ÇUKUROVA UNIVERSITY
INSTITUTE OF NATURAL AND APPLIED SCIENCES

PhD THESIS

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EFFECT OF FINISHING PROCESS ON ELASTANE CONTAINED DENIM FABRIC PROPERTIES

DEPARTMENT OF TEXTILE ENGINEERING

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ÖZ

DOKTORA TEZİ

BİTİRME İŞLEMLERİNİN ELASTAN İÇERİKLİ DENİM KUMAŞ ÖZELLİKLERİNE ETKİSİ

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Denim, güçlü ve uzun ömürlü bir geleneksel giyim olan dimi dokumaya sahip sıkı dokunmuş bir kumaştır. Streç kot, gençler arasında en popüler denim türüdür. Bu çalışmada, 78 dtex ve 127 dtex olmak üzere iki farklı lineer yoğunluğa sahip elastan özlü iplik kullanılarak iki seri denim kumaş üretilmiştir. Kumaşlar ayrıca 120°C ve 190°C olmak üzere iki farklı sıcaklıkta yıkanmış veya merserize edilmiştir. Malzemelerin yarısı 10 cm genişliğe gerilirken diğer yarısı değişmeden bırakılarak iki en değişkeni elde edilmiştir. Elastikiyet ve kalıcı uzama, genişlik, boyut değişimi gibi boyutsal parametreleri; kopma mukavemeti, yırtılma mukavemeti ve dikiş kayması gibi mukavemet parametreleri; hava geçirgenliği ve sertlik gibi konfor parametreleri ölçülmüştür. Ayrıca, renk ölçümü spektrofotometre ile yapılmış ve kumaş yüzeyinin morfolojisini görmek için SEM görüntü analizi yapılmıştır. İstatistiksel analiz için regresyon analizi, bağımsız örneklem t testi ve çoklu karşılaştırma testleri kullanılmıştır. Sonuçlar, 127 dtex denim kumaşların 78 dtex kumaşlara göre daha yüksek alan yoğunluğu, elastikiyet, çözgü yönlü kopma mukavemeti, atkı yırtılma mukavemeti ve sertlik değerlerine sahip olduğunu ancak daha düşük genişlik, kalıcı uzama, atkı yönlü kopma mukavemeti ve hava geçirgenliği değerlerine sahip olduğunu ortaya koymuştur. Ayrıca, iki kumaş arasında dikiş kayması, çekme ve çözgü yırtılma mukavemetinde önemli bir değişiklik olmamıştır. Elastanın doğrusal yoğunluğunun iki kumaş serisinin renk değerlerini etkilemediği ve merserize numunelerin yıkanmış numunelerden daha büyük renk değişim değerlerine sahip olduğu tespit edilmiştir.

Anahtar Kelimeler: Streç denim, Core-spun, Yıkama, Merserizasyon, Apre

ABSTRACT

Ph.D. THESIS

EFFECT OF FINISHING ROOCESS ON ELASTANE CONTANED DENIM FABRIC ROPPERTIES

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Denim is a tightly woven fabric with a twill weave that is a strong and long-lasting traditional wear. Stretch denim is the most popular type of denim among young people. In this study, two series of denim fabrics were produced using elastane core-spun yarn with two distinct linear densities: 78 dtex and 127 dtex. Fabrics were also washed or mercerized at two different temperatures: 120°C and 190°C. Half of the materials were stretched to a 10 cm width, while the other half were left unchanged, yielding two width variables. The dimensional parameters of elasticity and growth, width, shrinkage, and areal density; strength parameters, i.e., breaking strength, tearing strength, and seam slippage and comfort parameters like air permeability and stiffness, have been measured. Furthermore, the color measurement was done by spectrophotometer, and SEM image analysis was also done to see the morphology of the fabric surface. Regression analysis, the independent samples T-test, and multiple comparison tests were used for statistical analysis. The results revealed that 127 dtex denim fabrics featured higher areal density, stretch, warp way breaking strength, weft tearing strength, and stiffness values but lower width, growth, weft way breaking strength, and air permeability values than 78 dtex fabrics. Furthermore, there were no significant changes in seam strength, shrinkage, and warp tearing strength between the two fabrics. The linear density of elastane did not affect the color values of the two series of fabrics and mercerized samples had larger color change values than washed samples.

Keywords: Stretch denim, Core-spun, Washing, Mercerization, Finishing

GENİŞLETİLMİŞ ÖZET

Denim, çözgülerin normalde çivit rengi boyandığı ve atkıların genellikle boyanmadığı, dimi dokumaya sahip yoğun dokunmuş bir kumaştır. Denim kumaşın popülaritesi, model çeşitliliği, uzun ömürlülüğü, rahatlığı ve uygun fiyatı nedeniyle her geçen gün artmaktadır. Vücuda ideal uyum nedeniyle elastomerik iplikler son yıllarda streç denim kumaşlarda popüler hale gelmiştir. Son zamanlarda, streç kot talebi önceki beş yılda %70 oranında artmıştır.

Bununla birlikte, elastikiyette kontrolsüz bir artış giyimle ilgili sorunlara neden olabilmektedir. Deformeler ve kırışıklıklar, giyimde elastikiyetle ilgili en yaygın sorunlardan ikisidir. Artan kumaş büyümesi ve çekme oranları, giyim konforu üzerinde zararlı bir etkiye sahiptir ve anormal ölçülere sebep olabilmektedir. Sonuç olarak, giysilerin ömrü ve kalitesi azalmaktadır. Denim kumaşların çok fazla mukavemeti ve esnekliği olmakla birlikte aynı zamanda ideal olmayan çok fazla genişleme ve büzülmeye de sahiptir. Literatürde bu alanda yapılan birkaç çalışmaya atıfta bulunulmuştur.

Elastan, çekim oranı, elastikiyet, elastik geri kazanım, özlü iplik, çift özlü iplik ve bunların denim kumaş kaliteleri üzerindeki etkilerini görmek için çeşitli lineer yoğunluklar kullanılarak birçok deney yapılmıştır. Bununla birlikte, birkaç araştırma çalışması, sıcaklık, ön terbiye, germe genişliği farklılıkları ve atkı ipliklerinde değişen elastan doğrusal yoğunlukları gibi terbiye faktörlerini dikkate almıştır. Sonuç olarak, bu çalışma, denim kumaşın nihai özelliklerini tahmin etmek için terbiye faktörlerini optimize etmede özgün bir çalışmadır.

Picanol rapierli dokuma makinesinde 3/1 dimi dokumada iki farklı denim kumaş üretilmiştir. Kullanılan çözgü ipiği numarası Ne 7.12, çözgü sıklığı 25 tel/cm'dir. Atkı ipliği numarası Ne 10 olup, 78 dtex ve 127 dtex lineer yoğunluklarda elastan özlü iplik eğrilerek üretilmiştir. Atkı sıklığı 16.3 tel/cm'dir. Dokuma tezgahındaki tarak numarası 56/4, tarak eni 185 cm'dir. Bitirme işlemleri olarak yıkama ve merserizasyon kullanılmış, 120°C ve 190°C sıcaklıklarda ramözde kurutma yapılmıştır. İşlem sırasında kumaşların yarısının genişliği 10 cm arttırılmıştır. 78 dtex elastan içerikli atkı ipliği ile sekiz numune, 127 dtex elastan içerikli atkı ipliği ile diğer sekiz numune üretilmiştir. Böylece araştırmayı yürütmek için toplam 16 örnek geliştirilmiştir. Daha sonra mamul kumaşlar, durulama yıkama, enzim yıkama, taş yıkama ve kombine taş ve ağartma yıkama gibi endüstriyel yöntemlerle işlenmiştir. Son olarak, yıkanan örnekleri değerlendirmek için renk analizi ve SEM görüntü analizi yapılmıştır.

Elastikiyet ve kalıcı uzama, genişlik, büzülme ve alan yoğunluğunun boyutsal parametreleri ASTM D3107-07, ASTM D3774-96, ISO 675:2014 ve ASTM D3776 ile değerlendirilmiştir. Ayrıca TS EN ISO 13934-1:2013, TS EN ISO 13937-1 ve ASTM D4034 standartlarına göre; sırasıyla kopma, yırtılma ve dikiş (kayma) mukavemetleri değerlendirilmiştir. Hava geçirgenliği, TS 391 EN ISO 9237'ye göre 'Prowhite EP08 M Hava Geçirgenlik Test Cihazı' kullanılarak belirlenmiştir. ASTM D 1388-14e1 kapsamında Shirley'nin konsol sertlik ölçüm cihazı ile kumaş sertliği tespit edilmiştir. ASTM E1347, Minolta Spektrofotometre kullanılarak renk ölçümü yapılmıştır. James H. Heal FOM 71 CLS yıkama ve kurutma makinelerinde evsel yıkama ve kurutma yapmak için ISO 6330:2012 kullanılmıştır. Bitim işlemi görmüş numunelerin yüzey morfolojisi, Enerji Dağılım X-Işını Spektrometresi (EDXS) ile ASTM E2809-13'e göre incelenmiştir.

Test sonuçlarının ortalaması, standart sapma ve standart hata ortalamaları tanımlayıcı istatistikler kullanılarak belirlenmiştir. İki grup test bulgusunun ortalamalarını karşılaştırmak için bağımsız örneklem t-testi kullanılmıştır. Numunelerin farklı süreçlerdeki test sonuçları arasındaki istatistiksel fark, çoklu karşılaştırma testi kullanılarak belirlenmiştir. Regresyon analizi, yıkama ve merserizasyon nedeniyle test bulgularını tahmin etmek ve ramöz sıcaklığı ve genişliği değişikliklerinin çıktı değişkenleri üzerindeki etkisini araştırmak için kullanılmıştır.

Deneysel sonuçlara göre; terbiye işlemleri nedeniyle kumaşların ağırlığının %13-15 oranında azaldığı keşfedilmiştir. Buna ilave olarak, daha yüksek sıcaklıkta

(190ºC) yapılan gerdirme sonucunda kumaş yapıları daha gevşek bir form almış ve daha düşük gramaj (GSM) ile sonuçlanmıştır. Daha yüksek lineer yoğunluklu elastan kullanımı birim alanda çözgü yoğunluğunun artmasına neden olduğundan, 127 dtex denim, 78 dtex denimden %6 daha fazla gramaja sahiptir. Ancak bu durum, 127 dtex denim kumaşların, 78 dtex denim kumaşlardan %5 daha düşük genişlikte olması ile sonuçlanmıştır. Yıkanmış numuneler, merserize edilmiş olanlara göre %2 daha geniş ene sahiptir. Merserizasyon işleminde atkı ipliklerinin selüloz moleküllerinin büzülmesi neticesinde oluşan şişme sonucu ende azalma olmuştur. Tüm bitim işlemi nedeniyle mamul ve ham kumaşlar arasında %10'luk bir genişlik farkı tespit edilmiştir.

127 dtex denim kumaşın esneme yeteneği, 78 dtex'den %5 daha fazlayken, 78 dtex denim kumaşın kalıcı uzama değeri 127 dtex'e göre %8 daha yüksek bulunmuştur. Kalıcı uzama ve esnemeyi tahmin etmeye yönelik regresyon modelinin varyansların yüzde 85'inden fazlası için uygun olduğu belirlenmiştir. Elastan varlığından dolayı atkı yönündeki çekme değerleri çözgü yönüne göre %30 daha fazla olmuştur. 78 dtex denim kumaşın çözgü büzülmesi 127 dtex denim kumaşa benzer görünürken, 78 dtex denim kumaşın atkı büzülmesi 127 dtex denim kumaştan %11 daha düşüktür. Ancak bağımsız T-testi sonucunda, büzülme ortalamaları arasında önemli bir fark görülmemiştir. Çalışma sıcaklığının arttırılması, büzülme kontrolü üzerinde önemli bir etkiye sahiptir.

78 dtex kumaşın atkıları, 127 dtex kumaşa göre yırtılmaya karşı %18 daha dirençlidir. Bununla birlikte, her ikisi de aynı çözgü sıklığı ile üretildiğinden, iki kumaşın çözgü yırtılma mukavemetleri arasında önemli bir fark yoktur. Ayrıca 78 dtex kumaş %8 daha yüksek atkı yönü kopma mukavemetine,127 dtex kumaş ise %15 daha yüksek çözgü yönü kopma mukavemetine sahiptir. Dikiş kayması değerleri atrasındaki farkın da önemli olmadığı belirlenmiştir.

78 dtex denim kumaşın hava geçirgenliğinin, 127 dtex denim kumaşa göre daha fazla olduğu görülmüştür. Elastan doğrusal yoğunluğunun artması, sıkı bir kumaş yapısına sebep olarak hava geçirgenliğini önlemektedir. Sonuç olarak, ikinci

kumaş serisindeki hava geçirgenlik oranları düşüktür. 78 dtex elastandan yapılan kumaşların sertliğinin, 127 dtex elastan kumaşlara göre %34 düşük olduğu belirlenmiştir. Merserizasyon sonucunda kumaşlar daha yumuşak olduğu için yıkanmış numuneler merserize numunelere göre %15 daha serttir.

Merserize numunelerin renk tonunun, yıkanmış numunelere göre daha açık olduğu tespit edilmiştir. Ayrıca, genişletme uygulanmayan mamul kumaşların renkleri, genişletilmiş olanlara göre daha koyu tondadır. Denim kumaların a* değerleri pozitif ve b* değerleri negatif olduğu için kırmızımsı ve mavimsi görünmektedir. Genişletilmemiş kumaşlar daha güçlü renkler gösterirken, merserize ve genişletilmiş kumaşlar en düşük değerlere sahiptir. Renk şidetindeki farklar az olduğundan, her iki seri için aynı renk şiddetine sahip denilebilir. Elastan lineer yoğunluğundaki değişimin, iki kumaş serisi arasındaki renk değişimi (l, a ve b) değerleri üzerinde çok sınırlı bir etkisi olmuştur.

SEM görüntü analizine göre, kumaş numuneleri yıkanmadan önce pürüzsüz bir yüzeye sahiptir. Yıkanan numunelerin kumaş yüzeyi, durulama ve yıkamadan sonra normal deterjanla yıkanmış gibi daha temiz hale gelmiştir. Enzim yıkaması sırasında kısa liflerin uzaklaştırılmasıyla daha parlak bir yüzey elde edilmiştir. Bununla birlikte, taş yıkamanın ardından, bölgesel renk solmasına ve yüzey bozulmasına neden olan önemli bir mekanik işlem gerçekleştirilmiştir. Son olarak, taş ve ağartıcı yıkama nedeniyle selüloz zincirleri parçalandığı için daha fazla lifin yüzeyi zarar görmüştür. Aynı sonuçlar diğer örneklerde de gözlenmiştir.

Bu çalışmadan elde edilen tüm sonuçlar, dikkate değer bir istisna olmaksızın önceki çalışmalarla uyumludur. Deneylerin sonuçları, farklı lineer elastan yoğunluğuna ve çeşitli terbiye parametrelerine sahip denim tekstillerin sahip olduğu özellikleri göstermiştir. Bu sonuçların işletmeler tarafından kullanılarak, kumaşların göstereceği performansa yönelik üretimden önce tahminde bulunabilecekleri düşünülmektedir.

EXTENDED SUMMARY

Denim is a densely woven fabric with a twill weave, in which the warps are normally indigo dyed, and the wefts are usually grey or undyed. Denim fabric's popularity is growing day by day due to its variety of styles, longevity, comfort, and affordable pricing. Due to the ideal fit to the body, elastomeric yarns have been popular in stretched denim fabric in recent years. Recently, demand for stretch denim has surged by 70% in the previous five years.

However, an unchecked increase in elasticity might pose issues with clothing. Deformities and wrinkles are two of the most common problems with elasticity in apparel. Increased fabric growth and shrinkage rates have a detrimental impact on clothing comfort and produce abnormalities. As a result, the clothes' lifespan and quality are reduced. Denim materials have a lot of strength and elasticity, but they also have a lot of growth and shrinkage, which isn't ideal. A few studies in this field have been cited in the literature.

Many experiments have been conducted utilizing various linear densities of elastane, draft ratio, elasticity, elastic recovery, core-spun yarn, dual core spun yarn, and their effect on denim fabric qualities. However, a few research studies have considered finishing factors like temperature, pre-finishing, stretching width differences, and varying elastane linear densities in weft yarns. As a result, this study is unique in optimizing finishing factors to predict denim fabric final attributes.

Two denim textiles in a 3/1 twill weave were made on a Picanol rapier weaving machine. The warp count and density were 7.12 Ne and 25 ends per cm, respectively. The weft yarn is elastane core-spun with 78 dtex and 127 dtex linear densities, providing a count of 10Ne. The weave had a density of 16.3 picks per cm. The reed number on the weaving loom was 56/4, and the reed width was 185 cm. Washing and mercerization were used as finishing processes, followed by stentering at two temperatures 120 and 190°C. During processing, the breadth of 50% of the fabrics was increased by 10 cm. As a result, eight examples were manufactured with

78 dtex elastane contained weft yarn, whereas the other eight were made with 127 dtex elastane contained weft yarn. Thus total 16 samples have been developed to conduct the research. Then the finished fabrics were processed by industrial methods like rinse washing, enzyme washing, stone washing, and combined stone and bleach washing. Finally, color analysis and SEM image analysis have been done to evaluate the washed samples.

The dimensional parameters of growth & stretch, width, shrinkage, and areal density were assessed by ASTM D3107-07, ASTM D3774-96, ISO 675:2014, and ASTM D3776 accordingly. Furthermore, TS EN ISO 13934-1:2013, TS EN ISO 13937-1, and ASTM D4034 evaluated the breaking, tearing, and seam (slippage) strength, respectively. Air permeability was determined using a 'Prowhite EP08 M Air Permeability Tester' in accordance with TS 391 EN ISO 9237. Under ASTM D 1388-14e1, Shirley's cantilever stiffness measurement instrument tested bending rigidity. ASTM E1347 was used to measure color using a Minolta Spectrophotometer. ISO 6330: 2012 was used to do domestic washing and drying on James H. Heal FOM 71 CLS washing and drying machines. The surface morphology of the finished samples was examined according to ASTM E2809 –13 with an Energy Dispersion X-Ray Spectrometer (EDXS).

The test results' mean, standard deviation, and standard error means were determined using descriptive statistics. The independent samples T-test was used to compare the means of two groups of test findings. The statistical difference between the sample's test results in different processes was determined using a multiple comparison test. The regression analysis was used to predict the test findings because of washing and mercerizing and investigate the impact of stentering temperature and width changes on the output variables.

According to findings, it has been discovered that 13-15% of fabric weight has been decreased because of finishing. Stretching at a greater temperature (190ºC) generated less fabric compaction, resulting in lower GSM. Because higher linear density elastane causes increased warp density in the same measured area, 127 dtex denim has 6% more GSM than 78 dtex denim. But 127 dtex denim fabrics had 5% lower width values than 78 dtex denim fabrics. The washing processes resulted in a 2% wider fabric than the mercerizing process. The shrinkage of the cellulose molecules of the weft yarns caused by the swelling in the mercerizing process resulted in a reduction in width. Due to the total finish of the fabrics, a 10% width expansion has been detected.

The stretch of 127 dtex denim was 5% more than that of 78 dtex denim, whereas the growth of 78 dtex denim was 8% higher. For more than 85 percent of variances, the regression model for predicting growth and stretch was suitable. The shrinkage values in the weft direction were 30% higher than in the warp direction due to the presence of elastane. The warp shrinkage of 78 dtex denim appears to be like 127 dtex denim, whereas the weft shrinkage of 78 dtex denim appears to be 11% lower than that of 127 dtex denim. But the independent T-test showed no significant differences between the shrinkage means. Increasing the operating temperature has a substantial impact on shrinkage control.

The wefts of 78 dtex fabric were 18% more resistant to tearing than the 127 dtex fabric. However, there was no discernible variation in warp tearing strength between the two fabrics because both were produced with the same warp density. Aside from that, 78 dtex fabric has 8% higher weft breaking strength, but 127 dtex fabric has 15% greater warp breaking strength. A non-significant difference was also observed in seam slippage.

78 dtex denim was more air permeable, whereas 127 dtex denim was more compact. The increased linear density of elastane conforms to a tight fabric structure, preventing air permeability. As a result, the air permeability ratings in the second series of fabrics have been dropped. When the stiffness of fabrics made from 78 dtex elastane was compared to 127 dtex elastane, the 78 dtex fabrics were 34% less stiff. Mercerization made the fabric softer; therefore, washed samples were 15% stiffer than mercerized samples.

The color tone of mercerized samples was lighter than that of washed samples. Furthermore, finished fabrics with no enlarged width are darker than widthwise-extended samples. The denim fabrics appear reddish and blueish because a* values were positive and b* values were negative. Non-expanded fabrics showed increased color strength, whereas mercerized and expanded fabrics had the minimum values. Both series have the same color strength since the differences between the average values of 78 dtex denim and 127 dtex denim are minor. In a nutshell, the change in linear density of elastane had a very limited effect on the color change (l, a, and b) values between the two series of fabrics.

The fabric was smooth before washing the samples, according to the morphology of the denim fabric determined by SEM examination. The cloth surface of washed samples grew cleaner after rinse washing, as if it had been washed normally. Small projecting threads were removed during enzyme washing, resulting in a glossier surface. However, a large mechanical action was conducted following stone cleaning, resulting in localized color fading and surface degradation. Finally, as the cellulose chains fragmented because of the stone and bleach washing, the surface of more fibers was harmed. The same outcomes were observed in other samples. All the results from this study are consistent in accordance with previous studies, with no notable exceptions. In short, the results of the experiments demonstrated the consequences of denim textiles with a different linear density of elastane and various finishing parameters. It is thought that these results will be used by the manufacturers, and they can make predictions about the performance of the fabrics before production.

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ABBREVIATIONS

ADR	: Areal density reduction
AP	: Air permeability
BS	: Breaking strength
GSM	: Grams per square meter
SS	: Seam slippage
ST	: Stentering temperature
WI	: Width increment
WO	: Width opening
TS	: Tearing Strength

1. INTRODUCTION

Denim is one of the most popular (Okur, 2021), dynamic, and progressive textiles (Doba Kadem & Saraç, 2017). No other fabric has garnered as much appeal as denim among all textile items. People of all ages, socioeconomic backgrounds, and genders have used it extensively (S. Wang et al., 2022) (Farha et al., 2017). Denim is a durable and long-lasting warp-faced 3/1 twill cotton fabric (Yildirim et al., 2021) (Sezgin Bozok & Ogulata, 2021) and is woven with indigo dyed (Bansal et al., 2020) warp and white filler yarns (Akgül et al., 2021) (Venkatraman & Liauw, 2018). From the seventeenth century to the present, denim has been used to make pants, jackets, shirts, working clothes, bags (Mezarciöz & Toksöz, 2014), upholstery, and awnings (R. Paul, 2015) (S. Uğur & Sariişik, 2015) (Z. Yang et al., 2010) (Card et al., 2005) (Zervent Ünal, 2012). Denim fabric's global market value was approximately 90 billion USD in 2019, and it is expected to reach 105 billion USD by the end of 2023(Ahmad et al., 2022).

