TECHNICAL BULLETIN

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PRODUCING COLORFAST COTTON KNITS

SUMMARY

In home laundering, knit fabrics are subject to fabric-to-fabric and fabric-to-metal abrasion, deformation, and chemical exposure, all of which threaten to alter the knit fabric's original appearance. Through research, various elements have been identified that directly influence the color retention performance of a garment. Dye selection and finish selection, which includes softeners, resin, and enzyme treatment, all impact color care and if properly applied, can extend the life of the garment. These factors are important to provide the consumer with better quality cotton products.

INTRODUCTION

Cotton knit fabrics maintain a significant market share in men's knit shirts, children's tops, and women's wear garments. "Business Casual" product categories as well as "Casual Day" trends in the business arena have created demand and opportunities for 100% cotton knitwear products. Color retention of 100% cotton fabrics is largely dependent on how the garment fares through the home laundering/tumble drying (HLTD) process. The home laundry remains an area where improvements can be made with respect to the durability of color.

It has become apparent, through research at Cotton Incorporated, that dye selection is the number one consideration when producing colorfast cotton fabrics. Reactive dyes have been shown to provide the best washfastness properties on cotton fabrics that are subjected to home laundering.[1] Under these test criteria, reactive dyes consistently perform better than vat, direct, and sulfur dyes in today's home laundering environment.

Color loss can also be related to the degree of fuzzing or pilling of fibers on the surface of the fabric, generated during home laundering cycles. An 'apparent' color loss can be associated with surface abrasion, which may be related to dyestuff type and application method as well as detergent type used. However, there are certain steps that can be taken to alleviate a fabric's propensity for fuzzing. Preventative measures, which include cellulase enzyme treatment, durable press resin finishing, singeing, or a combination of the aforementioned processes will remove the fibers that protrude from the yarn bundle. These fibers are the ultimate culprits in creating the fuzzy surface that in turn deceives the eye into believing that color has been lost from the fabric.

As opposed to woven fabrics, knit fabrics are usually more loosely constructed of yarns with lower twist, or turns per inch, and so the yarns are bulkier. Of the different types of yarn systems used for cotton fiber, ring spinning produces the hairiest yarn. However, this is also the softest, strongest yarn and it can be spun into a wide range of counts. The ring spinning process is very prevalent in developing countries and these countries are exporting goods to the US.

This Technical Bulletin reviews various means to improve colorfastness of cotton knits through dye selection, fabric preparation, and fabric finishing.

COLORFASTNESS AS A FUNCTION OF DYE PERFORMANCE

DYE SELECTION

There are a variety of dyes available for use on cotton fabrics. The most popular are reactive, direct, vat, and sulfur dyes. For a very long period of time, the AATCC TM 61-2A wash was used as the standard for dyestuff performance as it related to the consumer. This accelerated wash is a very good tool for predicting catastrophic failure of a shade. For example, this test demonstrates that direct dyes, with their weak bonding system, are not fast to home laundering. However, this test is not sufficient to show how the color of a garment will perform under extended home launderings. It has only been through many hours of actually laundering garments in a home laundry machine that it was discovered reactive dyes perform better with today's detergent systems than vat dyes. The covalent bonds on the reactive dyes are better able to lock the color onto the fiber and are more resistant to today's detergents and washing aids. Recent advances in reactive dye technology have made it possible to put multiple reactive sites (or anchors) and chromophores on a dye molecule, thus enabling good exhaustion, fixation, and higher tinctorial strength. Multi-anchor reactive dyes appear to perform better through home laundering than reactive dyes, which have only one reactive anchor present. Multiple anchors provide the dye with more opportunity to bond with the cotton fiber.

