THE RELATION OF FIBER ELONGATION TO SELECTED SERVICEABILITY FEATURES OF EXPERIMENTAL COTTON SHEETINGS

by

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TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

For many years man has known that some cottons are better than others; that some fibers are longer, finer, stronger and more elastic than others. Just what effect this has on a finished product is not always easy to determine.

The stage has been reached in the textile industry that fiber properties can be easily determined in the raw state. However, the determination of fiber properties is no indication of how well a fabric will perform in use.

Extensive research has been directed toward the relationship of fiber properties to fabric quality, but little research has been undertaken which indicates the effect of the relationship of fiber properties to the serviceability of a finished product.

In response to this need for information a regional project has been undertaken. This project designated as Regional Research Project SM-18 is being conducted by the home economists of the agricultural experiment stations of six southern states under the direction of the Agricultural Research Service of the United States Department of Agriculture. This project is concerned with the relationship between fiber properties (length, strength, fineness and elongation) and the end product performance. The particular property being investigated at the present time is that of fiber elongation.[1]

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[1]Technical Committee Project SM-18, "The Relation of Selected Properties of Raw Cottons to Product Quality and End Product Performance," (Manual of Procedures, Southern Regional Research Project SM-18).

For the regional project four types of cotton similar in length, strength and fineness were selected. The four cottons differed in fiber elongation - two types representing cottons of high elongation and two of low elongation.

To determine the performance of the four types of cotton, sheets were to be manufactured and used in dormitories of four of the colleges participating in the study. The sheets were to be laundered in commercial laundries and withdrawn for sampling for laboratory tests after 0, 5, 15, 30, 45 and 60 intervals of use and laundering.

This thesis was a pilot study of the Regional Project. The purpose of this pilot study was to determine the relation of fiber elongation to serviceability features of the four types of cotton sheeting used in the serviceability testing at the Woman's College of the University of North Carolina.

The sheets were used weekly on the beds in selected girls' dormitories. At the end of each week the sheets were collected and checked for any indication of damage. If necessary, the sheets were repaired and sent to a commercial laundry. Each girl kept a daily record of the number of hours and nights the sheet was in use.

The tests used in this pilot study were only those tests performed in North Carolina: thread count, fabric weight, dimensional change and wrinkle recovery. Tests were performed on the sheets at the zero interval and on those withdrawn at the fifth and fifteenth laundering intervals.

Statistical tests were made of the differences between cottons of high and low fiber elongation which were indicated by the results of the above tests.

Chapter II is a review of the literature pertaining to the effect of fiber properties upon fabric performance and also to other studies involving the serviceability testing of sheets. Chapter III describes the procedures for the use of the sheets and for the laboratory tests. The compilation and results of the laboratory tests and the statistical significance of the differences in the cottons of high and low elongation are presented in Chapter IV. Chapter V includes the summary, conclusions and suggestions for processing the data for the Regional Research Project SM-18.

CHAPTER II

REVIEW OF LITERATURE

Fiber and Yarn Properties

"The cotton fiber, as the term is generally understood, is a hair which grows out of a single epidermal cell in the cottonseed coat."[1]

> The cotton fiber has a relatively broad basal end and a more or less tapering apical end. There is a wide variety of shapes of both the apical and basal ends. The cotton fiber is a translucent collapsed hollow tube which is convoluted. These convolutions tend to run in repeatedly changing directions along the length of the fiber.[2]

The number of twists or half convolutions in raw cotton fibers varies widely. Immature fibers are practically non-convoluted, while mature fibers of the same variety may be highly convoluted.[3]

Cotton fibers have three parts: primary cell wall, secondary cell wall and lumen. The primary wall is composed of pectin, wax and cellulose, and it is the only morphological component of cotton fiber which comes in physical contact with processing machines and with the walls of adjacent fibers during drafting, twisting and later strength tests on yarns.

The average length of the cotton fiber varies from 1.5 centimeters to 6.0 centimeters while width varies from 2.0 to 12.0 microns, according to species and variety of cotton.[4] Fiber breadth may not reveal the amount of functional substance the fiber contains.[5]

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[1]Herbert R. Maurersberger, Matthew's Textile Fibers, (New York: John Wiley and Sons, Inc.), 1957, p. 183.

[2]A. N. Gulati, The Physical Properties of Cotton, (India: Asia Publishing House), 1957, p. 6.

[3]Maurersberger, op. cit., pp. 183-184.

[4]Gulati, op, cit., p. 7.

[5]Ibid., p. 5.

Length. Staple length was of no concern to the hand spinner. A yarn as fine as a size one hundred could be easily spun by the hand spinner while yarns of a size ten were fit only for the machinery.[9]

Cotton fibers are remarkably uniform in length. It is very important to know the length of the fibers because the roll settings in various drafting and combing operations all depend on the length of the longest fibers. The length is indicated by the classer's staple length from the Fibrograph and by the fiber length array.[10]

According to Wakeham, fiber length is an important factor, but cotton fiber length distribution is equally important. In comparing a cotton with a length distribution definitely inferior to another cotton, Wakeham concluded that differences in fiber length distribution which seem to account for the differences in cotton quality are not readily detected by measurement of upper quartile length, length uniformity, or similar measurements now being made in mill or cotton testing laboratories. "Part of this failure is due to the practice of distributions. The general attitude seems to be that the short fibers in the sample, because they do not weigh much, are really not of much importance and hence can be ignored."[11]

Strength. Cheatham and Fiori have done extensive study on the effect of fiber properties on product quality. In regard to fiber

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[9]Gulati, op. cit., p. 4.

[10]Helmut Wakeham, "Cotton Fiber Length Distribution An Important Factor," Textile Research Journal, Vol. 25 (May, 1955), p. 428.

[11]Ibid.

strength, they report that strength, which is still the most important criterion used for evaluating yarn quality is influenced by the fineness, length, strength and to a lesser degree by the length variability of cotton fibers.[12] They also report that

> . . . high strength cottons produce stronger yarns than low strength cottons for any given yarn number or twist. In the case of appearance, the finer yarn numbers spun from the high strength cotton apparently spun into yarns of slightly better grade than those spun from the weaker cotton.[13]

A basic knowledge of the weak places in textile fibers is a basic requirement in fiber science and technology. Cotton has been selected as the fiber to be studied because of the many elements of weakness which each single fiber contains.

"It is widely believed that the weakest links in cotton fibers occur at the structural reversals." This was first studied by Balls and Hancock in 1926. As cotton increases in length, the strength decreases. The decrease is undoubtedly due to a very high frequency of weak linkages along the length of the fiber.[14]

"In order to determine the part cotton fiber reversals play in fiber rupture, it must be possible to distinguish between breaks which do or do not involve a reversal."[15] This can be done by examining fiber ends under a microscope used with a quarter wave red plate. From examination of these fibers, it is evident that not all breaks occur at the

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[12]Cheatham and Fiori, op. cit., p. 38.

[13]Ibid., p. 43.

[14]Helmut Wakeham and Nancy Spicer, "The Strength and Weaknesses of the Cotton Fibers," Textile Research Journal, Vol. 21 (April, 1951), p. 186.

[15]Ibid., p. 188.

fiber reversals. This does not eliminate the possibility that fibers may break preferentially at the reversals. If reversals were not weak places in the fiber, some of them would be involved in breaks simply by chance because there are so many of them along the length of the fiber. Studies show that 15 per cent of the fiber breaks involving a reversal may be taken as evidence of an unusual weakness in the fiber at the reversal.[16]

Fiori and others drew the following conclusions in a study on the effect that cotton fiber strength has on single yarn properties and processing behavior.

1. The strength of the fiber has little or no effect on processing efficiency through spinning.

2. High strength cotton produces stronger yarns than low strength cottons for any given yarn number or twist, a well known general relationship.

3. The amount of twist required to obtain maximum strength in single cotton yarns is not affected by fiber strength.

4. Fiber strength does not significantly affect the uniformity of slivers, rovings, or single yarns.

5. Fiber strength does not significantly affect yarn elongation.[17]

Fineness. Fiber fineness is one of the fiber properties which influences yarns. It has a great influence on nep formation and consequent appearance of the yarn, on the twist of the yarn and the turns per inch required to obtain maximum yarn strength and on the strength of the

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[16] Ibid., p. 188.

