To the Graduate Council:

I am submitting herewith a thesis written by Joan Leigh Bare entitled "The Effect of Stain Removal Procedures on Three Mold Stained Flame Retardant Finished Cottons." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Textiles and Clothing.

Anna Jean Treece
Major Professor

We have read this thesis and recommend its acceptance:

Charles J Noel

J. Orin Mundt

Robin G. Blakemore

Accepted for the Council:

Hilton A. Smith
Vice Chancellor
Graduate Studies and Research

THE EFFECT OF STAIN REMOVAL PROCEDURES ON THREE MOLD STAINED FLAME RETARDANT FINISHED COTTONS

A Thesis

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ABSTRACT

The objectives of the study were to determine an acceptable procedure for the removal of mold stain from three flame retardant treated cotton fabrics and to establish the effect of five stain removal procedures on these fabrics.

Stain removal procedures were evaluated by subjective and objective ratings with the results statistically analyzed by analysis of variance and Duncan's new multiple range. Flame retardancy was tested according to specifications of the Children's Sleepwear Standard, DOC-FF-3-71.

Objective and subjective ratings indicated Clorox bleach was the most acceptable procedure for the removal of mold stain from FR cottons, but flammability tests showed this procedure to be detrimental to the flame retardancy of the THPC-Urea and THPOH-NH_3 treated cottons. Char lengths were greatly increased on the Pyrovatex treated cotton. Therefore, Clorox bleach was not considered an acceptable procedure.

The second rated most effective procedure was Snowy bleach, and flammability tests showed no detrimental effects to the FR characteristics of the fabrics tested. Therefore, Snowy bleach was determined the most acceptable procedure for removal of mold stains on FR cotton fabrics in this study.

However, subjective ratings considered this procedure only fair because of its ineffectiveness to remove enough stain from the FR cottons for continued children's sleepwear use.

All other agents: Wisk, sunlight and lemon juice, and solvent were considered unacceptable for removal of mold stain due to the inability to restore fabric whiteness to an acceptable level.

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CHAPTER I

INTRODUCTION

"America is burning at a rate exceeding any technologically equivalent nation in the world" (1). Contributing to this high rate of fires is textile flammability, and in turn, apparel fires play a part in the tragic loss due to flammable products. With fire safety and many other safety factors of marketed products in mind, President John Kennedy in 1962 inferred that the Federal Government should be alert to consumer needs and rights. According to these rights, consumers have the "right to safety" and to be "protected against hazardous products in the market place" (2). Spurred by these rights, consumer advocates and the government pushed for further investigations and standards relating to textile flammability.

It became evident that some apparel and fabrics being marketed were hazardous due to their combustible nature, even though the 1952 Flammable Fabrics Act had been passed to protect the consumer from highly flammable fabrics. It was not until 1972 that a stringent enough standard was implemented to reduce burn injuries caused by textile fires. The Children's Sleepwear Standard, DOC FF-3-71, went into effect on July 29, 1973, requiring all children's sleepwear

from sizes 0 to 6X to pass the standard or be taken off the market (3). The standard was extended May 1, 1975, to cover children's sleepwear from sizes 7 to 14 as well. Only children's sleepwear has been covered to date because statistics showed this group contributed to more apparel fires than any other items reported, and children's sleepwear was more easily isolated for legislating protective measures. The elderly and the physically handicapped also are particularly vulnerable to clothing fires. Projections are their lounging and sleepwear garments will be included under flammability standards in the future (4).

Today, infants' sleepwear is made mostly of synthetic fibers. Before the Children's Sleepwear Standard became effective, cotton knit goods comprised the majority of the total production of infants' sleepwear according to estimates by the National Cotton Council of America (5). The switch to synthetics resulted because a 90 to 95 percent failure of the Children's Sleepwear Standard, DOC-FF-3-71, was projected for the previous sleepwear production (6). As a result, a greatly increased volume of flame retardant (FR) fabrics from a variety of fibers have reached the market place in the last few years. (Flame retardant will be abbreviated "FR" in this study.) The use of FR textiles is expected to maintain a solid growth rate of 30 percent each year, especially now that sizes 7-14 sleepwear are to be covered

by the flammability rules (7). Many of these new materials have been hurriedly developed to meet competition while effects of care practices have not been thoroughly investigated. The consumer consequently is confronted with many types of FR fabrics and varied information on the performance and care. The situation is currently confusing and in need of clarification.

One aspect in reference to care that has not been investigated is the removal of mildew from FR cottons and the effect the removal procedures have on the FR finish. Mildew is caused by mold growth and is a problem associated with cellulosic fibers when exposed to dampness and warmth. The earliest FR finishes were developed for military cottons used as tents and tarpaulins. These finishes were used also as mildew and rot proofing agents. Large amounts of finish were needed to achieve these qualities, thus making the hand of the fabric stiff and harsh (8). As the need for FR cotton apparel developed, the amount of finish applied to the fabrics was decreased to increase aesthetic appeal. The resulting apparel may not be protected from mildew and if mildew occurs on these FR cottons, traditional removal procedures are considered detrimental to the flame retardancy. Specifically, chlorine bleach and sunlight damage some FR finishes. Therefore, a study was designed to evaluate stain removal procedures for effective removal of mold stains, and

their effect on the flame retardancy of the FR cottons. This specific information about the care of FR cottons can then be brought to the consumers' attention for their continued safety and satisfaction.

I. OBJECTIVES

1. To determine an acceptable procedure for the removal of mold stain from three flame retardant treated cotton fabrics.

2. To establish the effect of five stain removal procedures on the flame retardancy of three flame retardant treated cotton fabrics.

II. ASSUMPTIONS

1. The 100 percent cotton FR fabrics used in the study will pass the Children's Sleepwear Standard, DOC-FF-3-71.

2. Mold will develop on 100 percent cotton treated with the following FR finishing agents: Pyrovatex, THPOH-NH_3, and THPC-Urea.

3. Mold growth does not appreciably damage the flame retardancy of the finished cottons.

4. The mold stain is an undesirable stain which cannot be removed by standard laundry procedures.

5. The effect of home stain removal treatments on FR cottons is not information readily available to the consumer.

III. HYPOTHESES

1. There will be no significant difference between the effectiveness of different stain removal treatments on three FR cotton fabrics.

2. The stain removal treatments tested will have no significant effect on flame retardancy of the THPOH-NH_3, Pyrovatex, or the THPC-Urea treated cottons.

IV. LIMITATIONS

1. The 100 percent plain weave cotton treated with Pyrovatex, THPOH-NH_3, and THPC-Urea were the only FR cottons studied.

2. Only five stain removal treatments were evaluated.

V. DEFINITIONS

1. "AATCC" is the American Association of Textile Chemists and Colorists, a national scientific body, whose members are chemists and others active in the dyeing, finishing, and other chemical phases of the textile industry, with a purpose to develop test methods (9).

2. The American Society for Testing and Material, "ASTM," is an organization, national in scope, that sets up standards for textiles and other merchandise (9).

3. Components in this study refer to fabric, stain removal treatments and applications of treatments.

4. A flammable fabric is a woven or knitted constructed textile fabric or product made from fabric which burns at an average rate of five inches in less than four seconds (9).

5. Flame retardant is often abbreviated "FR"; fabrics with a FR finish must pass the appropriate governmental standard for flame retardancy.

6. Mildew is a dark soil-like, irregular surface discoloration having a characteristic musty odor caused by mold (10).

7. Mold is a spore forming furry growth on the surface of organic matter caused by fungi in the presence of dampness or decay (10).

8. Perithecium is a flask-like case containing the spore sacs.

9. Pyrovatex, THPC-Urea, and THPOH-NH_3 are flame retardant finishes that are applied to cotton.

10. "SAS" means the Statistical Analysis System which embodies an integrated approach to the editing and statistical analysis of data (11).

11. A stain is the discoloration from foreign matter (10).

CHAPTER II

REVIEW OF LITERATURE

Consumer information on the care of FR apparel is limited. Therefore, this study was designed to provide information of use to consumers on the care of FR cottons when a mildew problem occurs by evaluating selected stain removal procedures for effectiveness of mold removal and the resulting effect on the finish of the FR cottons. Topics that will be discussed will include government action on textile flammability, development of FR textiles, cotton combustion, topical finishes: Pyrovatex CP, THPOH-NH_3, and THPC-Urea, stain removal, mold, and mildew removal.

I. GOVERNMENT ACTION ON TEXTILE FLAMMABILITY

The annual toll attributed to highly flammable fabrics is 3,000-5,000 deaths, 150,000-250,000 injuries, and financial losses exceeding a quarter billion dollars (12). Because this high rate of loss is associated with fabrics, the flammability behavior of textiles has been studied for many years and, within the last decade, legislation has been introduced in some countries establishing flammability requirements for certain end uses (13). Due to several fatal accidents involving brushed rayon cowboy suits and burns from

brushed sweaters, the 1952 Flammable Fabrics Act was passed in the United States. The Act removed from the market only those fabrics which burned rapidly and did little to reduce the total number of fabric burn injuries. On December 14, 1967, President Lyndon B. Johnson endorsed an amendment to the Flammable Fabrics Act. What resulted was immediate government action against fabrics shown to be unduly hazardous. This amendment led to the development of the Children's Sleepwear Standard, DOC-FF-3-71, which covers sleepwear from sizes 0 to 6X. This standard, effective July 29, 1973, ensured that all marketed children's sleepwear fabric or apparel met the requirements.

Considerable controversy has resulted from the passing of the Children's Sleepwear Standard. Textile and fabric producers maintained that this standard was impractical because the textile industry lacked the technology to provide the quantity of FR fabrics the standard required; plus, industry asserted, the consumer was not willing to pay the extra cost of FR apparel (14). Also predicted was the demise of 375-400 manufacturers of infant sleepwear or transfer of these producers into other manufacturing areas. However, the standard is now in force and considered effective. Even more apparel is expected to be covered in the future; thus, the use of flame retardant fabric is projected to maintain a solid growth rate, rising to 34-40 million pounds by 1978 (15).

II. THE DEVELOPMENT OF FLAME RETARDANT TEXTILES

Protection of flammable material against fire dates back to about 400 BC, but the earliest attempts to fireproof textile fabrics came about in 1640 when attention was drawn to the use of clay and plaster of Paris to fireproof canvas. Ammonium phosphate was suggested in 1786. However, no systematic investigation of fireproofing was done until 1820 when it was concluded that the most effective salts for fireproofing were those with a low melting point, capable of covering the material with a glassy layer; alternatively, effective salts were those which gave rise to nonflammable vapors on burning (16).

The historical development of flame retardants for textiles, particularly cellulosics, has evolved in four stages. The first retardants were borax-boric acid mixtures, ammonium sulfamates or ammonium phosphates, which, while affording good initial protection, were water-soluble and not resistant to laundering. These retardants are classified as nondurable. Next, semidurable flame retardants initially evolved from the deposition of insoluble retardants within the fabric. Precipitation of tungsten oxide and tin halides is an example of codeposits which add flame and glow resistance to textile fabrics. Later, durable flame retardants, introduced in the 1930's, used inorganic compounds

of antimony and titanium. Finally, during World War II, insoluble deposits such as antimony oxide combined with chlorinated paraffins were used widely in military application. Today, the area of most activity which had its beginning in the late 1930's, is based largely on the chemical modifications of cellulose through the hydroxyl groups. The use of phosphoric acid alone, urea phosphates and other phosphorylating agents confer FR properties to cellulose. Since World War II, the U.S. Department of Agriculture's Southern Regional Research Laboratory has been actively engaged in the development of FR treatments for cellulose, primarily based on phosphorus compounds. FR finishes based on tetrakis (hydroxymethyl) phosphonium chloride (THPC) alone, copolymerized with methylomelamine, amines, phenols, and other active hydrogen-containing compounds have been found to form insoluble deposits in cotton fiber, providing good flame and glow resistant products (17).

Flame retardants are used to control one or all of the following parameters: (1) flame spread, (2) heat contribution, (3) ease of ignition, and (4) smoke generation. When developing FR finishes, a researcher must control these parameters. Compounds containing the elements chlorine, bromine, phosphorus, antimony, boron, and nitrogen are basic elements of almost all current FR systems. Phosphorus, nitrogen, and boron react primarily by increasing char

formation, while chlorine, bromine, and antimony interfere with reactions between fuel and oxygen in the gaseous phase. Difficulty in achieving FR textile products arises from the necessity for topical application of large quantities of these elements (18).

Three approaches used to establish flame retardancy to fibers include addition of chemicals to extrusion baths, use of fibers having inherent flame retardant characteristics, and the addition of FR finishes to the fabric after weaving or knitting (7). This study is concerned only with the latter approach—application of FR finishes to cotton fabric.

III. COTTON COMBUSTION

Cotton is the generic name for a natural cellulosic white fibrous substance "that surrounds the seeds of certain plants of the mallow family, called Gossypium" (9). A basic component of the cellulose molecule in cotton is the glucose unit made up of the chemical elements: carbon, hydrogen, and oxygen. The burning test used to identify cotton and other cellulosic fibers characterizes the fibers as follows: burns quickly, gives off a white smoke, smells like burning paper or leaves, and has an afterglow. The afterglow, like the flame itself, is important, since if allowed to smolder, it can ignite a fire (19).

The ignition and combustion of cellulose is a multistage pyrolysis and flaring process. Rapid degradation begins at temperatures over 570°F and is accompanied by the formation of combustible gases and vapors which ignite at about 660°F. Combustion is then self-sustaining from 660°F. When cellulose is brought into contact with fire, one reaction is depolymerization, a decomposition of the cellulose into volatile and solid products, some of which are combustible (20). Due to this ease of ignition, achieving FR qualities on cotton presents a problem.

The properties of an ideal FR finish for cotton are:

(a) The finish should impart flame resistance and glow resistance adequate for intended use.
(b) It should not be removed by laundering, should should last for the useful life of the fabric, and be stable to light and weather.
(c) It should have no irritating effect on the skin, nor should it give off toxic fumes when charred.
(d) It should add little weight to the fabric, and preferably improve such properties as tensile and tear strength, hand, drape, color, air permeability and abrasion resistance.
(e) It should be applied by use of ordinary textile finishing equipment and not be hazardous to those applying it.
(f) It should be inexpensive. (21)

The FR finishes used in this study partially meet these ideal properties and are in commerical use today.

Approximately 80 percent of all sleepwear in sizes 0 to 6X was made from cotton prior to the Children's Sleepwear Standard (20). More than 800 million pounds of cotton per year was affected by the government standard that

required roughly 120 million pounds of FR chemicals to treat this quantity of cotton (15). Therefore, it may be difficult for cotton to regain its lost position in the sleepwear market!

IV. TOPICAL FINISHES

Pyrovatex

Pyrovatex is a fiber-reactive organic phosphorus compound which imparts a FR finish to natural and regenerated cellulosic fibers. Under suitable conditions, coupling takes place with the hydroxyl groups in the cellulose molecule. Depending on the fiber being treated, 1-3 percent phosphorus must be fixed on the substrate to ensure production of adequate flame retardancy. The phosphorus is applied in conjunction with trazine or melamine resins by a pad-dry-cure-afterwash process. In general, a FR finish must be stable to washing at a boil and to drycleaning. This, however, cannot be obtained with less than 25-30 percent Pyrovatex solids on the weight of fabric. Physically, Pyrovatex is a clear, colorless to slightly yellow liquid, miscible with water in all proportions. It is nontoxic, has no adverse effects on the skin, requires no ammonia cure, imparts a pleasant soft hand, and resists the effects of repeated launderings and drycleaning. When exposed to heat, it induces relatively low temperature carbonization of

fabric, suppressing the release of flame-propagating tars. The fabric self-extinguishes with no subsequent flaring or afterglow; and although the fabric chars, it holds together and provides a barrier that flame does not penetrate (20), (22), (23).