CHLORINE

In the US, consumers are moving toward the use of colder water for laundering. Heating tap water tends to drive off the chlorine. Therefore, cold tap water tends to contain more chlorine than warm or hot tap water. With this in mind, the selected dyes should have good cold water bleed characteristics and good color fastness to the low levels of chlorine present in municipal water for sanitation purposes (usually up to 3.0 ppm). The major brands of laundry detergent usually contain a chlorine scavenger. This is helpful for preserving color; however, there are at least one and sometimes two cold rinses, in which no scavenger is present, following the washing step. These rinses pose a problem for the dye that is not chlorine stable and the exposure to chlorine through repeated rinse cycles will break down the dye. Therefore the selected dyes should have good chlorine fastness. It was determined, through research, that the shading components in the formula, (example, red and yellow in a navy formula), are important to shade stability and should be chosen with as much care as is given to the principal color component. If a shading component loses its color it will affect the shade of a garment just as much as if the principal dye were to change. [2, 3]

COLORFASTNESS AS A FUNCTION OF THE FABRIC SURFACE

ABRASION

Previous studies have suggested that abrasion is a contributing factor to color loss in home laundering/tumble dry situations.[4] Abrasion on a knit fabric surface can occur in the washing machine as well as in the dryer. Abrasion causes surface fibers to be raised and this surface "fuzz" imparts a faded, washed out look to the garment. Recent studies indicate that fuzzing, or an abraded surface, gives rise to apparent color loss particularly on knit fabric. This illusory color loss can be referred to as a 'phantom color loss' phenomenon. Furthermore, this apparent color loss can be reduced, or nearly eliminated, if the fuzz is removed through an enzyme wash application at the mill level.[5]

It might be expected that some softeners applied to knit fabric may diminish the abrasion introduced through home laundering as softeners can have a lubricating effect on fabrics. Conversely, there have been some indications that certain types of softener chemistries may promote or aggravate fuzzing (abrasion) in home laundering.[2, 3, 5, 6]

Water level in home laundering may have a negative impact on color retention/color loss in cotton knit fabrics. At lower liquor ratios, more abrasion may occur for a standard weight load. A higher liquor ratio appears to reduce fabric-to-fabric abrasion thereby causing less fuzzing on knit fabric when laundered in a top-loading washing machine. A recent study shows that abrasion may be more of a factor in "apparent" (phantom) color loss than originally recognized. Abrasion may cause more color loss than residual chlorine levels in the wash and rinse cycles.[7] A study was conducted to evaluate color loss due to abrasion in knit fabrics that have been laundered in washing machines at different water level settings.[7]

Percent color strength measurements are shown in Table I. These percent color strength values are based on a comparison to the same finished fabric sample before it has been subjected to any laundering. Color strength was higher for the four-pound load of samples laundered in 18 gallons of water (B) compared to the same size load laundered in 14 gallons of water (A). The only difference in these two sample sets was the water level/liquor ratio. Both loads were of the same content and size and both wash water conditions were equal. A comparison was made between process water, where the chlorine had been "filtered" out (C), and municipal water that contains chlorine (B) (2.2 ppm total, 0.2 ppm free). There was not much difference in percent color strength between these two conditions (B and C). However, the color strength difference between samples laundered with different liquor ratios (condition A versus B) ranged from seven (7) to nine (9) percent lower for condition (A) in all cases. The consistent nature of this difference implicates fuzzing or surface abrasion to be a significant factor in apparent color loss.[7]

Table I. Percent Color Strength After 20 HLTD Cycles

Water Source	Finish					
	No Finish	Mild Cationic	Mild Cationic + Resin	Amino Funct. Silicone + PE	Amino Funct. Silicone + PE + Resin	Wetter Only
A	89.2	84.5	86	78.1	76.7	85.8
B	97.8	92.2	94.9	85.3	85.3	93.2
C	95.6	92.2	91.1	84.5	85.8	92.1

A = Municipal water, 14 gallons; B = Municipal water, 18 gallons; C = Process water, 18 gallons

