

Effect of Drying

Drying after wash does not sufficiently decrease bacterial count in contaminated fabrics. In a preliminary study of possible sanitizing or contaminating effects from drying clothes in a tumble dryer, Ridenour (1950) indicated that sanitization by a dryer cannot be considered as a substitute for good detergency or chemical sanitization in the wash or rinse cycles.

Schimph (1969) also concluded that tumble drying at a delicate setting could not be relied upon for sanitation. It was found that the low temperatures of the delicate setting was not hot enough to destroy the bacteria in the cloth.

Effect of pH

Better growth of many fungi is obtained on neutral or slightly alkaline media (Difco Laboratories, 1953). Cidal action is very sensitive to pH. Marmo (1969c) cited that at a pH of 8 a 99% kill of Bacillus Metiens spores took nine minutes; at pH 10, it took almost 10 times as long.

Summary of Review of Literature

Research has indicated that the fungus Trichophyton mentagrophytes continues to account for much of the extremely high rate of disease among combat troops in tropical climates. Transmission of the organism through the medium of clothing and insufficient laundry procedures seems to be indicated. It has been found that wash temperatures of 140°F. or higher, a

detergent concentration between 0.2 and 0.5%, and a prolongation of agitation time are needed to effectively remove soil and microorganisms during laundry. Drying has little, if any, effect on removal of the microorganism.

PROCEDURES

Laundry Equipment

The equipment used in this study consisted of a home automatic top-loading washer and an automatic tumble dryer.

Because small swatches and small loads of two pounds or less were washed, a small plastic inner tub called a "mini basket" was used with a low water setting of 25 liters. The length of the wash cycle was ten minutes. Agitation was delicate or approximately 85 rpm's. A medium spin speed spun out the wash water and was followed by a spray rinse to remove the detergent from the cloth. After a short pause and the rinse fill, the activated deep rinse cycled three minutes. Upon completion of the rinse period, the washer again paused a moment and then began the final spin, leaving the cloth damp dry. The completed wash cycle took 35 minutes.

The drying cycle was regulated by an electronic sensor which automatically determined when the cloth was perfectly dry. This drying time was approximately 30 minutes. A permanent press cycle setting having a cooler air temperature of 126°F. and an automatic cooldown period was used to reduce shrinkage of the wool fiber present in the fabric swatches.

Water Temperature

Three water temperatures were used for the study. A hot wash of 140 ± 2°F., and medium hot wash temperature of 120 ± 2°F. with a rinse temperature of 100 ± 2°F., and a warm water wash temperature of 100 ± 2°F. with a rinse temperature of 90 ± 2°F. were used. The water temperature was regulated by the use of a small electric hot water heater which heated only water for the laundry equipment. In this way, the water temperatures were held constant for the purposes of this research.

Preliminary testing indicated that the water used for the laundry procedure had a hardness of 7 grains and a pH of 7.0 to 8.0.

Detergent

Preliminary interviews in the fall of 1958 and again in 1970 were taken in the Manhattan, Kansas area to help establish a laundry procedure that would simulate home use. Interviews with managers of supermarkets revealed that one particular high sudsing synthetic detergent with brightening agents and enzymes was purchased most often by consumers in the area at the time of this research. Therefore, this particular detergent was used for this study. A 0.2% detergent concentration, found in previous studies to be effective in the removal of microorganisms from clothing, was used. This amount was determined quantitatively by measuring the volume of water held in the pump and the tub of the washer on the low water machine setting, and then calculating a 0.2% by weight. This quantity was found to be 43 grams. A 0.0% detergent concentration was used as a control.

It is significant to note that in preliminary work for this study when using detergent concentrations of 0.3% and 0.4% that the home automatic washing machine could not handle these higher percentages of high sudsing detergents. The suds were in such large quantities that they foamed out the top of the washer, thereby loosing the desired concentration.

Fabric Preparation and Sampling

A terry knit fabric of 50% wool, 30% nylon, and 20% cotton, meeting military specification S-486 was utilized (appendix C, pg. 75). The fabric was black United States Air Force sock fabric knitted in seamless tubes 7 to 8 inches in circumference and approximately 24 to 36 inches long.

The tubes were split and cut into swatches approximately 12 inches

in length. One inch by one inch squares were stitched on 540 swatches to be used in selection of the samples by random sampling. Care was taken in marking the areas for sampling to leave areas four square inches or larger that will be used for physical testing for another related research study.

Following the establishment of the laundry procedure, the prepared swatches were divided and marked for the treatment, detergent concentration, and number of preliminary launderings (Fig. 7). All of the swatches were prelaundered to remove any dust particles or remaining finish. To determine if damage by mechanical agitation in laundry had any effect on the damage seen microscopically on the swatches inoculated with the microorganism, one group of swatches were washed 14 times, a second group of swatches was washed 7 times, and a third group was washed one time prior to inoculation and experimental laundry. This microscopic damage will be done in connection with the above mentioned research study.

Inoculation Procedures

A randomly isolated laboratory "Downy" strain of the fungus Trichophyton mentagrophytes was inoculated into flasks of Sabouraud's Dextrose broth with the inhibitors chloramphenicol and cycloheximide. The strain used was an isolate from a laboratory infected guinea pig, and done under the auspices of the Department of Infectious Diseases at Kansas State University. The flasks of broth were then incubated on a shaking water bath without water at 72°F. for periods of eight to ten days or until adequate growth as fungal pellets had taken place (Fig. 1). The broth containing the fungal pellets was transferred to a food blender, where homogenization to a uniform hyphal suspension was accomplished. Approximately two minutes of homogenization was needed to form the suspension. The blenders used where

sterilized prior to use.

One half of the fabric swatches to be inoculated were premoistened in a synthetic soil solution to simulate the soiling of a fabric during a normal wearing period and to enhance the growth of the microorganism. The ingredients (Appendix D, p. 78) for the synthetic soil were mixed in a pre-sterilized food blender for five minutes to form a stable emulsion. All dry ingredients of the synthetic soil were sterilized in an ethyleneoxide gas chamber for 21 hours. All liquid ingredients were autoclaved at 250 F. for 15 minutes. The pH of the prepared synthetic soil was approximately 6.2. The second half of the fabric swatches to be inoculated were soaked in a control solution of sterilized distilled water. Different sterilized cake pans and gloves were used in the premoistening procedure and respective treatments.

After premoistening in either the synthetic soil or the distilled water, all samples were soaked in the hyphal suspension of the organism (Fig. 2). Sterile, defated, horse hair was randomly distributed in each solution of the hyphal suspension to help seed the organism on the cloth. The fat was removed because bacteria can live in it; and the hair was used as a place for the fungus to cling to before it began to grow on the cloth. This was a realistic procedure since the leg and foot of humans are covered with hair and can provide a lodging place for fungus. Following soaking, each fabric swatch was "wrung out" by hand.

The inoculated swatches were then hung in a model E_4 Isco chamber to incubate (Fig. 3). The environmental chamber was used to prevent the organism from infecting the surrounding rooms. The chamber was held at room temperature and 80% relative humidity. The humidity was kept constant by a pool of sterilized distilled water in the bottom of the chamber, and also by

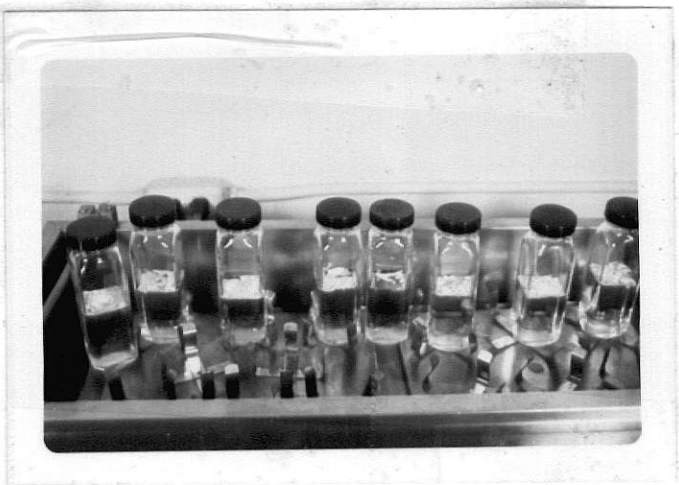

FIGURE 1

Incubating Flasks of Broth on Shaker

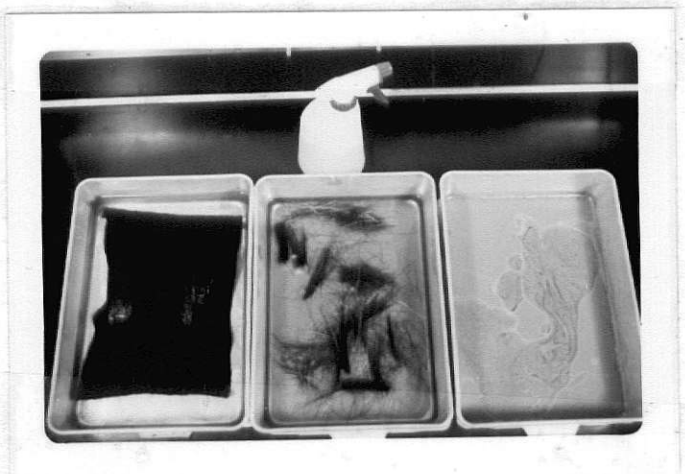

FIGURE 2

Receptacles Containing Solutions for Saturating Fabric: A. Sterile Distilled Water, B. Hyphal Suspension of the Organism with Horse Hair, and C. The Artificial Soil

daily application of a fine mist of sterilized distilled water to the swatches. Bacto-Yeast Extract was combined with this water and applied as a source of B vitamins and other growth promoting substances.

One-square-inch samples were cut, using sterilized hemostats and scissors, from the fabric swatches on the day of inoculation to confirm that the organism was viable and present on the fabric swatches. The above samples were plated on petri dishes with mycobiotic agar, a selective medium for the isolation of fungus, and incubated at room temperature. This procedure was repeated every three days to confirm the presence of growth during the entire incubation period. In eight to ten days, the fungus was usually visable on the cloth (Fig. 4). This time period coincides with the approximate time soiled damp socks containing spores might be held before laundering.

Experimental Laundry Sequence

Before washing, the swatches were removed from the chamber, and a sample of each inoculated swatch was plated to confirm growth of the organism on the day of laundering.

A wash load consisting of 15 swatches, weighing about two pounds, was used. To determine if any redeposition occurred during laundry, five swatches, of the 15 in each load, were uniformly unsoiled-uninoculated, five were uniformly soiled-uninoculated, and five were uniformly inoculated with the organism Trichophyton mentagrophytes. All swatches were sterilized in the etylene-oxide chamber prior to inoculation, soiling, and laundry to prevent contamination from outside sources.

Fifteen swatches, five of each of three treatments, were put into the "mini-basket," detergent added, and the washer started. One-square-inch samples were aseptically removed after two minutes of agitation and again

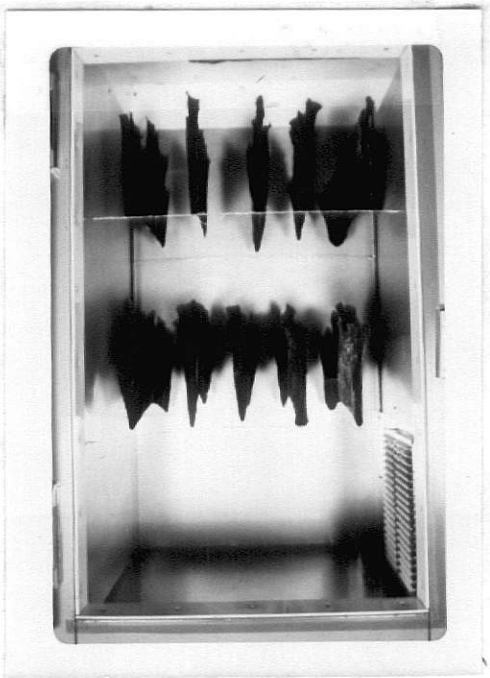

FIGURE 3

Swatches Hanging in Isco Chamber to Incubate

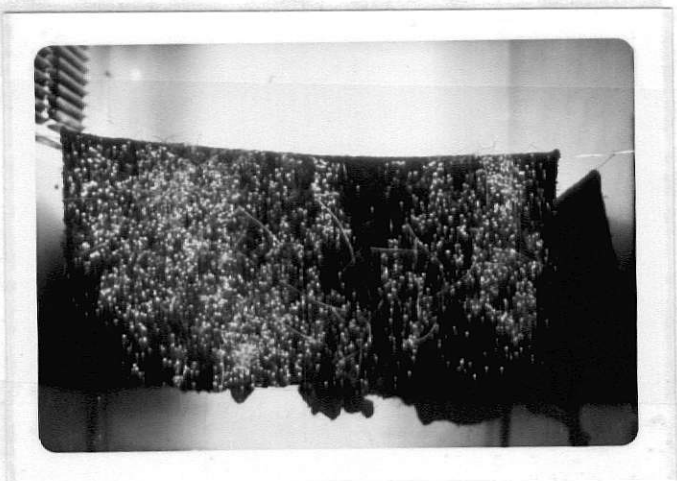

FIGURE 4

Trichophyton mentagrophytes Growing on the Fabric Swatch

on completion of the entire wash cycle. These samples were placed in culture plates with Mycobiotic agar, and incubated at room temperature.

To detect the presence of any spores in the wash water, two milliliters of the wash water and two milliliters of the rinse water were pipeted directly from the washing machine to a culture plate with Mycobiotic agar. Samples of the wash and rinse water were also taken for ascertaining pH of the water.

The presence of growth of the fungus on the plates obtained from the five inoculated swatches was used to determine the survival of the test organism, and the presence of growth on the plates obtained from the five unsoiled-uninoculated, and the five soiled-uninoculated swatches was used to ascertain the redeposition of the fungus (Fig. 5).

The laundered 12 by 8 inch swatches were then dried. Another one-inch-square was removed for plating.

To determine if there were any surviving mycelia left in the washer tub or the dryer, plates were streaked with swubes taken from the washer and dryer on completion of their respective operation (Fig. 6).

The above procedures were repeated three times for each of the experimental launderings. The washer was disinfected prior to use and in between each wash load by using one-half cup of chlorine bleach with hot water in a regular wash cycle. The dryer was disinfected by allowing it to run at a regular setting (196°F.) for thirty minutes. These disinfection methods were found to remove pathogenic microorganisms.

