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The major purpose of this study was to investigate the effects of a durable press finish upon strength and wrinkle recovery characteristics of selected cotton sheetings following a series of launderings. The objectives were (1) to compare the breaking strength, tear resistance, and wrinkle recovery of durable press treated sheetings with similar sheetings having no durable press treatment, and (2) to determine whether differences in treatment are reflected in the performance of cottons of varying fiber length and fiber strength used in the sheetings.

The ravelled strip method was used to test breaking strength, the Elmendorf test was used for tear resistance, and the Monsanto method was used for wrinkle recovery. All testing procedures were conducted according to specifications set by the American Society for Testing and Materials.

There was a highly significant difference between treated and untreated sheetings for the three tests conducted. The greatest amount of difference occurred in the initial testing period.

There were highly significant differences in the data for breaking strength and tear resistance tests of long and short staple fibers in treated and untreated fabrics. No significant differences between long and short staple fibers were noted for wrinkle recovery. No significant differences occurred in low and high strength fibers for any of the tests.

THE EFFECTS OF A SELECTED DURABLE PRESS FINISH UPON COTTON SHEETINGS

OF SELECTED FIBER CHARACTERISTICS

by

Linda Dick McFarland

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APPROVAL SHEET

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CHAPTER I

INTRODUCTION

Background of the Problem

One of the outstanding textile achievements of the decade has been the application of durable press finishes to apparel and home furnishing fabrics. These finishes were originally intended for use on cotton fabrics in order to maintain a neater appearance and provide ease of care characteristics. Since the crosslinking chemicals necessary to produce durable press qualities tend to weaken cellulose fibers, the finishing treatment has proven more satisfactory when applied to blends of cellulose and man-made fibers. "The hydrophobic polyester provides inherent toughness, a degree of resiliency, lightness in weight, and preservation of shape in a humid atmosphere."[1] However, interest in durable press finishes for all-cotton fabrics has continued because of their outstanding properties of ease of care, comfort, and pleasing texture.

The development of non-damaging finishes which might be applied to all-cotton fabrics would have a great potential to the manufacturers of home furnishing fabrics. Such finishes that would prove satisfactory in use would be helpful in maintaining the status of cotton in the textile market.

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[1]Suchecki, Stanley M. "Durable Press," Textile Industries, 129: 124, January, 1965.

Statement of the Problem

The major purpose of this study was to investigate the effects of a durable press finish upon strength and wrinkle recovery characteristics of selected cotton sheetings following a series of launderings. The effect of the finish upon certain properties of the fibers used in making the sheetings was also of interest.

The objectives of this study were:

1. To compare the selected performance characteristics (breaking strength, tear resistance, and wrinkle recovery) of durable press treated cotton sheetings with similar sheetings having no durable press treatment.

2. To determine by means of breaking strength, tear resistance, and wrinkle recovery whether the differences in treatment are reflected in the performance of cottons of varying properties of length and strength.

Description of Materials Used for Experimentation

The sheetings used were those manufactured specifically for the textile research project undertaken by the Home Economics Research personnel of six southern states as Regional Research Project SM-18.[2] This project was sponsored by the United States Department of Agriculture in order to determine the relation of fiber properties to end-product performance.

For the regional study eight bales of cotton differing in fiber length and fiber strength were selected and made into sheeting of 140 type muslin at Clemson University for sheets of single bed size.

[2]Technical Committee Project SM-18, "The Relation of Fiber Properties to End-Product Performance," (Manual of Procedures, Southern Regional Research Project SM-18).

This study is a contribution to SM-18. Four types of cottons were selected from the eight bales used in the original study. These represented two levels of length and two levels of strength. This total of 96 sheets was treated with a durable press finish recommended by a manufacturer of chemical finishing materials and applied by personnel of the School of Textiles at North Carolina State University. Half of the samples were laundered at The University of North Carolina at Greensboro and the remaining 48 sent to Oklahoma for laundering. Data reported in this study apply only to those sheets laundered at the North Carolina station.

Data were compared with the results of tests applied to the same types of sheeting which received no durable press finish. The sampling plan and tests were identical for both durable press treated sheets and untreated sheets. A control group, O, was not laundered. The remaining sheets were grouped according to specific intervals of 5, 15, 30, 45, and 60 launderings. At the end of each interval, sheets were removed for testing.

CHAPTER II

REVIEW OF THE LITERATURE

Development of Durable Press Finishes

Since the mid-fifties and the introduction of "wash and wear" fabrics, American consumers have been awaiting the arrival of such fabrics in reality. The innovation of wash and wear, which was over-advertised and under-tested, was grossly disappointing. Homemakers found that these fabrics which had been so favorably recommended by manufacturers and retailers still needed "touch-ups," if not an all-over pressing. Also, when washed, the garments lost their sharp creases.

A recently developed process which fulfills many of the hopes for wash and wear and is a logical extension of it, is known as durable press. Durable press, or permanent press, is defined as the "ability of a garment to keep its shape-retaining properties throughout its life. This means sharp creases, flat seams, and smooth appearance after washing or wearing."[1] The basic idea for durable press was proposed by J. David Reid and his associates at the Southern Regional Research Laboratory in 1956.[2] The most significant feature of this finish in

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[1]Claude M. Lee, "The Role of Synthetic Fibers in Durable Press Fabrics and Garments," Modern Textiles 46:46, September, 1965.

[2]J. David Reid, "Durable Press," Textile Industries 129:121, January, 1965.

addition to its permanent press is its no-care characteristics. Its goal is maximum wash and wear with minimum change in tensile strength and abrasion resistance.[3]

Permanent press resins were first introduced late in 1964. One year later, there was 150 per cent increase in the use of resins, or an increase from five million to 13 million pounds.[4] The permanent press concept was first applied to work pants and casual clothes for men. A durable press finish was used in 95 per cent of the 165 million pairs of trousers made in the United States in 1965. Durable press shirts were then introduced and were improved as manufacturers learned better sewing techniques and began to use cloth with high wrinkle recovery angles. After being used successfully in men's clothing, durable press finishes were then used in women's blouses and slacks and children's play clothes, where knits were once preferred for ease of care.[5] Permanent press is giving not only the advantage of permanent creases, but also freedom for the homemaker from having to iron most of her family's washable clothes.[6] Tablecloths and napkins, curtains, bedsheets, pillowcases, slipcovers, draperies, and shower curtains are also being promoted for use by busy homemakers and their families.[7]

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[3] Ernest J. Chorneyei, "Permanent Press Means Industry Profits," Modern Textiles 46:44, August, 1965.

[4] "Fiber Growth Presages Textile Chemical Surge," Chemical and Engineering News 43:30-31, October-December, 1965.

[5] Good Housekeeping Guide to Durable Press - 1965.

[6] A. H. McCullough, "Durable Press--The Promise and the Problems," Modern Textiles 46:16, August, 1965.

[7] Good Housekeeping Guide to Durable Press, op. cit.

