A COMPARISON OF THE CHEMICAL TENDERING
DURING LAUNDERING OF AMERICAN UPLAND
AND PIMA COTTON FIBERS

by

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A.B., Albion College, 1962

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A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Clothing and Textiles

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1964

Approved by:

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CHAPTER I

INTRODUCTION

Man learned to utilize the fine-textured fibers yielded by
the cotton plant nearly five thousand years ago, and research has
been conducted on these fibers ever since. During the fifty cen-
turies since its discovery, cotton, by virtue of its qualities,
has increased in production and consumption until for more than a
century it has been the world's leading textile fiber. Recently
the consumption of cotton in the United States has decreased
slightly. In order to regain some of this lost market, the cotton
producers have found new uses for the different varieties of cotton,
especially the longer staple cottons.

The purpose of this research was to analyze the chemical
tendering occurring during the laundering of American Upland and
Pima cotton fibers. These two varieties represent average and
extra-long staple cottons presently being used in sheeting. Although
American Upland fibers have been used in sheeting for many years,
the Pima fibers have only recently been introduced for use in this
household item.

Agriculture is the biggest single industry in the United States
and cotton represents the biggest single cash crop within this
industry (1). The United States is the world's largest individual
producer and consumer of cotton. From fiber to finished product,

cotton provides employment for some thirteen million people and repre-
sents a capital investment of over fifteen billion dollars (1).

Although this country produces close to half of the entire
world's raw cotton supply, the United States uses for its own con-
sumer and industrial needs less than a quarter of this amount (1).
The recent development and promotion of various manmade fibers has
accounted for part of this lowered consumption (63). Household
items consume over thirty per cent of the cotton processed in mills
in the United States. Forty per cent of the cotton processed goes
into clothing, twenty-five per cent is used in industrial goods,
and the remainder of the cotton is used in cotton byproducts (1,63).

Varieties of Cotton. The number of varieties of cotton has
increased since the discovery of this fiber. The three main varieties
of cotton grown in the United States at the present time are American
Upland, Pima, and Sea Island (63,64). Mauersberger (40) noted that
the common varieties of cotton available in the world market today
are very similar in general physical appearance. While the different
varieties may look more or less alike, they exhibit differences in
qualities and properties.

American Upland and Pima (American-Egyptian) cotton fibers,
two of the main varieties of cotton grown in the United States,
differ in amounts produced annually and the cost per bale to the
cotton processor. According to the 1962 Agricultural Statistics (58),
the 1960 production of American Upland fibers was 8,083,942 running
bales, and that of American-Egyptian was 75,156 running bales.

Cost per bale differences were noted among these two varieties of cotton. American Upland fibers had a cost of $16.87 per bale in 1961 as compared to American-Egyptian fibers which cost $28.76 during the same year. The farmers' share of the final retail cost for both types of cotton fibers in 1961 was approximately fourteen per cent (58).

American Upland Cotton. American Upland is a member of the Gossypium Hirsutum species of cotton which was developed in Mexico and later spread to the southern areas of the United States (42). Today cotton farmers in the United States grow principally American Upland cotton (34,58,64). This cotton, which is grown in nearly all of the cotton-growing regions of the United States and in many foreign countries, is often referred to as the standard American cotton (9). Linton(34) noted that because of the widespread production of American Upland cotton, the properties and characteristics of all other cottons are compared to this fiber.

Carmichael et. al. (9) defined American Upland fibers as being of medium fineness, with a white color tending toward cream. These fibers have a medium staple, ranging from fifteen-sixteenths of an inch to one-and-one-eighth inches in length (1). American cottons belonging to the Upland group generally have diameters ranging from fifteen to twenty-two millimicrons (40).

Pima Cotton. A longer staple cotton, known as Pima or American-Egyptian cotton, is classified by many cotton authorities as the outstanding variety of American-Egyptian cotton grown in the United

States (1,40). According to Merrill (42), Pima was originally developed
as an effort to produce Egyptian-type cottons in this country under
conditions as nearly like those in Egypt as possible. By 1920 Pima
was a well-known variety, and it was the sole variety of American-
Egyptian cotton being raised until 1934 (42).

A number of American-Egyptian strains, Pima, S x P, Earlipima,
Amsak, and Pima 32 have followed each other in the market (32). Each
strain was better than the preceding one, both in yields and quality,
but none has ever equaled Egyptian-grown Karnak cotton in both yields
and fiber properties. Pima S-1 is now being grown by many cotton
farmers in the United States, but almost one-half of the acreage of
Pima cotton is still in Pima 32 (32,34).

Pima cotton is a valuable cotton, yet it is difficult to pro-
duce in the United States (40). Modifications in Pima cotton throughout
the years have produced a cotton which is somewhat lighter in color
than the original strain developed. The newer strains have become
somewhat coarser than the earlier strains developed (59,60,61).
Pima S-1 has a greater mean length than the original strains of Pima
cotton, or the Egyptian Karnak. With continued improvements of these
long staple cotton fibers, production and consumption are expected to
rise sharply.

Chemical Tendering in Laundering. A limited amount of research
has been reported on the analysis of the chemical changes that occur
during laundering of American Upland and Pima cotton fibers. Since
American Upland is the variety of cotton raised in greatest quantity

in the United States, it has received the most attention in cotton
research while studies on the Pima fibers have been limited. Specific
studies comparing the chemical tendering of the cellulose chain structure
during laundering of these two fibers have not been published.

Rogers, Haya, and Wigington (52) used American Upland cotton
ranging from Middling to Strict Middling grade for a serviceability
study, and reported that the various grades of cotton reacted differently
to chemical analyses conducted after both laundering and wear. In
their study of cotton and viscose rayon fibers, McLendon and Davison (41)
indicated that both fibers showed changes in strength with an increased
number of launderings. Partida (48) reported that dormitory sheetings
made of American Upland fibers lost less strength when laundered only
than when laundered and used.

Studies published on the Pima cotton fibers in the recent years
have been concerned primarily with physical testing and analyses of
fiber and fabric properties due to various modifications in the mill
production of these fibers. Johnson (32) indicated in his investigation
of spinning tests on Pima S-1 fibers that they had an extremely high
strength. Brown et. al. (7) conducted a study to determine the value of
Pima S-1 for various end uses. They noted that yarns produced from
Pima 32 and Egyptian Karnak were not as strong as those yarns produced
from Pima S-1, but these authors did not investigate the changes in
strength of these yarns due to laundering.

The Consumer's Choice. Both American Upland and Pima cotton fibers are found in many fabrics available on the retail market at the present time. Although the consumer is often unaware of the variety of cotton fiber present in the fabric or garment she is buying, she may note an increased cost for a particular item as opposed to a similar item at a lower price; or she may note a difference in hand, or the feel, of the fabrics. She could certainly find these differences among sheeting fabricated of American Upland and Pima cotton fibers.

Increased costs of cotton production for certain varieties may add to the retail cost that the consumer pays. A higher strength, indicating increased wearing and serviceability qualities, may be part of the reason for higher costs for particular consumer, industrial, or household goods. Some varieties of cotton may have more desirable aesthetic properties than other varieties. The demand for a certain luster, hand, color, or general appearance might result in a higher cost. Wise decisions based on research must guide the consumer to the selection of fabrics that will best serve her needs and those of her family for household and clothing items.