Statistical Analysis

Statistical tests for the mean of each variable, an F test for variance for the variables of 2 temperatures, 2 detergent concentrations,

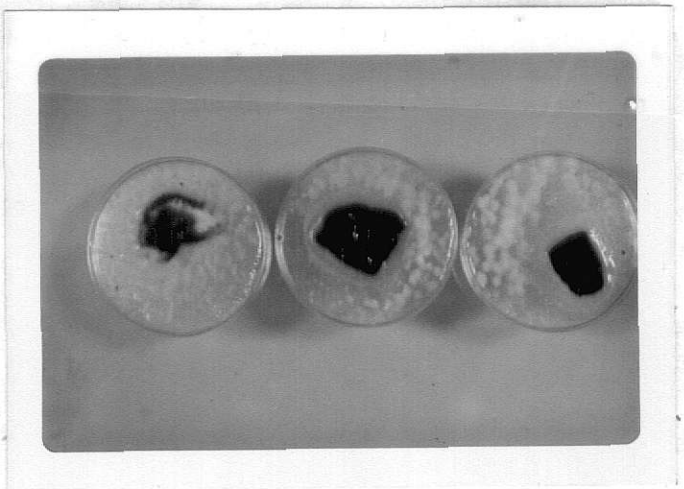

FIGURE 5

Growth of the Organism on Plated Swatches After Laundry

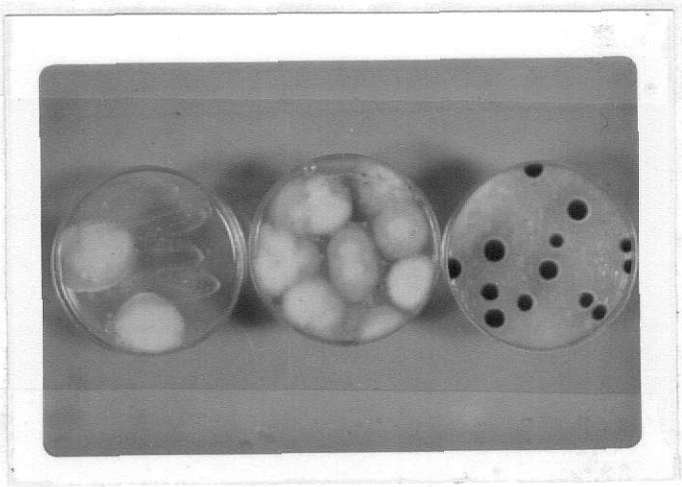

FIGURE 6

Growth of the Organism on Plates Streaked with Swubes Taken From: A. the Washer, B. the Dryer, and C. the Wash Water

EXPLANATION OF FIGURE 7

The experimental sequence was carried out for each washing load. The following combinations of water temperature, detergent concentration, number of preliminary launderings, and inoculation treatments were used.

1. 140°water temperature, 0.0% detergent concentration, 1 preliminary laundering, soiled-inoculated treatment
2. 140° water temperature, 0.0% detergent concentration, 7 preliminary laundering, soiled-inoculated treatment
3. 140° water temperature, 0.0% detergent concentration, 14 preliminary laundering, soiled-inoculated treatment
4. 140° water temperature, 0.0% detergent concentration, 1 preliminary laundering, unsoiled-inoculated
5. 140° water temperature, 0.0% detergent concentration, 7 preliminary laundering, unsoiled-inoculated
6. 140° water temperature, 0.0% detergent concentration, 14 preliminary laundering, unsoiled-inoculated
7. 140° water temperature, 0.2% detergent concentration, 1 preliminary laundering, soiled-inoculated
8. 140° water temperature, 0.2% detergent concentration, 7 preliminary laundering, soiled-inoculated
9. 140° water temperature, 0.2% detergent concentration, 14 preliminary laundering, soiled-inoculated
10. 140° water temperature, 0.2% detergent concentration, 1 preliminary laundering, unsoiled-inoculated
11. 140° water temperature, 0.2% detergent concentration, 7 preliminary laundering, unsoiled-inoculated
12. 140° water temperature, 0.2% detergent concentration, 14 preliminary laundering, unsoiled-inoculated

* The above combination of variables was repeated using 120°F. and 100°F. wash water temperatures.

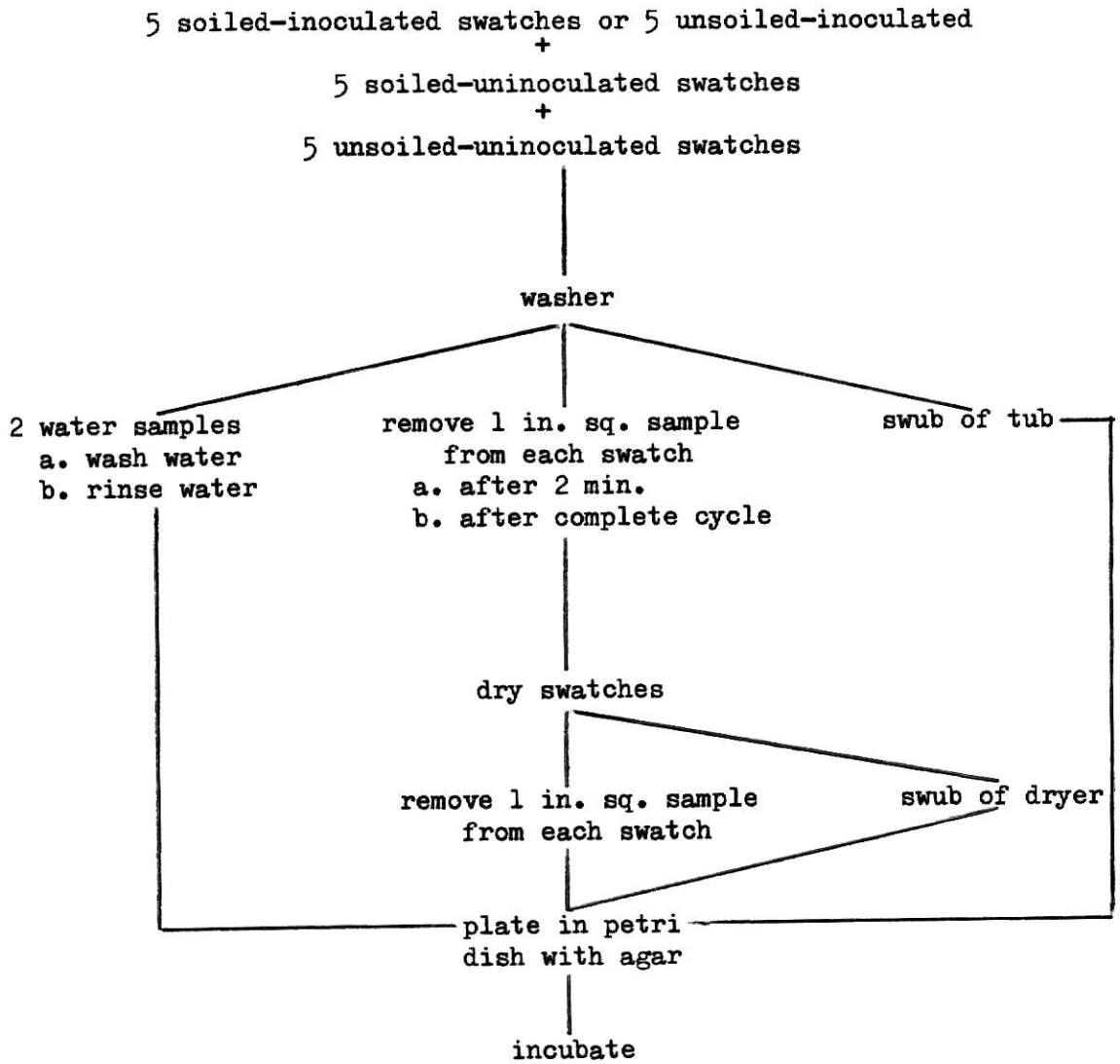

FIGURE 7

Flow Chart of Experimental Sequence

two inoculation treatments, three observation periods, and redeposition caused by washing unsoiled-uninoculated and soiled-inoculated swatches with either soiled-inoculated or unsoiled-inoculated swatches was run. The interaction of the variables was also calculated. Only two water temperatures were used in statistical analysis since it was obvious that at 140°F. there was almost no survival or redeposition of any kind.

RESULTS AND DISCUSSION

There were instances of survival of the test organism Trichophyton mentagrophytes at all three water temperatures used for testing even when the manufacturer's recommended concentration of detergent was used. Redeposition occurred and survival of the organism was found after drying.

The fluxuation of the water temperature and the successive washing operations resulted in difficulty in controlling the water temperature of the rinse period, even though the separate hot water heater made controlling the wash water accurate within ± 2°F. Thus, the rinse temperature varied to some extent (Table 10, Appendix B, p. 73). This situation also would be found, however, to exist in a home laundry situation, but is not ideal for critical evaluation.

Effect of Water Temperature

The water temperature was found to be by far the most significant variable in this study. It was significant in fungal removal, redeposition, survival after drying, survival in the wash and rinse water, and in the presence of the organism remaining in the washer tub and in the dryer (Fig. 8).

When hot water of 140°F. was used, there was only 2 instances of survival even with a 0.0% detergent concentration. Therefore, it can be concluded that the use of 140°F. wash water can result in almost a 100% kill. However, it must be kept in mind that the average hot water setting of the home washer is only 125° to 135°F.

Water temperatures of 120° and 100°F. were found to be statistically significant sources of variance by an F test of significant variance in the removal of the fungus occurring at both inoculation treatments and on their subsequent redeposition (Tables 1,2,3 & 4, Appendix B, pp.63-66).

A statistically significant difference at the 95% level in the variance of fungus survival on the unsoiled-uninoculated swatches was found to exist between the interaction of water temperature and detergent concentration. Specifically, at the 100°F. water temperature, the 0.2% concentration resulted in greater kill than at the 0.0% concentration. This however was not true at 120°F. (Table 4, Appendix B, p.66 and Fig. 23, 24, 27, and 28, Appendix A, pp. 59 & 61).

A significant difference at the 95% level was also shown between fungal survival at 120° and 100°F. water temperatures on the soiled-inoculated, unsoiled-inoculated, soiled-uninoculated, and unsoiled-uninoculated treatments (Tables 1, 2, 3, and 4, Appendix B, pp.63-66).

The water temperature also had an obvious effect on the presence of the organism Trichophyton mentagrophytes in the washer and the dryer after their respective cycles. No presence of the organism occurred either in the wash or rinse water or the washer or dryer at the 140° or the 120°F. water temperatures, but at the 100°F. water temperature, survival of the organism occurred in the wash and rinse waters as well as in the washer and dryer. In general, as the temperature of the wash water increased, there was a decrease in the survival of Trichophyton mentagrophytes at the end of 2 minutes of agitation, upon completion of the complete wash cycle, and after drying (Figures 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, & 28, Appendix A, pp. 56-61).

Effect of Detergent Concentration

The mean survival of Trichophyton mentagrophytes on soiled-inoculated, unsoiled-inoculated, and the redeposition on soiled-inoculated, and unsoiled-inoculated swatches was higher at the 0.0% concentration than

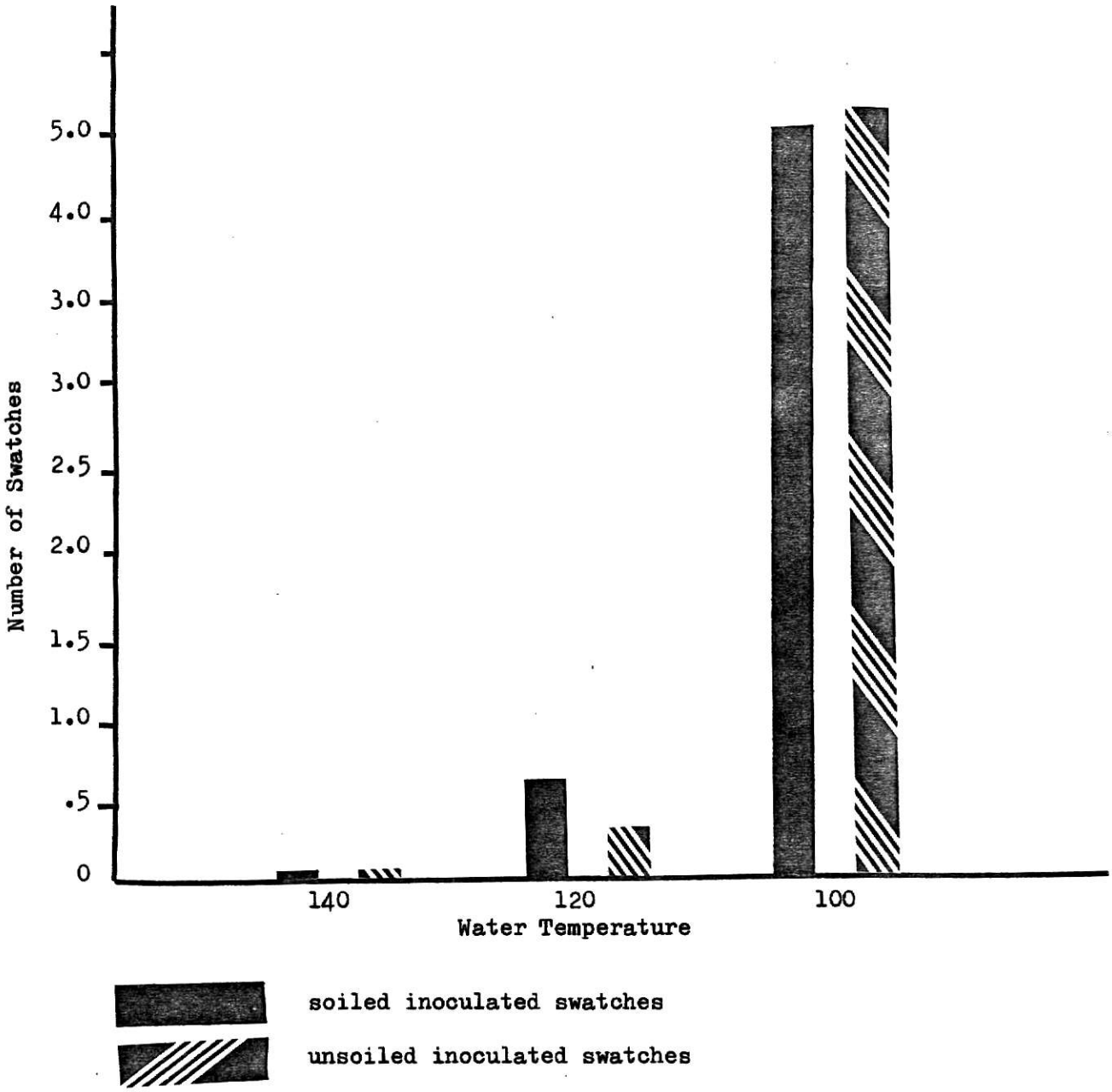

FIGURE 8

Mean Number of Swatches with Fungal Survival on Soiled Inoculated and Unsoiled-Inoculated Fabric at 3 Water Temperatures