The Chemical Processes

Four specific expectations for durable press were cited by G. I. Hollings in 1966. These were:

1) The ability to hold both during washing and wearing creases or pleats previously pressed into the garment by maker-up,

2) The ability to shed casual wrinkles occurring during washing and wearing ;

3) The ability to retain exactly its shape and appearance after washing, so that given reasonable care during washing, it will not require subsequent ironing;

4) Sufficient strength and resistance to abrasion to stand up to the rigours of every-day wear and frequent washing to the satisfaction of the consumer.[8]

The chemical process which is responsible for permanent press is crosslinking. Crosslinking takes place between cotton fibers in such a way that the cotton molecules are connected by a bifunctional reagent "which bridges two cellulose molecules by the reaction of each of its functional groups with a hydroxyl on the cellulose chain."[9] At the same time that the bonds are forming between the hydroxyl groups, a polymerizing reaction is also taking place. When both of these reactions are complete, the fabric or garment is said to be cured.[10] Curing can mean any insolubilization between polymers, polymers and fibers, or reactions to fibers.[11]

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[8] G. I. Hollings, "Permanent Press on Cellulose and Cellulose/ Synthetic Blended Fabrics," Textile Institute and Industries 4:326, November, 1966.

[9] "Semicure Gives Cotton Permanent Press," Chemical and Engineering News 43:88, October-December, 1965.

[10] Reid, op. cit., p. 122.

[11] Sydney M. Cone, Jr., "A Long Look at Newest Extension of Wash and Wear," Modern Textiles 46:40, August, 1965.

Pensa and others described the chemical state necessary for curing.

> The setting of cellulose fabrics requires the presence of a reactive chemical system on fabrics during the heating or curing step. The reactive chemical system can be, for example, a completely unreacted catalyzed reagent formulation, as in the case of the single step deferred cure process, or can be a crosslinking agent completely reacted in a swollen state, in conjunction with an appropriate activator, as in the case of the wet-reacted sulfone process.[12]

Permanent press treatments differ in chemical composition. The preferred resin in 1966 was dimethyl dihydroxy ethylene urea, DDEU. This resin was favored because it remained almost completely inactive for at least three months, so that spontaneous or shelf curing did not occur during storage. Also scarcely any tendency was noticed toward developing offensive odors. After being stored, the fabric could then be cured at 330 degrees for several minutes. However, this particular resin is satisfactory only for colored fabrics, because it has little resistance to commercial chlorination. Dimethyl propylene urea has been found satisfactory for white fabrics. It has all the advantages of DDEU, plus stability to chlorine.[13]

Other systems of resin treatment for deferred cure have been ruled out by manufacturers mostly because of an obnoxious odor. The fishy odor and the speed of cure of urea formaldehyde monomers and melamines make them unsatisfactory finishes. Carbamates and acetals

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[12] I. E. Pensa, G. C. Tesoro, R. O. Rau, and P. H. Egrie, "Two-Stage Curing in Crosslinking of Cellulosic Fabrics," _Textile Research Journal_ 36:279, March, 1966.

[13] Edward N. Alexander, "Deferred Cure Process for Durable Press," _American Dyestuff Reporter_ 55:60, August 1, 1966.

create excess free formaldehyde which yields an unpleasant odor.[14] Carbamates, however, do launder well commercially because of their outstanding resistance to chlorine and to hydrolysis in the souring operation. Most triazones have a fishy odor. Sulfonyl diethanol tends to yellow, and is toxic without an afterwash. Epoxy reactants give poor wrinkle recovery.[15]

The most effective catalysts are metal salts, such as magnesium chloride, zinc chloride, and zinc nitrate. These are delayed action catalysts and yield acid only at elevated temperatures.[16] Activators are cellulose swelling agents which permit crosslinking of cellulose in an unusually open position for improved wash and wear characteristics, and easier creasing. An activator overcomes resistance of tightly packed cellulose molecules to resin monomers and permits the best possible position of crosslinks for good wrinkle recovery. Activators function during catalysis of the crosslinking reaction. A typical formula for durable press application is:[17]

20% resin monomer
5% acrylate polymer
4% catalyst
4% softener
8% Activator 247

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[14]Robert W. Pinault, "The Durable Press Race: Can All-Cotton Stage a Comeback?" Textile World 116:85, June, 1966.

[15]Alexander, op. cit., p. 604.

[16]Ibid., p. 604.

[17]Ibid., p. 604.

The most satisfactory type of finish for a blended fabric should adhere to both the cotton and the man-made fibers to serve the dual purpose of protecting the cotton fibers and building fabric hand.[18] "It can be stated, in fact, that the full potential of durable press will not be realized until a resin or other means is found to avoid this severe loss of the cotton fiber character."[19] Binders and finishes can protect the cotton fiber by forming a coating that resists abrasion. The best materials for this are the newer reactive acrylate polymers that form a tridimensional crosslinked system by reacting with the thermosetting component itself.[20]

Methods of Curing Fabric

Five methods of curing have been in use since 1965.[21] The conventional crease-resistant or pre-cure is accomplished on the flat fabric and consists of a pad-dry-cure-afterwash process. Both the crosslinking of hydroxyl groups and the polymerization of monomeric resins occur. The final hot press at higher-than-normal temperatures after the garment is completed finishes the crosslinking and sets the creases.

A second method is the deferred cure, which takes place after the garment is made. The oven temperature is 350 degrees and the curing time is five minutes. The fabric is impregnated with chemicals, dried,

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[18] Ibid., p. 605 [19] Ibid., p. 604 [20] Ibid., p. 605.

[21] Stanley M. Suchecki, "DP" Textile Industries 129:128 January, 1965.

then cut, sewn, pressed, and cured.[22] A deferred cure process, Koratron, is the property of Koret of California, a sportswear firm. The process is highly successful, mainly because quality standards have been established for the project. The process is patented and available only under a license agreement between the Koratron Company and finishing plants. "Koratron restricts the speed of padding and keeps temperatures of drying below the level at which resin would begin to polymerize or to crosslink."[23] Fred Fortess and Robert Stultz have drawn distinctions between pre-curing and delayed curing as primarily those of the difference in chemicals being used and the quantity of chemical finishes being applied to fabrics. A fabric with either type of finish, after construction of the garment, is pressed on hot-head presses, but the delayed-cured garments are then cured.[24]

The J. P. Stevens Company has devised a deferred cure which they call Stevens' Super-Crease S. Reactive sulfones are used for crosslinking rather than resins. All the major changes in fabric properties happen in the finishing plant except dry crease recovery.[25] This process benefits the manufacturer in two ways. By reducing the final oven curing time, higher production rates and increased fabric storage stability result. Also, the fabric may be washed before the final cure so a cleaner product results.[26]

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[22] A Definitive Guide to Permanent Press--Technology, Procedures, End-Uses, Celanese Fibers Marketing Company. P. 15.

[23] Cone, op. cit., p. 41.

[24] Fred Fortess and Robert Stultz, "Contributions of Polyester Fibers," Modern Textiles 46:49-50, August, 1965.

[25] Suchecki, op. cit., p. 129.

[26] Chemical and Engineering News, op. cit., p. 90.

Another process, known as high-energy setting, was originated at Everprest, Incorporated. An extremely efficient method, Everprest processing takes only 15 to 20 seconds. A fully cured resin-treated fabric is cut and sewn into a garment and then pressed. The stability before cutting, and alleviation of oven-curing are advantages of this procedure; however, high-energy setting necessitates a controlled and electrically heated press, which can give the necessary high temperatures needed for this "pressure curing" process.[27]

The Williamson-Dickie process or garment treatment is another type of treatment in which the untreated fabric is sewn into a garment. The garment then is immersed into a resin mixture, steamed, pressed, dried, and creased, and then cured.[28] The impregnating liquor is formulated with ingredients to impart softness, improve tear strength and sewability, and add body.[29]

Two other methods have been found to be of commercial value. These are the re-cure and no-cure systems. The re-cure system allows some of the crosslinks to be broken in the presence of steam while pressing the garment. No problems with odor or limited shelf life have been encountered. The no-cure process makes use of thermoplastic fibers, usually polyester/acrylic, polyester/nylon, or 100 per cent polyester.[30] These fibers are easily heat-set to shape so that no chemicals are necessary.

