THE EFFECTS OF COMMON HOUSEHOLD CLEANING AGENTS AND AGING ON THE REMOVAL OF QUANTITATIVELY APPLIED FOOD STAINS FROM RAYON, NYLON, AND OLEFIN PILE UPHOLSTERY FABRICS

by

Brenda Hess Hofbauer

Thesis submitted to the Graduate Faculty of the

Virginia Polytechnic Institute and State University

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

in

Clothing, Textiles, and Related Art

APPROVED:

Mary Ann Zentner, Chairman
Associate Professor and Head
Clothing, Textiles, and Related Art

William L. Mauldin
Professor Emeritus of
Clothing, Textiles,
and Related Art

Barbara E. Densmore
Professor of Clothing,
Textiles, and Related Art

Michael A. Ogliaruso
Professor of Chemistry

March 1982

Blacksburg, Virginia

ACKNOWLEDGMENTS

The author wishes to express her sincere gratitude and appreciation to the following individuals for their assistance in completing this research project:

To members of her committee: Dr. Mary Ann Zentner, Dr. Barbara E. Densmore, Dr. William L. Mauldin, and Dr. Michael A. Ogliaruso.

To Dr. Mary Ann Zentner, a special thanks, for her guidance, patience, and support throughout this endeavor.

To Jacquelyn Hicks, Larry Runions, and others at Collins and Aikman Corporation who were responsible for donating the upholstery fabrics.

To Hoyt Wiggington and others at Fieldcrest Mills who donated mattress pads and towels to this research project.

To members of the consumer panel: Joan Council, Marsha Croushorn, and Harriet Mauldin, for the contribution of their time toward this pursuit.

To her parents, Mr. and Mrs. James R. Hess, for their loving support and constant faith in her abilities.

A special thanks to her father for building the frame used during the stain removal process.

Lastly, to her husband, Thomas, for his help, encouragement, and never-ending patience.

TABLE OF CONTENTS

Chapter | Page

LIST OF TABLES

LIST OF FIGURES

Chapter I

INTRODUCTION

Upholstered furniture has long been a popular item in the home. In 1976 it was estimated that in households throughout the United States there were 300 million pieces of upholstered furniture (1). It has met wide acceptance because it is comfortable, sturdy, durable, and comes in many shapes, sizes, colors, and patterns.

One of the major problems limiting the serviceability of upholstered furniture is soiling (2,3). With a predicted life expectancy of 11 to 14 years (3), upholstered furniture is sure to soil during use. A survey investigating consumer satisfaction found 53 percent of the respondents were not satisfied with the appearance or the ease of care of their home furnishings. Of home furnishings in general, upholstered furniture received the lowest satisfaction ratings (4). Soiling decreases the serviceability because it is often evaluated by appearance rather than by actual failure. The sanitation and the cleanliness are also frequently judged visually. Thus, a change in color or luster of an upholstery fabric may determine how long it is used (5).

The removal of soil from textile products is important. Besides detracting from the appearance, soil lowers the comfort and the hygenic value. Odors, the salts of perspiration, and other invisible soils change properties of fabrics without affecting appearance. Soil also shortens the wear-life of textiles by abrasion and the action of frequent cleanings (5).

Soiling is a unique problem with upholstery because of the difficulty in cleaning. Machine laundering or commercial dry cleaning are impossible since the fabrics are not easily removed from the furniture frame. The problem of removing soil and stains from upholstery fabric has been complicated by the large array of fibers and fabric styles now available. When choosing the proper cleaning method, consumers should consider both fiber content and fabric characteristics. However, research indicates that only 15 to 27 percent of the owners of upholstered furniture knew the fiber content of their upholstered pieces (6).

The soiling process and the soil removal from textiles have been common research topics. However, research that relates directly to consumers is somewhat sparse. The soils used and the manners in which they were applied have not been frequently encountered during the actual use of textile products. There is a need for research that directly relates laboratory test results to the product performance observed by consumers (7,8). Therefore, the general purpose of this research was to quantitatively apply food stains to selected upholstery fabrics, to attempt the removal of the stains with common household cleaners, and to determine the visual effects of stain removal and aging. A comparison was made between the results of reflectance and color measurements and the results of an evaluation by a consumer panel.

Chapter II

REVIEW OF LITERATURE

Types of Soils

Soils on textiles generally have been divided into three categories: (a) fluid soils such as oil or grease; (b) solid soils consisting of small, inert particles such as clay; and (c) stains which include dyestuffs, pigments, inks, iron salts, and fruits. Frequently fluid components and solid components combine in the soiling process. This combination of soils has been called oil bonding, and can be extremely difficult to remove (5).

There is almost an unlimited number of substances that soil textiles. The three main sources of soil on textiles are: direct contact with a soiled surface, and contact with liquid-borne or air-borne substances (5). A more complete list of the ways soil can come in contact with textiles includes diffusion, deposition, and electrostatic attraction (9).

The Soiling Process

The soiling process consists of two steps: the transport of soil to the fiber surface, and the adsorption of soil on the fiber surface (10). The steps have also been called the forces of impingement and the forces of retention (5). Either of these steps can determine the soiling rate (10). The transport of soil can take place by one of two mechanisms: static soiling or dynamic soiling. During static soiling the soil is transported to the fabric surface by gravity, air currents, or electrostatic attraction. The fabric remains motionless or the motion of the fabric does not affect soiling during this mechanism. When soil is deposited on a textile by contact transfer and the textile is subjected to mechanical action such as flexing, friction, and abrasion, dynamic soiling is the mechanism (11).

The forces of retention can be either a mechanical entrapment or a type of energy bond. Mechanical entrapment has been responsible for the largest weight of dirt accumulated by most textiles (5). Interfacial attraction can be caused by Van der Waals forces, electrostatic attraction, and/or hydrophobicity and oleophilicity (12,13). The cause of soiling depends on the type of soil, the type of fiber, the fabric construction, and the fabric finish.

The chemical constitution of the involved surfaces affects the degree of soiling. Polar groups such as ether, amide, hydroxyl, carboxyl, and sulfonate increase the ability of a fiber to bind soil molecules. For example, cellulose contains hydroxyl and acetalgroups, so it would be more likely to soil than polypropylene which does not contain any of these polar groups. The presence of polar groups also affects surface energy which in turn has been used to predict the ease of soiling and of removing soil. When a soil has a lower surface energy than the fiber surface, the soil will penetrate. Because oils have especially low surface energies, they have presented a difficult soiling problem on textiles (14).

The hydrophilicity and the oleophilicity of the fibers and the soil help to determine the ease of soiling. Hydrophobic (oily) soils tend to attach themselves to hydrophobic fibers such as polyester and cellulose made hydrophobic by crosslinking (13). Hydrophobic fibers tend to build up a large surface charge density from friction during use or launder-ing. Soil particles would be attracted to the fiber surface from the surrounding air or water (15).

Fabric construction and fiber geometry play a major role in deter-mining the soil resistance of textiles because the amount of soil ab-sorbed depends on the accessibility of the fiber surface area (16). The main mechanism involved in particulate soiling is geometric bonding. Geometric bonding has been divided into two categories: (a) micro-occlu-sion, when particles are trapped in fiber surface crevices; and (b) mac-ro-occlusion, when particles are trapped in fabric interstices (14). Dirt particles can be trapped in four general areas of a textile: be-tween yarns, in the spaces between the fibers of a yarn, in the angles formed by the bending and twisting of individual fibers, and on the fiber surface itself (5). Most soil tends to build up where natural irregu-larities are located on the fibers and on the fabric. However, soiling also occurs where irregularities are not apparent (17).

The textile construction is one factor influencing soiling. A tex-tile with fibers protruding from its surface is more likely to soil than a smooth fabric, due to the availability of soiling sites from the larger surface area (18). However, pile fabrics, with even larger surface areas, show less soil than nonpile fabrics. Sudnik (19) suggested that pile fabrics may not change brightness as much during soiling because they scatter light more than nonpile fabrics.

The tightness of the weave also affects the soiling properties of textiles. The points where the warp and filling yarns intersect are prime soiling sites. Since tightly woven textiles contain more cross-over points than loosely woven ones, they tend to soil badly (14). While loosely woven fabrics allow soil to penetrate easily, they allow for easier soil removal too. Soil among the yarns of a fabric normally is not difficult to remove. However, if it is not removed efficiently, clumps of soil will enlarge during further use. Loosely woven textiles trap soil between the fibers of a yarn more easily than tightly woven ones, because the yarns have more room to spread. If soil and pressure are present simultaneously, the soil will be trapped inside the yarn when the pressure is released (18).

The fiber content of a textile is another major factor associated with soilability. A number of research projects have attempted to rank generic fiber groups according to their soilability (9,20). The results were inconclusive because of their variability. However, certain fiber properties do affect soilability. Fiber surface area has been identified as one of these properties. Theoretically, a fiber with a minimum surface area per unit volume should resist soiling the best (5). For cotton fibers, Porter et al. (18) found soil pick-up to be directly related to specific surface characteristics. Coarse cottons soiled less than fine cottons. Other research also indicated that the degree of soil retention decreases with increasing filament denier. Soiling was primarily a function of the diameter and the cross-sectional shape of the fiber. Fibers of large diameters and smooth, round cross sections retained the least soil. The length and origin of the fibers did not seem to influence soiling (5,9). Weatherburn and Bayley (20) listed these fiber characteristics as influencing soil retention: (a) the presence of channels or striations, (b) the filament denier, and (c) the presence of pits and crevices. They concluded that for any one type of fiber, circular fibers retain less soil than irregularly shaped ones. Compton and Hart (21) also found a tendency for soil particle retention in the visible surface rugosities of fibers.