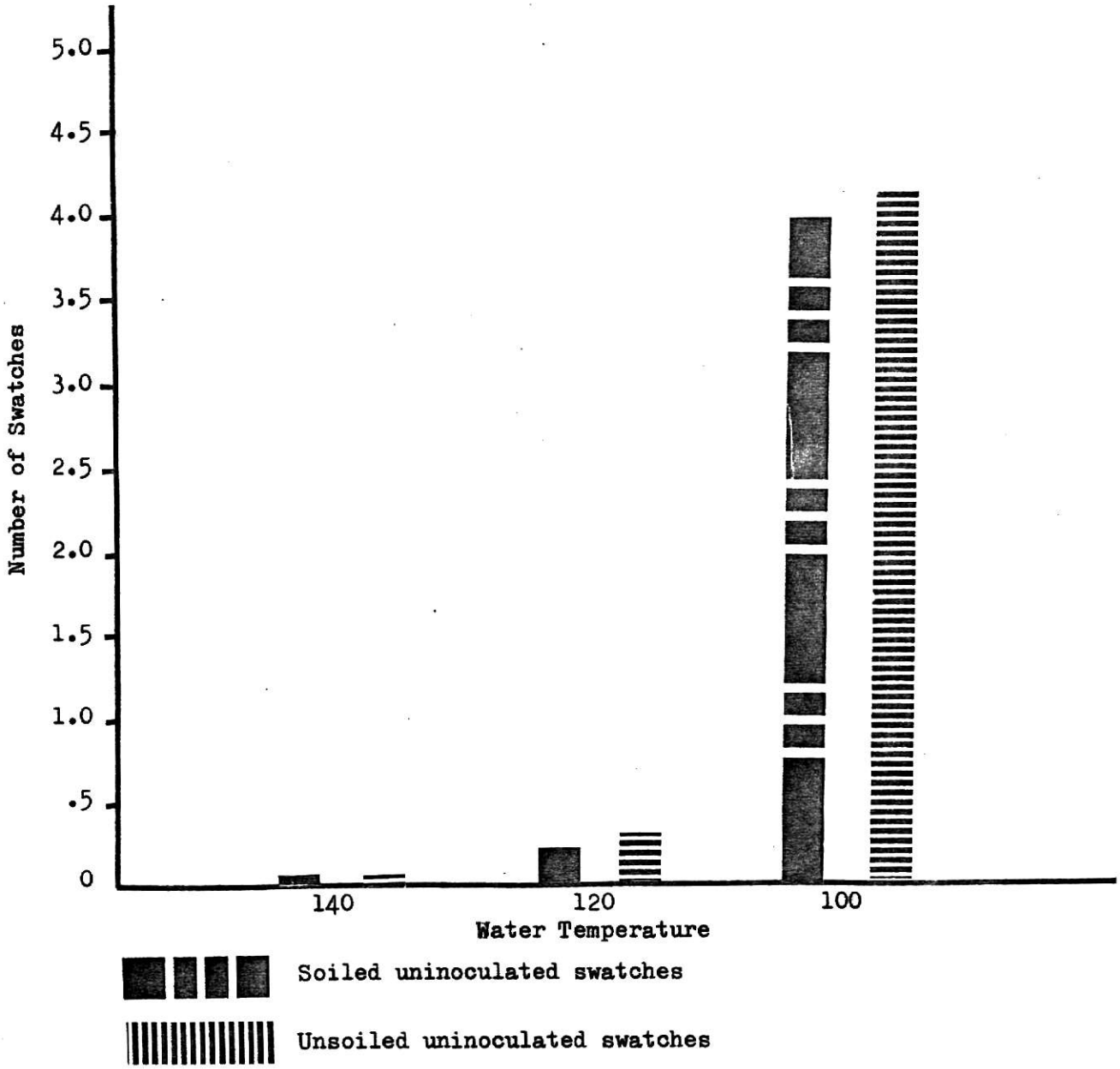

FIGURE 9

Mean Number of Swatches with Fungal Redeposition on Soiled-Uninoculated and Unsoiled-Uninoculated Fabric at 3 Water Temperatures

at the 0.2% detergent concentration (Figures 10 & 11).

The detergent concentration was found to be statistically significant in fungal survival on unsoiled-inoculated fabric and for redeposition on soiled-uninoculated fabric washed with soiled-inoculated and unsoiled-inoculated fabric (Tables 2 & 3, Appendix B, pp.64 & 65 , and Figures 17, 18, 21, 22, 23, & 24, Appendix A, pp. 56, 58, & 59). As can be seen from the figures, the survival at almost every observation point was significantly lower at the 0.2% than at the 0.0% detergent concentration.

The interaction of detergent concentration and observation period was significant at the 95% level for survival of the organism on unsoiled inoculated fabric. In this instance, the survival of the organism after two minutes was significantly less at the 0.2% detergent concentration than at the 0.0% concentration when the swatches were washed in 100°F. wash water (Figures 19 & 20, Appendix A, p.57). This fact may point to the greater significance detergent concentration may take on at low water temperatures and wash periods.

It is unknown what effect higher concentrations of detergents would have since the wash used in this study would not tolerate larger quantities of a high sudsing detergent.

Effect of Observation Points Within the Laundry Cycle

The mean survival of Trichophyton mentagrophytes at the end of two minutes of agitation, after a complete wash cycle, and after drying showed very little variance, and was not found to be significant by the F test for variance (Figure 16, and Tables 3 & 4, Appendix B, pp. 65 & 66). The average total survival and redeposition at combined observation points of the four fabric treatments was also insignificant (Figures 14 & 15).

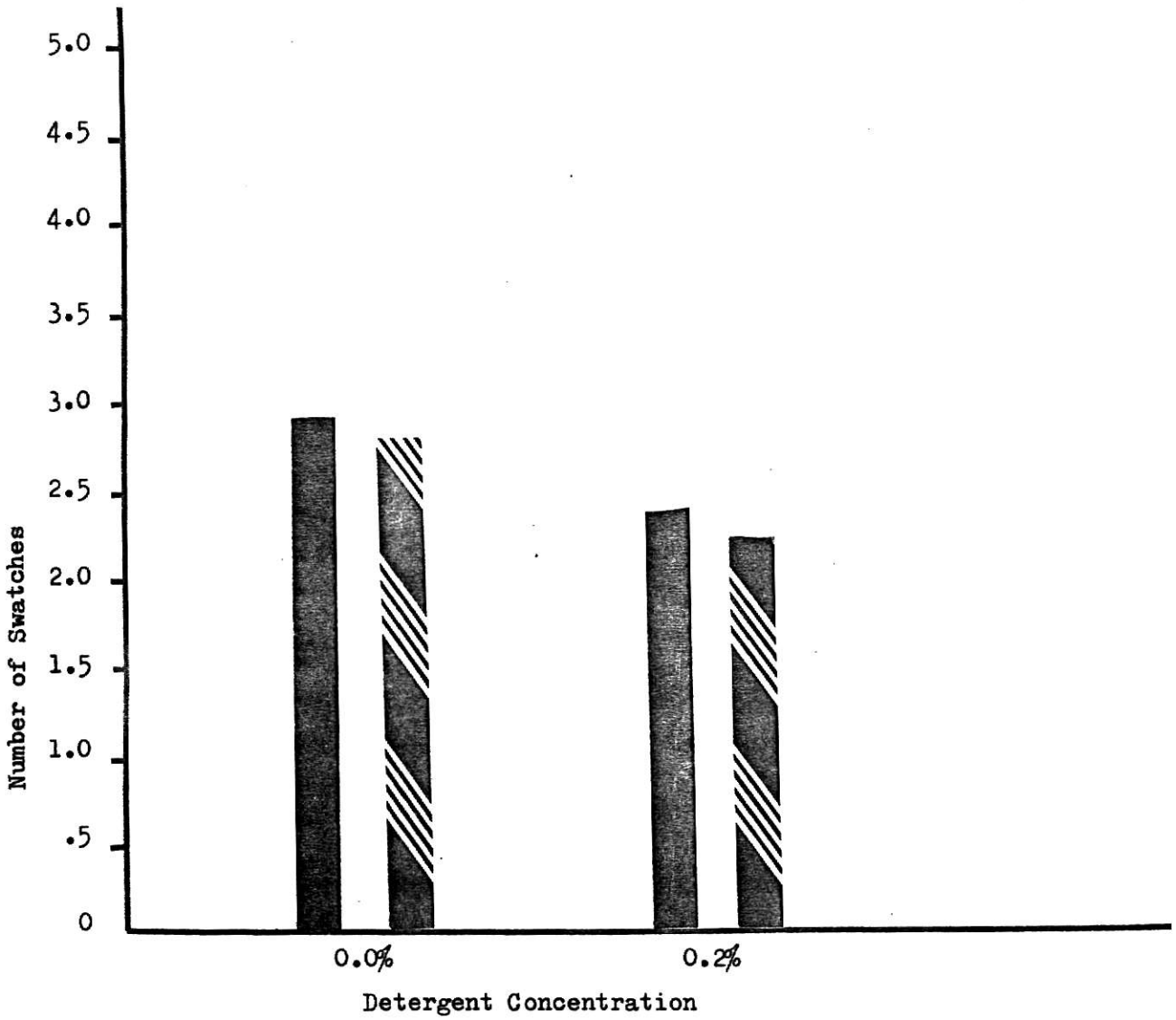

FIGURE 10

Mean Number of Swatches with Fungal Survival on Soiled-Inoculated and Unsoiled-Inoculated Swatches at 2 Detergent Concentrations

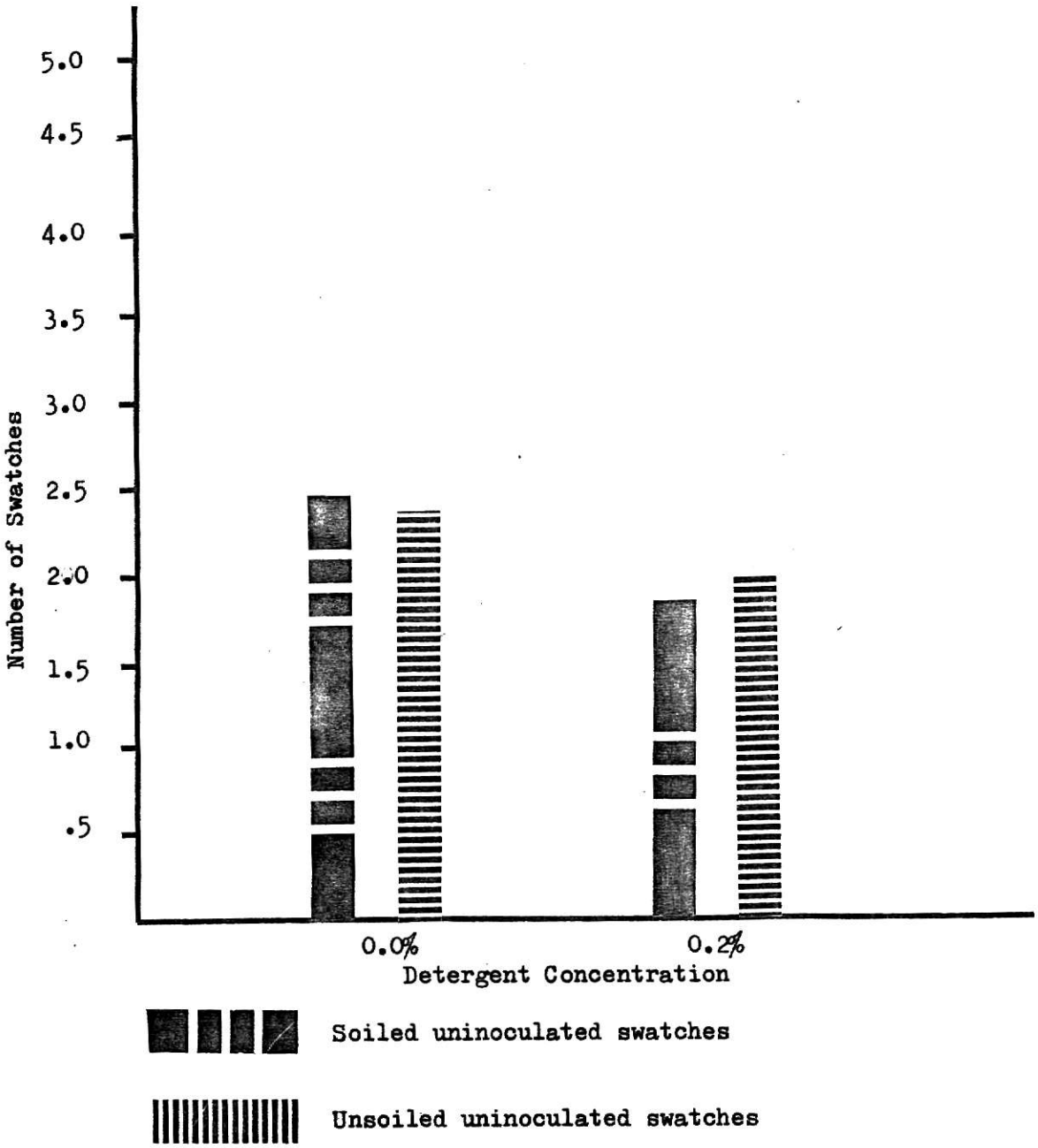

FIGURE 11

Mean Number of Swatches with Fungal Redeposition on Soiled-Uninoculated and Unsoiled-Uninoculated Swatches at 2 Detergent Concentrations

The significant interaction between detergent concentration and observation point of fungal survival on unsoiled-inoculated swatches has been previously discussed. It was found that at the two-minute observation point, swatches washed in 100°F. wash water showed a significantly lower survival at the 0.2% level of detergent concentration than at the 0.0% level. In this instance, it seemed that at the lower agitation time, the detergent concentration significantly reduced microbial survival. This did not occur at the other observation points, however.

This study seemed to indicate that an agitation time of more than 10 minutes would be needed to decrease the survival of Trichophyton mentagrophytes from the level found to be present at the end of two minutes of agitation. This finding was in agreement with Kohler's (1954) observation that prolongation of the agitation time resulted in a general increase in detergent action and thus a reduction in microbial survival only if the time was increased from 2 to 30 minutes.

The close relationship between the mean survival after only two minutes of agitation and that found after drying seems clearly to show that drying has no significant fungicidal or fungistatic effect on Trichophyton mentagrophytes. These findings are in agreement with Ridenour (1950) and Schimph (1969). It can thus be concluded that drying is no substitute for hot water and detergent action.