THPOH-NH_3

Another topical finish, THPOH-NH_3, is based on a widely used phosphorus compound for imparting durable flame retardance to cellulose textiles, tetrakis (hydroxymethyl) phosphonium chloride $(HOCH_2)_4PCL$, or THPC, first announced in 1953 by Reeves and Guthrie. Further research produced an improved flame retardant based on the reaction product of THPC NaOH. This product is prepared by adding a methanolic solution of sodium hydroxide to solid THPC with thorough mixing at room temperature or lower. The NaCl formed in the reaction is removed by filtration, and the product remaining in methanol is an equilibrium mixture of tetrakis (hydroxymethyl) phosphonium (THPOH) and tris (hydroxymethyl) phosphine (THP). The THPOH is exposed to ammonia to form a highly insoluble polymer. A typical treatment consists of padding fabric with a 20-25 percent solution of THPOH, drying the fabric to approximately 10 percent moistrue, and exposing it to ammonia vapors. The ammonia reacts immediately with the THPOH, forming a highly insoluble FR polymer, THPOH-NH_3, inside the fiber (24),(25).

THPC-Urea

This finish is based on tetrakis (hydroxymethyl) phosphonium chloride (THPC). In 1961, H. Coates developed THPC-Urea, a process that involved increasing the extent of polymerization and insolubility of further polymerizable methylol-phosphorus polymeric materials by reacting the polymeric material with ammonia. The four steps involved in making THPC-Urea are:

(1) Impregnating a cellulose material with an aqueous solution or dispersion of a further polymerizable methylol-phosphorus polymeric material;
(2) Drying the treated cellulose material;
(3) Exposing such treated and dried material to gaseous ammonia;
(4) Treating the material with an aqueous ammonia system. (26)

V. STAIN REMOVAL

"Stain removal implies removal of the stain with little or no damage to the fabric" (27). When removing stains, the primary considerations involved are the nature of the foreign agent causing the stain and the nature of the fabric to which it adheres. An important requirement of stain removal is stain identification. Stains may be identified by appearance, odor, location, or feel. After identifying the stain, it should be classified as to whether it can be removed by a dry solvent or a water solution. If a solvent is desired, a suitable solvent for the type of soluble substance in the stain must be selected. There are four ways a solvent can

be applied: soaking, applying pressure, sponging and back sponging. Stains such as carbon black, inks, gum, nail polish and oils can be removed with dry solvents. Blood, cream, egg, berry stains, liquor, tea and grass can be removed with water solutions. A water solution may call for enzyme products, if digestion is required for removal of the stain (28).

The treatment for removing a stain can be rated by severity. The least severe stain removal treatment uses solvents which seldom harm fabrics and dry rapidly. The next severe treatment involves the use of soap and water. Solubilizers such as digestive enzymes are more severe than the previous treatments. Oxidizers such as chlorine bleach which can cause tendering of fabric are rated severe. Stripping is the most severe treatment employed and is undesirable except as a last resort (27),(28). The stain removal treatments for removing mildew used in this research included all of these classes except strippers.

VI. MOLD

Because spores of mold and bacteria exist everywhere, the formation of fungal growth or mold is possible on most textile fabrics regardless of fiber or finish. Growth of these molds produces mildew, "a dark soil-like, irregular surface discoloration having a characteristic musty odor and

loss of fabric strength" (10). The essential conditions for the growth of mold are warmth, moisture, and poor ventilation. The type of finishing preparation on a fabric can act as a culture medium for the microorganisms. Actual destruction of the textile material is due to enzymes which are secreted by the microorganisms. For instance, the molds and bacteria which live on cellulose do not support themselves on the cellulose itself, but on its degradation products formed by the action of enzymes. The degradation of cellulose by enzymes is very similar to that which takes place in the presence of acids except that the enzyme is constantly regenerated. Cellulose fibers are attacked by a much larger number of different kinds of mold than other natural fibers. The two most common microorganisms causing mildew are Chaetomium globosum and Aspergillus niger (10), (16). Losses due to microbial attack in the U.S. textile industry run close to one billion dollars a year (29). In this study Chaetomium globusom was used to produce mold stains on the FR cottons.

VII. MILDEW REMOVAL

Upon detection of mildew, the sooner action is taken the greater is the chance of successfully removing the stain, and if treatment is necessary, the most common

procedures for removing mildew are the use of sunlight or chlorine bleach. Studies show, however, that hypochlorite bleaches tend to yellow FR fabrics, causing loss of strength and loss of flame resistance after 10 to 25 launderings (30). Studies also indicate that some FR finished fabrics are sensitive to sunlight and lose their resistance to burning after being subjected to relatively few home laundry-line-dry cycles or after brief exposure to sunlight followed by laundering (31). Strong soap solutions have also been recommended to remove new mildew, but soap has adverse effects on FR finishes. Soap, carbonate and silicate products in solutions of moderately hard water cause deposits to accumulate on the fibers, thus blocking the flame retardancy of the fabric surface (32).

The first FR finishes applied to military cotton tents and tarpaulins acted as mildew and rot proofing agents. This protective application required large amounts of chemicals and the resulting fabric was stiff and harsh. In order to achieve FR cottons suitable for apparel, the percent of topical finish had to be reduced. This reduction eliminated the benefits of rot and mildew resistance. Therefore, some FR cottons on the market are not mildew proof. This aspect of care needs to be investigated because stain removal treatments used in the past for mildew removal may damage the flame retardancy of some FR cottons. Thus,

it is evident that new procedures for removal of mildew may need to be developed so that the consumer can successfully remove mold stains without destroying unintentionally the flame retardancy of the fabric required by law.

CHAPTER III

PROCEDURE

The purpose of this study was to evaluate procedures for the removal of mold stain from FR cotton fabrics; the experiment included three FR finished cottons inoculated with mold, five stain removal treatments, and rating for acceptability of these fabrics by subjective and objective means. Procedures cover fabric requirements, specimens, growth of mold, inoculation of specimens, laundry/drying procedure, stain removal treatments, reflectance readings, judging, flammability testing, and statistical analysis.

I. FABRIC

Four 100 percent cotton fabrics with three different types of FR finishes and one unfinished cotton control were used for testing. All fabrics were plain weave, weighing 2.77 ounces per square yard and 3.25 ounces per linear yard. Yarns per inch were 87.8 in the warp and 53.2 in the filling. The width of the fabric was 42.3 inches. Fabrics were finished with 30 percent Pyrovatex, 20 percent THPOH-NH_3 and 16 percent THPC-Urea oxidized with a catalyst (noncrosslinking disodium hydrogen phosphate).

II. SPECIMENS

Fabrics were cut into 12" × 15" specimens. Specimens were zigzagged around the edge and coded in relation to finish by color of the thread. Specimens were then coded randomly in relation to the type of stain removal treatment applied. Corners were switched diagonally. The identification codes of fabrics and treatments were:

Fabric Identification Code

Fabrics	Color Code
Cotton Control	Green
THPOH-NH_3	Yellow
THPC-Urea	Black
Pyrovatex	Dark Green

Stain Removal Treatment Identification Code

Stain Removal Treatment	Code Number	Corners Stitched
Clorox bleach	0	0
Snowy bleach	1	1
Sunlight and Lemon juice	2	2
Solvent	3	3
Wisk detergent	4	4

III. GROWTH OF MOLD

Dr. P. B. Marsh, Plant Physiologist for the Plant Science Research Dvision of the USDA Agricultural Research Service in Beltsville, Maryland, recommended Cheatomium globosum, a standard mold used in governmental experiments.

A pure culture of this mold, number 1042.4, was supplied. A modification of Method 5751.1 of Federal Specification CCT-T-119 was used in growing the mold. Whatman No. 2 filter paper with 29 milliliters of salt agar was placed in petri plates for growth of mold. The contents of the agar media were:

Contents of Agar Media

NH_4NO	(Ammonium Nitrate)	3.000 g.
K_2HPO_4	(Dipotassium Phosphate)	1.000 g.
$MgSO_4$	(Magnesium Sulfate)	.250 g.
KCl	(Potassium Chloride)	.250 g.
Bacto Agar		10.000 g/l

The first petri plates were inoculated with mold from cold storage and left to incubate for two weeks at 27°C at a high relative humidity. After growth had occurred in the petri plates, a salt solution was prepared for harvesting the mold by adding chemicals to distilled water in the following proportions:

Salt Solution

NH_4NO_3	3.000 g.
K_2HPC_4	1.000 g.
$MgSO_4$	.250 g.
KCl	.250 g.
$ZnSO_4$	.050 g.
$MnSO_4$	.001 g.
$CuSO_4$	.001 g.
Distilled water	1 liter

The Chaetomium globosum was harvested by pouring a few milliliters of salt solution into the petri plates and

scraping the perithecia from the filter paper with a wire loop. This mixture was poured into 100 milliliters of salt solution, and with the addition of a magnetic stirring bar, placed on a magnetic stirrer for five minutes. The perithecia were broken open in this process and the spores released. The mixture was then filtered through cotton wadding to remove the unbroken perithecia. The spore suspension became a clear, dark green color. All mold suspension was filtered into a large flask to assure that each suspension was of equal value. The next set of petri plates was inoculated with this mold suspension using a pipette to distribute the mold suspension on the filter paper. Mold growth was continually kept in progress.

IV. INOCULATION OF FABRIC

Each 12" × 15" coded dry specimen was weighed, then dipped into fifty milliliters of mold suspension. The specimen was put through a hand wringer to assure equal distribution of mold suspension throughout the fabric. The fabric was weighed again on the Mettler P1000 balance to calculate weight gained. The percentage of weight gained from the suspension solution was as follows.

Percentage of Increased Weight

Control	142 percent
THPOH-NH_3	137 percent
THPC-Urea	138 percent
Pyrovatex	136 percent

After each specimen was inoculated, it was placed in a plastic bag with the other specimens. The plastic bag was placed in a desiccator filled with water and the desiccator was then placed in a dead oven to maintain a high relative humidity. The dead oven maintained a constant temperature of 26°C. Fabrics were left to incubate until a highly visible amount of mold growth appeared. The duration of the incubation period varied from one to three weeks, due to the different susceptibilities of the finished fabrics to the mold.

V. LAUNDRY/DRYING PROCEDURE

Specimens were laundered under simulated home laundry/drying conditions as specified in the AATCC Test Method 124-1974 (33). The specimens were subjected to this test method before inoculation of mold, after the inoculation period, and with every application of stain removal treatment.

VI. STAIN REMOVAL TREATMENTS

Each fabric in the study was subjected to five different stain removal treatments and one to five applications of each treatment. Two replications had one application of treatment and two had five applications of treatment. Each treatment was applied to a specimen of each fabric in the study. Four specimens, each representing a

different fabric, were treated alike and at the same time by each stain removal treatment. The order of treatments was random, but the order in which the fabrics were chosen for application of treatment was not random. The following steps of each treatment represent one application of treatment. These steps were repeated up to five times.

Chlorine Bleach

1. The specimens were soaked in a Clorox solution, 1/2 cup (118 ml.) per gallon (3612 ml.) of hot sudsy tap water, for five minutes. Ten grams of AATCC detergent was added to make the solution sudsy.

2. The specimens were washed according to AATCC Test Method 124 (33), plus the addition of one cup of Clorox bleach.

Sodium Perborate Bleach

1. Specimens were placed in a Snowy bleach solution (10 g. of Snowy to 500 ml. of hot tap water) and left to soak for thirty minutes.

2. Specimens were washed with 1/2 cup (60 g.) of Snowy bleach and 90 grams of AATCC detergent using the AATCC Test Method 124 (33).

Lemon Juice and Sunlight

1. Specimens were placed in a solution of 200 ml. of concentrated lemon juice and 500 ml. of water.

2. Immediately, each specimen was squeezed through a hand wringer for even distribution of treatment.

3. Specimens were hung in the sunlight until dry.

4. Specimens were laundered by the AATCC Test Method 124.

Solvent

1. Specimens were flushed with Stoddard dry solvent.

2. Specimens were sprayed with a combination of dry spotter (1 pt. coconut oil with 9 pts. dry solvent) and amyl acetate until wet and then rubbed gently.

3. Step 1 was repeated.

4. Specimens were flushed with water.

5. Specimens were sprayed with a wet spotter (1 pt. detergent, 1 pt. glycerine, and 8 pts. H_2O) until wet and then rubbed gently. Step 4 was repeated.

6. Step 5 was repeated.

7. Specimens were flushed with alcohol and rubbed gently.

8. Specimens were laundered by the AATCC Test Method 124.

Concentrated Detergent

1. Each specimen was pretreated with 20 ml. of concentrated Wisk detergent by rubbing detergent into the stain.

2. Immediately, specimens were laundered by the AATCC Test Method 124.

VII. REFLECTANCE READINGS

All specimens were checked for degree of whiteness and color value by the Hunterlab Model D25D2 Color Digital Difference Meter. Twenty reflectance readings were taken of each fabric in its original state, and these readings were averaged to obtain an initial reflectance reading mean. Readings were then taken after the incubation period and after each application of a stain removal treatment. To obtain consistent readings, each specimen was folded so that eight layers of fabric were placed under the light. One reading was taken from each layer of fabric by folding and refolding the specimen to the light. These readings were averaged and recorded for each individual specimen and used in the statistical analyses. The initial reflectance readings were not computed in the analyses.

The Hunter L, a, b scale was used from the Color Difference Meter. This scale was designed to give measurements of color in units of approximate visual uniformity throughout the specimen. Thus, L measures lightness and varies from 100 for perfect white to zero for black, approximately as the eye would evaluate it. The a reading measures redness when plus, gray when zero and greenness when

minus. The b reading measures yellowness when plus, gray when zero, and blueness when minus (34).

Before taking each set of readings, the Hunter Difference Meter was standardized against a white calibrated standard. The white standard's readings were:

Calibrated White Standard Values

L reading	94.5
a reading	-1.1
b reading	2.2

The changes that took place in the reflectance readings after each application of a treatment were important in evaluating the success of the stain removal treatments. It was desired in this study for a stain removal treatment to remove the mold stain sufficiently to restore the fabrics' white appearance. This white appearance was evaluated by the Hunter L, a, b readings taken from the fabric. The higher the L value, the whiter the specimen. This reading was the most useful in evaluating whiteness. The closer the a and b readings were to zero, the less color was evident in the specimens. The following scale illustrates the measurement values designating color and whiteness.

Measurement Values of Reflectance Readings

L readings

85.0 86.0 86.0 88.0 89.0 90.0 91.0 92.0

. . . . . .>

whiteness

a readings

greenness gray redness

-2.50 -2.00 -1.50 -1.00 -0.50 0.0 0.50 1.00 1.50 2.00 2.50 3.00

<. . . . . .>

b readiness

blueness gray yellowness

-2.50 -2.00 -1.50 -1.00 -0.50 0.0 0.50 1.00 1.50 2.00 2.50 3.00

<. . . . . .>

VIII. JUDGING

After all stain removal treatments had been applied, a panel of five judges evaluated the acceptability of the specimens for children's sleepwear. Specimens were judged after one application of treatment and five applications of treatments. Judges were told to rate the specimens from one to four as to their acceptability relating to whiteness for use in children's sleepwear. A score of one designated that the judge felt the specimen was unacceptable for children's sleepwear and a score of four meant the specimen was acceptable. The categories and appropriate scores follow:

Possible Answers Category	Assigned Scores
unacceptable	1
barely unacceptable	2
barely acceptable	3
acceptable	4

The five judges' scores were averaged by fabric, stain removal treatments and application of treatments and then computed in analyses. Results from judging were used as a consideration in evaluating the effectiveness of the stain removal treatment on the FR cottons in the study.

IX. FLAMMABILITY TEST

Finally, four strips, 10" × 3 1/2", were cut from the 12" × 15" specimens and burned according to the Children's Sleepwear Standard, DOC-FF-3-71. The strips were burned only after one and five applications of the stain removal treatments. All char lengths and burning rates were recorded. Any strip failing the standard was noted and the stain removal treatment used for that particular fabric was considered unacceptable. Four sets of burnings were executed, two replications representing one application of stain removal treatment and two representing five applications.

X. STATISTICAL ANALYSES

Significant data related to mold stain removal were identified by analysis of variance using the mean reflectance readings of the components: fabric, stain removal treatments, and number of applications of the treatment. Also, judges' ratings were computed to evaluate these same components. A Duncan's new multiple range was utilized to evaluate the overall effectiveness of the stain removal treatments, the

finish of the fabric, and the effect repeated applications of treatments had on the effectiveness of the treatments.

The SAS program was used to analyze reflectance readings and judges' ratings. Data were considered to be significant at the .01 probability level and highly significant at the .001 level.