Other fiber characteristics have been noted for influencing the soiling process. Fabrics made of staple fibers soil more easily and retain more of that soil upon removal than those made of continuous filament fibers (14). The hardness or softness of the fiber surface determines the strength of the adhesion to a soil particle. A stronger adhesion results when a hard soil particle is on a soft fiber surface or when a soft soil particle is on a hard fiber surface. The curvature of the fiber surface, related to cross-sectional shape, may affect soil adsorption. If the interfacial contact area between a fiber surface and a soil particle is increased, the strength of adhesion increases as the fiber surface conforms to the soil particle (16).

Laboratory Soiling of Textiles

Laboratory soiling tests should relate to the mechanism of soiling in use, utilize a cleaning method of removing loose soil, and use a soil with the same soiling characteristics as soil encountered by consumers (11). The first step of most laboratory soiling tests has been to soil textile specimens uniformly and reproducibly. Loose soil has been removed by vacuuming, shaking, and/or blowing. The amount of soil or the apparent extent of soiling on the specimens must be determined. Some soiling studies have ended with this evaluation step. Other research in soil removal, soil resistance, or soil release normally has included the additional steps of washing and cleaning, and of reevaluating to determine the amount of remaining soil (10,22). The variables involved in soil application have included the method of application, the soiling level, the aging time, and the amount of abrasion (14).

An almost unlimited number of methods have been used in applying soils in the laboratory. Dry soiling or combination dry and oily soiling has been accomplished by tumbling the test samples with soil or with soiled felt cubes, by using an abrasion-testing machine to force in dirt, by filtering dirty air through the fabric, or by using an Accelerotor® with dirt in the chamber but without the abrasive liner (3,5, 10,19,23,24). Soils have also been applied from a water medium in a Launder-Ometer®, Terg-O-Tometer®, washing machine, or by hand (9,19,21, 25,26). Liquid soils have also been applied with a spray gun, with a pad

---

Accelerotor® = Trademark for Atlas Electric Devices Company

Launder-Ometer® = Trademark for Atlas Electric Devices Company

Terg-O-Tometer® = Trademark for United States Testing Company mangle, or with a microburet, pipette, or eyedropper (15,22,23, 27).

For the quantitative application of soils, a known amount of soil has been applied in a uniform, reproducible manner. The percent soil add-on has been calculated from the difference in weight before and after soiling (28,29,30,31).

Problems have been associated with almost all of the soil application processes. When soils have been applied as 100 percent materials it was difficult to achieve uniformity and to avoid a high level of loading. The tumbling method may have developed abnormal static charges from friction and, if steel balls were added to hasten the soil application, might have abraded the fabrics. The use of abrasion-testing equipment may have increased available surface area for sorption and produced crevices for mechanical entrapment. When soils have been applied from a solvent or aqueous medium, sometimes the fibers have swollen (9,14,19).

The laboratory soiling of textiles in general has been criticized. The two greatest criticisms have been that the artificial soils used have not realistically represented the soils encountered in actual use, and that the levels of soiling used in the tests have been much higher than the values encountered in normal use (32).

Soil Removal

The removal of a soil particle from a fiber involves the breaking of an adhesive bond between the particle and the fiber. The strength of the bond and the energy required to break the bond depend on the attractive forces and the contact area between the soil particle and the fiber surface (33).

Soil removal by detergency is basically caused by the sorption of water and detergent and by mechanical action. The mechanisms of the sorption of water includes the roll-up of oily soil, the penetration of soil, and the solubilization and emulsification of the soil. The mechanical work consists of hydrodynamic flow, fiber flexing, abrasion, and the swelling of the fiber or the finish (34).

The ease of soil removal depends on how tightly the soil is held by the fabric. Loosely held soils are removed by vacuuming, brushing, shaking, or wiping. The removal of the remaining dirt is much more difficult. The smaller a particulate soil, the more difficult it is to remove. The ease of oily soil removal depends on the chemical nature, the degree of saturation, and the film-forming capacity of the oil. Substances which are unsaturated or capable of polymerization tend to be more difficult to remove (5).

Several factors affect the extent to which soil remains on a textile after the removal process. The chemical nature and the concentration of the soil influence soil retention (3,22). The amount of time between soiling and cleaning is another factor. Some soils are more difficult to remove after aging. But, Kissa (22) reported that for oily soils, soil retention decreased with increased time between soiling and laundering, unless the adhesion of the soil to the fiber became greater with time. This phenomenon occurred because the oil wicked, decreasing the concentration of soil on the fabric.

Soil Removal from Upholstery Fabrics

Since upholstery fabrics cannot be removed and laundered, they present special cleaning problems. Vaccum cleaning eliminates loose dirt such as dust, but it will not remove oily soils or combination oily and particulate soils. Wet-cleaning methods do not usually work well with upholstered furniture because they form rings. Sometimes solvent cleaning is successful, but it can damage adhesives and fillings on the furniture. Dry foam cleaners generally do the best job, but they leave sticky residues behind which allow resoiling to occur faster (3).

The American Carpet Institute and the American Hotel Association have recommended a cleaning solution that should be safe for general household use on carpets and upholstery. The solution is prepared by mixing one teaspoon of neutral detergent, one quart of warm water, and one teaspoon of white vinegar. The cleaning action should be a motion going from the outside toward the center of the stain. After the item has been cleaned it should be allowed to dry for at least 48 hours (27).

Sudnik (19) found little difference in various methods of cleaning upholstery fabrics. Most of the fabrics tested were easily cleaned, but none of them returned to their original shades after all treatments. The color change was probably due to migration of the dye in the fabric, the bleeding of the dye, or the loss of luster.

Evaluating Soiling and Soil Removal

The evaluation of the amount of soil on a textile can be optical, chemical, or physical. Gravimetric methods involve the weighing of the fabric sample prior to soiling, after soiling, and after cleaning. The differences in weight are calculated to find the weight of soil placed on the fabric and the weight of soil removed. The gravimetric method has yielded poor results when small amounts of soil markedly changed the appearance of a fabric, because it was difficult to weigh this small quantity accurately (23).

A microscope can be used to determine the distribution of soil and how it relates to fiber and fabric structure (17). It can also be used with a counting chamber to calculate the number of soil particles on a test sample (5).

Two chemical methods of evaluating the degree of soiling are quantitative analysis and the measuring of the optical density of a solution of soiled fabric and solvent. Quantitative analysis can be used when the soil is a pure one. Fabric soiled with iron oxide can be analyzed for its iron content. The amount of iron oxide can be calculated from the quantity of iron (11). The optical density method consists of dissolving soiled fibers in a solvent. Soil particles are left suspended in the solution which can then be tested for optical density with a spectrophotometer (20). A high degree of accuracy can be achieved by both of these chemical methods.

Radioactive methods of evaluating the degree of soiling are also very accurate. The soil is tagged with carbon-14 prior to the soiling procedure. After soiling the number of carbon-14 atoms on the fabric is determined with a Geiger Counter (22,35). One visual method is subjective evaluation. A panel of judges decides the apparent degree of soiling by comparing the test samples with photographic standards, by comparing them to each other, or by rating them on a continuous scale. Because this evaluation is subjective, ratings may differ considerably among judges (22). An advantage of subjective evaluation is that the fabric is judged by its appearance. Results are likely to indicate its acceptability during use.

Reflectance values often have been used to evaluate soiling and soil removal because they simulate visual appraisal without subjective judgments. When reflectance values are used for this purpose, it is assumed that light reflectance will decrease linearly with increasing amounts of soil, from an unsoiled fabric to the level after soiling. It is also assumed that reflectance will increase linearly during soil removal (14). Several equations exist for calculating soil removal with reflectance values. One of these equations incorporating the Kubelka-Munk equation is:

$$D = 100 \times \frac{\dfrac{(1 - R_{WF})^2}{2R_{WF}} - \dfrac{(1 - R_{SF})^2}{2R_{SF}}}{\dfrac{(1 - R_{OF})^2}{2R_{OF}} - \dfrac{(1 - R_{SF})^2}{2R_{SF}}}$$

where D = percent soil removed,

R_{WF} = reflectance after cleaning,

R_{OF} = initial reflectance,

R_{SF} = reflectance after soiling (14).

The Kubelka-Munk equation is

$$\frac{K}{S} = \frac{(1 - R)^2}{2R}$$

where R = reflectance,

K = absorption coefficient,

S = scattering coefficient (22).

Both equations account and correct for the scattering of light by the fabric and soil, but do not correct for textile and soil colors, wavelength of incident light, presence of fluorescent fabric brighteners, and textile construction (14).

Another related optical method of evaluating soiling is that of finding color difference. A colorimeter is used to find the difference in the X, Y, and Z tristimulus values before and after soiling, and, if desired, after soil removal. An equation used to find color difference is:

$$\Delta E = \left[(\Delta X)^2 + (\Delta Y)^2 + (\Delta Z)^2\right]^{1/2}$$

where ΔE = color difference,

ΔX, ΔY, ΔZ = differences in the tristimulus values of the soiled and unsoiled samples (15).

Difficulties have been encountered in assessing the degree of soiling on upholstery fabrics. Optical evaluations have been inaccurate sometimes because of nonuniform soiling due to effect threads, and a change in luster but not in color. The crushing of pile and the distortion of surface yarns often alter the appearance of textiles (19).

