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To the Graduate Council:

I am submitting herewith a thesis written by Dorothy Bangs Bishop entitled "A Study of the Effectiveness of Food Stain Removal from Flame Retardant Cotton Flannelette." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Textiles and Clothing.

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A STUDY OF THE EFFECTIVENESS OF FOOD STAIN REMOVAL FROM FLAME RETARDANT COTTON FLANNELETTE

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

Dorothy Bangs Bishop

March 1974

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ABSTRACT

The main purpose of the study was to evaluate the effectiveness of enzyme presoaking and regular laundering in removing certain food stains from flame retardant cotton flannelette and untreated cotton flannelette. A secondary purpose was to investigate the possibility of marked differences over time in the stain release characteristics of the treated fabrics.

Three staining substances (chocolate milk, grape jelly, and egg yolk) were applied to fabric specimens. Stain removal was measured by whiteness values calculated from the surface reflectance obtained with a Photovolt photoelectric reflection meter for fabric specimens after every fifth laundering (0, 5, 10, ..., 50).

Fabrics were compared for physical properties following ASTM and AATCC standards and for flammability according to U.S. Department of Commerce Standard DOCFF 3-71.

Mean whiteness values indicated that, on the whole, presoaking adversely affects stain removal of certain food stains from flame retardant cotton flannelette. Treated fabrics displayed negligible change in stain release characteristics over time, however. In fact, the treated fabric exhibited higher whiteness values over time than did the untreated fabric, whether stained or not.

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CHAPTER I

INTRODUCTION

In the July 29, 1971 Federal Register were promulgated the standards for the flammability of children's sleepwear. According to the statement issued by Maurice H. Stans, Secretary of Commerce, the law requires all children's sleepwear (up to size 6X) plus piece goods sold over the counter for use as children's sleepwear after July 29, 1972, to adhere to the new flammability standards or to carry a warning label that the merchandise does not comply (44). This legislation resulted from research done by the U.S. Department of Health, Education, and Welfare revealing that approximately 7,500 Americans die annually from burns attributed to flammable textiles with the total cost of these burns being estimated at more than 349 million dollars (35). The notice of the findings also states that for certain categories of clothing, children under six years old are injured relatively more often from apparel fires than members of most other age groups (43).

In 1954 the Flammable Fabrics Act was passed because of loss of life and extensive human injury resulting from flammable wearing apparel. Some specific items of wearing apparel, such as flash-burning rayon sweaters, flimsy negligees, and children's chaps, have helped motivate enactment of stricter control over flammable fabrics (13). With

governmental controls on flammability has come the responsibility of the textile industry to develop fabrics with satisfactory flame retardant properties.

The fiber content and fabric construction influence the degree of flame retardancy or flammability of a particular textile item. Asbestos and fiberglass are inherently fireproof while cotton is readily flammable. Thermoplastic fibers--nylon, polyester, and acrylics--melt before burning and the flame is carried away from the burning fabric by melted falling droplets (26). Blends can create further problems. If cotton is blended with a thermoplastic fiber it acts as a structured framework or "scaffold" upon which the thermoplastic fiber is retained and prevented from dripping away to extinguish the flame (36).

Extensive research has been in process for several decades in developing flame retardant finishes applicable particularly to 100 percent cotton and cotton blend fabrics. Although successful in developing flame resistant fabrics, the acceptability to the consumer has been a problem. Often the flame retardant finish can alter the hand and texture, impart a distinctive odor, and usually increase the cost of the finished product. This creates a problem since consumers are more interested in the functional and aesthetic properties of a textile product than in its flame resistant quality.

An important aspect of consumer satisfaction with the total performance of the textile product is color change

and/or loss of luster resulting from soiling--a complex interaction between fiber, fabric, finish, soil, and laundering. In ordinary usage, the words "soiling" and "staining" are used loosely and sometimes interchangeably. However, the term "stain" generally connotes a degree of permanency not associated with "soil." While soil can usually be removed by regular cleaning or laundering, it is often necessary to use special treatment to remove a stain (21). "Special treatments" for stains which have gained favor among homemakers since 1967 have been enzyme presoaks and enzyme laundry detergents. Enzymes are special protein catalysts which, when added to laundry products, aid in the breaking down of soil and stain, making them easier to remove. According to the manufacturers of enzyme-active products, the appropriate enzyme will remove difficult stains such as lipstick, grass, tea, beets, fruits, and chocolate (15).

Although research has been conducted separately on flammable fabrics, soiling, and detergency, the effectiveness of presoaks in removing food stains from flame retardant fabric has not been investigated.

I. PURPOSE OF STUDY

The main purpose of the study was to evaluate the effectiveness of enzyme presoaking and regular laundering in removing certain food stains from flame retardant fabric and a suitable untreated control. A second purpose was to

investigate the possibility of marked differences over time in the stain release characteristics of the treated fabrics.

II. ASSUMPTIONS

The major assumptions were as follows:

(1) The standardized AATCC laundering procedures and the presoaking procedures were representative of home laundering.

(2) Cotton flannelette treated with Pyrovatex (CIBA-Geigy) flame retardant finish was representative of fabric to be used for children's sleepwear from size 0 to 6X.

(3) The stains chosen were representative of those often found spilled on children's sleepwear.

III. LIMITATIONS

Limitations included the following:

(1) Cotton flannelette treated with Pyrovatex (CIBA-Geigy) flame retardant finish was the only fabric (beside controls) and finish studied.

(2) Stains were limited to chocolate milk, grape jelly, and egg yolk.

(3) Evaluation of the degree of stain removal was limited to the readings on the Photovolt Reflection Meter 670. Since treated and untreated fabrics alike were printed, special care became necessary both in staining and subsequent evaluation of stain removal.

IV. NULL HYPOTHESES

(1) There will be no significant difference in the degree of stain removal between (a) treated cotton flannelette stained and laundered and (b) untreated cotton flannelette stained and laundered.

(2) There will be no significant difference between the degree of stain removal of (a) treated and untreated cotton flannelette stained, presoaked, and laundered and of (b) treated and untreated cotton flannelette stained and laundered.

V. DEFINITION OF TERMS

1. AATCC - Abbreviation for the American Association of Textile Chemists and Colorists, a national technical and scientific body whose members are active in the textile wet processing industry (40).

2. ASTM - Abbreviation for the American Society for Testing and Materials, a nonprofit, educational, scientific, and technical society devoted to the promotion of knowledge of the materials of engineering and the standardization of specifications and the methods of testing (2).

3. Afterglow - Continuation of glowing of parts of a specimen after flaming has ceased (44).

4. Char length - The distance from the original lower edge of the specimen exposed to the flame to the end

of the tear or void in the charred, burned, or damaged area (44).

5. Combustibility - Ability of a textile to ignite after exposure to a heat source and to continue to burn under normal conditions (36).

6. Enzymes - Protein catalysts, substances which in very low amounts help speed up chemical reactions (29).

7. Fabric count - Number of warp yarns and filling yarns per inch.

8. Flame retardant finishes - Those finishes which appreciably slow down combustion compared to the untreated fiber once the source of heat is removed. The best result is immediate disappearance of the flame, with no subsequent flaring or afterglow, once the igniting agent is taken away (8).

9. Flammability or Ignitability - The degree and amount of heat required to set fire to a fabric of a given fiber composition and construction (8).

10. Flannelette - Soft, plain- or twill-weave cotton fabric lightly napped on one side. May be dyed solid colors or printed. Used for lounging and sleeping garments and shirts (46).

11. Stain - Dirt or soil which is extremely difficult or impossible to remove (21).

12. Treated fabric - Plain weave cotton flannelette

finished with Pyrovatex (CIBA-Geigy) to impart flame retardancy.

13. Untreated fabric - Plain weave cotton flannelette.

CHAPTER II

REVIEW OF LITERATURE

The literature reviewed included research studies concerning (a) flame retardant fabrics, (b) manner of soiling, (c) method of cleaning, and (d) measurement of whiteness.

A. FLAME RETARDANT FABRICS

History

With the discovery and utilization of fire by man, came the danger of the loss of life or permanent scarring. Consequently, man has tried to find ways to make readily combustible items flame retardant. In 1735, a patent on a method of making cellulose flame resistant was issued to Wyle (12). Early flame retardant finishes had their problems. Besides being made of water-soluble compounds which were easily removed in laundering, they produced a hard boardy fabric (12). By 1912, W. H. Perkins had discovered the first successful flame retardant finish which was laundry resistant (12).