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[27] Suchecki, op. cit., p. 129.

[28] Ibid., p. 129.

[29] Ibid., p. 132.

[30] A Definitive Guide to Permanent Press, op. cit., p. 17.

Problems Encountered with Durable Press

Despite the obvious success of durable press, it does still have a number of shortcomings. The most significant problem which has arisen with 100 per cent cotton fabrics is the weakening of the fibers by crosslinking. The tensile properties of resin-treated fabrics are affected by pretreatment, resin add-on, and strain applied during treatment processes.[31]

"The reduction of fiber toughness is produced by the lowering of fiber extensibility as the result of crosslinking cellulose molecules. A linear relationship exists between tear resistance and fiber toughness."[32] At a resin pick-up of six per cent, crosslinked all-cellulose fabrics show a 50 per cent reduction in abrasion resistance and tear strength.[33] The first durable press garments were made of all-cotton fabrics of heavy weight, about 11 ounces per square yard. The results obtained were encouraging. However, when the same finish was applied to a lighter weight all-cotton fabric, manufacturers were not so pleased.[34] The abrasion resistance and fabric strength were affected by the high concentration of chemicals and high temperatures necessary for durable press.

Another source of many complaints was the unpleasant odor of some treated materials. Most of these objections were alleviated

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[31]Joseph M. Grant, Rollin S. Orr, Ruby H. Tsoi, and Louis C. Weiss. "Strain Recovery Properties of Wash and Wear Cotton Fabrics," Textile Research Journal 36:642, January, 1966.

[32]F. B. Shippee, and D. D. Gagliardi, "Differential Distribution of Crosslinking Agents in Cotton Fabrics," Textile Research Journal 36:177, February, 1966.

[33]Cone, op. cit., p. 40

[34]Fortess, op. cit., p. 50.

either by an after-wash at the mill for pre-cured fabrics, or by the use of sulfones or imidazolidone for post-cureds.[35] This problem of odor was mainly one inherent to resin finishes. However, finishes which released formaldehyde during storage also had an objectionable odor. Generally, if the odor was still present when the garment was purchased, it would be eliminated with the first laundering. Although several finishes have recently been developed which claim to minimize the problem, odor still remains a live issue.

The yellowing of fabrics was noticed when men's white dress shirts began to be included in the durable press process. If this complication did not show up in curing, then it was likely to arise when the shirt was sent to a commercial laundry. Many of the finishes were not resistant to acid hydrolysis and chlorine bleach used by laundries, so they might not only yellow, but, if sent several times, would soon lose their durable press characteristics.[36] Use of carbamates is expanding, particularly on white goods, because of their high durability to both acidic and alkaline conditions, including chlorine.[37]

Progress in the Treatment of Cotton Fabrics

Although the problems encountered with 100 per cent cotton fabrics were considerable, research has been continued by the National

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35 A Definitive Guide to Permanent Press, op. cit., p. 4.

36 Stultz, op. cit., pp. 48-50.

37 Frick, J. G., Jr. "Crosslinking Finishes for Cellulosic Fabrics," American Dyestuff Reporter 56:586, August 28, 1967.

Cotton Council and the Southern Regional Research Laboratories. Murray Wyche reported the development of a two-step process by the Cotton Finishing Laboratory at the Southern Utilization Research and Development Division, SURDD. A plastic material is chemically linked into the cotton fiber, so that the fabric feels, drapes, and looks like untreated cotton. Methylol crosslinking agents are deposited on and in cotton for polymer formation, then a latent acid catalyst causes covalent crosslinking.[38] Strength and wrinkle-resistance are imparted by this method, which is called the polyset process.

The Cotton Finishing Laboratory at SURDD also has studied the effects of wear on treated summer-weight fabrics of cotton, mainly through the use of electron microscopy. Both the weave and thread count have been found to have a significant effect on fabric wear. A plain weave and higher thread count result in faster wear. Material of finer yarns wears faster than cloth woven of coarse yarns of a comparable weight and weave. Yarn twist has no appreciable effect. Louis A. Fiori, of the Cotton Mechanics Laboratory, in testing the importance of fiber properties to yarn and end breakage in spinning, has found that fiber strength contributes most to yarn strength. In addition, he finds fiber length most conducive to end breakage.[39]

The work with all-cotton fabric at SURDD includes polymer coating of fibers, blending of treated and untreated cotton, differential crosslinking, attaching side groups, change of fabric structure, and

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[38] Dr. Joseph H. Dusenbury, Machine Washability with Durable Press for Wool: The Challenge and the Achievement. Paper presented at Textiles Seminar, The University of North Carolina at Greensboro, June 13, 1967.

[39] "New Durable Press Process Adds Strength to Cottons," Daily News Record, Monday, May 1, 1967, pp. 1, 18.

change in stretch and elongation by slack mercerization and by mechanical means. Also being tested is the use of high tenacity yarns and fabrics, the use of reactive sulfones, the changes in crosslinking to improve abrasion resistance, and combinations of these methods. According to Reid, polymer addition holds possibilities for further investigation.[40] Urethane polymers "provide better abrasion resistance and tensile strength, a more durable finish with improved dimensional stability, and some improved wrinkle resistance."[41] These urethanes are available as water dispersions of high-molecular-weight urethane copolymers, which form strong elastic fibers when dried and heat fused at high temperatures. Urethanes are used in pre-treatment because they are unstable in the presence of acid catalysts generally used in cross-linking resin formations. Two problems have been noted with this treatment, however. Yarn bonding, which restricts the yarns, causing undue strain in one area, and yellowing have been noted.[42] Polyethylene gives a good hand, tear strength, and appearance, but contributes little to abrasion resistance. Films such as tough polymers, and silicones can help in this respect. The polymers apparently form crosslinkages with themselves to form a flexible coating which is wrinkle-resistant.[43]

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[40] J. David Reid, "Status and Further Developments in Durable Press," American Dyestuff Reporter 56:43, May 22, 1967.

[41] Eugene J. Blanchard, Robert J. Harper, Jr., Gloria A. Gautreaux, J. David Reid, "Urethanes Improve All-Cotton Durable Press," Textile Industries 131:116, January, 1967.

[42] Ibid., pp. 122, 143.

[43] Reid., op. cit., p. 48.

A number of suggestions for better quality cotton durable press were published in 1966. These recommendations included: better information on the correct temperature and time for curing, polymeric surface treatments such as polyvinyl acetate, acrylic, nitrile, styrene-butadiene polymers as binders, and silicones and polyethylene as lubricants.[44] This last method is relatively cheap, easy to apply, and helpful in preventing both fiber damage and removal, through binding fibers within the yarn and lubricating fiber surfaces.