CHAPTER II

REVIEW OF LITERATURE

A study of the chemical tendering of two varieties of cotton
is actually an investigation of the chemistry of cellulose, for it
is this polysaccharide, cellulose, which is the main constituent of the
cotton fiber. Therefore, it becomes essential to discuss the chemistry
of cellulose, its structure and the way it reacts. An investigation
of the method by which changes in the cellulose structure can be
measured is also necessary for complete understanding of the chemistry
of cellulose. A review of literature of previous studies reported
gives further insight into the value of this study in estimating the
chemical tendering of two varieties of cotton due to laundering.

Chemistry of Cellulose. Cellulose is a natural high polymer,
its long chain molecules consisting of an aggregate of many glucose
anhydride units. These chains are arranged more or less parallel to
each other and are stabilized in the lateral direction by secondary
valences (26). Although the chain-like molecules of cellulose are
fully extended, there is some rotation of the chains along the main
axis (37).

It has been theorized that the hydroxyl groups of the glucose
units within the chain exert the forces which hold the chains together (65).
The polar character of these hydroxyl groups renders cellulose hydro-
plastic rather than thermoplastic. Cellulose does not dissolve in

water because the majority of these hydroxyl groups are mutually satisfied and thus are inaccessible to water; however, the hydroxyl groups in each glucose unit are still capable of other chemical reactions (38).

Heuser (26) noted that x-ray analysis, the primary means of elucidating the fine structure of natural polymers, had definitely shown cellulose to be of crystalline nature. He conceived of the chain bundles as representing hypothetical, submicroscopic units, of varying length but of fixed breadth and thickness. These units are termed micelles by many authorities (17,38,65). The micelles build up the fibrils, the first constituent of the fiber which may be detected under the microscope.

Heuser (26) further noted that in defining the term cellulose, distinction must be made between cellulose as it exists in plants and cellulose in its isolated form, because in the plant it may be chemically combined with other plant constituents. No method is yet available which permits the isolation of cellulose from its various sources without breaking a greater or smaller number of linkages which unite the glucose residues in the individual chains. Heuser (26) indicated that, as a result, isolated cellulose possesses a shorter average chain length than cellulose in the plant. Upon isolation and purification, oxidation may take place and thus give rise to a further change in certain groups of the isolated product.

Cellulose, a polysaccharide, is 88 to 99 per cent of the composition of cotton (17,23,26,37). According to Heuser (26), scoured, bleached,

dry cotton fabric is approximately 99 per cent cellulose. The variation in values for the cellulose content of raw cotton fibers is due mainly to natural variations brought about by conditions of soil, climate, variety of cotton, and especially conditions which arrest fiber development such as drought, disease, and early frost. Low cellulose content usually indicates considerable numbers of thin-walled, immature fibers which contain a high proportion of non-cellulosic substances (46).

Doree (17) has noted that deviations from the normal cellulose structure in a sample of cotton may result from the nature of its growth, the method of its isolation, or the action of physical and chemical agencies upon the cellulose. These deviations which generally result from alterations in the structural balance of the fiber are accompanied by shortened chain length, and the development of reducing properties in the cellulose. A decreased strength may also be noted in the fiber.

Cellulose can be dispersed in only a few aqueous media of certain concentrated solutes (49). The solvent has to overcome the secondary valence forces between the main valence chains, and, in addition, must be a dispersing agent for these long chains with molecular weights of about 500,000. According to Plunguian (49), when a reagent has disrupted the secondary valence forces holding the crystallite together, the cellulose exists in the form of a single long-chain molecule, rather than a molecule composed of many interconnected chains.

Skinkle (55) reported that when cellulose was dispersed in a concentrated solute, it formed a balloon-like structure with intensive

swelling occurring. Marsh et. al. (39) noted that this balloon formation was due to the rupturing of the primary wall into a series of constriction bonds which restrain the expanding cellulose. Thus, the swelling is dependent in part on the orientation of fibrils in the secondary wall and, in part, on the constricting influences of the primary wall. This limitation is removed to some degree whenever the outer wall is weakened or broken by a deteriorative agency. This deteriorative agency may be a physical or chemical force acting upon the cellulose. With fewer restrictions on the primary wall the cellulose will swell more, and thus, have faster reactions with many concentrated solvents (55).

When changes occur in the composition or properties of cellulose, the term "degradation" is often used. Hartsuch (23) defined degraded cellulose as cellulose that had shortened polymeric chains due to either oxidative or hydrolytic action. Ott et. al. (46) further extended Hartsuch's definition by classifying cellulose degradation into four general divisions: 1) hydrolytic, where cellulose is reduced in the degree of polymerization and shows an increase in reducing power; 2) oxidative, where cellulose is reduced in degree of polymerization and the product shows the development of carboxyl and carbonyl groups; 3) microbiological, where cellulose is reduced in the degree of polymerization, but loss of strength is the most pronounced effec., and 4) mechanical, where cellulose is reduced in the degree of polymerization if the fiber is severely treated.

The most common degradative process occurring to cellulose is a decrease in the average degree of polymerization which is evidenced by a loss of tensile strength in the fiber (10,11,17). This physical change is usually accompanied by a chemical modification of the cellulose molecular structure, such as an increase in reducing power or the development of reactive groups along the chain. Clibbens and Ridge (12) stated that the loss of tensile strength caused by the action of acids or oxidizing agents is a phenomenon known as "chemical tendering." They continued by noting that this tendering is one of the most important and disastrous consequences of "chemical modification," and that tendering occurs often in industry. Lomax (35) also spoke of the chemical change occurring within the cellulose structure as a tendering reaction.

Ward (65) indicated that the breakdown of the complex molecular structure of cellulose generally implies a rupture of the glycosidic linkages and reduction of the average chain length due to the action of oxidizing agents, acid hydrolysis, light, heat, or micro-organisms. The hydrolysis of the oxygen linkage of cellulose which results in shorter chains is also accompanied by an oxidation of the hydroxyl groups to aldehyde groups, and further oxidation to carboxyl groups.

During laundering processes an oxidative degradation occurs with hydroxyl groups being replaced by aldehyde, ketone, and carboxyl groups on the complex cellulose chain (46). A mechanical degradation is also known to occur during the laundering process. Such degradation is due to agitation and friction and it causes a tendering of the fibers (65).

Austin and Roberts (4) suggested in a study of methods for determining the density of cotton that the water absorptive capacity of cellulose decreased with an increased number of launderings due to a reduction in the number of available hydroxyl groups. The aldehyde, ketone, and carboxyl groups present did not absorb water at the same rate as the hydroxyl groups as degradation processes occurred. It has been indicated by Ward (65) that both reduced strength and lowered viscosity are also observed in cotton tendered by progressive oxidation during laundering. When the oxidation occurring during laundering had been carried out in a neutral or acid medium, the ensuing change in the chemical structure of the cellulose was not attended by a parallel loss of strength.