Although research continued in this area, a concerted effort to develop flame-resistant fibers and to prohibit highly flammable fabrics did not occur until tragedy intervened. The Boston Coconut Grove fire on November 28, 1942, which killed 432 and injured 214 of 750

persons involved, led to Federal impetus for flame retardant fabrics and flammability standards in general. Deaths caused by flash burning of brushed nylon sweaters, children's cowboy chaps, and flimsy negligees also contributed to the sense of urgency for flammability standards (13).

Current research has led to the development of suitable chemical treatments for fabrics to make them flame retardant. Today, phosphorus-containing compounds are by far the most important class of compounds used to impart durable flame resistance to cellulose (13). When used in combination with a nitrogenous polymer, these agents can impart a high degree of flame resistance without the degree of undesirable qualities resulting with earlier treatments. However, calcium and magnesium ions from washing and exposure to sunlight from line drying have negative effects on flame retardants (13).

Another widely used flame resistant finish for cotton in industrial applications is the antimony oxide-chlorinated paraffin or vinyl chloride type applied to tents, tarpaulins, and other outdoor products (11). They are termed FWWMR (flame, water, weather, and mildew resistant) treatments.

Legislation

The Coconut Grove Fire, the brush rayon "touch" sweaters, the highly flammable cowboy chaps, and similar tragedies led to Congressional passage of the National

Flammable Fabrics Act in 1953 (19). The act prohibited the sale of highly flammable textiles including wearing apparel regardless of fiber content or construction. The standards for testing the flammability of textiles were also established. The 1967 bill amending the original Act strengthened and extended the law to cover paper, plastics, synthetic fibers, foams, interior furnishings, and apparel fabrics (12). Authority was given to the Department of Health, Education, and Welfare to "investigate and define the problem of burns from clothing and furnishings" (38). Textile industries had stated prior to the passage of the 1967 bill that they felt statistics on burns were lacking and that public education was a more positive means of reducing clothing burns than technology. Meanwhile, the government and medical profession contended that adequate technology could be developed and offer financial returns besides (38). The public hearings and discussions have been held concerning apparel and textile flammability standards. Besides children's sleepwear, standards have been approved for carpets and rugs (40).

Why was children's sleepwear chosen among the first items to have flammable standards promulgated? According to a prepared statement presented by Dr. L. M. Branscomb, Director, National Bureau of Standards, before the Consumer Subcommittee on the Committee of Commerce, United States Senate, on June 11, 1970,

> The data and information that we have received to date indicate that top priority for future standards should be for children's apparel. The National Advisory Committee for the Flammable Fabrics Act agreed with out view that we should move immediately to standards for children's dresses and sleepwear.
>
> Other priorities which we are studying include apparel for elderly citizens, wearing apparel for the general public, and interior furnishings, especially upholstered furniture and draperies (42).

Deaths and injuries from ignited clothing run third to auto accidents and household accidents as a major cause of deaths, injuries, and property losses (3). Of deaths from fire, three times as many occur among children under age five as in the ages five to sixty years (24). These figures explain why time and effort was spent on establishing flammability standards for children's sleepwear.

Research and Development

The proposal and passage of flammability standards have encouraged chemical producers to seek ways of producing chemicals that can impart flame retardancy to fibers. Mills are also cooperative and willing to evaluate new chemical finishes and fibers to improve the flame retardant properties of their products. Segments of industry, acting through trade associations for the most part, have cooperated in the development and evaluation of test methods (43).

An article in Clothes magazine for August 7, 1971, touched upon the problems of additional cost that are associated with adding flame retardant finishes to fabrics:

> It will also be the fabrics suppliers who will be the first to absorb the cost of compliance which, of course, will be passed on to the consumer who, it is estimated, will be asked to pay about two dollars more per sleepwear item at retail.
>
> . . . this increased price added to a rather low unit retail will dramatically alter the number of sleepwear units sold across the counter as well as the entire make-up of the sleepwear industry . . . (30).

Another article on children's sleepwear and carpet flammability standards predicted high additional costs:

> All children's nightwear will cost 25 to 50 percent more. Service life of many nightwear items will be reduced one-third to one-half. All garments which pass the standard will have to carry permanent labels which caution against conditions which can cause them to fail . . . (7).

The responsibility for flammability testing of fabrics lies with the manufacturers themselves, who may have independent laboratories perform the testing, and their fabrics must comply with the Federal standards and guidelines. Previously they could rely on a guarantee from their suppliers (7). The attempts at testing and complying with standards for different types of fibers and flame retardants has resulted in frustration and various predictions of failure by some industry figures. George S. Buck, speaking as Director of Research for the National Cotton Council, made these remarks concerning testing for flame resistance:

> It also appears . . . that consumers will have to give up polyester-cotton and polyester-rayon blends --and therefore most durable press uses--in children's sleepwear items, because there is no way to make these products fire resistant if they contain 35 percent or more polyester. In fact, it now appears likely that all blends and mixed

> fabrics--even polyester with rayon--will fail the proposed test and will have to be abandoned for children's sleepwear use (7).

By way of contrast, George E. Paules, President of the Carpet and Rug Institute, reported recently that every company will be ready to comply with carpet standard DOC FFI-70 by the April 15 deadline (7). Less stringent tests and the nature of carpet fiber help make this possible.

Initially, much of the controversy in industry testing for meeting flammability standards centered around the tests themselves. Some garments failed the vertical-strip test (now specified by law for sleepwear) but passed others; some fabrics burned differently when hung as a strip than when sewn into a garment. Carpets that passed a "pill test" which ignites a fuel pellet and measures the burn radius failed a "tunnel" test which measured carpet flammability under much more severe conditions (3). Thus much of the past and present work in flammability development centers in valid testing techniques that reflect accurately the flame resistant quality of fabrics and fibers.

The effect of all the flammability controversy on the consumer is being forecast in rather negative terms by textile industry spokesmen. Some predict that suitable fabrics will not be available in expected quantities and varieties to maintain current sales. Thus, they argue, consumers will have to settle for less variety and greater cost if they elect to purchase flame retardant fabrics, or

else choose to make their own sleepwear garments at home. One leader in the cotton industry described the future thusly:

> Mills and cutters will now be scrambling to see whether sufficient materials can be developed to supply the children's sleepwear market. . . . Probably fire-resistant cotton flannels and brushed nylon tricots will be the staple items for this market until the problems with knits are overcome and the uncertainties with other thermoplastics are eliminated.
>
> It is quite clear that at this time there is no practical way to keep mothers from sewing sleepwear garments for their children from fabrics which don't comply with the standard. This may be the only way consumers can obtain certain types of sleepwear items which they desire (6).

The required testing of fabrics by manufacturers will also force some small firms out of business, due to the complexity and expense necessary to equip and maintain testing facilities. Thus it may be seen that the introduction of flammability standards for children's sleepwear and other fabrics and fibers--while providing increased safety and peace of mind--may result in increased costs and curtailed variety of garments by fabric types from which to choose.

Finishes

Although fire retardant finishes for cotton fabrics have been known about for two hundred years, the past twenty-five years has seen the most progress in this area. Making flame retardant finishes durable to laundering while retaining acceptable aesthetics has been a major goal of recent research.

Dr. Bruce LeBlanc, in describing past and present efforts to make cotton fire resistant, classified the types of finishes being used commercially thusly:

1. Those non-durable treatments, like ammonium phosphate, ammonium sulfamate, and borax and boric acid.

2. Semi-durable finishes like urea phosphate and combinations of dicyandiamide and phosphoric acid.

3. Durable finishes like tetrakis hydroxymethyl phosphonium chloride (THPC), tris aziridinyl phosphine oxide (APO), combinations of antimony oxide and chlorinated compounds (as in FWWMR finish), and N-methylol dialkyl phosphonopropionamide (CIBA's Pyrovatex CP) (36).

Of the above finishes those achieving commercial attention are FWWMR, various THPC finishes, APO-thiourea finish, and Pyrovatex CP finish (26, 27).

Antimony oxide and chlorinated paraffin is a flame retardant finish improved by the Southern Regional Research Laboratory. It is applied to tents, tarpaulins, and other outdoor products and is durable throughout the entire service life of the products. FWWMR (flame, water, weather, and mildew resistant) treatment adversely affects the hand or feel, the drape, and the color of the fabric since add-ons must be up to 60 percent to obtain adequate durability of the flame resistant treatment (14).