Effect of Inoculation Treatment

Whether or not the fabric swatches were inoculated with soil or without soil did not prove to be significantly different in either the initial growth of the organism on the fabric swatches, its survival after laundry (Tables 6, 7, 8, 9, & 10, Appendix B, pp. 69-73), or its subsequent

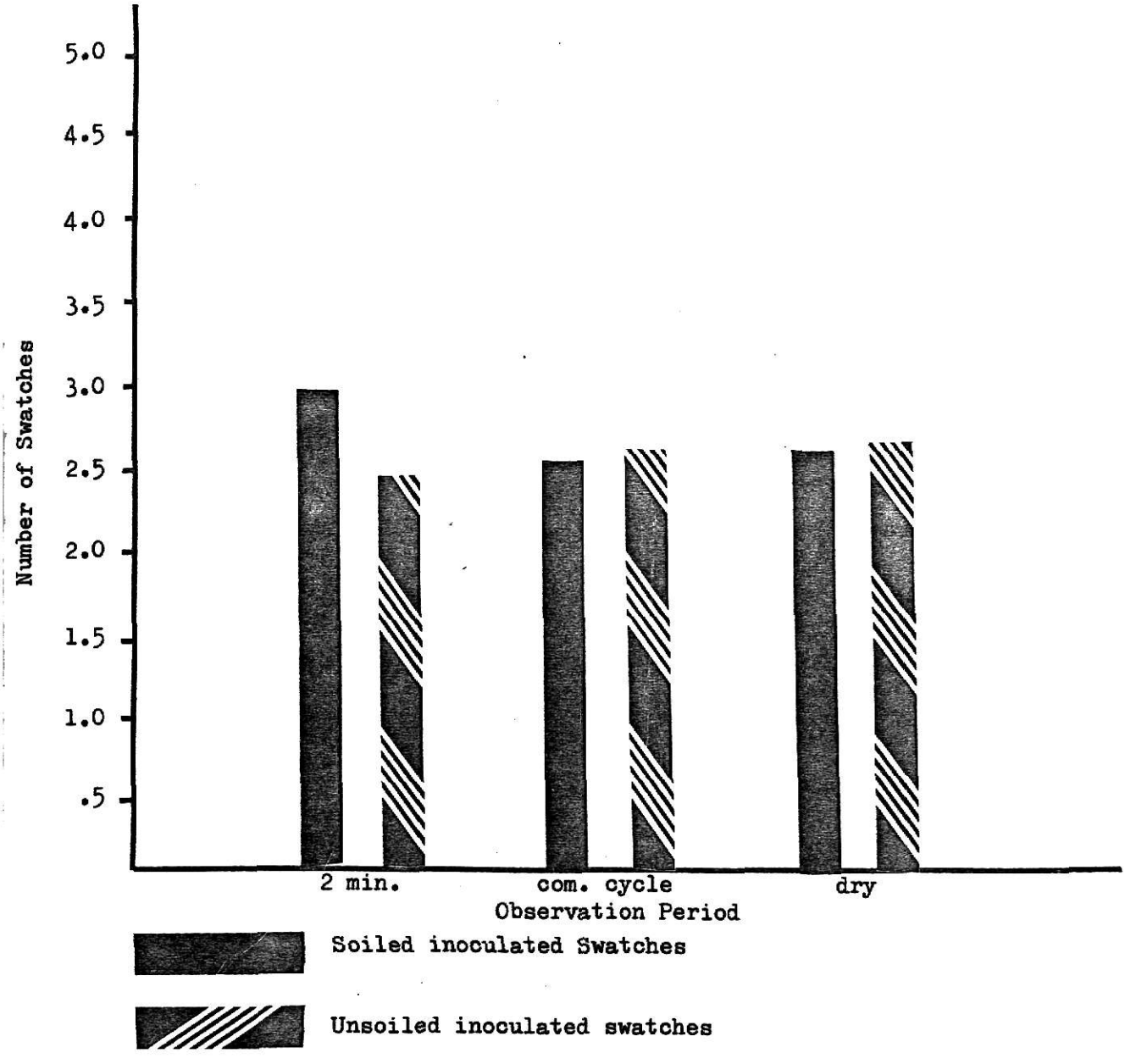

FIGURE 12

Mean Number of Swatches with Fungal Survival on Soiled-Inoculated and Unsoiled-Inoculated Swatches After 2 Minutes of Agitation, After the Completed Cycle, and After Drying

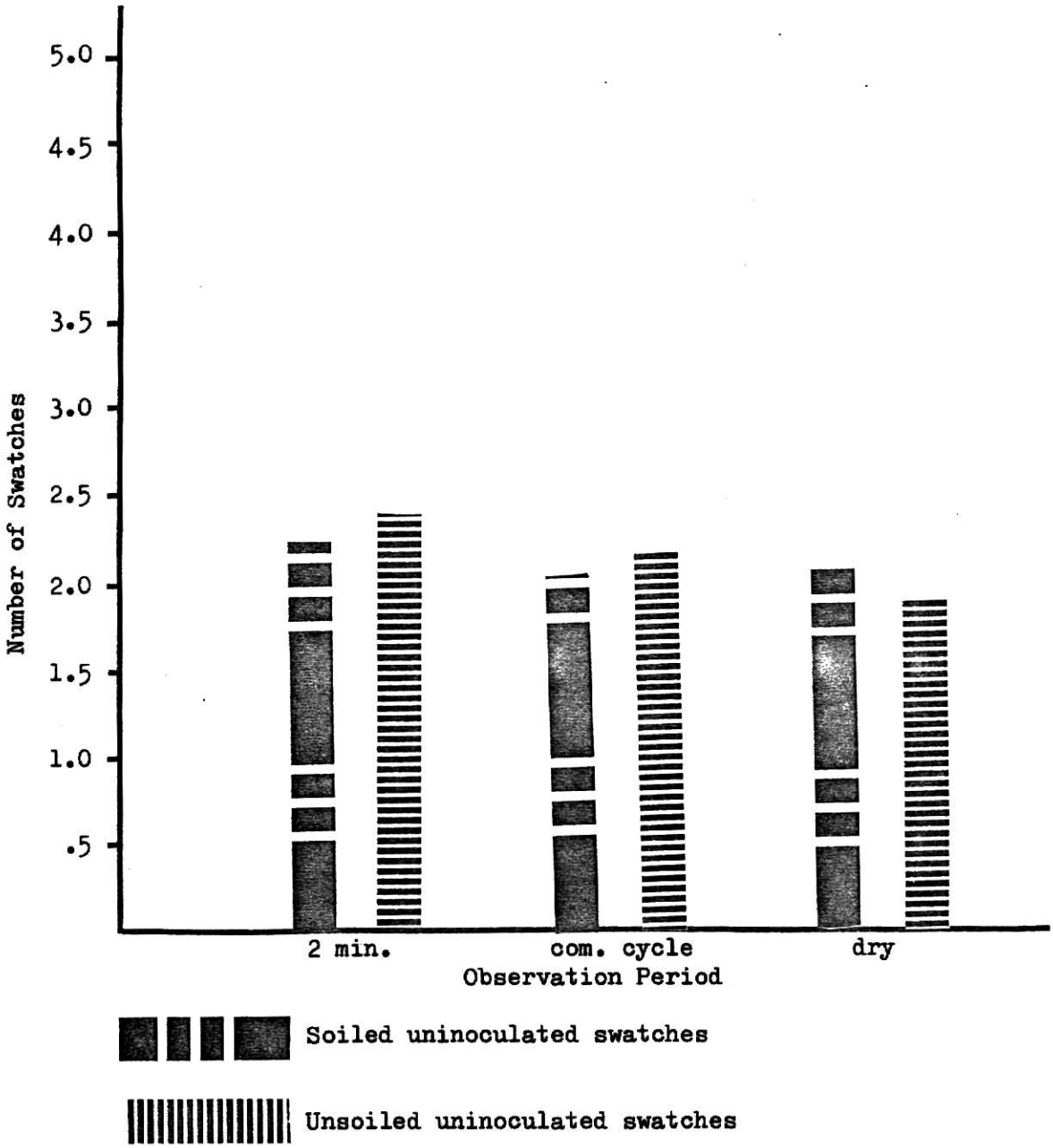

FIGURE 13

Mean Number of Swatches with Fungal Redeposition on Soiled-Uninoculated and Unsoiled-Uninoculated Swatches After 2 Minutes of Agitation, After the Complete Cycle and After Drying

redeposition on uninoculated fabric swatches (Tables 3 & 4, Appendix B, pp. 65 & 66).

In addition to the above fact, whether or not the uninoculated swatches were soiled or unsoiled made no significant difference in their acceptance of the organism Trichophyton mentagrophytes caused by redeposition during laundry (Tables 6, 7, 8, 9, & 10, Appendix B, pp. 69-73).

The mean survival of the organism, however, was slightly less on unsoiled-inoculated fabric than on the soiled-uninoculated fabric. The mean redeposition on the soiled-uninoculated and the unsoiled-uninoculated fabric was also just slightly less when washed with the unsoiled-inoculated swatches versus the soiled-inoculated (Fig. 16). The above results indicated that the presence of soil on the swatches had only a slight effect on the survival, removal, and redeposition of this microorganism during laundry.

Fungal Redeposition

Redeposition of the Trichophyton mentagrophytes organism from the inoculated fabric to the non-inoculated fabric followed the same pattern as fungal survival on the inoculated fabric at 3 water temperatures, 2 detergent concentrations and at 3 observation points (Figures 8, 9, 10, 11, 14, & 15, Appendix A, pp. 35, 36, 38, 39, 44, & 46). Previous studies by Schimph (1969) and Myers (1968) found that an equilibrium in bacterial count on the fabric was approached for all materials washed together due to redeposition. This seemed to be true also in the case of this particular fungus.

The water temperature and the detergent concentration were found to cause statistically significant differences in variance of the fungal redeposition by an F test (Tables 3 & 4, Appendix B, pp. 65 & 66). Figures 9 and 10 show that as the water temperature and detergent concentration

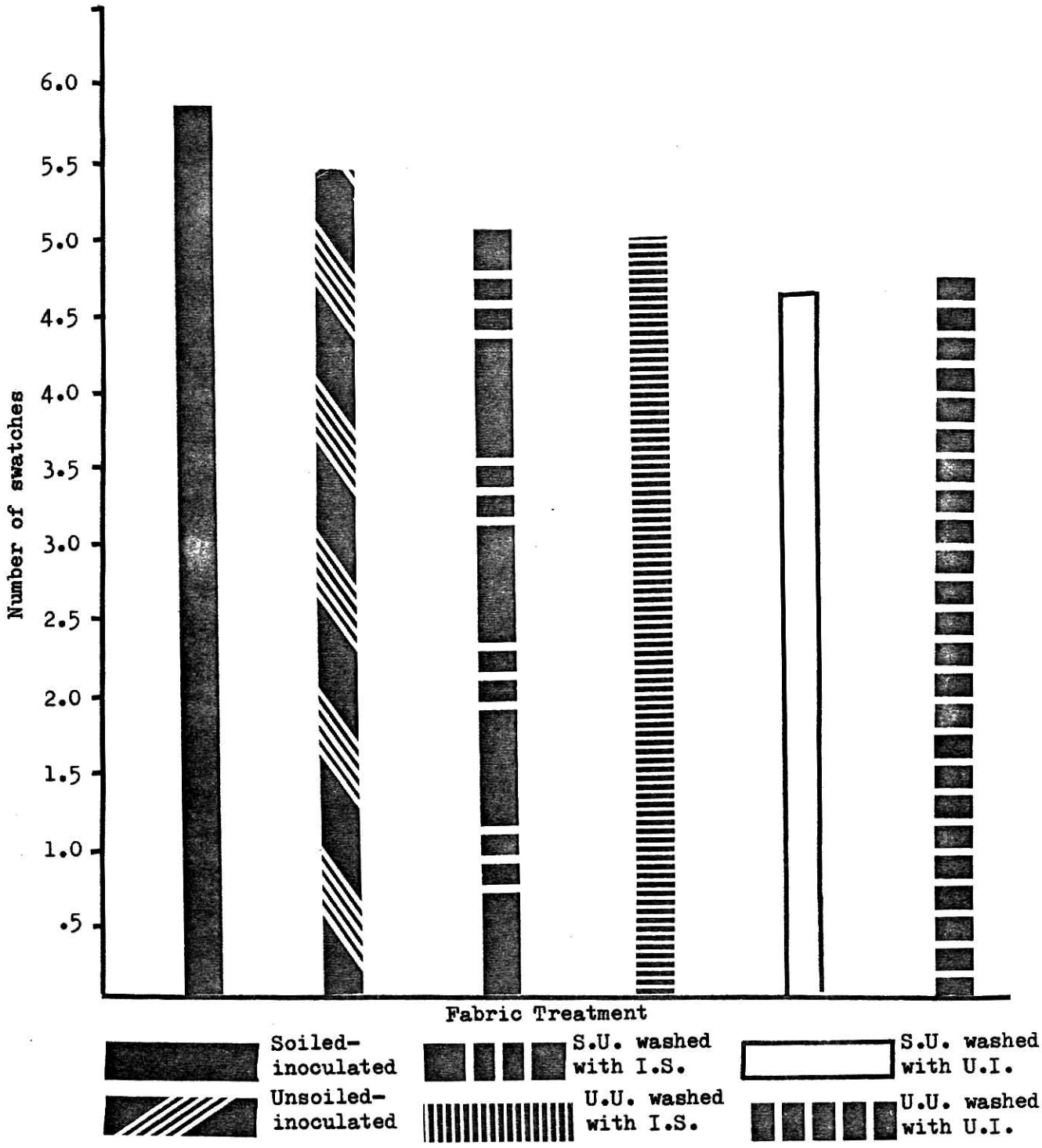

FIGURE 14

Average Number of Swatches with Fungal Survival After Laundry at Combined Observation Points of 4 Fabric Treatments

increased, there was a decrease in fungal redeposition.

There was also found to be a significant interaction between water temperature and detergent concentration for redeposition on unsoiled-uninoculated fabric (Table 4, Appendix B, p. 66).

The inoculation treatment had no effect on the redeposition, and whether or not the uninoculated fabric was soiled or unsoiled was not significant in its susceptability to redeposition (Fig. 14).

The survival of Trichophyton mentagrophytes in the wash water and the rinse water at 100°F. is a further indication that redeposition can be carried not only by direct contact but can be present in the water itself (Figures 12 & 13).

The presence of the organism in the washer tub at the end of the wash cycle and its presence in the dryer at the end of the drying time also indicated that the laundry facilities themselves are sources of microbial transfer (Figures 12, & 13). Fungal survival in the washer and dryer were only present when the swatches were washed in water at 100°F. and were not present when washed at 120° or 140°F. Survival of the fungus in the washer and dryer are a ready means of microbial transference to succeeding loads washed or dried in the same machine.