Measurement of Cellulose Tendering. Often it is not possible to detect change in cellulose by purely physical testing. Modification of the cellulose chain structure of cotton fibers must be detected in its early stages in order to prevent great strength losses in yarns and fabrics made from these fibers. Both Ward (65) and Doree (17) have stated that the method for detecting change in the cellulose structure must be one that can detect any strength loss in the early stages of degradation. Methods of analyzing chain length in the cellulose structure are often used industrially as a means of control against excessive kier-boiling or over bleaching which may result in a drastic strength loss in the fabric (11,37).

Several authorities on the chemistry of cellulose (5,12,15) have indicated that the measurements of the viscosity or fluidity of

a cellulose-cuprammonium solution are by far the most sensitive tests
of change in cellulose. Ward (65) noted that this test is widely used
for measuring damage due to light, heat, laundering, and chemicals,
such as acids, alkalies, oxidizing and reducing agents. According to
Lomax (35), the fluidity of cellulose in a cuprammonium solution can
be used to identify and measure chemical change undergone by this
cellulose structure from many different causes. He concluded that
fluidity is the most reliable of all tests for chemical tendering
in cotton, viscose, and cuprammonium rayons, whether qualitative
or quantitative.

Dorse (17) reported that Dr. Ost was the first scientist
to suggest that the determination of the viscosity of a cuprammonium-
cellulose solution could be used as a measure of change within the
structure of the fiber. Clibbens and Geake (10) developed a standard
method for viscosity measurements in industry in 1928. The method
was revised by Clibbens and Little (11) in 1936, and it was a modifi-
cation of this revision which was later adopted by the American Society
for Testing Materials (2) as the standard method for use today.

Viscosity and fluidity are terms which are inversely related
to each other. Viscosity is defined in the Handbook of Chemistry
and Physics (28) as the internal friction of a liquid on itself, or
its resistance to flow, its units being in dynes per square centimeter
per centimeter per second, or in poises. Grant (21) defined fluidity
as the property of flowing easily, measured in rhe, the reciprocal
of a poise. Carl Conrad (13) noted in a personal communication that

fluidity has been much more widely used than viscosity in the field of textile work. He suggested that this came about through the origin of the technique of fluidity by the British, and the more common usage of fluidity than of viscosity in Great Britain.

It has been reported by Reinhardt and Reid (51) that the solubilization of cellulose in a cuprammonium hydroxide solution was accomplished by the complex formation of copper with two hydroxyl groups at the two and three positions of the glucose unit, and with these positions only. The shorter chains appear to be more easily solubilized than the long chain units. Heuser (26) noted that in this solubilization process, the cellulose forms an alcoholate with the cupric solution and this alcoholate merges into a complex compound upon reaction with more of the copper in solution. It is the rate of flow of this cellulose-cupric alkaline solution which is measured in viscosimeters, thus indicating change in the cellulose structure.

Cupriethylene diamine hydroxide is another well-known solvent for cellulose. This solvent, as defined by Ward (65), is a copper complex formed by the solution of copper oxide or hydroxide in ethylene diamine solution. Segal and Creely (54) noted that slightly more than sixty per cent cupriethylene diamine hydroxide was needed for complete conversion of crystalline cellulose to a complex. The cupriethylene diamine content of the complex is greater than eighteen per cent unless fiber swelling is restrained, as in a woven fabric. According to these authors (54), penetration and complexing of the cupriethylene diamine hydroxide with the cellulose are substantially complete within one minute.

Plunguain (49) stated that when cellulose was treated with a strong alkaline solution, such as cupriethylene diamine hydroxide, the mature fibers began to swell and twist, forming balloon-like structures. As this alkaline solution reacted with the cellulose, the cellulose disintegrated and amorphous fragments from the primary wall and lumen of the cotton fiber remained as residue in the solution. After considerable agitation, these parts of the cotton fiber also dispersed into the alklaine solution.

When cellulose is dispersed in a cupriethylene diamine hydroxide solution, or a cuprammonium solution, the fluidity can be measured with the aid of viscosimeters. Doree (17) stated that cupriethylene diamine hydroxide in combination with cellulose was a precise method for the determination of cellulose fluidity. Several authorities (14,20,23) noted in their respective studies that fluidity is directly proportional to the lengths of chains in the cellulose polymer. A study by Marsh (37) of the chemical and mechanical degradation of cotton fibers indicated that a certain rise in fluidity caused the same percentage decrease in tear and tensile strength. Trotman (57) mentioned that strength loss was directly related to fluidity increase. Several investigators (10,18,41,56) noted that when fluidity values were plotted against chemical tendering a straight line resulted. Predictions of strength loss could be made due to this linear relationship. A recent study by Noll (45) summarized these statements appropriately by concluding that the higher the fluidity, the greater the damage that had occurred. Thus, fluidity has become an index of chemical degradation.

The complete fluidity scale for cellulose-copper suspensions extends from a value of two for cotton cellulose purified by the mildest methods to about seventy, the fluidity of the pure solvent (11). The part of the scale of interest in cotton technology is restricted to a range from about two to forty since the chemical degradation of the cellulose corresponding to this upper limit is accompanied by almost complete mechanical disintegration of the cotton fiber.

Mauersberger (40, p. 244) summarized fluidity values as an indication of degradation as follows:

Class	Fluidity	Remarks
1	1 - 5	Very mildly scoured cotton
2	5 - 10	Normally scoured cotton
3	10 - 20	Significant loss in strength
4	20 - 30	Overbleached, serious strength loss
5	30 - 40	Loss of fibrous structure
6	40 or above	Highly degraded by chemical attack

Plunguian (49) stated that the best cotton had fluidity values ranging from one to five. Marsh (37) noted that a fluidity value of ten indicated a ten per cent strength loss, with a fluidity value of twenty indicating a twenty per cent strength loss. Lomax (35) stated that after a fluidity value of twenty rhes, the strength loss increased rapidly.

Cotton Fibers and Fluidity. Cotton is the source of cellulose which combines with cupriethylene diamine hydroxide solution in this study. As has been mentioned previously, cotton is composed of approximately ninety per cent cellulose, thus it is a very good source

of this polysaccharide. Studies reported on cotton fibers of different varieties have indicated the need for more investigation into the behavior of these fibers during laundering.

It has been reported by McLendon and Davison (41) in a serviceability study of cotton, rayon, and cotton-rayon blends in sheeting that cuprammonium fluidity readings indicated very little chemical degradation in any of these fabrics. In a preliminary study by these authors (41), fluidity values obtained varied little from five to seventy-five launderings for the American Upland fibers analyzed. The increasing fluidity values for both the sheets laundered only, as well as those laundered and used, were significant when measured on commercially laundered sheets. Very little chemical degradation was noted in those sheetings laundered only and not used. Fluidity values remained approximately the same from five through seventy-five launderings.

This study by McLendon and Davison (41) indicated that the cotton sheeting showed the largest change of fluidity values and degree of polymerization as compared to rayon sheeting or cotton-rayon blends. In all cases, the laundered-and-used sheetings showed a greater increase in fluidity and decrease in degree of polymerization than those sheetings laundered only. It was noted, however, that even in the used sheetings, laundering accounted for a large part of the total chemical damage. From results gathered in this study, it was concluded by the authors that either fluidity or degree of polymerization measurements could be

used equally well for determining chemical damage due to laundering and wear of cotton, rayon, and cotton-rayon fabrics.