CHAPTER IV

RESULTS AND DISCUSSION OF DATA

The main thrust of the study was an evaluation of the effectiveness of five stain removal treatments to remove mold stain from three FR cotton fabrics without destroying the FR characteristics. Reported in this chapter are the interaction of fabrics, stain removal treatments and repeated applications of treatments; evaluation of the overall means of the components and significant differences as designated by Duncan's multiple range subscripts; and results of the flammability test.

I. INTERACTION OF FABRIC, TREATMENTS, AND APPLICATIONS

Data revealed that the effectiveness of each stain removal treatment was affected by their repeated application and related significantly to the fabric's susceptibility to the mold inoculation. Data were based on reflectance readings and subjective judging and evaluated and compared according to the fabrics. Three way interaction of the components was found highly significant for the L readings, significant for the a readings, and nonsignificant for the b readings and subjective judging. Data are grouped by type of reflectance

reading, subjective judging, and presented in the figures according to fabric.

L Reflectance Readings

The L readings were considered the most useful in evaluating the effectiveness of the stain removal treatments and provided the basis for evaluation and comparison that follows. The effect of the incubation period and stain removal treatments on the fabric is discussed and presented by fabric in Figures 1-4.

Cotton control. The initial reflectance reading for the cotton control was 96.2 based on 100 (Figure 1). The incubation period decreased whiteness but mold staining was varied among specimens. Application of the first stain removal treatments showed Clorox bleach had the highest L values and solvent the lowest, while repeated application of Snowy bleach and Wisk detergent initiated continued increasing values. Overall, the readings indicated that Clorox bleach was the most effective treatment, followed by Snowy bleach.

THPOH-NH_3. This treated cotton had an initial reflectance reading of 94.7 (Figure 2). A fairly large range of values was recorded among the five specimens after the incubation period, but all L readings were decreased. The readings indicated that Clorox bleach was the most effective treatment in removing the mold stain regardless of the number

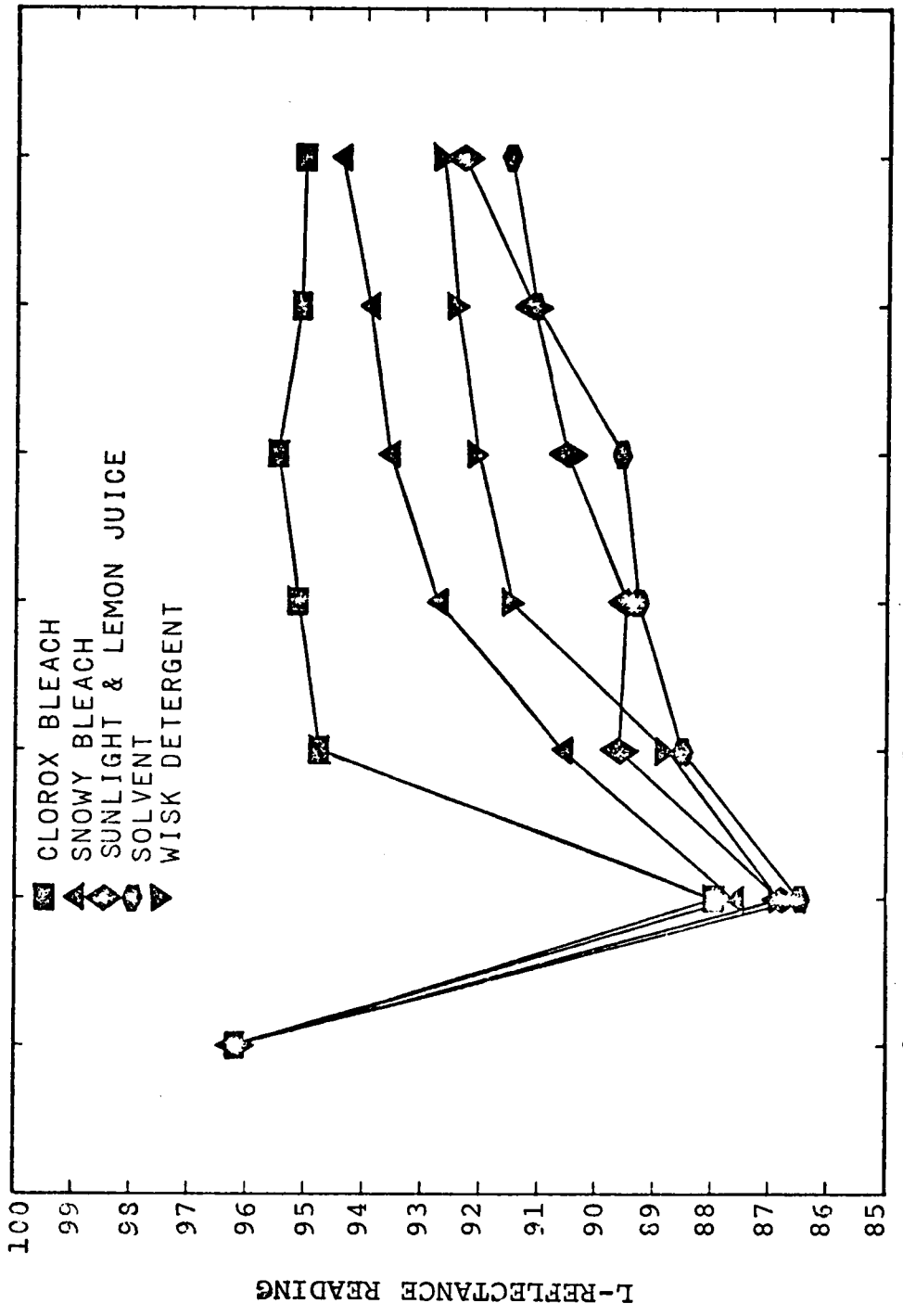

Figure 1. The Effects of Fabric*Treatment*Application Interaction on the L Readings for the Cotton Control.

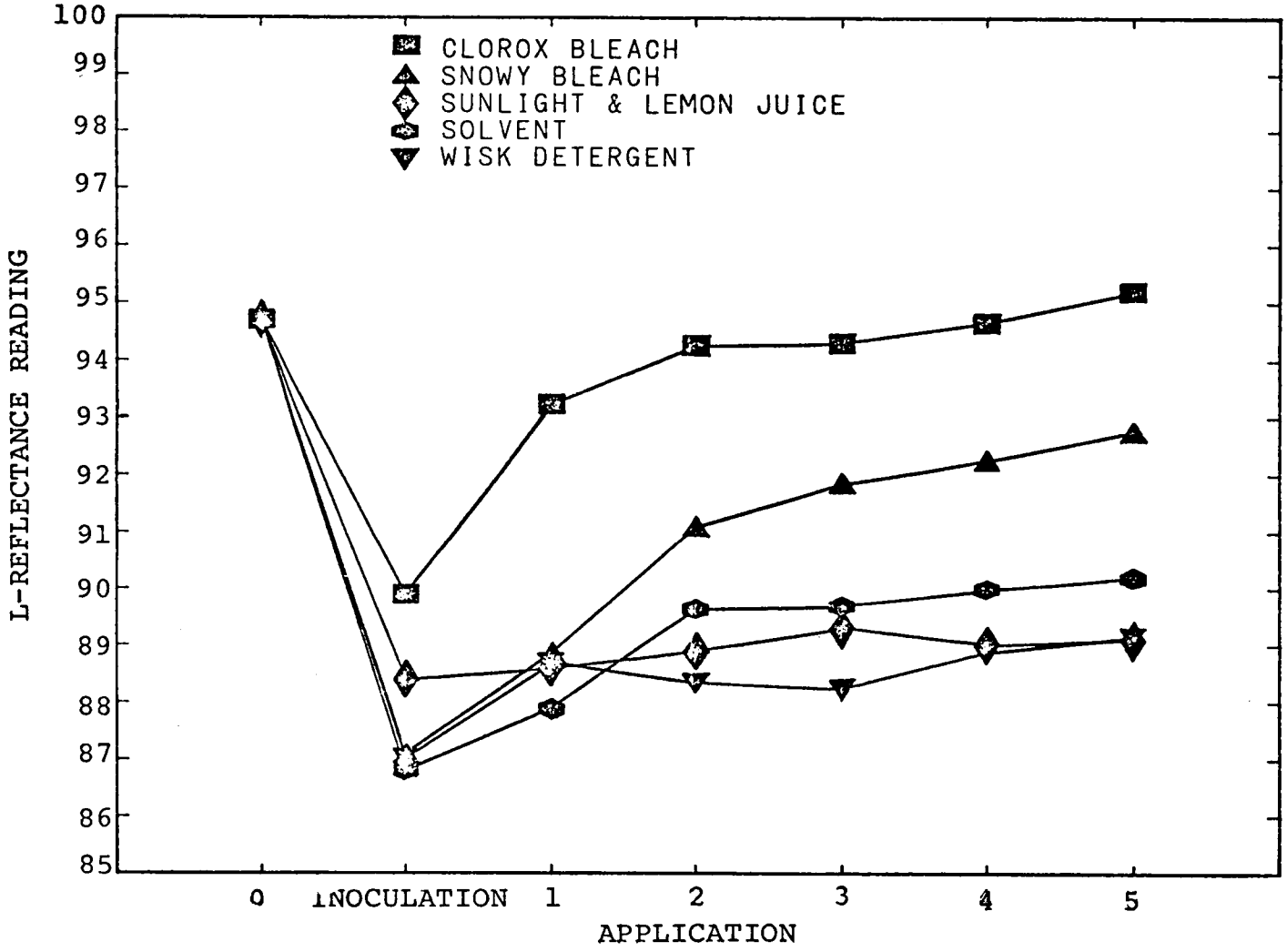

Figure 2. The Effects of Fabric*Treatment*Application Interaction on the L Readings for the THPOH-NH_3 Treated Cotton.

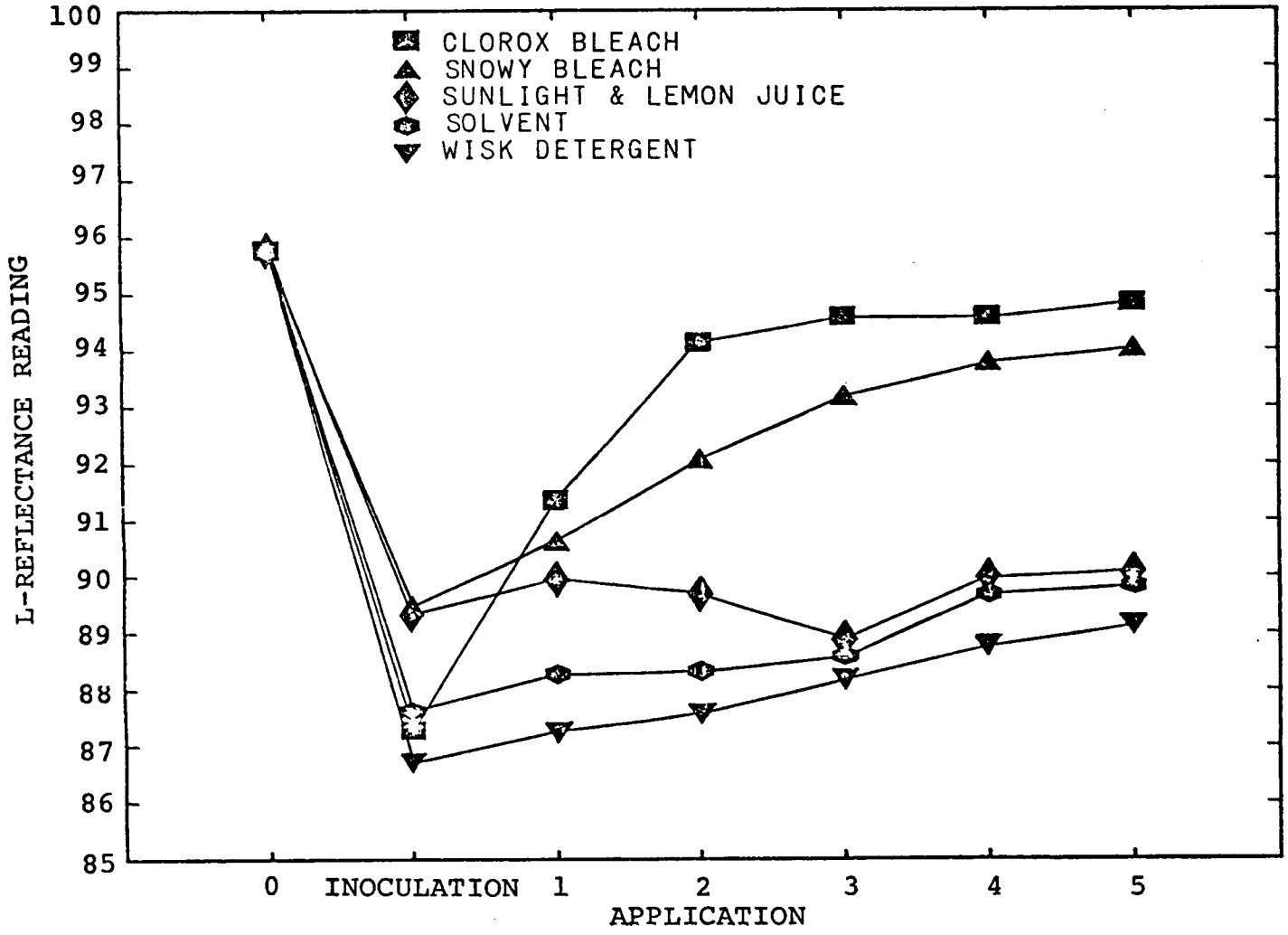

Figure 3. The Effects of Fabric*Treatment*Application Interaction on the L Readings for the THPC-Urea Treated Cotton.

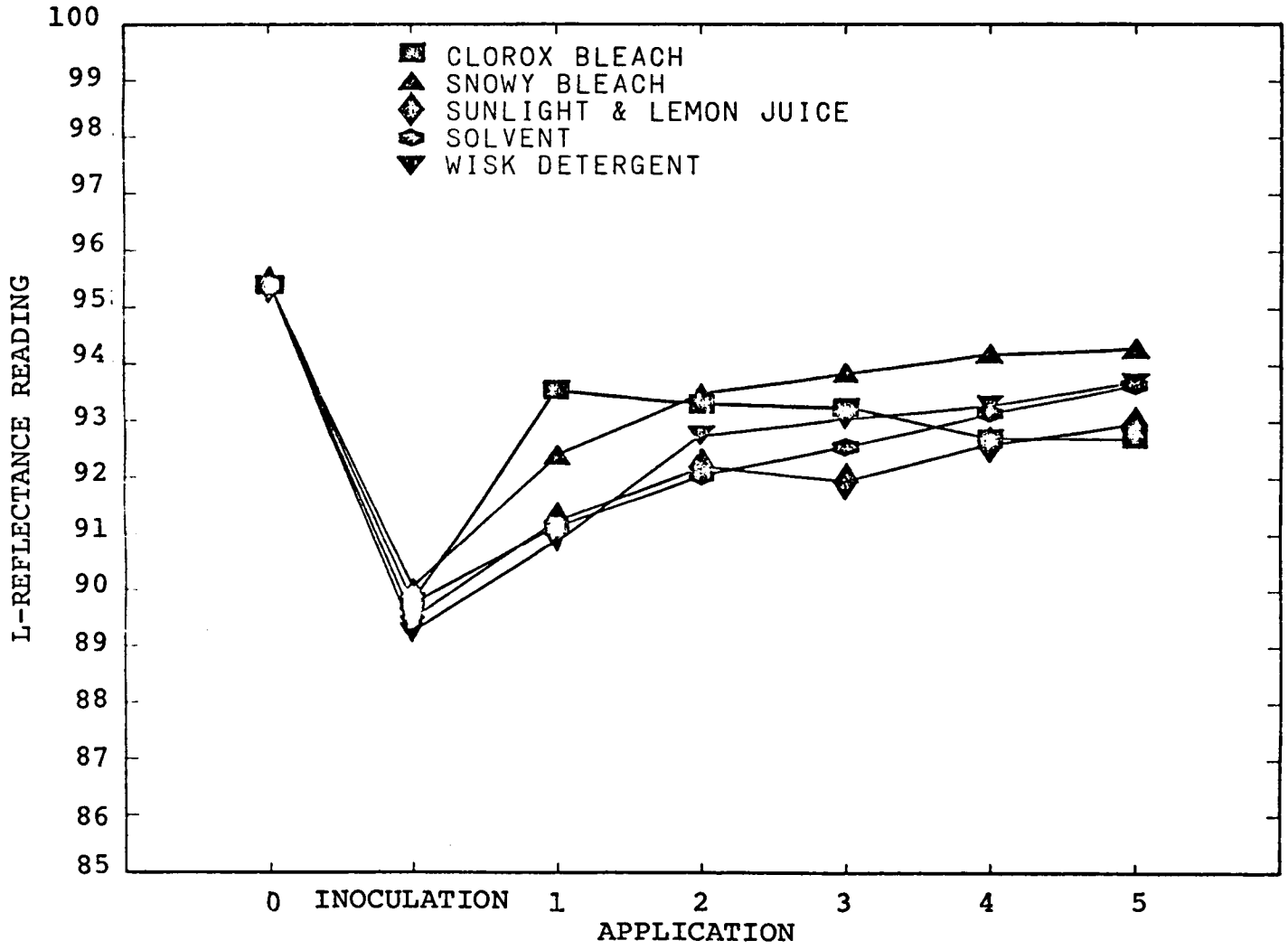

Figure 4. The Effects of Fabric*Treatment*Application Interaction on the L Readings for the Pyrovatex Treated Cotton.

of applications of treatment. The Snowy bleach values indicated repeated application of treatment increased the L readings substantially; consequently, this treatment was rated second to Clorox in effectiveness. The other three treatments effected little change on the L readings, indicating poor stain removal.