[17] L. A. Fiori and others, "Effect of Cotton Fiber Strength on Single Yarn Properties and On Processing Behavior," Textile Research Journal. Vol. 24 (June, 1954), p. 506-7.

yarn itself.[18] It is not only considered in determining the strength of a yarn, but also the proper amount of twists to insert in roving in order to maintain efficient operating conditions.[19] Fiori and Brown concluded from a study of the effects of cotton fiber fineness on the physical properties of single yarns that yarns made from coarse fibers lost strength more rapidly as the turns per inch decreased from a point of maximum strength than did the yarns made from fine fibers. With finer yarn numbers the fine fibers required less twist than the coarse fibers to attain maximum yarn strength. Fine fibers spun into a stronger yarn than coarse fibers; fiber fineness contributes more to the strength of low twist yarns than those of high twist yarns.[20]

Fiori drew these conclusions from a study of the effect of fiber fineness on yarn properties and processing techniques. A close relationship exists between fiber fineness and turns per inch required for maximum yarn strength in a single yarn. Fiber fineness influences roving twists required for optimum operating conditions. Fineness does not materially influence yarn elongation. Fine fibers attain maximum yarn strength at a slightly lower twist than do the coarse fibers. Fine fibers spin into stronger yarn than do coarse fibers with the exception of coarser yarn numbers of high twist. As twist decreases, coarse fibers lose strength more rapidly than fine fibers.[21]

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[18] Cheatham and Fiori, op. cit., p. 39.

[19] Ibid.

[20] Louis A. Fiori and John J. Brown, "Effects of Cotton Fiber Fineness on the Physical Properties of Single Yarns," Textile Research Journal, Vol. 21, (Oct., 1951) P. 750.

[21] L. A. Fiori, "Effect of Fiber Fineness on Yarn Properties and Processing Techniques," (State Experiment Station Southern Laboratory Conferences). (March 19-21, 1951). P. 33.

L. Rebenfeld, of the Textile Research Institute, has done research in the field of cotton. This research was directed mainly toward the evaluation of the characteristics and the quality of the fiber and the relationships of those fiber characteristics to processing efficiency and end product performance. Recent research at the Textile Research Institute shows that single fiber properties relate to roving, sliver and yarn characteristics.[22]

> . . . Fiber properties are not greatly altered by processing operations. The average fiber breaking stress is decreased significantly only by resin-finishing. Fiber breaking elongation decreases steadily throughout the entire processing line as would be expected in view of the tensions exerted on the fibers by all textile operations.[23]

The average breaking elongation for the cottons tested in this study showed a decrease from bale to the bleached and mercerized fabric. The results also showed that this decrease was a function of the original fiber breaking elongation. Cottons with a high breaking elongation showed a greater decrease in this one property than cottons with a low breaking elongation.[24]

> Very little is known about the effect that fiber properties have on yarn elongation. It is suspected that perhaps fineness is not materially important as contributing to yarn elongation. Length appears to have some effect on elongation, but the overall effect when considering cottons ranging from 1 to 1 3/4 inches is so small that small differences in length would exert no significant effect. High strength cottons usually produce low elongation yarns so the implication is that fiber strength is inversely related to yarn elongation. Limited studies conducted at the Southern Utilization

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[22] L. Rebenfeld. "The Effect of Processing On Cotton Fiber Properties," Textile Research Journal, 1957, Vol. 27, p. 473.

[23] Ibid.

[24] Ibid.

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[22]L. Rebenfeld. "The Effect of Processing On Cotton Fiber Properties," _Textile Research Journal_, 1957, Vol. 27, p. 473.

[23]_Ibid._

[24]_Ibid._

> Research and Development Division Laboratory have indicated that another fiber property, elongation, hitherto not considered important, may contribute to the elongation of both single and ply yarns. It was also found that fibers of high initial elongation produced yarns of unusually high elongation.[25]

No research has been done to indicate the relation of fiber elongation to end product performance, however, L. Rebenfeld has drawn this conclusion in a study of the transmission of cotton fiber strength and extensibility. In a comparison made of single fiber breaking tenacity and hypothetical textile structure breaking tenacity, it was found that the differences are larger for low elongation cottons than for high elongation cottons.[26]

Serviceability Tests

The results of the studies just reviewed show that fiber and yarn properties can be studied effectively by using testing equipment designed for such purposes. Knowledge of these properties does not prove how well a fabric made from these fibers will perform in use.

Until 1934 there was no known study of the durability of a fabric made from known grades of cotton. There had been small studies performed on ginghams, sheetings and shirts and the effect laundering had on these various fabrics. A study was done by the United States Department of Agriculture to compare the behavior of yarn in manufacturing and the durability of three grades of cotton - middling, good middling, and strict

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[25] Cheatham and Fiori, op. cit., p. 37.

[26] L. Rebenfeld, "Transmission of Cotton Fiber Strength and Extensibility," Textile Research Journal, 1958, Vol. 28, p. 586.

good ordinary. Sheetings were made from these three grades of cotton and were subjected to wear testing. The results of the physical tests indicated that the sheetings of strict good ordinary were weaker initially and throughout their wear life than those made of middling and good middling. The chemical and physical tests performed showed that the maximum wear on the sheets occurred in the section occupied by the shoulders.[27]

In 1942 M. B. Hays and R. Elmquist Rogers did a study of four classes of sheets during service. Those studied were fine count percale, medium weight muslin I and II and heavyweight muslin. Results showed that the heavy weight muslin sheet wore longer than any other. The percale wore next longest. The medium weight muslin sheets which cost the least gave the least service. It was found that the amount of service given by these sheets was closely related to their filling-breaking strength. The sheets shrank in length and gained in width.[28]

Wear as well as laundering affects the life of a fabric. Many investigations have attempted to evaluate the durability of a fabric by merely laundering repeatedly. This procedure does not simulate the conditions of actual use and it does not reveal the changes which occur during service. Rogers, Hays and Wigington conducted a study of the manufacture and serviceability tests on sheeting made from two selected

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[27]United States Department of Agriculture, _A Study of the Cotton and the Yarns and Sheeting Manufactured from Three Grades of American Upland Cotton_, Technical Bulletin 406 (Washington: Government Printing Office, 1934). P. 48.

[28]M. B. Hays and R. Elmquist Rogers, "A Study of Four Classes of Sheets During Service," _Journal of Home Economics_, Vol. 34 (January, 1942) P. 115.

mill types of cotton. The sheets were used in a hotel and were evaluated by physical and chemical determinations. Wear and laundering produced a progressive tendering of the fabric. The first laundering removed the largest percentage of starch, but some was still present after the twenty-fifth laundering. None was present after the fiftieth. Wear had more effect on the physical than on the chemical properties of the sheeting. This was indicated by the fact that the physical values for the sides of the sheets after 250 washings were similar to those of the center after 200 launderings, while the chemical values of these sides were approximately equal to the centers after 225 launderings. The final conclusion drawn was that there was no significant difference between the two types of sheeting as affected by use.[29]

The latest study made on the serviceability of sheets was done by McLendon and Davidson of the United States Departmeht of Agriculture in 1955. The sheets used in this study were composed wholly or in part of cotton and viscose staple yarn. Three types of fabrics were used: all cotton, one-half cotton and one-half viscose, all rayon. The yarns and sheetings were made with certain specifications. The conclusions drawn were that the all cotton sheeting had the highest breaking strength, followed by the all rayon blends. The all rayon fabric showed the greatest elongation (both wet and dry) but the all cotton had a greater elongation than most of the blended fabrics.[30]

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[29] R. E. Rogers, M. B. Hays and J. T. Wigington. Manufacture and Serviceability Tests on Sheeting Made Two Selected Mill Types of Cotton, United States Department of Agriculture, Technical Bulletin 645 (Washington, Government Printing Office, 1939), pp. 30-31.

[30] V. I. McLendon and Suzanne Davidson, Serviceability of Sheets Composed Wholly Or In Part of Cotton and Viscose Staple Yarn, United States Department of Agriculture, Technical Bulletin 1103 (Washington: Government Printing Office, 1955), p. 8.

CHAPTER III

METHOD OF PROCEDURE

Since this is a pilot study of the Regional Research Project SM-18, part of the data and procedures used in this study are taken from that project.[1] The testing procedures for thread count, fabric weight and dimensional change as formulated for the Regional Project were based on procedures given in the *ASTM Standards on Textile Materials* for November, 1957.

Selection and Use of Sheets

Selection of Raw Fiber

The sheets used in the study were made from four types of experimental strains of cotton. All four are normal cottons and were carefully selected for their similarity in length, strength and fineness. The chief difference was in fiber elongation. The fiber was spun and woven into type 140 muslin sheeting. The sheeting was then made into single bed sheets according to commercial specifications.[2]

Use in Dormitories

The sheets were used weekly as bottom sheets in the girls' dormitories at The Woman's College of the University of North Carolina. At the end of each week the sheets were collected, checked and sent to a commercial laundry. Each sheet was coded and had a log record indicating

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[1] Technical Committee Project SM-18, "The Relation of Selected Properties of Raw Cottons to Product Quality and End Product Performance," (Manual of Procedures, Southern Regional Research Project SM-18).