Soil Resistant Finishes

Two major types of finishes have been developed to protect textiles from soils. Soil resistant finishes prevent or restrict the penetration of liquid soils. Soil release finishes facilitate soil removal by making the fibers hydrophilic. Finishes have also been developed that are soil resistant in air and soil release in water. The most widely used soil resistant finishes are made from fluorochemicals (14,36,37).

Fluorocarbons make textiles soil repellent because they have very low surface energies. If textiles treated with fluorocarbons have lower surface energies than liquid soils applied to them, the soils will not be able to penetrate and stain the fabric surface. These finishes also protect fabrics against the wicking of soils and the forming of rings due to solvent spotting. The importance of acting on a stain immediately is not as great if the fabric has a good fluorocarbon finish on it (14).

The literature reviewed gives evidence of the great variety of factors affecting soiling and soil removal processes as they relate to textiles. The variables normally involved include: the soils, the methods of soiling, the fiber contents of the fabrics, the fabric constructions, the finishes applied to the fabrics, the cleaning agents, the soil removal procedures, and the methods of evaluation. Each of these variables were considered in the formulation of this research project.

Chapter III

STATEMENT OF THE PROBLEM

The general purpose of this research project was to determine the effects of common household cleaning agents and aging times on the removal of quantitatively applied food stains from rayon, nylon, and olefin pile upholstery fabrics. In addition, a comparison was made between instrumental measurements and the consumer panel ratings.

With the general purpose in mind, the following specific objectives were formulated for investigation in this research project:

1. To quantitatively apply food stains on a rayon, a nylon, and an olefin pile upholstery fabric.
2. To determine the effects of four stain removers on the removal of the food stains from the three upholstery fabrics, by measuring light reflectance values and color values.
3. To determine the effects of two stain aging times on the removal of the food stains from the three fabrics, by measuring light reflectance values and color values.
4. To compare and correlate the reflectance values and color values obtained through the use of the Hunter Color-Difference Meter® with ratings obtained from a consumer panel evaluation of the test specimens after cleaning.

Hunter Color-Difference Meter® = Trademark for Hunter Associates Lab, Incorporated.

Null Hypotheses

The hypotheses formulated for this research are stated in the null form for statistical analyses.

H_1: No significant difference will exist in the instrumental values for color change as they relate to:

a) the fabrics,

b) the food stains,

c) the aging times,

d) the stain removers.

H_2: No significant difference will exist in the values for stain removal assigned by the consumer evaluation panel as they relate to:

a) the fabrics,

b) the food stains,

c) the aging times,

d) the stain removers.

H_3: No relationship will exist between the instrumental values for color change and the values of stain removal assigned by the consumer evaluation panel.

Definition of Terms

An upholstery fabric is the outermost layer of fabric encasing the main support system of a piece of furniture (28). A large variety of these fabrics are on the market, but one characteristic which they have in common is that they are normally quite heavy.

Soil or dirt is a complex mixture spread over the surface of a fabric. On textiles, its composition depends on the environment, fabric use, and the activities of the user (4).

A stain normally consists of a single substance. Since stains normally occur on a molecular scale, they usually penetrate the fiber surface, making their removal especially difficult (4).

Assumptions

During the course of this research it was necessary to make certain assumptions. It was assumed that an equal amount of stain and stain remover was applied to each specimen, and that the manner of scrubbing the stains during the removal process did not vary among specimens. In addition, it had to be assumed that all equipment used was standardized and calibrated correctly to yield accurate and precise results.

Limitations

As with any research project, restrictions must be made and recognized. The major limitations of this research were:

1. Only three particular pile upholstery fabrics were involved in this research: rayon, nylon, and olefin. Upholstery fabrics are available in a wide variety of fiber contents, constructions, and finishes.
2. Only two of the three fabrics were treated with a soil resistant finish. Scotchgard® was applied to the rayon and olefin

---

Scotchgard® = Trademark for Minnesota Mining and Manufacturing fabrics by the manufacturer, but the nylon did not receive this treatment.

3. Mustard, vegetable oil, milk, and a pancake-type syrup were the only stains used in this research. Upholstery fabrics are soiled by many other substances.
4. Only two aging times were selected: one day and two weeks. Many other aging times could be studied as well.
5. A detergent-vinegar solution, perchloroethylene, isopropyl alcohol, and ammonia water were the only stain removal agents used. Many other products are available for this purpose.
6. The number of specimens was limited because of the amount of time involved in performing the experimental procedures.
7. The specimens were evaluated after stain removal by a three-member consumer panel. Perhaps a larger, better-trained panel would have yielded more consistent results.

It is believed that the information gathered in this research will be helpful to consumers for the removal of food stains from upholstery fabrics. Food stains are commonly acquired on these fabrics during use, and frequently they are very difficult to remove. The use of stain removers that are normally found in the home should make these techniques of stain removal simple and convenient. To know if the aging of food stains is detrimental to the ease of their removal could also be of value to consumers. The information resulting from this research might help to determine if a relationship exists between objective laboratory evaluations with reflectance values and color values, and a subjective consumer panel evaluation.

Chapter IV

PROCEDURE

This research deals with the quantitative application of four food stains onto three selected upholstery fabrics, and the subsequent attempted removal of them with four cleaning agents. It also investigates the effects of aging on stain removal.

Description of Fabrics

Three pile upholstery fabrics were obtained from the current inventory of a major textile producer. Since they came from the domestic upholstery division, they should represent fabrics available on furniture that would be purchased for residential purposes. All three fabrics have a pile construction, but one is ribbed, not unlike the surface of corduroy. A thin layer of a latex-type substance such as carboxylated styrene butadiene has been applied to the back of all the fabrics. The fabrics differ in color, fiber content, weight, and finish.

The rayon fabric has a red crushed pile surface and an acrylic backing. The weight is 21.50 ounces per linear yard and the width is 56.00 inches. Pile height is 0.12 inches. A Scotchgard® finish was applied for soil resistance.

The brown nylon fabric is constructed with an acrylic backing. It is 56.50 inches wide and weighs 19.53 ounces per linear yard. The pile height is 0.12 inches. No soil resistant finish was applied.

The third fabric has a ribbed surface, and is polypropylene with a rayon backing. This brown fabric has small off-white dots woven into it which give it an even overall pattern. A diagonal effect is formed by the dots which are spaced about one-half inch apart. The weight is 19.60 ounces per linear yard. The width is 57.75 inches. Pile height is 0.09 inches, and it has been finished with Scotchgard®.

Prior to any treatment or testing, all fabrics were conditioned for at least 24 hours. The conditions were 70 ± 2 degrees Fahrenheit and 65 ± 2 percent relative humidity.

To simulate the padding used on upholstered furniture, pieces of mattress pads were used. The pads consisted of a 100 percent polyester filling, a 50/50 cotton/polyester blend top covering, and a 100 percent olefin bottom covering. The pads were cut into rectangles the same size as the fabric specimens, then placed under them and held in place with a straight pin in each of the top two corners. The padding was attached to the fabric specimens except during evaluations.

Sampling Procedure

The test specimens were made by cutting the fabrics into 6.00 inch by 12.00 inch rectangles. The shorter sides of the rectangles followed the warp direction. All of them were cut at least 12.00 inches long to fit on the frame used to simulate a chair arm. The 6.00 inch width was chosen because it would be large enough to cover the area illuminated by the Hunter Color-Difference Meter®. The size also allowed sufficient room for the stains to spread.

A total of 111 specimens from each of the three fabrics was needed to complete three replications for the experiment. The cut specimens were assigned to a treatment by random selection and were subsequently coded to designate that treatment. The specimens for each replication were divided into four groups of eight. Each of these groups was treated with a different stain. The groups were divided again into two groups of four. These smaller groups were aged two different times. Each of the four specimens in the groups was treated with a different removal agent. Five specimens were used as controls for each replication. One of the controls did not receive any treatment. The removal procedure was performed on the other four controls by using a different removal agent for each specimen. No stains were placed on the controls.

Preparation of the Food Stains

Preliminary experiments using a number of different foods were completed to determine which ones would stain the fabrics most effectively. The four foods chosen to be used were mustard, vegetable oil, milk, and a thin pancake-type syrup. All of these products were commercially prepared and were typical of ones purchased at a grocery store.

Since the food stains were applied to the specimens from an eyedropper, all had to be in liquid form. The oil, syrup, and milk were usable from the bottles or cartons in which they were purchased. The mustard was thick and had to be diluted. After some experimentation to find the best consistency, it was determined that for every 65.00 grams of mustard, 50.00 milliliters of distilled water needed to be added. The average density of the mustard after dilution was 1.03 grams per milliliter. The ingredients in the mustard were vinegar, mustard seed, water, salt, turmeric, paprika, and natural flavoring. The vegetable oil consisted of partially hydrogenated soybean oil and polyglycerides, and it had an average density of 0.91 grams per milliliter. The milk used was vitamin D whole milk with an average density of 1.03 grams per milliliter. The syrup contained 81.6 percent corn syrup, 14.1 percent water, 3.0 percent maple syrup, 0.6 percent artificial flavor and caramel color, and 0.1 percent potassium sorbate. Its average density was 1.32 grams per milliliter.

Application of the Food Stains

Each of the test specimens, along with a layer of padding, was placed in 8-inch circular embroidery hoops for the application of soil. The embroidery hoops served to keep the fabric semi-taut as it appears on furniture. One length-wise edge was measured and marked into thirds. A 4.00 inch by 6.00 inch sheet of clear plastic with a 1.00 inch diameter circle cut out of the center was placed on each specimen over the center third. The plastic sheet, called a template, served as a guide for the placement of the stains on the specimens and to ensure that each stain was the same size.