In 1953 another finish developed at Southern Regional Research Laboratory was announced by Reeves and Guthrie. These durable flame retardant finishes for cotton are based on tetrakis hydroxymethyl phosphonium chloride

(THPC) and are applied to the fabric by a pad-dry-cure technique. In many cases, particularly when applied to lightweight fabrics, there is a loss in strength and a change in hand. THPC-amide retardants are known by trade names such as Lynrus FR-1, Permaproof, and Roxell. They are padded to a 70 percent wet pick-up on an 8 ounce fabric (twill or sateen), dried, cured two minutes at 325 degrees Fahrenheit, washed in a hot solution of perborate and soda ash and then rinsed. Finally the fabric is top-softened and dried. It will not propagate flame even after 25 commercial launderings (26).

THPC-melamine or THPC alone are a little more expensive than THPC-amid retardants and are used when a softer hand is desired. They too are padded to a 70 percent wet pick-up on an 8 ounce fabric (twill or sateen). After being dried and cured one minute at 325 degrees Fahrenheit, additional curing is effected at 140 degrees Fahrenheit in a solution of ammonium sulfate and soda ash; then the fabrics are rinsed and dried. The fabric will not support flame even after more than 25 commercial launderings. They and THPC-amide retardants show rot, mildew, weathering, and wrinkle resistance.

APO-Thiourea contains more nitrogen than phosphorous--the reverse of THPC-amide retardants and THPC, Melamine--although used in the same areas. It is padded to a 70 percent wet pick-up on 8 ounce fabric, dried, cured for

two minutes at 325 degrees Fahrenheit, washed in a little wetting agent, rinsed, and dried, causing the fabric to be flame retardant for more than 25 commercial launderings (26). Other qualities are:

1. Good wrinkle resistance
2. Good rot resistance
3. Good hand
4. No odor or fumes during processing
5. Ease of preparation of bath
6. Usual mill conditions for processing
7. Very little shade change on most dyes (25).

Pyrovatex CP is a durable flame retardant finish primarily for cotton and may be used for certain special rayons as well. The application of this finish is similar to the others previously cited. This finish was developed by the CIBA-Geigy Corporation.

When made available to the public late in 1968, the Pyrovatex-treated fabrics proved to have no afterglow or after-flame with samples burned to an average char length not exceeding 5.5 inches (with no individual sample exceeding 6.5 inches) when tested during the AATCC Test Method 34-1966 vertical flame test. These properties were shown durable to 50 home washes using 50 grams of Tide per washer load with temperatures up to 140 degrees Fahrenheit (18). Pyrovatex CP is recommended for flame-proofing protective clothing, nightwear, furnishing fabrics, cotton sheeting, and tablecloth fabrics (8).

Finally, among the advantages and benefits claimed for Pyrovatex CP are:

1. Non-toxic, non-skin-irritating
2. Conventional application method
3. No ammonia cure of finish necessary
4. Allows limited use of chlorine bleach
5. Durable to laundering and dry cleaning
6. No effect on aesthetic properties of fabric (8).

B. MANNER OF SOILING

According to Getchell (21), "soiling" and "staining" are used loosely and often interchangeably. However, the term "stain" has always implied a degree of permanency not connected with soil or dirt. While dirt or soil can usually be removed by ordinary cleaning or laundering, special means are sometimes needed to remove a stain. A stain then is dirt or soil confined to a small area and is extremely difficult or impossible to remove. Area of discoloration as well as the degree of penetration of the fiber determines whether a fabric is stained or soiled.

While the finest of colloidal dirt particles or large, nonpolar molecules of oils and greases are usually wholly restricted to the fiber surface, most water-soluble inorganic salts and many soluble organic molecules such as dyestuffs can penetrate to the internal areas of the water-swollen fiber. As recognized in current advertisements for stain-resistant fabric finishes, stains are usually the result of contact with such aqueous solutions. Therefore--except for some borderline cases--soiling can be considered a surface condition and staining a function of fiber interiors.

Snell (38) classifies soil found in clothing as (1) a fluid component (usually oil, wax, or grease--all of which are nonpolar and not easily wet by water) and (2) a soil component of small inert particles (negatively charged, or occasionally positively charged). Food stains are a special type of soil which consists of sugar, starch, salts, coloring matter, and proteins. Although sugar, starch, and salts are readily soluble in water, proteins such as egg and blood are only partially water-soluble. There are various other stains which may be more or less water-soluble or which may require special removal treatment other than the usual detergent laundering. Mechanical and chemical forces, electrostatic attraction, and oil bonding may cause soil retention regardless of cleaning procedures.

Compton and Hart (9) have outlined the following as soil retention mechanisms:

1. Macro-occlusion, or entrapment of particles in the intra-yarn or inter-yarn spaces.
2. Micro-occlusion, or entrapment of particles in the irregularities of the fiber surface.
3. Sorption of materials by van der Waals or coulombic forces at the surface or within pores and crevices.

Mechanical forces are undoubtedly responsible for the largest portion of dirt accumulated by textile fabrics; they might also be responsible for the high tenacity of soil retained. As portrayed by Compton and Hart,

> Soil may be contained within a fabric structure in four general areas--in the relatively large

> spaces between the yarns, in the smaller system of pores between the fibers of a yarn, in the tiny angles formed by single fibers, and in or on the microscopic fiber surface itself. Yarn and fabric construction determine the geometry of the first two areas, while fiber morphology governs the latter two (21).

Bowers and Chantrey, in a study involving a regular polyester fiber and a modified polyester in staple, yarn, and fabric forms, explained the role of fiber construction in soiling and soil removal thusly:

> . . . We hypothesize that regular polyester in staple form has a high hydrophobic surface area. When this is subsequently made into yarn, the surface area decreases and, therefore, soiling decreases; this is carried a step further when the yarns are woven into fabric. On the other hand, the modified polyester presents a comparatively high hydrophilic surface area to the soil solution; therefore, it soils considerably less and cleans up much better when it is in staple form. This improvement is decreased as it is spun into yarn, for the same reason as the regular, i.e., the hydrophilic surface area is decreased, and it soils more (5).

Their work also involved cleanability of fabrics of four constructions. Fabric appearance gradually deteriorated as fabric weights increased. The softer, loosely woven fabric containing large low-twist yarns was easier to clean than closely woven fabric with small, highly twisted yarns (21).

Those fabrics treated for stain repellency may cause a would-be stain to bead up on the surface so that it is easily removed by blotting. However, even this fails when dynamic forces, such as those encountered with a spill or the pushing of a liquid into a fabric, are introduced.

Waterborne stains are prevented from deep penetration but certain oily stains soak in between yarns (34). If these stains or soils are not removed, they accumulate causing the fabric to have a yellowish-gray cast associated with gradual deterioration in appearance of whiteness (33).

C. METHOD OF CLEANING

Detergency studies have found temperature, detergent type and detergent concentration to be of primary importance in soil removal. More recently, enzyme-based laundry products have appeared on the market claiming to remove difficult stains which could not otherwise be removed.

Effect of Temperature

Bowers and Chantrey (5) found that washing temperatures ranging from 80 to 160 degrees Fahrenheit had very little effect on soil removal from cotton and polyester fabrics. (The fabrics were laundered for 10 minutes in a Tergotometer with one gram per liter of Tide.) However, Lewis (28) reported a greater degree of initial stain release from cotton and polyester fabrics laundered at 120 degrees Fahrenheit than from those washed at 140 and 160 degrees Fahrenheit.

Effect of Detergent Type

Commercial detergents are generally nonionic or anionic. Both Bowers and Chantrey (5) and Lewis' (28)

studies showed better stain removal qualities on cotton fabric laundered in an anionic detergent, while nonionic detergents cleaned polyester fabrics more effectively.

Effect of Detergent Concentration

Bowers and Chantrey (5) concluded that cotton fabrics were cleaned by laundry procedures recommended by detergent manufacturers, but polyesters required three times the recommended amount to be cleaned equally as well.