CELLULASE ENZYME TREATMENT

Enzymes have long been used in the textile industry to remove size from woven fabrics as the first step in preparation. In the 1980's, cellulase enzymes were introduced to aid in the washing of denim. These enzymes have also proven useful in removing the surface fibers from other types of cotton fabric. Cellulase enzymes are often applied following the dyeing stage because the process of dyeing a knit fabric can cause the surface of the fabric to become fuzzy, as a result of fabric-to-fabric and fabric-to–machine abrasion, thus creating an undesirable product. At this point, cellulase enzymes are used to remove the surface fibers and leave the fabric looking smooth. This process is durable and will enable the fabric surface to remain smooth through multiple home launderings. However, it has been shown that to be most effective, the enzyme should be applied after preparation and prior to dyeing.[4, 14] If done at this stage, the fabric can maintain a clean, smooth appearance through 20+ home laundering cycles. The application of cellulase enzyme after dyeing is generally not as effective, possibly due a blocking of the amorphous regions by the dye. In addition, shades may be adversely affected by acid cellulase enzyme application conditions when performed after the dye cycle, which would in turn create difficulty in shade matching. Also, because the enzyme is removing fiber, if used after dyeing it is removing dyed fiber and this can have a noticeable effect on the shade of the fabric.

The following is a recommended procedure for the removal of surface fiber from cotton knit fabric in a jet dyeing machine:

Acid Cellulase Enzyme	2.0 g/l
Buffer	to pH 4.5-5.5
Soda Ash	0.5 g/l

Fill machine to level with water and heat water to 135°F (55°C).
Add buffer and check pH.
Add enzyme and run for 30-60 minutes (depends on fabric and machine).
Drain and refill.
Heat water to 170°F (77°C) and add soda ash while heating.
Run 10 minutes.
Drain, fill warm (120°F/49°C).
Run 5 minutes.
Drain and unload or begin dyeing process.

Acid cellulase enzymes run best in a narrow window of temperature and pH range. These factors must be carefully monitored. Live steam injections into the bath will deactivate the enzymes so it is important that the enzyme is added after the heating stage is complete. Closed coil steam heat or a heat exchanger should be used to maintain temperature.

The addition of soda ash in the rinse will raise the pH enough to deactivate the enzyme. This is important as the enzyme should be deactivated after a certain period of time so it does not continue to digest the cotton fiber and further weaken the fabric.

An acid cellulase enzyme is rather aggressive and must be carefully controlled so as not to result in undesirable fabric strength and weight loss. Because the enzyme digests the cellulose, there will always be a reduction in fabric strength and fabric weight. This can be controlled by regulating enzyme type, concentration, pH, time, and temperature.

The cellulase will remove the surface fuzz and maintain a garment's appearance similar to the condition as purchased. Through multiple home laundering cycles, as long as the enzyme treatment is followed by a dye formula comprised of quality reactive dyes that are not susceptible to degradation caused by chlorine (present in the municipal water system) or the alternative bleaching agents in detergents, retaining a smooth surface means there will be very little perceived color loss on the garment even after extended (20+) home laundering/tumble dry cycles.

In one study, knit interlock fabrics dyed to a black shade were treated with an acid cellulase enzyme AFTER being laundered 20 times.[8] Prior to enzyme treatment the reactive dyed fabric had lost an average of 8.7% color strength. Once these fabrics were processed through a cellulase enzyme treatment they regained almost 100.0% of their lost color strength. Some of the fabrics went from having color strength values of 86.0% (of the original color strength) after 20 launderings up to 98.5% following the enzyme treatment. This indicates that the base color is still there, it is just being obscured by light refraction from surface fibers. Once the surface fibers are removed, the actual color of the fabric can be measured.[8]

Enzymes rely on fabric-to-fabric and fabric-to-machine abrasion to assist in removing surface fibers. Therefore, enzymes will be much more efficient in a garment dye machine than in a jet as the fabric-to-fabric contact is much greater in a garment machine. Once the enzyme treatment has been completed, there are many loose fibers in the bath. When fabrics are enzyme treated in garment form, the cellulose fibers removed by the enzyme are easily rinsed away and any that remain after the garment wash step will be removed in the tumble dryer. However, when the enzyme is applied to fabric in the jet, the loose fibers that are generated by the enzyme become entrapped inside the knit tube and remain in the tube throughout processing. It may be necessary to invert the tube and rinse the fabric again if the loose fibers pose a problem in subsequent processing. Table III lists the advantages and disadvantages of cellulase enzyme treatments on knit fabrics.