Through preliminary research, it was determined that 1.50 milliliters of stain solution approximately covered a 1-inch diameter area. This amount was applied to each test specimen with an eyedropper. To determine the number of drops to be applied, each stain solution was dropped into a graduated cylinder until it was filled to the 1.50 milliliter mark.

The general procedure used in applying the food stains follows:

1. A test specimen and a piece of padding, mounted in embroidery hoops, were placed flat on a table.

2. One and one-half milliliters of the appropriate food stain were dropped from an eyedropper from 1 inch above the fabric surface. The drops fell through the hole in the template and onto the test specimen.

3. The food stain was rubbed lightly for 1.50 minutes with the end of a glass stirring rod to facilitate penetration of the stain into the fabric. Care was taken to duplicate the procedure for each test specimen.

4. The embroidery hoops were removed.

5. The specimen, with padding beneath it, was placed flat on an elevated wire mesh screen to dry in a conditioned environment.

6. The specimen was allowed to dry for a minimum of 24 hours.

7. The effect of the staining process on the appearance of the padding was noted.

Light Reflectance and Color Measurement

After the specimens were stained and aged for either 1 or 14 days, the Hunter Color-Difference Meter® was used to measure the light reflectance (L), the green-red value (a), and the blue-yellow value (b) of each. Just prior to taking the measurements, the padding was removed and each specimen was folded into thirds so that the center third with the stain in the middle was facing up. After they were folded, the specimens measured 4 inches by 6 inches. All specimens were brushed in the direction of the nap before the reflectance and color values were measured. The procedure for taking these measurements was taken from the Hunter Color-Difference Meter Instruction Manual (38).

1. A color temperature check was made prior to each use.

2. The instrument was standardized by using the calibrated standard of color which best matched the color of the specimen.

3. The specimen, folded in thirds, was placed with the spot of stain directly under the eye of the instrument.

4. The L, a, and b readings were taken by turning the L, a, and b switch to the correct position.

5. A second set of readings was taken with the specimen rotated at a 90 degree angle from its original position.

6. An average of the two readings was calculated for the L, a, and b measurements of each specimen.

This same procedure was followed for taking the reflectance and color readings of the specimens after the stain removal process and of the control specimens.

Stain Removal

Two times were selected for aging the stains. One set of stains for each fabric was aged for 24 to 48 hours before stain removal was attempted. The other set was aged for two weeks. Then the stain removal process was completed within 24 hours.

Four cleaning agents were used in this research. The first, a solution recommended by the American Carpet Institute and the American Hotel

Association, was prepared by mixing one teaspoon of neutral detergent (such as that used for fine fabrics) with one quart of distilled water and one teaspoon of white vinegar (27). The second solution was perchlor-oethylene. It was used to represent commercially available spot removers because it is frequently a major ingredient of these products. The third cleaning solution was isopropyl (rubbing) alcohol. It was used full strength from the bottle. The final solution was ammonia water, typical of the kind available in a grocery store.

The general procedure for stain removal follows:

1. Using a hard bristled toothbrush, the stained area was brushed from the outside of the stain toward the inside for 1.00 minute. The brushing helped to loosen excess, dried-on food residue.

2. The loose soil was removed by using the hose attachment of a vacuum cleaner.

3. The test specimen was placed over the wooden chair arm frame depicted in Figure 1. The specimen, with padding beneath, was attached to the frame by pushing the nails on one side of the frame through one edge of the fabric. The edge of the specimen was parallel to the nails. Then the opposite side of the specimen and the padding was flipped over the top of the frame and attached in the same manner to the row of nails on the other side of the frame.

4. One and one-half milliliters of the appropriate cleaning solution were applied directly to the stain from an eyedropper in the same manner as were the stains.

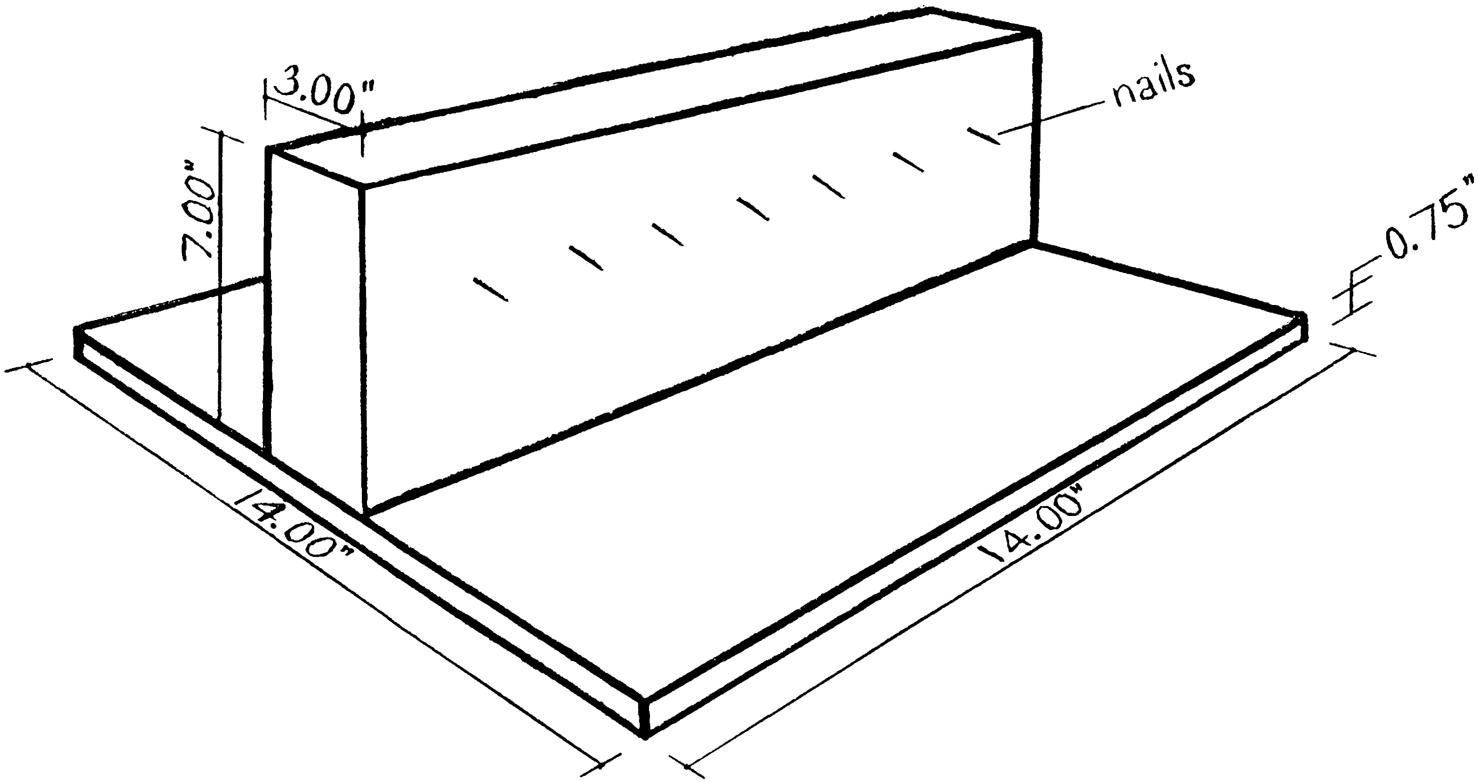

Figure 1

Wood Frame for Stain Removal Process

5. A clean 4-inch square piece of white cotton terry cloth was used to scrub the stain. It also absorbed the excess cleaning solution and loosened stain matter. The scrubbing was done from the outside of the stain toward the center in straight motions. The first motion began at the 12 o'clock position; the second started at the 1 o'clock position; and so on, until the whole circle had been scrubbed. The same procedure was continued until 1.00 minute had passed.

6. Steps 4 and 5 were repeated three times.

7. The rinsing process was much the same as that for cleaning. One and one-half milliliters of distilled water were placed on the stained area with an eyedropper. The scrubbing motion described in Step 5 was repeated for 1.00 minute.

8. Step 7 was repeated once.

9. The color(s) adhering to the terry cloth swatches was noted.

10. The test specimen was removed from the frame and, along with the padding, placed on an elevated wire mesh screen to dry for at least 24 hours.

11. The reflectance and color values were measured again on the Hunter Color-Difference Meter®.

12. The visual effect of the stain removal process on the appearance of the padding was noted.

Subjective Evaluation

After the stain removal procedure, each test specimen was evaluated by three consumers. They were females who had been in charge of a household for at least five years. The test specimens were compared to the untreated control under a MacBeth Spectralight® on a daylight setting. The consumer judges rated the degree of stain removal exhibited by the specimens, by comparing them to the AATCC Stain Release Replicas. The replicas formed a one to five interval scale. A rating of one represented the highest degree of change from the untreated control, while a rating of five was equivalent to no apparent change. The judges were also asked if the degree of change would be acceptable if it were on a chair in their living rooms. If it was not, they were asked to tell whether it was objectionable because of deformed pile, remaining stain, or both. A copy of the form the consumer judges completed for each specimen is located in the Appendix.

Statistical Analysis

After all evaluations had been completed, the ratings of the three consumer judges were averaged for each specimen. The average L, a, and b values were calculated for each specimen from the two readings taken at a 90 degree angle to each other. The difference in values between the original untreated specimens and the test specimens after staining and stain removal was calculated. The differences were represented by ΔL, Δa, and Δb. The following equations show the method of calculation:

$$\Delta L = L_u - L_t$$

$$\Delta a = a_u - a_t$$

$$\Delta b = b_u - b_t$$

MacBeth Spectralight® = Trademark for a division of Kollmorgan Corporation.

where L_u = reflectance of untreated specimen,

L_t = reflectance of treated specimen,

a_u = green-red value of untreated specimen,

a_t = green-red value of treated specimen,

b_u = blue-yellow value of untreated specimen,

b_t = blue-yellow value of treated specimen.