THPC-Urea. This treated fabric had an initial reflectance reading of 95.8 (Figure 3, page 36). After the incubation period, the L values dropped but mold stain severity varied among specimens. Clorox bleach almost returned the L readings to their original values, indicating good stain removal. Repeated application of treatment resulted in a gradual increase in values for the Snowy bleach, thereby ranking it as the second most effective treatment. The Wisk detergent was least effective on this FR treated cotton.

Pyrovatex. The initial reflectance reading for this fabric was 95.4 (Figure 4). The incubation period dropped the values and mold staining was similar among all specimens. Clorox bleach was the most effective treatment for removing the mold stain after the first application of the treatments, but repeated application of Clorox bleach decreased L values. Visual observation attributed the decreasing values to the yellowing of the fabric caused by the Clorox. Overall, Snowy bleach had the highest values, and was considered the

most effective treatment for removing mold stain from Pyrovatex finished cotton. However, effectiveness of all stain removal treatments was similar.

Comparison. The cotton control had the highest initial L reflectance reading and the THPOH-NH_3 the lowest; therefore, the cotton control was the whitest fabric in the beginning of the study and the THPOH-NH_3 the least white. After the mold incubation period, the mold stain was more varied among the THPOH-NH_3 and the THPC-Urea specimens than the cotton control and the Pyrovatex specimens. Also, the Pyrovatex fabric had the highest values and the cotton control the lowest; therefore, these readings indicated the Pyrovatex treated cotton had a low acceptability to mold growth and the cotton control had a high acceptability.

Clorox bleach was the most effective of the stain removal treatments for all fabrics after repeated applications. One exception was the Pyrovatex treated fabric which was yellowed by Clorox bleach. Snowy bleach was the next best treatment and effectiveness improved with repeated application of treatment. Wisk, sunlight and lemon juice, and solvent affected each fabric in a slightly different manner, but these treatments were considered least effective in removing the mold stain from all fabrics in the study. The above three treatments were grouped together because

overall the end result was similar, although their stain removal effectiveness changed with each fabric.

a Reflectance Readings

The a readings designated red and green value change on the fabrics due to the effect of the application of stain removal treatments and the incubation period. These readings are the basis for the evaluations that follow. The effects of the incubation period and the stain removal treatments are discussed, compared and presented by fabric in Figures 5-8.

Cotton control. The control specimens had a .06 red value (see page 29) for an initial reflectance reading (Figure 5). The incubation period caused all specimens to have an even greater red value. The Clorox bleach reduced the a values while the other four stain removal treatments effected a slight increase in the a values by the fifth application of the treatments.

THPOH-NH_3. These speicmens had a -0.7 green value for an initial reflectance reading (Figure 6). The incubation period reduced the green value; while no stain removal treatment affected the color value dramatically. The large jump in the value resulting from the third application of the Snowy bleach is unexplainable.

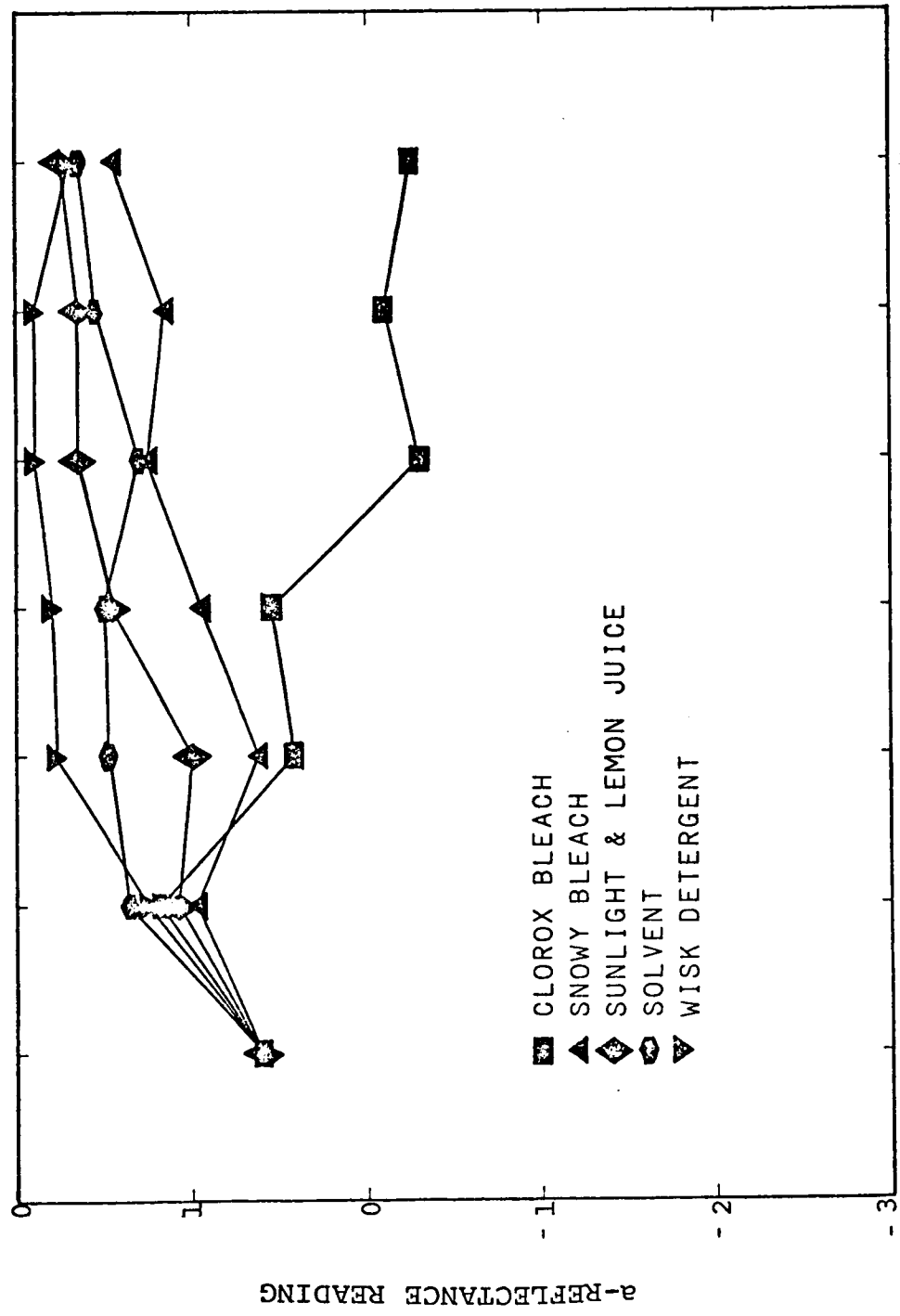

Figure 5. The Effects of Fabric*Treatment*Application Interaction on the a Readings for the Cotton Control.

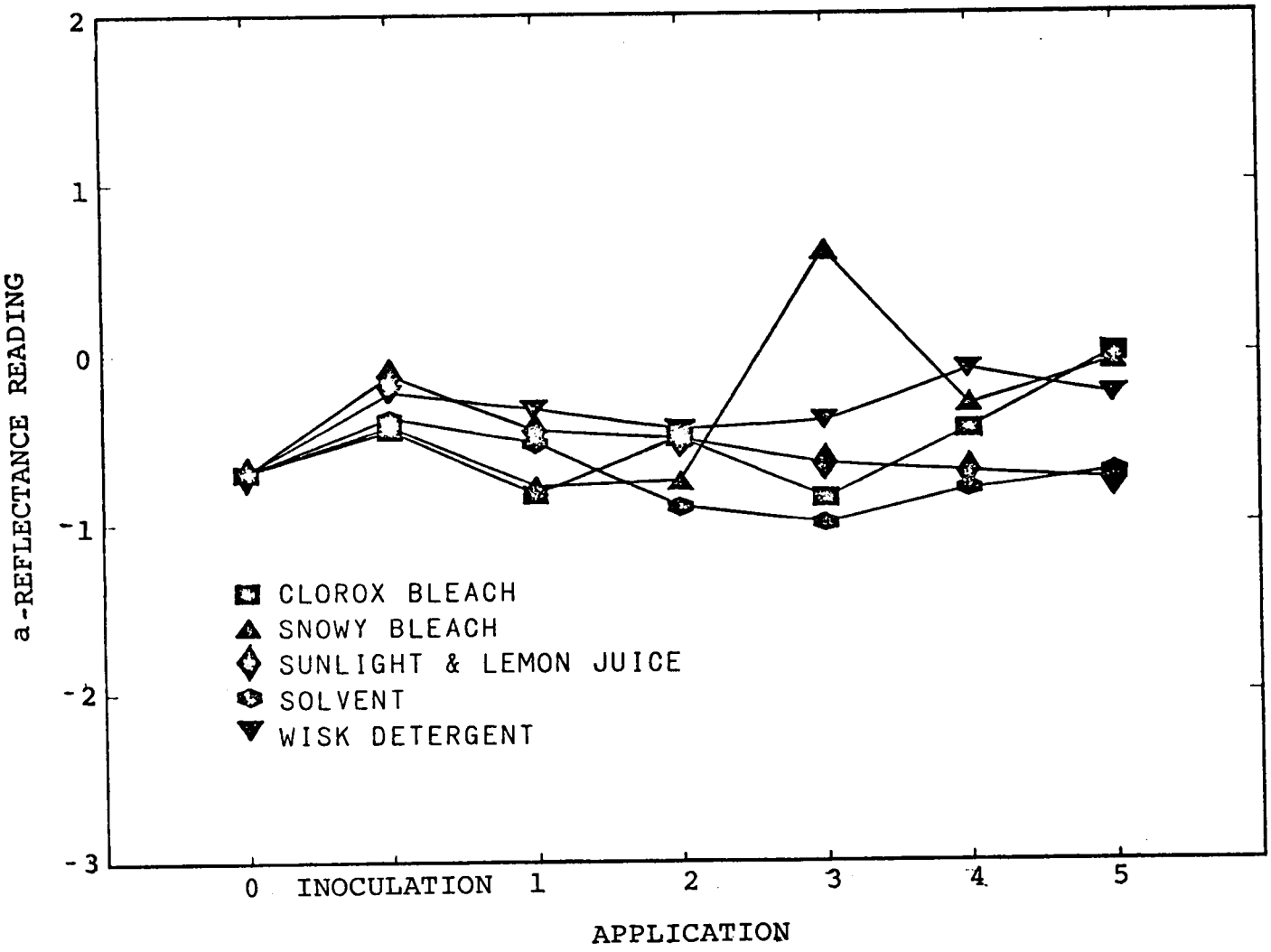

Figure 6. The Effects of Fabric*Treatment*Application Interaction on the a Readings for the THPOH-NH_3 Treated Cotton.

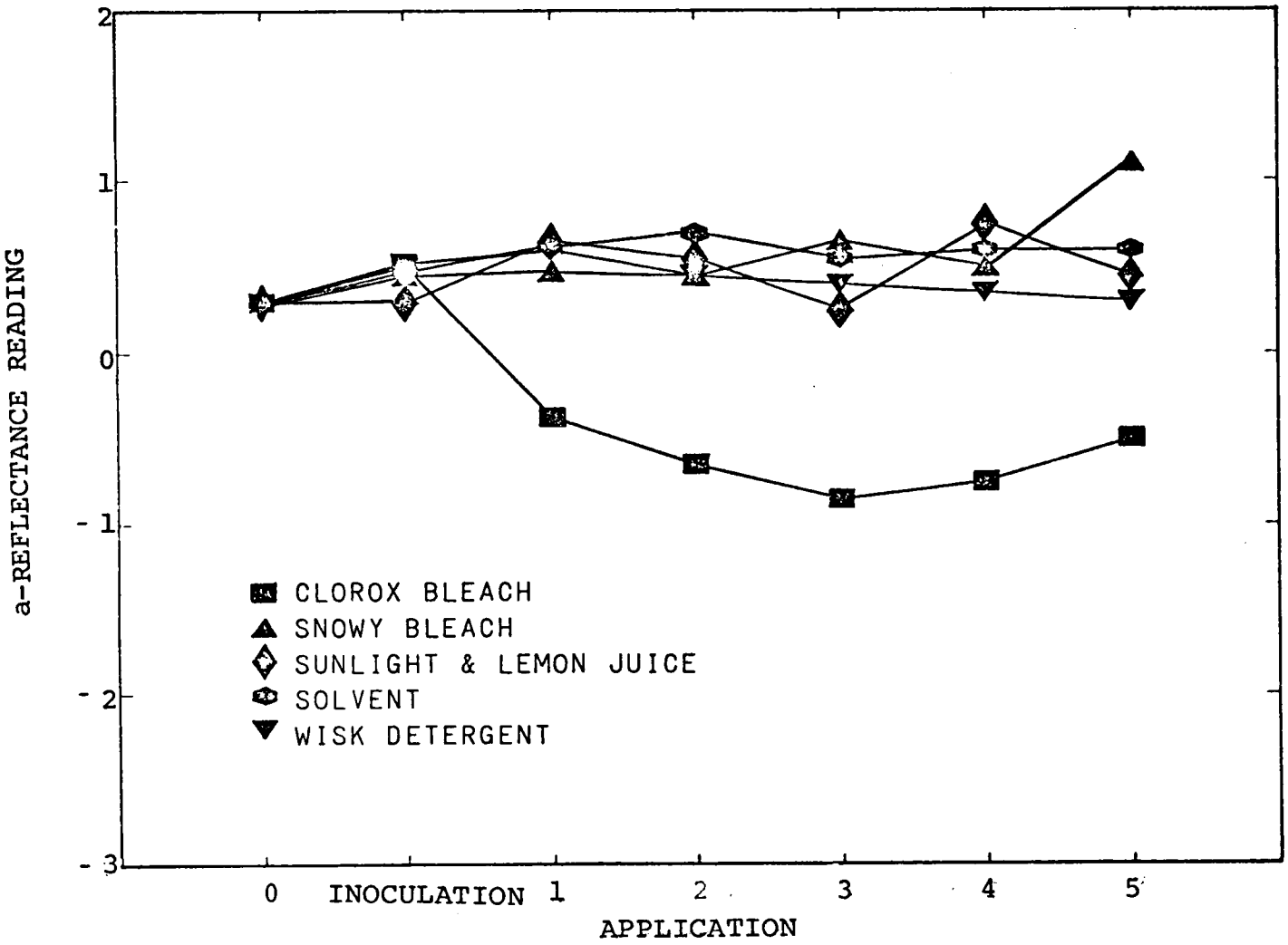

Figure 7. The Effects of Fabric*Treatment*Application Interaction on the a Readings for the THPC-Urea Treated Cotton.