A development which would benefit durable press cotton is differential crosslinking--treating parts of the fabric differently, sometimes with two different finishes. Selected areas of the fiber, yarn, or fabric structure are kept free of crosslinkages, or low cross-link density is imparted to some areas, and high density to others. Having a two-component system would yield improved wrinkle recovery and maintain fiber toughness and high extensibility. This process was proposed by Dr. Leonard Smith of the National Cotton Council.[45]

The two methods of differential crosslinking are back coating and catalyst inactivation. In back coating, the fabric is coated with a viscous solution which contains a crosslinking agent, catalyst, and auxiliary finishing agents. The catalyst inactivation consists of a resin formation mechanically padded on the fabric and one or both sides

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[44] Wilson A. Reeves, Albert S. Cooper, Jr., William G. Sloan, and Robert J. Harper, Jr., "All-Cotton Fabrics for Durable Press," Textile Industries 129:74-78, October, 1965.

[45] Shippee and Gagliardi, op. cit., p. 79.

of the fabric treated with the catalyst inactivator. Mercerizing, stretching, or otherwise changing the fabric structure improves abrasion resistance.[46]

Grafting polymers onto cotton to build polymer structures into the fiber, by both the vapor and liquid phases, is used. In vapor phase technology, the cloth can be pre-treated for later application of vapor-phase chemicals, or the entire process can be carried out as a post-cure in the presence of gaseous formaldehyde. Low curing temperatures, flexibility in application, and low cost are advantages of this process, and result in high abrasion resistance and crease recovery.[47]

A gamma ray curing process for deferred cured garments was developed at the Virginia Research Association. It was found to be highly satisfactory since it only takes eight seconds of oven-curing time, rather than the usual 15 minutes.[48]

A double-curing process, to increase the strength of durable press cotton, permits the use of almost any wash and wear curing system, rather than conventional delayed cure methods dependent on resin stability. This procedure consists of adding inert material to the fiber by means of a crosslinking agent. Then, the first agent is washed out, a new catalyst is added, and a second curing is carried out.[49]

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[46]Reeves et al, op. cit., p. 86.

[47]Stanley M. Suchecki, "Durable Press: Phase II," Textile Industries 130:167-80, 87. April, 1966.

[48]"Gamma Ray Process for Deferred Cure," Daily News Record, September 17, 1966.

[49]Reid, op. cit., p. 48.

Wet fixation is another means of improving strength of treated cotton by swelling the fiber structure and polymerizing a resin monomer within the fiber. This process is analogous to the dyeing process and occurs in two stages: wetting out and swelling of fibers, and diffusion and fixation of dye. The wetting out and swelling are achieved with water. Then the resin monomer diffusing to internal fiber sites containing hydrogen ions starts to polymerize and so is immobilized or fixed into position. The altered mechanical properties of wet-fixed cotton systems suggest that the resin polymer present in the fibers is responsible for improved strength and resilience. Apparently, penetration of resin into cotton is so deep and intimate that a new cellulose-polymer substance is formed with fewer weak points at which break under strain can occur.[50]

In spite of the problems of durable press cotton cited in the literature some advantages of using cotton are pointed out in the report of the Technical Advisory Committee of the American Apparel Manufacturing Association in 1966. First of all, durable press is dependent on cotton for its permanent set which makes maintenance of shape and creases possible. All-cotton durable press has the advantages of not requiring any special care in laundering, drying, or handling. Blends, on the other hand, do need special attention. Cotton can be tumble-dried, spin-dried, or line-dried, and give superior performance in

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[50] Norman R. S. Hollies, "Wet-Fixation Durable Press Process-Polymer Deposition," Textile Research Journal 37:280, April, 1967

laundering. Cotton is resistant to pilling. Also, cotton presents fewer problems with cutting, sewing, and pressing, and is cheaper to produce than blended fabrics.[51]

Summary

Durable press, in spite of its shortcomings, is an established process, most producers believe. As products become increasingly better, homemakers will demand uniformity of quality in garments. Continued research will be necessary to produce the desired durable press characteristics in cotton fabric while maintaining its strength and comfort to the wearer.

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[51]"All-Cotton DP Products Offer 10 Plus Values," Cotton Research Notes 4:1-8, April, 1966.

CHAPTER III

PROCEDURE

This study was a supplement to Phase II of the Southern Regional Research Project SM-18. The purpose of the project was to investigate the relation of fiber properties to end-product performance of fabrics made from selected types of cotton. The object of study for Phase I was the property of fiber elongation. The properties of length and strength were studied in Phase II.

This study was conducted to determine the effect of a durable press finish on laundering characteristics of cotton sheeting, and to discover if fiber properties of length and strength have any influence upon performance characteristics of durable press finished sheeting.

Sampling Plan

The untreated sheets reported in this study were a part of Phase II of the Regional Project SM-18. The data recorded in Phase II for breaking strength, tear resistance, and wrinkle recovery were used for comparison with data from durable press treated sheeting. Only data for bales 2, 4, 6, and 8 were used, in order to have corresponding data with the treated sheets.

A durable press finish was applied to a group of sheetings which had not been laundered or used. Only the even numbered bales, 2, 4, 6, and 8 were used for this supplemental study, since not all 8 bales had a sufficient number of sheets left to test. These sheetings were treated with a durable press finish at North Carolina State University according to the following formula for 100-pound mix:

16% Reactant (Dimethyl dyhydroxy ethylene urea)	16 pounds
20% Catalyst (Zinc nitrate) (Catalyst per cent based on amount of reactant)	3.2 pounds
3% Polyethylene softener	3 pounds
0.01% Wetting agent (Polyethylene oxide ether of nonyl phenol)	45 grams

The temperature of the pad bath was 120 degrees Fahrenheit. The fabric was padded at three tons pressure for 80 per cent wet pickup. The speed of pad and drier was seven yards per minute. The fabric was dried at 230 degrees Fahrenheit until the moisture content of the fabric was approximately six to eight per cent. Then the fabric was cured at 320 degrees Fahrenheit for six minutes.

Both treated and untreated sheets were laundered by the same commercial establishment. The two groups were not laundered at the same time, but were laundered under the same specified conditions established for the regional project.

The treated sheetings were divided into groups, withdrawing two sheets of each bale type following 5, 15, 30, 45, and 60 launderings. A control group, referred to hereafter as the 0 interval, was unlaundered. Then samples for testing were taken from each sheet.

<u>Testing Procedures</u>

The testing procedures for tests were conducted according to the Manual of Procedures established for Project SM-18. The samples for all tests were prepared at the North Carolina station. Those to evaluate breaking strength were sent to Tennessee, those for tear resistance to Missouri, and tests for wrinkle recovery were performed at the North Carolina station. The home economists at North Carolina were involved only in wrinkle recovery testing.

Breaking strength. The test for breaking strength used the ravelled strip method. A constant-rate-of-traverse type (CRT) of testing machine was used. The testers were set so that the break would occur at or above 30 per cent full scale of any given range, and within 20 ± 3 seconds from the beginning of the test. The breaking load was recorded by means of an autographic recording device on the machine.

Two sets of five specimens were required, one set for warp breaking strength, having the longer dimension parallel to the warp yarns; and the other set for filling breaking strength, having the longer dimension parallel to the filling yarns. The specimens were cut 6 x 1¼ inches, and were ravelled to one inch in width. No two specimens for warp breaking strength contained the same warp yarns, or for filling breaking strength, the same filling yarns.

The test specimen was secured centrally between two clamps of the testing machine with the longer dimension of the specimen parallel to the direction of application of the load. The number was read and recorded to the nearest 0.1 pound.

The breaking strength reported represented the average of all satisfactory breaks in the warp or filling direction.