The overall color change, represented by ΔE, was calculated by using the ΔL, Δa, and Δb values in the equation:

$$\Delta E = \left[(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2\right]^{\frac{1}{2}}$$

Computer programs from the Statistical Package for the Social Sciences were used to analyze the data. The independent variables of fabric, stain, aging time, and removal agent were used in multifactor analyses of variance for each of the dependent variables of ΔL, Δa, Δb, ΔE, and the average ratings from the consumer evaluations. Each of the independent variables was used in a one-way analysis of variance with each of the dependent variables. Duncan's multiple range test was performed at the 0.05 level. A Pearson product-moment correlation was completed for ΔL, Δa, Δb, ΔE, and the average ratings of the consumer evaluations. Each of the independent variables was used in a one-way analysis of variance with each of the dependent variables. Duncan's multiple range test was performed at the 0.05 level. A Pearson product-moment correlation was completed for ΔL, Δa, Δb, ΔE, and the average ratings of the consumer evaluations.

Chapter V

FINDINGS AND DISCUSSION

The data were acquired according to the procedure presented in Chapter IV. Specimens were evaluated by light reflectance and color values that were obtained using a Hunter Color-Difference Meter®. In addition, they were evaluated by a consumer panel using the AATCC Stain Release Replicas. The following sections review observations made and discuss results obtained throughout this research project.

Application of the Food Stains

The food stains used in this study were mustard, vegetable oil, milk, and a pancake-type syrup. These stains were chosen after preliminary screening because they stained the fabrics very effectively. They also represented different types that may be encountered by consumers.

The method of applying the stains with an eyedropper was chosen to simulate soiling in households, as well as to yield consistent, reproducible results. Assumptions were made that the application of the food stains resulted in equal amounts of stains on each specimen. Generally, the specimens appeared to be equally soiled; however, the food stains sometimes spread beneath the plastic template used for the placement of the stains. When this occurred, the stains covered more than the 1-inch diameter anticipated. The spreading of the stains thus lowered the concentration of the soil on the specimens. In addition, a small amount of the soils adhered to the plastic templates and to the stirring rods used to force in the stains.

All stains were visible on the specimens immediately after application. After aging, some were very difficult to detect. The vegetable oil was hardly visible on the nylon fabric. This phenomenon probably occurred because the oil wicked into a much larger area of the specimens and into the padding beneath them. Oil was visible on the back of the specimens covering a much larger circular area than the 1-inch diameter circle to which it was originally applied. It was also visible on the brown paper placed between the padding and the wire mesh screens on which the specimens were dried and conditioned. It is likely that some wicking of the oil also occurred on the rayon and olefin fabrics even though it was not as apparent.

Light Reflectance and Color Measurement

Light reflectance and color values (L, a, b) were measured after staining and aging, and after the stain removal process. This method was chosen because it simulates visual appraisal without the subjectiveness of human judgment. The measurements made after staining and aging were taken to determine whether the method of soil application was reproducible. The measurements varied considerably, and it is likely that this was due to the pile on the fabric surfaces, as reported by Sudnik (19). The staining and removal processes distorted the pile on many of the specimens. According to Schick (14), other factors which may have affected the light reflectance and color measurements include the scattering of light by the fabrics and stains, the colors of the stains, and the wavelength of incident light. The two measurements taken at 90 degree angles from each other for each specimen were averaged to alleviate some variation. The measurements taken after attempted stain removal were the only ones used for the statistical analyses.

Stain Removal

The stain removal procedure used in this research was chosen because it could be easily reproduced. In addition, it could be simulated by consumers in their homes. The four cleaning solutions were chosen because they are often readily available in many households. It was assumed that the stain removal process was completed exactly in the same manner for each specimen. The procedure was repeated with as much accuracy and precision as possible, but it is likely that it varied slightly among specimens as to pressure, and the number of strokes. Although the stains were scrubbed gently, the stain removal process deformed the pile on the specimens even more than the staining procedure. It was difficult to determine if the resulting color change was due to remaining stain, to deformed pile, or to a combination of both factors.

Several observations were made about the stain removal process. Every time the ammonia solution was used to clean mustard stains, the mustard turned from bright yellow to brownish-red. A salt was probably formed when the ammonia water reacted with the vinegar in the mustard. The color change was evidently the result of the turmeric in the mustard behaving as an indicator. Perchloroethylene did not work well on mustard or syrup stains. Prior to the application of the rinse water, the majority of the stains remaining. The distilled water acted as a solvent for the stains as well as a rinse for the perchloroethylene. Mustard and syrup are both water-soluble substances; they have little solubility in organic solvents. When the ammonia solution came into contact with the nylon, a dull purple color was released onto the scrub cloths. The purple was probably due to the transfer of dyes from the nylon fabric.

White 4-inch squares of cotton terry cloth were used to scrub the stains. A new cloth was used each time the cleaning solution or rinse water was placed on the stained specimens. The cloths were checked for colors and substances remaining after stain removal. Dye, stain, and short fibers were removed from most of the specimens. On some, it was difficult to distinguish between stain and dye. A light yellow-tan substance was removed from the brown nylon specimens stained with oil or milk. This substance may have been stain, dye, or a combination of both. Because of the red dye in the rayon fabric its removal was easily detected. All rayon specimens released dye and short fibers onto the scrub cloths. Little or no difference was detected among the cloths used on stains which were aged one day and those used on stains aged for two weeks.

Padding was placed under all specimens to simulate the upholstered furniture system. The padding was evaluated after staining and aging, and after stain removal. If a stain was visible, its color, size, and depth were noted. The padding was evaluated to determine what might occur to the upholstered furniture system during soiling and stain removal.

None of the stains or removal agents seemed to damage the padding in any manner other than discoloration. The bottom sides of the paddings were seldom discolored prior to stain removal. However, afterwards many of the stains penetrated all layers. If the padding was discolored after staining, it remained discolored after stain removal. In some instances when a specimen appeared to be clean, the padding beneath remained stained. The stains on the paddings tended to become larger, and sometimes lighter, during stain removal. Generally, the stain removal process forced the soils further into the fabrics and padding.

The vegetable oil and the milk usually were not visible on the padding. Some of the stain removal agents served as carriers, therefore permitting the dye to penetrate into the padding. Several pieces of padding used along with the rayon specimens were stained pink. It is assumed that the cleaning solutions, with the exception of perchloroethylene, served as solvents for the red dye. When the control specimens were inspected it was noted that the detergent-vinegar solution and the ammonia water also carried dye from the nylon fabric into the padding. The perchloroethylene sometimes carried dye from the olefin fabric into the padding. Sometimes a color appeared on the padding that was not expected. For example, every time alcohol was used on the nylon specimens, the padding beneath was stained. A dull red spot surrounded by a darker red ring was evident. The red stain released from the brown nylon fabric was probably a dye which was soluble in alcohol.

Consumer Evaluations

A three-member consumer panel evaluated the specimens after stain removal to determine whether differences existed between the test specimens and their respective, untreated controls. In addition, their ratings were compared to the Hunter Color-Difference Meter® measurements using a Pearson Correlation.

Prior to rating the test specimens, the consumers were instructed how to use the AATCC Stain Release Replicas and how to complete the evaluation form for each specimen. To become familiar with the general procedure, they were asked to evaluate 16 other specimens made of fabrics similar to those used in this research. All three of the consumers said that they found it difficult to rate the specimens because of the color change caused by the remaining stain and deformed pile.

General inconsistency existed among the judges. This was most apparent when the first replication was evaluated. With practice, the judges were more consistent in the second and third replications. One of the judges rated most of the specimens notably lower than the other two. Of the three fabrics, the rayon specimens were rated lower overall than the nylon or olefin ones, which were rated fairly close to each other.

For each specimen the judges were asked if the change from the untreated control would be acceptable to them on chairs in their living rooms. All three judges rejected the rayon specimens more often than they did nylon and olefin ones. They were in agreement on the acceptability of a specimen over 50 percent of the time. The specimens were evaluated on a scale of one to five, where one represented the most stained and five was the least. The average rating given to an acceptable specimen was four.

If a judge said a specimen was unacceptable, she was asked to state whether she felt the objection was due to the stain, the pile, or both. The results indicated that the consumers rejected the rayon specimens primarily because of deformed pile. However, stains were the major cause of rejection for the nylon specimens. The olefin fabric was judged unacceptable about the same number of times for deformed pile and remaining stain.

The results of the stain versus pile question only indicate what the consumer judges thought about the specimens. When a judge rejected a specimen because of stain, it did not necessarily mean a stain existed. The judges evaluated the controls that were not stained but were treated with removal agents. When several of these specimens were rated, they perceived that remaining stain was the reason for unacceptability. In reality, the objections were probably due to deformed pile or loss of dye.

Analysis of the Instrumental Color Change Values

The purpose of the first hypothesis was to determine differences in the instrumental values in color change as they related to the fabrics, the food stains, the aging times, and the stain removers. These differences were tested to see if they were significant by doing multiclassification analyses of variance, one-way analyses of variance, and Duncan's multiple range tests. Each of the instrumental values of light reflectance (ΔL), green-red (Δa), blue-yellow (Δb), and total color change (ΔE), were tested against the independent variables.