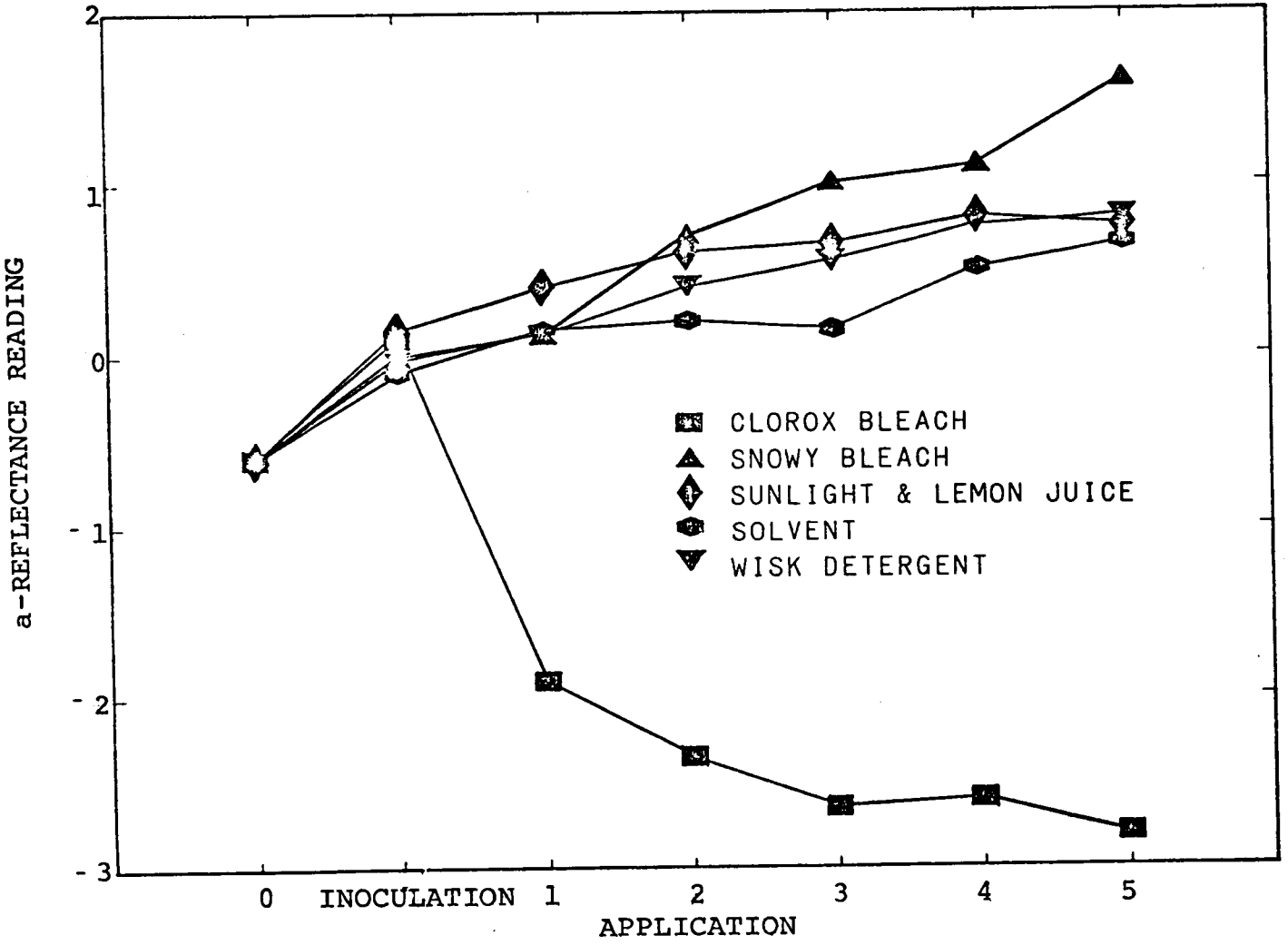

Figure 8. The Effects of Fabric*Treatment*Application Interaction on the a Readings for the Pyrovatex Treated Cotton.

THPC-Urea. The initial reflectance reading for these specimens was a 0.3 red value (Figure 7, page 43). The incubation period and most treatments changed the color values only slightly; however, Clorox bleach substantially affected the readings with movement into the green range. There was not much evidence of stain removal represented for this fabric.

Pyrovatex. The specimens had an initial -0.6 green value reading (Figure 8). The incubation period reduced this green value into the gray zone. The application of the Clorox bleach caused a dramatic increase in the green value, attributed to yellowing of the fabric (Figure 9) which actually produced a yellow-green value change. The Snowy bleach caused an increasing red value change which was an opposite and also undesirable change compared to Clorox. The other three treatments effected slight changes in color values indicating poor stain removal.

Comparison. The a color value of the four fabrics in their initial state was different. Pyrovatex and THPOH-NH_3 fabric had an initial green value while the cotton control and the THPC-Urea fabrics had an initial red value. The incubation period did not affect the color value of any of the fabrics dramatically and all value changes were in the same direction.

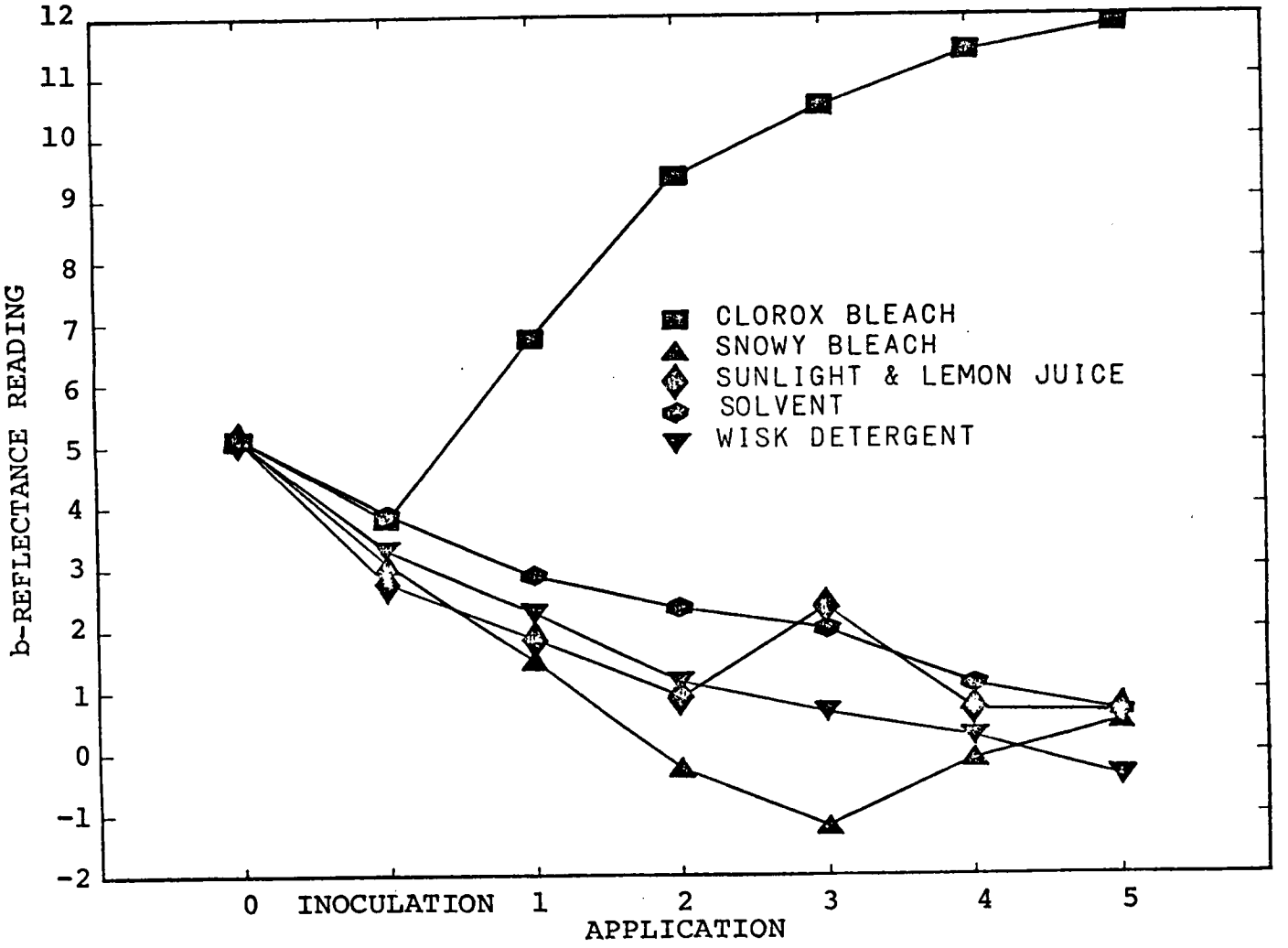

Figure 9. The Effects of Fabric*Treatment*Application Interaction on the b Readings for the Pyrovatex Treated Cotton.

The a color value of each fabric was affected differently by the stain removal treatments. Clorox bleach effected the most value change on all fabrics followed by Snowy bleach. Sunlight and lemon juice, solvent, and Wisk effected a slight color value change on all fabrics but in varying degrees with each fabric. Readings indicated that no one treatment was effective in removing mold stain on all fabrics.

b Reflectance Readings

The b reflectance reading designated yellow and blue value change on the fabrics due to the effects of the incubation period and stain removal treatments. These readings were the basis for evaluation that follows. The effect of the components is discussed, compared, and presented by fabric in Figures 9-12.

Cotton control. The initial b reflectance reading for this fabric was a 2.1 yellow value (Figure 10). The incubation period affected this value very little. Overall, stain removal treatments tended to reduce the yellow value to different degrees.

THPOH-NH_3. The initial b reading for the THPOH-NH_3 treated cotton was a 5.7 yellow value (Figure 11). This fabric had a high yellow value in the initial state. The incubation period increased the yellow value dramatically.

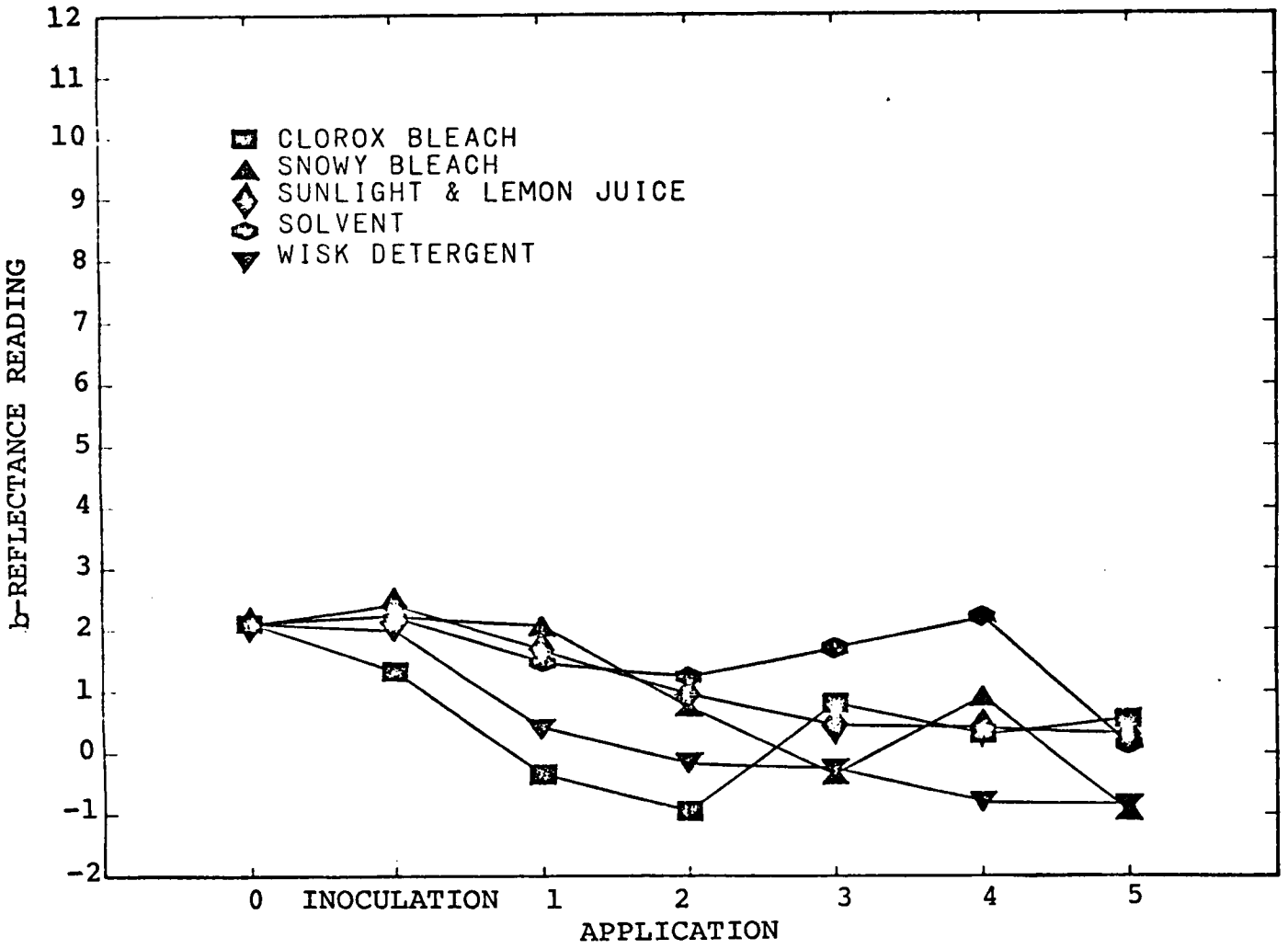

Figure 10. The Effects of Fabric*Treatment*Application Interaction on the b Readings for the Cotton Control.

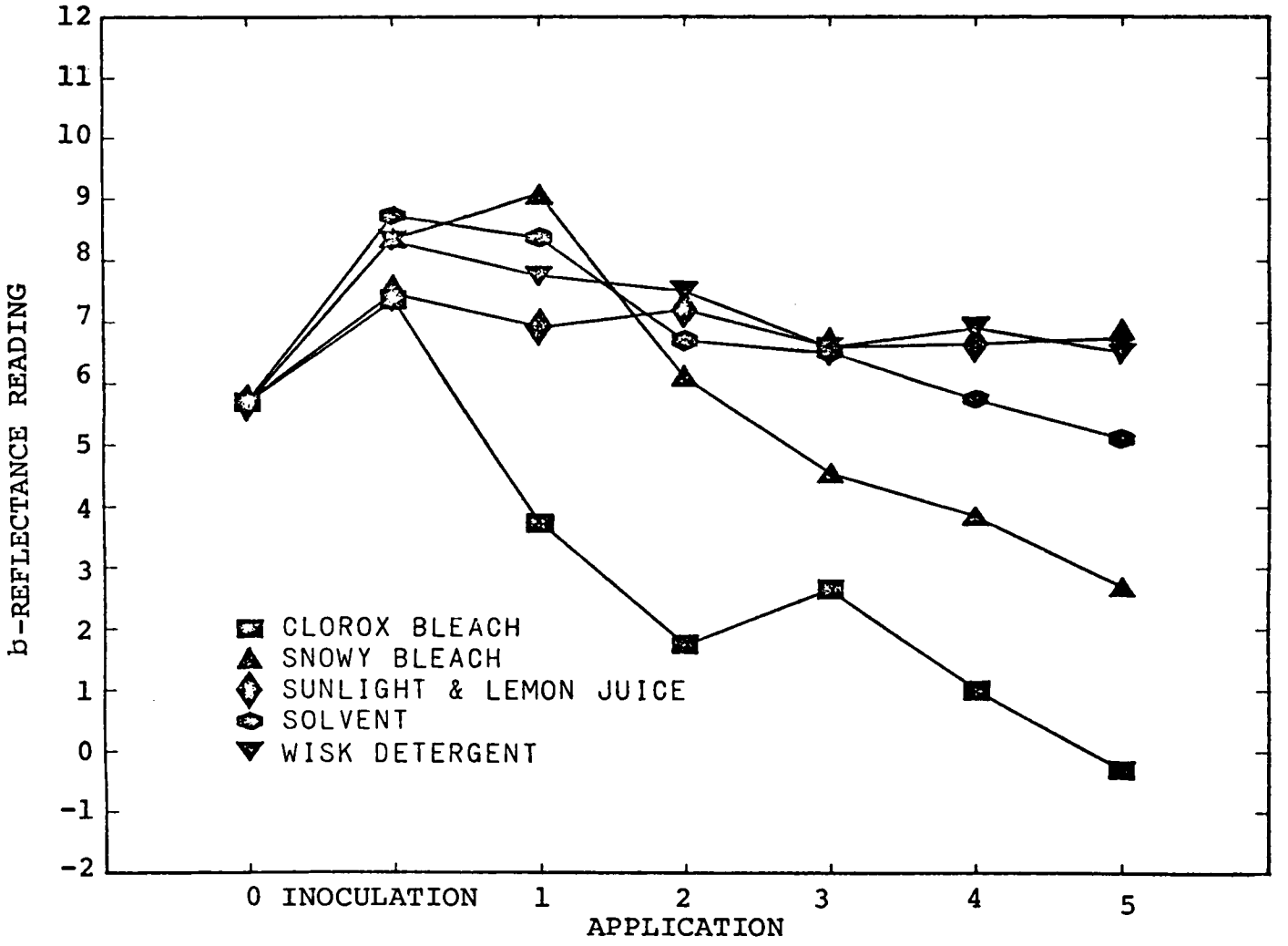

Figure 11. The Effects of Fabric*Treatment*Application Interaction on the b Readings for the THPOH-NH_3 Treated Cotton.