The term 'denim' is considered to have come from the French serge de Nimes, a fabric made in the French town of Nimes. Denim has always been manufactured of cotton, even though it was once comprised of silk and wool. Another fabric, fustian made of cotton, linen, and/or wool blends, was known as jeans and came from Genoa, Italy. Denim was woven with one colored warp yarn and one white weft yarn, whereas jean fabric was woven with two skeins of the same color (R. Paul, 2015).

1.1. Fibers for denim production

Cotton is the most frequent fiber used in denim production. Denim is made from 10% of the world's total cotton production (Muthu, 2017). Every year, 2.16 million tons of denim jeans are thrown away worldwide, with the majority of them ending up in landfills (Haque & Naebe, 2022) (Temmink et al., 2018). So, recycled cotton has been discovered to be an excellent raw material for denim fabric production (Mezarcıöz et al., 2021). In addition to the cotton fiber, regenerated cellulosic fibers are becoming increasingly popular (Üstüntağ et al., 2022). Denim is made from other fibers such as flax, hemp, hemp, and synthetic fibers such as lycra, polyester, and lyocell (Ibrahim et al., 2018). Park et al. (2018) used Hanji paper yarn to make denim fabrics and discovered no significant difference between it and existing stretch denim fabrics. They also claimed that Hanji paper yarn has properties 90% similar to the cotton yarn of the same yarn count (Park & Kim, 2018). The fineness of regenerated cellulosic fiber and its derivatives ranges from 1–2 dtex. Solvent spinning is used to create these fibers made from wood pulp. The tenacity of the fibers is around 30–40 cN/tex. In water, however, they have a reduced toughness. The fibers are usually blended with cotton fibers at up to 25%. These fibers are well-suited for usage in denim because of their high-water absorption (Raina et al., 2015). Certain beneficial fibers are present in minimal amounts in denim used for jeans. These fibers are utilized to give denim jeans functional qualities like stretch. For example, spandex fibers, utilized in a filament form, offer stretch. Spandex fibers have a 200 percent elongation, and around 5% of these fibers are inserted into the core of denim yarns (Fein Azoulay, 2005).

1.2. Yarn for denim fabric

Yarns used to make denim must have specific characteristics to use in the fabric. The fineness of the yarn used in bottom-weight jeans ranges from 50 to 150 tex (Ne 12.5/1– 4.0). For lower-weight jeans, finer yarns are employed. The count of these yarns can range from 20 to 50 tex (Ne 12.5–30.0). High yarn strength, pilling resistance, compactness, and less hairiness and evenness/uniformity are some essential properties to manufacture a yarn for denim. Different spinning technologies can be used to provide these various yarn properties. Ring spinning, compact spinning, and open-end (rotor) spinning are the most common spinning processes used to make denim yarns (Raina et al., 2015). Denim usually uses open-end yarns, but ring-spun or compact yarns are used in significant amounts. Hybrid denim fabrics can also be made with ring-spun and rotor-spun yarns (Kim et al., 2009).

1.3. Typical denim constructions, weaves, and weights

Proper and developed fabric constructions must be designed to achieve better comfort features (Rahman et al., 2010). Cotton denim fabric for jeans is woven in a twill weave with at least three warp threads and three weft threads in a pattern repeat. The interlacing points of denim fabrics are mainly in the Z direction. A bottom weight 14.5-ounce denim is traditionally constructed using 60–64 warp threads per inch and 38–42 filler yarns per inch. The warp density is a term that refers to the number of warp yarns per inch. The size of the yarn used, the fabric weave design, and the fabric tightness influence the weight. The quantity of size left on the completed fabric also affects the fabric weight. Other denim fabrics and look-alikes may have a warp yarn count of 52 to 70 per inch and a pick count of 36 to 52 per inch. Denim is usually woven in 3/1 twill, 2/1 twill, 3/1 broken twill, or 2/2 broken twill patterns (Morris & Prato, 1978). The completed fabrics' weights might range from 3.5 to 16.5 ounces per square yard (Raina et al., 2015). The cloth is called a right-hand twill weave when the twill line rises to the right, and the upward ascending sequence continues. If the twill line climbs to the left, the design is a left-hand twill. In broken twills, the twill line is broken up at different intervals, preventing it from being in a straight line (Gries et al., 2015). Uren et al. (2019) discovered that a 3/1 twill weave had significantly better tactile properties than a 2/1 twill weave (Uren & Okur, 2019).

The weight of denim fabric usually ranges from 5 to 15 oz/yd2. For medium denim, weight lies between 5 to 10 oz/yd^{2,} whereas the weight range of heavy denim fabric is 10–15 oz/yd2. Medium denim is suitable for dresses or tops that require draping, softness, and versatility, while heavy denim is suitable for pants and skirts with blue jeans (Akter et al., 2021). Denim waste and polypropylene fibers have been combined to create a three-dimensional composite for structural applications (S. Wang et al., 2022). Watts et al. (2009) also made concrete with denim waste and polyester, modifying the surface to increase mechanical qualities(Watts & Worner, 2009).

1.4. Denim preparation

1.4.1. Warp and weft preparation

The most crucial phase in the manufacture of denim fabric is the warping process. Yarns are transported from spinning machines or winding machines into a single package assembly during the warping process. Smaller yarn packets are placed in creels that can be customized to fit the number of yarn bobbins available. The warping method involves putting several yarns from separate yarn packages onto a single package assembly. The yarns are twisted in a ball, on a dye beam, or on a regular beam. After the strands have been twisted, the coloring process begins (Raina et al., 2015).

In the weft preparation, the threads are wound from the feed onto a bobbin, typically a conical or cylindrical tube made of cardboard, plastic, or (rarely) metal. Winding is done for various reasons, including increasing the size of the yarn packet for cost and handling, improving the ability to draw off water, and improving the quality of a yarn by removing thick and thin areas, among others (Cakmak, 2013).

14.1.1. Ball warping and dyeing

250 to 400 yarn ends are plucked from the creel during ball warping. The yarns travel through a reed (a comb-like device) that maintains each warp yarn distinct and parallel to its surrounding ends. A lease string is laid across the sheet of warp yarns at intervals of 1000 or 2000 meters. The strands are then sent through a tunnel-shaped device (also known as a trumpet or condenser) that collapses and condenses the yarn sheet into rope form. The condenser at the bottom of the warper head moves back and forth, directing the newly created yarn rope onto a log. The rope must be coiled at a constant tension to keep the strands from tangling (Cakmak, 2013).

After the warp yarns have been turned into balls to make denim, the warp yarns are rope dyed. Regularly, indigo is used to color the ropes. As is well known, most good ring yarn denim is rope dyed. 12–36 strands are dipped in a series of dye boxes in a typical indigo dye range. The ropes are then dried and delivered to the department that shines them (Raina et al., 2015).

1.4.1.2. Beam dyeing

Warp yarns are coiled directly onto a perforated drum in this method. After that, the beam is colored in a dye bath at a precise pressure and temperature. Fluid flow from the interior to the outside of the beam, and vice versa, pass through the dye liquid. Because the individual beams are colored separately, this is a discontinuous dyeing procedure. In addition, this method allows the beam to be directly sized and woven after drying(Raina et al., 2015).

1.4.1.3. Slasher dyeing

Slasher dyeing is a continuous dyeing method as well. The entire beam is made up of warp strands parallel to each other in this operation. The dye baths are pulled into, and the warp yarns are dried. The next step entails applying sizing directly to the warp yarns. As a sizing reagent, starch, PVA, CMC, and acrylates can be used; however, starch is the most commonly used, and a combination of PVA and starch can also be used (Maryan & Montazer, 2013) (W. Wang et al., 2012). The sized warp yarns are coiled onto a beam, which can be used for weaving right away. The warp does not need to be re-beamed before being placed on the weaving loom in this method (Raina et al., 2015).

1.4.2. Drawing in and tying in warp yarns

When a new denim style is added to a weaving machine, the warp yarns must be drawn through stop motion devices (drop wires), weave design control devices (harnesses and heddles), and filling "beat-up" devices (reed). Each yarn requires its unique element, which can be done manually or automatically using drawing-in equipment. If the same style is being made and the current loom beam is nearly empty of yarn, a full beam of yarn identical to the old beam can be connected to the yarns of the old beam. A tying-in machine selects an end of yarn from the old beam and ties it to the right end on the new beam. Before the fabric is produced, the knots are drawn through the weaving machine. The faulty tying-in of the warp strands is well established as the cause of numerous loom stoppages.

1.4.3. Weaving of denim

Rapier and air-jet weaving are the most common machine technologies used to make denim. These technologies are capable due to their capacity to deliver great products and the ability to process denim textiles with various yarn fineness (Raina et al., 2015).

1.4.3.1. Rapier loom

Interlocking weft insertion is used on rapier looms. The gripper head captures and transfers the yarn end from the feed bobbin through the shed. The yarn is transferred to the opposing second gripper in the middle of the fabric. The basics of rapier weft insertion are shown in Figure 1.1. At every stage of the procedure, the weft insertion is monitored. As a result, this technique is adaptable and ideal for fragile fabrics. Rapiers are available in both stiff and flexible versions (Raina et al., 2015).

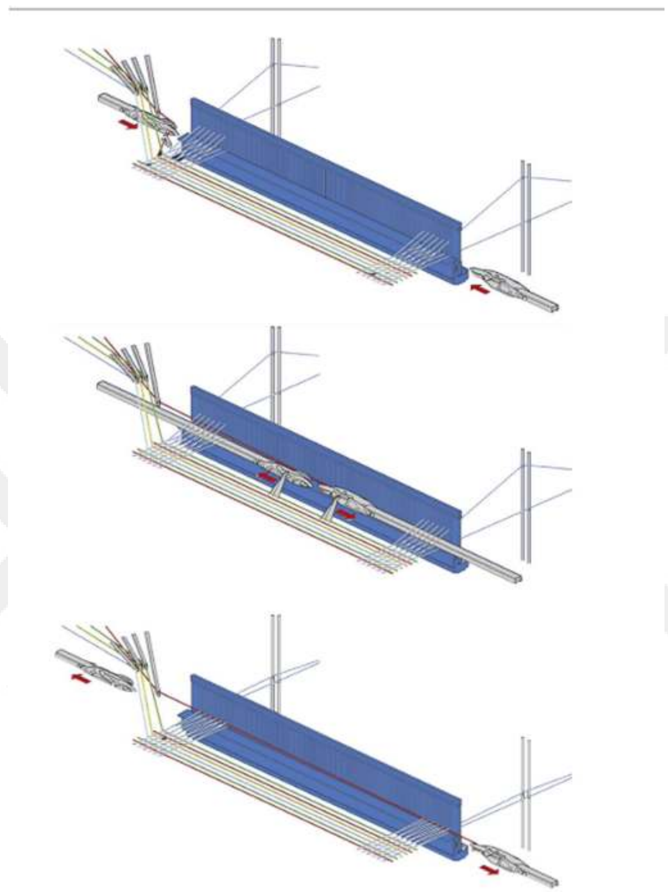


Figure 1.1. Weft insertion in rapier weaving (Lindauer DORNIER GmbH, 2013).

Filling insertion technology, which assures positive control of filling yarn transfer in the fabric center, and an open shed filling insertion function, which offers the greatest level of flexibility and quality assurance, are two aspects of the rapier machine that have been invented. The newly developed Quickset Tuck-in mechanism enables the cost-effective production of label selvedges on a rapier weaving machine, especially for thin selvedges of just 8 mm wide, while eliminating weft yarn elasticity loss on the exit side. Picanol NV, situated in Ieper, Belgium, is known for its denim fabric production machinery. For the manufacturing of denim textiles, Picanol provides the OptiMax rapier weaving machine. The Ergo option is highly recommended for decreasing weft waste and managing the release of elasticated wefts in the fabric. It allows each unique weft type to be controlled separately at the precise moment of release (Raina et al., 2015).

1.5. Indigo dyeing

Indigo, the most consumed dye (Buscio et al., 2015), produces a deep blue color with a few carbon atoms in its molecule. Due to partial penetration in cotton fibers, indigo is remarkable in its capacity to impart surface color. When indigo-dyed cotton yarn is untwisted, the inner layers are shown to be colorless. The color is also constantly fading and abrading. With several types of washing and finishing processes, indigo allows denim fabric to achieve its ultimate worn look (Maryan, Montazer, & Damerchely, 2015). In addition, it will enable denim fabric to respond to finishing applications, bringing the fabric to life. Indigo has maintained its popularity for denim dyeing despite the availability of numerous other blue dyestuffs. The ability to achieve wash down effects on repeated washings without losing the freshness of the color is a unique quality of indigo-dyed denim. Another benefit of indigo-dyed denim is that, unlike many other colors, it does not cause health problems. Indigo is so safe for living things that it's been used to color polyester medical sutures for a long time. Indigo is also a culinary color and an intravenous medicinal indication (Chavan, 2015).

1.6. Washing

Denim fabrics that have not been treated are uncomfortable to wear because of their thick and inflexible structures. Thus, they must be softened to make those comfortable wearing (Ebrahimi et al., 2018). Denim finishing is a significant textile process used to increase the value of fabrics and make them more appealing to customers (Üstüntağ et al., 2022) (Telli & Babaarslan, 2017). Both wet washes and dry processes are included in this value-adding process(Sarkar et al., 2022).

Washing can be considered the finishing process in denim production and is the essence of denim finishing. Denim washing is directly related to the chemical, mechanical and aesthetic properties (Asim & Mahmood, 2017), quality, and value of denim garments (Ticha & Meksi, 2021). In embroidery, sizing and coloring form the basis of color in denim garments. However, the washing process is key to creating style in denim garments, which has become the art of creating fashion trends. The three-dimensional (3D) effect and worn appearance can be achieved with different finishing and washing processes. Other final effects can be obtained in denim garments with various chemicals, washing conditions, and washing equipment (Roshan Paul, 2015). The treatments used to finish denim garments during washing are essential factors influencing the fabric's shade and mechanical properties. (Khedher et al., 2009).

1.6.1. Rinse washing

It is also known as the regular washing method for denim garments. This most used method is prevalent to obtain the slight color fading with uniformity (Ticha & Meksi, 2021) (Abdelileh et al., 2020). Detergent is used for regular washing for about 15 min at temperatures between 60°C and 90 °C. Softener is added after the washing. Three types of rinse washing according to time and chemicals used are as follows: (1) light washing (washing time about 5 min); (2) regular washing (washing time about 15 min); and (3) heavy washing (washing time about 30 min) (Chong, 1994). According to Xu et al. (2020), the washing temperature (30-60°C), cellulase concentration (1-4 percent on the weight of fabric), and processing time (10-40 minutes) have the most significant impact on washing performance (Xu et al., 2020).

The General regular washing process is as follows:

Wetting → Desizing → Regular washing → Softening.

1.6.2. Stone washing

A wet treatment with pumice stones bathed in potassium permanganate or sodium hypochlorite is the traditional procedure for achieving the desired roughness in denim clothes. (Yavuz et al., 2014) (Maryan, Montazer, & Harifi, 2015). More apparent but less uniform color fading and distressed look (Midha et al., 2017) are done by volcanic rocks or pumice stones as abradants during washing. Washing time: 60-120 mins, stone ratio 0.5:1 to 3:1, size of stone: diameter 1-7cm, and liquor ratio (~10:1). The basic steps of denim stone washing are as follows(Roshan Paul, 2015):

> Desizing (10–15 min) → Rinsing → Stone washing → Rinsing (with perborate and optical brightener if necessary) → Softening.

The disadvantages of pumice stones in washing are that they are difficult to remove and may clog the machine drainage. Nowadays, cellulase replaces pumice stones in washing(Tarhan & Sarıışık, 2009). Stone washing causes a 3% weight loss, a tensile and tearing strength reduction, and increased rubbing fastness (Fraj et al., 2021).

1.6.3. Enzyme washing

Cellulase enzymes hydrolyze the cellulose in enzyme washing (Z. Yang et al., 2010). As a result of catalyzation, the protruding fibers become weaker, and they get removed during washing, and color fading occurs. Two types of cellulase are used: neutral cellulases are applied at P^H 6-7 while acid cellulases are applied at P^H 4.5-5.5, enzyme dose: 2-4 g/L (Roshan Paul, 2015). The basic steps of denim enzyme washing are shown as follows (Chong, 1994):

> Desizing (10–15 min) → Rinsing → Enzyme washing, e.g., 30–60 min at 50–60 °C with P^H 4.5–5.5 → Hot rinsing, e.g., 80 °C → Softening

During enzymatic treatment, removed indigo can re-deposit on white denim yarn. Back-staining ruins the look of a denim garment. An ideal bio-stoning enzyme would be abrasive with low back staining(Cavaco-Paulo et al., 1998). Although some research has been done on back-staining, the issue remains a concern for manufacturers (Tarhan & Sarıışık, 2009). The instantaneous or synchronous action of cellulases and mechanical agitation will abrade the fiber surface. Dye or dye aggregates with cotton will be released from yarns in denim fabrics due to enzyme abrasion, resulting in blue color contrasts. Because the fibrillation that occurs during the aging process results from the synergistic action of cellulases and mechanical movement, the aged appearance can be replicated with less abrasive action (Montazer & Maryan, 2008; C. Q. Yang et al., 2003). There are acid and neutral cellulases on the market, with acid cellulase being the most popular (Paulo et al., 1996). On the other hand, acid cellulase may degrade cotton fibers when applied in an acidic medium (pH 5.5) (Vishnu Vardhini & Selvakumar, 2006). But cellulase immobilized on a surface has enormous potential for bio-washing denim fabrics (Yu et al., 2013).

1.6.4. Stone and bleach combined washing

In this process, stone washing is done with the presence of pumice stones. The bleach wash is unavoidable, even though it decomposes the cellulose and destroys the fabric, turning it yellow and necessitating neutralization, which increases the cost and processing time. Bleaching agents, particularly chlorine bleaches, are toxic to humans and the environment (Sarkar & Khalil, 2014). Sodium hypochlorite bleaching is more popular because of its low cost and ability to bleach at room temperature. Still, it comes with the risk of yellowing, reduced strength, and health hazards (Zhang et al., 2018).

1.7. Mercerization

In textiles, mercerization is a chemical treatment done to cotton fibers or fabrics to increase their affinity for dyes and other chemical finishes permanently. Mercerizing also gives cotton material improved tensile strength, better absorptive characteristics, and, depending on the process, a high degree of shine. The yarn or fiber is immersed in a sodium hydroxide (caustic soda) solution for a brief time, often less than four minutes. The substance is subsequently treated with water or acid to neutralize the sodium hydroxide. The material is kept from shrinking significantly if held under tension throughout this stage; if no stress is applied, the material may shrink by as much as one-fourth. Mercerization is a process that allows higher-quality cotton fabrics to take brighter, longer-lasting colors with less dye(*Mercerization*, 2022).

1.8. Other applications of denim

Apart from fashion and clothes, there are other innovative variants of denim that are finding applications in several industrial areas like cosmetic textiles (Issazadeh- Baltorki & Khoddami, 2014). One such application is denim in non-apparel products like furniture, upholstery, car and house interiors, technical equipment, and so on. Denim insulation and absorbent (Mendoza-Castillo et al., 2016) are also likely to be used and encouraged in future green buildings (Raina et al., 2015). Cordero-Lanzac et al. (2018) obtained activated carbon cloths from denim fabric waste and made this ACC appropriate for use in an electric double-layer capacitor (Cordero-Lanzac et al., 2018).

Organic cotton, eco-efficient non-indigo dyes, intelligent weaving machines, customized garment dyeing, digital printing, biotechnological as well as reduced water washings, functional finishing, non-apparel denim products, recycling of denim waste, and reduction and treatment of effluents are some of the future areas of growth in this direction.

1.9. Fabric properties

1.9.1. Stretch

Fabric stretch is the length difference between benchmarks prior to application of the tension and while under pressure. As a result, growth is the ability of a yarn or fabric to return to its previous length, form, and size. Because these values are based mainly on elastane characteristics, it is believed that no elastane was destroyed during the processes. Stretch capacity and wrinkle prevention can be improved by combining a cotton and spandex yarn blend (Babaarslan et al., 2018). Fabric stretching is being calculated by the equation (1.1).

1.9.2. Growth

Growth is defined as the length difference between the benchmarks before applying the tension and after relaxation. Growth rates for core-spun in the weft direction are slightly higher than elastic core-spun yarn in denim fabric. The sheath is made up of elastic yarns, while the central part of the stretch yarn structure comprises spandex or Lycra® (Boubaker et al., 2017a; Jaouachi & Sahnoun, 2007). Fabric growth is being calculated by the equation (1.2).

1.9.3. Elastic recovery

When a compressive force is removed, an elastomer's ability to recover its original shape is measured by its elastic recovery, also known as resilience. Elastic recovery is affected by the length, intensity, and amount of stress applied to the material. For example, when a textile material is stretched with force not more significant than its breaking strength and then allowed to recover, it does not immediately return to its original length. Permanent deformation, immediate recovery, and delayed recovery are the three types of elastic recovery properties (Baghaei et al., 2010). Elastic recovery is being calculated by the equation (1.3).

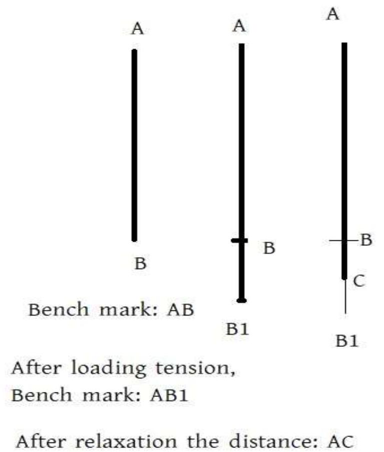


Figure 1.2. How to calculate the stretch, growth, and elastic recovery

AB=X= Distance between upper and lower benchmark =250 mm

AB_1=Y= Distance between the mark points after loading for 30 minutes

AC=Z = Distance between the mark points after loading for 30 minutes and 1 hour of relaxation

$$\text{Fabric stretch (\%)} = \frac{BB_1}{AB} = \frac{AB_1 - AB}{AB} = \frac{Y-X}{X} \times 100 \tag{1.1}$$

$$\text{Fabric growth (\%)} = \frac{BC}{AB} = \frac{AC-AB}{AB} = \frac{Z-X}{X} \times 100 \tag{1.2}$$

$$\text{Elastic recovery (\%)} = \frac{B_1C}{BB_1} = \frac{AB_1 - AC}{AB_1 - AB} = \frac{Y-Z}{Y-X} \times 100 \tag{1.3}$$

1.9.4. Shrinkage

Cloth shrinkage occurs when a piece of fabric shrinks in length and width after exposure to water, steam, or a chemical treatment. Cotton materials shrink in length and width, while other fabrics shrink just in one dimension (*Fabric Shrinkage*, 2022). Shrinkage has been calculated (Dhouib et al., 2016) by the equation (1.4)

$$\text{Shrinkage}=\frac{L_0-L}{L_0}\times 100 \tag{1.4}$$

L_0 = Initial length of the tested fabric before washing

L = Length of the tested fabric after washing

1.9.5. Air permeability

Air permeability is the rate at which air moves perpendicularly through a known area when the air pressure difference between two surfaces of a material is set to a certain value. Air permeability has an impact on how comfortable a garment feels. The fabric's ability to allow air to pass through when there is a differential air pressure on each side of the fabric's surface is an essential factor to consider when studying and comparing the breathability characteristic (Perlmutter, 2015).