Multiclassification analyses of variance were used with the differences of the instrumental measurements after stain removal to determine significance. The F-ratios, and the degrees of freedom for each of the independent variables and the two-way interactions are given in Table 1. Also included are the multiple R^2 values which approximate the percentage of the variation accounted for by the independent variables. Results indicate that the fabric and stain variables had a significant effect on all four of the instrumental measurements, and thus on the perceived degree of stain removal. The length of the aging time significantly affected Δa values, and the type of stain remover significantly affected Δb values. Several two-way interactions were also significant.

One-way analyses of variance were used with each of the instrumental values of color change for each of the independent variables to determine if significant differences existed among the means. In addition, Duncan's multiple range tests were completed at the 0.05 level to group the means. The results of these tests on fabrics are given in Table 2. Alphabetical designations were used to show which means were different. Those with the same subset letter were not significantly different from each other, but were significantly different from means designated by a different letter.

The three fabrics were significantly different from each other on ΔL and ΔE. In these tests, the red rayon changed the most, the brown olefin changed the least, and the brown nylon was in between. This result was expected because rayon fibers are generally more absorbent than nylon or olefin ones. Thus, the rayon fibers probably absorbed more of

Table 1

Multiclassification Analyses of Variance for Instrumental Color Change Values

	Light Reflectance (ΔL)		Green-Red (Δa)		Blue-Yellow (Δb)		Total Color Change (ΔE)	
	DF	F-ratio	DF	F-ratio	DF	F-ratio	DF	F-ratio
Main Effects								
Fabric	2	93.88**	2	18.60**	2	14.83**	2	164.46**
Stain	3	14.90**	3	10.07**	3	50.91**	3	7.71**
Aging	1	0.18	1	20.16**	1	2.83	1	0.38
Remover	3	1.09	3	1.35	3	6.46**	3	2.34
Two-Way Interactions								
Fabric-stain	6	2.45*	6	12.55**	6	19.66**	6	9.94**
Fabric-aging	2	3.78*	2	9.11**	2	8.40**	2	1.30
Fabric-remover	6	2.07	6	8.50**	6	6.80**	6	2.15*
Stain-aging	3	2.11	3	6.51**	3	3.95**	3	3.93**
Stain-remover	9	1.27	9	2.07*	9	9.16**	9	3.23**
Aging-remover	3	2.33	3	0.59	3	1.69	3	1.15
Multiple R^2		0.43		0.17		0.28		0.49

*Significant at the 0.05 level. **Significant at the 0.01 level.

Table 2

One-Way Analysis of Variance and Duncan's Multiple Range Test

For Instrumental Color Change Values by Fabric

Light Reflectance (ΔL)

Fabrics	Olefin	Nylon	Rayon
Means	1.99	3.32	5.14
Subsets	A	B	C
DF = 2			
F-ratio = 78.32**			

Green-Red (Δa)

Fabrics	Rayon	Olefin	Nylon
Means	-2.68	-0.49	-0.33
Subsets	A	B	B
DF = 2			
F-ratio = 13.56**			

Blue-Yellow (Δb)

Fabrics	Olefin	Rayon	Nylon
Means	0.58	0.80	1.12
Subsets	A	A	B
DF = 2			
F-ratio = 6.56**			

Total Color Change (ΔE)

Fabrics	Olefin	Nylon	Rayon
Means	2.78	3.70	7.86
Subsets	A	B	C
DF = 2			
F-ratio = 124.21**			

**Significant at the 0.01 level.

the stain. The olefin fiber is one of the least absorbent and impregnable available in the marketplace; perhaps the stains remained on the surfaces rather than penetrating into the fibers. The rayon fibers may have soiled to a greater extent than the nylon or olefin ones because of their irregular cross-sectional shape. This would coincide with the findings of Weatherburn and Bayley (20). In addition, the differences in fabric colors must be considered. On the Δa values, the rayon specimens changed significantly less than the olefin or the nylon specimens. The change in Δb values was significantly higher for the nylon fabric than for the olefin and rayon fabrics which did not differ significantly. These results can be attributed to the differences in fabric colors.

The stains were found to produce significant differences on each of the four instrumental color change values; however, the results were varied, as given in Table 3. The milk and mustard stains tended to have the least effect on the perceived degree of soil removal, while the oil and syrup stains affected it to a greater extent. The behavior of the controls was not predicted. Since they had been cleaned, but had not been stained, it was expected that they would change color the least. Instead, there were always one to three stain types which exhibited less of a change than the controls.

The aging times tended not to affect the instrumental color change values when tested by one-way analysis of variance. The means, degrees of freedom, and F-ratios are given in Table 4. The average Δa values were significantly different for the one day and the two week aging times. For the ΔL, Δb, and ΔE values, the aging times did not give a significant

Table 3

One-Way Analysis of Variance and Duncan's Multiple Range Test

For Instrumental Color Change Values by Stain

Light Reflectance (ΔL)

Stains	Milk	Mustard	Syrup	Controls	Oil
Means	2.78	2.88	3.68	3.86	4.41
Subsets	A	A	B	B	B

DF = 4
F-ratio = 6.90**

Green-Red (Δa)

Stains	Milk	Mustard	Controls	Oil	Syrup
Means	-2.46	-1.75	-1.02	-0.51	-0.03
Subsets	A	AB	ABC	BC	C

DF = 4
F-ratio = 4.76**

Blue-Yellow (Δb)

Stains	Mustard	Milk	Controls	Oil	Syrup
Means	0.19	0.48	0.76	1.11	1.58
Subsets	A	AB	BC	C	D

DF = 4
F-ratio = 20.49**

Total Color Change (ΔE)

Stains	Mustard	Controls	Milk	Oil	Syrup
Means	4.01	4.36	4.73	4.83	5.76
Subsets	A	AB	AB	AB	B

DF = 4
F-ratio = 2.67*

*Significant at the 0.05 level.

**Significant at the 0.01 level.

Table 4

One-Way Analysis of Variance for Instrumental Color Change Values

By Aging Time

Light Reflectance (ΔL)		
Aging Times	Two Weeks	One Day
Means	3.48	3.49
DF = 1		
F-ratio = 0.00		
Green-Red (Δa)		
Aging Times	One Day	Two Weeks
Means	-1.79	-0.40
DF = 1		
F-ratio = 10.69**		
Blue-Yellow (Δb)		
Aging Times	One Day	Two Weeks
Means	0.77	0.92
DF = 1		
F-ratio = 1.41		
Total Color Change (ΔE)		
Aging Times	Two Weeks	One Day
Means	4.75	4.80
DF = 1		
F-ratio = 0.02		

**Significant at the 0.01 level.

difference. Aging times probably did not have a large effect on the degree of soil removal because of the Scotchgard® finish applied to the rayon and olefin specimens. This effect of soil resistant finishes was reported in Schick (14).

The final variable tested was the type of stain remover. The results of the one-way analyses of variance and the Duncan's multiple range tests are shown in Table 5. The types of stain removers did not give a significant difference for ΔL, Δa, or ΔE. Sudnik (19) also found little difference among methods of cleaning upholstery fabrics. When the effects of stain removers were tested on Δb values, two groups of means were formed. The ammonia water, the detergent-vinegar solution, and the isopropyl alcohol were in the group which changed the Δb value the least, while the isopropyl alcohol and the perchloroethylene formed the group with the greatest change.

The first hypothesis stated that no significant difference would exist in the instrumental values for color change as they related to each of the following variables: (a) the fabrics, (b) the food stains, (c) the aging times, and (d) the stain removers. According to the results of the above described statistical tests, the first hypothesis must be rejected for the fabric and the stain variables. It cannot be rejected for the aging time and the stain remover variables.

Analysis of the Consumer Panel Ratings

The purpose of the second hypothesis was to determine differences in the consumer ratings of stain removal as they related to the fabrics, the

Table 5

One-Way Analysis of Variance and Duncan's Multiple Range Test

For Instrumental Color Change Values by Stain Remover

Light Reflectance (ΔL)

Stain removers	Ammonia	Detergent-Vinegar	Alcohol	Perc.
Means	3.26	3.40	3.53	3.74
Subsets	A	A	A	A
DF = 3				
F-ratio = 0.66				

Green-Red (Δa)

Stain removers	Detergent-Vinegar	Ammonia	Alcohol	Perc.
Means	-1.62	-1.35	-1.03	-0.66
Subsets	A	A	A	A
DF = 3				
F-ratio = 0.93				

Blue-Yellow (Δb)

Stain removers	Ammonia	Detergent-Vinegar	Alcohol	Perc.
Means	0.68	0.69	0.85	1.11
Subsets	A	A	AB	B
DF = 3				
F-ratio = 2.55				

Total Color Change (ΔE)

Stain removers	Detergent-Vinegar	Ammonia	Alcohol	Perc.
Means	4.46	4.49	4.99	5.18
Subsets	A	A	A	A
DF = 3				
F-ratio = 0.94				

food stains, the aging times, and the stain removers. Multiclassification analysis of variance, one-way analyses of variance, and Duncan's multiple range tests were the statistics used to determine differences among the variables.

The results of the multiclassification analysis of variance are given in Table 6. The fabric, stain, and remover types had significant effects on the consumer ratings. The length of the aging time showed no effect. The two-way interactions that were significant included: fabric-stain, fabric-remover, stain-aging, and stain-remover.