Effect of pH

Addition of the 0.2% detergent concentration logically raised the pH of both the wash and the rinse water (Table 10, Appendix B, p. 73). There was no apparent difference in the pH of the wash or rinse water between the soiled and the unsoiled treatments. There was also no significant difference between water temperature and pH at the 0.0% detergent concentration, but at the 0.2% level, the pH of the wash water and the rinse water was less

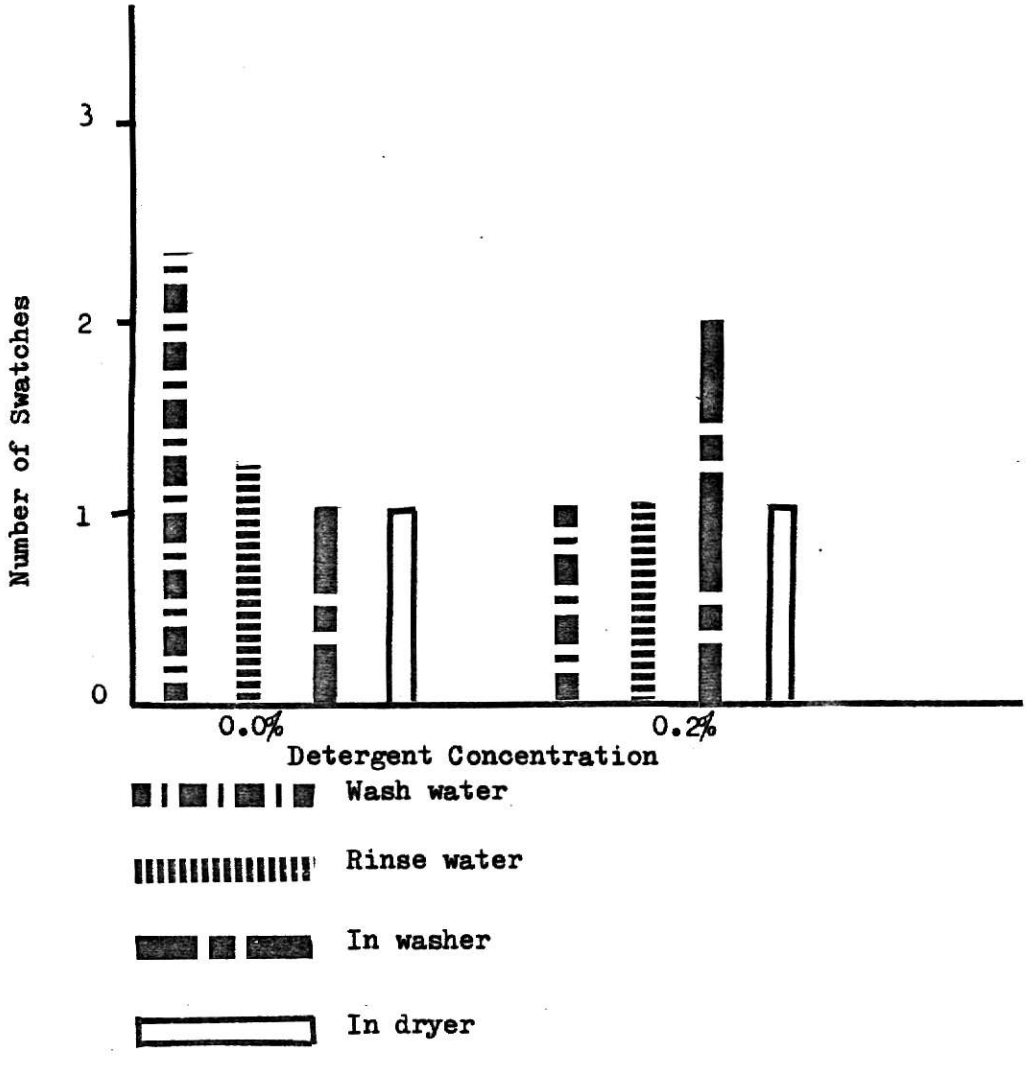

FIGURE 15

Survival of Trichophyton mentagrophytes in the Wash Water, Rinse Water, Washer Tub, and Dryer After Washing Inoculated-Unsoiled Swatches at 100 F. and with 2 Detergent Concentrations

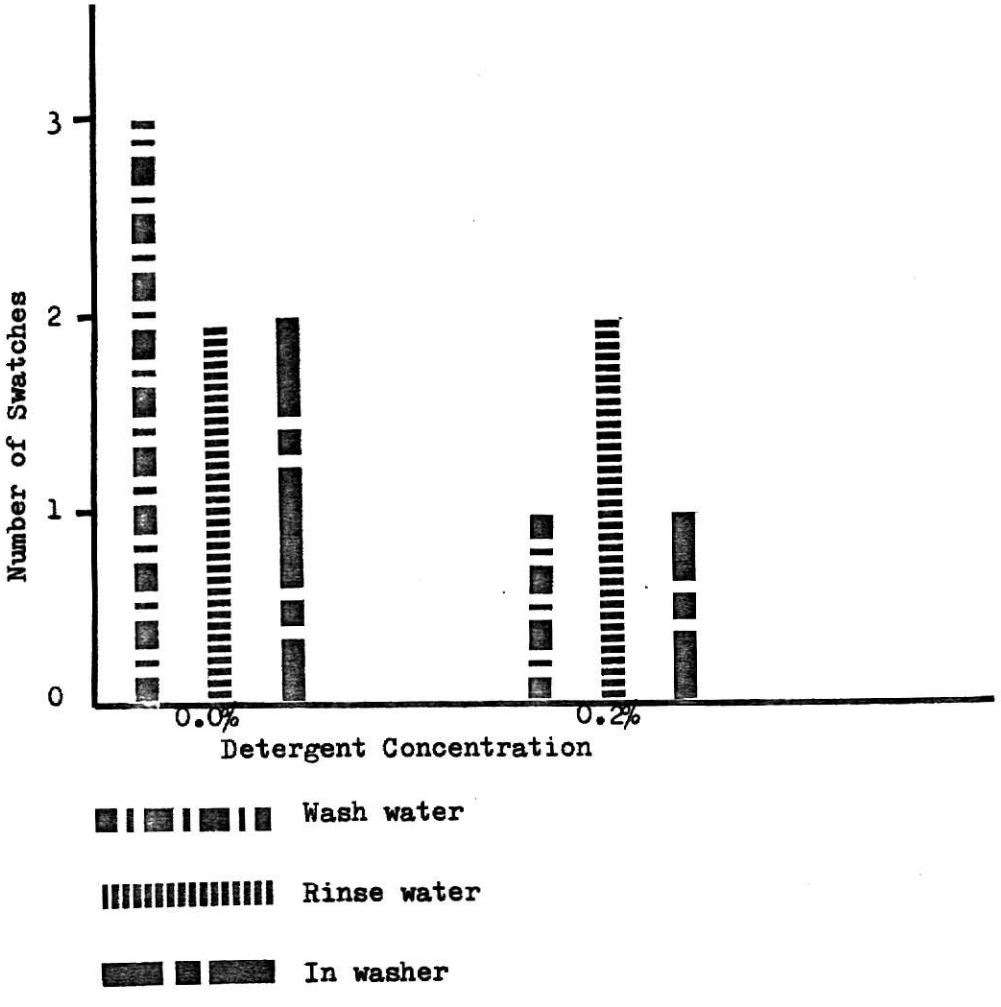

FIGURE 16

Survival of Trichophyton mentagrophytes in the Wash Water, Rinse Water, and Washer Tub After Washing Inoculated-Unsoiled Swatches at 100 F. and with 2 Detergent Concentrations

at 120° and 100°F. wash water than was the pH of the wash and rinse water at 140°F. (Table 10, Appendix B, p.73).

There was also a significant difference in the pH of the wash water and its respective rinse water (Table 10, Appendix B, p. 73). The pH of the rinse water was higher in every case than was the wash water, even when detergent was present in the wash water. A possible explanation of this fact was that a reaction took place between the fungus and the soil or the fungus and the yeast on the inoculated fabric while it was held in the chamber. The presence of a "sour" odor might have indicated that the reaction caused the fabric to become somewhat acidic before it was laundered. The detergent would then have to have sufficient alkalinity to neutralize the acidic reagents and then the soil and or the organism, thus causing a more neutral range than would be otherwise expected.

CONCLUSIONS AND RECOMMENDATIONS

Water temperature was found to be the most significant variable in this study. The mean of three washes washed at 140°F. water temperature indicated that this temperature would be very effective in both removing and preventing the spread of the organism Trichophyton mentagrophytes when used in a home laundry situation. The mean of three washes at 120° and 100°F., however, did not result in removal of the organism after washing or drying. In general, as the temperature of the wash water increased, there was a decrease in the survival of Trichophyton mentagrophytes at the end of two minutes of agitation, upon completion of the entire washing cycle, and after drying. The critical water temperature required for the prevention of growth of this organism after laundry was found to be between the temperatures of 120° and 140°F. Additional studies are needed to determine critical temperatures or to narrow this range.

The mean survival of the organism on soiled-inoculated, unsoiled-inoculated swatches and the redeposition that resulted was higher when the swatches were washed in a 0.0% detergent concentration than when washed in a 0.2% concentration. At the lower water temperature of 100°F., there was significantly less survival of the organism at the end of two minutes of agitation when a 0.2% detergent concentration was used. This fact may point to the greater significance detergent concentration may take on at lower water temperatures and wash periods.

The mean survival and redeposition of Trichophyton mentagrophytes at the end of two minutes of agitation, after a complete wash cycle, and after drying was not found to be significantly different by the F test for Variance. This study seemed to indicate that an agitation time of more than ten minutes

is needed to reduce the level of survival and redeposition beyond that found after two minutes. Further research in this area could be beneficial in determining the time that would be required to cause a reduction in the survival of the organism. It can also be concluded that drying at temperatures in a dryer in the permanent press or delicate cycle does not in any way destroy or prevent the transfer and spread of Trichophyton mentagrophytes. This fact can be partially accounted for because the fabric is damp and does not take on the temperature of the dryer, and at the time in the drying process when the fabric gets hot enough to effect the survival of the organism, the dryer, with its electronic sensor, turns off because the fabric is dry.

The presence of soil on the fabric swatches before inoculation proved non significant in this study, either to inhance the visible growth of the organism on the cloth, to affect the survival of the organism during or after the laundry cycle, or to affect the amount of redeposition.

The amount of redeposition and survival of Trichophyton mentagrophytes in the wash and rinse water, and in the washer and dryer indicate the very real danger of cross-contamination that can occur within the wash load itself and to succeeding loads. This would be a very important consideration in the use of public laundry facilities and in the home, especially at the lower water temperatures. It is suggested that known infected garments be not only washed separately from the family's laundry, but be stored in a separate laundry bag to avoid contamination that could occur before laundry. Disinfection of laundry equipment before and after use is also recommended to further prevent any cross contamination as a result of infected laundry facilities.

Since the organism survived when the manufacturer's recommended detergent concentration was used at 120° and 100°F., and the organism survived

drying, the prime importance of wash temperature in removal of microorganisms and preventing their spread should be recognized. The temperature setting of the hot water heater in the home should perhaps be evaluated in terms of laundry requirements. Certainly the person doing the laundry is going to have to make a value judgement between the retention of the appearance for longer periods of time of some of the articles of clothing in a family's laundry or the prevention of possible transmission of microorganisms through the laundry process.

If the findings of Blank (1969) that much of the laundry in Vietnam is done by native girls in local streams, are still correct, the rate of infection, reinfection, and disease transference could greatly be reduced by altering the laundry practices.

There are many questions that were brought to light in this study and are recommended for future study. A suggestion would be to use temperatures lower than 100°F. and various other kinds of detergents. The effect of higher detergent concentrations in a low sudsing form might also be used. The hardness of the water, not a variable in this study, may want to also be included in determining its effect on the survival of Trichopyton mentagrophytes. Further investigation also seems to be indicated in the area of fabric and finishes that might influence the susceptibility of the fabric to microbial attack or its removal and transference during laundry.

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APPENDIX A

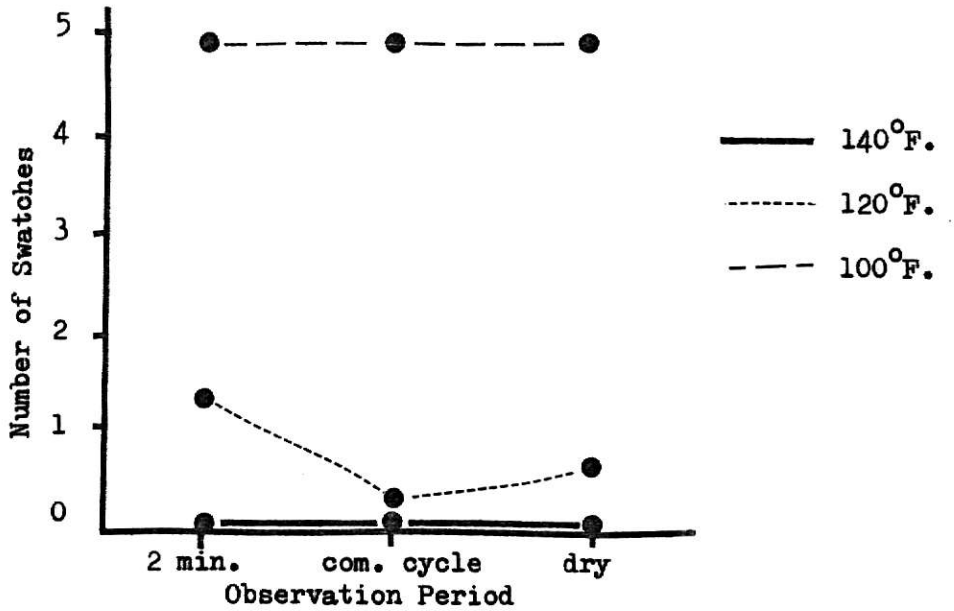

FIGURE 17

Mean Number of Swatches with Fungal Survival on Inoculated-Soiled Fabric at 3 Observation Points, 3 Water Temperatures, and Washed in a 0.0% Detergent Concentration