[1]Manual of Procedures, Regional Research Project SM-18, p. 32.

Tear Resistance

This test method employed the falling-pendulum apparatus, or Elmendorf tester, for determining either the average force or energy required to propagate a tear starting from a cut in a woven fabric. This method was applicable for treated and untreated fabrics including those heavily sized or coated.[1]

The test samples consisted of five warp and five filling specimens. These were rectangles of cloth cut 102 mm. long and 75 mm. wide. A notch 12 mm. square was cut in the middle of one 102 mm. side to prevent ravelling out of last yarns, and insure their being torn during the test.

The pendulum of the machine was raised to the starting position and the pointer was set against its stop. The straight edge of the longer side of the specimen was aligned parallel to the top of the jaws, and the widthwise yarns were perpendicular to the jaws with the notch side up. A slit was cut extending from the bottom edge of the specimen to a point 20 mm. above the top edge of the jaws, leaving a tearing distance of 43 mm. up to the notch. The sector release, which controlled the pendulum, was pressed and held down for one complete swing, permitting the sector to fall and the pendulum clamp to move away from the fixed clamp so as to tear the specimen. The sector scale was read to the nearest .25 between divisions on the appropriate scale.

[2]Manual of Procedures, Regional Research Project SM-18, p. 33.

Wrinkle Recovery

The testing used to estimate the wrinkle recovery of woven fabrics was conducted with controlled relative humidity, temperature, pressure applied to the fold, time under pressure, and recovery time. The testing was conducted at North Carolina, using the Monsanto Wrinkle Recovery Tester.[2]

Six test specimens 1.5 cm. wide and 4 cm. long were cut with a die from warp and filling directions. Specimens were handled with tweezers during testing. Each specimen was placed between the leaves of a metal holder, with one end directly under the 1.8 cm. mark. The exposed end of the specimen was lifted over to the 1.8 cm. mark on the short metal leaf and held there by the left thumbnail. The holder and specimen were inserted in the press so that the jaw with the small raised platform was outside and parallel to the longer metal strip of the holder. The flat thicker jaw was brought into contact with the specimen, pressing only enough to hold the sample. The press-holder combination was inverted on a table top with the small platform upward and a load of 500 grams was gently applied. After exactly five minutes, the load was removed and the sample in its holder was inserted in the clamp on the tester. The specimen holder was adjusted by aligning the crease in the sample with the guide line in the center of the tester. For the next five minutes, the specimen end was kept aligned with the vertical guide line on the tester as the specimen recovered. At the end of five minutes, the final adjustment was made and a reading taken

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[3]Manual of Procedures, Regional Research Project SM-18, p. 45.

from the protractor scale of the tester. The results were averaged, and the mean reported for warp and filling of each sheet.

Analysis of Data

A single-variable ANOV was used comparing length and strength at each interval and with both treatments. In addition, an ANOV measuring the difference in treatments, and a split-plot combining all intervals and treatments was used. A computer program was used to analyze all data and to determine the F ratios. The ANOV was used to test the significance of the difference in durable-press treated and untreated cotton sheeting as measured by breaking strength, tear resistance, and wrinkle recovery after 0, 5, 15, 30, 45, and 60 periods of laundering. Findings were considered significant at the .05 level and highly significant at the .01 level.

CHAPTER IV

PRESENTATION OF DATA

The major objectives of this thesis were to compare the performance of durable press treated sheetings with sheetings having no durable press treatment, and to determine whether the differences in treatment are reflected in the performance of sheetings with fiber properties of varying length and strength. Performance was judged on the basis of breaking strength, tear resistance, and wrinkle recovery tests.

Compilation and Treatment of Data

The untreated sheetings used for this study were a part of Phase II of the Regional Project SM-18. A comparable group of 96 sheetings, which had not been laundered or used, was treated with a durable press finish. The sample was composed of a total of 192 sheetings which had been withdrawn from the study following 0, 5, 15, 30, 45, and 60 periods of laundering. None of the sheetings had been subjected to consumer use. Measurements of both warp and filling yarns were obtained in the tests for breaking strength, tear resistance, and wrinkle recovery. An analysis of variance was used to measure the significance of difference in treatments, and to determine the significance of differences in two levels of fiber length and two levels of fiber strength at each interval and with both treatments. Findings were considered significant at the .05 level and highly significant at the .01 level of significance.

Results of Breaking Strength Tests

The differences in untreated and durable press treated sheetings before and after laundering are shown in Table I. A graphic representation of this data is shown in Figure 1. There was a highly significant difference between the breaking strength of the untreated and durable press treated fabrics at the 0 interval. This was true in both warp and filling directions, as shown by the 50 per cent loss in the warp strength and the 62 per cent loss in filling strength of the durable press treated fabrics.

There were also highly significant differences in breaking strength characteristics of the two groups of fabrics at each subsequent testing interval. However, the data indicated that the difference was not as great as at the 0 interval. The strength of the untreated sheetings in both warp and filling directions decreased progressively through the 60th laundering. The sheetings to which the durable press finish had been applied showed little change at subsequent intervals. The mean percentage loss for untreated fabric was 42 per cent in both warp and filling directions. In comparison, the treated fabric had a 12 per cent loss of strength in the warp direction, and 14 per cent loss in the filling direction. At no time was the breaking strength of the untreated fabric as low as that for treated fabric.

A highly significant difference between long and short staple fibers was noticed from the statistical analysis of data. The long-staple cottons had a consistently higher breaking strength in both warp and filling directions, and in treated and untreated fabric. When the

TABLE I

BREAKING STRENGTH OF UNTREATED AND DURABLE PRESS TREATED SHEETS

BEFORE AND AFTER LAUNDERING

Interval	Untreated					Durable Press				
	Fiber Properties					Fiber Properties				
	Staple length		Fiber strength		Mean	Staple length		Fiber strength		Mean
	Short	Long	Low	High		Short	Long	Low	High	
WARP										
Zero	51.2	60.7	54.8	57.1	55.9	25.6	30.0	28.8	26.8	27.8
Five	51.7	57.5	53.5	55.7	54.6	26.6	28.5	27.0	28.0	27.5
Fifteen	44.4	52.2	45.6	51.0	48.3	27.7	29.5	30.3	26.9	28.6
Thirty	38.6	44.5	40.1	43.0	41.6	26.4	30.8	29.6	27.6	28.6
Forty-five	33.6	39.2	36.0	36.8	36.3	24.9	27.1	27.0	25.0	26.0
Sixty	31.0	34.4	31.8	33.6	32.7	23.1	26.0	24.6	24.6	24.6
FILLING										
Zero	62.2	72.3	62.4	72.1	67.3	23.4	27.8	25.4	25.9	25.6
Five	61.3	68.4	62.0	67.8	64.9	24.2	27.7	25.4	26.5	26.0
Fifteen	60.4	68.3	61.4	67.2	64.3	25.5	28.5	28.5	25.5	27.0
Thirty	51.6	59.4	51.8	59.3	55.6	25.0	28.2	26.9	26.3	26.6
Forty-five	41.4	48.8	42.2	47.9	45.1	20.3	26.5	23.4	23.4	23.4
Sixty	37.4	40.4	38.3	39.5	38.8	19.4	24.4	22.1	21.7	21.9