[2] *Ibid.*, p. 2.

the number of nights and approximate number of hours of use, number of launderings and notations on periodic inspection. Each student participating in the study kept a weekly record of the number of nights and approximate number of hours the sheets were used.[3]

Withdrawal for Testing

All sheets were desized before coding by a normal commercial laundering procedure. Six sheets of each type to be used as originals or at the zero interval were taken out and marked for all test areas. Six sheets of each type to be used for laboratory tests were withdrawn at the fifth and fifteenth intervals.

Laundering Procedure

The laundering procedure was a normal commercial procedure. The sheets were washed in a 200 pound load according to the following procedure:

Wash Procedure

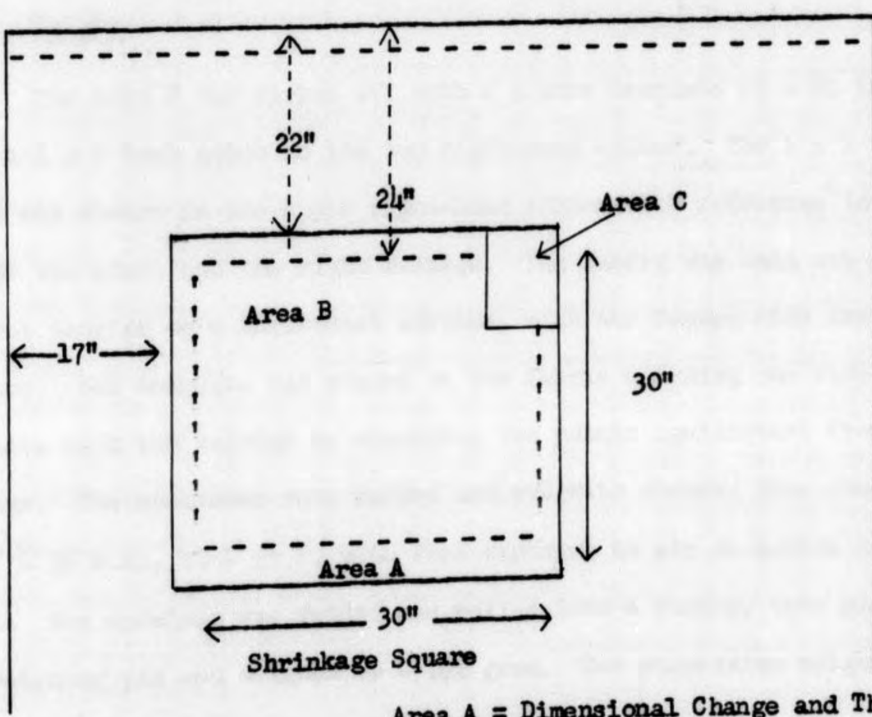
	Water level in washer (inches)	Temperature °F.	Time in minutes
Sudsing			
1	6	140	8
2	6	150	8
3	6	160	8
4	—	—	—
Rinses			
1	12	Hot	5
2	12	Hot	3
3	12	Split	3
4	12	Cold	3
Sour			
5	12	Cold	3

[3] Ibid., p. 8.

The chemicals used in the laundering procedure were (1) a stock soap solution of a high titer soap, alkali and water; (2) bleach; and (3) sour.[4]

Laboratory Tests

The testing area of each sheet was marked. One 30 x 30 inch square on each sheet, 22 inches from the top edge was marked for dimensional change. Area A was marked within the shrinkage square by using a template which was placed 24 inches from the top edge and the center was placed at the center of the sheet. Tests made in North Carolina and the ones used in this study were taken from the areas as designated.[5]



Area A = Dimensional Change and Thread Count
Area B = Fabric Weight
Area C = Wrinkle Recovery

[4]Information supplied by Lane's Laundry, Greensboro, North Carolina.

[5]*Manual of Procedures*, Southern Regional Research Project SM-18, *op. cit.*, p. 5.

Thread Count

Thread count is the number of yarns per inch in the warp and filling directions. A thread count was made on all sheets used in the study. The number of warp yarns in one inch of the fabric was counted with a pick counter in two places in Area A of the sheets. The two counts were made in places which differ in both warp and filling yarns and was made in approximately the same two places before and after laundering. The average number of warp yarns was calculated.

The number of filling yarns per inch was determined by the same procedure.[6]

Fabric Weight

The Area B was marked off with a square template 21 x 21 inches with a 1 x 2 inch notch in the top right-hand corner. The 1 x 2 inch notch was always in the upper right-hand corner with reference to the top of the sheet and the right selvage. The fabric was laid out smooth without tension on a horizontal surface, with the hemmed side facing the surface. The template was placed on the fabric aligning one side of the template with the selvage by measuring two points equidistant from the selvage. The specimens were marked and cut with shears, then conditioned at 65 ± 2% r.h., 70 ± 2° F. with free exposure to air in motion for 24 hours. The specimen was folded and rolled into a bundle, then placed on the weighing pan and weighed to ± .01 gram. Two successive weighings were made at 15 minute intervals.

An analytical balance weighing accurately to 0.001 grams was used to weigh the specimen.

[6] Ibid., p. 12.

The weight determined was the weight of 439 square inches of fabric. This result was multiplied by a constant factor of .1041 to produce the weight of the fabric in ounces per square yard. It was reported to the nearest 0.001 ounces.[7]

Dimensional Change

The specimen for the determination of dimensional change was a 30 inch square taken on each sheet numbered 1 through 15. This square was marked on the wrong side of the sheet and located exactly 22 inches from the top of the wide hem and 17 inches in from the left selvage.

The sheets were laid out without tension on a flat surface. The distance determined by means of a 36 inch steel rule (marked off in hundredths of an inch) and a metal T-square was marked with a permanent type laundry pencil. Three distances each of 30 inches was marked on the specimen in both warp and filling directions. The distances were parallel to the warp and filling threads, at least 10 inches apart.

To determine the dimensions after the 5th and 15th launderings, the sheets were laid out on a flat surface and measured to the nearest 0.10 inches at the marked distances.

The dimensional change was calculated. The averages obtained from the three marked distances in the warp and the filling directions were used to determine the percentage dimensional change. This change in laundering was either the increase or decrease and was expressed as a percentage of the original dimension. The following formula was used:

$$\frac{\text{Original - laundered fabric}}{\text{Original}} \times 100$$ [8]

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[7] Ibid., p. 13.

[8] Ibid., p. 12.

Wrinkle Recovery

The instrument used to determine the wrinkle recovery was the Monsanto Wrinkle Recovery Tester.

Five warp and five filling specimens from Area C were cut 1.5 cm. wide and 4 cm. long. They were conditioned at 65 ± 2% r.h., 70 ± 2° F for twelve hours. The specimens were exposed separately, flat and free from wrinkles.

The test specimens were placed between the metal leaves of the specimen holder with one end flush with the longer metal strip. The exposed end was turned back so that the edge fell on a line on the shorter metal leaf. The metal holder was inserted into the plastic press. The side of the plastic press having the small raised platform was outside of and parallel to the longer metal strip of the holder. The flat, thicker side of the holder was brought into contact with the fabric at the left thumbnail and the press was closed to form a crease about 1/16 inch from the end of the thin metal leaf. This produced the maximum amount of crease. The press holder was placed on the table top with the small platform upward. A load of 500 grams was applied to the platform for five minutes. The weight was removed and the specimen mounted into the tester. The crease was aligned with a spot at the center of the outer disc of the tester and the dangling leg of the specimen was aligned with the vertical guide line on the back panel. The degree of recovery was read after a five minute period.[9]

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[9] Monsanto Wrinkle Recovery Tester, Bulletin No. T-7, A Book of Instructions Prepared by the Monsanto Chemical Company, Boston 10, Massachusetts, p. 3.

Analysis of Data

An analysis of variance was the statistical procedure used to indicate the significance of differences in the cottons of high and low fiber elongation. Variability among the sheets in tests performed was first subdivided into that associated with the differences among sheets made of the four fabric types. The three degrees of freedom used were then broken into individual degrees of freedom to make a comparison of the 3100 as compared to the 3400 series and of the 3200 as compared to the 3300 series. Orthogonal comparisons provide for this analysis. The five per cent level of significance was chosen as the point beyond which a null hypothesis would be rejected.

The statistical procedure was programmed and the analyses were computed by the Remington Rand Univac 1105 Computer.

CHAPTER IV

PRESENTATION OF DATA

Fiber Properties

The fiber properties of the four types of cotton used in the sheetings made for the regional project conformed to the plan for the selection of cottons. The four types of cotton were similar in length, strength and fineness but differed in elongation. Table I is a summarization of the results of fiber tests performed at the Texas Agricultural Experiment Station; the Louisiana State University; and the Southern Utilization Research and Development Division of the United States Department of Agriculture.