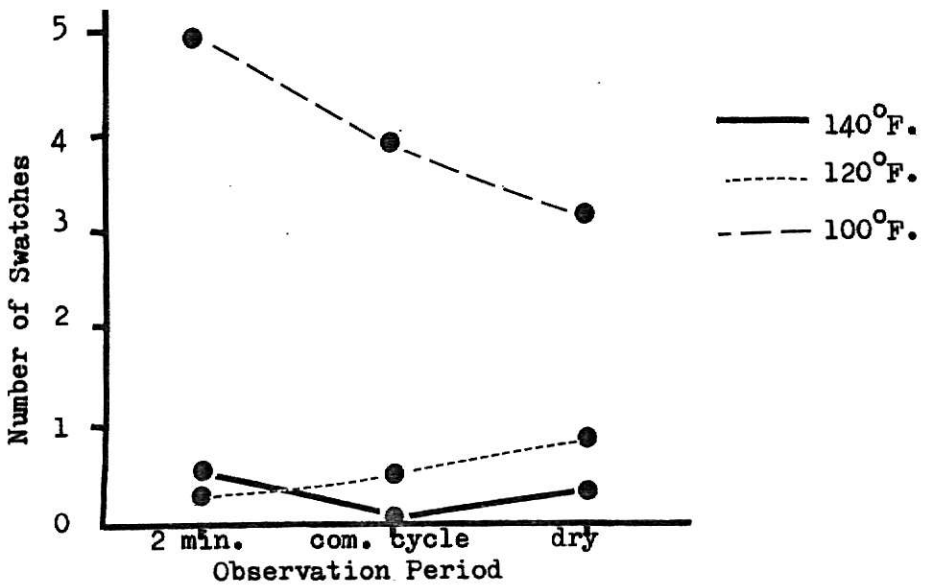

FIGURE 18

Mean Number of Swatches with Fungal Survival on Inoculated-Soiled Fabric at 3 Observation Points, 3 Water Temperatures, and Washed in a 0.2% Detergent Concentration

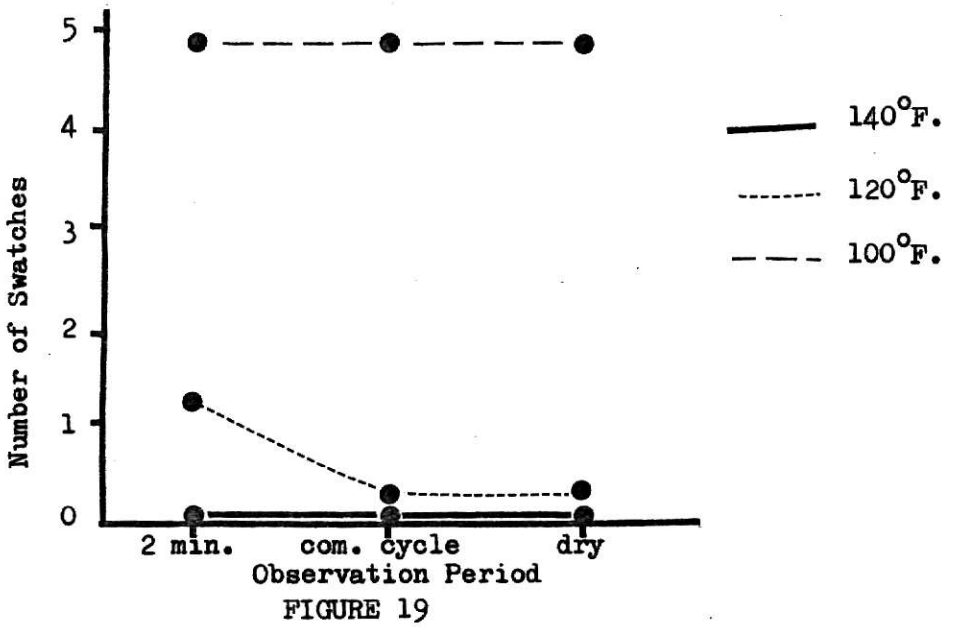

FIGURE 19

Mean Number of Swatches with Fungal Survival on Unsoiled-Inoculated Fabric at 3 Observation Points, 3 Water Temperatures, and Washed in a 0.0% Detergent Concentration

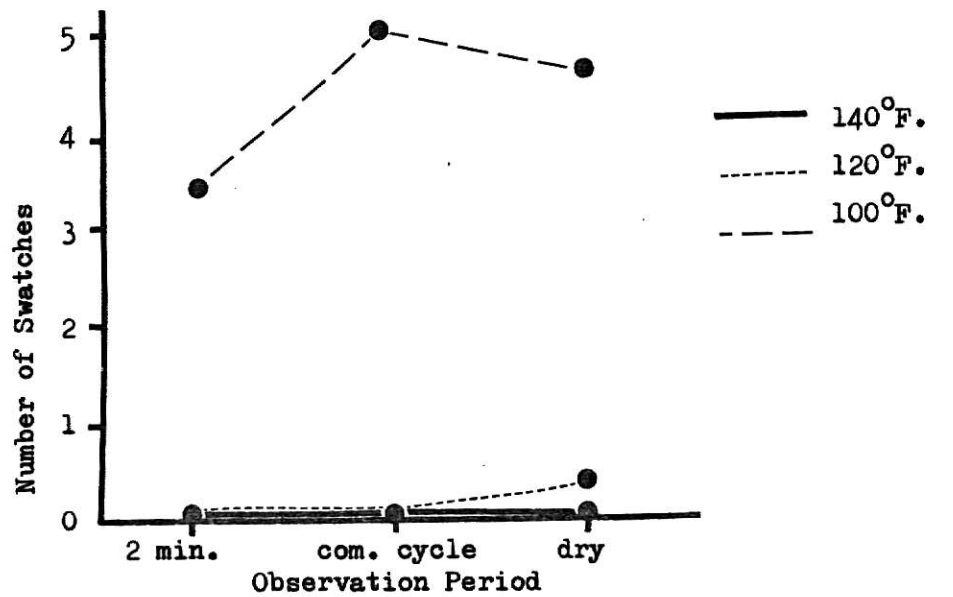

FIGURE 20

Mean Number of Swatches with Fungal Survival on Unsoiled-Inoculated Fabric Swatches at 3 Observation Points, 3 Water Temperatures, and Washed in a 0.2% Detergent Concentration

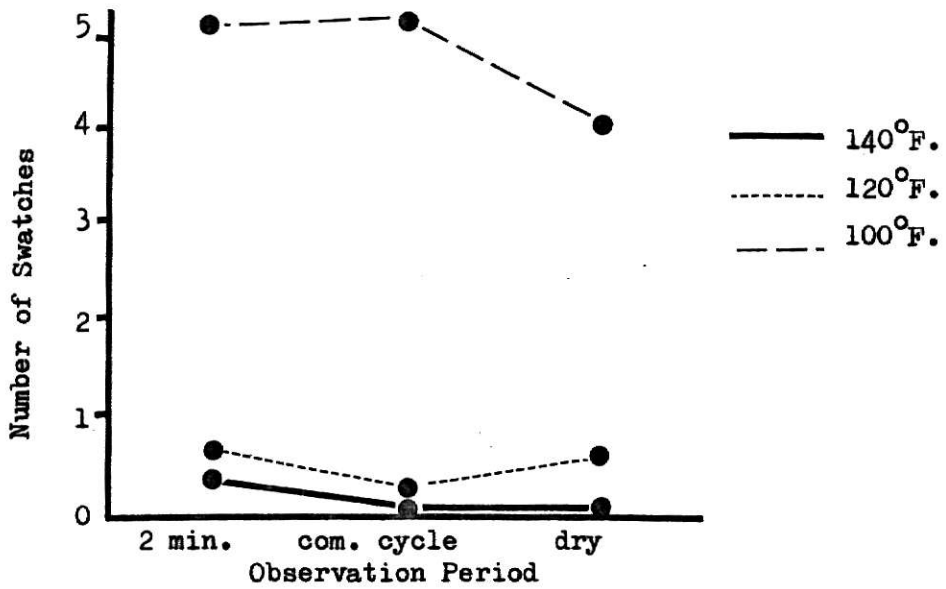

FIGURE 21

Mean Number of Swatches with Fungal Redeposition on Soiled-Uninoculated Swatches Washed with Inoculated-Soiled Swatches at 3 Water Temperatures, 3 Observation Points, and in a 0.0% Detergent Concentration

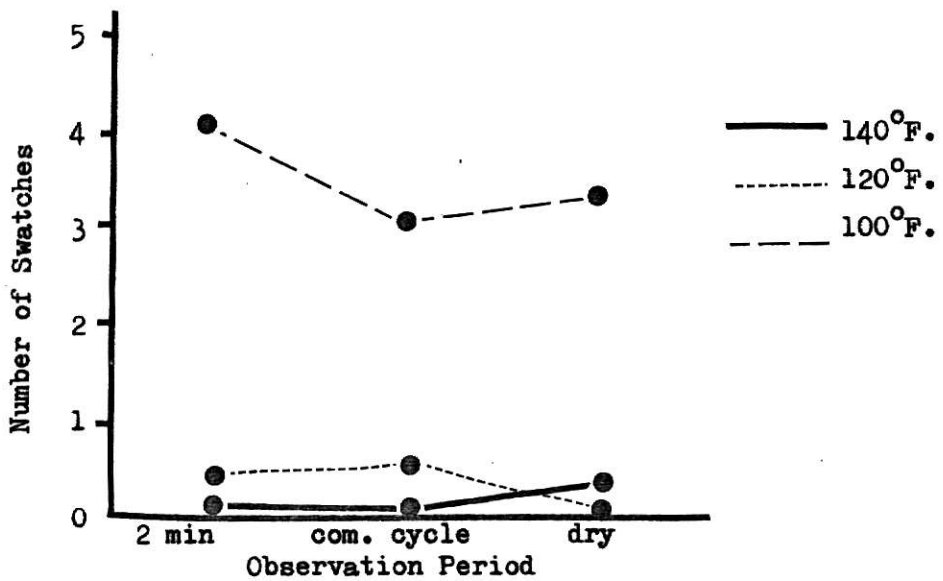

FIGURE 22

Mean Number of Swatches with Fungal Redeposition on Soiled-Uninoculated Swatches Washed with Inoculated-Soiled Swatches at 3 Water Temperatures, 3 Observation Points, and in a 0.2% Detergent Concentration

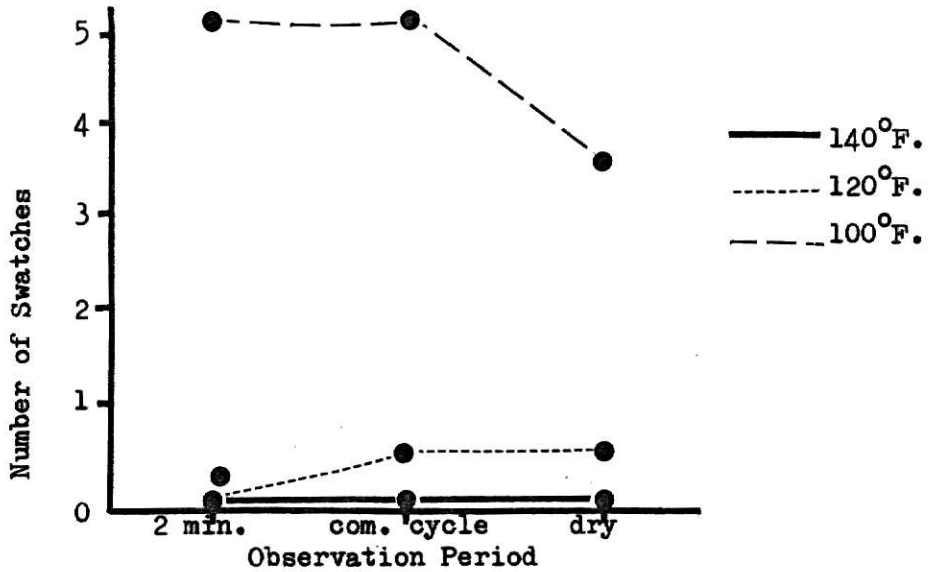

FIGURE 23

Mean Number of Swatches with Fungal Redeposition on Unsoiled-Uninoculated Swatches Washed with Inoculated-Soiled Swatches at 3 Water Temperatures, 3 Observation Periods, and in a 0.0% Detergent Concentration

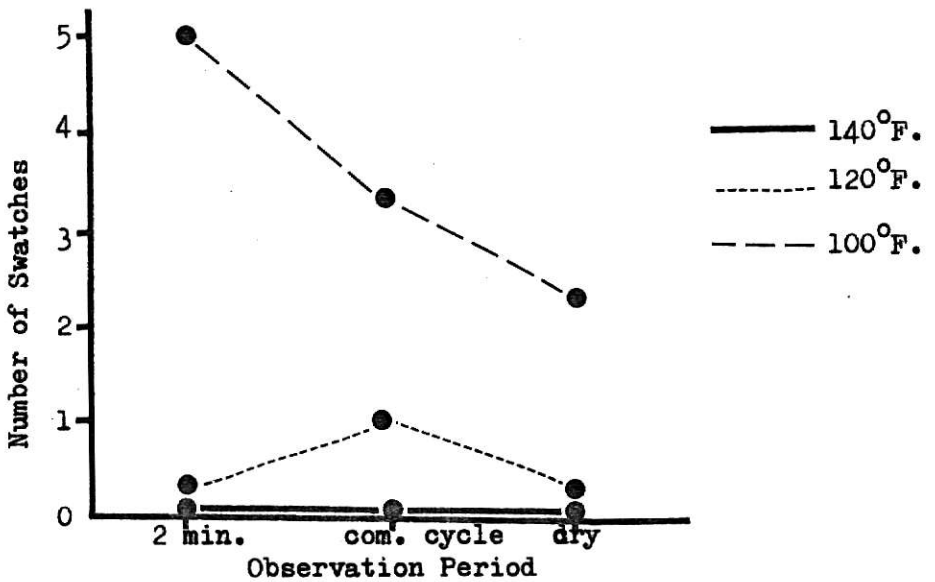

FIGURE 24

Mean Number of Swatches with Fungal Redeposition on Unsoiled-Uninoculated Swatches Washed with Inoculated-Soiled Swatches at 3 Water Temperatures, 3 Observation Periods, and in a 0.2% Detergent Concentration