1.9.6. Stiffness

Fabric stiffness can affect the hand feel, draping effect, and comfort sensation while wearing. A fabric's stiffness is unique: the natural inclination to remain upright without any support. Therefore, it is crucial to understand the fabric's handle and drape properties. Laundry cycles progressively make the yarn more flexible, resulting in a decrease in stiffness in the materials. Cationic and nonionic softener agents have been used to reduce stiffness (Sezgin Bozok & Ogulata, 2021).

1.9.7. Breaking strength

The maximum amount of tensile stress that a material can bear before failure is known as its breaking strength. It varies depending on the mass stress at the time of rupture. The value of breaking is when a material switches from elastic to plastic deformation. The strength is measured lengthwise or warp-wise and width-wise or weft-wise (Baghaei et al., 2010).

1.9.8. Tearing strength

Under specific conditions, the force necessary to begin or continue to tear a cloth in either the weft or warp direction is defined as tearing strength. The tearing force is also described as "weft longitudinal" or "warp longitudinal," depending on whether the tear occurs along the weft (weft threads break) or warp (warp threads break), respectively. It describes the gradual, thread-by-thread fabric rupture along a line, whereas all the yarns are broken during a tensile strength test. As a result, the tensile strength value (in kilograms) is larger than the tearing strength value (Eryuruk & Kalaoğlu, 2015).

1.9.10. Seam slippage

The tendency for a seam to open due to applying a force perpendicular to the seam direction is known as seam slippage. It's a measurement of yarn slippage along the seam of a cloth. If the stitches are more between the seam and cut edge, the force against slippage is more. The quality of the stitching has a significant impact on the overall quality of the garment. The efficiency, elongation, bending, stiffness, abrasion resistance, seam-slippage strength, puckering, tightness, boldness, and seam damage evaluate seam quality. A good seam must meet both functional and aesthetic criteria. A comparison test is done between an unseamed test piece of fabric and a seamed fabric specimen to measure seam strength. The sample is dragged under tension until it breaks, comparable to a grab test. The woven textile is considered to have 100% seam efficiency if the unseamed component fails before the seam fails (Saville, 1999).

1.10. Purpose of the study

The main goal of this project is to determine the best finishing settings for denim fabric processing while keeping the physical and mechanical properties in mind. One of the most critical targets was to find the suitable spandex linear density in core-spun yarn used as weft. In addition, the goal was to determine the relative importance of washing and mercerizing. Furthermore, we attempted to determine the optimal finishing temperature and width opening during the finishing process.

2. LITERATURE REVIEW

The qualities of stretch denim fabric were investigated in this Ph.D. study by varying different finishing parameters. Because elastane content fabric processing is influenced by temperature, time, and other mechanical processes, it is critical to forecasting the denim fabric's ultimate qualities. In the literature review, various properties of denim fabrics have been studied. Different yarn processing, dimensional, mechanical, and comfort features of denim fabrics have been written in order in this literature study. Furthermore, the literature review described finishing parameters that had previously been explored by other researchers.

Denim is a densely woven fabric with a twill weave where the warps usually are indigo dyed, and wefts are grey or undyed. Other colors have been added to the blue series production, and weaving patterns have become more varied (Park & Kim, 2018). The consumers of denim fabric are increasing day by day for various looks, longevity, comfort (Akgül et al., 2021), and reasonable price. In recent years, the trends of using elastomeric yarns (Babaarslan, 2001) in stretched denim fabric have been observed due to the perfect fit to the body (AK & Bansal, 2018). As a result, stretch denim demand has increased by 70% in the last five years (Sarwar et al., 2017).

Ring-spun denim has a better appearance and is more durable than open-end denim (Husworth et al., 1978). Open-end yarn fabrics have lower breaking, tear, and abrasion resistance than fabrics made from ring-spun yarns. Core-spun threads are created by ring frame (Sinha et al., 2017) and are always hairier than staple yarns of the same fibers (Babaarslan, 2001). During the spinning process, elastane enters the twisting zone from the delivery roller and receives twist with the thread in this area, resulting in core-spun yarn. Meanwhile, elastane is left in the yarn's core (Babaarslan, 2001) and covered with cotton or other staple fibers. Using a thread guide device and proper spandex tension control helps keep the spandex in the yarn's center, improving the elastomeric yarn's quality (Su & Yang, 2004).

However, using core-spun yarns with only elastane in the core position causes fabric growth, and using them as warp yarns causes some weaving problems (Yildirim et al., 2021). Dual-core yarn construction is one of the innovative approaches in denim production to address these issues. It allows fabric stretch properties to be improved and the properties of two or more materials to be used simultaneously (Sabry & Bakry, 2017). The core-spun weft yarns are more liable for greater growth values, tensile strength, and tear strength than the double core weft yarns. The strength of the yarn and the structure of the fabric determine the fabric's tear and tensile strength (Adanur & Qi, 2008). (Bedez Ute, 2019) manufactured denim fabrics using core-spun and double core weft yarns with varied weft densities, then investigated the dimensional and mechanical properties of the materials. She discovered that fabrics woven with double core weft yarns showed better elongation and elasticity values.

(Su et al., 2004) found that the 19.7 tex elastic core-spun yarn has better tensile and elastic recovery with a spandex draw ratio of 3.5.The core/sheath ratio should be increased to increase the tensile strength of the manufactured core-spun fiber (M. Ertekin & Kirtay, 2015)**.** Other researchers focused on elastane containing core-spun yarns in terms of elastane draft, elastane ratio, elastane linear density, elastic yarn positioning, twist factor, etc., to obtain optimum yarn properties (Shi & Xuling, 2012). A twist parameter of 670 turns per meter and a core draft ratio of 3.3 elastane draft ratio was found more appropriate for dual-core yarn production (Yildirim et al., 2021).

Sinha et al. (2017) investigated the effects of twist multiplier, linear density, stretch percent, and applied load on the elastic performance and tenacity of cotton/spandex core-spun yarn. They discovered that spandex/cotton core-spun yarn with a lower linear density, lower stretch, and a smaller twist multiplier performs better in terms of elasticity. Using one to five percent lycra/cotton blend allows the fabric to "stretch" over the body for a more comfortable fit (Sinha et al., 2017).

(Mezarciöz et al., 2020) evaluated the growth and elasticity of denim textiles woven with core and siro spun yarn. They discovered that the weft yarn count, elastane draft ratio, elastane linear density, spinning method, and density parameters had a significant association with fabric elasticity and growth qualities. They also discovered that using elastane is one of the most effective ways to reduce the growth value and that raising the weft draft ratio improved fabric growth and elasticity.

El-Ghezal et al. (2009) studied the effect of the finishing procedure and the elastane ratio on the mechanical properties of denim fabrics. They discovered that the mercerization process resulted in significant width-wise relaxing, which increased weight per unit area and reduced weft shrinkage. Sanforizing also reduced washing shrinkage and boosted warp direction extensibility. The fibers were mechanically degraded due to excessive heat during processing. They also noticed an upward tendency in the elastane ratio and a downward trend in the elongation at break (El-Ghezal et al., 2009). The yarns with a higher elastane are more flexible, and the fabric is woven. This yarn can extend easily and show elastic recovery after relaxation without deformation (Meric & Gurarda, 2002). Fabrics showed a positive trend for stretchability and stretch growth recovery as the percentage of spandex in the weft yarn increased, but fabric growth showed a negative trend (Akter et al., 2021).

Draft ratio is defined as the ratio of the linear winding velocity to the filament exit velocity through the aperture. The draft ratio and linear density of elastane on the mechanical and physical qualities of denim fabrics manufactured with core-spun cotton yarns were investigated by Qadir et al. (2014**)**. They concluded that these two properties were crucial for yarn elongation and toughness. The mechanical properties could not be improved solely by increasing the draft ratio. Elastane linear density must be compatible with the overall yarn linear density to achieve the best elongation performance (Qadir et al., 2014).

Gürkan Ünal and Konal (2021) conducted a study to determine the influence of weft yarn characteristics on stretch denim fabric elastic recovery and elasticity. They discovered that increasing the PES content in yarn showed better performance in shrinkage control of denim samples (Gürkan ünal & Konal, 2021). In addition, the effects of human motion on clothing 20%–30% of a fabric's elasticity have been found to provide an acceptable level of movement and comfort (Sarwar et al., 2017).

Bansal et al. (2020) discovered that the tensile strength of denim made with core-spun yarn increases as the linear density and stretch percentage decrease. They concluded that denim fabric made of finer stretch yarns is more robust and elastic than denim fabric made of coarser yarns due to its better recovery behavior (Bansal et al., 2020). Mourad et al. also found that air permeability and tearing strength decreased significantly with a high spandex content. Therefore, the woven fabrics will have a higher spandex content, making them thicker and more compact (M et al., 2012).

Durability and comfortability of garments during consumption are very much vital features. Comfort is a sensory perception based on the feeling and experience of the consumer when touching the fabrics (Okur, 2021) (Fraj et al., 2021). According to Haque and Naebe (2022), Fabric weight and elastane percentage affect denim garments' physicomechanical properties to produce denim products that meet the needs of their customers (Haque & Naebe, 2022). It has been found that some mechanical properties like stiffness, shear, drape and bending are greatly influenced by the softening and bleaching process. These two processes also have a significant and positive impression on thermal comfort properties such as thermal conductivity, thermal diffusion values, and thermal absorptivity. As the denim fabric containing elastane yarn is more thermal and water vapor resistant, it ensures warmness and comfort to the consumer during winter. Water vapor resistance(WVR) and water vapor permeability (WVP) are free of the influence of the finishing process (Eryuruk, 2019).

Özdil evaluated the mechanical properties of five different denim textiles with varying amounts of elastane. According to the study, increasing the amount of elastane in denim fabric improves comfort. In addition, elastane-containing core-spun yarns had a lower breaking strength than non-elastane yarns, and higher elastane stiffened denim fabrics (Özdil, 2008).

Perspiration, or the removal of sweat in liquid form from the body surface, is affected by the moisture management properties of fabrics. It's vital for performance and functional textiles because it gives customers the comfort and protection they want (Özkan & Kaplangiray, 2017; Repon et al., 2021). The porosity of a material determines its air permeability (Midha et al., 2017), and the number of pores affects the porosity (G. Ertekin, 2017). Microporosity and macroporosity are two types of porosity found in woven fabrics. Microporosity determines air permeability, whereas macro and microporosity determine fabric thermal resistance and water vapor permeability (Zupin et al., 2012). In addition, increased filament fiber composition increases air permeability for the same fabric structure (Onal & Yildirim, 2012).

Draw ratio of elastance, weft sett, and weave type considerably affect the air permeability of bi-stretch denim fabric. As the weft density increases, the air cannot pass due to less air flux. Balance twill weave shows the decreasing effect on air permeability with the rise in draw ratio (Çelik & Kaynak, 2017). (Midha et al., 2017) investigated the moisture management and permeability of enzyme-washed and unwashed denim under repeated laundering, finding that unwashed fabrics have more permeable cotton weft yarns than lycra weft yarns.

Another study considered spandex linear density, twist multiplier, and fabric weight per unit area to assess the tensile strength and breaking elongation. The test results exposed that breaking elongation increases and tensile strength decreases with increasing the lycra content in the fabric (Choudhury et al., 2018). In addition, the tenacity and stretching properties at the different weft and warp densities with various elastane ratios have been measured. An increasing trend has been found in breaking tenacity as the washing cycle increased, whereas a negative trend has been noticed regarding breaking elongation (EK et al., 2018).

Ertaş et al. (2016) researched finishing parameters and elastane on the denim fabric properties. They discovered that the density of dual-core weft yarn containing the elastane has a greater significant impact on the width and mass per unit area than the elasticity ratio. The depth of color shade differs with the change of elastane contained weft density (Ertaş et al., 2016).

Boubaker et al. (2017) examined the effect of steaming temperature, relaxing time, linear density, and steaming duration on the mechanical properties of denim yarn and discovered that there were significant relationships between them (Boubaker et al., 2017b). Comparatively, a lower growth value is preferred to produce a supple fabric with reduced shrinkage (Babaarslan & Dasan, 2020).

The home laundering treatment of denim fabrics affects the fabric's shade and mechanical properties(Ş. S. Uğur et al., 2017). For example, the dry-relaxed samples with a low spandex draw ratio showed a higher elasticity value. Conversely, the finished-relaxed samples did not affect the spandex draw ratio. In the above study, researchers found the optimum value of the elastane draw ratio was 3.07, and the maximum load was 25 N for the lowest permanent stretch and the highest for the laundered samples (Kaynak, 2017).

Dhouib et al. (2016) developed a MINITAB model to predict shrinkage based on different finishing treatments under industrial conditions, which was extremely useful in avoiding unnecessary costing and size corrections (Dhouib et al., 2016). Litim et al. (2017) experimented with different resin applications and finishing conditions on cotton denim fabrics. They revealed that when compared to untreated fabric, crease recovery improves after washing, but breaking strength decreases by more than 40% (Litim et al., 2017). In addition, fabric with elastane-based dual-core weft yarns provides more elongation properties and elastic recovery (Pannu et al., 2020).

Many studies have been undertaken using varied linear densities of elastane, draft ratio, elasticity, elastic recovery, core-spun yarn, dual core spun yarn, and their effect on denim fabric properties, as shown in the literature reviews. However, few studies have considered finishing characteristics like temperature, pre-finishing, stretching width variations, and different linear densities of elastane in weft yarns. As a result, this research is the exception in terms of optimizing finishing parameters to forecast the final attribute of denim fabrics.

3. MATERIALS AND METHODS

3.1. Materials

Picanol rapier weaving machine produced two denim textiles in a 3/1 twill weave. Ne 7.12 and 25 ends per cm were the warp count and density, respectively. The weft yarn is elastane core-spun with two different linear densities of 78 dtex and 127 dtex, yielding a count of Ne 10. The density of the weft was 16.3 picks per cm. The weaving loom's reed number was 56/4, and the reed breadth was 185 cm. The finishing techniques included washing and mercerization, followed by stentering. The suffocating temperatures were from 120 to 190°C. 50% of the fabrics' width was extended by 10 cm during processing. As a result, eight samples were made from 78 dtex elastane with weft yarn, while the remaining eight were made from 127 dtex (Table 3.3). The warp and weft yarn properties have been depicted in Table 3.1.

Table 3.1. Yarn properties

Test criteria	Warp: 7.12/1 Ne Ring card cotton		Weft-1: 10/1 Ne Ring card cotton+ 78 dtex Elastane		Weft-2: 10/1 Ne Ring card cotton + 127 dtex Elastane	
	Mean	%CV	Mean	%CV	Mean	%CV
Ne	7.17	1.20	9.97	1.20	9.80	1.60
U%	14.42	17.63	9.67	12.35	10.23	13.04
Thin (-50%/km)	0.10		0.00		0.20	
Thick (+50%/km)	76.30		78.70		104.00	
Neps (+200%/km)	63.50		341.80		86.30	
Hairiness	8.00		7.00		8.71	
Elongation (%)	7.04	6.52	8.33	7.08	8.30	6.67
RKM	19.40	8.42	21.50	6.54	17.17	7.50
Breaking force (g)	1609.00	8.42	1147.00	6.64	1014.00	7.50

Table 3.2 describes the quality report for spandex yarn used in weft yarn preparation.

Table 3.2. Quality report for spandex yarn

Test criteria	Units	Results	
		78 dtex	127 dtex
Linear density	d/9000 m	65.8	114.8
	dtex	73.1	127.5
Tenacity	g/d	1.09	1.38
Elongation at break	%	519	518
Oil pick-up	%	5.8	4.4
Package relaxation	%	10.5	10.8

Table 3.3. Manufacturing strategy for denim processing

Series	Weft	Process	Temp (°C)	Width opening (cm)	Sample No.	Identity
01	10 Ne+78 dtex EA	Washing	120	0	A1	78W120(0)
		Mercerization			B1	78M120(0)
		Washing		10	C1	78W120(10)
		Mercerization			D1	78M120(10)
		Washing	190	0	E1	78W190(0)
		Mercerization			F1	78M190(0)
		Washing		10	G1	78W190(10)
		Mercerization			H1	78M190(10)
02	10 Ne+127 dtex EA	Washing	120	0	A2	127W120(0)
		Mercerization			B2	127M120(0)
		Washing		10	C2	127W120(10)
		Mercerization			D2	127M120(10)
		Washing	190	0	E2	127W190(0)
		Mercerization			F2	127M190(0)
		Washing		10	G2	127W190(10)
		Mercerization			H2	127M190(10)

Table 3.3 shows that the A1 sample was made from 78 dtex elastane core-spun yarn that had been washed and stretched at 120°C with no width expansion. B1 sample was made from 78 dtex elastane core-spun yarn that had been mercerized and stretched at 120°C with no width expansion. C1 sample was made from 78 dtex elastane core-spun yarn that had been washed and stretched at 120°C with 10 cm width expansion. D1 sample was made from 78 dtex elastane core-spun yarn that had been mercerized and stretched at 120°C with 10 cm width expansion. E1 sample was made from 78 dtex elastane core-spun yarn that had been washed and stretched at 190°C with no width expansion. F1 sample was made from 78 dtex elastane core-spun yarn that had been mercerized and stretched at 190°C with no width expansion. G1 sample was made from 78 dtex elastane core-spun yarn that had been washed and stretched at 190°C with 10 cm width expansion. H1 sample was made from 78 dtex elastane core-spun yarn that had been mercerized and stretched at 190°C with 10 cm width expansion.

A2 sample was made from 127 dtex elastane core-spun yarn that had been washed and stretched at 120°C with no width expansion. B2 sample was made from 127 dtex elastane core-spun yarn that had been mercerized and stretched at 120°C with no width expansion. C2 sample was made from 127 dtex elastane core-spun yarn that had been washed and stretched at 120°C with 10 cm width expansion. D2 sample was made from 127 dtex elastane core-spun yarn that had been mercerized and stretched at 120°C with 10 cm width expansion. E2 sample was made from 127 dtex elastane core-spun yarn that had been washed and stretched at 190°C with no width expansion. F2 sample was made from 127 dtex elastane core-spun yarn that had been mercerized and stretched at 190°C with no width expansion. G2 sample was made from 127 dtex elastane core-spun yarn that had been washed and stretched at 190°C with 10 cm width expansion. H2 sample was made from 127 dtex elastane core-spun yarn that had been mercerized and stretched at 190°C with 10 cm width expansion.

Then the finished fabrics were processed by industrial methods like rinse washing, enzyme washing, stone washing, and combined stone and bleach washing. Finally, color analysis and SEM image analysis have been done to evaluate the washed samples. All the fabric samples were produced in the denim manufacturing factory named "BOSSA" in Adana Industrial Area.

3.2. Methods

Table 3.4 illustrates denim fabric processing methods with material name, amount, processing time, and temperature.

Table 3.4. Different processes with material details

Process	Details	
Warp Dyeing	Material	Quantity
	Sequestering agent	0.002 g/L
	Dispersive agent	0.001 g/L
	Indigo vat dye	0.25 g/L
	Caustic soda	0.007 g/L
	Hydro sulfide	0.001 g/L
	Wetting agent	0.003 g/L
Sizing	Starch-based	
	Size material	Quantity
	Starch	0.005 g/L
	Sizing material	0.01 g/L
	Acrylic emission	0.001 g/L
	Viscosity increaser	0.002 g/L
Washing/ Mercerization	35 m/min, 50°C	
Singeing	Face burning, 35 m/min, 10 mbar	
Finishing/fixing	120°C 45 m/min speed – 190°C 45 m/min speed.	
	Chemical name	Quantity
	Acetic acid	3 g/L
	Softener	10 mL/L
	Wetting agent	2 g/L
Sanforizing	At 45 m/min speed	

In the case of finishing followed by washing, a single machine was used for singeing, washing, and drying, with a J-box at the feeding position. The brush received the raw cloth from the J-box. The flies that had passed through the brush were cleansed and then the fabric was taken to the burning chamber. With a burning pressure of 10 mbar and a burner distance of 20 mm, the front of the fabric was burned. The machine moves at a rate of 35 meters per minute. After being burned, the fabric was washed in seven washing tubs at a temperature of 50°C and then tumble dried.

In the case of finishing followed by mercerizing, all processes like singeing, mercerizing, washing, and drying were all done in the single machine. The fabric collects in the J-box at the machine's entry, ensuring no downtime while the machine is running. The brush received the raw cloth from the J-box. Flies are removed from the fabric as it goes through the brush. The face side of the fabric cleaned was subjected to singeing. The combustion process was carried out at a pressure of 10 mbar and a spacing of 20 mm between the burners. The machine runs at a 35 m/min speed. After being burned, the cloth is sent through the mercerizing chamber. The caustic soda was used here. After treatment, the cloth was washed in seven washing tubs at a temperature of 50°C and dried in a tumble dryer.

Following pre-treatment, the materials were fed into a stentering machine and processed at two different temperatures: 120 and 190°C. Fabrics were processed through eight chambers at a pace of 45 m/min in this machine and then through one finishing chamber.

Table 3.5 depicts denim washing with details on the material amount, processing time, and temperature.

Table 3.5. Denim washing with process parameters

Process	Steps	Step details			
		Time (min.)	Temperature (ºC)	Chemical name	Quantity
Rinse washing	Softening	2	30	Non-ionic softener	3 mL/L
				Semi-micro silicone emulsion	3 mL/L
	Drying	45	80		
Enzyme washing	Enzyme washing	30	45	Enzyme	0.8 %
	Drying	30	40		
Stone washing	Enzyme+stone washing	30	45	Enzyme	0.8 %
	Rinse	4			
	Drying	30	40		
Stone and bleach washing	Desizing	10	60	Amylase enzyme	1 mL/L
				Dispersing agent	1 mL/L
	Rinse	2	-		
	Squeeze	-	-		
	Stone wash	40	30	Liquid cellulose	1 mL/L
				Dispersing agent	1 mL/L
				Pumice	100%
	Rinse	4	-		
	Squeeze				
	Remove stones				
	Rinse	2	-		
	Squeeze				
	Bleaching	15	40	Hypochlorite	40 mL/L
	Neutralization	10	40	Peroxide	3 mL/L
	Rinse	4			
	Squeeze				
	Softener wash	10	40	Softening	4 mL/L
	Dry				
Enzyme washing	Enzyme washing	30	45	Enzyme	0.8 %
	Drying	30	40		

3.4. Test methods

3.4.1. Tearing strength

Tearing strength test was done by TS EN ISO 13937-1 with James H. Heal (Elmatear model) tearing strength testing apparatus. Five samples in the warp direction and five samples in the weft direction were cut according to a template suggested by the method. All samples were taken at a distance of at least 15 cm from the previous one. Furthermore, specimens for warp way samples were taken from different warps, and specimens for weft way samples were taken from different wefts.