Rogers, Hays, and Wigington (52) have indicated in their study of sheeting composed of American Upland cottons ranging from Middling to Strict Middling grade that the fluidities of the cuprammonium solutions of the bleached and finished sheetings were higher than those of unbleached materials. Similar to the study conducted by McLendon and Davison (41), this research indicated that as service progressed, the fluidity for each of the three sheetings studied increased. Experiments conducted on samples randomly selected from various areas of the sheetings indicated that some of the chemical deterioration of the sheetings was caused by body wear. Fluidity values also increased for samples that were stored for periods of time up through four years.

Potter (50) conducted a study dealing with various methods of home laundering. One of the areas of his study dealt with strength losses occurring during the laundering period. He noted that after laundering a fabric one hundred times, or during a two year period, the ultimate decline in tensile strength of the fabric was down to sixty per cent of the original strength. The strength decline was gradual at first, but increased rapidly with increased launderings. Partida (48) reported that sheets laundered only lost much less strength than those which were used on beds and laundered by the same method. The warp yarns lost more strength than the filling yarns in those sheetings which had been laundered only.

One of the early studies of American Upland cotton by Elmquist and Hays (18) stated that the lower grades of cotton investigated were weaker throughout the experiment. There was a significant rise of fluidity for all grades of cotton with service and wear. When the fluidity values for each grade of American Upland fibers were plotted against the breaking strength of the warp yarns, the relationship was approximately linear. This was also true with filling yarn breaking strengths.

Another study by Hays and Rogers (24) indicated that as service continued on five groups of sheetings, a progressive deterioration was noted. This, again, was measured by the fluidity test. It was also noted by these authors that the price of the sheetings that were analyzed was not related to breaking strength, weight, or chemical quality of the fabric. No appreciable difference was noted in the length of service between percale and fine count sheetings, although the muslin sheetings had a shorter serviceability period.

A joint study by the Bureaus of Agricultural Economics and Home Economics of the United States Department of Agriculture (8) indicated that although the relationship of staple length of raw cotton to strength and fineness of yarns is generally recognized, these strength and fineness qualities are neither thoroughly understood nor mathematically evaluated. These authors stated that there is only fragmentary information on the relation of quality, as indicated by grade, to wearing quality and serviceability of the resulting fabrics.

This study (8) of three grades of American Upland cotton indicated a

significant rise in fluidity with service; however, this rise was not directly correlated with the grades of cotton. The Middling grade cotton showed a higher strength loss than the Strict Good Ordinary, a lower grade of cotton.

Summaries of varieties of cotton grown in the United States in 1956 (59), 1957 (60), and 1958 (61) indicated that strength readings for Pima S-1 cotton are generally higher than readings for American Upland varieties. The Pima S-1 fibers were classified as having a strong to very strong strength, while the American Upland fibers had an average strength. It was reported in these studies (59,60,61) that the longer staple cottons have become somewhat coarser and the short staple cottons finer in the recent years. Johnson (32) also stated in his study of Pima S-1 cotton that coarser strains have been developed in the last fifteen years. Fiber fineness is no longer the main variable that may contribute to yarn strength.

Brown et. al. (7) conducted a study to determine the value of Pima S-1 cotton for various end uses. In comparison with Pima 32, and Karnak, an Egyptian cotton, the strength of Pima S-1 was slightly weaker. This Pima S-1 fiber was also more coarse that the other two fibers; however, yarns produced were stronger than comparable yarns produced from Pima 32 and Karnak. These stronger yarns were used in fabrics where a high strength was desired.

Additional studies were not available which would indicate further research into the physical and chemical properties of Pima

cotton fibers. It was evident from the studies reviewed that the
majority of cotton research in this area has been conducted on the
shorter staple fibers.

CHAPTER III

METHOD OF PROCEDURE

The measurement of the viscosity or fluidity of a cellulose
compound dispersed in a cupriethylene diamine hydroxide solution
is reported to be a measure of the extent of chemical tendering, as
well as strength loss, that has occurred within the cellulose structure
(14,17). The linear relationship between the fluidity values obtained
and the strength loss that has occurred becomes the means by which
the behavior of fibers, yarns, or fabrics may be predicted.

The methods of procedure used in this study were those that
would best fulfill the objectives of the study, these objectives
being: 1) to analyze the chemical tendering of American Upland and
Pima cotton fibers due to a varying number of launderings; and
2) to predict the serviceability of fabrics in which either the
American Upland or Pima cotton fibers had been used.

A.S.T.M. Method for Fluidity Determinations. The specific
method used was outlined by the American Society for Testing Materials (2)
entitled, "Apparent Fluidity of Dispersions of Cellulose Fibers."
Three sub-methods were presented by A.S.T.M. under this general heading;
each method differing slightly from the other two in materials,
equipment, and procedure. Although the methods differed, each was
reported to give approximately the same fluidity values, and thus
indicate the same amount of strength change to the fiber being examined.

Method B of the A.S.T.M. designation: D539-53 was used. This procedure involved the use of a cupriethylene diamine hydroxide solution as the cellulose solvent, and the use of U-tube or Cannon-Fenske viscosimeters, as opposed to the cuprammonium solutions and capillary viscosimeters often used in fluidity determinations. This method was chosen because of the equipment and laboratory facilities available.

Varieties of Cotton. Two staple lengths of cotton fibers were analyzed for degradation, or tendering, occurring during laundering. The American Upland fibers represented the medium staple fibers that were studied, while the Pima cotton fibers were an extra-long staple.

Each of these staple fibers comprised the yarns of sheeting available on the retail market in Manhattan, Kansas. The American Upland fibers were used in combed yarns in percale sheeting. Denny (16) noted that percale sheets are finer and lighter in weight than muslin, with the combed yarns being superior to carded yarns. Pima cotton sheets were the source of the extra-long staple Pima fibers. These yarns had also been combed.

No information was available as to the specific variety of cotton used in the sheetings, or the area of the country in which it was grown. Thus, it was assumed that the fibers were of average staple length for the particular cotton species, and with this assumption in mind, conclusions were drawn from the data collected which would relate to the characteristics of the fiber variety as a whole.

Laundering of the Sheeting. A review of literature indicated
that a varying number of launderings was necessary in order to ac-
curately measure any change in the cellulose structure. Laundering
times were chosen to simulate periods of laundering that might occur
in the home. These were: one, five, ten, twenty, thirty, forty,
fifty, and seventy-five launderings. Six sheets were randomly selected
for each of these periods of launderings. Three percale and three Pima
cotton sheets comprised the total number of six sheets per group.

Before any laundering processes were begun, each sheet was
divided in half. This was done in order to have a specific control
for each laundered half; thus, fluidity values obtained for a laundered
half could be compared to those values obtained from the same sheet
on the half which had not been laundered.

The laundering of the sheeting was done in an automatic
agitator-type washer according to the manufacturer's directions. A
low-sudsing synthetic detergent, known by the commercial name of
"All", was used in each wash cycle. Three percale and three Pima
half-sheets were laundered at one time. Each half-sheet of the six
in the group was submitted to the same environmental conditions
occurring during the laundering process. The sheets in each group
were dried in an automatic tumbler-type drier according to the
manufacturer's specifications.