Table II. Advantages and Disadvantages of Cellulase Enzyme Treatment on Knits

Advantages	**Disadvantages**
Smooth surface	Weight loss
Treatment durable through 20+ HLTD cycles	Strength loss
Improved color retention	Lint in tube (for jet treated goods)
Soft hand	Color change may occur upon treatment
Low propensity for surface fuzzing to occur	

When fabrics are treated with enzymes prior to dyeing, the dye shade may require some adjustment to match a pre-determined shade as the surface of the fabric has changed. Usually, a slight increase in the amount of dye is required to produce a similar shade when compared to fabric that has not been cellulase enzyme treated.

DURABLE PRESS RESIN TREATMENT

Cross-linking resins have been used extensively over the past several decades on woven cotton fabrics for imparting smoothness and reducing the amount of shrinkage. It has also been noted that cross-linking resins assist in maintaining the original color of the woven fabrics after multiple home launderings. Wrinkle-resistant khaki pants are now the norm in both men's and women's casual wardrobes.

In effort to keep knit fabrics looking smooth and wrinkle-free out of the dryer, a durable press resin is sometimes applied. This resin will help to maintain a knit fabric's dimensional stability and will also contribute to a smooth surface appearance through multiple home launderings.[9] Regardless of the fabric construction, a durable press resin will typically reduce certain physical properties (tensile strength, burst strength, etc.) of the material. Therefore, care must be taken when determining how much resin to apply, the proper curing conditions, and what other additives are needed to ensure a good balance of properties such as strength, softness, abrasion resistance, and smoothness.

Resin is finish chemistry so it is applied to the fabric after dyeing. Care should be taken as it is not unusual for resin to strip some level of dye from the fabric as it is being pad applied. The low pH of the resin bath may also cause acid hydrolysis of some reactive dyes and thereby alter the final shade of the fabric.

In one study, different levels of durable press resin were padded onto 100% cotton interlock fabric. The resin was then dried and cured. These samples were then processed through multiple home laundering / tumble dry (HLTD) cycles to determine the effect of laundering on the resin treated knit fabric performance and surface smoothness. Typically, the greater the number of HLTD cycles through which a knit garment is processed, the greater the amount of resulting color loss. This color loss can be attributed to the gradual removal of the dye chromophore from the cellulose or can be caused by an alteration in the surface reflectance of the material created by fuzzing. A change in reflectance is related to the raising of surface fibers, which is a result of fabric-to-fabric and fabric-to-machine abrasion experienced in the HLTD cycles. The surface fuzz causes an increase in the scattering of incident light, thus causing the knit fabric to appear lighter in color.[9]

This study also shows that as the level of durable press resin increases, the degree of color loss after multiple HLTD cycles decreases. Combining enzyme treatment with a cross-linking resin will also reduce the amount of color loss experienced by a knit fabric through multiple HLTD cycles because there are so few surface fibers present to create fuzz. An increase in the level of cross linking resin causes an increase in the resistance to pilling which can be a measure of the propensity to create surface fuzz. However, it was shown that fabrics treated with less than 6.0% cross-linking resin began to fuzz as the number of home launderings approached 20. Fabrics that were enzyme treated in addition to any level of resin (including 0.0%) did not fuzz.[9] Table III contains a listing of the advantages and disadvantages of applying a durable press resin to knit fabric.

The following is the procedure used to give the best balance of colorfastness and smoothness for a variety of knit fabrics. This procedure may be altered for specific fabric types.

Finishing Chemicals	On Weight of Bath
Wetting Agent	0.3%
DMDHEU Resin	5.0%
Catalyst, $MgCl_2$	1.5%
Polyethylene (high density)	1.0%
Silicone Emulsion* (amino functional)	3.0%

Pad on chemical bath
Dry at 240°F (116°C), first pass
Cure at 340°F (171°C), second pass: 15-30 seconds

*May cause poor colorfastness to home laundering due to surface fuzz developments and other mechanisms (as much as 20.0% color loss has been recorded after 20 HLTD cycles even when using the best quality reactive dyes).