The test specimens were inserted into the gripping jaws with long sides parallel to the gripping jaws' upper edge. Then it is compressed by pressing the jaws against the lower fulcrum of the jaws and centering them. A 20±0.5 mm long notch was cut with the knife from the edge opposite the recess, leaving 43±0.5 mm between the recess and the edge. The stop lever was pressed to release the pendulum. The pendulum was stopped in its rotating oscillation without affecting the position of the indicator. With the measurement approximation, the indicator was read in kilograms.

3.4.2. Breaking strength

Breaking force and elongation at maximum force tests were performed using the strip method with a commercial TITAN tensile testing apparatus by TS EN ISO 13934-1:2013. Five samples in the warp direction and five samples in the weft direction were cut into 5cm×30cm dimensions. All samples were taken at a distance of at least 15 cm from the previous one. Furthermore, specimens for warp way samples were taken from different warps, and specimens for weft way samples were taken from different wefts. The distance between two jaws is 30 cm. The test specimen was placed in the upper jaw clamps and allowed to hang freely under its mass before being manipulated by hand to achieve perpendicular alignment to the line of pulling force while closing the lower jaw. The test specimen's extension was determined by measuring the force/extension curve point that corresponded to the pre-tensioning force. Any break within 5 mm of the jaws' clamping line was recorded. The results obtained at the end of the five tests have been taken.

3.4.3. Seam slippage

Seam slippage was measured by ISO 13936-1:2004/ ASTM D4034/D4034M-19 method.

3.4.5. Air permeability

The materials were tested for air permeability using a 'Prowhite EP08 M Air Permeability Tester' following TS 391 EN ISO 9237. The measuring area was 20 centimeters square, the air pressure was 100 Pa, and the air volume passed was10 dm^3. The test samples were put on the circular sample holder such that the fabric surface was neither distorted nor wrinkled. At least five readings were taken from five distinct locations.

Air permeability has been calculated with equation (3.1).

$$\text{Air permeability} = \frac{Q_v}{A} \times 167 \tag{3.1}$$

Q_v= Arithmetic means of air flow rate (dm^3/min)

A= The test area of the sample (20 cm^2)

167 = conversion factor from dm^3/min to mm/s

Figure 3.1. Air permeability tester (Prowhite EP08M)

3.4.6. Stiffness test

Shirley's cantilever stiffness measurement device assessed bending rigidity under ASTM D 1388-14e1. The samples for the bending rigidity test were 2.5 cm×15 cm in size. Four warp samples and four weft samples were cut with the long side parallel to the warp lines and the long side parallel to the weft. Samples were taken from various locations, all of which were far from the edges. Curled and bent surfaces were flattened by slightly compressing them.

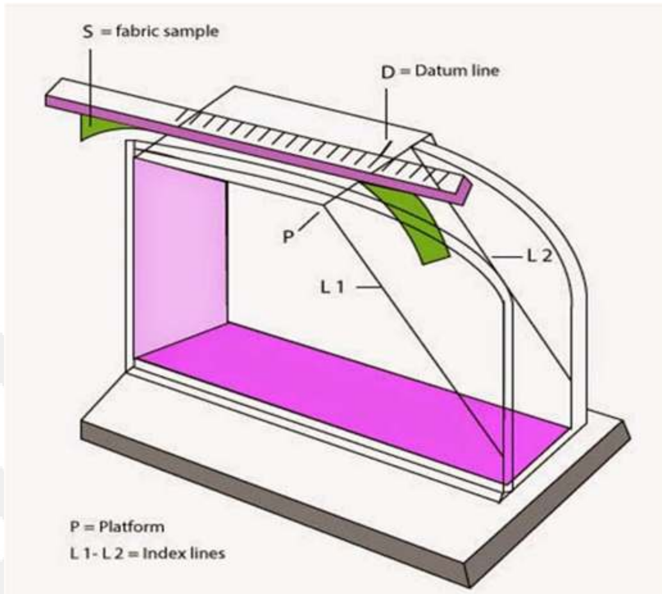


Figure 3.2. Shirley stiffness tester(Sayed, n.d.)

It was confirmed that the instrument was horizontal with a spirit level by placing it on a flat surface. The test sample was sandwiched between the plane and the strand, with one end overlapping the P plane's edge and the strand's start line D. Forward plane by bending under the weight of the sample and gradually shifting it from the edge. The bar halted when the sample's tip contacted the L1 and L2 lines, and the overhang length was measured on the scale. The L1 and L2 lines are placed on the test specimen midway if the sample was bent. Warp way stiffness, weft way stiffness and total stiffness were calculated by the equations (3.2) to (3.4).

Warp way stiffness, $G_{wa} = 0.1 \times W \times L^3$ mg.cm (3.2)

Weft way stiffness, $Gwe = 0.1 \times W \times L^3$ mg.cm (3.3)

Overall flexural strength or stiffness, $Go = \sqrt{(G_{wa} \times G_{we})}$ mg.cm (3.4)

Here, L = average bending length in cm
W= mass per unit area (g/m^2)
G_{wa} = Warp way bending strength
G_{we} = Weft way bending strength
G_o = Overall flexural strength

3.4.7. Color measurement

Color measurement was done by ASTM E1347 with Minolta (CM 3600D) Spectrophotometer. The instrument was calibrated initially, and then spectral reflectance values were collected at 10 nm intervals from 400 nm to 700 nm in the visible spectrum. All the color measurements and visual evaluations were conducted in the same direction. During the measurements, the luminance component (Specular component included, SCI) is included in the reflectance.

Figure 3.3. Minolta (CM 3600D) Spectrophotometer

The samples' color measurements were taken with the CIELAB system and a 10° standard observer in D65 light. The Real Color1.3v software packages calculated the color difference values. The CIELAB coordinates (L*, a*, b*, C*, h), K/S (color strength) values, and color differences (ΔE*) were measured. The L* value represents lightness and varies from 0 (black) to 100 (white). The a* and b* values refer to redness-greenness and yellowness blueness. The chroma, C*, measures color saturation. The hue angle, h, runs between a 0° to 360° color range, and angles of 0°, 90°, 180°, and 270° refer to red, yellow, green, and blue shades, respectively (Duran, 2001). The dyed fabric's color depth was determined by using the Kubelka-Munk equation (3.5) to determine the K/S value of a specific dyed specimen (Darda, 2020).

Where R is the percentage of reflectance, K denotes the absorption coefficient, and S denotes the dye scattering coefficient. Those results derived from the ratio of light particle attenuation due to absorption and scattering, which was calculated using reflectance data.

$$\frac{K}{S} = \frac{(1-R)^2}{2R} \tag{3.5}$$

The color change measured from one color sample to the next is Delta E (Finn, 2021). The ΔE* was obtained according to the CIEL*a*b* (1976) equation. Color is described in a 3D color space using three-point axes, and visual perception might vary. Hence, Delta E. Measurement of color difference represents the difference between one color, and another is significant for two reasons. The first purpose is to match colors to assure dyeing accuracy before making garments. The second purpose is to assess the degree of change over time, commonly referred to as fading. Using the Hunter Lab color scale and a Spectrophotometer, color is measured in three dimensions: L, a, and b. To ensure a positive number, each reading's distance to compute the Delta E variation from the produced color to the target (to provide a positive number) must be squared. Then, the Delta E variance is calculated with equation (3.6) by adding all the squares of those readings and taking the square root of that value.

$$\Delta \mathrm{E} = \sqrt{\{(L2 - L1)^2 + (a2 - a1)^2 + (\mathrm{b2} - \mathrm{b1})^2\}} \tag{3.6}$$

A lower Delta E indicates a minor color change, and a greater Delta E means a more significant color change. There is no international standard for defining the tolerance of acceptance considering the total color difference. In this experimental study, absolute color difference tolerance was assumed as one. Until the 1970s, denim items were made without any additional washing processes. Denim textiles may be washed using several techniques and chemicals to achieve various looks and effects. This study assessed fabric color values following rinse, enzyme, and stone & bleach washing.

3.4.8. Growth & stretch

After three home launderings, the elasticity and growth qualities were measured according to ASTM 3107. A stretch testing apparatus consisting of a frame with independent clamps mounted at the top and bottom was used to determine the stretch qualities of the materials. After marking a 250 mm index in the center section of each specimen, three strips from the weft direction were strung on the device. Three times a 1360-gram load was applied to the sample, which was placed as per fabric weight in the bottom hook, and after the fourth application, the specified distance was measured. After hanging the samples for 30 minutes, the length was measured again to determine elasticity. After 1 hour of rest, the distance between the designated mark point was measured more for growth.

3.4.9. Mass per unit area

Fabric mass per unit area was calculated according to TS 251 EN ISO 3801.

3.4.10. Domestic washing and drying

Domestic washing and drying have been done by ISO 6330: 2012 using James H. Heal FOM 71 CLS washing and drying machines.

3.4.11. SEM analysis

Scanning electron microscopy equipped with Energy Dispersion X-Ray Spectrometer (EDXS) operating at 15 kV accelerating voltage (FEI Quanta FEG 650, Holland) was used. ASTM E2809 –13 was followed to examine the surface morphology of the finished samples (0.5×0.5 cm^2). All specimens were coated with a thin coating of gold for 3 minutes using an ion sputter coater (Q150R ES Plus, QUORUM, UK) with a rotary pumped dual sputtering and evaporation system. The coating was done to improve electrical conductivity of the samples.

Figure 3.4. Ion sputter (Q150R ES Plus)

Figure 3.5. Scanning Electron Microscope (FEI Quanta FEG 650)

4. RESULTS AND DISCUSSION

Various test results with analysis have been presented in this chapter. The physical properties of denim fabric, such as areal density and fabric width; dimensional properties, such as growth, stretch, and shrinkage; comfort properties, such as air permeability and stiffness; and mechanical properties, such as breaking strength, tearing strength, and seam slippage results are illustrated. In addition, each property's interpreted statistical analysis results have been stated. Finally, the color measurement findings have been elaborated with the appropriate chart and explanation at the end of this chapter.

4.1. Areal density

The fabric's areal density determines the weight of a particular area. The weight of the fabrics A1, B1, C1, and D1 samples were 475, 472, 462, and 470 g/m^2. These values are higher than those of E1 (419), F1 (408), G1 (394), and H1(395). It indicated that a comparatively higher temperature (190º C) of stretching causes less compaction of fabric that causes less GSM have been found in Figure 4.1. The average reduction in GSM of the series one samples was 57.92 (*SD* = 20.6).

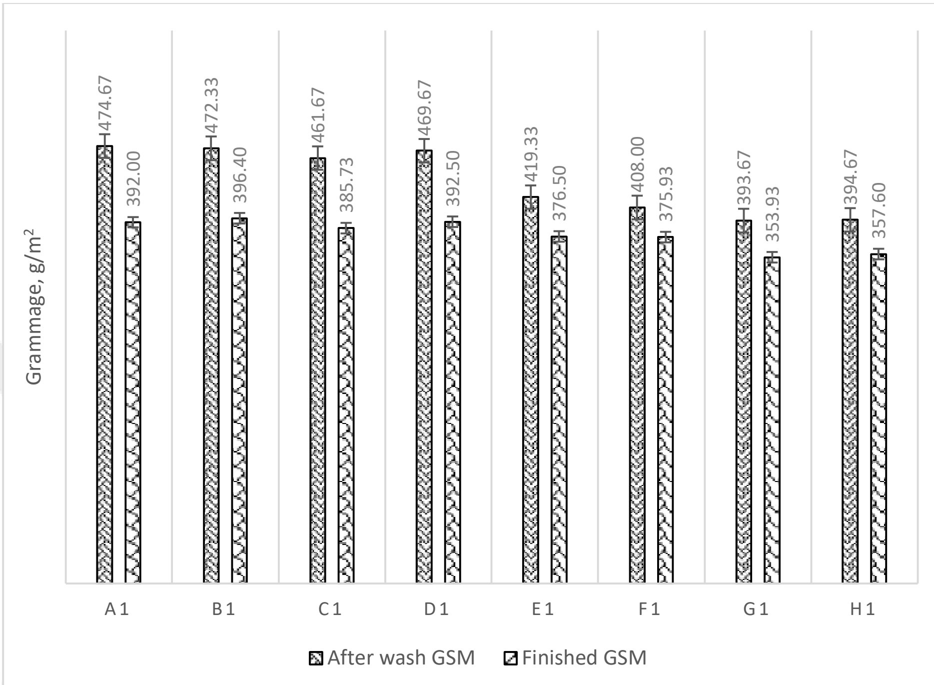


Figure 4.1. GSM of Series 1

The GSM values under 120º C of A2, B2, C2, and D2 were 573, 521, 473, and 461 (Figure 4.2). The GSM values of E1, F1, G1, and H1 under 190ºC were 470, 448, 435, and 422. In the case of zero stretching, GSM was comparatively higher than the 10 cm width opening. Because the stretching causes a decrease in warp density, thus decreasing the GSM. Besides these, fabrics finished at 120°C temperature have higher areal density than fabrics processed at 190°C temperature. The average reduction in GSM of the series two samples was 69.33 (SD = 20.20).

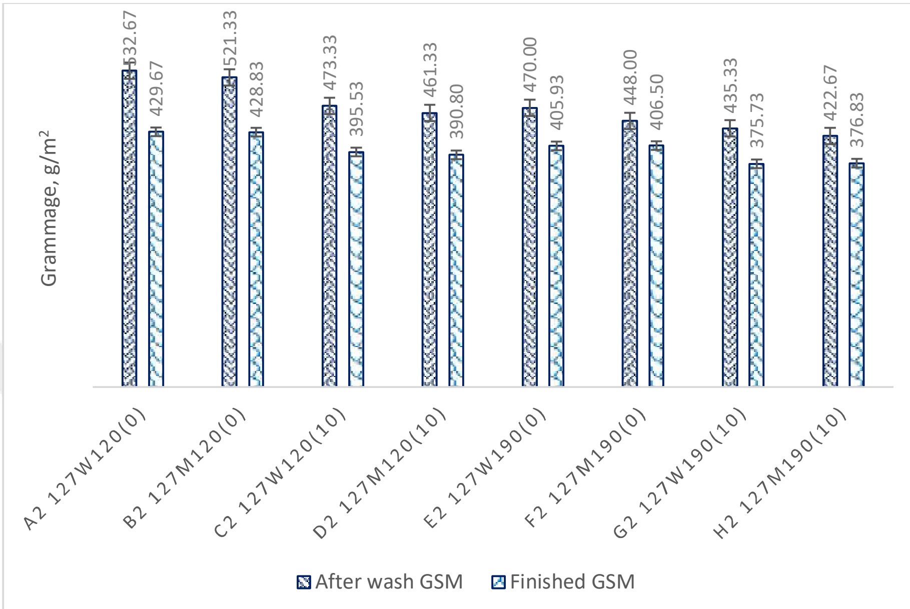


Figure 4.2. GSM of series 2

As previously stated, series one fabric included 78 dtex elastane in the weft direction, while series two fabric had 127 dtex elastane in the weft direction. The wefts in series two fabric were more compact due to the greater linear density of elastane. As a result, GSM rose in the latter group. The graph in Figure 4.3 depicts the GSM depletion of the samples from both series 1 and 2. Series 1 GSM values were reduced by 83, 76, 76, 77, 43, 32, 40, 37, and Series 2 values were reduced by 103, 93, 78, 71, 64, 42, 60, and 46. GSM difference values were greater in fabrics containing 127 dtex elastane. As a result, fabrics with a higher elastane content had a higher GSM and a greater GSM difference.

In the instance of 78 dtex denim, the overall weight has been reduced by 13% due to finishing. Stentering temperature influenced weight change, with 17% weight loss at 120°C and only 9% weight loss at 190°C. In 127 dtex denim fabric, the overall GSM loss was 13%, 17% at 120°C, and 12% at 190°C.

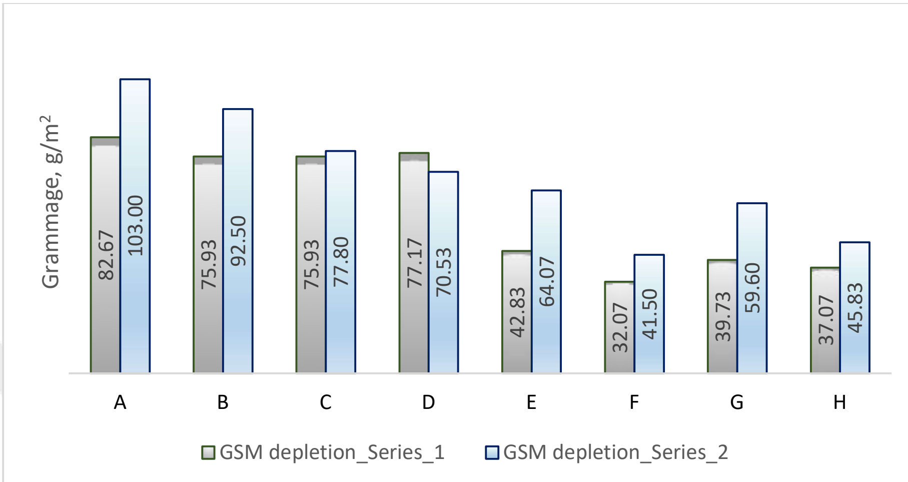


Figure 4.3. The difference in GSM due to finishing

Independent samples test (Table appx 4.5) has been done to compare the means between the two series. This study reveals that GSM reduction of the fabrics made from 78 dtex elastane had statistically lower values (M = 57.92, SD = 20.59) compared to the fabrics made by 127 dtex elastane (M = 69.33, SD = 20.21) with significant difference, t (78) = -2.502, p = 0.014.

In the case of series one, multiple regression (Table appx 4.35) was used to forecast the GSM change due to washing and examine the effect of ST and WO on GSM change. The R^2 value .99 indicated that the predictors explained 99% variance in the outcome variable with F (2,17) = 1784.93, p = .000. The findings (Table appx 4.42) revealed that ST (β = -.99, p =.000) and WO (β = -.13, p = .000) both have negatively predicted the areal density reduction (ADR_1). In the mercerizing process (Table appx 4.36), the R^2 value .99 indicated that the predictors explained 99% variance in the outcome variable with F (2,17) =1483.91, p=.000. The findings (Table appx 4.42) revealed that ST negatively predicted the GSM change (β = -.99, p = .000) and WO positively predicted the ADR_1 (β = .07, p = .000).

In the case of washing in series two (Table appx 4.37), the R^2 value .91 indicated that the predictors explained 91% variance in the outcome variable with F

(2,17) = 80.8, p = .000. The findings (Table appx 4.42) revealed that ST (β = -.85, p =.000) and WO (β = -.44, p = .000) both have negatively predicted the ADR. And for mercerizing process in series 2 (Table appx 4. 38.), the R^2 value of .90 indicated that the predictors explained 90% variance in the outcome variable with F (2,17) =71.15, p=.000. The findings revealed (Table appx 4.42) that both ST (β = -.92, p = .000) and WO (β = -.22, p = .014) negatively predicted the GSM change. The equations for predicting the ADR from the regression model have been written in equations (4.1) to (4.4).

Washing effect (S-1) $ADR_1 = 146.93-0.543\times ST-4.92\times WO$ (4.1)

Mercerizing effect (S-1) $ADR_1= 147-0.6\times ST-0.31\times WO$ (4.2)

Washing effect (S-2) $ADR_2 = 146.47-0.41\times ST-1.47\times WO$ (4.3)

Mercerizing effect (S-2) $ADR_2 = 150.81-0.54\times ST-.88\times WO$ (4.4)

The effect of different finishing parameters on the GSM change was investigated using LSD multiple comparison analysis (Table appx 4.9 & Table appx 4.10) with a significance threshold of α = 0.05. All the results were found to be significant at p <.05 accept B1:D1 (p = .136), C1:D1 (p = .136), and B1:C1 (p = 1.00) for series 1, and all the results are found significant at p < .05 for series 2.

4.2. Width

Figure 4.4 depicted the breadth of the cloth of series 1 in centimeters before and after the finishing procedure. Before washing, the widths were 127, 126, 127, 127, 143, 142, 145, and 145 cm, while the final widths were 149, 145, 149, 147, 153, 149, 155, and 152 cm. The initial widths of the textiles were 9% less than the finished widths. This signifies that the stretching procedure increased the breadth. The average increment of the series one sample's width was 14.56 cm (*SD* = 6.40).

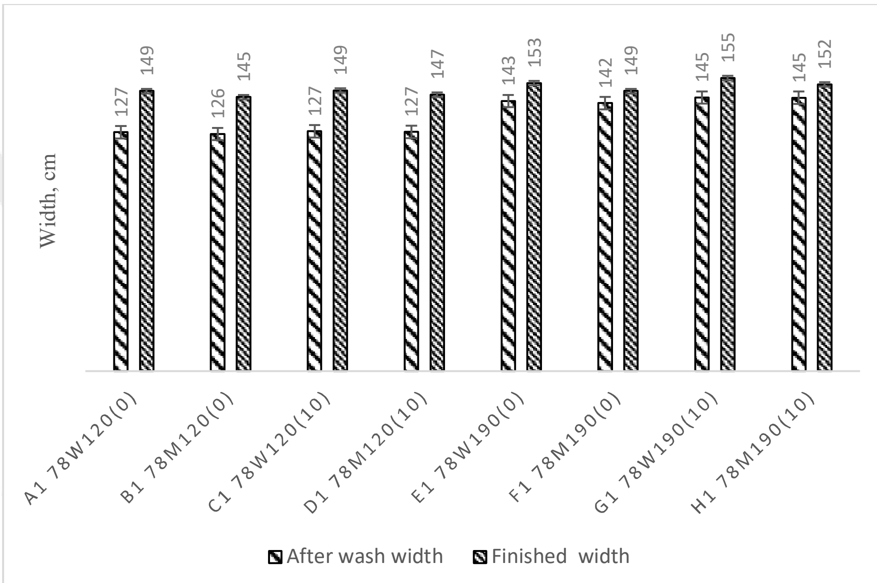


Figure 4.4. Width changes in series 1 fabrics

The graphic displayed the width of the series 2 fabrics in cm before and after the finishing process. The widths were 114, 113, 127, 126, 131, 132, 135 and 136 cm before washing, and 137, 135, 143, 139, 146, 143, 148, and 147 cm after washing (Figure 4.5). The fabrics' original widths were 11% smaller than their final widths. This indicates that the stretching technique broadened the width. The average increment of the series two samples' width was 15.60 cm (*SD*=4.57).