Sample Selection. A diagram was designed to aid in the selection
of samples from each half-sheet. Positions for sample selection were

chosen to allow selection of areas of the sheeting containing different warp and filling yarns. Since the various areas of the sheeting were not being compared to other areas to determine degradation that had occurred, the three samples from each half-sheet were treated as a whole from this point throughout the remainder of the research.

Pretreatment of Samples. Most fabrics as purchased are known to have sizing and other external finishes on the fabric surface. Cotton sheeting also has these finishes. These materials must be removed before valid fluidity readings can be obtained from the fabrics being analyzed (2). The A.S.T.M. Method: D629-59T was followed for the complete removal of nonfibrous materials of the fiber and substances added by the manufacturer. Starch, China clay, soaps, waxes, some nondrying oils, certain resins, and the usual natural constituents of the fiber are in this category.

A Soxhlet extraction apparatus was used in the first step to remove soaps and cationic finishes from the fabric. The samples from each half-sheet were placed in the Soxhlet extraction apparatus, and ninety-five per cent ethyl alcohol was siphoned over the samples for two hours, or a minimum of six times. When the siphoning processes were complete for each set of samples, they were removed, rinsed well in distilled water, allowed to dry, and then weighed.

Water-soluble materials were removed from the fabric samples as the next step of this procedure. The samples were immersed in a fifty degree centigrade water bath for approximately thirty minutes.

The samples were agitated in the water several times during this period. At the completion of this interval, samples were rinsed in fifty degree centigrade distilled water, allowed to dry, and then weighed.

The final step in the removal of nonfibrous materials from the fabric samples was the immersion of the samples in an enzyme solution for one-half hour. The amylolytic and proteolytic enzyme solution, known commercially as "Talase", was prepared according to directions given by the manufacturer. This process was designed to remove starches, gums, gelatins, and the various sizings used on fabrics. At the completion of the time period, the samples were rinsed with hot distilled water, allowed to dry, and then weighed.

Conversion to Fibrous State. The samples from each half-sheet were ground in a Wiley Mill, with a one millimeter sieve being used in the mill. This sieve size was selected as the one which would least lower the intrinsic viscosity of the sample, thus giving the most valid results possible in a study of this type.

Moisture Content Determination. Each ground sample was analyzed for moisture content before the fluidity determinations were made. This was necessary for the determination of the weight of cellulose in each sample. This information would be used later in the study.

A portion of the ground sample from each sheet was removed and placed in a weighing bottle. This portion was allowed to come to equilibrium for approximately twenty-four hours in a conditioning room maintained at seventy degrees Fahrenheit and sixty-five per cent relative humidity. At the conclusion of this interval, the sample was weighed, this weight being termed its "conditioned weight". Each sample was then placed overnight in a drying oven maintained at 103 degrees centigrade. The dried sample was placed in a desiccator to cool, with calcium sulfate being used as the desiccant. The sample was weighed when cool, this weight being its "oven – dry weight". From the differences between the conditioned weight and oven-dry weight, the moisture content was calculated as:

$$\% \text{ moisture} = \frac{100 \ (A - B)}{A}$$

A is the conditioned weight
B is the oven-dry weight

Preparation of Fiber for Fluidity Analysis. An 0.15 to 0.20 gram portion of the ground sample was used in the fluidity determination. It was necessary to know the weight of cellulose in each sample, thus this value was calculated from the sample weight and moisture content as:

$$\text{Weight} = W \ (100 - M)$$

W is the sample weight
M is per cent moisture in the sample

Calibration of Viscosimeters for Fluidity Determinations.

The viscosimeters, or viscometers as they are sometimes termed, were selected according to specifications recommended by the A.S.T.M. Method: D539-53 (2). These U-tube or Cannon-Fenske viscosimeters were calibrated with an oil in order to obtain a pipet constant for each viscosimeter.

A sixty-five per cent solution by weight of glycerine was used as the calibrating fluid. This particular per cent solution was suggested in the literature where fluidity tests were used (14,37,55). The particular concentration of glycerine used had a time of flow equal to that of an one-half per cent solution of cotton which had suffered the maximum permissible chemical attack in bleaching and finishing (37).

The time of flow of the glycerine solution was measured as the time required for the meniscus of the solution to pass between two etched marks on the capillary side of the U-tube viscosimeter. This rate of efflux was measured after the solution in the viscosimeter had come to equilibrium with a twenty-five degree centigrade water bath. From the data collected as to the time of flow, and the known density and fluidity of a sixty-five per cent glycerine solution at twenty-five degrees centigrade, a pipet constant was calculated as:

$$C = d \times F \times t$$

d is density of glycerine at 25° centigrade
F is fluidity of a 65% solution
t is time of flow in seconds

The density for a sixty-five per cent solution of glycerine, 1.168, was used in calibration of the viscosimeters (6,28,33,43). The fluidity of the glycerine solution at twenty-five degrees centigrade was 8.09 rhes, this value being the reciprocal of the viscosity of glycerine at this concentration and temperature. These values, along with the observed time of flow, could then be substituted into the formula to obtain the pipet constant.

Preparation of Cupriethylene Diamine Hydroxide Solution.

The cellulose solvent used in this research was a cupriethylene diamine hydroxide solution. This solution was purchased in an one molar concentration from a commercial firm, as suggested by A.S.T.M. (2).

The cellulose solvent was first analyzed for its copper content. This was necessary for the determination of the existent molarity of the solution, and thus, changes could be made to adjust the solution to the desired molarity. The cupriethylene diamine hydroxide was standardized against an 0.1 normal sodium thiosulfate solution by a titrametric analysis. The thiosulfate solution had previously been standardized against potassium dichromate according to the method suggested by the American Association of Agricultural Chemists (29).

The copper content of the cupriethylene diamine hydroxide solution was calculated as:

$$M_{cu} = \frac{A \times B}{2.5}$$

A is milliliters of thiosulfate used
B is normality of thiosulfate solution

The second analysis of the cellulose solvent was for its ethylene diamine content. A 0.5 normal sulfuric acid solution was titrated against the cupriethylene diamine solution until a pH of 3.25 was reached. This was considered to be the end point of the titration. From the information gathered in this titration, the ethylene diamine content was calculated as:

$$M_{ed} = \frac{C \times D \times 0.333}{2.5}$$

C is milliliters of sulfuric acid required
D is normality of sulfuric acid

The ratio between the copper content and ethylene diamine content was calculated as:

$$\frac{M_{ed}}{M_{cu}}$$

A ratio of between 1.95 and 2.00 was suggested by A.S.T.M. (2) as being appropriate for this solution.

The cellulose solvent was then divided into two parts, water being added to adjust the solutions to 1.0 molar and 0.167 molar, $\pm$ 0.005. Titration against sodium thiosulfate indicated when the proper molarity had been reached.

Apparatus Used. A simple arrangement of storage bottles, nitrogen tank, and burets was constructed. Two four-liter bottles were connected in a series and each was also connected to a buret

which was used for dispensing the particular solution contained in the bottle. The solutions were stored in bottles covered with black bags. Both the contents of the storage bottles and the burets were kept under nitrogen pressure. The use of nitrogen in both bottles and burets was necessary to minimize the decomposition of the cupriethylene diamine hydroxide solutions due to action of the oxygen found in the atmosphere.