Effect of Enzymes

Although enzyme-based cleaning products have been used by dry cleaners for several years, they have been available to the housewife for only five years. Enzyme-based laundry products presently are available as (1) detergents with enzymes and (2) presoaking products. Examples of the first type are Drive, Gain, Punch, and Bold. These are used like conventional heavy-duty detergents, but can also be used for presoaking laundry. Presoak products are designated for soaking stained articles only and are not meant to be detergent substitutes (15). However, since 1968 when commercial brands of presoak products such as Axion and Biz first appeared, there has been a continual cry from enzyme producers that their products will clean and whiten clothes "far beyond detergents or bleach," or that they will "put brilliance into whites and colors" (15). Even though Consumer Union (22) reported that overnight presoakings in

regular detergent did "surprisingly well" as compared to ones soaked overnight in Axion and Biz, these presoaks continue to be popular items in home laundering scales. Finally, many washing machine manufacturers (e.g., Whirlpool and General Electric) have responded to the appeal of the presoaks by offering models with presoak cycles (16).

D. MEASUREMENT OF WHITENESS

Whiteness is often defined as the total of reflected light relative to the reflection by a magnesium oxide standard (1). A material would be said to have a whiteness of 100 percent by the CIE (Commission Internationale de l'Eclairage) system if it reflected light from a standard source exactly the same as the magnesium oxide standard (10). The reflectance of a fabric usually is defined as "that value obtained when a sufficient number of fabric thicknesses are employed so that the background effect on the reflectance readings becomes negligible" (36).

Since it is considered next to impossible to restore some types of soiled fabrics to their original whiteness values, a quantitative measure of whiteness was needed to detect changes in levels of relative whiteness. Reflectance readings have been most commonly used because they do not rely on human judgment or memory (31). Today, several instruments are used to measure whiteness, yellowness, and

soil retention of fabrics. Galbraith (20) measured 45 degree light reflectance on six types of white, plain-weave fabrics using a Gardner Color Difference Meter (20). This instrument is equipped to read three values for each color measured--the light reflectance, L; the a_L which is redness when positive, gray when zero, and greenness when negative; and the b_L which is yellowness when positive, gray when zero, and blueness when negative (20). These readings showed a composite effect of an increase in blueness caused by optical brighteners in detergents and an increase in yellowness caused by multiple launderings in the presence of soil (20).

Bowers and Chantrey (5) used a Model 610 Photovolt Reflectometer equipped with a green tristimulus filter on soiled fabrics to compute soil pick-up and soil retention. The formulae used were:

$$\text{Percent soiled (before washing)} = \frac{R_O - R_S}{R_O} \times 100$$

where R_O= reflectance of original
R_S= reflectance of soiled unwashed

$$\text{Percent soiled (after washing)} = \frac{R_O - R_W}{R_O} \times 100$$

where R_O- reflectance of original
R_W= reflectance of soiled washed

An alternate instrument Bowers and Chantrey (5) used for measuring loss of whiteness of fabrics was a Hunter Model D-40 Reflectometer using green and blue reflectance and substituting in the formula:

$$W = G - 4(G-B) = 4B - 3G$$

where W= % whiteness relative to MgO
B= Blue reflectance value
G= Green reflectance value.

In an attempt to relate reflectance to the quantitative amount of soil remaining on the fabric surface the Kubelha-Munk equation of K/S values has been used. Berch and Peper (4) calculated the extent of soiling from reflectance values measured with a Hunter Multipurpose Reflectometer using a green filter. K/S values were calculated using:

$$*K/S = (1-R)^2/2R$$

where R= observed reflectance
K= coefficient of reflectivity
S= coefficient of light scattering

*K/S is nearly a linear function of the amount of pigment present on the fabric while reflectance is not

Snell et al (37) using the Photovolt Reflectance Meter substituted the reading in the following way:

$$\text{Percent soil removed} = \frac{W - U}{O - U} \times 100$$

where W= reflectance of soiled washed samples
U= reflectance of soiled unwashed samples
O= reflectance of original.

CHAPTER III

PROCEDURES

The purpose of this study was to compare the effectiveness of enzyme presoaking and regular laundering in removing chocolate milk, grape jelly, and egg yolk from flame retardant cotton flannelette and untreated cotton flannelette. Also investigated was the possibility of an observable difference in the stain release characteristics of the treated fabric over a period of 50 launderings.

I. SELECTION OF FABRIC

The two printed cotton flannelette fabrics used were donated by M. Lowenstein and Sons, Inc. Thirty-three yards of 45 inch, orange printed fabric treated with Pyrovatex flame retardant finish was supplied, as was thirty yards of 36 inch, blue printed fabric, untreated. Both fabrics were plain weave.

II. PREPARATION OF SPECIMENS

One hundred nineteen specimens measuring 6 by 12 inches were cut from each of the two fabrics, resulting in a total of two hundred thirty-eight specimens. Specimens were cut six to a row horizontally from the 45 inch wide treated fabric, and five to a row horizontally from the 36 inch wide untreated fabric. The position of the specimens was no

nearer than two inches to the selvages and the ends of the fabric. Three rows of specimens were cut per yard, allowing the 12 inch length to run parallel to the warp yarns. The edges of the specimens were finished with a zig-sag stitch using black or white mercerized cotton thread, size 60.

The following identification code was used to label eight specimens (two swatches per category) of both treated and untreated fabrics (N=16) in a pilot study:

TABLE I[a]

STAINING AND LAUNDERING CODE FOR PILOT STUDY

Treatment	Code
Stained 24 hours, presoaked, washed	Two notches, white thread
Stained 24 hours, washed	One notch, white thread
Stained 2 hours, presoaked, washed	Two notches, black thread
Stained 2 hours, washed	One notch, black thread

[a]Treatments applied to both fabrics.

The remaining two hundred twenty-two specimens were also coded by the color of thread zig-zagged along the edges and by the number of corners cut off at 45 degree angles. Table II gives this coding information:

TABLE II

STAINING AND LAUNDERING CODE

Fabric	Treatment	Code
Treated	Stained, presoaked, washed	Two notches, black thread
Untreated	Stained, presoaked, washed	Two notches, black thread
Treated	Stained, washed	One notch, black thread
Untreated	Stained, washed	One notch, black thread
Treated	Unstained, washed	No notch, white thread
Untreated	Unstained, washed	No notch, white thread

III. STAINING PROCEDURES

Three staining substances considered to be representative of stains frequently found spilled on children's sleepwear were selected. The staining substances were: (1) chocolate milk, (2) grape jelly, and (3) egg yolk. A detailed description of the staining substances is presented in Table III.

To insure better repeated location of the stains, a plastic template 6 by 12 inches with three, 2-inch circles cut out at even intervals along the length, and notched in the upper right hand corner, was used to guide repeated staining. Staining procedures employed by Lewis (28) were used. Grape jelly and egg yolks were applied with 5/8 inch

TABLE III

DESCRIPTION OF THREE STAINING SUBSTANCES

Staining Substances	Brand	Ingredients
Chocolate milk (one part syrup, four parts milk, four parts distilled water)	Hershey's Syrup Pet Evaporated Milk	Sugar, water, corn syrup, cocoa, salt, and vanillin, an artificial flavoring.
Grape jelly	Welch's	
Egg yolk (boiled four minutes)		

corks immersed in the appropriate stain and pressed to the fabric with sufficient pressure to produce a uniform spot on the surface. Fresh stain was applied to the cork for each application. All specimens were placed on a single thickness of paper towel and none of the stains were blotted so that excess staining media was permitted to penetrate the fabric. For the liquid stain, three drops of chocolate milk were placed on the specimens using the same medicine dropper. The specimens were allowed to dry for approximately two hours prior to laundering. This particular time interval was decided upon after having conducted a pilot study. Two specimens of each fabric in this pilot study were given four different staining and laundering treatments (N=16) as described in Table I. After one staining and one presoaking and laundering, there was no observed difference

between specimens stained 2 hours and those stained 24 hours. Due to the time element involved, two hours was chosen as the staining period.

IV. PRESOAKING AND LAUNDERING PROCEDURES

All specimens were laundered one time to remove any unreacted chemicals that might have been applied in the finishing process.

Seventy-four specimens of each fabric type were presoaked using an enzyme-active product, Axion, for approximately 30 minutes. The Axion concentration was 1/2 cup in medium water level setting with the initial water temperature of 105 ± 5 degrees Fahrenheit. At the end of the presoaking period, specimens received a rinse in a three minute prewash cycle and one minute spin to remove excess water.