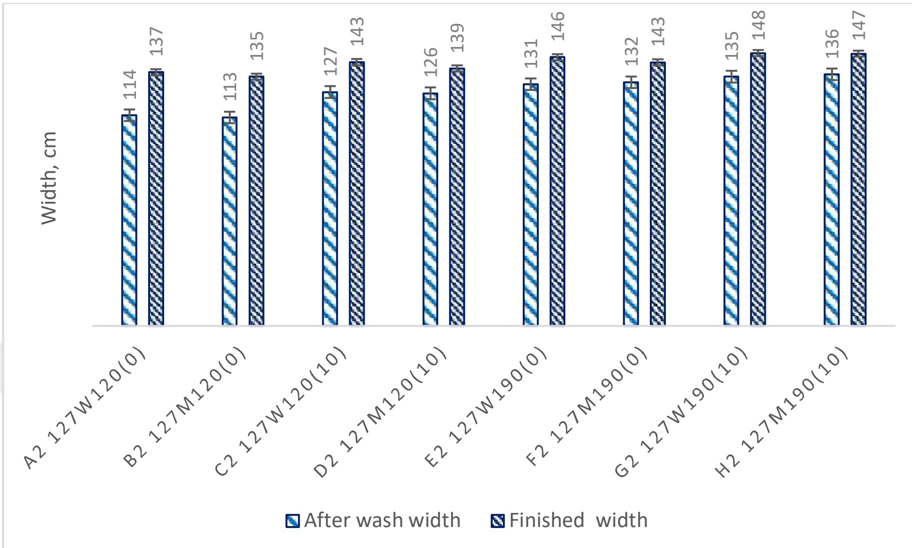


Figure 4.5. Width changes in series 2 fabrics

Figure 4.6 depicts the final width of series 1 and 2. In this case, the second series fabrics were narrower than the first series. It was discovered that in the second group, increasing linear density caused the width to shrink.

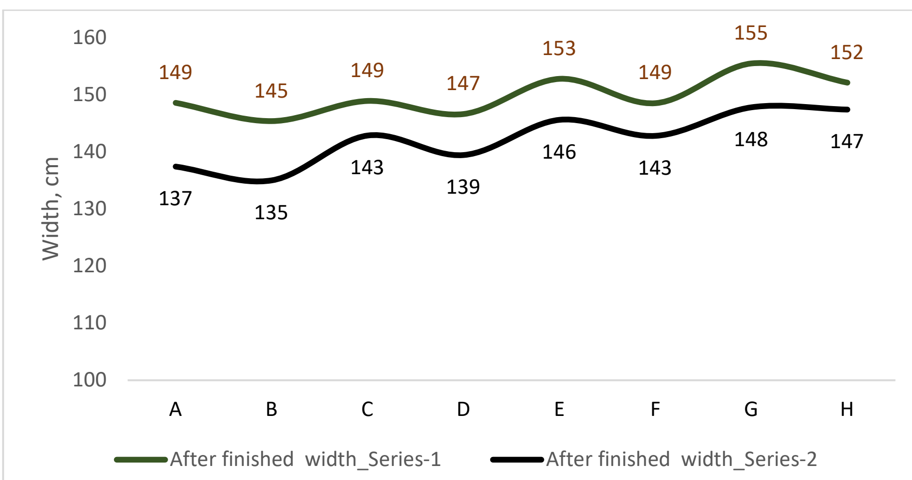


Figure 4.6. Comparison of width after finishing

Figure 4.7 shows the increased values of width due to the finishing. Except for C and D, all the values of series 1 are smaller than those of series 2. Width enhancement values in series 2 were 2% higher than the series 1. The washing technique resulted in a wider fabric by 2% than the mercerizing process. The shrinkage of the cellulose molecules of the weft yarns caused by the swelling in the mercerizing process resulted in a reduction in width (Aboalasaad et al., 2017). In the instance of 78 dtex denim, the overall width has been increased by 11% due to finishing. Stentering temperature influenced width change, with 16% width enhancement at 120°C and only 6% at 190°C. In the instance of 127 dtex denim fabric, the overall width increment was 13%, 16% in 120°C, and 9% in 190°C.

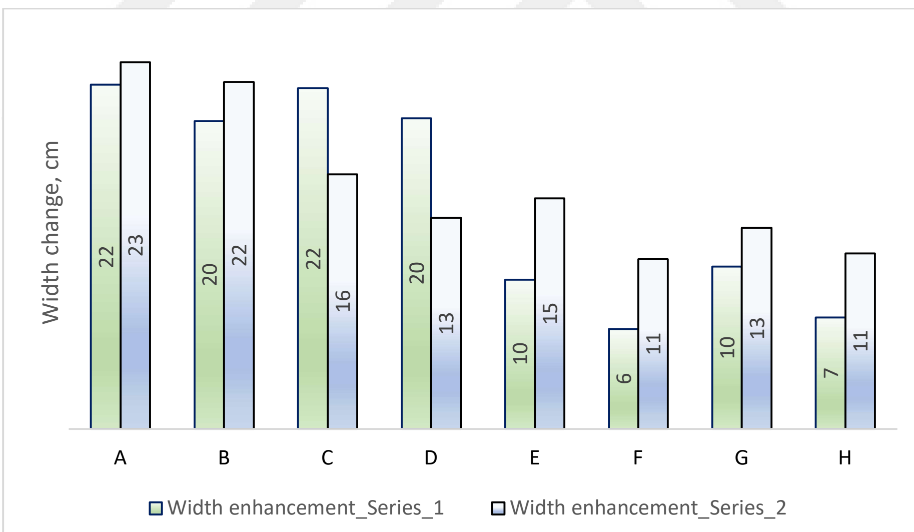


Figure 4.7. Width enhancement due to finishing

Independent samples test **(**Table appx 4.5**)** has been done to compare the means between the two series. This study reveals that width increment of the fabrics made from 78 dtex elastane had lower values (M = 14.58, SD = 6.40) compared to the fabrics made by 127 dtex elastane (M = 15.60, SD = 4.57) with non-significant difference, t (78) = -0.811, p = 0.420.

Multiple regression **(**Table appx 4.35**)** was used to forecast the width change caused by washing (series 1), as well as to examine the effect of ST and WO on width increase. The R^2 value .99 indicated that the predictors explained 99% variance in the outcome variable with F (2,17) =1074.08, p = .000. The findings (Table appx 4.47) revealed that ST negatively predicted the width change (β = -1.00, p = .000) and WO positively predicted the width change (β = .03, p = .000). In case of mercerizing process (Table appx 4. 36), the R^2 value .98 indicated that the predictors explained 98% variance in the outcome variable with F (2,17) = 707.41, p = .000. The findings (Table appx 4.47) revealed that ST negatively (β = -.99, p = .000) and WO positively predicted the width change (β = .05, p = .000).

Due to washing process in series 2 (Table appx 4.37) the R^2 value .88 indicated that the predictors explained 88% variance in the outcome variable with F (2,17) =62.17, p = .000. The findings (Table appx 4.47) revealed that ST (β = -0.75, p = .000) and WO (β =-0.56, p = .000) both have negatively predicted the width change. And for mercerizing process in series 2 (Table appx 4. 38.), the R^2 value .75 indicated that the predictors explained 75% variance in the outcome variable with F (2,17) = 25.68, p = .000. The findings (Table appx 4.47) revealed that ST negatively (β = -0.74, p = .000) and WO (β = -0.045, p = .002) both have negatively predicted the width change. The equations for predicting the width increment from the regression model has been written in equations (4.5) to (4.8).

Washing effect (S-1) $$WI_1 = 41.97 - 0.17\times ST + 0.3\times WO \quad (4.5)$$

Mercerizing effect (S-1) $$WI_1 = 41.13 - 0.18\times ST + 0.68\times WO \quad (4.6)$$

Washing effect (S-2) $WI_2 = 32.72 - 0.88\times ST - 0.46\times WO$ (4.7)

Mercerizing effect (S-2) $WI_2 = 31.42 - 0.097\times ST - 0.41\times WO$ (4.8)

LSD multiple comparison analysis (Table appx 4.11 and Table appx 4.12) was performed with a significance threshold of $\alpha = 0.05$ to examine the effect of different finishing parameters on the width change, and all the results are found significant at $p < .05$ accept B1:D1 ($p = .620$) and A1:C1 ($p = .563$) for series 1 and F2:H2 ($p = .170$) for series 2.

4.3. Breaking strength

The breaking strength of the warp way is roughly double that of the weft direction (Figure 4.8). Because there are more warp strands per unit length, it takes more energy to tear a greater number of warp in the same test area. Therefore, the warp way breaking strength of the G1 sample is the highest, while the weft way breaking is the lowest. The average BS_{wa} and BS_{we} of the samples were 97.17 kgf (*SD* = 7.43) & 54.18 kgf (*SD*=2.14), respectively.

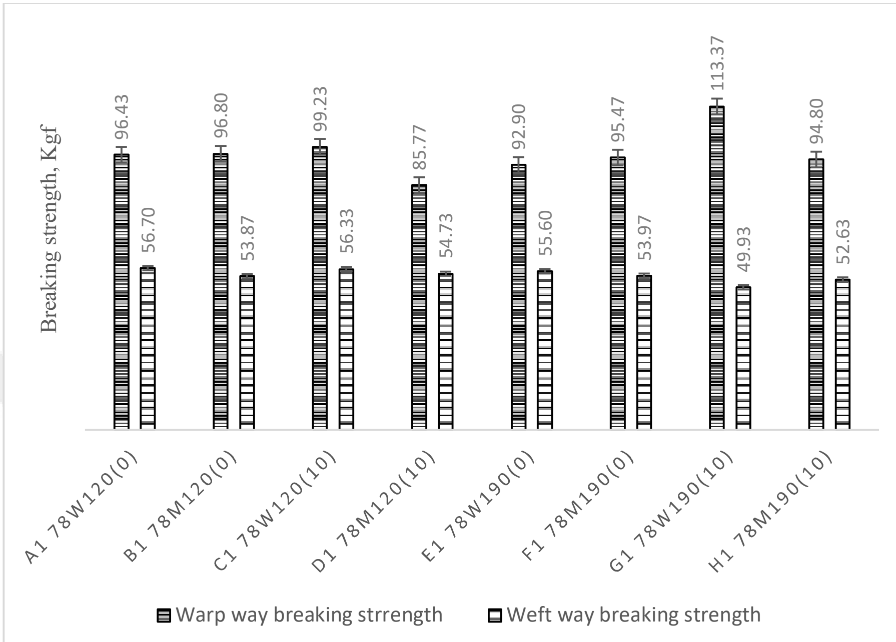


Figure 4.8. Breaking strength of series 1 fabrics

The influence of ST and WO was investigated using multiple regression to anticipate the breaking strength due to washing (Table appx 4.35). The R^2 value .67 indicated that the predictors explained 67% variance in warp way breaking strength with F (2,17) =17.56, p = .000. The findings (Table appx 4.43) revealed that ST (β = 0.34, p = .025) and WO (β = 0.75, p = .000) both positively predicted the warp way breaking strength (BS_{1wa}). As for weft way breaking strength (BS_{1we}), the R^2 value .75 indicated that the predictors explained 75% variance in BS_{1we} with F (2,17) =25.93, p = .000. The findings (Table appx 4.44) revealed that ST (β = -0.68, p = .000) and WO (β = -0.54, p = .000) both negatively predicted the outcome variance.

Due to the mercerizing process (Table appx 4.36), the R^2 value .47 indicated that the predictors explained 47% variance in the outcome variable with F (2,17) = 7.561, p = .004. The findings (Table appx 4.43) revealed that ST positively (β = 0.51, p = .010) and WO negatively predicted the BS_{1wa} (β = -0.46, p = .019). As for weft way breaking strength (BS_{1we}), the R^2 value .43 indicated that the predictors explained 43% variance in the outcome variable with $F\ (2,17) = 6.46$, $p = .008$. The findings (Table appx 4.44) revealed that ST ($\beta = -0.62$, $p = .003$) and WO ($\beta = -0.21$, $p = .275$) both negatively predicted the outcome variance, BS_{1we}. The equations for predicting the warp and weft way breaking strength of series 1 from the regression model have been written in equations (4.9) to (4.12).

Washing effect (S-1)	$BS_{1wa} = 82.93 + 0.08 \times ST + 1.16 \times WO$	(4.9)
Mercerizing effect (S-1)	$BS_{1wa} = 84.75 + 0.073 \times ST - 0.46 \times WO$	(4.10)
Washing effect (S-1)	$BS_{1we} = 64.45 - 0.05 \times ST - 0.30 \times WO$	(4.11)
Mercerizing effect (S-1)	$BS_{1we} = 56.45 - 0.02 \times ST - 0.04 \times WO$	(4.12)

The warp way breaking strength was also roughly double that of the weft direction in series 2 (Figure 4.9). Because there are more warp strands per unit length as the warp density increases, it takes more energy to tear them. Therefore, the warp way breaking strength of the C2 sample is the highest, while the weft way breaking is highest in sample E2. The average BS_{wa} and BS_{we} of the samples were 114 kgf (*SD* = 13.65) & 49.87 kgf (*SD*=1.59), respectively.

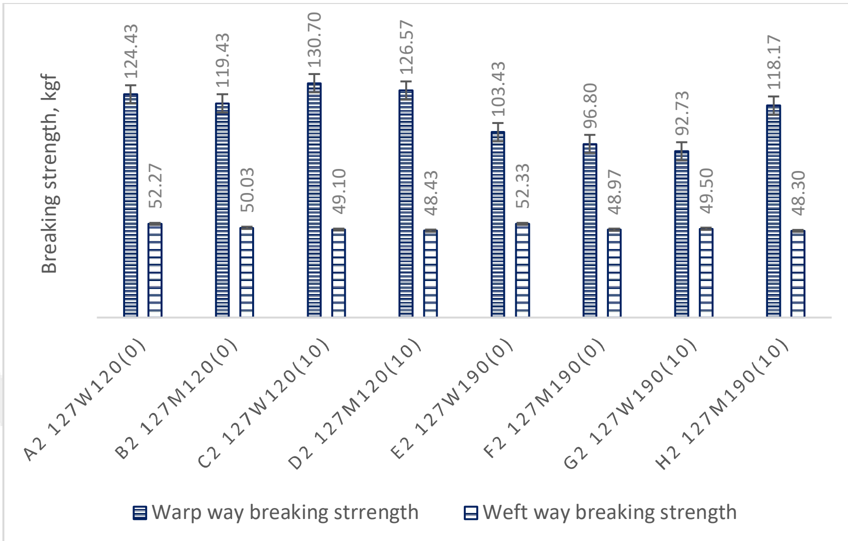


Figure 4.9. Breaking strength of series 2 fabrics

The influence of ST and WO on warp way breaking strength (BS_{2wa}) in series two was investigated using multiple regression (Table appx 4.37) to anticipate the BS produced by washing. The R^2 value .92 indicated that the predictors explained 92% variance in BS_{2wa} with F (2,17) = 99.99, p = .000. The findings (Table appx 4.43) revealed that ST (β = -0.96, p = .025) negatively predicted the outcome variance whereas WO (β = -0.07, p = .315) has no significant effect on BS_{2wa}. In case of weft way breaking strength (BS_{2we}), the R^2 value .92 indicated that the predictors explained 92% variance in BS_{2we} with F (2,17) = 99.24, p = .000. The findings (Table appx 4.44) revealed that ST has no significant effect (β = 0.07, p = .351) whereas WO (β = -0.96, p = .000) has negatively predicted the outcome variance.

In case of mercerizing process (Table appx 4.38), the R^2 value .89 indicated that the predictors explained 89% variance in BS_{2wa} with F (2,17) =72.29, p = .000. The findings (Table appx 4.43) revealed that ST negatively (β = -0.70, p = .000) and WO positively predicted the outcome variance (β = 0.64, p = .000). In case of BS_{2we}, the R^2 value .63 indicated that the predictors explained 63% variance in the outcome variable with F (2,17) = 14.41, p = .000. The findings (Table appx 4.44) revealed that ST (β = -0.37, p = .022) and WO (β = -0.70, p = .000) both negatively predicted the outcome variance. The equations for predicting the BS_{2wa} and BS_{2we} from the regression model have been written in equations (4.13) to (4.16).

Washing effect (S-2) $BS_{2wa} = 179.04 - 0.42\times ST - 0.22\times WO$ (4.13)

Mercerizing effect (S-2) $BS_{2wa} = 142.48 - 0.22\times ST + 1.42\times WO$ (4.14)

Washing effect (S-2) $BS_{2we} = 51.87 + 0.003\times ST - 0.303\times WO$ (4.15)

Mercerizing effect (S-2) $BS_{2we} = 50.83 - 0.009\times ST - 0.113\times WO$ (4.16)

Comparison of BS between series 1 and 2

127 dtex denim fabrics are 15% more stronger in warp direction than 78 dtex denim fabrics. During the yielding step, warp yarns are expanded before breaking. As a result, the warp yarn became straight, and the warp crimps disappeared, and the elastane-containing weft yarns provided further resistance to warp decrimping. Warp density is more in 2nd fabric due to having lower width than 78 dex denim, so more warps to be broken in the same sample area (Figure 4.10). Higher temperature reduced the strength of fabrics. Mercerized samples are 10% weaker than washed samples.

Independent samples test (Table appx 4.6) has been done to compare the means between the two series. This study reveals that the BS_{wa} of the fabrics made from 78 dtex elastane had statistically lower values (M = 97.17, SD = 7.43) compared to the fabrics made by 127 dtex elastane (M = 114.02, SD = 13.65) with significant difference, t (78) = -6.859, p = 0.000.

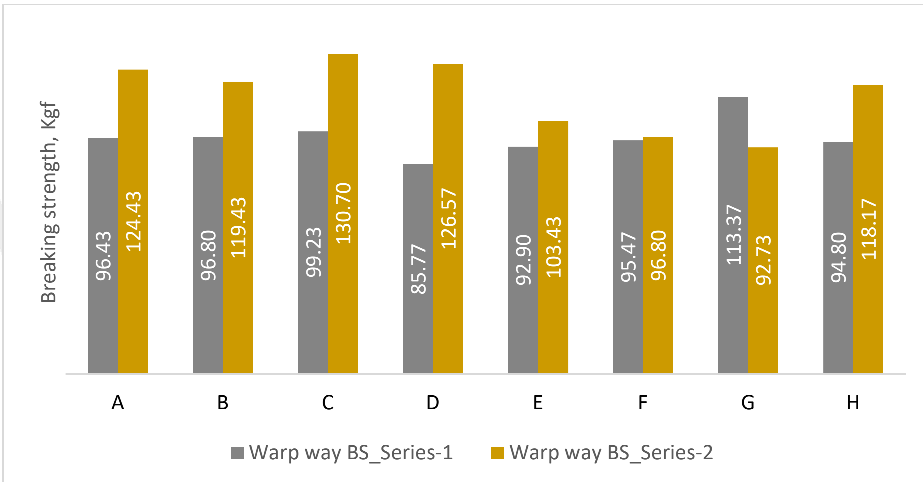


Figure 4.10. Comparison of warp way breaking strength between two series

LSD multiple comparison analysis (Table appx 4.13 and Table appx 4.14) was performed with a significance threshold of α =0.05 to examine the effect of different finishing parameters on the BS_{wa}, and the results were found significant at $p < .05$ for both series 1 & 2.

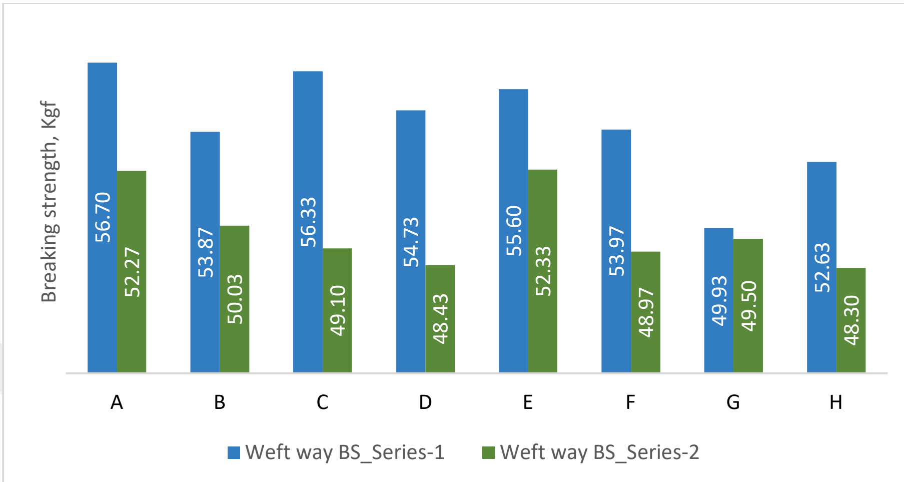


Figure 4.11. Comparison of weft way breaking strength between two series

Figure 4.11 showed that the comparison the weft way strengths of two series. Weft density is less than warp density in the tested denim fabric. So, weft way breaking strength is less than warp way breaking strength. Fabrics containing 78 dtex elastane are stronger than those with 127 dtex in the weft direction. So it can be revealed that Finer elastane (78 dtex) is stronger than coarser elastane (127 dtex); same findings have been noticed by (Bansal et al., 2020). Mercerized samples are 3-5% weaker than washed samples. Because NaOH treatment damages the surface of the fibers and consequently decrease of tensile strength (Oushabi et al., 2017).

Independent samples test (Table appx 4.6) has been done to compare the means between the two series. This study reveals that the BS_{we} of the fabrics made from 78 dtex elastane had statistically higher values (M = 54.19, SD = 2.14) compared to the fabrics made by 127 dtex elastane (M = 49.87, SD = 1.59) with significant difference, t (78) = 10.224, p = 0.000.

LSD multiple comparison analysis (Table appx 4. 15 and Table appx 4.16) was performed with a significance threshold of α =0.05 to examine the effect of different finishing parameters on the BS_{we}. Most of the results were found significant at p< .05 accept B1:F1 (p = .682) and A1:C1 (p = .139) for series 1; A2:E2 (p =

.966), B2:G2 & D2:F2 (p = .091), C2:F2 (p = .666) and C2:G2 (p = .201) for series 2.

4.4. Tearing strength

From Figure 4.12, the tearing strength (TS) of the warp way was greater than the tearing strength of the weft way. Because weft yarns were torn during the tearing of the warp way, and it takes more effort to break the elastane-containing weft yarn. The average TS_{wa} and TS_{we} of the samples were 6.67 kgf (*SD* = 1.43) & 5.05 kgf (*SD*=4.33), respectively.