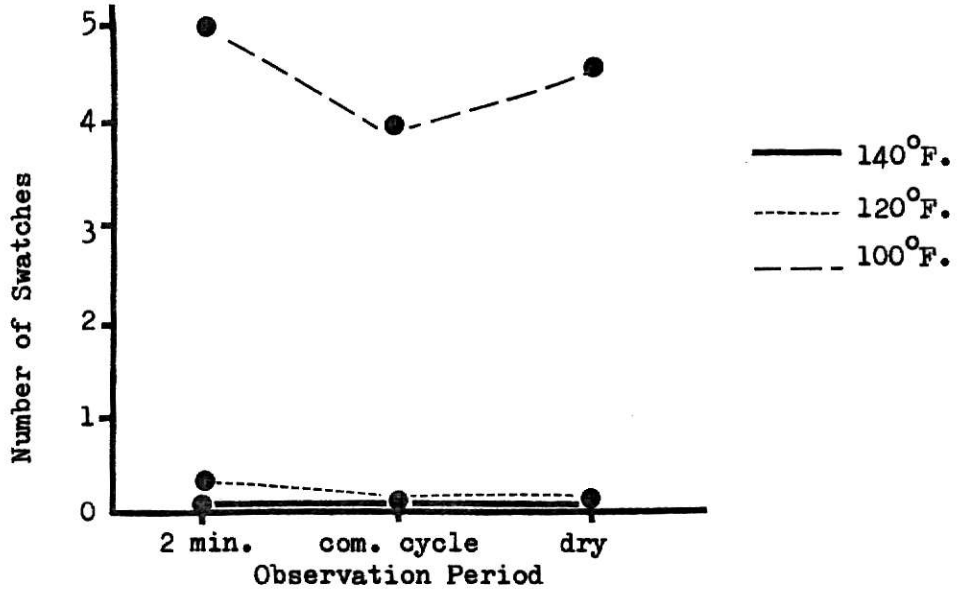

FIGURE 25

Mean Number of Swatches with Fungal Redeposition on Soiled-Uninoculated Swatches Washed with Unsoiled-Inoculated Swatches at 3 Water Temperatures, 3 Observation Points, and in a 0.0% Detergent Concentration

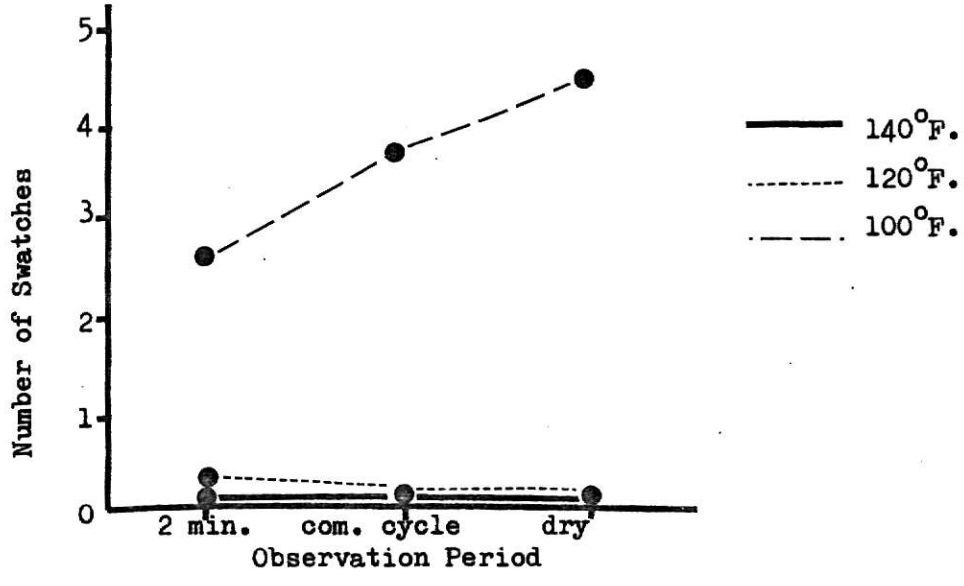

FIGURE 26

Mean Number of Swatches with Fungal Redeposition on Soiled-Uninoculated Swatches Washed with Unsoiled-Inoculated Swatches at 3 Water Temperatures, 3 Observation Points, and in a 0.0% Detergent Concentration

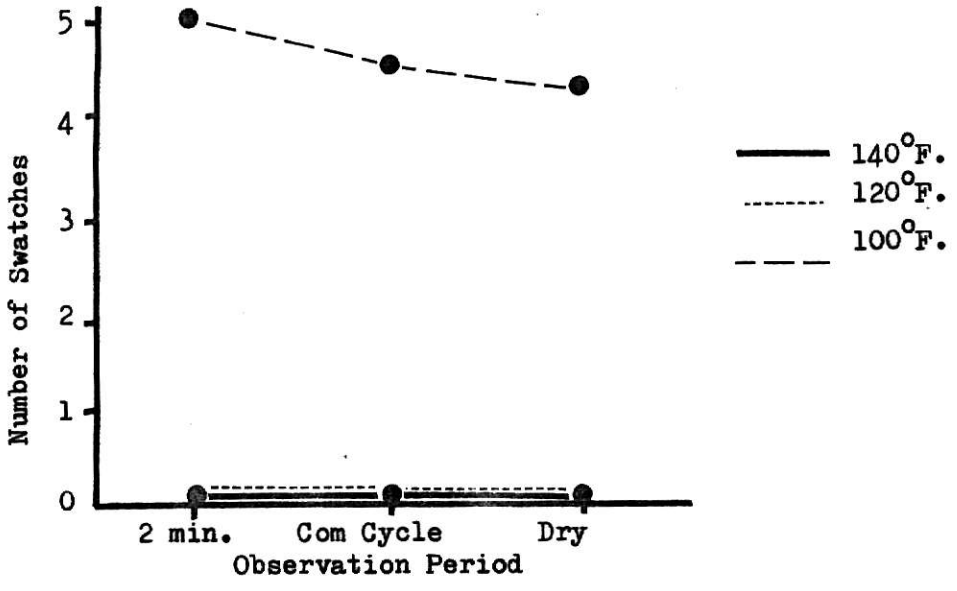

FIGURE 27

Mean Number of Swatches with Fungal Redeposition on Unsoiled-Uninoculated Swatches Washed with Unsoiled-Inoculated Swatches at 3 Water Temperatures, 3 Observation Points, and in a 0.0% Detergent Concentration

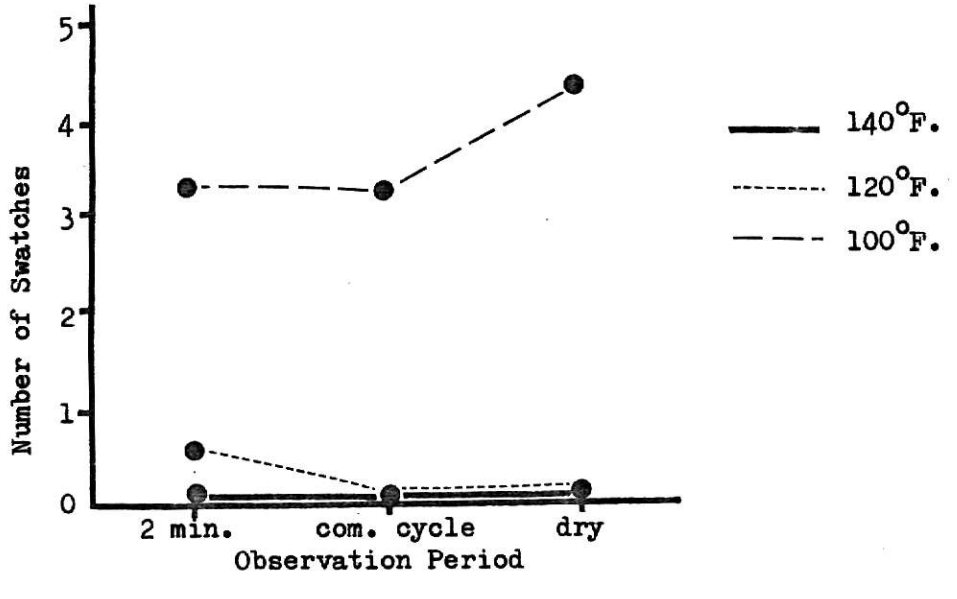

FIGURE 28

Mean Number of Swatches with Fungal Redeposition on Unsoiled-Uninoculated Swatches Washed with Unsoiled-Inoculated Swatches at 3 Water Temperatures, 3 Observation Points, and in a 0.2% Detergent Concentration

APPENDIX B

Table 1

Analysis of Variance for Survival of Soiled Inoculated Fabric after Laundry

Source of variance	Degrees of freedom	F test for significance
Water temperature	1	132.25124*
Detergent concentration	1	2.25002
Observation period	2	0.69445
Water temp. x Det. conc.	1	1.36112
Water temp. x Obs. period	2	0.58334
Det. conc. x Obs. period	2	0.08333
Water temp. x Det. conc. x Obs. period	2	1.86112
Error	24	
Total	35	

*Significant at 95% level.

Table 2

Analysis of Variance for Survival of Unsoiled Inoculated Fabric after Laundry

Source of variance	Degrees of freedom	F test for significance
Water temperature	1	304.19727*
Detergent concentration	1	4.99996*
Observation period	2	0.15000
Water temp. x Det. conc.	1	0.20000
Water temp. x Obs. period	2	3.14997
Det. conc. x Obs. period	2	3.64997*
Water temp. x Det. conc. x Obs. period	2	0.05000
Error	24	
Total	35	

*Significant at 95% level.

Table 3

Analysis of Variance for Redeposition on
Soiled Uninoculated Fabric

Source of variance	Degrees of freedom	F test for significance
Water temperature	1	192.67578*
Inoculation treatment	1	0.37502
Detergent concentration	1	5.04192*
Observation period	2	0.21876
Water temp. x Inoc. treat.	1	0.37502
Water temp. x Det. conc.	1	3.37516
Water temp. x Obs. period	2	0.07292
Inoc. treat. x Det. conc.	1	0.16667
Inoc. treat. x Obs. period	2	0.59378
Det. conc. x Obs. period	2	0.32293
Water temp. x Inoc. treat. x Det. conc.	1	0.00000
Water temp. x Inoc. treat. x Obs. period	2	0.78129
Water temp. x Det. conc. x Obs. period	2	0.59378
Inoc. treat. x Det. conc. x Obs. period	2	0.44794
Water temp. x Inoc. treat. x Det. conc. x Obs. period	2	0.96880
Error	48	
Total	71	

*Significant at 95% level.

Table 4

Analysis of Variance for Redeposition on
Unsoiled Uninoculated Fabric

Source of variance	Degrees of freedom	F test for significance
Water temperature	1	193.50331*
Inoculation treatment	1	0.25774
Detergent concentration	1	2.31969
Observation period	2	0.95881
Water temp. x Inoc. treat.	1	0.83509
Water temp. x Det. conc.	1	4.54660*
Water temp. x Obs. period	2	1.00004
Inoc. treat. x Det. conc.	1	0.01031
Inoc. treat. x Obs. period	2	1.06190
Det. conc. x Obs. period	2	0.27836
Water temp. x Inoc. treat. x Det. conc.	1	0.01031
Water temp. x Inoc. treat. x Obs. period	2	2.25783
Water temp. x Det. conc. x Obs. period	2	0.40208
Inoc. treat. x Det. conc. x Obs. period	2	0.62890
Water temp. x Inoc. treat. x Det. conc. x Obs. period	2	0.75261
Error	48	
Total	71	

*Significant at 95% level.

Table 5

Number of Changes in the Presence of Trichophyton mentagrophytes After Laundry

Water temp.	Sample	Observation period	Inoculated-Soiled						Inoculated-Unsoiled					
			IS*	SU*	UU*	IS	SU	UU	UI*	SU	UU	UI	SU	UU
			0.0% Detergent concentration			0.2% Detergent concentration			0.0% Detergent concentration			0.2% Detergent concentration		
140°	1	2 min.	5	1	0	4	0	0	5	0	0	5	0	0
	2	2 min.	5	0	0	4	0	0	5	0	0	5	0	0
	3	2 min.	5	0	0	5	0	0	5	0	0	5	0	0
	1	completed cycle	5	0	0	5	0	0	5	0	0	5	0	0
	2	completed cycle	5	0	0	5	0	0	5	0	0	5	0	0
	3	completed cycle	5	0	0	5	0	0	5	0	0	5	0	0
	1	dryer	5	0	0	5	0	0	5	0	0	5	0	0
	2	dryer	5	0	0	5	0	0	5	0	0	5	0	0
	3	dryer	5	0	0	4	1	0	5	0	0	5	0	0
120°	1	2 min.	4	0	0	5	1	0	5	0	0	5	0	1
	2	2 min.	3	0	0	4	0	1	3	1	0	5	1	1
	3	2 min.	4	2	0	5	0	0	3	0	0	5	0	0
	1	completed cycle	5	1	2	3	2	3	5	0	0	5	0	0
	2	completed cycle	5	0	0	5	0	0	5	0	0	5	0	0
	3	completed cycle	5	0	0	5	0	0	5	0	0	5	0	0
	1	dryer	3	2	2	3	0	1	5	0	0	4	0	0
	2	dryer	5	0	0	4	0	0	4	0	0	5	0	0
	3	dryer	5	0	0	5	0	0	5	0	0	5	0	0

Table 5 (continued)

Water temp.	Sample	Observation period	Inoculated-Soiled						Inoculated-Unsoiled					
			IS*	SU*	UU*	IS	SU	UU	UI*	SU	UU	UI	SU	UU
			0.0% Detergent concentration			0.2% Detergent concentration			0.0% Detergent concentration			0.2% Detergent concentration		
	1	2 min.	0	5	5	0	3	5	0	5	5	0	5	5
	2	2 min.	0	5	5	0	4	5	0	5	5	4	2	2
	3	2 min.	0	5	5	0	5	5	0	5	5	1	1	3
	1	completed cycle	0	5	5	3	0	0	0	3	4	0	5	5
100°	2	completed cycle	0	5	5	0	4	5	0	4	5	0	2	1
	3	completed cycle	0	5	5	0	5	5	0	5	5	0	4	4
	1	dryer	0	5	4	4	0	0	0	4	3	0	5	4
	2	dryer	0	3	2	1	5	2	0	5	5	0	5	5
	3	dryer	0	4	5	0	5	5	0	5	5	1	3	4

Table 6

Presence of Trichophyton mentagrophytes on Soiled Inoculated Swatches Before Washing; Its Survival After Two Minutes of Agitation, After Complete Cycle and After Drying; and the Presence of this Organism in the Wash Water, Rinse Water, Washer Tub and Dryer (Numbers are the number of swatches the organism is present on)

Wash #	Water temp.	Det. conc.	Initial org. present before laund.	Survival after 2 min.	Survival after complete cycle	Survival after drying	Presence in wash water	Presence in rinse water	Presence in washer tub	Presence in dryer
1	100°	0.0%	5	5	5	5	+	+	+	-
2	100°	0.0%	5	5	5	5	+	-	-	-
3	100°	0.0%	5	5	5	5	-	-	-	+
1	100°	0.2%	5	5	2	1	-	-	-	-
2	100°	0.2%	5	5	5	4	-	-	+	+
3	100°	0.2%	5	5	5	5	+	+	+	-
1	120°	0.0%	5	1	1	2	-	-	-	-
2	120°	0.0%	5	2	0	0	-	-	-	-
3	120°	0.0%	5	1	0	0	-	-	-	-
1	120°	0.2%	5	0	0	0	-	-	-	-
2	120°	0.2%	5	2	0	1	-	-	-	-
3	120°	0.2%	5	2	0	0	-	-	-	-
1	140°	0.0%	5	0	0	0	-	-	-	-
2	140°	0.0%	5	0	0	0	-	-	-	-
3	140°	0.0%	5	0	0	0	-	-	-	-
1	140°	0.2%	5	1	0	0	-	-	-	-
2	140°	0.2%	5	1	0	0	-	-	-	-
3	140°	0.2	5	0	0	1	-	-	-	-