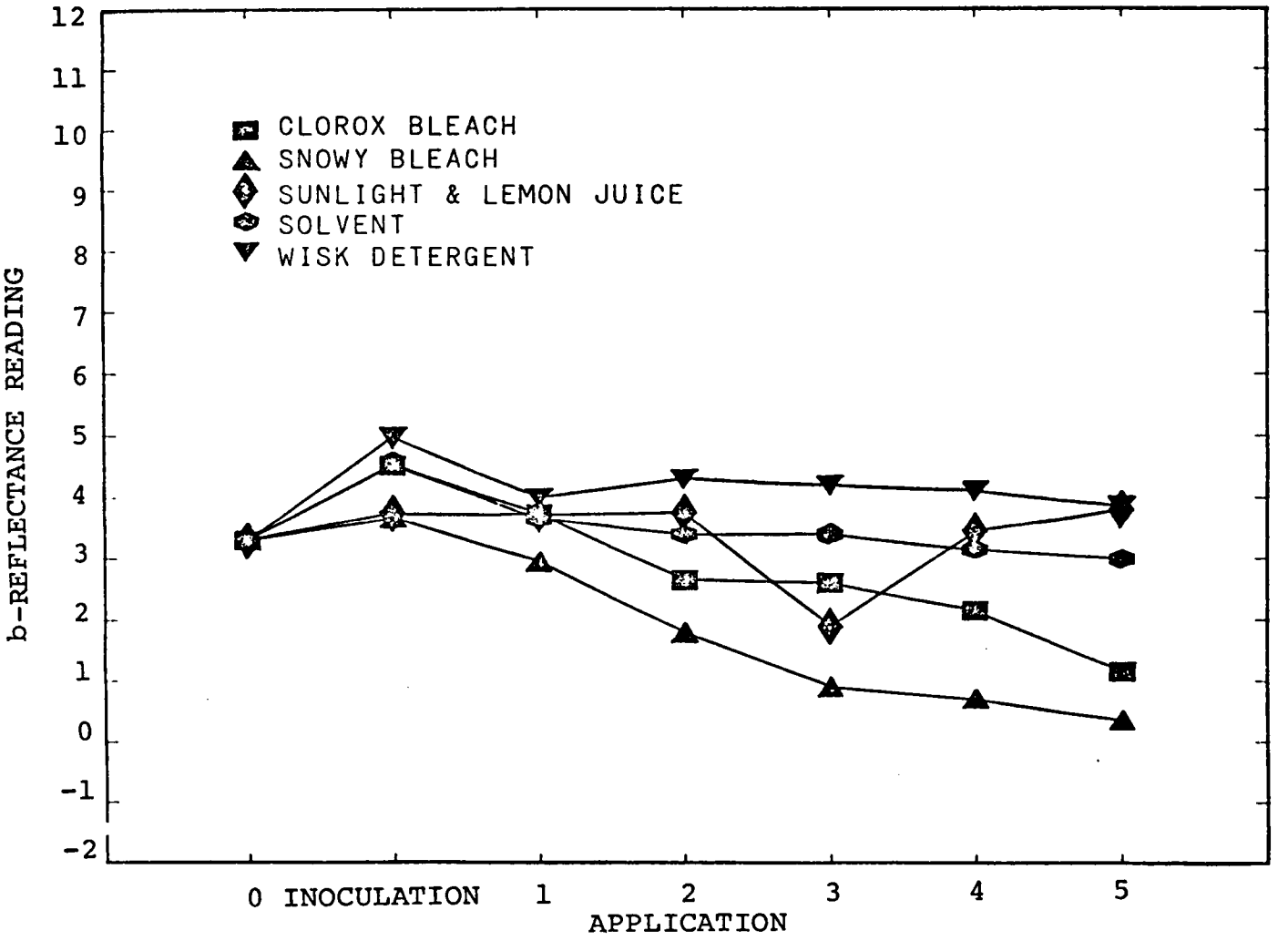

Figure 12. The Effects of Fabric*Treatment*Application Interaction on the b Readings for the THPC-Urea Treated Cotton.

Visual observation also supported this change because a great deal of mold stain resulted from the incubation period. Readings indicated the Clorox bleach was the most effective treatment, followed by Snowy bleach for removing the mold stain. An interesting observation after the first application of Snowy bleach was that the stain became brighter; however, repeated applications of Snowy bleach reduced the yellow values, indicating removal of some mold stain. The other three treatments were less effective in removing the stains.

THPC-Urea. The initial color value of the THPC-Urea fabric was a yellow 3.3 (Figure 11, page 49), and the incubation period caused little effect on this value. The Snowy bleach was the most effective treatment for reducing the yellow value, followed by Clorox bleach. The other three treatments did not substantially lower the yellow value.

Pyrovatex. This finished fabric began with a 5.1 initial b reflectance reading (Figure 9, page 46). The incubation period decreased the yellow value of all the specimens, and all treatments continued to reduce the yellow values except Clorox bleach. In this case, the readings indicated an extreme increase in the yellow value for every application of Clorox bleach, thereby showing the dramatic yellowing effect Clorox had on the Pyrovatex finished cotton.

Comparison. All fabrics had an initial b yellow value. The incubation period affected each fabric differently. The yellow values remained about the same for the cotton control, increased the yellow values slightly on the THPC-Urea fabric, increased the yellow value dramatically on the THPOH-NH_3 fabric and decreased the yellow value on the Pyrovatex fabric.

Overall, the treatments tended to decrease the yellow value of all fabrics, with Snowy bleach the most effective treatment. The only dramatic adverse treatment was the Clorox bleach on the Pyrovatex where yellowing of the fabric was quite evident.

Judging

Five judges rated the specimens in relation to acceptable whiteness for children's sleepwear. They judged the specimens only after the first and fifth application of the treatments. All ratings were averaged and computed. Data revealed that three way interaction among the components was not significant. Interaction between the stain removal treatments and the fabrics was significant, and differences between the fabrics were found highly significant. Judges ratings are evaluated and compared by fabrics in Figures 13-16.

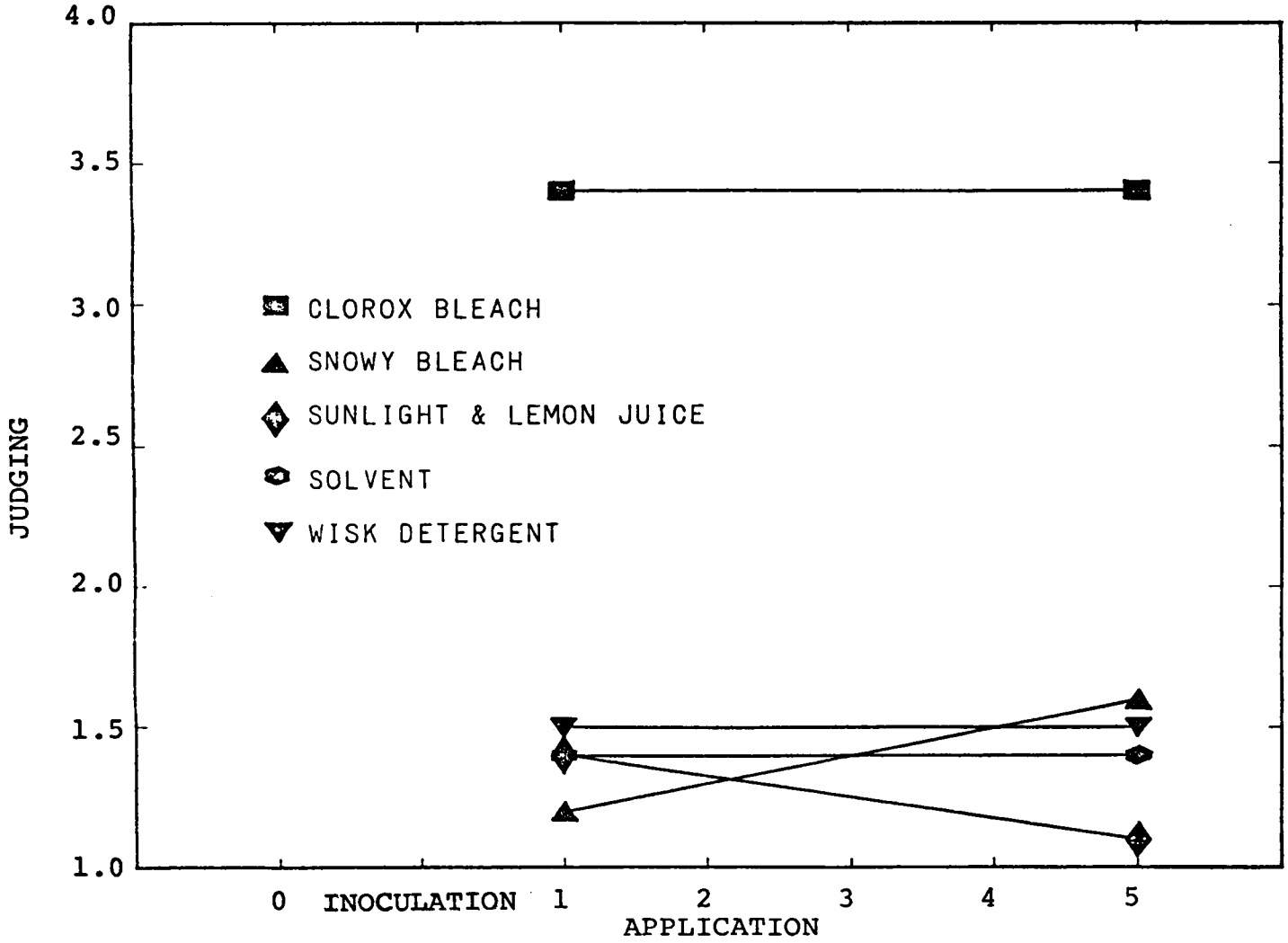

Figure 13. The Effects of Fabric*Treatment*Application Interaction on the Judges' Ratings for the Cotton Control.

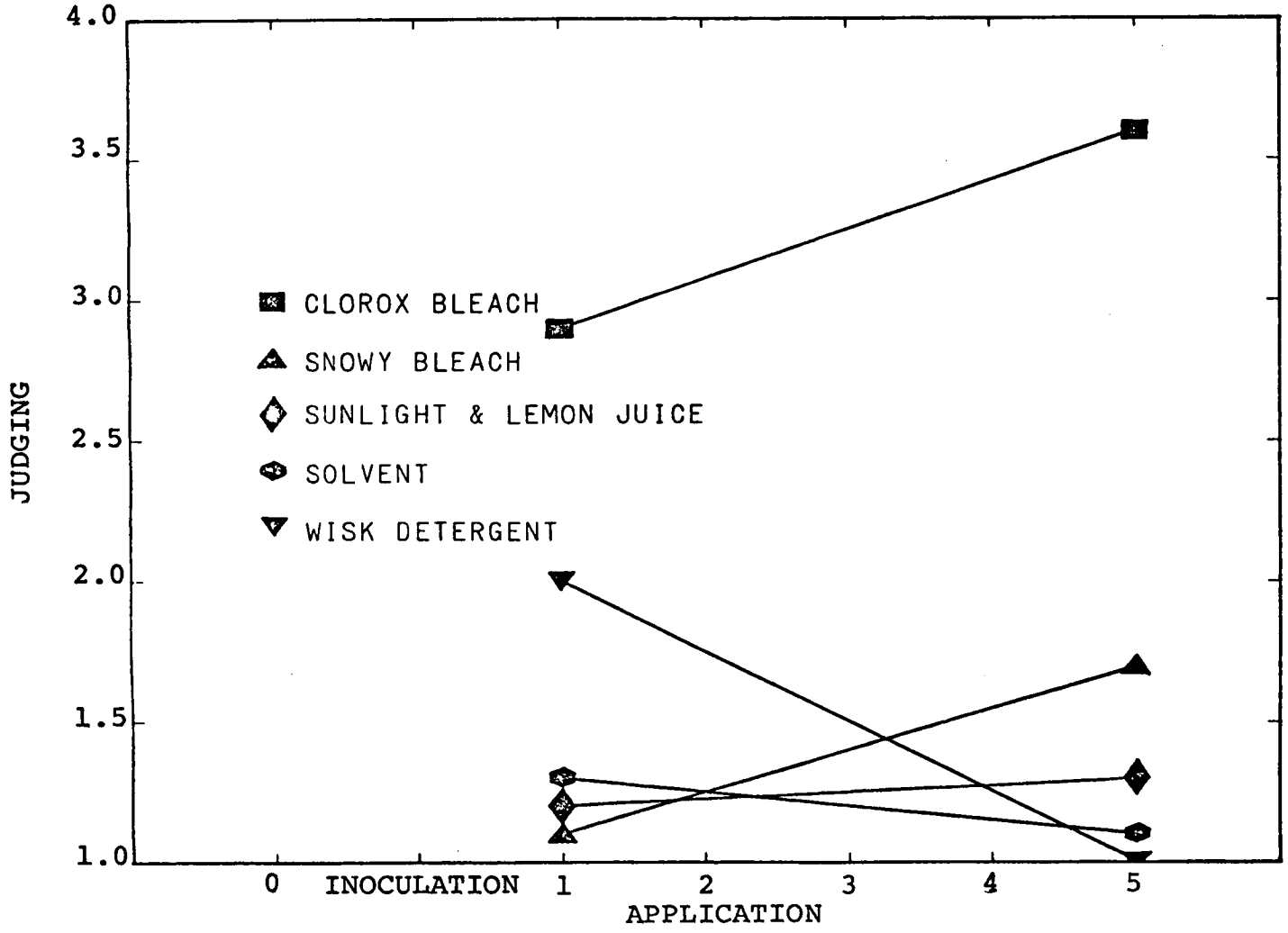

Figure 14. The Effects of Fabric*Treatment*Application Interaction on the Judges' Ratings for the THPOH-NH_3 Treated Cotton.