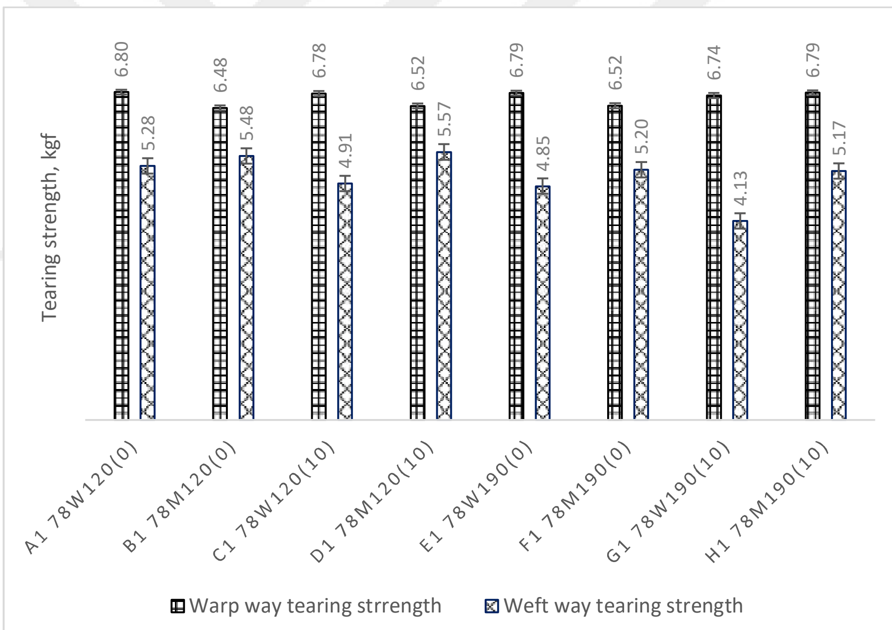


Figure 4.12. Tearing strength of series 1 fabrics

The influence of ST and WO was investigated using multiple regression (Table appx 4.35) to anticipate the warp way tearing strength (TS_{wa}) caused by washing (series 1). The R^2 value .20 indicated that the predictors explained 20% variance in TS_{wa} with F (2,17) =2.087, p = .155. The findings (Table appx 4.45) revealed that ST (β = -0.25, p = .263) and WO (β = -0.37, p = .111) both have no

significant effect on TS_{wa}. For weft way tearing strength (TS_{we}). the R^2 value .95 indicated that the predictors explained 95% variance in TS_{we} with F (2,17) =156.53, p = .000. The findings (Table appx 4.46) revealed that ST (β = -0.72, p = .000) and WO (β = -0.66, p = .000) both have negatively predicted the outcome variance.
Due to mercerizing process, the R^2 value .68 indicated that the predictors explained 68% variance in the outcome variable with F (2,17) =17.87, p = .000. The findings (Table appx 4.45) revealed that ST (β = 0.59, p = .001) and WO (β = 0.57, p = .001) both have positively predicted the TS_{wa}. As for TS_{we}, the R^2 value .76 indicated that the predictors explained 76% variance in the outcome variable with F (2,17) = 27.06, p = .000. The findings (Table appx 4.46) revealed that ST (β = -0.87, p = .000) has negatively predicted the outcome variance whereas WO (β = -0.09, p = .439) has non-significant effect on TS_{we}. The equations for predicting the TS_{wa} and TS_{we} from the regression model have been written in equations (4.17) to (4.20).

Washing effect (S-1) $$TS_{wa1} = 6856.65 - 0.40\times ST -3.95\times WO \quad (4.17)$$

Mercerizing effect (S-1) $$TS_{wa1} = 6162.4 + 2.183\times ST +14.89\times WO \quad (4.18)$$

Washing effect (S-1) $$TS_{we1} = 6390.58- 8.55\times ST -54.35\times WO \quad (4.19)$$

Mercerizing effect (S-1) $$TS_{we1} = 6258.55 - 5.93\times ST - 4.50\times WO \quad (4.20)$$

From Figure 4.13, it was revealed that the TS_{wa} was more significant than the TS_{we} in series 2. Because weft yarns were torn during the tearing of the warp manner. As a result, breaking the elastane-containing weft yarn requires greater effort. The average TS_{wa} and TS_{we} of the samples were 6.63 kgf (SD = 2.69) & 4.17 kgf (SD=2.55), respectively.

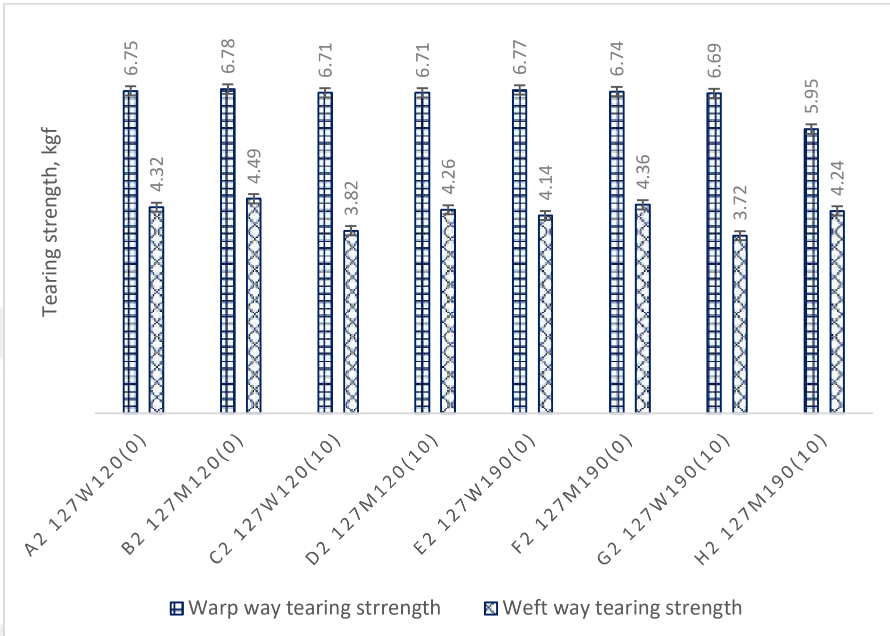


Figure 4.13. Tearing strength of series 2 fabrics

The influence of ST and WO was investigated using multiple regression (Table appx 4.37) to anticipate the TS_{wa2} due to washing. The R^2 value .38 indicated that the predictors explained 38% variance in warp way TS_{wa2} with F (2,17) =5.37, p = .016. The findings (Table appx 4.45) revealed that ST (β = -0.01, p = .963) has no significant effect whereas WO (β = -0.62, p = .004) has negatively predicted the TS_{wa2}. In case of weft way tearing strength, TS_{we2}, the R^2 value .98 indicated that the predictors explained 98% variance in with F (2,17) =455.93, p = .000. The findings (Table appx 4.46) revealed that ST (β = -0.28, p = .000) and WO (β = -0.95, p = .000) both have negatively predicted the outcome variance.

In case of mercerizing process, the R^2 value .72 indicated that the predictors explained 72% variance in the outcome variable, TS_{wa2} with F (2,17) =22.18, p = .000. The findings (Table appx 4.45) revealed that ST (β = -0.58, p = .000) and WO

(β = -0.62, *p* = .000) both have negatively predicted the TS_{wa2}. In case of TS_{we2}, the R^2 value .81 indicated that the predictors explained 81% variance in the outcome variable with F (2,17) = 37.06, *p* = .000. The findings (Table appx 4.46) revealed that ST (β = -0.35, *p* = .004) and WO (β = -0.83, *p* = .000) both have negatively predicted TS_{we2}. The equations for predicting the TS_{wa2} and $TS_{we2}$from the regression model have been written in equations (4.21) to (4.24).

Washing effect (S-2) $TS_{wa2} = 6763.12 - 0.01 \times ST - 5.98 \times WO$ (4.21)

Mercerizing effect (S-2) $TS_{wa2} = 7655.11 - 5.77 \times ST - 43.35 \times WO$ (4.22)

Washing effect (S-2) $TS_{we2} = 4517.77 - 1.9 \times ST - 45.37 \times WO$ (4.23)

Mercerizing effect (S-2) $TS_{we2} = 4596 - 1.09 \times ST - 17.90 \times WO$ (4.24)

Independent samples test (Table appx 4.6) has been done to compare the means between the two series. This study reveals that the TS_{wa} of the fabrics made from 78 dtex elastane had higher values (*M* = 6676, *SD* = 143.23) compared to the fabrics made by 127 dtex elastane (*M* = 6637, *SD* = 269.31) with non-significant difference, t (78) = 0.802, *p* = 0.425. Number of warps are same in both fabrics, so nonsignificant difference is found (Figure 4.14).

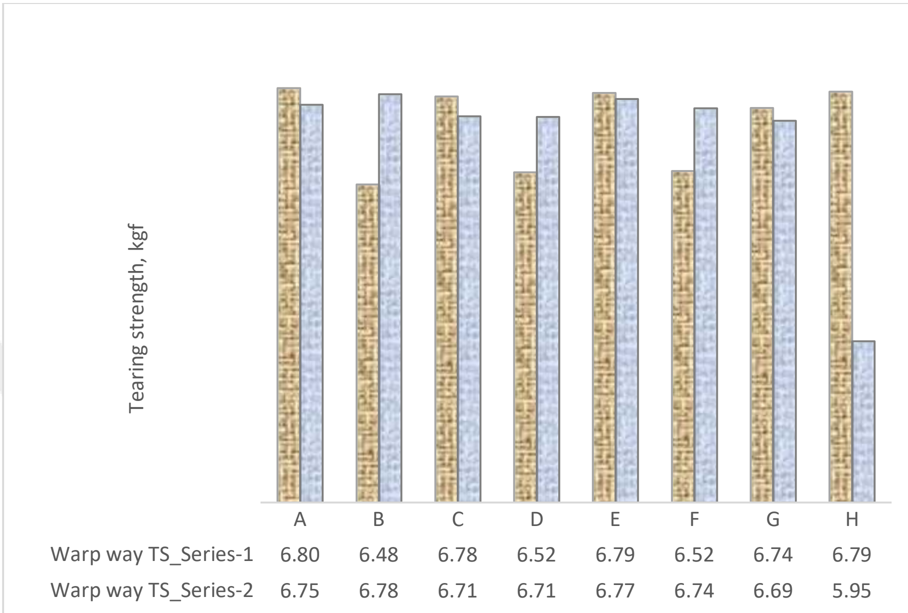


Figure 4.14. Comparison of warp way tearing strength between two series

LSD multiple comparison analysis (Table appx 4.17 and Table appx 4.18) was performed with a significance threshold of α =0.05 to examine the effect of different finishing parameters on TS_{wa}. Few of the results are found significant at $p < .05$ for series one, whereas most data were discovered non-significant for series 2.

A substantial difference in tearing was observed due to the change of elastane in weft yarn. The weft way tearing strength of 78 detex denim was 18% greater than that of 127 dtex denim (Figure 4.15). So, 78 dtex elastane is more robust in tearing than 127 dtex (Bansal et al., 2020). Independent samples test (Table appx 4.6) has been done to compare the means between the two series. This study reveals that the TS_{we} of the fabrics made from 78 dtex elastane had statistically lower values (M = 5055.30, SD = 433.53) compared to the fabrics made by 127 dtex elastane (M = 4166, SD = 254.96) with significant difference, t (78) = 11.171, p = 0.000.

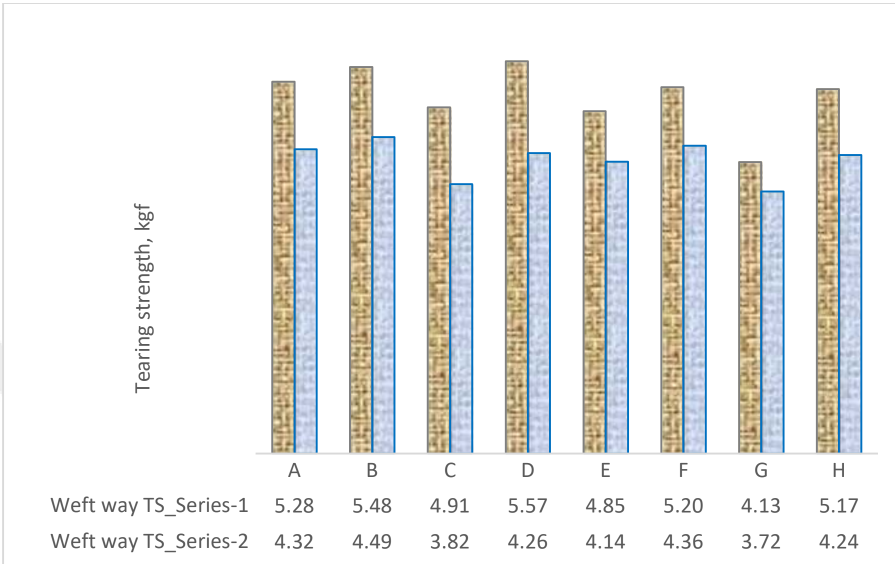


Figure 4.15. Comparison of weft way tearing strength between two series

Stentering at a higher temperature lessens tearing strength substantially. The average weft tearing strength of 78 dtex denim fabric finished at 120°C was 5.31 Kgf, compared to 4.84 kgf at 190°C, which was 9% lower. Furthermore, the average weft tearing strength of 127 dtex denim fabric finished at 120°C was 4.22 Kgf, compared to 4.11 Kgf at 190°C, which was 3% lower.

LSD multiple comparison analysis (Table appx 4.19 and Table appx 4.20) was performed with a significance threshold of $\alpha = 0.05$ to examine the effect of different finishing parameters on the TS_{we}. All the results are found significant at $p < .05$. But A1:F1 ($p = .128$) and C1:E1 ($p = .296$) for series 1 and D2:H2 ($p = .290$) and A2:D2 ($p = .075$) for series 2 were shown to have no significant relationship.

4.5. Seam slippage

Figure 4.16 indicates the seam slippage (SS) values in kgf for series 1 and 2. The maximum and minimum seam slippage for series one was measured at G and B, respectively, whereas the maximum and lowest SS for series two were measured at

D and E. When the stretching temperature was increased from 120 to 190°C, the SS curves between two series were inversed. At 120°C Series 2 has higher SS strength than the series 1 but at 190°C series 1 shows more SS strength than the series 2 cloths. Independent samples test (Table appx 4. 6) has been done to compare the means between the two series. This study reveals that SS of the fabrics made from 78 dtex elastane had lower values (M = 38.07, SD = 3.18) compared to the fabrics made by 127 dtex elastane (M = 39.18, SD = 3.76) with non-significant difference, t (78) = -1.414, p = 0.161.

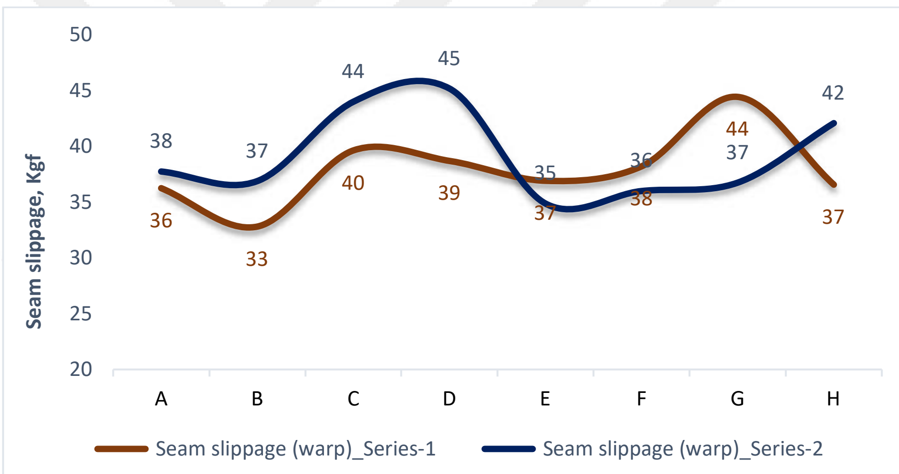


Figure 4.16. Comparison of seam slippage of the fabrics

The influence of ST and WO was investigated using multiple regression (Table appx 4.35) to anticipate the SS_1 influenced by washing. The R^2 value .88 indicated that the predictors explained 88% variance in SS with F (2,17) = 64.71, p = .000. The findings (Table appx 4.48) revealed that ST (β = 0.42, p = .000) and WO (β = 0.84, p = .000) both have positively predicted the outcome variance. In case of SS of series 2 (SS_2), the R^2 value .89 indicated that the predictors explained 89% variance in SS_2 with F (2,17) =68.19, p = .000. The findings (Table appx 4.48) revealed that ST (β = -0.74, p = .000) has negatively predicted whereas WO (β = 0.59, p = .000) has positively predicted the SS_2.

In case of mercerizing process (Table appx 4.36) in series 1, the R^2 value .49 indicated that the predictors explained 49% variance in the outcome variable with F (2,17) = 8.15, p = .003. The findings (Table appx 4.48) revealed that ST (β = 0.44, p = .021) and WO (β = 0.54, p = .006) both have positively predicted SS_1. In case of series 2 (Table appx 4.38), the R^2 value .98 indicated that the predictors explained 98% variance SS_2 with F (2,17) = 349.64, p = .000. The findings (Table appx 4.48) revealed that ST (β = -0.26, p = .000) and WO (β = 0.95, p = .000) both have negatively predicted SS_2. The equations for predicting the SS from the regression model have been written in equations (4.25) to (4.28).

Washing effect (S-1) $$SS_1 = 30.51+0.04\times ST +0.55\times WO \tag{4.25}$$

Mercerizing effect (S-1) $$SS_1 = 30.62 +0.31\times ST +0.27\times WO \tag{4.26}$$

Washing effect (S-2) $$SS_2 = 47.50- 0.07\times ST +0.41\times WO \tag{4.27}$$

Mercerizing effect (S-2) $$SS_2 = 40.84– 0.03\times ST+ 0.72\times WO \tag{4.28}$$

LSD multiple comparison analysis (Table appx 4.21 and Table appx 4.22) was performed with a significance threshold of α =0.05 to examine the effect of different finishing parameters on the **SS**. All the results were found significant at p< .05 but A1:E1 (p = .141), D1:F1 (p = .266), E1:H1 (p=.076) and F1:H1 (p=.274) for series one and B2:G2 (p =0.446) for series two were discovered to be insignificant.

4.6. Air permeability

The air permeability (AP) values of series one and series two are portrayed in Figure 4.17. Both curves are similar, indicating that the obtained results are consistent. It should be noted that series one textiles had 78 dtex elastane, whereas series two fabrics contained 127 dtex elastane. The AP of A1, B1, C1, D1, E1, F1, G1, and H were 75, 48, 79, 42, 44, 48, 52, and 55 mm/s, respectively. The AP of A2, B2, C2, D2, E2, F2, G2, and H2 was 58, 36, 72, 33, 37, 36, 36, 40 mm/s. Fabric with 78 dtex is more air permeable and 127 dtex denim was more compact. The high linear density elastane in the center of spun yarn creates a tight structure in the denim twill weave, preventing air from easily penetrating. As a result, the AP values fell in the instance of series 2. Washed samples are more air permeable than mercerized samples at 120°C.

Independent samples test (Table appx 4.7) has been done to compare the means between the two series. This study reveals that the AP of the fabrics made from 78 dtex elastane had statistically higher values (M = 55.47, SD = 14.67) compared to the fabrics made by 127 dtex elastane (M = 43.41, SD = 13.72) with significant difference, t (78) = 3.800, p = 0.000.

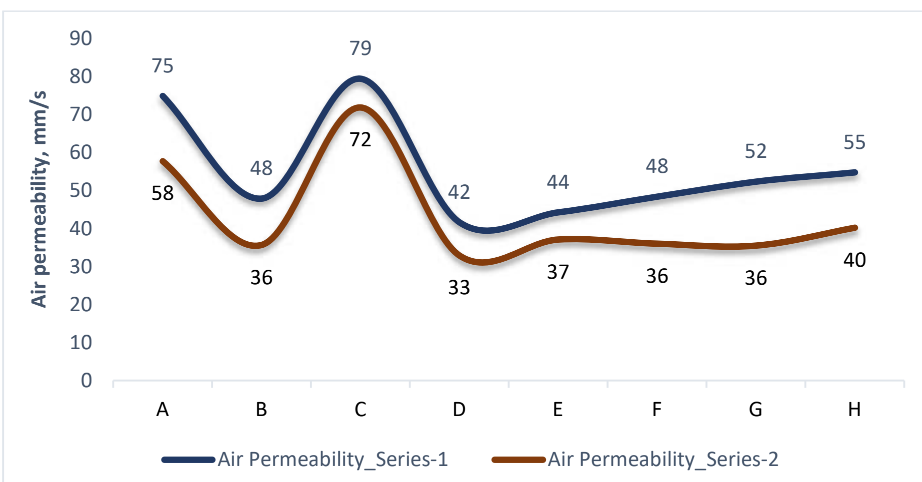


Figure 4.17. Comparison of air permeability of the fabrics

Stentering at a higher temperature lessens air permeability substantially. The average air permeability of 78 dtex denim fabric finished at 120°C was 61 mms^{-1}, compared to 50 mms^{-1} at 190°C, which was 18% lower. Furthermore, the average air permeability of 127 dtex denim fabric finished at 120°C was 50 mms^{-1}, compared to 37 mms^{-1} at 190°C, which was 31% lower.

The influence of ST and WO was investigated using multiple regression to anticipate the AP influenced by washing. The R^2 value .85 indicated that the predictors explained 85% variance in AP_1 with F (2,17) = 47.14, p = .000. The findings (Table appx 4.50) revealed that ST (β = -0.90, p = .000) has negatively predicted whereas WO (β =0.20, p = .053) has non-significant effect on the outcome variance. In case of AP_2, the R^2 value .89 indicated that the predictors explained 89% variance in air permeability with F (2,17) = 69.52, p = .000. The findings (Table appx 4.50) revealed that ST (β = -0.92, p = .000) has negatively predicted whereas WO (β = 0.20, p = .022) has positively predicted the outcome variance.

In case of mercerizing process, the R^2 value .20 indicated that the predictors explained 20% variance in the AP_1 with F (2,17) = 2.15, p = .148. The findings (Table appx 4.50) revealed that ST (β = 0.45, p = .054) and WO (β = 0.00, p = .988) both have non-significant effect on the AP_1. In case of series 2. the R^2 value .15 indicated that the predictors explained 15% variance in the AP_2 with F (2,17) = 1.53, p = .244. The findings (Table appx 4.50) revealed that ST (β = 0.38, p = .103) and WO (β = 0.07, p = .749) both have no significant effect on the AP_2. The equations for predicting the AP from the regression model have been written in equations (4.29) to (4.32).