All four cottons were considered normal cottons. The x-ray angles and photomicrographs of cross sections and tests for maturity, color and cavitoma were considered good.

The chief difference in the four cottons was that of fiber elongation. Two types, Stardel 674235 (3100 series) and Magnolia 567063 (3200 series) represented cottons of low fiber elongation. The other two types, EBU-52 Magnolia 941817 (3300 series) and EBU-43 Magnolia 948243 (3400 series) represented cottons of high elongation. Because of the similarity in properties other than elongation, the sheets were paired so as to make it possible to compare the performance features of the sheetings and to determine differences due to fiber elongation.

Cottons in the 3100 series with a fiber elongation of 6.56 per cent were compared with those of the 3400 series with a fiber elongation

TABLE I

FIBER PROPERTIES

Properties	Variety of Cotton: Stardel 624235 (3100)	Magnolia 567063 (3200)	EBU-52 Magnolia 941817 (3300)	EBU-43 Magnolia 948243 (3400)
Fiber length array[1]				
Upper Quartile (Inches)	1.20	1.15	1.22	1.21
Mean Length (Inches)	.98	.95	1.00	1.01
Coefficient of variation (per cent)	31	29	30	29
Maturity (Per Cent)[1]				
Array	89	82	82	84
Causticaire	81	77	77	79
Polarized Light	87	82	78	80
Fineness (Micrograms per inch)[2]	4.68	4.15	4.38	4.03
Strength[2]				
Pressley "O" Gauge	8.66	8.64	7.32	7.30
Stelometer "1/8" Gauge (grams/tex)	20.10	19.26	18.50	18.23
Elongation (Per Cent)[2]	6.56	6.36	9.93	10.10

[1]Fiber data from Texas Agricultural Experiment Station.

[2]Fiber data from Louisiana State University and the Southern Utilization Research and Development Division of the United States Department of Agriculture.

of 10.10 per cent. The pair of cottons used as a replicate were the 3200 series with an elongation of 6.36 and the 3300 series with an elongation of 9.93 per cent.

Yarn and Fabric Construction

The four bales of cotton were processed into yarn and sheeting at Clemson College. Data pertaining to the yarn processing is given in Table II.

TABLE II

YARN PROCESSING[1]

Variety of Cotton	Single Strand Strength (gm.)	Single Elongation (%)	Uster Eveness (%U)	Corrected[2] Skein Strength (lb.)	Ends Down Per 1,000 Spindle Hours (ends)
Stardel 624235					
Warp	501	6.5	15.9	127.9	8.04
Filling	441	5.6	17.7	114.1	13.82
Magnolia 567063					
Warp	489	6.4	16.7	125.5	7.65
Filling	441	7.0	17.3	106.5	18.27
Magnolia EBU-52					
Warp	408	7.7	16.8	112.7	11.55
Filling	385	7.8	17.8	98.3	8.68
Magnolia EBU-43					
Warp	423	8.7	18.7	111.3	3.88
Filling	403	8.7	18.1	95.6	9.44

[1]Yarn data from Textile School, Clemson College, South Carolina.

[2]Strength adjusted to strength of 22.0's yarn.

The sheetings were woven at Clemson College according to specifications usually used for cottons of this quality and finished by a nearby manufacturer according to procedures used for type 140 sheets. These specifications are as follows:

Width................	Greige 72"
Weight...............	4.6 ounces per square yard
Thread Count.........	140 (72" x 68")
Yarn Number..........	22's
Twist Multiplier.....	4.50 warp, 3150 filling
Finished Width.......	63"
Finished Length......	108" torn length, 3" top hem, 1" bottom hem
Bleaching............	Peroxide (continuous process)
Sizing...............	Starch content 1-2%, wetting agent, whitener
Sanforized	

Descriptive Data Pertaining to Use of Sheets

Coding. A colored thread was woven into the selvage of each sheet to designate the type of cotton used. Each sheet was coded by using Arabic numbers. The number 3000 represented sheets used in North Carolina. The second digit represented the fabric type and the last two digits represented the sheet number.

Extent of Use. A record was kept of the (1) number of nights and hours of use, (2) the number of launderings and (3) any comments about the sheets. Table III shows the amount of time each sheet was used.

At the fifth laundering interval the mean number of nights and hours the sheets in each series had been used varied only slightly. The mean number of nights three of the fabric types (3200, 3300, and 3400) were used was 31.16 hours. That of the 3100 series was 32.33. The mean number of hours of use ranged from 225.50 in the 3300 series to 239.45 hours in 3100 series or a difference of approximately 14 hours.

TABLE III

TIME SHEETS WERE USED

Fabric type		Number of Launderings					
		Sheet number	Five		Sheet number	Fifteen	
			Number of nights	Number of hours		Number of nights	Number of hours
3100		01	33	228.25	07	97	735.75
		02	32	255.00	08	101	740.25
		03	34	246.50	09	98	734.75
		04	30	214.00	10	101	763.50
		05	32	246.00	11	99	742.25
		06	33	247.50	12	93	681.00
	Total		194	1436.75		589	4397.50
	Mean		32.33	239.45		98.16	732.91
3200		01	34	253.50	07	100	747.00
		02	29	202.75	08	98	730.25
		03	31	231.50	09	93	647.75
		04	32	248.50	10	96	705.50
		05	29	217.00	11	91	674.00
		06	32	232.75	12	89	647.50
	Total		187	1385.00		567	4152.00
	Mean		31.16	230.83		94.50	692.00
3300		01	34	251.50	07	98	699.50
		02	28	198.50	08	95	650.25
		03	28	220.50	09	94	690.75
		04	34	243.00	10	93	715.25
		05	33	230.00	11	96	696.50
		06	30	209.50	12	97	686.00
	Total		187	1353.00		573	4138.25
	Mean		31.16	225.50		95.50	689.70
3400		01	34	254.00	07	98	686.00
		02	32	230.50	08	96	689.50
		03	29	210.00	09	95	719.25
		04	30	212.50	10	97	708.25
		05	34	239.25	11	94	686.00
		06	28	227.75	12	96	703.25
	Total		187	1374.00		576	4192.25
	Mean		31.16	229.00		96	698.71

There was very little difference at the fifteenth interval in the mean number of nights the four fabric types were used. There was a greater variability in the mean number of hours of use, ranging from 689.70 hours in the 3300 series to 732.91 hours in the 3100 series.

Student Preferences. While handling the sheets, the laboratory assistants noticed differences in the quality of the fabrics. As a matter of curiosity, an opinionnaire was sent to the students who had slept on the sheets to see whether they had noticed any differences. A total of 57 opinionnaires were distributed and returned. Fifty-one per cent of the students had not noticed any differences in the sheets. Forty-nine per cent of the students had noticed differences and ranked the sheets in the order as shown in Table IV. The sheets of the 3200 series were ranked first by the majority of the students as to the fineness of quality of cloth, smoothness, coolest, most comfortable, and most resistant to wrinkling. The 3100 series was placed second in regard to the above qualities. The 3100 series ranked first according to soil resistance. According to the results of the opinionnaire, there was little noticeable difference in the quality of the sheets of the 3300 and 3400 series. The results indicated that the sheets made from cottons of low fiber elongation possessed more desirable qualities, as noticed by the users, than those of high fiber elongation.

TABLE IV

STUDENT'S RANK ORDER OF SHEET QUALITIES

Qualities	Series			
	3100	3200	3300	3400
Fine quality cloth	2	1	4	3
Feels smooth	2	1	3	4
Cool and comfortable	2	1	3.5	3.5
Resists wrinkling	2	1	3.5	3.5
Resists soiling	1	2	4	3

Results of Laboratory Tests

Six sheets from each series were withdrawn from the study at the zero, five, and fifteen laundering intervals for laboratory testing. The tests performed on the sheets in North Carolina and those used in this study were thread count, fabric weight, dimensional change and wrinkle recovery. Detailed results of the laboratory tests performed at the original, fifth and fifteenth intervals are found in Table V.

Thread Count. The mean warp thread count for the four fabric types ranged from 75.6 to 76.4 at the original interval. The mean filling thread count ranged from 69.5 to 70.9.

At the fifth laundering interval the mean warp thread count of the four fabric types ranged from 73.3 to 74.2 as compared to a range of 70.2 to 72.9 in the mean filling thread count.

The mean warp thread count at the fifteenth interval ranged from 75.0 to 75.8. The mean filling thread count ranged from 71.1 to 72.8.

There was a slight decrease in the mean warp thread count after the fifth laundering. The mean warp thread count at the fifteenth interval showed a slight decrease from the fifth interval. The mean filling thread count showed an increase at the fifth interval and an increase after the fifteenth interval in the 3100 and 3300 series. There was a slight increase in the mean filling thread count of the 3200 and 3400 series at the fifteenth interval. These changes were probably due to the dimensional change in the sheets after laundering.