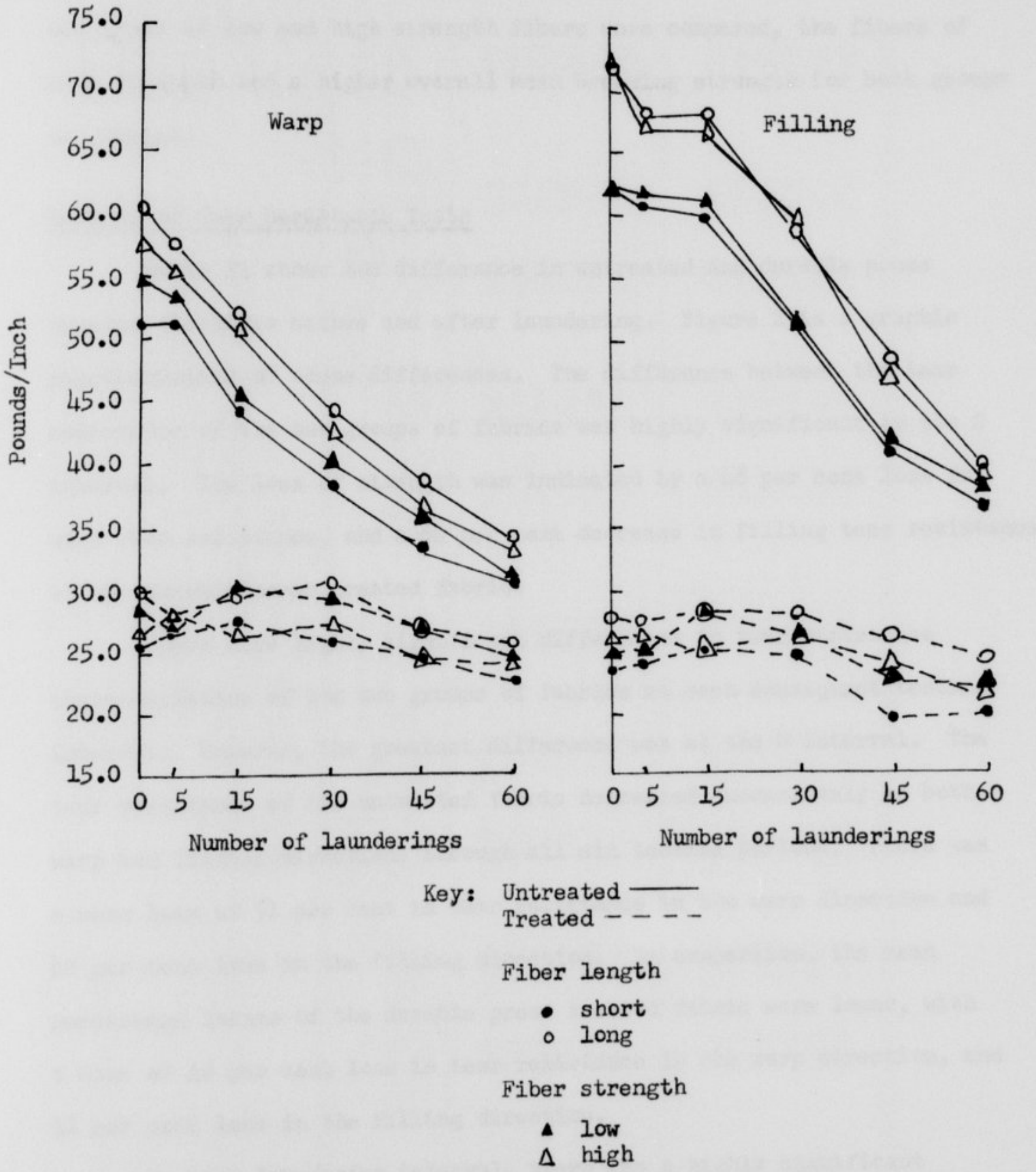


FIGURE 1

MEAN BREAKING STRENGTH OF DURABLE PRESS TREATED AND UNTREATED SHEETINGS OF VARYING LEVELS OF FIBER LENGTH AND STRENGTH two types of low and high strength fibers were compared, the fibers of high strength had a higher overall mean breaking strength for both groups of fabrics.

Results of Tear Resistance Tests

Table II shows the difference in untreated and durable press treated sheetings before and after laundering. Figure 2 is a graphic representation of these differences. The difference between the tear resistance of the two groups of fabrics was highly significant at the 0 interval. The loss of strength was indicated by a 48 per cent loss in warp tear resistance, and a 64 per cent decrease in filling tear resistance of the durable press treated fabric.

There were highly significant differences in tear resistance characteristics of the two groups of fabrics at each subsequent testing interval. However, the greatest difference was at the 0 interval. The tear resistance of the untreated fabric decreased successively in both warp and filling directions through all six testing periods. There was a mean loss of 51 per cent in tear resistance in the warp direction and 46 per cent loss in the filling direction. In comparison, the mean percentage losses of the durable press treated fabric were lower, with a mean of 18 per cent loss in tear resistance in the warp direction, and 16 per cent loss in the filling direction.

At each laundering interval, there was a highly significant difference between long and short staple fibers. Both groups of fabric with fiber properties of long staple and high strength had a consistently higher tear resistance in warp and filling directions. Only at the 60th

TABLE II

TEAR RESISTANCE OF UNTREATED AND DURABLE PRESS TREATED SHEETS

BEFORE AND AFTER LAUNDERING

Interval	Untreated					Durable Press				
	Fiber Properties					Fiber Properties				
	Staple length		Fiber strength		Mean	Staple length		Fiber strength		Mean
	Short	Long	Low	High		Short	Long	Low	High	
WARP										
Zero	968	1189	1068	1089	1078	472	641	542	571	557
Five	789	975	853	911	882	470	580	498	552	525
Fifteen	855	968	907	916	912	458	512	506	463	485
Thirty	714	849	735	828	781	472	560	512	521	516
Forty-five	675	780	686	769	728	398	490	443	445	444
Sixty	480	569	506	542	524	412	499	466	445	456
FILLING										
Zero	935	1153	1019	1069	1044	336	422	355	404	380
Five	778	976	841	914	877	345	411	368	388	378
Fifteen	898	971	926	942	934	322	388	366	342	354
Thirty	734	876	742	868	805	363	394	378	379	378
Forty-five	678	819	698	800	749	270	349	296	323	309
Sixty	516	602	545	572	559	264	375	346	292	319