The remaining one hundred forty-eight specimens were laundered with the presoak specimens under simulated home laundry-drying conditions according to AATCC Test Method 124-1969 in a Kenmore 600 automatic washer. This testing procedure is outlined in Appendix A. Specimens were subjected to repeated launderings through fifty launderings. At the end of each five intervals (0, 5, 10, 15, . . . , 50) three specimens of each fabric were pulled, except that five were withdrawn at intervals 0 and 50 for flammability testing. Drying was done in two, 4 pound loads in a Kenmore 70 dryer at 150 ± 5 degrees Fahrenheit for 30 minutes. The

final five minutes was a cooling down cycle. The internal air temperature of the dryer was measured on a recording potentiometer (Honeywell-Brown Electronik) placed in the lint exhaust filter.

V. EVALUATION

To check the fabric specifications, specimens at 0 and 50 laundering intervals were cut into specified sizes for laboratory determinations of weave pattern, fabric count, weight, thickness, whiteness, and flammability. Specimens were conditioned according to ASTM Designation: D1776-67. A temperature of 70 ± 2 degrees Fahrenheit and a relative humidity of 65 ± 2 percent were maintained.

Physical Properties

Weave pattern. Both treated and untreated cotton flannelette fabrics were plain weave construction.

Fabric count. ASTM Designation: D1910-64 was followed in determining the number of warp and filling yarns present per inch in both fabrics. Five counts for each fabric were made on a 6 by 12 inch specimen using a micrometer counter and light box. Counts were made at 0 and 50 launderings and averaged for each direction to the nearest whole yarn.

Fabric weight. The weight of the fabrics was established according to ASTM Designation: D1910-64. Five two-inch specimens of each fabric were weighed on a Mettler, semiautomatic, analytical balance. Mean values were converted from weight in grams to ounces per square yard by the formula

$$\text{weight in ounces per square yard} = \frac{\text{weight of specimen, in grams} \times 45.72}{\text{length of specimen, in inches} \times \text{width of specimen, in inches}}.$$

Fabric weight was recorded to the nearest 0.1 ounce.

Fabric thickness. ASTM Designation: D1777-67 describes the method used to determine the thickness of each fabric. The instrument used was a Federal Thickness Gage with a 0.1875 inch wide pressure foot and a pressure of 13.6 pounds per square inch. After a five-second load time, one reading to the nearest 0.0005 inch was taken on five 2 inch square specimens. Mean thickness values were reported to the nearest 0.001 inch.

Stain Removal

Each one of the two hundred twenty-two 6 by 12 inch specimens were used to determine whiteness. Whiteness readings were calculated to indicate degree of Stain removal. Objective measurement of the surface reflectance was obtained with a Photovolt photoelectric reflection meter 670 (32). A standard of 75 was established for each tristimulus filter (blue and green) used. A search unit was placed

against the specimen on each stain location. The following formula described by two authors (1, 5) was used to calculate whiteness:

$$W = G - 4(G - B) = 4B - 3G$$

where W = % whiteness relative to MgO
B = Blue reflectance value
G = Green reflectance value.

Flammability Testing

The U.S. Department of Commerce Standard DOCFF 3-71 was followed in conducting the flammability testing of both fabrics (44). Five samples 3.5 by 10 inches were cut from the five 6 by 12 specimens which had been laundered o and 50 times. They were then mounted on specimen holders, conditioned in a drying oven at 221 degrees Fahrenheit for 30 minutes, cooled in a dessicator for 30 minutes, and finally ignited in a standardized test cabinet. The value of the char length, the residual flame time, and average char length for each set of five specimens was recorded.

VI. DATA ANALYSIS

Flame retardant cotton flannelette and untreated cotton flannelette were compared in terms of stain removal measured by whiteness values calculated at every fifth laundry interval. A Wang 700A Advanced Programming Calculator was used for computations.

Since laundry intervals were equally spaced, orthogonal coefficients were used in a multiple linear regression

analysis to determine the significant relationships of whiteness to launderings. From this analysis, the sum of squared deviations for linear through quintic components were calculated. These values were checked for significance against F ratio at the 95.0 percent confidence level (Table IV). Linear and curvilinear regression analyses were then run for components of significance.

Comparisons between the means for treated fabric and untreated fabric were made to determine the effect of the flame retardant finish and presoaking treatment on the removal of food stains. For comparison linear and curvilinear regression for whiteness values versus laundering were plotted and their equations checked against the mean whiteness values read at each laundry interval. In addition, all data gathered were presented in a series of tables preceding each graph depicted.

TABLE IV

ANALYSIS OF VARIANCE F RATIOS FOR SIGNIFICANCE[a]

Fabric	Stain	Laundry Treatment	$F(x_1)$	$F(x_2)$	$F(x_3)$	$F(x_4)$	$F(x_5)$
Treated		Control	15.08*	0.00	1.02	15.32*	4.09
Untreated		Control	21.38*	7.13*	0.68	0.33	0.05
Treated	Chocolate milk	Presoaked	2.30	0.03	0.73	0.61	0.00
Treated	Chocolate milk	Not presoaked	30.10*	1.43	23.22*	4.89*	8.71*
Untreated	Chocolate milk	Presoaked	2.43	0.58	0.24	0.19	0.37
Untreated	Chocolate milk	Not presoaked	3.85	8.35*	9.81*	3.69	1.91
Treated	Grape jelly	Presoaked	70.63*	28.34*	0.66	0.56	2.13
Treated	Grape jelly	Not presoaked	33.07*	2.18	0.09	3.18	0.21

[a]F ratios significant at the 95.0 percent level of confidence.

CHAPTER IV

PRESENTATION OF DATA AND DISCUSSION OF FINDINGS

Data on the physical properties and stain removal and flammability characteristics of fabric A (flame retardant cotton flannelette) and fabric B (untreated cotton flannelette) are reported and discussed in this chapter. Fabrics A and B are compared with respect to both their initial properties and characteristics, and to those obtained after repeated stainings and launderings.

I. PHYSICAL PROPERTIES

Fabric count, fabric weight, and fabric thickness measurements were taken at 0 and 50 launderings to determine whether the two fabrics were alike in structure and dimensions. The results of laboratory determinations of physical properties of fabrics A and B are given in Table V.

Fabric Count

Both fabrics showed a very slight increase in yarn count in the interval from 0 to 50 launderings. While fabric A increased in the fill by one yarn, fabric B increased in both warp and fill by one yarn. In short, both fabrics showed excellent dimensional stability by this measure.

TABLE V

FABRIC DIMENSIONS AND STRUCTURE BEFORE AND AFTER FIFTY LAUNDERINGS

Fabric (code)	Weave (type)	Launderings (number)	Fabric Count[a] (yarns/inch)	Fabric Weight (oz./sq.yd.)	Thickness (inches)
A (treated)	plain	0	47x45	5.0	0.011
		50	47x46	4.9	0.014
B (untreated)	plain	0	46x46	3.5	0.010
		50	47x47	4.0	0.014

[a]Warp x filling yarns.

Fabric Weight

An examination of the fabric weights revealed that fabric A showed essentially no weight change as the result of 50 launderings. Fabric B, however, gained in weight after 50 launderings. The increase in weight was not accounted for by the slight increase in fabric count reported above, and probably reflected either pick-up from laundering or normal variation in fabric uniformity.

Fabric Thickness

Both fabrics experienced a slight increase in thickness after 50 launderings. Also, they were nearly identical (0.001 difference) at 0 launderings and identical at 50 launderings.

II. EVALUATION OF STAIN REMOVAL

Stain removal was evaluated in terms of whiteness, which in turn was calculated from blue and green reflectance values of the specimens. These blue and green reflectance values for fabrics A and B control (unstained) specimens from 0 to 50 launderings are given in Table VI.

Whiteness

Both control fabrics, as seen in Table VI, showed a loss in whiteness although neither were stained. The whiteness for each fabric was described as a curvilinear regression (Figure 1). Fabric B exhibited an immediate loss of

TABLE VI

PHOTOVOLT REFLECTANCE VALUES FOR TREATED CONTROL AND UNTREATED CONTROL FABRICS, UNSTAINED

Fabric	Laundry Interval	Mean Reflectance Values		Calculated Whiteness[a]
		Blue	Green	
A Treated	0	73.6	78.5	59.7
	5	75.0	80.1	57.8
	10	76.9	81.5	64.2
	15	77.1	81.9	62.7
	20	78.0	84.5	58.5
	25	78.6	84.3	61.5
	30	78.9	83.7	64.3
	35	78.3	84.0	61.4
	40	79.0	83.4	65.0
	45	79.1	82.4	69.2
	50	79.1	84.9	61.7
B Untreated	0	79.2	85.0	61.7
	5	73.7	84.0	42.7
	10	73.5	83.6	43.1
	15	72.3	84.3	36.4
	20	72.7	85.0	35.7
	25	71.6	85.0	31.9
	30	72.4	85.3	33.7
	35	73.0	85.6	35.2
	40	73.0	85.7	35.0
	45	72.1	86.0	30.3
	50	73.5	86.0	36.7

[a]Whiteness = 4 Blue - 3 Green

whiteness with laundering which continued until laundry interval 25, after which the process slowed. Meanwhile fabric A showed no noticeable change in whiteness except for an unusually high value at laundry interval 45. Thus it was seen that control fabric A, unstained, exhibited fairly stable whiteness with repeated laundering, while control fabric B, unstained, showed a marked deterioration in whiteness with repeated laundering.