Weight Per Square Yard. The differences in the weight per square yard of the sheets in each series was slight at the original interval.

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There was a slight decrease in the mean warp thread count after the fifth laundering. The mean warp thread count at the fifteenth interval showed a slight decrease from the fifth interval. The mean filling thread count showed an increase at the fifth interval and an increase after the fifteenth interval in the 3100 and 3300 series. There was a slight increase in the mean filling thread count of the 3200 and 3400 series at the fifteenth interval. These changes were probably due to the dimensional change in the sheets after laundering.

Weight Per Square Yard. The differences in the weight per square yard of the sheets in each series was slight at the original interval.

TABLE V

RESULTS OF LABORATORY TESTS

Sheet Number		Zero Laundering Interval				
		Thread Count		Weight Per Square Yard (Ounces)	Wrinkle Recovery (Degrees)	
		Warp	Filling		Warp	Filling
3143		76.5	70.5	4.903	73.6	73.6
3144		76.5	70.5	4.967	71.4	71.6
3145		76.5	69.0	4.826	69.4	68.2
3146		76.5	69.0	4.879	73.2	78.0
3147		75.0	68.5	4.840	68.8	63.6
3148		76.5	70.0	4.892	71.6	74.6
	Total	457.5	417.5	29.307	428.0	429.6
	Mean	76.2	69.5	4.884	71.3	71.6
3243		77.5	70.5	4.812	68.2	75.8
3244		77.0	69.5	4.804	71.0	75.8
3245		76.5	71.0	4.830	73.0	65.0
3246		77.0	70.5	4.914	71.2	74.2
3247		75.0	70.0	4.889	79.4	74.6
3248		75.5	69.5	4.878	72.6	75.6
	Total	458.5	421.0	29.127	435.4	441.0
	Mean	76.4	70.1	4.843	72.6	73.5
3343		75.0	71.5	4.895	72.2	78.6
3344		76.0	72.0	4.844	69.4	73.6
3345		75.5	70.0	4.824	71.4	70.4
3346		75.5	71.5	4.863	64.4	73.0
3347		76.0	71.0	4.817	71.0	71.0
3348		75.5	69.5	4.812	76.0	71.0
	Total	453.5	425.5	29.308	424.4	437.6
	Mean	75.6	70.9	4.842	70.7	72.9
3443		76.0	70.5	4.943	73.8	71.8
3444		78.0	69.0	5.018	66.8	69.8
3445		76.0	70.5	4.926	74.6	75.6
3446		75.5	69.5	4.914	68.8	70.6
3447		75.5	70.5	4.857	75.6	77.6
3448		75.0	71.0	4.809	73.4	73.6
	Total	456.0	421.0	29.467	433.0	439.0
	Mean	76.0	70.2	4.911	72.2	73.2

TABLE V (continued)

Sheet Number		Fifth Laundering Interval						
		Thread Count		Weight per Sq.Yd. (Oz.)	Dimensional Change (Per Cent)		Wrinkle Recovery (Degrees)	
		Warp	Filling		Warp	Filling	Warp	Filling
3101		72.5	71.0	4.950	-2.73	+2.67	72.4	82.2
3102		76.0	68.0	4.853	-1.40	+1.17	74.4	80.2
3103		74.5	71.5	4.928	-1.80	+1.83	78.6	85.8
3104		74.0	69.5	4.809	-0.56	+1.76	79.2	77.4
3105		73.5	70.0	4.933	-1.56	+0.67	80.6	80.6
3106		74.5	71.0	4.978	-1.73	+1.53	78.6	81.6
	Total	445.0	421.0	29.451	-9.78	+9.63	463.8	487.8
	Mean	74.2	70.2	4.908	-1.63	+1.60	77.3	81.3
3201		72.5	74.5	4.855	-1.06	+2.83	73.8	79.8
3202		75.5	73.5	4.820	-1.33	+1.50	79.8	79.8
3203		74.0	72.0	4.911	-1.83	+1.86	75.6	82.0
3204		72.0	73.5	4.849	-2.06	+3.16	73.8	79.0
3205		74.0	72.0	4.828	-1.33	+2.00	75.0	76.6
3206		74.0	72.0	4.812	-2.06	+2.33	68.8	70.4
	Total	442.0	437.5	29.075	-9.67	+13.68	446.8	467.6
	Mean	73.7	72.9	4.845	-1.61	+2.28	74.5	77.9
3301		73.0	73.0	4.879	-2.30	+0.16	70.6	81.8
3302		74.0	71.5	4.865	-1.46	+1.26	72.6	80.6
3303		73.0	73.5	4.845	-1.40	+1.16	77.6	82.2
3304		74.0	72.5	4.863	-1.00	-0.13	74.6	80.2
3305		75.0	72.5	4.851	-1.93	+0.90	76.0	78.8
3306		73.0	69.5	4.860	-2.06	+1.13	74.4	77.0
	Total	442.0	432.5	29.163	-10.15	+4.48	445.8	480.6
	Mean	73.7	72.1	4.860	-1.69	+0.74	74.3	80.1
3401		73.0	72.0	4.882	-2.23	+2.70	78.0	79.2
3402		73.5	71.0	4.839	-2.00	+1.67	77.0	81.4
3403		74.0	71.5	4.856	-1.33	+1.83	76.8	78.4
3404		73.0	73.0	4.880	-2.23	+2.93	79.0	84.2
3405		73.0	70.0	4.841	-2.00	+2.43	77.2	82.0
3406		73.5	71.0	4.858	-0.66	+1.83	78.4	83.4
	Total	440.0	428.5	29.156	-10.45	+13.39	466.4	488.6
	Mean	73.3	71.4	4.859	-1.74	+2.23	77.7	81.4

TABLE V (continued)

Sheet Number		Fifteenth Laundering Interval					
	Thread Count		Weight per Sq.Yd. (Oz.)	Dimensional Change (Per Cent)		Wrinkle Recovery (Degrees)	
	Warp	Filling		Warp	Filling	Warp	Filling
3107	74.5	70.5	4.808	-1.63	+0.67	76.2	78.8
3108	76.0	71.0	4.896	-2.00	+1.33	73.8	78.0
3109	75.5	71.5	4.857	-1.40	+0.93	73.2	78.4
3110	74.0	72.5	4.865	-1.90	-0.30	77.4	81.6
3111	75.0	71.5	4.856	-2.13	+1.03	73.8	77.2
3112	75.0	72.5	4.829	-1.46	+1.00	77.2	79.8
Total	450.0	429.5	29.171	-10.52	+4.66	451.6	473.8
Mean	75.0	71.6	4.852	-1.75	+0.78	75.3	79.0
3207	76.5	73.5	4.871	-1.80	-0.13	73.0	83.8
3208	76.0	71.0	4.818	-2.63	0.00	82.0	81.4
3209	74.0	73.0	4.807	-1.17	+1.03	77.0	82.8
3210	75.0	72.0	4.820	-1.57	+0.33	79.0	85.8
3211	76.5	72.5	4.813	+1.47	-0.50	78.4	78.6
3212	75.0	71.0	4.900	-2.46	+0.33	72.6	77.6
Total	453.0	433.0	29.029	-11.10	+1.06	462.0	490.0
Mean	75.5	72.2	4.838	-1.85	+0.18	77.0	81.7
3307	75.0	73.0	4.804	-2.73	+0.27	77.6	78.0
3308	76.5	72.5	4.747	-2.06	-0.63	76.6	78.6
3309	74.5	73.0	4.709	-1.80	+0.53	70.2	74.0
3310	74.5	74.0	4.787	-2.33	+0.60	75.6	80.4
3311	74.5	71.5	4.834	-2.00	+0.86	79.0	83.2
3312	76.0	73.0	4.786	-1.80	-0.30	74.0	80.4
Total	451.0	437.0	28.667	-12.72	+1.33	453.0	474.6
Mean	75.2	72.8	4.778	-2.12	+0.22	75.5	79.1
3407	76.5	71.5	4.840	-2.16	+0.36	81.4	79.4
3408	75.5	72.5	4.855	-1.16	+0.03	79.2	84.6
3409	75.5	69.0	4.855	+0.63	+0.67	73.6	87.0
3410	74.0	72.0	4.734	-1.33	+1.43	78.0	80.6
3411	75.5	71.5	4.874	-2.40	+1.70	79.6	83.4
3412	78.0	70.0	4.759	-0.57	-0.57	80.0	81.4
Total	455.0	426.5	28.917	-8.25	+3.62	471.8	496.4
Mean	75.8	71.1	4.819	-1.37	+0.60	78.6	82.7

The mean weight per square yard of the four fabric types ranged from 4.911 ounces in the 3400 series to 4.842 in the 3300 series.