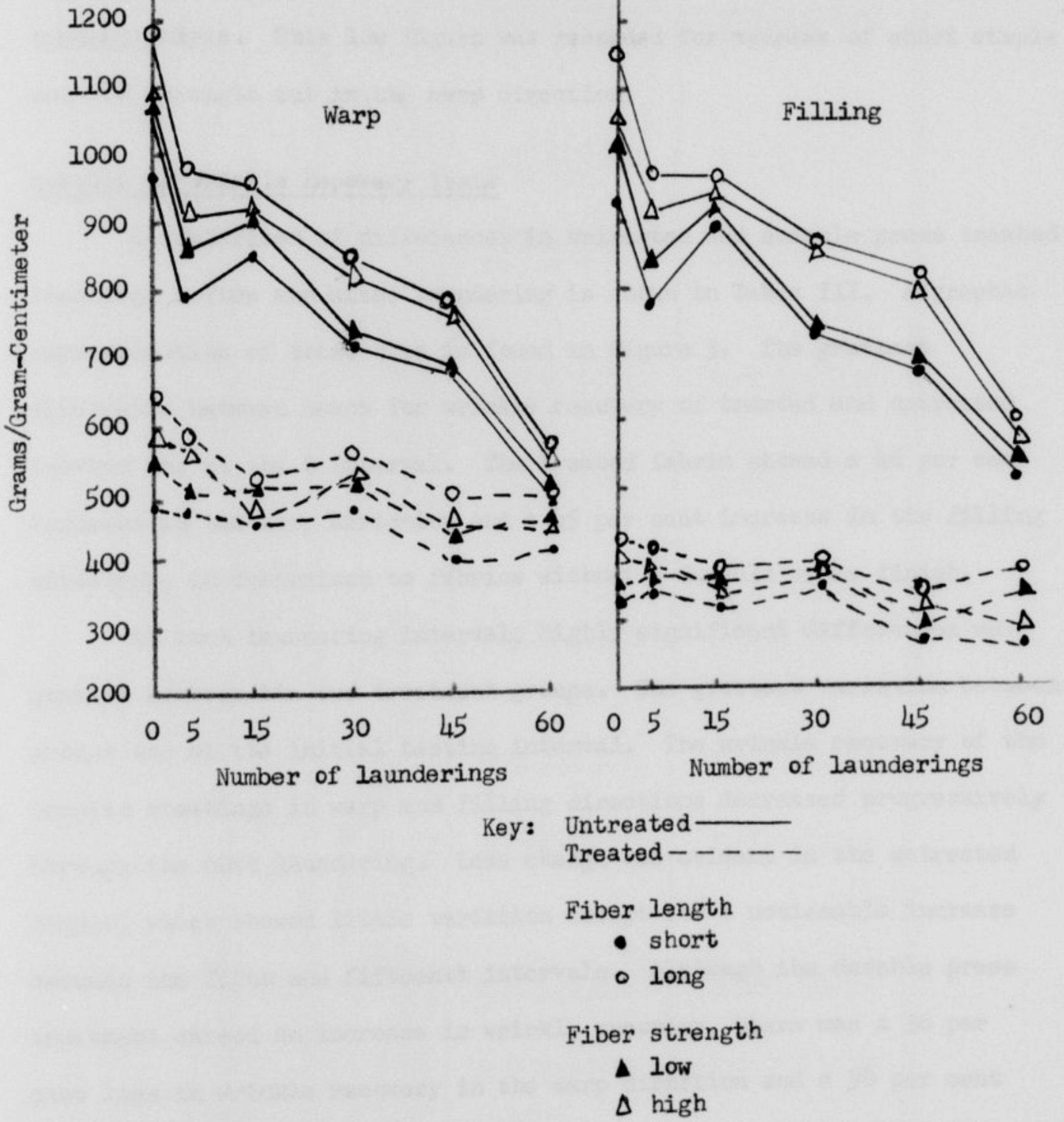


FIGURE 2

MEAN TEAR RESISTANCE OF DURABLE PRESS TREATED AND UNTREATED SHEETINGS OF VARYING LEVELS OF FIBER LENGTH AND STRENGTH interval was the tear resistance for untreated fabric as low as that for treated fabric. This low figure was recorded for samples of short staple and low strength cut in the warp direction.

Results of Wrinkle Recovery Tests

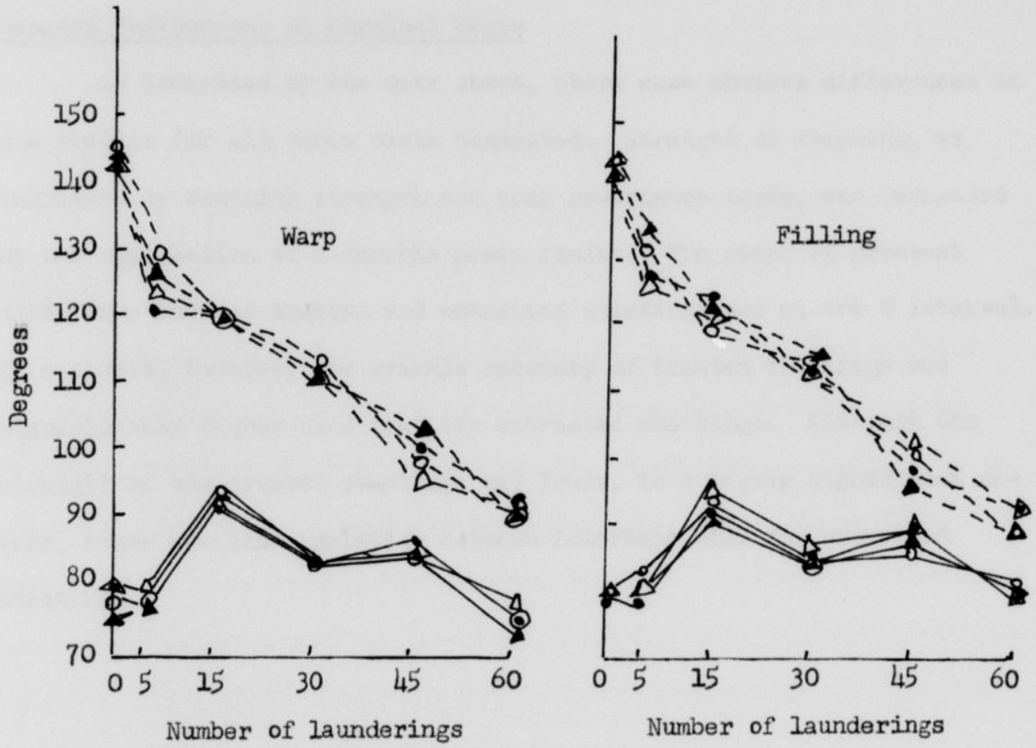
A comparison of differences in untreated and durable press treated sheetings before and after laundering is shown in Table III. A graphic representation of these data is found in Figure 3. The greatest difference between means for wrinkle recovery of treated and untreated fabrics was at the 0 interval. The treated fabric showed a 46 per cent increase in the warp direction and a 45 per cent increase in the filling direction, in comparison to fabrics without a durable press finish.

At each laundering interval, highly significant differences were present between the two treatment groups. The greatest variation between groups was at the initial testing interval. The wrinkle recovery of the treated sheetings in warp and filling directions decreased progressively through the 60th laundering. Less change was evident in the untreated fabric, which showed little variation except for a noticeable increase between the fifth and fifteenth intervals. Although the durable press treatment caused an increase in wrinkle recovery, there was a 36 per cent loss in wrinkle recovery in the warp direction and a 38 per cent loss in the filling direction for all six intervals averaged. In contrast, however, the wrinkle recovery of the untreated fabrics decreased only three per cent in the warp direction and showed no appreciable change in the filling direction, from the 0 through 60th laundering.