A. $\hat{Y} = 58.8 + 1.199X - 0.1172X^2 + 0.00389X^3 - 0.0000399X^4$
$R^2 = 0.502$

B. $\hat{Y} = 55.9 - 1.48X + 0.0221X^2$
$R^2 = 0.747$

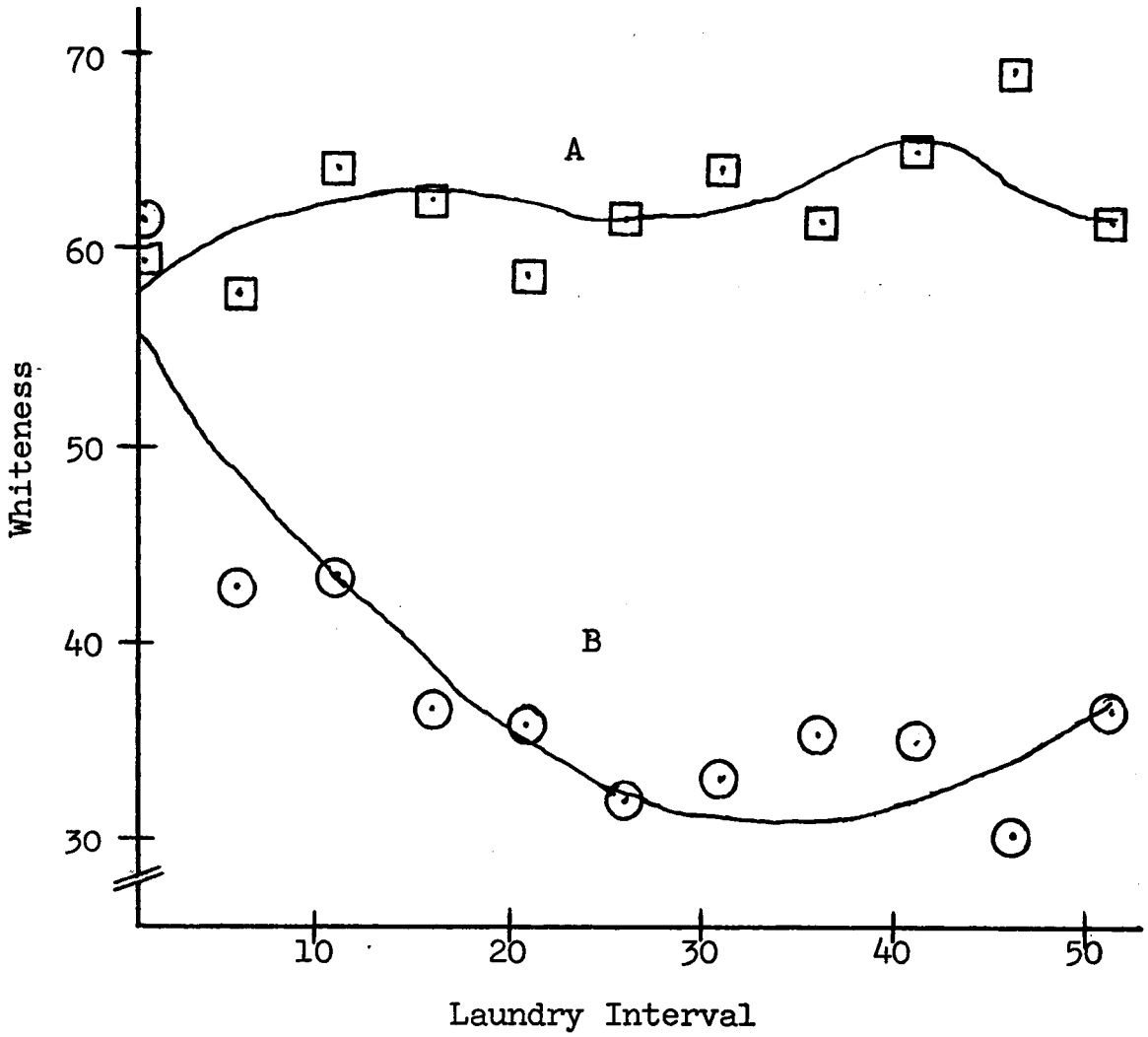

Figure 1. Regression for whiteness of treated controls (fabric A) and untreated controls (fabric B) from 0 through 50 laundry intervals.

Egg Yolk Stain

Neither fabric A nor fabric B ever showed visible (or measurable) evidence of staining with egg yolk after ten stain applications and 50 laundering intervals.

Chocolate Milk Stain

Calculated whiteness values which show the effect of presoaking vs not presoaking are shown in Table VII for both the treated fabric A and the untreated fabric B, stained with chocolate milk. The untreated fabric B is seen to lose whiteness rapidly at the five wash interval and more slowly thereafter. There is little, if any difference between the presoaked and not presoaked samples. Further, comparing these data with those given in Table VI for the unstained, untreated fabric, shows that the loss in whiteness accompanying chocolate milk staining is much the same as the loss in whiteness with no applied stain. The untreated fabric appears not to retain chocolate milk stains.

For the treated fabric A, there does appear to be a retention of chocolate milk stains. Comparing the data in Table VII with those in Table VI shows a loss in whiteness for the stained samples compared to the unstained controls. Further, presoaking with enzymes before laundering appears to hinder stain removal. The presoaked samples begin to show loss in whiteness after twenty launderings (four stainings) while the samples not presoaked only begin to show loss in whiteness after thirty launderings (six stainings).

TABLE VII

WHITENESS VALUES OF TREATED AND UNTREATED FABRICS STAINED WITH CHOCOLATE MILK

Laundry Interval	Treated		Untreated	
	Not Presoaked	Presoaked	Not Presoaked	Presoaked
0	59.7	59.7	61.7	61.7
5	57.7	63.0	38.0	40.5
10	61.8	61.0	42.0	41.3
15	66.2	60.0	37.0	41.0
20	65.5	56.2	36.0	36.3
25	59.7	55.6	38.4	37.0
30	51.0	54.3	33.2	38.4
35	52.0	45.4	36.7	29.4
40	46.4	44.9	35.3	33.7
45	51.3	50.9	31.4	35.9
50	54.5	52.9	30.9	31.2

Reflectance data from which the whiteness falues were computed for the non-presoaked samples are given in Table VIII. Comparing these data with those in Table VI shows that both Green and Blue reflectances are significantly reduced by stains for the treated fabric A. Loss of whiteness for the untreated fabric B is caused by yellowing of the fabric (decrease in Blue reflectance) with no reduction in Green reflectance. Regression curves are shown in Figure 2.

Grape Jelly Stain

Through ten stainings and fifty launderings the untreated fabric B showed no sign of any staining with grape jelly. Loss in whiteness parallels that shown above for unstained, untreated fabric and for fabric stained with chocolate milk. However, there was significant staining of

TABLE VIII

PHOTOVOLT REFLECTANCE VALUES FOR TREATED (STAINED[a] AND WASHED) AND UNTREATED (STAINED[a] AND WASHED) FABRICS

Fabric	Laundry Interval	Mean Reflectance Values Blue	Green	Calculated Whiteness[b]
Treated	0	73.6	78.5	59.7
	5	72.9	78.1	57.7
	10	73.7	79.0	61.8
	15	75.8	79.0	66.2
	20	75.0	78.1	65.5
	25	74.7	79.7	59.7
	30	71.0	77.7	51.0
	35	69.6	76.1	52.0
	40	67.6	74.6	46.4
	45	66.8	72.0	51.3
	50	66.3	73.6	54.5
Untreated	0	79.2	85.0	61.7
	5	72.5	83.7	38.0
	10	74.0	84.7	42.0
	15	72.7	85.0	37.0
	20	72.8	85.1	36.0
	25	73.0	84.6	38.4
	30	72.3	85.3	33.2
	35	72.5	84.4	36.7
	40	70.8	82.7	35.3
	45	69.4	82.0	31.4
	50	66.0	77.4	30.9

[a]Stain is chocolate milk.