There was a slight increase in the mean weight per square yard of the sheets after the fifth laundering interval, but a slight decrease in the mean weight per square yard after the fifteenth laundering interval.

Dimensional Change. The dimensional change of the sheets in the four fabric types at the fifth laundering interval was a shrinkage ranging from 1.61 per cent to 1.74 per cent in the warp direction and a stretch in the filling direction ranging from 0.74 per cent to 2.28 per cent. At the fifteenth interval the range of shrinkage in the warp direction was 1.37 per cent to 2.12 per cent and the range of stretch was 0.18 per cent to 0.78 per cent in the filling. There was a slight increase in the amount of shrinkage in the warp direction from the fifth to the fifteenth laundering interval in each series except the 3400, in which there was a slight decrease. There was a decrease in the amount of stretch in the filling direction in each series of sheets at the fifteenth laundering interval.

Wrinkle Recovery. The mean number of degrees of wrinkle recovery in the warp direction of the four fabric types ranged from 70.7 to 72.6. The mean number of degrees of wrinkle recovery in the filling direction ranged from 71.6 to 73.5 at the original interval. At the fifth laundering interval, there was an increase in the mean number of degrees of wrinkle recovery in both the warp and filling directions. The mean number of degrees of wrinkle recovery in the warp direction at the fifth interval ranged from 74.3 in the 3300 series to 77.7 in the 3400 series.

The mean number of degrees of wrinkle recovery in the filling direction at the fifth interval ranged from 77.9 in the 3200 series to 81.4 in the 3400 series.

With the exception of the 3100 series there was a slight increase in the mean number of degrees of wrinkle recovery in the warp direction at the fifteenth laundering interval. There was a decrease in the mean number of degrees of wrinkle recovery in the filling direction of the 3100 series and the 3300 series. However, the 3200 series and the 3400 series showed a slight increase in degrees of wrinkle recovery.

Statistical Analysis of the Data

The purpose of this study, part of a larger research project, was to determine differences in the sheetings made from cottons of low and high fiber elongation through the fifteenth laundering interval. The data for the larger study will be collected from four states and will involve many tests in addition to those used in this study. Since the data for the complete project will be extensive, this study served as a pilot study to develop a statistical procedure which would indicate significance of differences in the cottons and to program the statistical procedure for the Remington Rand Univac 1105 Computer.

Experimental Design. Variability among the sheets in tests performed was first subdivided into that associated with the differences among sheets made of the four fabric types and the difference among sheets within the same series.

Sheets from the 3100 and 3200 series were made from fibers of low elongation and sheets from the 3300 and 3400 series were made from fibers of high elongation. Since sheets from the 3100 series and the 3400 series were very similar in fiber properties (length, strength, fineness and maturity), but differed in fiber elongation; they were considered a pair. Similarly, sheets of the 3200 and 3300 series were made a pair. Comparison of the 3100 and 3400 series and of the 3200 and 3300 series would be comparisons between sheets made with fibers of low and high elongation. These comparisons were planned in advance of the examination of the experimental results.

The three degrees of freedom used in the analysis of the differences among sheets made of the four types of fabrics were broken into individual degrees of freedom. The following selected treatment comparisons were used.

TABLE VI

SYMBOLIC REPRESENTATION OF SELECTED TREATMENT COMPARISONS

Comparisons	Fabric Types 3100	3200	3300	3400
C_1 - 3100 and 3400 series vs. 3200 and 3300 series	+1	-1	-1	+1
C_2 - 3100 vs. 3400 series	+1	0	0	-1
C_3 - 3200 vs. 3300 series	0	+1	-1	0

Orthogonal comparisons in this table provided for comparisons of the two pairs of sheets and comparisons between the sheets within each pair, ignoring the other pair. The latter comparisons were the most important since this was comparing sheets made from fibers of low elongation with sheets made from fibers of high elongation.

The five per cent level of significance was chosen as the point beyond which a null hypothesis would be rejected. The method presented by Ostle was used in computing the analysis of variance.[1]

Sheets were submitted to laboratory tests and the data analyzed (1) at the zero interval, (2) after five launderings and (3) after fifteen launderings.

Program for Computation. The Remington Rand Univac 1105 Data Automation System in the Research Computation Center of the Consolidated University of North Carolina was available for the processing of data. Following a series of six lectures on the preparation of programs for the computer, the statistical procedure was translated into the IT (Internal Translator) language. The data from each of the laboratory tests were recorded on paper tape. Punched cards were used to interpret to the IT compiler the allocation of the storage of data and the statements necessary for the solution of the problem. The program developed in the IT language is shown below.

```
N 0006  Y 0024  Z 0027  S 0024  W 0000          H
                                                F
N1 : 6                                          F
N2 : 24
```

[1]Bernard Ostle, Statistics in Research, (Ames: Iowa State College Press): 1957, p. 267.

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```
N 0006  Y 0024  Z 0027  S 0024  W 0000              H

N1 : 6                                              F
N2 : 24                                             F
```

[1]Bernard Ostle, Statistics in Research, (Ames: Iowa State College Press); 1957, p. 267.

```
            N3 : 3                                              F
            N4 : 20                                             F
            N5 : 4                                              F
            N6 : 2                                              F

0001        Y1 T# Y24, ###n#Y, INPUT                            F
            Z1 : Y1 + Y2 + Y3 + Y4+ Y5+ Y6                      F

            Z2 : Y7 + Y8 + Y9 + Y10 + Y11 + Y12                 F

            Z3 : Y13 + Y14 + Y15 + Y16 + Y17 + Y18              F

            Z4 : Y19 + Y20 + Y21 + Y22 + Y23 + Y24              F

0002        T (1)  TZ1                                          F
0003        T (2)  TZ2                                          F
0004        T (3)  TZ3                                          F
0005        T (4)  TZ4                                          F

            Z5 :  (Y1 x Y1) + (Y2 x Y2) + (Y3 x Y3) +

                  (Y4 x Y4) + (Y5 x Y5) + (Y6 x Y6)             F

            Z6 :  (Y7 x Y7) + (Y8 x Y8) + (Y9 x Y9) + (Y10 x Y10) +

                  (Y11 x Y11) + (Y12 x Y12)                     F

            Z7 :  (Y13 x Y13) + (Y14 x Y14) + (Y15 x Y15) + (Y16 x

                  Y16) + (Y17 x Y17) + (Y18 x Y18)              F

            Z8 :  (Y19 x Y19) + (Y20 x Y20) + (Y21 x Y21) +

                  (Y22 x Y22) + (Y23 x Y23) + (Y24 x Y24)       F

0006        T (5)  TZ5                                          F
0007        T (6)  TZ6                                          F
0008        T (7)  TZ7                                          F
0009        T (8)  TZ8                                          F

            Z9  :  Z1/N1                                        F

            Z10 :  Z2/N1                                        F

            Z11 :  Z3/N1                                        F

            Z12 :  Z4/N1                                        F
```

```
0010    T (9)  TZ9                                        F
0011    T (10) TZ10                                       F
0012    T (11) TZ11                                       F
0013    T (12) TZ12                                       F

        Z13 : Z1 + Z2 + Z3 + Z4                           F

        Z14 : Z5 + Z6 + Z7 + Z8                           F

        Z15 : (Z13 x Z13)/N2                              F

        Z16 : Z14 - Z15                                   F

0014    T(16)  TZ16                                       F

        Z17  :  (((Z1 x Z1) + (Z2 x Z2) + (Z3 x Z3) +
        (Z4 x Z4))/N1) - Z15                              F