A 1.0 molar solution of cupriethylene diamine hydroxide was placed in the first storage bottle, and a 0.167 molar solution placed in the second bottle. By the application of two pounds of nitrogen pressure, a siphoning action was started which allowed the solutions to flow from the bottles to their respective burets. The burets were then used to dispense the proper amounts of solution, this amount being dependent on the weight of cellulose in each sample.

Fluidity Determination. The ground sample was ready for the final step in this fluidity analysis. Specific portions of both the 1.0 molar and 0.167 molar solutions of the cellulose solvent were added to each sample. One hundred twenty times the weight of cellulose per sample gave the amount of 0.167 molar solution to add. This was followed by the addition of eighty times the weight of cellulose per sample for the number of milliliters of 1.0 molar solution to add. The addition of these two solutions gave thirty to forty milliliters of solution containing 0.5 grams of cellulose per 100 milliliters and 0.5 moles of copper per liter.

The proper amounts of solutions of each concentration were added to the ground sample, and then nitrogen was bubbled over the surface of this solution for two minutes. The nitrogen was used to minimize decomposition due to the action of oxygen in the air. The four-ounce solution bottle was tightly stoppered with a rubber stopper, wrapped in a black cloth bag to prevent the entrance of light that would lead to the decomposition of the contents. The bottle was then placed in a rotating box overnight, with this apparatus rotating at approximately six revolutions per minute. This agitation time was suggested by several authorities (10,11,19) as necessary for complete dispersion of the cotton fibers into solution.

Each sample was run in duplicate through a specific viscosimeter after its agitation period overnight. A portion of the cellulose-cupriethylene diamine hydroxide solution was drawn into the viscosimeter, allowed to come to equilibrium with a twenty-five degree centigrade water bath for ten minutes, and then the rate of efflux of the solution was measured as had been done previously for the glycerine solution. From the data collected the observed fluidity was calculated as:

$$F_o = \frac{f_t}{t_o}$$

f_t is the viscosimeter constant
t_o is the time of flow of the cellulose solution

CHAPTER IV

FINDINGS AND DISCUSSION

The American Upland and Pima cotton fibers were analyzed for
the presence of nonfibrous materials, and for moisture content before
fluidity determinations were made on specific fibrous specimens.
The removal of nonfibrous materials, both the natural constituents
of the fiber and substances added by the manufacturer, was an essential
first step in the experimental procedure. The moisture content
determination was necessary for the calculation of the percentage of
cellulose in each fibrous sample. The fluidity measurement involved
the rate of flow of fibrous samples dispersed in a cupric alkaline
solution through an U-tube viscosimeter. The higher the fluidity
of the solution, the greater the chemical tendering of the cellulose
structure.

Removal of Nonfibrous Materials. The set of three samples from
the laundered and control halves of each sheet was subjected to three
extraction processes to remove nonfibrous materials from the fabric
surface. An oven-dry weight for each set of samples prior to the
extractions ranged from 0.9 to 1.0 grams for the percale samples, and
from 0.8 to 0.9 grams for the Pima cotton samples. In all cases, the
weight of the set of samples from the laundered sheeting was higher
than its control.

Samples were submitted to an ethyl alcohol extraction to remove soaps and cationic finishes which might have been present. A weight loss from 0.1 per cent to 11.25 per cent was noted in all samples after this extraction. The aqueous treatment of samples was designed to remove water-soluble materials from the fabric surface. Weight gains or losses ranged from 0.01 per cent to 7.5 per cent, with some samples gaining weight.

An amylolytic and proteolytic enzyme preparation was used in the last step of these extractions to remove any starches, gums, gelatins, and sizing adhering to the fabric surface after the two preceding treatments. Weight losses ranged from 0.1 per cent to 8.75 per cent after this extraction, with a few samples having a final weight higher than their original oven-dry weight. The enzyme treatment was responsible for the greatest weight loss among the three steps followed in this procedure.

The total per cent weight loss of the fabric samples was used as an indication of the types and amounts of nonfibrous materials present on the fabric surface and within the fiber. Samples of the American Upland and Pima cotton fibers which had been laundered only one time showed the greatest loss of nonfibrous materials. The lowest loss of nonfibrous materials was on both the Pima and American Upland fibers laundered forty times. There was no distinct pattern of amount of nonfibrous materials lost when related to the number of launderings the samples had received.

The per cent weight losses for control sheeting samples were higher for Pima cotton sheeting samples than for the percale sheeting specimens. This weight difference between Pima and percale samples was greater among the control samples than among the laundered samples. Nonfibrous materials, such as sizing, were apparently easily removed when the Pima samples were laundered. Table I. indicates specific per cent weight losses for both the control and laundered samples of each fiber content.

Moisture Content. The American Upland and Pima cotton fibers were analyzed for moisture content prior to their use in the fluidity determinations. Each sample was analyzed for its moisture content. With this information the weight of cellulose in each fibrous sample could be calculated.

There was no consistent pattern of moisture content noted among either the Pima or Upland samples before or after laundering. The mean per cent moisture content for all laundered samples was 7.53 per cent. The mean moisture content for the control, or unlaundered, samples was 8.22 per cent. Table II. indicates specific moisture contents for the laundered and unlaundered samples of each fiber content.

Fluidity Determination. The fluidity determination involved the measurement of the rate of flow of a cellulose-cupric alkaline solution through an U-tube viscosimeter. Fluidity determinations were made in one of four viscosimeters, each viscosimeter having been

TABLE I

TOTAL WEIGHT LOSS, IN PER CENT, OF NONFIBROUS MATERIALS IN AMERICAN
UPLAND AND PIMA SAMPLES BEFORE AND AFTER LAUNDERING

Launderings and Sample Number	Total Per Cent Weight Loss			
	American Upland		Pima	
	Laundered	Control	Laundered	Control
One Laundering				
1	8.70	8.36	9.05	7.02
2	7.14	3.07	9.87	7.60
3	8.32	2.43	9.49	6.70
Five Launderings				
4	2.19	3.55	3.08	5.71
5	2.20	2.78	3.67	5.86
6	3.36	3.84	2.02	6.06
Ten Launderings				
7	- .71	1.76	1.34	4.35
8	- .60	2.37	.81	7.08
9	- .30	1.31	1.36	5.32
Twenty Launderings				
10	-1.19	.58	- .70	2.48
11	-1.92	- .65	-2.67	3.08
12	-1.59	.80	.40	2.33
Thirty Launderings				
13	- .01	-1.05	-2.08	2.56
14	.70	1.77	-1.36	2.02
15	.34	- .63	-1.41	1.87
Forty Launderings				
16	- .64	.46	.10	2.62
17	- .57	.67	- .09	3.44
18	- .86	.31	.69	4.42
Fifty Launderings				
19	1.17	1.84	1.40	6.77
20	.87	2.78	1.21	6.86
21	1.61	2.96	1.96	5.94
Seventy-five Launderings				
22	4.83	6.98	6.48	10.32
23	4.72	6.68	5.82	10.46
24	4.62	6.09	6.48	9.85