The means, the degrees of freedom, and the F-ratios obtained through the one-way analyses of variance are given in Table 7. All of the variables produced significant differences in ratings. The rayon fabric was rated significantly lower than the nylon and olefin fabrics which were not significantly different. For the stain variable, the syrup received the lowest ratings, while the control specimens received the highest ratings. The mustard, milk, and oil stained specimens were in between and were not significantly different. According to the one-way analysis of variance, the specimens aged two weeks had a significantly lower mean than the specimens aged for one day. The stain removers were divided into two significantly different groups by the Duncan's multiple range test. The group with the lowest average consumer ratings consisted of perchloroethylene and isopropyl alcohol. The alcohol was also in the group with the higher means, along with ammonia water, and detergent-vinegar solution.

Table 6

Multiclassification Analysis of Variance

for Consumer Panel Evaluations

	Consumer Rating	
	DF	F-ratio
Main Effects		
Fabric	2	128.96**
Stain	3	15.43**
Aging time	1	0.00
Remover	3	13.21**
Two-Way Interactions		
Fabric-stain	6	6.74**
Fabric-aging	2	1.63
Fabric-remover	6	18.47**
Stain-aging	3	3.26*
Stain-remover	9	8.86**
Aging-remover	3	0.43
Multiple R^2 = 0.410		

*Significant at the 0.05 level.

**Significant at the 0.01 level.

Table 7

One-Way Analysis of Variance and Duncan's Multiple Range Test

For Consumer Panel Evaluations

Fabrics	Rayon	Nylon	Olefin
Means	2.26	3.09	3.29
Subsets	A	B	B
DF = 2			
F-ration = 53.25**			

Stains	Syrup	Mustard	Milk	Oil	Controls
Means	2.42	2.84	2.85	2.94	3.83
Subsets	A	B	B	B	C
DF = 4					
F-ratio = 18.45**					

Aging Times	Two Weeks	One Day
Means	2.76	2.97
DF = 1		
F-ratio = 4.55*		

Stain Removers	Perc.	Alcohol	Ammonia	Detergent-Vinegar
Means	2.64	2.86	2.99	3.04
Subsets	A	AB	B	B
DF = 3				
F-ratio = 3.29*				

*Significant at the 0.05 level.

**Significant at the 0.01 level.

The second hypothesis was that no significant difference would exist in the values for stain removal assigned by the consumer evaluation panel as they related to: (a) the fabrics, (b) the stains, (c) the aging times, and (d) the stain removers. As a result of the statistical analyses associated with the consumer ratings, the second hypothesis must be rejected for all four of the independent variables.

Correlation of Consumer Evaluations with Instrumental Values of Color Change

The third hypothesis stated that no relationship would exist between the instrumental values for color change and the values for stain removal assigned by the consumer panel. Mean consumer ratings obtained from the three panel members are given in Table 8. The ratings were based on a one to five scale, where a score of one indicated the most change from the control, and a score of five indicated no change from the control.

The relationships between the consumer ratings and each of the instrumental color change values were determined by using a Pearson correlation. The correlation coefficients (r values) are given in Table 9. A significant relationship was apparent for the consumer ratings with ΔL, Δb, and ΔE. The consumer ratings did not correlate significantly with the Δa values. In addition, significant correlations existed for ΔL with Δb, ΔL with ΔE, Δa with Δb, and Δb with ΔE.

It should be noted that significant negative correlations were generated between the consumer ratings and instrumental values for color change. For the consumer evaluations, a high rating represented a low

Table 8

Mean Consumer Ratings

According to the AATCC Stain Release Replicas

Stain	Stain Remover	Aging Time	Fabric		
			Rayon	Nylon	Olefin
Mustard	Detergent-Vinegar	1 day	2.6	2.7	3.9
		2 weeks	2.7	2.2	3.2
	Perchloro-ethylene	1 day	2.2	3.2	2.9
		2 weeks	1.8	2.3	2.4
	Alcohol	1 day	2.2	3.3	3.5
		2 weeks	2.4	3.1	3.6
	Ammonia	1 day	2.1	2.9	3.5
		2 weeks	2.6	3.2	3.7
Oil	Detergent-Vinegar	1 day	1.7	3.2	3.6
		2 weeks	1.8	3.2	4.2
	Perchloro-ethylene	1 day	1.8	4.0	2.8
		2 weeks	2.8	4.1	3.2
	Alcohol	1 day	1.5	3.3	3.4
		2 weeks	2.1	2.8	3.8
	Ammonia	1 day	1.9	3.1	3.4
		2 weeks	2.2	2.6	4.0
Milk	Detergent-Vinegar	1 day	2.4	3.3	3.6
		2 weeks	2.6	3.4	3.7
	Perchloro-ethylene	1 day	2.4	3.7	2.3
		2 weeks	2.6	3.8	1.9
	Alcohol	1 day	3.1	2.9	3.1
		2 weeks	2.5	2.8	2.8
	Ammonia	1 day	2.3	2.2	3.1
		2 weeks	2.9	2.3	3.4

Table 8

(Continued)

Stain	Stain Remover	Aging Time	Fabric		
			Rayon	Nylon	Olefin
Syrup	Detergent-Vinegar	1 day	2.6	2.9	3.7
		2 weeks	2.0	2.4	3.8
	Perchloro-ethylene	1 day	1.0	2.1	1.2
		2 weeks	1.0	2.8	1.0
	Alcohol	1 day	1.6	2.7	3.4
		2 weeks	1.1	2.7	2.8
	Ammonia	1 day	2.2	3.1	3.9
		2 weeks	1.4	2.8	3.9
Controls	Detergent-Vinegar	______	3.2	3.7	3.9
	Perchloro-ethylene	______	3.9	4.6	3.4
	Alcohol	______	3.2	3.9	4.3
	Ammonia	______	3.8	3.8	4.2

Table 9

Correlations Between Consumer Evaluations

And Instrumental Color Change Values

Variables	r Values
ΔL and Δa	0.01
ΔL and Δb	0.54**
ΔL and ΔE	0.80**
ΔL and Consumer ratings	-0.34**
Δa and Δb	0.60**
Δa and ΔE	-0.02
Δa and Consumer ratings	0.03
Δb and ΔE	0.52**
Δb and Consumer ratings	-0.24**
ΔE and Consumer ratings	-0.48**

**Significant at the 0.01 level.

degree of color change. However, a larger number for the instrumental values indicated a high degree of color change. The correlations were negative because of the inverse nature of the two measures.

The results of the Pearson correlation must be considered in the decision of whether or not the third hypothesis should be rejected. Since three out of four of the instrumental values of color change correlated significantly with the consumer rating of stain removal, this hypothesis has been rejected.

Chapter VI

SUMMARY AND CONCLUSIONS

The objectives of this research were to quantitatively apply food stains on a rayon, a nylon, and an olefin pile upholstery fabric; and to determine the effects of four cleaning agents and two aging times on their removal by measuring light reflectance and color values. Another objective was to compare and correlate the reflectance and the color values with ratings obtained from a consumer panel evaluation of the test specimens after cleaning.

Mustard, vegetable oil, milk, and syrup were the food stains applied from an eyedropper, then aged in controlled environmental conditions for one day or two weeks. The stain removers used included a mild detergent-vinegar solution, perchloroethylene, isopropyl alcohol, and ammonia water. A specified amount of the cleaning agents was applied from an eyedropper. Clean terry cloth squares were used with the cleaning agents as well as with the rinse water to remove the stains from the specimens.

The degree of soil removal was determined by light reflectance and color values measured on a Hunter Color-Difference Meter®. A consumer panel determined the degree of soil removal by rating the specimens according to AATCC Stain Release Replicas.

The following conclusions were reached after analyzing the data:

1. The fabric and the stain variables had a statistically significant effect on ΔL, Δa, Δb, and ΔE values. Other significant effects

included the length of the aging time on Δa, and the type of the remover on Δb.

2. The fabrics were significantly different. The rayon fabric changed color more than the nylon, which changed more than the olefin on ΔL and ΔE values. In addition, the rayon specimens changed significantly less than the nylon or the olefin on Δa values. The Δb values were significantly higher for the nylon fabric than for the olefin and rayon fabrics.

3. The stains were significantly different. The milk and mustard stains tended to have the least effect on the degree of soil removal, while the oil and syrup stains had a greater effect. The surprising result was that the controls did not exhibit the least amount of color change according to all four of the instrumental measures.

4. The aging times did not affect the instrumental color change values significantly, except Δa values were significantly smaller for the specimens aged one day than those aged two weeks.

5. The stain removers were not significantly different from each other on the instrumental color change values.

6. The fabric, stain, and remover variables had a significant effect on the ratings given by the consumer judges. The aging times exhibited no significant effect.

7. Rayon specimens were rated significantly lower by the consumers than the nylon or olefin ones. Nylon and olefin were not rated significantly different from each other.

8. The consumer judges gave the syrup stained specimens the lowest ratings, and rated the controls the highest. Those specimens stained with mustard, milk, or oil were in between and were not significantly different.

9. Although the multiclassification analysis of variance indicated that aging time did not affect the consumer ratings, the one-way analysis of variance showed that the specimens aged for one day were rated significantly higher than those aged for two weeks.

10. Specimens treated with perchloroethylene and isopropyl alcohol stain removers received the lowest consumer ratings and were not significantly different. In addition, the alochol did not differ significantly from ammonia water and detergent-vinegar solutions in affecting consumer ratings.

11. Significant correlations existed between the consumer ratings and ΔL, Δb, and ΔE values. The inverse nature of the correlations indicated that as the consumer ratings decreased the change in instrumental values increased. No significant correlation existed between the consumer ratings and Δa.