TABLE III

WRINKLE RECOVERY OF UNTREATED AND DURABLE PRESS TREATED SHEETINGS BEFORE AND AFTER LAUNDERING

Interval	Untreated					Durable Press				
	Fiber Properties					Fiber Properties				
	Staple length		Fiber strength		Mean	Staple length		Fiber strength		Mean
	Short	Long	Low	High		Short	Long	Low	High	
WARP										
Zero	78	78	76	80	78	143	146	144	145	144
Five	79	78	77	80	78	121	130	127	124	126
Fifteen	92	95	94	93	93	120	120	120	120	120
Thirty	84	84	84	84	84	114	113	113	114	114
Forty-five	88	86	87	87	87	102	100	104	98	101
Sixty	76	76	74	78	76	93	92	92	93	92
FILLING										
Zero	78	80	78	80	79	142	145	144	142	144
Five	78	83	81	80	80	127	132	133	126	130
Fifteen	92	94	91	95	93	124	119	123	120	121
Thirty	84	85	84	86	84	113	112	114	112	113
Forty-five	89	86	87	88	87	98	100	96	101	98
Sixty	78	80	78	79	79	92	88	88	92	90



Key: Untreated
Treated

Fiber length
short
long

Fiber strength
low
high

FIGURE 3

MEAN WRINKLE RECOVERY OF DURABLE PRESS TREATED AND UNTREATED SHEETINGS OF VARYING LEVELS OF FIBER LENGTH AND STRENGTH

General Indications of Physical Tests

As indicated by the data above, there were obvious differences in the results for all three tests conducted. Strength of sheeting, as indicated by breaking strength and tear resistance tests, was decreased by the application of a durable press finish. The point of greatest difference between treated and untreated sheetings was at the 0 interval. In contrast, however, the wrinkle recovery of treated sheetings was significantly higher than that for untreated sheetings. Although the strength of the treated sheetings was lower, to a highly significant degree, there was less variation between intervals than for untreated sheetings.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

Cotton is a popular fabric because of its comfort, washability, and pleasing texture. In spite of these desirable qualities, cotton fabrics wrinkle easily and are difficult to keep smooth-looking. In an effort to make cotton competitive with man-made fibers for no-care characteristics, durable press finishes have been developed. Crosslinking resins are used to give "no-iron" characteristics to cotton fabrics. However, these resins produce a damaging effect in cotton, so that its strength in wear is appreciably reduced.

The purpose of this study was to investigate the effects of a selected durable press finish upon fabric strength and wrinkle recovery characteristics of selected cotton sheetings following a series of launderings. The effect of the finish upon the fiber properties of length and strength was also of interest. This study was planned to compare effects of laundering alone, with none of the sheetings being subjected to consumer use. The sheetings used in the study were of 140 type muslin manufactured specifically for Regional Research Project SM-18. This project was undertaken by the home economics research personnel of six southern states and was sponsored by the United States Department of Agriculture in order to determine the relation of fiber properties to end-product performance.

Breaking strength, tear resistance, and wrinkle recovery tests were chosen to evaluate differences in fabric strength and wrinkle recovery. The data for untreated sheetings were taken from the regional project. The data for the treated sheetings were furnished by tests performed specifically for this supplemental study.

The objectives of this study were:

1. To compare the selected performance characteristics (breaking strength, tear resistance, and wrinkle recovery) of durable press treated cotton sheetings with similar sheetings having no durable press treatment.
2. To determine by means of breaking strength, tear resistance, and wrinkle recovery whether the differences in treatment are reflected in the performance of cottons of varying properties of length and strength.

The laboratory analysis of the samples measured changes in breaking strength, tear resistance, and wrinkle recovery. An analysis of variance was used to determine the significance of the three variables, (1) treatment, (2) fiber length, and (3) fiber strength, after 0, 5, 15, 30, 45, and 60 periods of laundering.

Breaking strength was measured by the Scott constant-rate-of-traverse testing machine, in pounds per inch. Five samples were cut with the longer threads running in the warp direction, and five samples were cut in the filling direction. These samples were tested for both groups at each interval.

Tear resistance was measured in grams per gram-centimeter by the Elmendorf tester. Five samples from both warp and filling directions were tested for each treatment group at each interval.

The Monsanto Wrinkle Recovery Tester was used to measure changes in wrinkle recovery by degrees of recovery. Six test samples were cut from both warp and filling directions, for treated and untreated fabrics, at each testing period.

Results of experimentation indicated differences in the performance of the two groups of sheeting for all three tests conducted. The application of the finish caused a loss in strength of the sheeting, as indicated by results of breaking strength and tear resistance tests. The point of greatest difference between the two treatment groups was at the 0 interval, where there was a highly significant difference in strength of the two groups of sheetings. There was less variation between intervals within the treated group than within the untreated group of sheetings. The durable press treatment, however, did improve the wrinkle recovery of treated sheetings significantly.

Breaking strength. The highly significant difference between the treated and untreated cotton sheetings indicated a loss of strength due to the application of a durable press finish. The greatest difference between the two groups was indicated at the initial testing period. However, progressive loss of strength was significantly greater for untreated fabric. The fabric with durable press finish apparently was stabilized, for the sheetings to which the finish was applied showed little change at subsequent intervals. Staple length and fiber strength of the cottons used in the sheetings appeared to influence breaking strength. The long-staple cotton fibers had a consistently higher breaking strength than the short-staple fibers in both warp and filling directions for both treatment groups. The breaking strength for high-strength fibers was consistently higher than that for low strength fibers in both warp and filling directions and in both treatment groups.

<u>Tear resistance</u>. There were highly significant differences in the two groups of fabrics at all testing periods. The greatest difference was at the 0 interval. The untreated fabrics decreased in tear resistance at each subsequent testing period, while the treated fabrics showed a much lower successive loss in strength.

A highly significant difference was indicated between long and short staple fibers at each testing period. Both treatment groups of fabric with fiber properties of long staple had a consistently higher tear resistance in warp and filling directions than fabric with short staple fibers. Both treated and untreated fabric made of fibers with high strength also had a higher tear resistance in both warp and filling directions.

<u>Wrinkle recovery</u>. The differences between the groups of fabric were highly significant at each testing period, with the greatest variation between groups at the initial testing period. The wrinkle recovery of the sheetings with a durable press finish decreased progressively in both warp and filling directions through all six testing periods. This effect was apparently caused by loss of finish during laundering. Although the wrinkle recovery of the untreated fabric was significantly lower than that of the treated fabric at the 0 interval, the testing results within the untreated group showed much less fluctuation and decrease. No consistently significant difference between fiber properties of long and short staple and low and high strength of the two groups was noted, either from statistical analysis or graphical presentation of data.

Conclusions

The results of this study indicated the following conclusions:

1. There were highly significant differences in breaking strength, tear resistance, and wrinkle recovery due to the application of the durable press finish to 100 per cent cotton fabric.

2. There were highly significant differences in breaking strength and tear resistance characteristics between short and long staple fibers of both untreated and durable press treated fabrics.

3. There were no significant differences in breaking strength or tear resistance between low and high strength fibers in either type of fabric.

4. There was no significant difference in wrinkle recovery between low and high strength or long and short staple fibers in either type of fabric.

5. It is possible that a loss of finish occurred due to the after-sour used in the laundering procedure. The greatest difference in strength and wrinkle recovery occurred at the 0 interval where the amount of finish on the fabric was heaviest. There were indications that most of the finish had been removed by the 15th interval.

Recommendations for Further Study

The following recommendations are made for further study:

1. A study similar to this one be conducted in which both groups of sheetings are laundered simultaneously. Half of each group would be used and laundered, to determine the effect of use, particularly on strength characteristics.

2. A study be conducted to include a determination for the amount of loss in finish which occurs during use and multiple launderings. The fabric should be tested after each of the first five launderings as well as after longer periods of laundering.

3. A comparison be made of performance of sheetings commercially available to the homemaker. These sheetings would be of cotton man-made fiber blends.

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