TABLE II

MOISTURE CONTENT, IN PER CENT, OF AMERICAN UPLAND AND PIMA FIBERS
BEFORE AND AFTER LAUNDERING

| Launderings and Sample Number | Per Cent Moisture Content | | | |
| | American Upland | | Pima | |
	Laundered	Control	Laundered	Control
One Laundering				
1	8.49	8.73	6.70	8.38
2	9.56	9.36	9.12	8.66
3	7.59	9.34	8.45	9.86
Five Launderings				
4	6.73	5.67	9.72	9.70
5	9.48	7.14	7.47	8.98
6	7.30	9.22	9.19	8.31
Ten Launderings				
7	5.97	4.77	5.41	6.16
8	6.90	6.32	6.98	6.25
9	7.40	4.14	6.31	7.67
Twenty Launderings				
10	8.74	9.52	8.95	9.31
11	11.99	11.17	8.96	9.24
12	8.99	10.31	8.43	9.10
Thirty Launderings				
13	5.84	5.77	4.89	7.03
14	6.35	6.83	5.21	6.08
15	6.15	6.04	4.87	6.68
Forty Launderings				
16	7.24	6.58	9.79	6.39
17	9.63	6.61	6.97	7.79
18	7.50	7.80	6.72	6.99
Fifty Launderings				
19	5.03	10.25	10.60	13.90
20	9.18	11.87	11.21	10.15
21	10.41	9.56	11.15	14.15
Seventy-five Launderings				
22	8.03	7.20	4.49	7.14
23	7.18	7.66	4.19	7.21
24	7.91	7.37	6.34	7.22

previously calibrated with a glycerine solution. Duplicate measure-
ments of each sample were made.

A standard of cotton was used each day before sample determinations
were begun in order to assure that each sample had been submitted to
the same conditions, and that the alkaline solutions had not undergone
decomposition. The maximum variation of the rate of efflux of the
standard solution was twenty seconds.

The fluidity values, as measured in rhes, were different for
the American Upland and Pima cotton samples. The range of fluidity
values for the American Upland samples was from a mean of 0.72 rhes
at one laundering to a mean of 1.42 rhes at seventy-five launderings.
Control American Upland samples had an average fluidity of 0.84 rhes.
The fluidity of the laundered Pima cotton samples ranged from a mean
of 1.53 rhes at one laundering to a mean of 2.12 rhes at seventy-five
launderings. At five, twenty, and forty launderings, there was a slight
decrease in the fluidity values for the Pima cotton samples. Control
Pima cotton samples had an average fluidity of 1.38 rhes. There was
a difference of 0.54 rhes between the mean fluidity values of the
control Pima and American Upland samples, compared to a difference
of 0.74 rhes between the mean fluidity values of the laundered American
Upland and Pima samples. Table III. indicates the fluidities for
specific samples, the values given being the average of the duplicate
determinations for each sample.

TABLE III

FLUIDITY, IN RHES, OF AMERICAN UPLAND AND PIMA FIBERS
BEFORE AND AFTER LAUNDERING

Launderings and Sample Number	Fluidity in Rhes			
	American Upland		Pima	
	Laundered	Control	Laundered	Control
One Laundering				
1	.84	.95	1.53	1.02
2	.66	.86	2.02	1.41
3	.67	.60	1.05	1.26
Five Launderings				
4	.78	.89	1.18	.98
5	.88	.59	1.07	.95
6	.86	.63	1.36	1.19
Ten Launderings				
7	.84	.68	1.43	1.31
8	.68	.66	2.45	2.14
9	.61	.64	1.21	.98
Twenty Launderings				
10	.96	.76	1.13	.99
11	.81	.66	1.23	1.17
12	.79	.81	1.23	.96
Thirty Launderings				
13	.97	.70	2.47	1.37
14	.81	.87	2.38	1.95
15	1.17	.85	2.01	1.64
Forty Launderings				
16	1.09	1.05	1.36	.91
17	1.58	1.10	2.07	1.85
18	.76	1.42	1.55	1.78
Fifty Launderings				
19	1.91	.90	2.22	1.22
20	.79	.69	2.19	1.62
21	.91	1.07	1.82	.94
Seventy-five Launderings				
22	1.26	1.00	2.07	1.89
23	1.63	1.11	2.26	1.82
24	1.38	.96	2.04	1.83

Statistical Analysis of Data. An analyses of variance was the
statistical method employed to test the null hypothesis that there
was no difference between the rates of chemical tendering of American
Upland and Pima cotton fibers due to laundering. The results of this
analysis are presented in Table IV.

TABLE IV

ANALYSES OF VARIANCE OF FLUIDITY VALUES

Source of Variation	D.F.	Ss	Ms	F
Mean	1	3.812051	3.812051	21.78***
Fiber (F)	1	.412126	.412126	2.36 ns
Launderings (L)	7	1.334204	.191030	1.09 ns
F x L	7	.465833	.066548	.38 ns
Samples: F x L	32	5.599933	.174998	570.03***
Determinations: Samples	48	.014750	.000307	
Total (uncorrected)	96	11.641900		

ns — the "F" value is non significant
*** — the "F" value is significant at P = .001

The mean, as a source of variation among samples in this study,
was found to be significant at the 0.1 per cent level. This significance
was due to the difference between the laundered and control samples
from each sheet always being greater than zero. The difference between
fluidity values of the laundered and control portions of each sheet
indicated chemical tendering after one laundering and through seventy-
five launderings.

An analysis of the variety of fiber used in this study was non-significant. There appeared to be no difference in rates of chemical tendering among either American Upland or Pima fibers. The differences between the control and laundered samples of each fiber were approximately the same. Thus, these two varieties of cotton used in this study apparently tendered at a similar rate.

When the fibers were analyzed for chemical tendering due to an increased number of launderings, the results were non-significant. An increased number of launderings did not appear to cause an increased tendering of the fibers being studied. Many studies cited previously (48,50,52) also reported little tendering occurring on fibers that were laundered only. Those fibers, or fabrics, that had been laundered as well as used showed a much higher rate of chemical tendering.

A non-significant relationship was also noted between fibers as related to the number of launderings they had received. Each fiber reacted similarly with the various launderings, with no difference noted between laundered and control specimens of each fiber.

The relationship between individual samples within a particular laundering period, and for determinations for the same sample were found to be significant at the 0.1 per cent level. There was variation from sample to sample within the same laundering period, with few samples showing the same difference between their laundered and control fluidity values. The two determinations for each sample varied from 0.01 to 0.03 rhes in a limited number of cases.

The null hypothesis that there was no difference in the rate of chemical tendering between the American Upland and Pima cotton fibers was not rejected. Two variables in this study, the mean, and the samples as related to fiber and laundering period, proved to be significant at the 0.1 per cent level. However, these variables were overshadowed by the non-significance of fiber, laundering, and fiber as related to laundering variables. These latter sources of variance indicated that there was no difference in the rate of chemical tendering of the American Upland and Pima cotton fibers used in this study.