Washing effect (S-1) $$AP_1 = 123.42 - 0.41 \times ST + 0.63 \times WO \quad (4.29)$$

Mercerizing effect (S-1) $$AP_1 = 33.20 + 0.09 \times ST + 0.005 \times WO \quad (4.30)$$

Washing effect (S-2) $AP_2 = 110.6 - 0.41 \times ST + 6.24 \times WO$ (4.31)

Mercerizing effect (S-2) $AP_2 = 27.4 + 0.05 \times ST + 0.07 \times WO$ (4.32)

Different finishing parameters on AP were investigated using LSD multiple comparison analysis (Table appx 4.23 and Table appx 4.24) with a significance threshold of $\alpha = 0.05$. In series 1, the relationship between A2 and others and C2 and others on air permeability was found to be significant at $p<.05$, and the rest of the comparisons were found to be insignificant; similarly, only a few of the results in series two were found to be significant at $p<.05$.

4.7. Stiffness

Figure 4.18 exhibits the stiffness values of denim materials. According to the graph, Series 1 cloth is less rigid than Series 2 fabric. It is also due to the linear density of elastane. As the linear density increases, the stiffness values of the fabrics also increase. An Independent samples test (Table appx 4.7) has been done to compare the means between the two series. This study reveals that Stiffness of the fabrics made from 78 dtex elastane had statistically lower values (M = 866.55, SD = 290.70) compared to the fabrics made by 127 dtex elastane (M = 1284.26, SD = 575.79) with significant difference, t (78) = -4.096, p = 0.000.

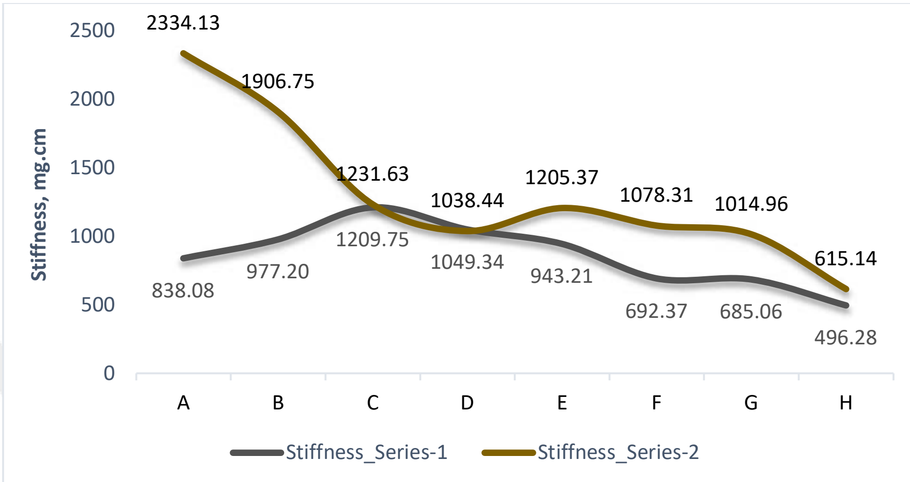


Figure 4.18. Comparison of stiffness of the fabrics

Stentering at a higher temperature lessens stiffness substantially. The average stiffness of 78 dtex denim fabric finished at 120°C was 1018 mg-cm, compared to 704 mg-cm at 190°C, which was 31% lower. Furthermore, the average stiffness of 127 dtex denim fabric finished at 120°C was 1628 mg-cm, compared to 978 mg-cm at 190°C, which was 40% lower.

The influence of ST and WO was investigated using multiple regression to anticipate the stiffness influenced by washing. The R^2 value .12 indicated that the predictors explained only 12% variance in stiffness_1 with F (2,17) =1.17, p = .334. The findings (Table appx 4.49) revealed that ST (β = -0.34, p = .150) and WO (β =0.06, p = .800) both have non-significant effect on the outcome variance, stiffness_1. In case of series 2, the R^2 value .57 indicated that the predictors explained 57% variance in stiffness_2 with F (2,17) =11.41, p = .001. The findings (Table appx 4.49) revealed that ST (β = -0.53, p = .004) and WO (β = 0.54, p = .003) both have negatively predicted the outcome variance, stiffness_2.

Due to the mercerizing process, The R^2 value .62 indicated that the predictors explained 62% variance in the outcome variable, stiffness_1 with F (2,17) = 13.57, p = .000.

The findings (Table appx 4.49) revealed that ST (β = -0.77, p = .000) has negatively predicted whereas WO (β = -0.13, p = .406) has no significant effect on $stiffness_1$. In case of series 2, the R^2 value .76 indicated that the predictors explained 76% variance in the outcome variable with $F(2,17) = 26.83$, p = .000. The findings (Table appx 4.49) revealed that ST (β = -0.59, p = .000) and WO (β = -0.64, p = .000) both have negatively predicted the $stiffness_2$. The equations for predicting the stiffness from the regression model have been written in equations (4.33) to (4.36).

Washing effect (S-1) $\quad Stiffness_1 = 1360.81 - 2.90 \times ST + 3.46 \times WO \qquad (4.33)$

Mercerizing effect (S-1) $\quad Stiffness_1 = 1741.69 - 5.83 \times ST - 6.77 \times WO \qquad (4.34)$

Washing effect (S-2) $\quad Stiffness_2 = 3170.57 - 9.16 \times ST - 65.48 \times WO \qquad (4.35)$

Mercerizing effect (S-2) $\quad Stiffness_2 = 2741.51 - 8.27 \times ST - 63.11 \times WO \qquad (4.36)$

LSD multiple comparison analysis (Table appx 4.25 and Table appx 4.26) was performed with a significance threshold of α =0.05 to examine the effect of different finishing parameters on the stiffness, and few of the results are found significant at $p< .05$ for series 1 & 2.

4.8. Growth

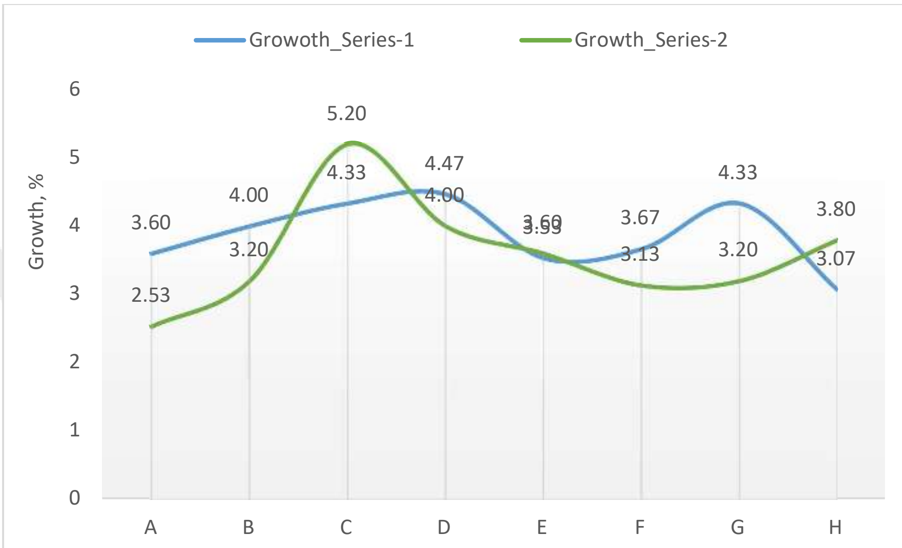


Figure 4.19. Comparison of growth of the fabrics

78 dtex denim fabric has 8% higher growth values than 127 dtex denim fabrics. Independent samples test (Table appx 4.8) has been done to compare the means between the two series. This study reveals that growth property of the fabrics made from 78 dtex elastane had statistically higher values (M = 3.90, SD = 0.45) compared to the fabrics made by 127 dtex elastane (M = 3.60, SD = 0.75) with significant difference, t (78) = 2.196, p = 0.031.

The influence of ST and WO was investigated using multiple regression to anticipate the growth influenced by washing. The R^2 value .84 indicated that the predictors explained only 84% variance in $Growth_1$ with F (2,17) = 44.25, p = .000. The findings revealed that ST (β = -0.041, p = .688) has no significant effect whereas WO (β =0.92, p = .000) positively predicted the $Growth_1$. In case of series 2, the R^2 value .39 indicated that the predictors explained 39% variance in $Growth_2$ with F (2,17) = 5.34, p = .016. The findings revealed that ST (β = -0.26, p = .194) has no significant effect whereas WO (β = 0.57, p = .009) positively predicted the outcome variance, $Growth_2$.

Due to mercerizing process (series 1), the R^2 value .69 indicated that the predictors explained 69% variance in the outcome variable with F (2,17) = 18.63, p = .000. The findings revealed that ST (β = -0.83, p = .000) negatively predicted whereas WO (β = 0.02, p = .868) has no significant effect on the $Growth_1$. In case of series 2, the R^2 value .91 indicated that the predictors explained 91% variance in the outcome variable with F (2,17) = 81.73, p = .000. The findings revealed that ST (β = -0.17, p = .035) negatively predicted whereas WO (β = 0.94, p = .000) positively predicted the $Growth_2$. The equations for predicting the growth from the regression model have been written in equations (4.37) to (4.40).

Washing effect (S-1) $$Growth_1 = 3.64 + 0\times ST + 0.77\times WO \tag{4.37}$$

Mercerizing effect (S-1) $$Growth_1 = 5.56 - 0.01\times ST + 0.002\times WO \tag{4.38}$$

Washing effect (S-2) $$Growth_2 = 4.21 - 0.007\times ST + 0.11\times WO \tag{4.39}$$

Mercerizing effect (S-2) $$Growth_2 = 3.46 - 0.002\times ST + 0.073\times WO \tag{4.40}$$

The effect of different finishing parameters on the growth property was investigated using LSD multiple comparison analysis (Table appx 4.27 and Table appx 4.28) with a significance threshold of α = 0.05. All the results were found to be significant at $p < .05$ for series 1, and most of the results are found significant at $p < .05$ accept B2:G2 (p = .464) and B2:F2 (p = .464) for series 2.

4.9. Stretch

Stretch values of two series of fabric have been depicted in Figure 4.20. 127 dtex denim fabric has 5% higher stretch values than 78 dtex denim fabrics. Stretch values are stable at 190°C as the curve has no ups and down in this portion. Independent samples test (Table appx 4.8) has been done to compare the means between the two series. This study reveals that stretch property of the fabrics made from 78 dtex elastane had statistically lower values ($M = 23.08$, $SD = 7.36$) compared to the fabrics made by 127 dtex elastane ($M = 27.40$, $SD = 6.52$) with significant difference, $t\ (78) = -2.778$, $p = 0.007$.

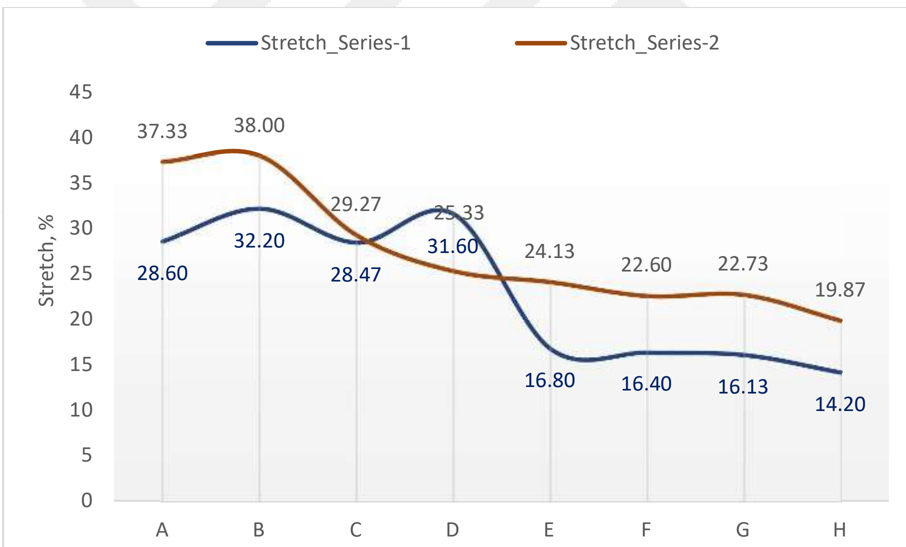


Figure 4.20. Comparison of stretch of the fabrics

The influence of ST and WO was investigated using multiple regression to anticipate the stretch influenced by washing. In case of series 1, the R^2 value .99 indicated that the predictors explained only 99% variance in $Stretch_1$ with $F\ (2,17) = 2755$, $p = .000$. The findings (Table appx 4.41) revealed that ST ($\beta = -1.00$, $p = .000$) and WO ($\beta = -0.03$, $p = .025$) both negatively predicted the $Stretch_1$. As for series 2. the R^2 value .91 indicated that the predictors explained 91% variance in $Stretch_2$ with $F(2,17) = 86.23$, $p = .000$. The findings (Table appx 4.41) revealed that ST ($\beta = -0.86$, $p = .000$) and WO ($\beta = -0.41$, $p = .000$) both negatively predicted the $Stretch_2$.

Due to mercerizing process (series 1), The R^2 value .99 indicated that the predictors explained 99% variance in the outcome variable, $Stretch_1$ with $F(2,17) = 2030$, $p = .000$. The findings (Table appx 4.41) revealed that ST ($\beta = -1.00$, $p = .000$) and WO ($\beta = -0.08$, $p = .000$) both negatively predicted the outcome variance. In case of series 2, the R^2 value .87 indicated that the predictors explained 87% variance in the outcome variable, $Stretch_2$ with $F(2,17) = 56.70$, $p = .000$. The findings (Table appx 4.41) revealed that ST ($\beta = -0.75$, $p = .000$) and WO ($\beta = -0.55$, $p = .000$) both negatively predicted the $Stretch_2$. The equations for predicting the stretch from the regression model have been written in equations (4.41) to (4.44).

Washing effect (S-1) $$Stretch_1 = 49.42 - 0.17 \times ST + 0.40 \times WO \quad (4.41)$$

Mercerizing effect (S-1) $$Stretch_1 = 60.77 - 0.241 \times ST - 0.13 \times WO \quad (4.42)$$

Washing effect (S-2) $$Stretch_2 = 52.50 - 0.14 \times ST - 0.47 \times WO \quad (4.43)$$

Mercerizing effect (S-2) $$Stretch_2 = 53.40 - 0.15 \times ST - 0.77 \times WO \quad (4.44)$$

LSD multiple comparison analysis (Table appx 4.29 and Table appx 4.30) was performed with a significance threshold of $\alpha = 0.05$ to examine the effect of different finishing parameters on the stretch. Most of the results were found significant at p<

.05 accept A1:C1 ($p = .610$), E1:F1 ($p = .132$), and F1:G1 ($p = .311$) in series 1; F2:G2 ($p = .647$) in series 2.

4.10. Shrinkage

The shrinkage values of the series 1 samples were depicted in Figure 4.21. Contraction is indicated by the negative values of shrinkage. In this case, raising the operating temperature considerably influenced shrinkage values. The warp shrinkage values were less than 5%, within the acceptable range. Because there was no elastane in the warp yarn, the shrinkage numbers in the length direction were relatively typical. The shrinkage values were greater in the weft direction due to the presence of elastane. Warp shrinkage was normal in range, but in the case of elastane, denim shows very high weft shrinkage. Because elastic core-spun weft yarn shrinks after washing due to a relaxing tendency. Under 120°C, A1, B1, C1, D1 textiles had an average shrinkage of 15%, whereas E1, F1, G1, H1 fabrics had a reduced average shrinkage of 6% under 190°C. The average shrinkage_{wa} and shrinkage_{we} of the series 1 samples were -3.38% (*SD* = 0.71) & -10.53% (*SD*=4.50) respectively.

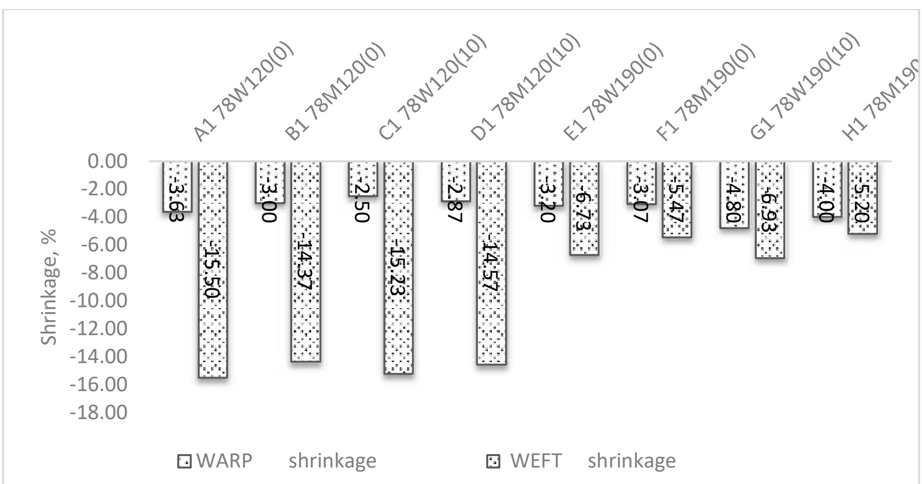


Figure 4.21. Shrinkage of series 1 fabrics

Figure 4.22 represents the shrinkage values of series two samples. In this case, typical warp shrinkage values were less than 5%, while weft shrinkages were significantly greater than warp shrinkages. Maximum weft shrinkages were measured for A2 and B2, finished with a 0-width opening. Raising the operation temperature decreased weft shrinkage in F, G, and H samples. The average $shrinkage_{wa}$ and $shrinkage_{we}$ of the series 2 samples were -3.32% (*SD* = 0.99) & -11.81% (*SD*= 3.39) respectively.

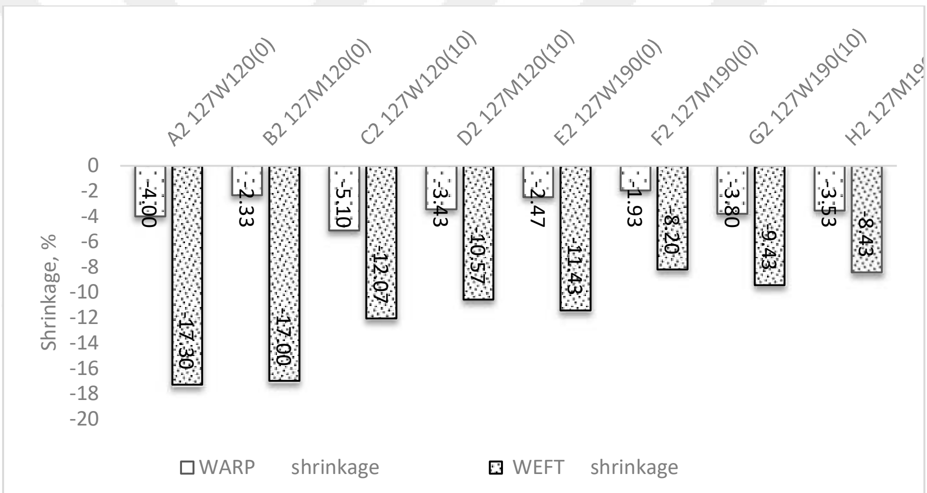


Figure 4.22. Shrinkage of series 2 fabrics

A comparison of warp shrinkages between two series is depicted in Figure 4.23. Mercerized samples have 8% lower shrinkage values than washed samples. Independent samples test (Table appx 4.8) has been done to compare the means between the two series. This study reveals that $shrinkage_{wa}$ property of the fabrics made from 78 dtex elastane had lower values (*M* = -3.38, *SD* = 0.71) compared to the fabrics made by 127 dtex elastane (*M* = -3.33, *SD* = 0.99) with non-significant difference, *t* (78) = -0.306, *p* = 0.760.

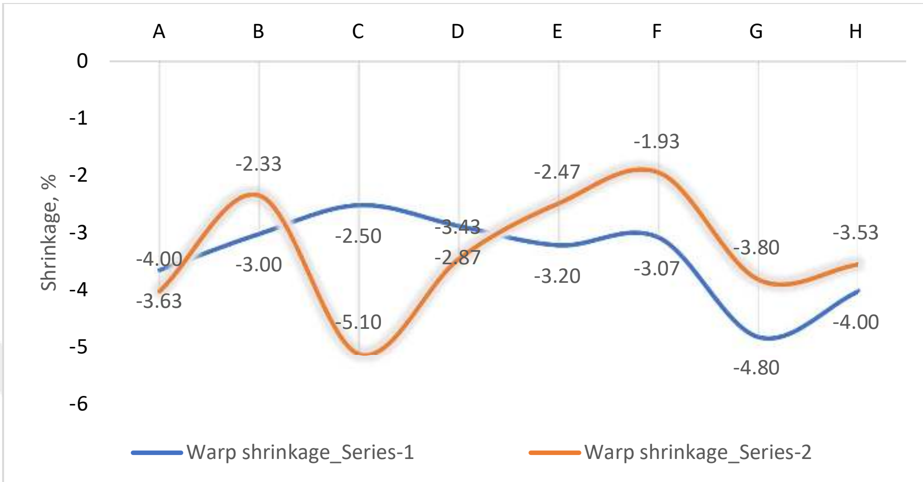


Figure 4.23. Comparison of warp shrinkages between two series

The influence of ST and WO was investigated using multiple regression to anticipate the warp shrinkage influenced by washing. In case of series 1, the R^2 value .33 indicated that the predictors explained only 33% variance in warp shrinkage with F (2,17) =4.12, p = .000. The findings (Table appx 4.39) revealed that ST (β = -0.55, p = .013) and WO (β = -0.14, p = .495) both negatively predicted the outcome variance, $Shrinkage_{1wa}$. In case of series 2, the R^2 value .97 indicated that the predictors explained 97% variance in warp shrinkage with F (2,17) =288, p = .000. The findings revealed that ST (β = 0.75, p = .000) positively whereas WO (β = -0.64, p = .000) negatively predicted the $Shrinkage_{2wa}$.

Due to mercerizing process (series 1), the R^2 value .59 indicated that the predictors explained 59% variance in the warp shrinkage with F (2,17) = 12.35, p = .000. The findings (Table appx 4.39) revealed that ST (β = -0.64, p = .001) and WO (β = -0.43, p = .013) both negatively predicted the $Shrinkage_{1wa}$. In case of series 2, the R^2 value .94 indicated that the predictors explained 94% variance in the outcome variable with F (2,17) = 126.63, p = .000. The findings revealed that ST (β = 0.11, p = .097) positively predicted whereas WO (β = -0.962, p = .000) negatively predicted the $Shrinkage_{2wa}$. The equations for predicting the warp shrinkage from the regression model have been written in equations (4.45) to (4.48).