Table III. Advantages and Disadvantages of Resin Finishing Knit Fabrics

Advantages	**Disadvantages**
Smooth fabric for consumer	May incur color change upon application
Less propensity for fuzzing for consumer	Fabric strength loss
Improved color retention for consumer	Low levels of formaldehyde
Improved dimensional stability for consumer	Requires pad-dry-cure of fabric or garment application
Overall higher quality end products	

SOFTENER APPLICATION

Data indicates that the softener can have an impact on color change and color loss. As an example, silicone softeners are widely used on apparel, as they are known to improve fabric hand. However, they are suspected to aggravate fuzzing in cotton knit fabrics and can lead to poor color retention values with deterioration of surface appearance.

In one study, eleven finishes using various silicone softeners were evaluated with respect to fabric fuzzing and color change after multiple home launderings.[6] Some of these finishes were on enzyme treated goods and some of the finishes contained a durable press resin system. After 20 home laundering cycles, not one finish had color strength greater than 90%. The occurrence was regardless of the presence of resin, which is usually thought to improve color retention. One softener formulation, containing an amino functional silicone and medium density polyethylene softener, had a significant negative effect on color strength.[3, 6] Earlier studies have also indicated that silicone softeners may contribute to poor color retention and surface appearance after multiple HLTD cycles.[10, 11] In a follow up study the evaluation was repeated but without the presence of the silicone softener. The fabric that was treated with a cationic softener plus resin achieved 98.0% color strength retention after 20 HLTD cycles. When resin was subtracted from this formula, the color retention was 91.6%.[12]

SINGEING

Singeing is a less common method to remove surface fibers from a knit fabric. Such surface fibers can ultimately lead to abrasion related color loss. Although singeing is primarily performed on woven fabrics, there are singers designed specifically for knit fabrics. The Vollenweider Pyrotrop tubular and open-width singer is a stand-alone unit and was used in a study. Fabric was singed either before preparation or after jet dyeing, when the surface of the fabric would be abraded generating protruding surface fibers.[13]

Singeing improved the original surface appearance of the fabrics and removed the protruding fibers. If singeing was performed after dyeing it had a more lasting effect on the fabric's surface appearance through multiple home launderings. Singeing after dyeing requires that the fabric be processed through a mild scour to remove the singed fibers from the fabric.[13]

One advantage to singeing versus enzyme treating is that singeing will not adversely affect the fabric's weight or strength as enzymes can. However, enzyme treatment will enable a knit fabric to retain its smooth surface for a longer period of time than singeing.

CONCLUSION

Colorfastness depends on processing, treatment and care of the fabric. Colorfastness or improved color retention may be achieved on cotton knit fabric through proper reactive dye selection followed by appropriate softener selection. Cellulase enzyme treatment and resin finishing are also important techniques used to achieve improved color retention on knit fabrics.

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RESEARCH AND TECHNICAL SERVICES

Cotton Incorporated is a research and promotion company representing cotton worldwide. Through research and technical services, our company has the capability to develop, evaluate, and then commercialize the latest technology to benefit cotton.

- Agricultural research leads to improved agronomic practices, pest control and fiber variants with properties required by the most modern textile processes and consumer preferences. Ginning development provides efficient and effective machines for preservation of fiber characteristics. Cottonseed value is enhanced with biotechnology research to improve nutritional qualities and expand the animal food market.
- Research in fiber quality leads to improved fiber testing methodology and seasonal fiber analyses to bring better value both to growers and then mill customers.
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- The Company operates its own dyeing and finishing laboratory, knitting laboratory, and a laboratory for physical testing of yarn, fabric, and fiber properties including High Volume Instrument testing capable of measuring micronaire, staple length, strength, uniformity, color, and trash content.

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