CONCLUSIONS AND RECOMMENDATIONS

This study was an exploratory probe into the behavior of two
different staple lengths of cotton fiber as available in sheeting on
the retail market in Manhattan, Kansas. The two fibers analyzed in
this study, American Upland and Pima, tendered, or lost strength,
at approximately the same rate. Each fiber showed increased fluidity
values with an increased number of launderings. The increased fluidity
values were not as great for some laundering periods as for others.

Fluidity is linearally related to strength. Strength is
directly related to serviceability of a fabric. Although the two
varieties of cotton fiber analyzed in this study tendered at ap-
proximately the same rate due to laundering, the American Upland cotton
had a higher initial strength, or lower fluidity, than did the Pima
cotton. This strength difference was noted throughout increased
launderings.

There may be several reasons for the strength difference noted
between these two fiber varieties. It is generally assumed that the
longer the staple, the greater the fiber strength. Pima cotton fibers
have a longer staple than American Upland fibers. Since percale sheets
were being tested against Pima cotton sheets in this study, the combed
yarns of the percale sheets may have represented the finest and longest
staple yarns available of American Upland cotton. A difference of
one-fourth inch is noted in the U.S.D.A. cotton staple grading system

the longest American Upland fiber and the shortest Pima cotton fiber. Thus, the two lengths of staple being tested may have varied little in length.

Clibbens and Ridge (12) noted in their study of strength as related to the fluidity of cotton that the strength of finished cotton materials depends not only upon the chemical treatment which they have received in processing, but also upon the nature of their spun and woven structure. A deficiency in strength may be due to either faulty mechanical structure, or to faulty chemical bleaching and finishing. The chemical processes to which American Upland and Pima cotton fibers had been submitted may have differed. The Pima cotton fibers could have had a higher initial strength in the original fibrous state than the American Upland fibers, but industrial processing treatments could have lowered this strength to a point where it was below that of the shorter American Upland fibers.

The source of American Upland fibers used in this study was from percale sheets. These sheets have been available to the consumer on the retail market for many years. The Pima cotton sheets, as the source for the Pima fibers used in this study, were introduced on the retail market in Manhattan, Kansas, in 1962. It is entirely possible that more research has been done on the percale sheets throughout the years to produce the best possible sheet for the consumer. Special care and precautions may have been established over the years to insure maintenance of the optimum strength of the fibers used in these sheets.

Since Pima cotton sheets are relatively new on the market the research and processing conditions may be much less advanced than those established for the percale sheets. It is recommended that more research needs to be conducted in this area.

It is further recommended that fibers to be analyzed in future studies be laundered a greater number of times in order to accurately chart tendering that has occurred. If a larger number of samples could be analyzed for each group of launderings, perhaps some pattern would emerge that would indicate the direction in which degradation was occurring. The number of sheets laundered at one time in this study was six, this number constituting one wash load. Because of the time available for this study, hundreds of samples were not laundered for a varying number of launderings.

Many investigators in this field have made use of a cuprammonium solution as the cellulose solvent. The results reported from such studies have indicated accuracy of the highest order. Since fluctuations were noted in this study among fluidity readings obtained on the same sample, and on the standard cotton sample, it is suggested that in future studies this cuprammonium solution might be used.

More information as to the exact variety of cotton used in the sheeting analyzed in this study would have been very helpful. A staple length analysis prior to fabrication, if possible, would have proved helpful in determining the relationship between fluidity and staple length of each fiber analyzed in this study. Without this information, the researcher had to assume that the staple length of

each fiber was an average length for that particular variety. It
was only a conjecture that the length of these two fibers was approxi-
mately the same.

The two fibers analyzed in this study appeared to lose strength,
or degrade, at approximately the same rate. Neither fiber lost a
great amount of strength, but it is important to note that some
strength loss did occur due to shortening of the cellulose chains.
The fluidity values for these fibers were only slightly different.
It is predicted that American Upland and Pima cotton fibers, when used
in sheeting as in this study, would have about the same serviceability
in home use. Although about $1.50 per sheet more is paid for the
Pima fibers, a corresponding strength increase is not noted when
compared to the American Upland fibers used in percale sheets. The
responsibility rests upon the consumer to make wise purchases in
her selection of houshold and clothing items. Aesthetic values,
appearance, or price may not always be true measures of the performance
of the fiber or fabric in home use.

ACKNOWLEDGMENTS

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A COMPARISON OF THE CHEMICAL TENDERING

DURING LAUNDERING OF AMERICAN UPLAND

AND PIMA COTTON FIBERS

by

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AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Clothing and Textiles

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1964

The purpose of this research was to compare the chemical tendering occurring during laundering of American Upland and Pima cotton fibers. Chemical tendering, or loss of strength, can be measured through the use of fluidity determinations, accurate and sensitive indications of change in the cellulose chain structure.

Agriculture is the largest single industry in the United States, and cotton is the biggest single cash crop within this industry. Since the consumption of cotton has declined slightly in the United States in recent years, producers and manufacturers of cotton have developed new uses for the various varieties of cotton, especially the longer staple cottons.

American Upland and Pima cotton are two of the main varieties of cotton grown in the United States at the present time. American Upland, a long staple cotton, is the principal cotton grown in the United States and many foreign countries. Pima is an extra-long staple cotton. Due to the low yield per acre of Pima cotton, its cost, both on a wholesale and retail level, is considerably higher than that of American Upland cotton. This fiber has recently been introduced in a variety of household and clothing items where Pima cotton had never been used before.

The two fibers analyzed in this research were those found in sheeting purchased on the retail market in Manhattan, Kansas. The American Upland fibers were found in combed percale sheeting, while the Pima cotton fibers were found in Pima cotton sheets, recently introduced on the retail market in Manhattan, Kansas.

Sheets were laundered for one, five, ten, twenty, thirty, forty, fifty, and seventy-five launderings in an automatic agitator-type washer. One-half of each sheet was laundered, and the other half was held as a control. The sheets were dried in an automatic tumbler-type drier according to manufacturer's specifications.

Method 629-59T of the American Society for Testing Materials was followed for the removal of nonfibrous materials from the fiber and fabric surfaces. Method 539-53 of A.S.T.M. was used for the determination of the fluidity of the fibrous samples. Sub-method B using cupriethylene diamine hydroxide and U-tube viscosimeters was followed. Both the control and laundered samples were submitted to this fluidity determination.

An analyses of variance was the statistical method employed to analyze data collected in this study. Neither the American Upland nor the Pima cotton fibers showed any difference in the rate of chemical tendering with increased launderings. There was a significant relationship at the 0.1 per cent level when the mean was analyzed as a source of variation. A significant relationship at the 0.1 per cent level was also noted between samples within specific laundering periods.

The American Upland fibers had a higher initial strength than the Pima cotton fibers, and this relationship continued throughout the study. The Pima cotton fibers may have had a higher initial strength in their original fibrous state, but industrial processing treatments such as bleaching and finishing may have lowered the strength of these fibers to less than that of American Upland fibers.

It is suggested that fibers to be analyzed in future studies be laundered a greater number of times in order to accurately chart tendering that has occurred. The use of a cuprammonium solution as a cellulose solvent might lead to further accuracy of results in the fluidity measurements. The responsibility rests upon the consumer to make wise purchases in her selection of household and clothing items. Aesthetic values, appearance, or price may not always be true measures of the performance of the fiber or fabric in home use.