Table 7

Presence of Trichophyton mentagrophytes on Unsoiled-Inoculated Swatches Before Washing; Its Survival After Two Minutes of Agitation, After a Complete Wash Cycle, and After Drying; and the Presence of this Organism in the Wash Water, Rinse Water, Washer Tub, and the Dryer (Numbers are the number of swatches the organism is present on)

Wash #	Water temp.	Det. conc.	Initial organ. present before laund.	Survival after 2 min.	Survival after complete cycle	Survival after drying	Presence in wash water	Presence in rinse water	Presence in washer tub	Presence in dryer
1	100°	0.0%	5	5	5	5	+	–	–	–
2	100°	0.0%	5	5	5	5	+	+	+	–
3	100°	0.0%	5	5	5	5	+	+	+	–
1	100°	0.2%	5	5	5	5	+	+	+	–
2	100°	0.2%	5	1	5	5	–	–	–	–
3	100°	0.2%	5	4	5	4	–	+	–	–
1	120°	0.0%	5	0	0	0	–	–	–	–
2	120°	0.0%	5	2	0	1	–	–	–	–
3	120°	0.0%	5	2	0	0	–	–	–	–
1	120°	0.2%	5	0	0	1	–	–	–	–
2	120°	0.2%	5	0	0	0	–	–	–	–
3	120°	0.2%	5	0	0	0	–	–	–	–
1	140°	0.0%	5	0	0	0	–	–		
2	140°	0.0%	5	0	0	0	–	–	–	–
3	140°	0.0%	5	0	0	0	–	–	–	–
1	140°	0.2%	5	0	0	0	–	–	–	–
2	140°	0.2%	5	0	0	0	–	–	–	–
3	140°	0.2%	5	0	0	0	–	–	–	–

Table 8

Presence of Trichophyton mentagrophytes on Soiled Inoculated Swatches Before Washing and the Redeposition of the Organism to Unsoiled Uninoculated and Soiled Uninoculated Swatches at Two Minutes of Agitation, After a Complete Wash Cycle, and After Drying
(Numbers are the number of swatches the organism is present on)

Wash #	Water temp.	Det. conc.	Initial org. present on SU before laund.	Survival on SU after 2 min.	Survival on SU after complete cycle	Survival on SU after drying	Initial org. present on UU before laund.	Survival on UU after 2 min.	Survival on UU after complete cycle	Survival on UU after drying
1	100°	0.0%	0	5	5	5	0	5	5	4
2	100°	0.0%	0	5	5	3	0	5	5	2
3	100°	0.0%	0	5	5	4	0	5	5	5
1	100°	0.2%	0	3	0	0	0	5	0	0
2	100°	0.2%	0	4	4	5	0	5	5	2
3	100°	0.2%	0	5	5	5	0	5	5	5
1	120°	0.0%	0	0	1	2	0	0	2	2
2	120°	0.0%	0	0	0	0	0	0	0	0
3	120°	0.0%	0	2	0	0	0	0	0	0
1	120°	0.2%	0	1	2	0	0	0	3	1
2	120°	0.2%	0	0	0	0	0	1	0	0
3	120°	0.2%	0	0	0	0	0	0	0	0
1	140°	0.0%	0	1	0	0	0	0	0	0
2	140°	0.0%	0	0	0	0	0	0	0	0
3	140°	0.0%	0	0	0	0	0	0	0	0
1	140°	0.2%	0	0	0	0	0	0	0	0
2	140°	0.2%	0	0	0	0	0	0	0	0
3	140°	0.2%	0	0	0	1	0	0	0	0

Table 9

Presence of Trichophyton mentagrophytes on Unsoiled-Inoculated Swatches Before Washing; and the Redeposition of the Organism to Unsoiled-Uninoculated and Soiled-Uninoculated Swatches at Two Minutes of Agitation, After a Complete Wash Cycle, and After Drying (Numbers are the number of swatches the organism is present on)

Wash #	Water temp.	Det. conc.	Initial org. present on SU before laund.	Survival on SU after 2 min.	Survival on SU after complete cycle	Survival on SU after drying	Initial org. present on UU before laund.	Survival on UU after 2 min.	Survival on UU after complete cycle	Survival on UU after drying
1	100°	0.0%	0	5	3	4	0	5	4	3
2	100°	0.0%	0	5	4	5	0	5	5	5
3	100°	0.0%	0	5	5	5	0	5	5	5
1	100°	0.2%	0	5	5	5	0	5	5	4
2	100°	0.2%	0	2	2	5	0	2	1	5
3	100°	0.2%	0	1	4	3	0	3	4	4
1	120°	0.0%	0	0	0	0	0	0	0	0
2	120°	0.0%	0	1	0	0	0	0	0	0
3	120°	0.0%	0	0	0	0	0	0	0	0
1	120°	0.2%	0	0	0	0	0	1	0	0
2	120°	0.2%	0	1	0	0	0	1	0	0
3	120°	0.2%	0	0	0	0	0	0	0	1
1	140°	0.0%	0	0	0	0	0	0	0	0
2	140°	0.0%	0	0	0	0	0	0	0	0
3	140°	0.0%	0	0	0	0	0	0	0	0
1	140°	0.2%	0	0	0	0	0	0	0	0
2	140°	0.2%	0	0	0	0	0	0	0	0
3	140°	0.2%	0	0	0	0	0	0	0	0

Table 10

Actual Wash and Rinse Temperatures of Experimental Washings and pH of Wash and Rinse Water

		Soiled Inoculated				Unsoiled Inoculated			
Wash #	Det. conc.	Actual wash temp.	Actual rinse temp.	pH of wash water	pH of rinse water	Actual wash temp.	Actual rinse temp.	pH of wash water	pH of rinse water
1	0.0%	141°	101°	8.9	9.1	140°	100°	8.3	9.2
2	0.0%	138°	100°	8.7	9.0	138°	97°	9.0	9.2
3	0.0%	130°	104°	8.4	8.9	138°	104°	8.7	9.3
1	0.2%	138°	103°	9.4	9.7	138°	100°	9.2	9.4
2	0.2%	140°	100°	9.1	9.6	142°	105°	9.2	9.5
3	0.2%	140°	105°	9.3	9.7	138°	104°	9.4	9.8
1	0.0%	118°		8.8	9.4	118°	97°	8.9	9.2
2	0.0%	120°	94°	8.9	9.2	120°	95°	8.8	9.2
3	0.0%	118°	109°	8.7	9.1	122°	122°	9.1	9.3
1	0.2%	117°	93°	9.1	9.5	118°	95°	9.2	9.5
2	0.2%	118°	95°	8.8	9.1	120°	93°	9.1	9.3
3	0.2%	120°	107°	9.3	9.7	99°	70°	9.1	9.2
1	0.0%	102°	72°	9.0	9.6	102°	102°	8.7	9.3
2	0.0%	100°	68°	9.4	9.9	98°	68°	9.0	9.4
3	0.0%	100°	90°	8.6	9.4	104°	70°	8.7	8.8
1	0.2%	102°	102°	9.4	9.6	100°	101°	9.4	9.5
2	0.2%	100°	95°	9.1	9.6	109°	95°	8.9	9.4
3	0.2%	100°	70°	9.0	9.1	99°	70°	9.1	9.2

APPENDIX C

MIL-S-48G
6 December 1962
Pages 1 to 5.

MILITARY SPECIFICATION
SOCKS, MEN'S WOOL, CUSHION SOLE, STRETCH TYPE

This specification is mandatory for use by all Departments and Agencies of the Department of Defence. Class 1 - Black - 197

3.2 Materials.-

3.2.1 Yarn -

3.2.1.1 Stretch-type knitting yarn.- The yarn for knitting the top of foot and leg portion adjacent to the high heel, and for plating the high heel, heel, sole, toe, and ring toe shall consist of a single end of the merino yarn specified in 3.2.1.1.1, twisted or plied with the nylon stretch yarn specified in 3.2.1.1.2, using knitting twist. A stretch core yarn will not be acceptable.

3.2.1.1.1 Merino yarn.- The merino yarn shall be 1/30 (worsted count) yarn, made from fleece, pulled sheep's wool, or a combination of both not lower in grade than 56's, U.S. Standard, and cotton, blended in such proportion that the finished yarn contains not less than 50 percent wool on a dry weight basis when tested as specified in 4.3.2. Cotton core yarn will not be acceptable. The merino yarn shall be spun on either the cotton or worsted system.

3.2.1.1.2 Nylon stretch yarn.- The yarn shall be a 140 denier ± 5%, 2 ply, nylon stretch yarn.

3.2.1.3 Terry stitch yarn.- The yarn for the terry stitch on the inside of the high heel, heel, sole, toe, and ring toe shall be made from wool not lower in grade than 50's, U.S. Standard. The yarn shall be spun on the worsted system. Not finer than 1/16s, 1/18s, and 1/20s or equivalent yarn count shall be used for 108 to 114, 116 to 122, and 124 to 136 needle machines respectively.

3.2.1.4 Looping yarn.- The yarn for looping the toe of the sock shall be as specified in 3.2.1.1.

3.3 Color.- The color of the finished socks shall be as specified. The use of sulfur dyes and dyes containing elementary sulfur or compounds capable of oxidation to sulfuric acid is prohibited. The dyestuffs shall be chosen and applied so that the dyed socks shall show no more free or sulfide sulfur than the standard samples when tested as specified in 4.3.3.

3.3.2 Colorfastness.- The dyed socks shall show fastness to perspiration, laundering and crocking equal to or better than the standard sample. In comparing the colorfastness of the standard sample with that of the material under test, specific care will be taken to insure that the same area of both the standard and the test material are taken for testing by any specific test method. When no standard sample is available, the dyed black-197 socks shall

show "good" fastness to perspiration and "fair" fastness to laundering and crocking. Testing shall be as specified in 4.3.3.

3.5 Shrink resistant treatment. All of the wool for the finished sock shall be treated for resistance to felting shrinkage in stock, top, yam or sock form by a controlled oxidation process approved by the contracting agency. The shrink resistant treatment shall not be identified by name or trademark on the socks or on the package.

3.6 Design.- The socks shall be seamless, stretch-type, with a true rib-knit top and a plain knit leg and foot with a terry or tuft stitch on the inside of the high heel, heel, sole, toe and toe ring.

3.7 Construction.-

3.7.1 Knitting.- The socks shall be knit seamless on a circular machine of not less than $3\frac{1}{2}$ nor more than 4 inches in cylinder diameter with not less than 108 nor more than 136 needles. A minimum of 15 gore needles shall be used in knitting the heel, and a minimum of 15 gore needles shall be used in knitting the toe. The socks shall be knit so that they will finish to the proper size and length without undue stretching during boarding.

3.7.1.2 High heel, remaining portion of leg and foot.- The high heel, the remaining portion of the leg adjacent to the high heel, and the foot, shall be plain knit with one end of the stretch-type knitting yarn specified in 3.2.1.1. The high heel, heel, sole, toe and ring toe shall be reinforced with a terry stitch thrown to the inside, made with the wool terry yarn specified in 3.2.1.3, and every knitting course of these areas. The terry yarn, for the high heel and sole, shall be laid in at a point not less than 3 needles after the last short butt needle in the heel gore. The knitting on all of these needles shall be terried. The terry stitch may be omitted from not more than two courses before the looping course, provided the terry yarn is knit with the stretch-type knitting yarn into the knitting of the looper rounds. The two yarns shall be knit together for at least two courses beyond the looping or loose course.

APPENDIX D

ARTIFICIAL SOIL USED IN RESEARCH

Original Recipe*	Modified Recipe
15 gm. Gold Medal Flour	15 gm. Gold Medal Flour sterilized in ethylene oxide chanber 21 hours
15 gm. Argo Corn Starch	15 gm. Argo Corn Starch sterilized in ethylene oxide chamber 21 hours
15 gm. Domino Cane Sugar	15 gm. Domino Cane Sugar in 50 ml. of water and autoclaved 15 minutes
1 gm. powdered carbon	1 gm. powdered carbon sterilized in ethylene oxide chamber 21 hours
15 ml. Wesson oil	15 ml. Wesson oil in 100 ml. of water and autoclaved 15 minutes
15 ml. mineral oil	15 ml. mineral oil in 100 ml. of water and autoclaved 15 minutes
13.25 gm. Carnation evaporated milk	13 gm. Carnation nonfat dry milk in 87.5 ml. water and autoclaved 18 minutes
250 ml. water	———

*Ridenour, 1950. p. 95.

THE EFFECTS OF VARIOUS LAUNDRY TEMPERATURES, OBSERVATION POINTS, AND DETERGENT CONCENTRATIONS ON THE SURVIVAL OF TRICHOPHYTON MENTAGROPHYTES ON MILITARY SOCK FABRIC

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AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

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1971

The importance of the laundry in disease transference has been established in previous studies. Increasing use of household automatic clothes washers in self-service public installations, the use of cold water detergents in cold water, shorter washing cycles, and the fact that the military population in Southeast Asia is suffering from "foot infactions," possibly spread by improper laundry methods, all focus attention on the spread of the dermatological disease of "ringworm" and "athletes foot." The specific causal organism Trichophyton mentagrophytes was studied to determine the effects of laundry conditions on its survival and to determine if transference of the organism occurred during laundry.

A knitted wool and nylon sock fabric meeting military specifications was used for the study. Soiled and unsoiled fabric swatches were inoculated with Trichophyton mentagrophytes, washed at water temperatures of 100°, 120°, and 140°F., with detergent concentrations of 0.0% and 0.2%, and with sterilized swatches to determine redeposition. The survival after washing and drying, the redeposition, survival in the wash and rinse water, pH of the wash water, and the survival of the organism left in the washer and dryer were analyzed statistically.

Water temperature was found to be the most significant variable in this study. Only wash water of 140°F. was effective in the significant decrease in survival and redeposition of the organism. The mean survival of the organism and its redeposition was higher when washed in a 0.0% detergent concentration. The mean survival and redeposition of the organism after two minutes of agitation, upon completion of the wash cycle, and after drying was not significantly different, indicating that longer washing cycles are required and that drying did not destroy or prevent the transfer of the test organism. The presence of soil on the fabric before inoculation proved non-significant in this study.