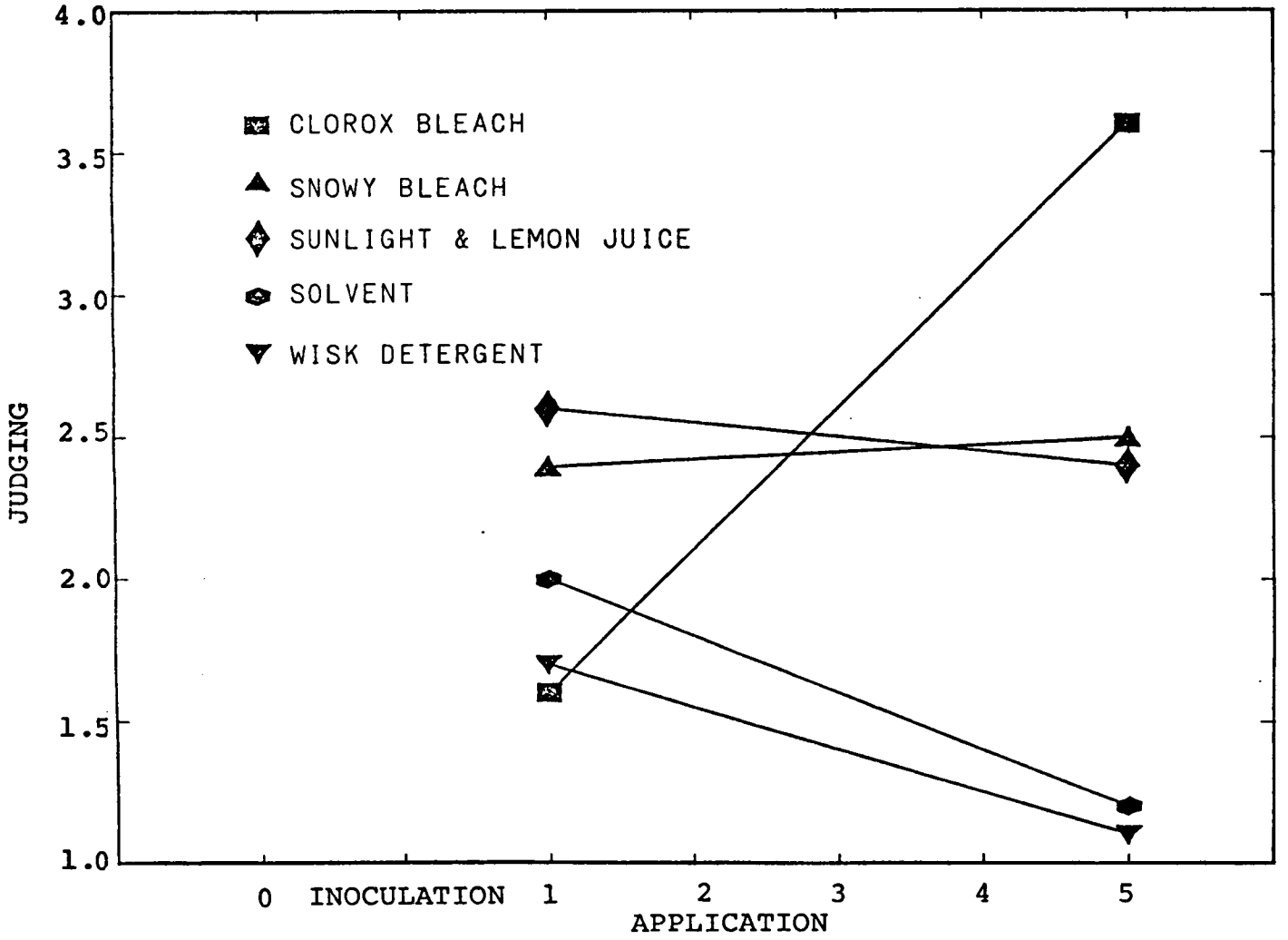

Figure 15. The Effects of Fabric*Treatment*Application Interaction on the Judges' Ratings for the THPC-Urea Treated Cotton.

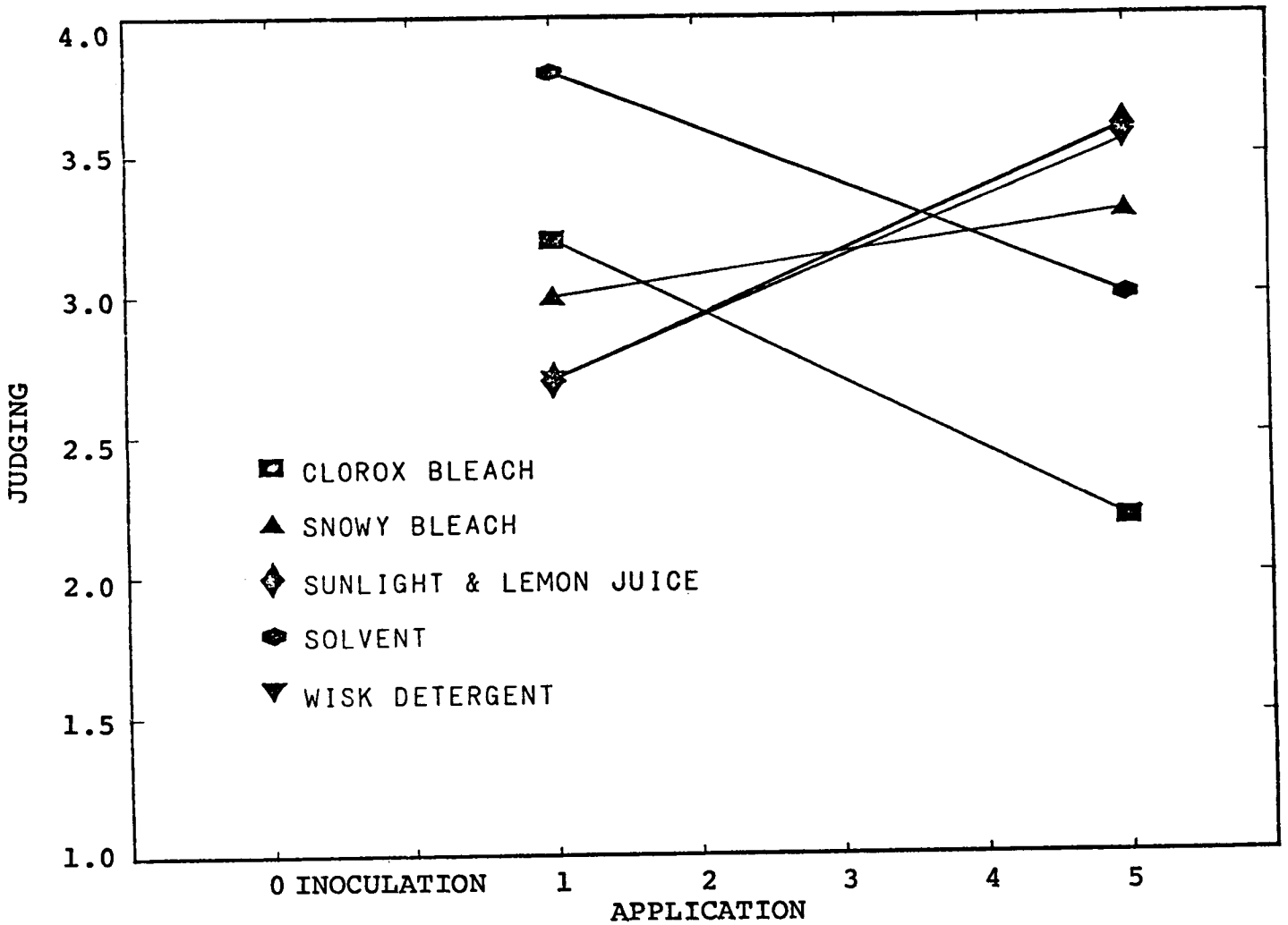

Figure 16. The Effects of Fabric*Treatment*Application Interaction on the Judges' Ratings for the Pyrovatex Treated Cotton.

Cotton control. The judges rated the Clorox bleach as the only effective treatment that removed enough mold stain from the cotton control to find it acceptable for children's sleepwear (Figure 13, page 53). All other treatments were ineffective in removing the mold stain sufficiently from the specimens to be rated acceptable. However, the judges' rating showed evidence of an increase in the effectiveness of Snowy bleach after repeated application, and a decrease in effectiveness of sunlight and lemon juice in removing mold stain from the cotton control.

THPOH-NH_3. The Clorox bleach was the only effective treatment that removed the mold stain sufficiently for this fabric to be rated acceptable for children's sleepwear (Figure 14, page 54). All other treatments were found ineffective. A shift in the ratings due to the number of applications of stain removal treatments showed an increase in Snowy bleach's effectiveness and a decrease in Wisk's effectiveness.

THPC-Urea. Snowy bleach and sunlight and lemon juice were found effective on this fabric (Figure 15, page 55). Repeated application of the treatments increased the effectiveness of Clorox bleach dramatically with ratings shifting from last to first in acceptability. Repeated applications of Wisk and solvent were judged to be slightly adverse on this fabric.

Pyrovatex. All treatments were rated effective on the Pyrovatex (Figure 16, page 56). Visually, this effectiveness was attributed to Pyrovatex being resistant to the mold. Snowy bleach, sunlight and lemon juice, and Wisk detergent were considered more successful after repeated applications than solvent and Clorox bleach.

Comparison. Overall, the judges' ratings indicated that Clorox was the most effective treatment on all fabrics except Pyrovatex finished cotton. The yellowing of this fabric due to the Clorox was evident in the ratings. Snowy bleach was rated next best; however, fabrics were found unacceptable for wear with this treatment. Wisk, solvent, and sunlight and lemon juice were all found ineffective in removing sufficient mold stain for continued use in children's sleepwear.

Overall, the judges' ratings indicated that Pyrovatex finished cotton was the most acceptable fabric regardless of stain removal treatment applied. However, Clorox bleach was the least effective treatment on this fabric. THPC-Urea finished cotton was rated next best, but most fabrics were rated unacceptable after treatments for continued children's wear. Rating proved higher in relation to fabric than stain removal treatments, indicating the resistance of the fabric to the mold was more effective for fighting mildew than the stain removal treatments themselves.

II. OVERALL EVALUATION OF THE COMPONENTS

The next evaluation of the fabrics, the effectiveness of the stain removal treatments, and the effects of repeated application of the treatments are based on the overall means taken from the reflectance readings. The Duncan's multiple range was used to designate significant differences. Evaluation, comparisons and Tables I-III, representing the components, are contained in this section.

Fabric

The reflectance readings shown on Table I represent the mean of all reflectance readings taken after the incubation period and the application of the stain removal treatment by fabrics. Differences among overall fabric means were highly significant for the L, a, and b reflectance readings and repeated applications.

The Pyrovatex finished cotton L reflectance readings were significantly different and the highest of the L readings for all fabrics. These readings indicated that Pyrovatex was overall the whitest fabric after the incubation period and during the repeated applications of stain removal treatments.

For all the fabrics, the a and b readings indicated there was a significant difference between the color values throughout the study. Pyrovatex exhibited the most

TABLE I

OVERALL MEANS OF THE FABRICS

Fabrics	$\bar{L}$ Readings	Fabrics	$\bar{a}$ Readings	Fabrics	$\bar{b}$ Readings
One Application of Treatment					
Pyrovatex	90.77[a]	THPOH-NH_3	-0.45[a]	Cotton Control	1.54[a]
THPC-Urea	88.81[b]	Pyrovatex	-0.10[b]	Pyrovatex	3.20[b]
Cotton Control	88.81[b]	THPC-Urea	0.42[c]	THPC-Urea	3.96[c]
THPOH-NH_3	88.65[b]	Cotton Control	1.11[d]	THPOH-NH_3	7.61[d]
Five Applications of Treatment					
Pyrovatex	99.93[a]	THPOH-NH_3	-0.46[a]	Cotton Control	0.93[a]
Cotton Control	90.64[b]	Pyrovatex	-0.03[b]	Pyrovatex	2.96[b]
THPC-Urea	89.91[b]	THPC-Urea	0.36[c]	THPC-Urea	3.35[b]
THPOH-NH_3	89.75[b]	Cotton Control	1.17[d]	THPOH-NH_3	6.33[c]

[1]Means of same superscript are not significantly different.

[2]Duncan's New Multiple Range computed separately for each type of reflectance reading and application.

TABLE II

OVERALL MEANS OF THE STAIN REMOVAL TREATMENTS

Treatment	$\bar{L}$ Readings	Treatment	$\bar{a}$ Readings	Treatment	$\bar{b}$ Readings
One Application of Treatment					
Clorox Bleach	90.00[a]	Clorox Bleach	-0.17[a]	Sun/Lemon	3.81[a]
Snowy Bleach	89.60[a]	Snowy Bleach	0.18[ab]	Clorox Bleach	3.86[a]
Sun/Lemon	89.20[a]	Sun/Lemon	0.38[b]	Snowy Bleach	4.11[a]
Solvent	88.32[b]	Solvent	0.38[b]	Wisk	4.12[b]
Wisk	88.20[b]	Wisk	0.46[b]	Solvent	4.46[a]
Five Applications of Treatment					
Clorox Bleach	92.66[a]	Clorox Bleach	-0.55[a]	Snowy Bleach	2.69[a]
Snowy Bleach	91.41[a]	Solvent	0.40[b]	Sun/Lemon	3.37[a]
Sun/Lemon	89.85[a]	Snowy Bleach	0.46[b]	Wisk	3.42[a]
Solvent	89.45[a]	Sun/Lemon	0.46[b]	Clorox Bleach	3.72[a]
Wisk	89.41[a]	Wisk	0.55[b]	Solvent	3.75[a]

[1]Means of same superscript are not significantly different.

[2]Duncan's New Multiple Range computed separately for each type of reflectance reading and application.

TABLE III

OVERALL MEANS OF THE TREATMENT APPLICATIONS

Time Sequence	L Readings	a Readings	b Readings
One Application of Treatment			
After the inoculation period	88.20[a]	0.33[a]	4.44[a]
After one application of treatment	90.32[b]	0.16[a]	3.72[a]
Five Applications of Treatment			
After the inoculation period	88.20[c]	0.33[ab]	4.44[a]
After one application of treatment	90.32[b]	0.16[c]	3.72[b]
After two applications of treatment	91.31[ab]	0.21[bc]	3.03[bc]
After three applications of treatment	91.65[ab]	0.21[bc]	2.83[cd]
After four applications of treatment	92.07[a]	0.29[abc]	2.70[cd]
After five applications of treatment	92.39[a]	0.38[a]	2.27[d]

[1]Means of same superscript are not significantly different.

[2]Duncan's New Multiple Range computed separately for each type of reflectance reading and application.

satisfactory a readings while the cotton control exhibited the most satisfactory b readings.

Table I, page 60, revealed that overall, Pyrovatex performed better than the other cotton fabrics tested. Through visual observation, the success of the Pyrovatex finished cotton was attributed to its resistance to the mold during the incubation period, thus causing the fabric to be whiter and reflectance readings to be higher.

The table also revealed an independent reaction of the fabrics to the inoculation of the mold and the application of the treatments. This was apparent in the a and b readings because all fabric means were significantly different from each other, and visually, each fabric had a different color value. Most obvious was the THPOH-NH_3 finished cotton which acquired a yellowish stain from the mold inoculation. The cotton control had a reddish mold stain, the THPC-Urea a reddish brown stain, and the Pyrovatex a light brown stain. Therefore, it was concluded that different types of FR finishes caused mold to stain significantly different color values on the cotton.

Treatment

Table II, page 61, presents the data concerning overall effectiveness of the treatments on the fabrics and represents the mean of all readings taken of each fabric throughout the study. Differences among overall treatment

means were significant for the L and a readings and nonsignificant for the b readings.

The data revealed that Clorox bleach treatment had the highest overall L readings, followed by Snowy bleach and sunlight and lemon juice respectively. The a readings revealed that Clorox bleach treatment had the most satisfactory values, but all a readings were considered satisfactory for each treatment. The b readings showed no significant difference between the treatments, but showed rather high yellow values. Overall, five applications of treatment were slightly more effective in removing the mold stain than a single application of treatment. No one treatment was overall significantly different from any other after five applications.

Therefore, no treatment was considered superior or outstanding, yet through visual observation and compared readings, Clorox bleach was considered the most effective in removing the mold stain, followed by Snowy bleach.

Application

Table III, page 62, illustrates the overall effects repeated application of stain removal treatments had on the reflectance readings recorded for treatment applications. Differences among overall means of the treatment applications were highly significant for the L readings and significant for the a and b readings.

Significant difference as revealed by the Duncan's multiple range was between the inoculation of mold and the first application of treatment; therefore, it was concluded that overall the stain removal treatments were effective in removing a significant amount of stain only after one treatment. Repeated applications resulted in more satisfactory values but not to the degree of effectiveness of the first application.

III. FLAMMABILITY TEST

Tables IV-VII present the results from the flammability test after one and five applications of treatments to the fabrics.

One Application

All fabrics passed the test after one application of treatment except two THPC-Urea strips treated with a Clorox bleach. Consequently, Clorox bleach was considered detrimental to the flame retardancy of THPC-Urea finished cotton.