[b]Whiteness = 4 Blue - 3 Green

the treated fabric A with grape jelly, and there was a significant difference in stain removal depending on whether or not presoaking with enzyme was employed in laundering. These data are given in Table IX, and the regressions with laundering are given in Figure 3. Again, the data show that stain removal is actually hindered by the use of an enzyme presoak. The presoaked sample shows a greater loss in

A. $\boxdot \hat{Y} = 59.658 - 2.284X + 0.4727X^2 - 0.02751X^3 + 0.000602X^4 - 0.00000447X^5$

$R^2 = 0.760$

B. $\odot \hat{Y} = 57.2 - 2.56X + 0.094X^2 - 0.001X^3$

$R^2 = 0.046$

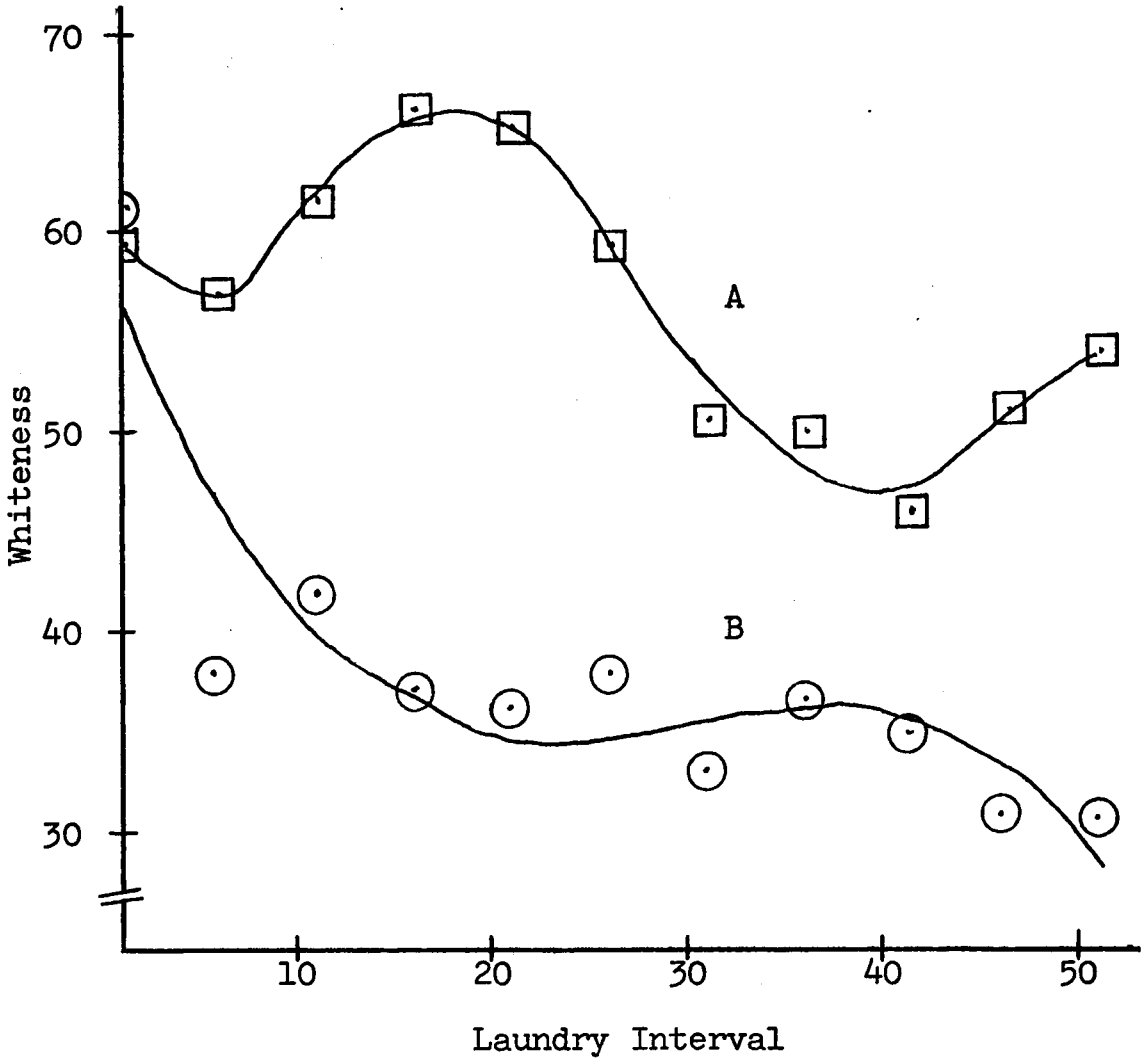

Figure 2. Regression for whiteness of treated fabric A (stained[a] and washed) an untreated fabric B (stained[a] and washed) from 0 through 50 laundry intervals.

[a]Stain is chocolate milk.

TABLE IX

PHOTOVOLT REFLECTANCE VALUES FOR TREATED (STAINED[a] AND NOT PRESOAKED) AND TREATED (STAINED[a] AND PRESOAKED) FABRICS

Fabric	Laundry Interval	Mean Reflectance Values Blue	Green	Calculated Whiteness[b]
A_1 treated, stained, not presoaked	0	73.6	78.5	59.7
	5	71.0	74.4	60.9
	10	64.1	72.3	49.4
	15	63.3	68.0	49.1
	20	52.5	62.3	23.0
	25	48.7	59.9	15.2
	30	44.1	56.9	5.8
	35	48.0	56.1	23.8
	40	45.9	58.9	6.7
	45	47.8	56.8	20.7
	50	42.3	56.6	- 0.67
A_2 treated, stained, presoaked	0	73.6	78.5	59.7
	5	59.3	66.7	36.5
	10	55.8	63.4	33.3
	15	55.2	62.1	34.4
	20	48.9	59.4	14.3
	25	45.9	59.4	5.36
	30	45.5	55.0	9.63
	35	44.3	53.7	13.4
	40	42.2	51.4	11.2
	45	41.5	50.5	14.4
	50	34.0	45.9	11.9

[a]Stain is grape jelly.

[b]Whiteness = 4 Blue - 3 Green

whiteness compared to the non-presoaked sample up until twenty-five launderings (five stainings). In subsequent stainings and launderings the fabrics remain at about the same level; both are heavily stained by the grape jelly. Table IX shows that both Blue and Green reflectance are greatly reduced.