0015    T(17)  TZ17                                       F

        Z18 : Z17/N3                                      F

0016    T(18)  TZ18                                       F

        Z19 : (Z16 - Z17)/N4                              F

0017    T(19)  TZ19                                       F

        Z20 : Z18/Z19                                     F

0018    T(20)  TZ20                                       F

        Z21 : (Z1 + Z4) - (Z2 + Z3)                       F

        Z22 : (Z21 x Z21)/(N5 x N1)                       F

0019    T(22)  TZ22                                       F

        Z23 : ((Z1 - Z4) x (Z1 - Z4)/(N6 x N1)            F

0020    T(23)  TZ23                                       F

        Z24 : ((Z2 - Z3) x Z2 - Z3))/N6 x N1)             F

0021    T(24)  TZ24                                       F

        Z25 : Z22/Z19                                     F

        Z26 : Z23/Z19                                     F

        Z27 : Z24/Z19                                     F
```

```
0022    T(25)  TZ25                                       F
0023    T(26)  TZ26                                       F
0024    T(27)  TZ27                                       F
        G1                                                FF
```

In this program, N values were assigned to fixed numbers as follows:

N1 = 6 (number of tests in each series)
N2 = 24 (the total number of tests for all four series.
N3 = 3 (the degrees of freedom among sheets of the four fabric types).
N4 = 20 (the degrees of freedom within sheets of the four fabric types).
N5 = 4 (the number of fabric types)
N6 = 2 (fabric types in each comparison)

There was a total of 24 tests for each variable. Each test result was assigned Y values as follows:

3100 series = Y1 to Y6
3200 series = Y7 to Y12
3300 series = Y13 to Y18
3400 series = Y19 to Y24

Computations used in completing tables were taken from the following statements in the program.

Z1 = total results of laboratory tests in the 3100 series.
Z2 = " " " " " " " 3200 "
Z3 = " " " " " " " 3300 "
Z4 = " " " " " " " 3400 "

Z9 = the mean of the results of the 3100 series.
Z10= " " " " " " " 3200 "
Z11= " " " " " " " 3300 "
Z12= " " " " " " " 3400 "

Z20= F value for among sheets of the four fabric types
Z25= F value for comparison C1 in Table 6
Z26 = F value for comparison C2 in Table 6
Z27= F value for comparison C3 in Table 6

Analysis of Thread Count. The first variable analyzed was thread count. There was no evidence that the first hypothesis should be rejected. This hypothesis was: there is no initial difference in warp thread count among sheets of the four fabric types. The analysis is reported in Table VII.

TABLE VII

ANALYSIS OF VARIANCE OF WARP THREAD COUNT AT THE ZERO INTERVAL

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F	F .05
Among sheets of four fabric types	3	2.36	0.79	1.23	3.10
Within sheets made of the same fabric type	20	12.80	0.64		
Total	23	15.16			

Analysis of the filling thread count indicated that there was no initial difference in the filling thread count among sheets of the four fabric types. These sheets were similar in both warp and filling thread count at the zero interval.

Six hypotheses concerning initial differences in warp and filling thread count were tested by breaking the two above analyses into individual degrees of freedom. Those hypotheses used are listed below.

1. There is no initial difference in the warp thread count between sheets of the 3100 and 3400 series as compared to the 3200 and 3300 series.

2. There is no initial difference in the warp thread count between sheets of the 3100 and 3400 series.

3. There is no initial difference in the warp thread count between sheets of the 3200 and 3300 series.

4. There is no initial difference in the filling thread count between sheets of the 3100 and 3400 series as compared to the 3200 and 3300 series.

5. There is no initial difference in the filling thread count between sheets of the 3100 and 3400 series.

6. There is no initial difference in the filling thread count between sheets of the 3200 and 3300 series.

When the above hypotheses concerning warp thread count were analyzed (Table VIII), the F values were 0.14, 0.29 and 3.25, numbers which were not significant at the five per cent level of probability.

TABLE VIII

ANALYSIS OF VARIANCE OF WARP THREAD COUNT AT THE ZERO INTERVAL

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F	F .05
3100 and 3400 series vs. 3200 and 3300 series	1	0.09	0.09	0.14	4.35
3100 series vs. 3400 series	1	0.19	0.19	0.29	
3200 series vs. 3300 series	1	2.08	2.08	3.25	
Within sheets made of the same fabric type	20	12.80	0.64		
Total	23	15.16			

Analysis of the filling thread count in regard to the hypotheses listed above indicated that there were no significant differences in filling thread count at the zero interval. Similar hypotheses were tested to see if there were significant differences in warp and filling thread count after the sheets had been laundered five times and after they had been laundered fifteen times. The same kinds of analyses performed at the zero interval were performed at these intervals.

When the warp thread count was analyzed after the fifth laundering interval, the F values were not significant in either of the analyses. Therefore, the null hypotheses were not rejected.

When the filling thread count was analyzed after the fifth laundering, the hypothesis that there is no difference in filling thread count among sheets of the four fabric types was rejected. The F value was 5.49 (Table IX). Examination of the means (Table X) shows that sheets

TABLE IX

F VALUES OF DIFFERENCES IN THREAD COUNT OF SHEETS

Source of Variation	Periods of Use					
	Zero		Fifth		Fifteenth	
	Warp	Filling	Warp	Filling	Warp	Filling
Among sheets made from the four fabric types	1.23	2.73	0.70	5.49*	0.81	3.32*
3100 and 3400 series vs. 3200 and 3300 series	0.14	4.07	0.04	11.89*	0.41	7.93*
3100 vs. 3400	0.29	1.56	2.21	3.18	2.07	0.73
3200 vs. 3300	3.25	2.57	0.00	1.41	0.33	1.29

*Significant at the 0.5 level of probability.

from the 3200 and 3300 series had the highest filling thread counts. The mean filling thread counts of the 3100 and 3400 series after the fifth laundering were lower, 70.2 and 71.4.

TABLE X

MEAN FILLING THREAD COUNT AFTER LAUNDERING

Fabric Type	Fifth Interval	Fifteenth Interval
3100	70.2	71.6
3200	72.9	72.2
3300	72.1	72.8
3400	71.4	71.1

The hypothesis that there was no difference in the filling thread count between sheets of the 3100 and 3400 series as compared to sheets of the 3200 and 3300 series after the fifth laundering interval was rejected. The F value was 11.89 (Table IX), a number which was not significant. Examination of the means (Table X) shows that the filling thread count of the 3200 and 3300 series was higher than that of the 3100 and 3400 series.

Hypotheses concerning differences in filling thread count between sheets within each pair were tested and were not rejected. There was no significant difference in the filling thread count of sheets made of low and high fiber elongation after the fifth laundering, even though the two pairs were significantly different.

After the fifteenth laundering, the data concerning warp and filling thread count were analyzed. The F values indicated no significance of differences among sheets made of the four fabric types in warp thread count. When the sheets of low and high fiber elongation were compared, the difference in warp thread count was not significant after the fifteenth laundering.

However, the analysis of the filling thread count after the fifteenth laundering was similar to the results of analysis after the fifth laundering. There was a significant difference among sheets made from the four fabric types. The F value was 3.32 (Table IX). When the analysis of individual degrees of freedom was made to determine differences between the pairs of sheets, the F value was 7.93 (Table IX). The null hypothesis was rejected. Examination of the mean filling thread count after the fifteenth laundering interval (Table X) shows that the 3300 series had the highest thread count of 72.8. The thread count of the 3200 series was 72.2. The filling thread count of the 3100 and 3400 series was 71.6 and 71.1 respectively. Although there was a difference in filling thread count after the fifteenth laundering interval between the two pairs of sheets, there was no difference between the sheets within each pair made from low and high fiber elongation.

The same kinds of analyses used to test for differences among the sheets of four fabric types and differences between the sheets of low and high fiber elongation were used to test for differences in regard to fabric weight, dimensional change and wrinkle recovery. Some of the tests which indicated no significance will not be discussed.

Analysis of Fabric Weight. There was no initial difference in the fabric weight of the sheets. Analysis of fabric weight after the fifth laundering interval indicated a significant difference between sheets of the 3100 and 3400 series. The F value was 4.93 (Table XI). However, there was no difference between the sheets of the 3200 and the 3300 series. Examination of the mean fabric weight shows that the weight per square yard for the 3100 series was 4.91. The weight per square yard for the 3300 and 3400 series was 4.86 and for the 3200 series 4.84 (Table XII).

TABLE XI

F VALUES OF DIFFERENCE IN FABRIC WEIGHT OF SHEETS

Source of Variation	Periods of Use		
	Zero	Fifth	Fifteenth
Among sheets made from the four fabric types	1.40	3.07	3.24*
3100 and 3400 series vs. 3200 and 3300 series	2.50	3.85	2.39
3100 vs. 3400 series	0.35	4.93*	1.63
3200 vs. 3300 series	0.08	0.43	5.67*

*Significant at the five per cent level of probability.

TABLE XII

MEAN WEIGHT PER SQUARE YARD AFTER LAUNDERING

Fabric Type	Fifth Laundering	Fifteenth Laundering
3100	4.91	4.85
3200	4.84	4.85
3300	4.86	4.78
3400	4.86	4.82

There was a significant difference in fabric weight between sheets of low and high fiber elongation in one pair, but not for the other pair after the fifth laundering.

After the fifteenth laundering, there was a significant difference in weight per square yard among the sheets of the four fabric types. The F value was 3.24 (Table XI). There was also a significant difference between sheets of the 3200 and 3300 series after the fifteenth laundering.