Five Applications

Most fabrics passed the test after five applications of the treatments. Exceptions were the THPOH-NH_3 and THPC-Urea finished cotton treated with Clorox bleach. In the case of sunlight and lemon juice treatment, one strip

TABLE IV

RESULTS OF FLAMMABILITY TEST ON THE FLAME RETARDANT COTTONS—SECTION I

One Application

	Flame Time (seconds)					Char Length (Metric) cm.				
	1	2	3	4	Av.	1	2	3	4	Av.
Chlorine Bleach										
THPOH-NH_3	3.4	3.8	4.0	4.8	4.0	7.7	10.3	5.4	7.9	7.8
THPC-Urea	14.4	3.6	4.0	13.8	10.0	25.4	8.4	8.6	25.4	17.0
Pyrovatex	3.8	3.8	3.8	3.8	3.8	9.3	10.2	7.8	8.9	9.1
Snowy Bleach										
THPOH-NH_3	4.0	3.8	3.6	4.0	3.9	6.8	7.3	7.6	6.8	7.1
THPC-Urea	3.8	3.6	3.8	4.0	3.8	3.6	5.3	5.2	5.1	4.8
Pyrovatex	3.6	3.5	3.6	3.6	3.6	8.1	8.8	7.9	9.3	8.5
Sun and Lemon Juice										
THPOH-NH_3	3.4	3.7	3.8	3.6	3.6	6.0	5.8	3.0	5.8	5.2
THPC-Urea	3.4	3.6	3.8	4.0	3.7	5.3	6.9	6.6	5.5	6.1
Pyrovatex	3.7	3.8	3.9	4.2	3.9	8.4	9.5	8.8	9.0	8.9
Solvent										
THPOH-NH_3	3.8	3.9	3.8	3.7	3.8	6.5	5.4	3.8	4.7	5.1
THPC-Urea	3.9	3.8	3.9	3.8	3.9	6.8	6.0	6.5	6.3	6.4
Pyrovatex	3.6	3.6	3.3	3.8	3.6	7.9	7.8	6.8	7.1	7.4
Wisk										
THPOH-NH_3	4.0	4.0	4.2	3.6	4.0	7.3	8.8	6.0	4.5	6.7
THPC-Urea	3.8	3.7	3.8	5.0	4.1	6.6	6.5	7.2	6.5	6.7
Pyrovatex	3.8	3.6	3.8	3.8	3.8	7.5	10.5	7.7	10.5	9.1

TABLE V

RESULTS OF FLAMMABILITY TEST ON THE FLAME RETARDANT COTTONS—SECTION II

One Application

	Flame Time (seconds)					Char Length (Metric) cm.				
	1	2	3	4	Av.	1	2	3	4	Av.
Chlorine Bleach										
THPOH-NH_3	3.8	3.8	3.8	3.9	3.8	6.8	4.4	4.9	7.8	6.0
THPC-Urea	3.8	3.9	4.0	3.8	3.9	7.6	5.8	7.9	6.9	7.1
Pyrovatex	3.8	4.0	3.8	3.8	3.9	11.0	11.5	5.5	8.1	9.0
Snowy Bleach										
THPOH-NH_3	3.7	3.5	3.8	3.8	3.7	6.4	4.1	5.1	8.3	6.0
THPC-Urea	3.8	3.8	4.0	3.9	3.9	6.2	5.2	5.8	4.4	5.4
Pyrovatex	3.7	3.8	3.8	3.8	3.8	8.5	7.2	9.2	7.8	8.2
Sun and Lemon Juice										
THPOH-NH_3	3.8	3.6	3.9	4.0	3.8	6.4	6.2	3.1	4.8	5.1
THPC-Urea	3.8	4.0	3.8	4.0	3.9	6.8	6.0	4.4	6.2	5.9
Pyrovatex	3.8	3.6	4.0	3.8	3.8	8.3	7.4	8.3	7.7	7.9
Solvent										
THPOH-NH_3	3.8	3.9	4.0	3.8	3.9	8.1	7.6	5.5	5.9	6.8
THPC-Urea	3.6	3.7	3.7	3.9	3.7	7.2	3.9	5.9	6.8	6.0
Pyrovatex	3.7	3.6	3.8	3.8	3.7	6.6	9.4	8.9	9.0	8.5
Wisk										
THPOH-NH_3	3.6	3.6	3.8	3.8	3.7	6.7	3.4	4.2	7.2	5.4
THPC-Urea	3.7	3.7	3.7	3.6	3.7	7.4	4.4	6.0	5.9	5.9
Pyrovatex	3.7	3.6	3.6	3.7	3.7	9.2	8.1	7.7	7.0	8.0

TABLE VI

RESULTS OF FLAMMABILITY TEST ON THE FLAME RETARDANT COTTONS—SECTION III

Five Applications of Treatment

	Flame Time (seconds)					Char Length (Metric) cm.				
	1	2	3	4	Av.	1	2	3	4	Av.
Chlorine Bleach										
THPOH-NH_3	17.0	18.0	11.0	11.0	14.3	24.5	24.5	24.5	24.5	24.5
THPC-Urea	12.0	16.0	13.5	22.0	15.9	24.5	24.5	24.5	24.5	24.5
Pyrovatex	3.8	3.8	3.7	3.8	3.8	15.5	15.4	15.4	16.2	15.6
Snowy Bleach										
THPOH-NH_3	3.8	3.8	3.6	3.8	3.8	9.9	9.0	8.4	9.6	9.2
THPC-Urea	3.6	3.8	3.6	3.7	3.7	7.0	11.9	8.5	8.4	9.0
Pyrovatex	4.2	3.8	4.0	3.6	3.9	12.3	11.7	11.5	14.9	12.6
Sun and Lemon Juice										
THPOH-NH_3	4.0	3.6	3.8	3.8	3.8	9.4	8.8	9.0	10.3	9.4
THPC-Urea	3.6	15.0	4.0	3.9	6.6	9.9	29.0	8.6	9.6	14.3
Pyrovatex	4.0	3.6	4.0	3.8	3.9	13.0	12.8	11.2	10.0	11.8
Solvent										
THPOH-NH_3	3.8	3.9	3.7	3.8	3.8	9.7	10.0	8.0	8.0	8.9
THPC-Urea	7.0	4.0	3.8	4.5	4.8	16.1	8.0	6.9	7.8	9.7
Pyrovatex	3.8	3.8	3.8	3.6	3.8	12.8	11.2	13.0	12.0	12.2
Wisk										
THPOH-NH_3	3.8	3.6	4.0	3.8	3.8	9.5	10.3	10.4	9.1	9.8
THPC-Urea	3.7	3.6	3.7	3.6	3.7	10.7	10.2	9.3	10.3	10.1
Pyrovatex	3.8	3.7	3.8	3.9	3.8	13.0	10.5	12.5	11.0	11.8

TABLE VII

RESULTS OF FLAMMABILITY TEST ON THE FLAME RETARDANT COTTONS—SECTION IV

Five Applications of Treatment

	Flame Time (seconds)					Char Length (Metric) cm.				
	1	2	3	4	Av.	1	2	3	4	Av.
Chlorine Bleach										
THPOH-NH_3	18.0	17.5	13.0	15.2	15.9	24.5	24.5	24.5	24.5	24.5
THPC-Urea	13.8	12.0	14.4	13.8	13.5	24.5	24.5	24.5	24.5	24.5
Pyrovatex	4.4	4.5	4.9	3.7	4.4	14.1	12.0	13.5	11.3	12.7
Snowy Bleach										
THPOH-NH_3	3.8	3.8	3.7	3.9	3.8	9.7	5.5	9.1	8.2	8.1
THPC-Urea	3.7	3.6	3.6	4.0	3.7	7.4	7.0	7.2	6.8	7.1
Pyrovatex	3.8	3.7	4.2	4.1	4.0	8.7	8.6	9.4	8.8	8.9
Sun and Lemon Juice										
THPOH-NH_3	3.6	3.8	3.7	3.8	3.7	6.5	7.9	8.7	7.9	7.6
THPC-Urea	3.8	4.0	3.8	3.9	3.9	5.0	5.4	7.9	8.0	6.6
Pyrovatex	3.6	3.6	3.7	3.6	3.6	10.2	9.9	8.4	8.0	9.1
Solvent										
THPOH-NH_3	3.5	3.5	3.5	3.5	3.5	8.2	6.8	4.5	7.2	6.7
THPC-Urea	3.8	4.2	4.0	4.7	4.2	8.7	7.5	9.0	7.0	8.0
Pyrovatex	4.0	3.8	4.2	3.9	4.0	10.6	10.3	10.4	8.7	10.0
Wisk										
THPOH-NH_3	3.5	3.8	3.7	4.0	3.8	10.5	8.0	8.7	9.2	9.1
THPC-Urea	3.8	3.8	3.8	3.8	3.8	6.8	6.0	8.0	7.8	7.2
Pyrovatex	3.5	3.5	3.5	4.0	3.6	11.3	10.2	9.0	9.7	10.1

of the THPC-Urea finished cotton failed the test. Pyrovatex strips with Clorox bleach treatment had greatly increased char lengths and most char lengths of all specimens increased slightly after repeated applications of treatments. Based on these burning data, Clorox bleach treatment was considered detrimental to the flame retardancy of the THPC-Urea and the THPOH-NH_3 finished cottons.

CHAPTER V

SUMMARY AND CONCLUSIONS

The objectives of this study were to determine acceptability of procedures for removal of mold stain from FR cottons, and to establish the effect the procedures had on the flame retardancy of the fabrics. These procedures included five stain removal treatments: Clorox bleach, Snowy bleach, sunlight and lemon juice, solvent, and Wisk detergent. The FR cotton finishes studied were Pyrovatex, THPC-Urea, and THPOH-NH_3. Mold used for inoculation was Cheatomium globosum.

Subjective and objective ratings of properties after inoculation of mold and after one to five applications of the stain removal treatments served as a basis for evaluating the relative effectiveness of the stain removal treatments. The effect of the stain removal treatments on the FR characteristics was evaluated by the flammability test specified in the Children's Sleepwear Standard, DOC-FF-3-71 (3).

Analysis of variance and Duncan's new multiple range were used to determine significant differences and interaction among the components: fabrics, stain removal treatments, and applications of treatment.

I. SUMMARY

The inoculation of the mold was considered successful in staining all fabrics because it reduced the initial reflectance readings substantially. Data revealed that the cotton control was the most susceptible fabric to the mold, with THPOH-NH_3, THPC-Urea, and Pyrovatex finished cottons following respectively. Also, the degree of stain severity varied among the individual specimens of THPC-Urea and the THPOH-NH_3 finished cottons.

Data indicated the mold inoculation had a profound effect on the color values of the fabrics as shown in Figures 5-8, pages 41-44, Figure 9, page 46, and Figures 10-12, pages 48-50. A comparison of the fabrics revealed significant differences in color values. After the incubation period, a reflectance readings showed Pyrovatex and THPOH-NH_3 fabrics with a green value and THPC-Urea and cotton control with red values. The b reflectance readings showed all fabrics with a yellow value but these values varied significantly also.

The removal of the mold stain from the FR cottons was considered moderately successful. The reflectance readings indicated a significant amount of stain was being removed from all fabrics by the stain removal treatments; however, subjective judging rated most fabrics after application of

the stain removal treatments unacceptable for children's wear because the specimens were still visibly stained.

The L reflectance readings were the most useful in evaluating the effectiveness of the stain removal treatments. These readings indicated that Clorox bleach was overall and significantly the most effective treatment for all fabrics, followed by Snowy bleach. Readings indicated that with repeated application of Snowy bleach, a significant increase in effectiveness was exhibited.

The direction of color value change on the fabrics was also used as an indicator for evaluating the effectiveness of the stain removal treatments. The a and b readings indicated that Clorox bleach initiated more significant color value change than any other treatment. Of most significance was the large increase in the yellow and green values on the Pyrovatex treated fabric after each application of the Clorox, and the large decrease in the yellow value on the THPOH-NH_3 after each application of Clorox also. Therefore, Clorox was considered adverse on the Pyrovatex and effective on the THPOH-NH_3 treated fabric. Snowy bleach ranked second in initiating color value change. The most effective changes occurred on the THPOH-NH_3 and the THPC-Urea treated cottons where Snowy bleach decreased the yellow values substantially indicating effective stain removal.

The subjective judging of the fabrics was used as the final evaluation of the effectiveness of the treatments. Clorox bleach was rated the most effective for all fabrics except Pyrovatex where the yellowing of the fabric was reflected in the ratings. The ratings also indicated that Snowy bleach was the second most effective treatment and rating improved consistently after repeated application of treatment, yet the treatment was still considered ineffective in removing enough stain to find the fabrics acceptable for children's wear. All other stain removal treatments were rated poorly overall and considered ineffective on these FR cottons. Overall, the judging indicated the ineffectiveness of the treatments to remove the mold stain from the fabrics.

Judges' ratings in relation to fabrics were very poor for the cotton control and the THPOH-NH_3 finished cotton. Rating improved slightly on the THPC-Urea, and improved significantly on the Pyrovatex fabric. This overall improvement in the ratings indicated that the fabric's increasing resistance to the mold corresponded positively to the higher ratings of the judges. The L readings indicated that Pyrovatex and THPC-Urea finished cotton retained the least amount of mold stain from the incubation period. Therefore, it is evident that the fabric's finish was related to the effectiveness of the treatments.

The flammability results were used for final determination of an acceptable procedure for removal of mold stain from FR cottons. The test revealed that Clorox bleach destroyed the flame retardancy of the THPOH-NH_3 and THPC-Urea treated cottons and repeated application of Clorox bleach increased char lengths of the Pyrovatex finished cotton. Also, repeated application of sunlight and lemon juice on the THPC-Urea treated cotton resulted in one failure. Therefore, only Clorox bleach was rejected as an acceptable procedure for removal of mold stain from FR cottons.

II. CONCLUSIONS

Conclusions based on the data evaluated will be drawn relative to the formal null hypotheses.

Hypothesis 1

There will be no significant difference between the effectiveness of different stain removal treatments on three FR cotton fabrics.

Clorox bleach was found significantly different in effectiveness from the other four stain removal treatments in the study. Therefore, Hypothesis 1 was rejected.

Hypothesis 2

The stain removal treatments tested will have no significant effect on flame retardancy of the THPOH-NH_3, Pyrovatex, or the THPC-Urea treated cottons.

The flame retardancy of the THPOH-NH_3 and the THPC-Urea finished cottons was destroyed with five applications of Clorox bleach. Therefore, Hypothesis 2 was rejected.

III. RECOMMENDATIONS TO CONSUMERS

Judicious use of stain removal treatments is recommended to consumers in the removal of mold stain from FR cottons. Five applications of Snowy bleach appears to be effective for the removal of mild mildew stains with no detrimental effects on the FR finish. In the case of severe mold stain, only one application of Clorox bleach may be successful for removal of mold stain without destroying the FR characteristic. Repeated applications of the same stain removal treatment does not favorably remove more stain with the exception of Snowy bleach.

IV. RECOMMENDATIONS FOR FURTHER STUDY

1. Investigation is needed to test susceptibility of other FR fabrics to mold.

2. Investigation is needed to test other stain removal procedures to determine their effect on the flame retardancy of the FR fabrics and their effectiveness in removing mold stain.

3. A survey should be conducted to determine to what extent the problem of mildew is actually occurring on FR garments in the home.

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APPENDIX

LABELED INGREDIENTS OF STAIN REMOVAL TREATMENTS

Clorox bleach: Sodium Hypochlorite 5.25 percent Inert ingredients 95.75 percent

Snowy bleach: Sodium Perborate

Lemon juice: Reconstituted, natural strength, Realemon (brand name), water, lemon concentrate, preserved with .03 percent Sodium Benzoate and .020 Sodium Bisulfite

Wisk: Phosphorous 3.5 percent Biodegradable surfactants (A heavy duty liquid laundry detergent)

Stoddard Solvent: Petroleum distillate

VITA

Joan Leigh Bare was born in Henderson, Kentucky, on May 27, 1950. She began her education in Henderson County and later graduated from Henderson City High in 1968. Undergraduate studies were pursued at Western Kentucky University where she received a BS degree in Textiles, Clothing and Merchandising in 1972. On December 29, 1971, she married Stephen Grant Bare, and together they resided in Bowling Green, Kentucky, until Stephen received a BA in Journalism from Western Kentucky University in 1973.

She entered The University of Tennessee in September, 1973, as a graduate research assistant in the Textiles and Clothing Department, College of Home Economics. Stephen began pursuing a BM degree in voice and classical guitar. Together they are moving to Oxford, Ohio, where she has received an instructionship at Miami University. They will continue to pursue academic excellence to interrelate for the best of both.