A_2. $Y = 55.8 - 2.62X + 0.0363X^2$
$R^2 = 0.224$
A_1. $Y = 58.4 - 1.197X$
$R^2 = 0.003$

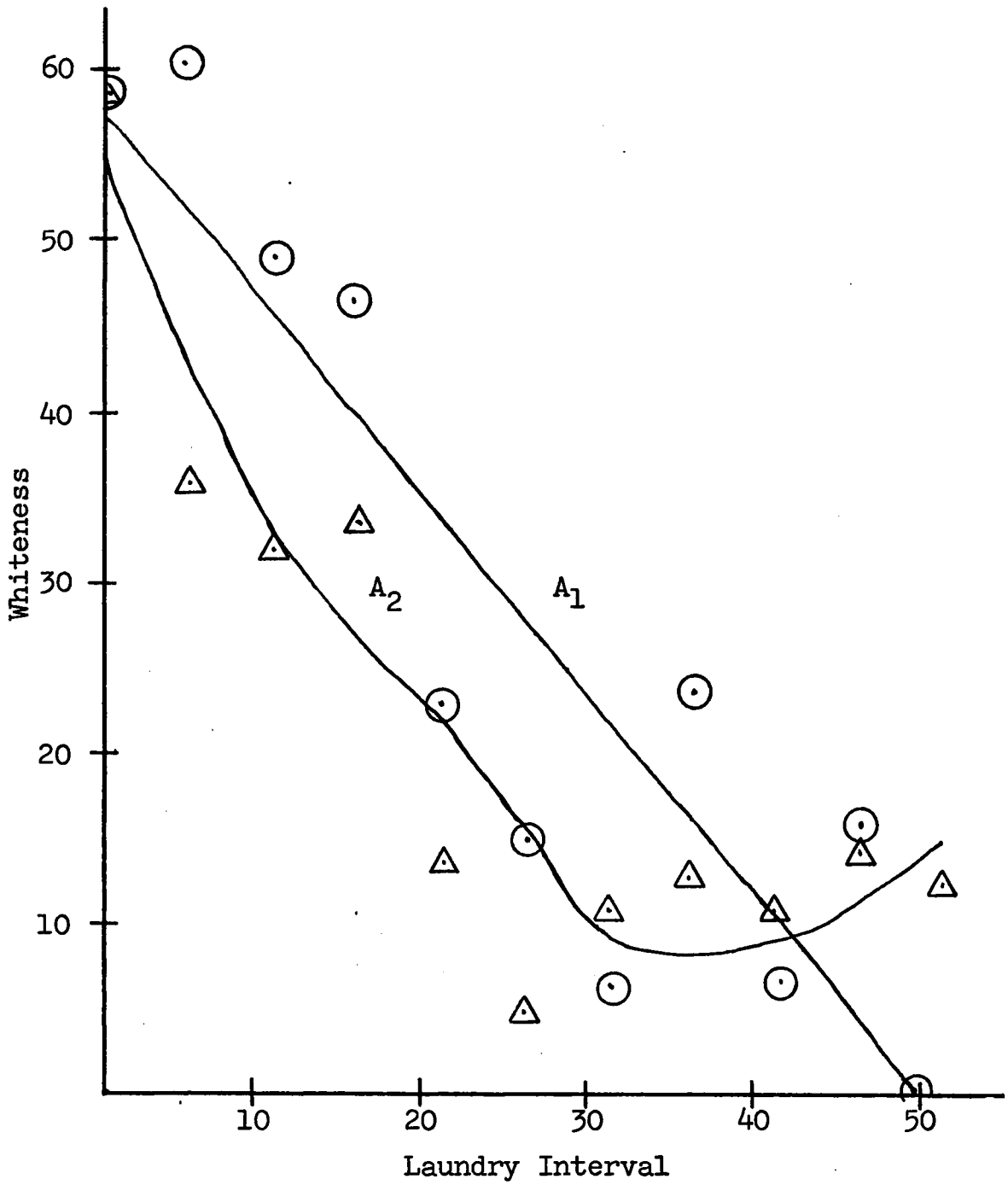

Figure 3. Regression for whiteness of treated fabric A_2 (stained[a] and presoaked) and treated fabric A_1 (stained[a] and not presoaked) from 0 through 50 laundry intervals.

[a]Stain is grape jelly.

III. FLAMMABILITY TESTING

All the specimens of fabric A which were burned (regardless of laundry treatment) had a char length of less than 4.0 inches (federal standards allow a char length of 7 inches) and a residual flame time of under 2 seconds. However, fabric B burned the entire length of the test sample, and had a residual flame time of 10 seconds. Only the control specimens of fabric B were tested for flammability since the federal test procedures state: "If the char length of any individual specimens of an item equals 25.4 cm (10 inches) that item fails to meet the acceptance criterion and testing may be stopped (44)." The data are shown in Table X.

TABLE X

FLAMMABILITY TEST RESULTS FOR TREATED AND UNTREATED FABRICS

Fabric	Laundry Interval	Char Length[a] (inches)	Residual Flame Time (seconds)
Treated	0	3.0	1.1
Treated, Unstained	50	3.0	1.0
Treated, Stained, Presoaked	50	3.8	1.1
Treated, Stained, Not Presoaked	50	3.6	1.7
Untreated	0	B.E.L.[b]	10.0
Untreated	50	B.E.L.	10.0

[a]Average of five determinations

[b]Burned entire length (10 inches)

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The main purpose of this study was to evaluate the effectiveness of enzyme presoaking and regular laundering in removing certain food stains from fabric A (treated) and fabric B (untreated). The tendencies of both fabrics to retain certain food stains was also observed. The fabrics were as follows: Fabric A, 100 percent cotton flannelette treated with the flame retardant finish Pyrovatex; fabric B, 100 percent cotton flannelette untreated. The food stains were egg yolk, chocolate milk, and grape jelly.

Calculated whiteness values were used to evaluate the degree of stain removal. Fabrics were laundered fifty times using home laundry/drying conditions according to AATCC Test Method 124-1969; fabric reflectances were measured after every five launderings. Stains were applied initially and after every reflectance reading. AATCC and ASTM testing procedures were followed throughout the entire study. Physical properties that were evaluated included fabric count, fabric weight, and fabric thickness. Whiteness determination centered on the evaluation of stain removal of egg yolk, chocolate milk, and grape jelly.

Comparisons of fabrics A and B were made to determine whether presoaking would affect the stain removal characteristics of either fabric. Linear and curvilinear

regression analyses were used to determine the relationship between laundry intervals and the degree of stain removal.

Evaluation of Physical Properties of Fabrics A and B

The presence of the flame retardant finish Pyrovatex seemed to have little if any significant effect on the physical properties of the fabrics tested in the study. In general, fabric A had less change in fabric count, weight, and thickness with respect to laundry intervals than did fabric B. Fabric A retained its appearance better than Fabric B.

Evaluation of Stain Removal and Flammability Characteristics

Stain removal characteristics of fabrics A and B were studied to evaluate how certain food stains would affect whiteness, and whether enzyme presoaking would assist in stain removal during laundering.

The untreated cotton flannelette (fabric B) did not retain any of the three stains applied. Laundering of stained samples gave the same degree of loss of whiteness as laundering unstained controls. There was no difference seen between those samples which had been presoaked with enzyme prior to laundering and those which had not.

The flame-resistant cotton flannelette, made so by finishing with CIBA-Geigy's Pyrovatex, also resisted staining by egg yolk. However, chocolate milk and grape jelly stains were retained by this fabric, and the presence or

absence of an enzyme presoak in the wash cycle did affect the degree of stain removal. Grape jelly was the most tenaciously held stain of the two appearing on the fabric after one staining and presoaking and five launderings, or after two stainings and ten launderings with no presoaking. Chocolate milk was retained after four stainings and presoakings and twenty launderings, or after six stainings and thirty launderings with no presoaking. In the case of both stains, presoaking with enzyme increased the difficulty of stain removal. This led to the rejection of the null hypothesis concerning the effect of presoaking on the degree of stain removal. Clearly, when laundering flame resistant children's sleepwear of 100 percent cotton finish with Pyrovatex, the consumer should not use enzyme presoak products.

From the evaluation made of fabrics A and B, no physical properties seem to have been altered due to the addition of a flame retardant finish; however, the treated fabric did appear to retain certain food stains more than the untreated fabric. Thus the null hypothesis regarding the effect of a Pyrovatex finish on stain removal was rejected. Similarly, the flammability remained the same regardless of laundry treatment or interval.

Consumer acceptance of flame retardant finishes will have to cope with the knowledge that certain treated fabrics do retain some food stains to a greater extent than do

untreated fabrics, and that presoaking with enzymes hinders the removal of stains thought not affecting the flammability.

Recommendations for Further Study

1. Further studies could use other natural fiber or man-made fiber fabrics suitable for children's sleepwear. Examples of these might be a cotton broadcloth or a polyester flannel.

2. Future testing of stain removal properties of fabrics A and B could include different stains (maple syrup, margarine, or orange juice) that are often associated with staining of children's sleepwear.

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APPENDIX

APPENDIX

LAUNDRY/DRYING PROCEDURE

AATCC Test Method 124-1969
Washington procedure III
Drying procedure B

Machine:	Kenmore 600
Wash:	140 ± 5 degrees Fahrenheit for 14 minutes (Normal setting)
Detergent:	90 grams of Tide (1 cup)
Rinse:	105 ± 5 degrees Fahrenheit for 10 minutes
Spin:	6 minutes
Load:	8 pounds (222 specimens and terry cloth filler)

Following final spin, specimens were untangled and tumble dried.

Machine:	Kenmore 70
Drying:	150 ± 5 degrees Fahrenheit for 30 minutes. Last 5 minutes was a cool down period.

Specimens were withdrawn randomly after dryer stopped.

VITA

Dorothy Bangs Bishop was born in Brevard, North Carolina, on January 20, 1949. She graduated from Brevard High School in June 1967. She received an Associate of Arts degree from Brevard College in 1969. In June 1971 she received the Bachelor of Science degree in Home Economics with a major in Textile Technology from the University of Tennessee, Knoxville. Immediately following, she entered the Graduate School at the same University with a major in Textiles and Clothing.

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