The F value was 5.67 (Table XI). Examination of the means shows that the 3100 and 3200 series had the highest weight per square yard of 4.85. The weight per square yard of the 3400 series was 4.82 and of the 3300 series 4.78 (Table XII). There was a significant difference in fabric weight between sheets made of low and high fiber elongation in one pair, but not in the other pair after the fifteenth laundering. This difference is probably no indication of the change in weight per square yard after many repeated launderings. Since the sheets used in this study were laundered only fifteen times, the change in weight may be due to the amount of sizing removed.

Analysis of Dimensional Change. Analysis of dimensional change after the fifth laundering interval was significantly different in the filling direction among the sheets of the four fabric types and between the sheets of the 3200 and 3300 series. The F value for among sheets made from the four fabric types was 8.39. The F value for determining differences between the sheets within each pair was 19.26 for sheets of the 3200 and 3300 series (Table XIII). Examination of the means shows

TABLE XIII

F VALUES OF DIFFERENCE IN DIMENSIONAL CHANGE OF SHEETS

Source of Variation	Periods of Use			
	Fifth		Fifteenth	
	Warp	Filling	Warp	Filling
Among sheets made from the four fabric types	0.06	8.39*	2.01	1.24
3100 and 3400 series vs. 3200 and 3300 series	0.02	2.69	3.74	3.49
3100 vs. 3400 series	0.11	3.22	1.51	0.22
3200 vs. 3300 series	0.05	19.26*	0.77	0.01

*Significant at the five per cent level of probability.

that sheets of the 3200 series stretched 2.28 per cent after the fifth laundering. Sheets of the 3400 series stretched 2.23 per cent while sheets of the 3100 and 3300 series stretched only 1.61 and 0.74 per cent respectively (Table XIV). There was a significant difference in the amount of stretch between sheets of high and low fiber elongation in one pair. The difference between the other pair was not significant.

TABLE XIV

MEAN DIMENSIONAL CHANGE IN FILLING DIRECTION AFTER LAUNDERING

Fabric Type	Fifth Laundering	Fifteenth Laundering
3100	+1.61	+0.78
3200	+2.28	+0.18
3300	+0.74	+0.22
3400	+2.23	+0.60

There was no difference in dimensional change of the sheets after the fifteenth laundering interval. The dimensional change of the sheets after laundering was related to thread count. The sheets shrank in the warp direction and stretched in the filling direction after laundering. Due to this process of shrinking and stretching, the warp thread count decreased and the filling thread count increased in each of the series. After each of the laundering intervals, the percentage of dimensional change was calculated from the original fabric.

Analysis of Wrinkle Recovery. There was no initial difference in the wrinkle recovery of the sheets in either the warp or the filling direction. Analysis of wrinkle recovery in the warp direction after the fifth laundering interval indicated a significant difference between the two pairs of sheets. The F value was 7.89 (Table XV). However, there

TABLE XV

F VALUES OF DIFFERENCES IN WRINKLE RECOVERY OF SHEETS AT THREE PERIODS OF USE

Source of Variation	Periods of Use					
	Zero		Fifth		Fifteenth	
	Warp	Filling	Warp	Filling	Warp	Filling
Among sheets of the four fabric types	0.36	0.27	2.69	1.89	1.73	2.86
3100 and 3400 series vs. 3200 and 3300 series	.005	0.26	7.98*	3.99	0.35	0.18
3100 vs. 3400 series	0.19	0.47	0.08	.006	4.03	5.74*
3200 vs. 3300 series	0.90	0.06	0.01	1.69	0.80	2.66

*Significant at the five per cent level of probability.

was no difference in the wrinkle recovery between the sheets of low and high fiber elongation after the fifth laundering interval. Examination of the mean wrinkle recovery in the warp direction after the fifth laundering interval shows that the sheets in the 3100 and 3400 series had the highest number of degrees of wrinkle recovery (Table XVI).

TABLE XVI

MEAN WRINKLE RECOVERY IN WARP DIRECTION AFTER LAUNDERING

Fabric Type	Fifth Laundering	Fifteenth Laundering
3100	77.3	75.3
3200	74.5	77.0
3300	74.3	75.5
3400	77.7	78.6

After the fifteenth laundering, there was a significant difference in the wrinkle recovery in the filling between the sheets of the 3100 and 3400 series. The F value was 5.74 (Table XV). Examination of the mean wrinkle recovery in the filling direction after the fifteenth laundering shows that the 3200 and 3400 series had the highest number of degrees of wrinkle recovery (Table XVII). There was a significant

TABLE XVII

MEAN WRINKLE RECOVERY IN FILLING DIRECTION AFTER LAUNDERING

Fabric Type	Fifth Laundering	Fifteenth Laundering
3100	81.3	79.0
3200	77.9	81.7
3300	80.1	79.1
3400	81.4	82.7

difference in the wrinkle recovery in the filling direction of sheets made from low and high fiber elongation in one pair, but not for the other pair after the fifteenth laundering interval.

CHAPTER V

SUMMARY AND CONCLUSIONS

The making of fabrics has been a concern of man for many years. Improvements in the textile industry are being made constantly. New devices are being invented to test fiber properties so that fabric behavior may be predicted. However, these devices cannot always predict the end product performance of a fabric. Fiber properties do affect performance, but the fiber property which has the greatest effect on serviceability has not been determined. It has been proposed that fiber elongation may be one of the fiber properties which does have an effect on end product performance. In response to this need for information Regional Research Project SM-18 is being conducted by the home economists of the agricultural experiment stations of six southern states under the direction of the Agricultural Research Service of the United States Department of Agriculture. This project is concerned with the relationship between fiber properties (length, strength, fineness and elongation) and the end product performance. The particular property investigated at the time this study was made was that of fiber elongation.

The purpose of this thesis, a pilot study for the regional study, was to determine the relation of fiber elongation to serviceability features of the four types of cotton sheeting used in the serviceability testing at the Woman's College of the University of North Carolina.

In order to determine this relationship, these objectives were established.

1. To determine differences in the sheets as noticed by those girls who used the sheets.

2. To set up a statistical procedure which could be used to determine differences in the sheetings.

3. To investigate the possibility of using the Remington Rand Univac 1105 Computer as an efficient method of processing the data.

The data were results of the laboratory tests performed on the sheets used in the girls' dormitories. Tests used in this pilot study were only those tests performed in North Carolina: thread count, fabric weight, dimensional change and wrinkle recovery. These tests were performed on the sheets at the zero interval and on those sheets withdrawn at the fifth and fifteenth laundering intervals.

There were noticeable differences in the quality of the sheets. These differences were noticed by research personnel who coded and distributed the sheets and also by the students who used them. Sheets made of low elongation fibers (3100 and 3200 series) were ranked above those of high elongation fibers (3300 and 3400 series) with respect to (1) fineness in quality of cloth, (2) smoothness, (3) coolness and comfort and (4) resistance to wrinkling and soiling.

An analysis of variance was the statistical procedure used to indicate the significance of differences in the cottons of low and high fiber elongation. Variability among the sheets in tests performed was first subdivided into that associated with the differences among sheets made of the four fabric types. The three degrees of freedom used were then broken into individual degrees of freedom to make comparisons between sheets of low and high fiber elongation. Orthogonal comparisons provided for this analysis.

The data from the laboratory tests were successfully computed on the Remington Rand Univac 1105 Computer. This was an efficient method of computation since all data on all tests were read into the machine and mathematical computations completed in 45 seconds. From these computations, it was a relatively simple matter to select from the type-out statements the F values which would be used to indicate the significance of differences.

Tests performed indicated that there were no initial differences in the sheets of the four fabric types. This was expected, since the four types of cotton were carefully selected so that they were very similar in all fiber properties except fiber elongation.

After the fifth laundering interval, there was a significant difference in the filling thread count and in the filling direction of dimensional change among the sheets made of the four fabric types. The difference in thread count is related to dimensional change. Stretch in the filling direction caused an increase in the number of filling threads per inch. There was also a significant difference between the pairs of sheets in the filling thread count and in warp wrinkle recovery. There were significant differences in weight per square yard between sheets of the 3100 and 3400 series and in the filling direction of dimensional change in the 3200 and 3300 series after the fifth laundering interval.

After the fifteenth laundering interval, there was a significant difference in the filling thread count and the weight per square yard among the sheets of the four fabric types. There was also a significant difference in filling thread count between the pairs of sheets. There was a significant difference in the wrinkle recovery of the filling direction between sheets of the 3100 and 3400 series and in weight per square yard of the 3200 and 3300 series after the fifteenth laundering.

From these findings, it can be concluded that there were few differences in the sheets made of low and high fiber elongation in the tests performed. Differences in the sheets were not necessarily expected to be evident through the fifteenth laundering interval in the particular tests performed. Results from additional tests which were performed at other participating states to indicate serviceability (abrasion, tensile strength, and tearing strength) would in all probability indicate more evident differences in the sheets of low and high fiber elongation.

It is suggested that further study be made:

1. To analyze differences in the sheetings using all tests performed in all states through the fifteenth laundering.

2. To develop a technique of determining wrinkle recovery which will produce more consistent test results.

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