A wide variety of research projects similar to this one could be conducted. Different fabrics, stains, aging times, and stain removers could be used to gather more information on the staining of and the stain removal from upholstery fabrics. In addition, more research needs to be completed which relates laboratory testing to actual consumer acceptance and use.

REFERENCES

1. "The UFAC Report," Presented to the Consumer Product Safety Commission on July 15, 1976 by the Upholstered Furniture Action Council (1976).

2. Brown, T. M., and D. J. Morley, "Assessment of the Soiling Properties of Upholstery Fabrics," Textile Institute and Industry 9, No. 12, 344-348 (1971).

3. Furniture Flammability Committee, "Potential Flammability Hazards of Upholstered Furniture--Progress Report on Industrial Activities to the Consumer Product Safety Commission by the Furniture Flammability Committee" (1974).

4. Nichols, Barbara, and Rachel Dardis, "Consumer Satisfaction with Home Furnishings," Textile Chemist and Colorist 5, No. 10, 167-171 (1973).

5. Getchell, Nelson F., "Cotton Quality Study, Part III: Resistance to Soiling," Textile Research Journal 25, No. 2, 150-194 (1955).

6. Harabin, Doris, Edward Ostrander, and Evelyn Stout, "Properties of Textile Upholstery Fabrics and Their Importance to Consumer Satisfaction," A publication of the New York State College of Human Ecology, Cornell University (1973).

7. Smith, G. M., "What Do Our Laboratory Tests Tell Us?" Sources and Resources 10, No. 5, 28-29 (1977).

8. St. John, W., "A Suggested Consumer Product Standard Procedure," Sources and Resources 10, No. 5, 28-29 (1977).

9. Weatherburn, A. S., and C. H. Bayley, "The Soiling Characteristics of Textile Fibers, Part I," Textile Research Journal 25, No. 6, 549-558 (1955).

10. Kissa, Erik, "A Rapid and Reproducible Method for the Determination of Dry-Soil Resistance," Textile Research Journal 41, No. 7, 621-629 (1971).

11. Kissa, Erik, "Model Particulate Soils for Soil Resistance Evaluation," Textile Chemist and Colorist 5, No. 11, 249-54 (1973).

12. Reeves, Wilson, John Beninate, R. M. Perkins, and G. L. Drake, Jr., "Soiling and Soil Removal Studies on Cotton and Polyester Fabrics," American Dyestuff Reporter 57, No. 26, 35-38 (1968).

13. Wham, George, "Stain and Soil Release Finishes: Introductory Remarks," Modern Textiles 48, No. 12, 51-52 (1967).

14. Schick, M. J., editor, Surface Characteristics of Fibers and Textiles, Part II, New York: Marcel Dekker, (1977).

15. Venkatesh, G. M., N. E. Dweltz, G. L. Madan, and R. H. Alurkar, "A Study of the Soiling of Textiles and Development of Anti-Soiling and Soil Release Finishes: A Review," Textile Research Journal 44, No. 5, 352-362 (1974).

16. Kissa, Erik, "Adsorption of Particulate Solids on Textiles," Textile Research Journal 43, No. 2, 86-95 (1973).

17. Tripp, Verne, Anna Moore, Blanche Porter, and Mary Rollins, "The Surface of Cotton Fibers, Part IV: Distribution of Dry Soil," Textile Research Journal 28, No. 6, 447-452 (1958).

18. Porter, Blanche, Charles Peacock, Verne Tripp, and Mary Rollins, "The Surface of the Cotton Fiber, Part III: Effects of Modification on Soil Resistance," Textile Research Journal 27, No. 11, 833-845 (1957).

19. Sudnik, Z. M., "Practical Approach to Quality Testing of Upholstery Fabrics," Journal of the Textile Institute 52, No. 10, T442-T463 (1961).

20. Weatherburn, A. S. and C. H. Bayley, "The Soiling Characteristics of Textile Fibers, Part II: The Influence of Fiber Geometry on Soil Retention," Textile Research Journal 27, No. 3, 199-208 (1957).

21. Compton, Jack, and W. J. Hart, "Soiling and Soil Retention in Textile Fibers: Cotton Fiber--Grease-Free Carbon Black Systems," Industrial and Engineering Chemistry 43, No. 7, 1564-1569 (1951).

22. Kissa, Erik, "A Reproducible Method for the Evaluation of Soil Release," Textile Chemist and Colorist 3, No. 10, 49-55 (1971).

23. Rees, Howard, "A Study of the Optics of Soiling of Textile Materials Using Artificial-Soil Techniques," Journal of the Textile Institute 53, No. 5, T230-T247 (1962).

24. Berch, Julian, Henry Peper, and Joanne Ross, "Laboratory Method of Measuring the Dry Soilability of Fabrics," American Dyestuff Reporter 56, No. 6, 27-31 (1967).

25. Sontag, Suzanne, Mary Purchase, and B. F. Smith, "Changes in Appearance of Cotton and Polyester Fabrics," Journal of Home Economics 62, No. 4, 251-256 (1970).

26. Matson, T. P., and M. A. Johnson, "A Wet Method for Pure Particulate Soiling of Test Cloths for Detergency Screening Tests," Journal of the American Oil Chemists Society 53, No. 5, 218-219 (1976).

27. Duffield, Frances Jean, "The Effects of Soiling and Subsequent Cleaning on the Flammability of Acrylic, Nylon, Polypropylene, and Wool Carpet Fibers," An unpublished master's thesis from Virginia Polytechnic Institute and State University (1969).

28. Hicks, Jacquelyn S., "The Quantitative Application of Oily and Particulate Soils and Their Effects on the Flammability of Rayon, Nylon, and Olefin Upholstery Fabrics," An unpublished master's thesis from Virginia Polytechnic Institute and State University (1979).

29. Dehnbostel, Mary Lynne, "The Quantitative Application of Mineral Oil and Its Effect on the Flammability of Polyester and Acetate/Polyester Flame Retardant Fabrics Used for Women's Nightgowns," An unpublished master's thesis from Virginia Polytechnic Institute and State University (1978).

30. Remsberg, Sara Catherine, "The Effects of Laundry Conditions on the Removal of Quantitatively Applied Soils from White Cotton and Polyester Fabrics," An unpublished master's thesis from Virginia Polytechnic Institute and State University (1981).

31. Wright, Kirsten Joanne, "The Effects of Laundering Conditions on the Removal of Quantitatively Applied Oily and Particulate Soils from Dyed 100 Percent Cotton and 100 Percent Polyester Fabrics," An unpublished master's thesis from Virginia Polytechnic Institute and State University (1981).

32. Byrne, G. A., "Wet-Soiling Behaviour of Textiles," Journal of the Society of Dyers and Colourists 88, No. 2, 64-68 (1972).

33. Kissa, Erik, "Kinetics and Mechanisms of Detergency, Part III: Effect of Soiling Conditions on Particulate Soil Detergency," Textile Research Journal 49, No. 7, 384-388 (1979).

34. Kissa, Erik, "Kinetics and Mechanisms of Detergency, Part I: Liquid Hydrophobic (Oily) Soils," Textile Research Journal 45, No. 10, 736-741 (1975).

35. Fort, Tomlinson, Jr., H. R. Billica, and T. H. Grindstaff, "Studies of Soiling and Detergency, Part II: Detergency Experiments with Model Fatty Soils," Textile Research Journal 36, No. 2, 99-112 (1966).

36. Ranney, M. W., Soil Resistant Textiles, Park Ridge, New Jersey: Noyes Data, (1970).

37. Grajeck, E. J., and W. H. Petersen, "Oil and Water Repellent Fluorochemical Finishes for Cotton," Textile Research Journal 32, No. 4, 320 (1962).

38. Hunterlab Model D25 Color and Color-Difference Meter Instruction Manual (Fairfax, Virginia: Hunter Associates Laboratory, Inc.).

APPENDIX

PANEL EVALUATION

Sample Number __________

Staining Score (1.0 - 5.0) __________

Would the change in the sample from the original fabric be acceptable to you on a chair in your living room?

Yes _____ No _____

If no, is it because of:

- deformed pile _____
- remaining stain _____
- both _____

The vita has been removed from the scanned document

THE EFFECTS OF COMMON HOUSEHOLD CLEANING AGENTS
AND AGING ON THE REMOVAL OF QUANTITATIVELY APPLIED
FOOD STAINS FROM RAYON, NYLON, AND OLEFIN
PILE UPHOLSTERY FABRICS

by

Brenda Hess Hofbauer

(ABSTRACT)

The objectives of this research were to quantitatively apply food stains to a rayon, a nylon, and an olefin pile upholstery fabric, and to determine the effects of aging times and cleaning agents on their removal. Another objective was to correlate the instrumental color change measurements with ratings obtained from a consumer panel.

The specimens were soiled with mustard, vegetable oil, milk, and syrup. After aging for one day or two weeks, the specimens were treated for stain removal with a detergent-vinegar solution, perchloroethylene, isopropyl alcohol, or ammonia water while attached to a simulated chair arm.

Soil removal was evaluated by measuring light reflectance and color values on a Hunter Color-Difference Meter®. A consumer panel rated the specimens according to AATCC Stain Release Replicas, and stated whether or not each specimen was acceptable for use in their homes.

Statistical analyses indicated the following major conclusions: (1) the fabric and stain variables significantly affected the instrumental values of color change; (2) the variables exhibiting a significant effect on the consumer ratings were fabric, stain, and stain remover; (3) the rayon fabric tended to react the most unfavorably of the three fabrics to the treatment; (4) the milk and mustard stains tended to be the most easily removed, while the oil and the syrup stains were more difficult; and (5) a correlation existed between instrumental values and consumer ratings of color change.