Washing effect (S-1) $Shrinkage_{1wa} = -1.35 -0.013\times ST -0.023\times WO$ (4.45)

Mercerizing effect (S-1) $Shrinkage_{1wa} = -1.71 -0.09\times ST -0.04\times WO$ (4.46)

Washing effect (S-2) $Shrinkage_{2wa} = -6.37+0.02\times ST -0.12\times WO$ (4.47)

Mercerizing effect (S-2) $Shrinkage_{2wa} = -2.46 +0.002\times ST -0.135\times WO$ (4.48)

The effect of different finishing parameters on warp shrinkage was investigated using LSD multiple comparison analysis (Table appx 4.13 and Table appx 4.14) with a significance threshold of $\alpha = 0.05$. All the results were found to be significant at $p < .05$ except B1:D1 ($p = .137$), B1:F1 ($p = .438$), and E1:F1 ($p = .137$) for series 1; B2:E2 ($p = .171$) and D2:H2 ($p = .311$) for series 2.

A comparison of weft shrinkages between two series has been depicted in Figure 4.24. Weft shrinkage is 30% higher than the warp shrinkage of the fabrics. Shrinkage control was better at 190°C. Independent samples test has been done to compare the means between the two series. This study reveals that $shrinkage_{we}$ property of the fabrics made from 78 dtex elastane had higher values (M = -10.53, SD = 4.49) compared to the fabrics made by 127 dtex elastane (M = -11.81, SD = 3.39) with non-significant difference, t (78) = 1.442, p = 0.153.

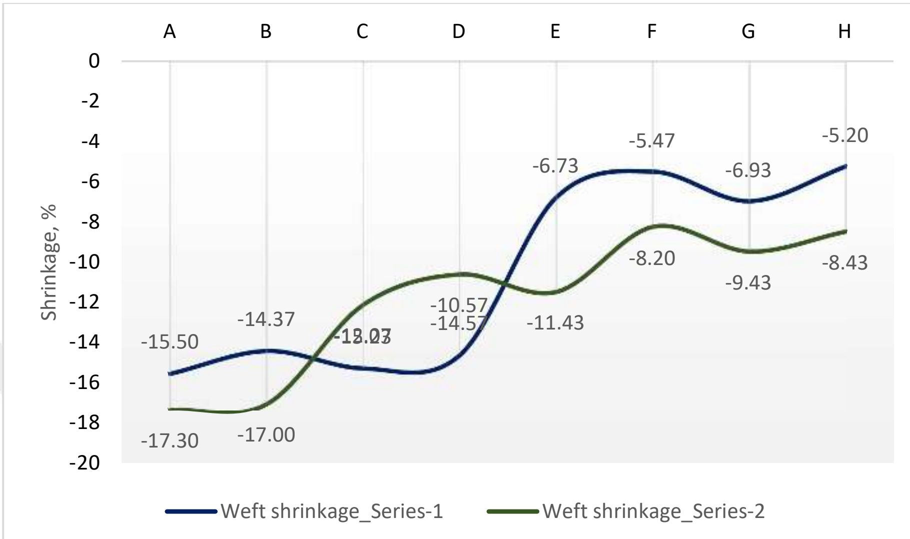


Figure 4.24. Comparison of warp shrinkages between two series

The influence of ST and WO was investigated using multiple regression (Table appx 4.35) to anticipate the weft shrinkage influenced by washing. In case of series 1, the R^2 value .99 indicated that the predictors explained only 99% variance in Shrinkage_{1we} with F (2,17) =2886, p = .000. The findings (Table appx 4.40) revealed that ST ($\beta = 0.99$, $p = .000$) positively predicted whereas WO ($\beta = 0.004$, $p = .770$) has no significant effect on the Shrinkage_{1we}. In case of series 2, the R^2 value .92 indicated that the predictors explained 92% variance in weft shrinkage with F (2,17) =94.6, p = .000. The findings revealed that ST ($\beta = 0.73$, $p = .000$) positively whereas WO ($\beta = -0.62$, $p = .000$) negatively predicted the $\text{Shrinkage}_{2we.}$

Due to the mercerizing (Table appx 4.36) process (series 1), the R^2 value .99 indicated that the predictors explained 99% variance in the Shrinkage_{1we} with F (2,17) = 2042, p = .000. The findings (Table appx 4.40) revealed that ST ($\beta = 0.99$, $p = .000$) positively whereas WO ($\beta = -0.621$, $p = .000$) negatively predicted the Shrinkage_{1we}. In case of series 2, the R^2 value .78 indicated that the predictors explained 78% variance in the Shrinkage_{2we} with F (2,17) = 30, p = .000. The findings (Table appx 4.40) revealed that ST (β = -0.17, p = .097) and WO (β = -0.962, p = .000) both negatively predicted the $Shrinkage_{2we}$. The equations for predicting the weft shrinkage from the regression model have been written in equations (4.49) to (4.52).

Washing effect (S-1) $$Shrinkage_{1we} = -30 + 0.12\times ST + 0.003\times WO \qquad (4.49)$$

Mercerizing effect (S-1) $$Shrinkage_{1we} = -29.90 - 0.13\times ST - 0.008\times WO \qquad (4.50)$$

Washing effect (S-2) $$Shrinkage_{2we} = -23.87 + 0.06\times ST + 0.36\times WO \qquad (4.51)$$

Mercerizing effect (S-2) $$Shrinkage_{2we} = -24.7 + 0.08\times ST - 0.31\times WO \qquad (4.52)$$

LSD multiple comparison analysis (Table appx 4.33 and Table appx 4.34) was performed with a significance threshold of $\alpha = 0.05$ to examine the effect of different finishing parameters on the weft shrinkage. Most of the results are found significant at $p < .05$ accept A1:C1 ($p = .135$), F1:H1 ($p = .913$), and E1:G1 ($p = .259$) for series 1, and all the results are found significant at $p < .05$ for series 2.

4.11. Color measurement:

4.11.1. Reflectance variance

The spectrophotometer's reflectance curves indicate the shade depth of the denim fabric in the visible spectrum, i.e., 400–700 nm wavelength region. Figure 4.25 depicts the reflectance variance in series one. All the curves were similar, but higher reflectance values (5-5.5%) were obtained at 410-430 nm and 690. Sample A1 has lower reflectance values, whereas sample H1 has higher reflectance values; thus, the upper curve position belongs to H1.

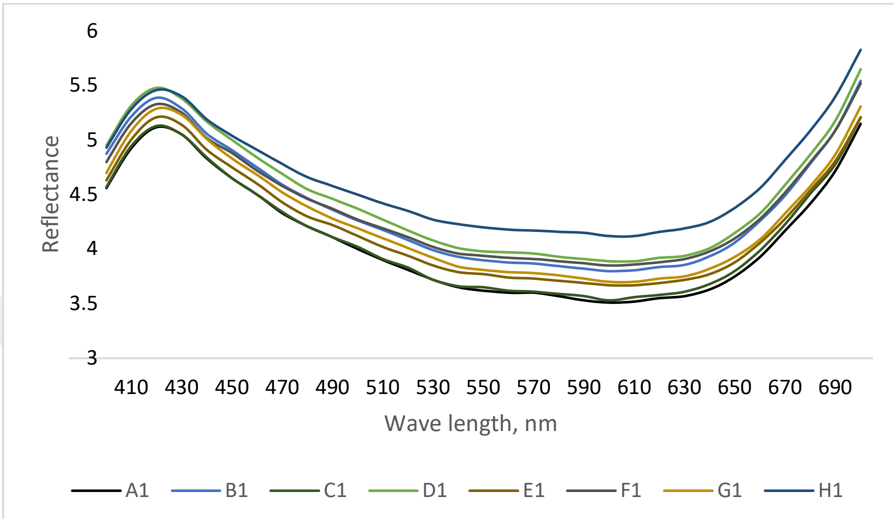


Figure 4.25. Reflectance variance of series 1 fabrics

The spectrophotometer's reflectance curves for series 2 were like the curves of series 1 (Figure 4.26). All the curves are similar, but higher reflectance values (5-5.5%) were obtained at 410-430 nm and 690 nm. Sample A2 has lower reflectance values, whereas sample H2 has higher reflectance values; thus, the upper curve position belongs to H2. At the beginning (410-430 nm), a pattern of reflectance value rise was identified, followed by a lowering trend (450-650 nm), and then an increasing trend starting from 670 nm to 690 nm was found.

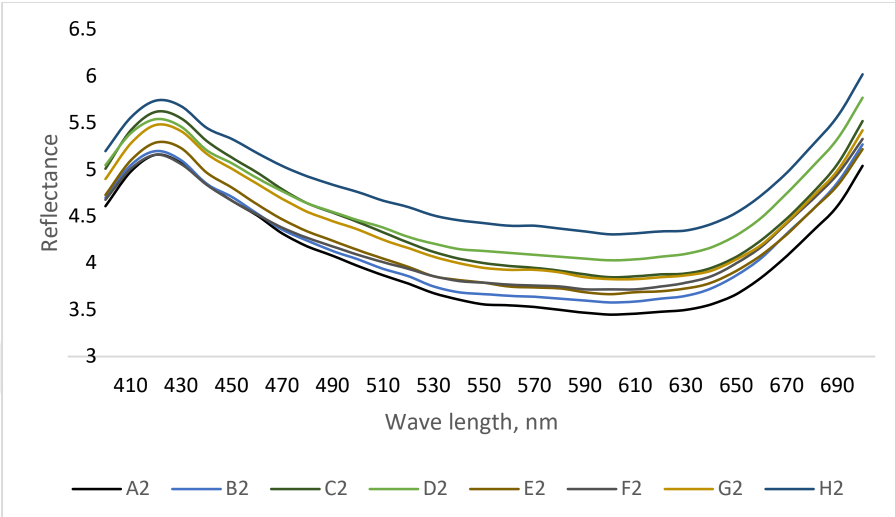
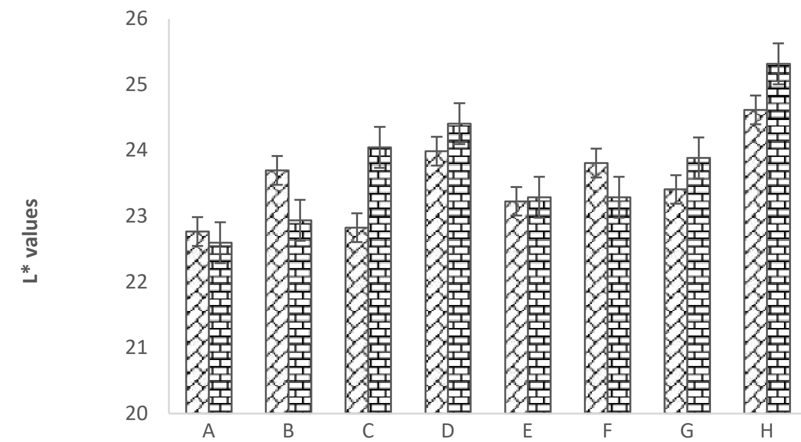


Figure 4.26. Reflectance variance of series 2 fabrics

4.11.2. Comparison of L values

Figure 4.27 compares the L values of denim fabrics from two different series. Higher L values suggest a sample that is whiter or light in color. The color of mercerized samples is lighter than that of washed samples. Widthwise extended samples are lighter than finished fabrics with no expanded width. Washed, non-expanded samples finished at 120°C have the darkest color, whereas samples finished at 190°C temperature, mercerized, and widthwise extended samples have the lightest shade. All the numbers are in the 20-25 range. A, B, and F have higher values than series 2, whereas C1, D1, G1, and H1 have lower values than C2, D2, G2, and H2. The variations in L values between the two series were -0.20, -0.76, 1.22, 0.42, 0.06, -0.52, 0.48, and 0.70; the lightness difference between the two series was not significant because the differences were not high.



	A	B	C	D	E	F	G	H
L* values Series-1	22.77	23.7	22.83	23.99	23.23	23.81	23.41	24.62
L* values Series-2	22.6	22.94	24.05	24.41	23.29	23.29	23.89	25.32

Figure 4.27. Comparison of L values

4.11.3. Comparison of a* values

The a* values describe the reddish or greenish tones of the material; positive values imply reddish tones, while negative values represent greenish tones. The denim samples are reddish because all the a* values were positive (Figure 4.28). However, the differences in a* values were -0.02, 0.15, -0.26, -0.02, 0.04, 0.12, -0.10, and -0.18. Because the changes were negligible, it's reasonable to think that the linear density of elastane did not influence the change in a* values.

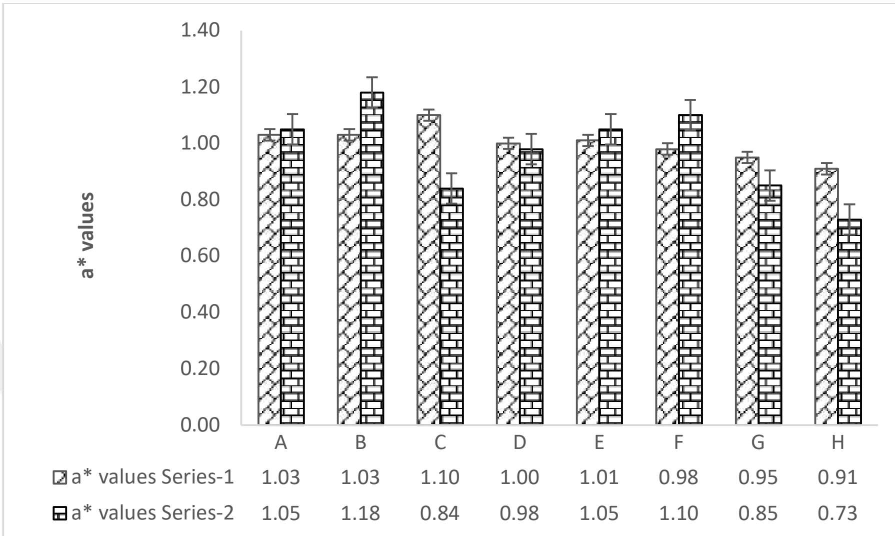


Figure 4.28. Comparison of a* values

4.11.5. Comparison of b* values

The b* values characterize the material's yellowish or blueish tones; positive values indicate yellowish tones, while negative values indicate blueish tones. The denim samples are more blueish because all the b* values were negative (Figure 4.29). -0.34, -0.25, -0.24, 0.37, -0.17, 0.08, -0.03, and -0.10 were the disparities in b* values. It's plausible to assume that the linear density of elastane did not affect the change in b* values because the differences were so small.

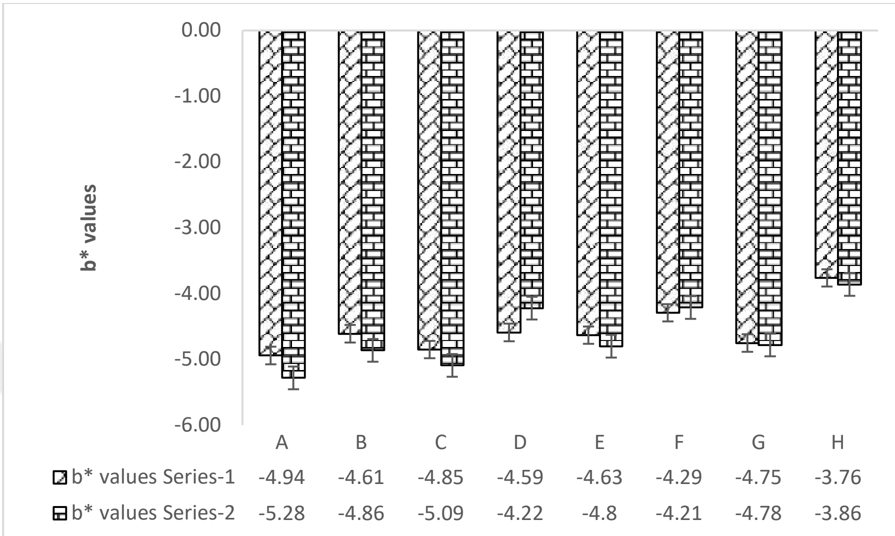


Figure 4.29. Comparison of b* values

4.11.6. Comparison of c* values

The degree of vividness of a color, or how pure it is relative to its equivalent on the color wheel, is referred to as chroma in color theory. It's also known as color intensity or saturation(*Chroma (Color)*, 2022). The plane is neutral or achromatic at the center. The chroma (C*), or color saturation, is represented by the distance from the center axis. For an achromatic color, C* is 0 in the center and grows as the distance from the center increases. The square root of the sum of squares of a and b values gives us the diagonal distance from the center axis. 0.33, 0.28, 0.18, -0.36, 0.17, -0.05, 0.01, 0.06 were the differences in C between the series (Figure 4.30). The difference in a and b values between the two series was minor; similarly, the difference in c values was also less significant.

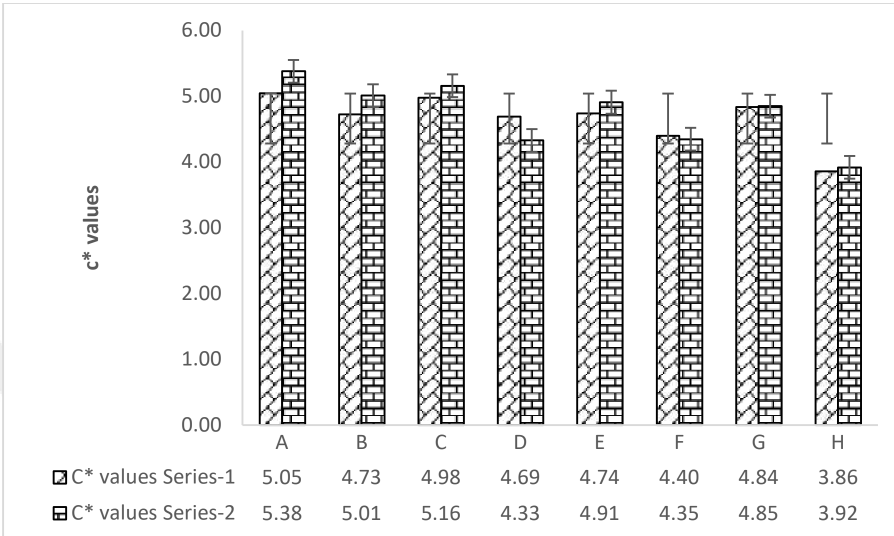


Figure 4.30. Comparison of c* values

4.11.7. Comparison of h* values

Colors in the CIE 1976 color space can also be described and located by providing their L*, C*, and h* coordinates. The L* coordinates are the same as in L*a*b*, but the C* and h* coordinates are calculated from the a* and b* coordinates in this technique. The color is still in the same place in the color space, but CIE L*a*b* and CIE L*C*b* are two distinct ways of describing it. Colors are located using cylindrical coordinates in the CIE L*C*h* color space, which is three-dimensional: The lightness coordinate (L*) is the same as L*a*b*. The chroma coordinate, or distance from the brightness axis, is represented by C*. h* the hue angle, expressed in degrees, with 0° being a location on the + a* axis, continuing to 90° for the +b* axis, 180° for -a*, 270° for -b*, and back to 360° = 0°. The differences in h between two series were -0.56, 1.12, -3.38, 0.83, 0.11 1.75 -1.16, and -2.82 (Figure 4.31).

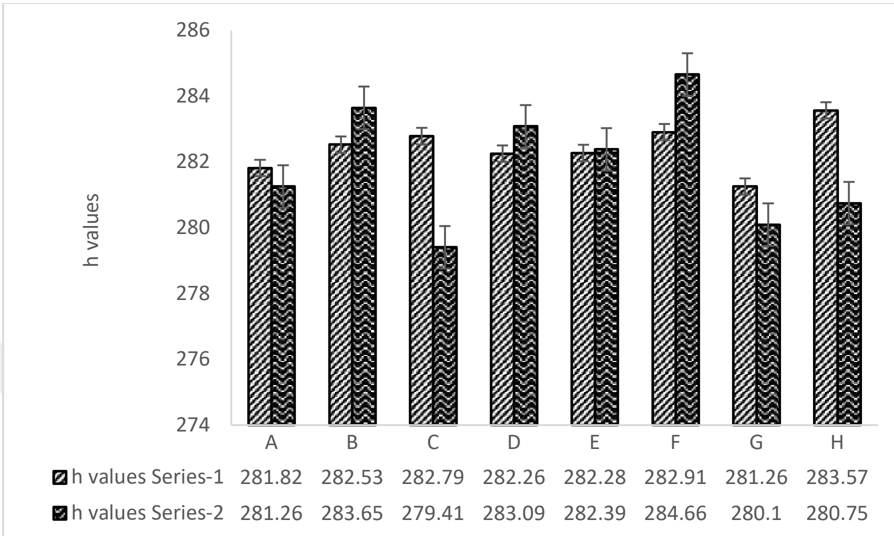


Figure 4.31. Comparison of h* values

4.11.8. Comparison of K/S values

The color yield (K/S) was measured at 600 nm. The differences of K/S values between two series were 0.48, 0.8, 1.17, 0.44, 0.45, 0, 0.46, and 0.54 (Figure 4.32). Increased color strength was obtained at non-expanded fabrics. Minimum values were observed for mercerized and expanded fabrics. Width widening caused a lowering of the K/S values. Both series have identical color strength, as differences are minor. As the differences are minor, so the effect of changing the linear density has no impact on color change after washing or mercerizing.

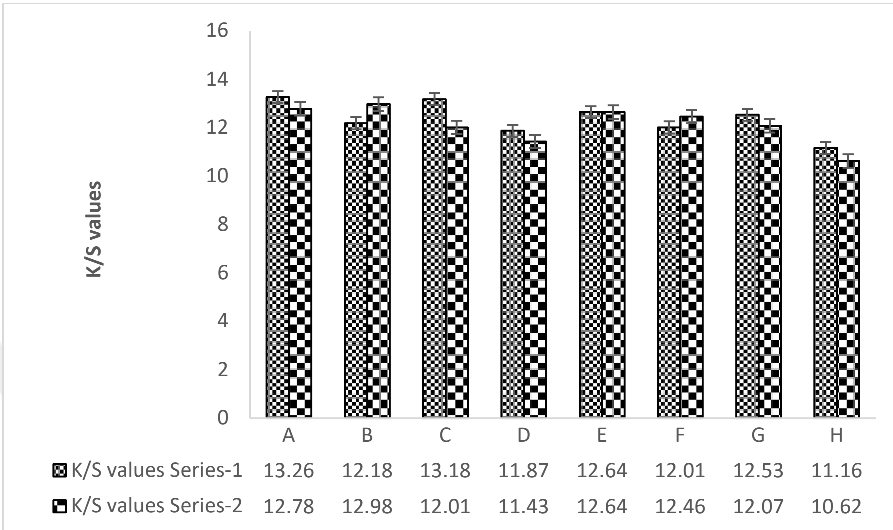


Figure 4.32. Comparison of K/S values

4.11.9. Color changes

The color changes value as depicted in Figure 4.33. Color changes within the series have been calculated by taking the A sample as a reference or control fabric. In case of color differences between the series, series one samples were considered reference fabrics. For example, the A2 sample had been compared with the A1 as reference fabric. Similarly, B1:B2, C1:C2, D1:D2, E1:E2, F1:F2, G1:G2, and H1:H2 samples were compared. The color differences are significant within the series as 50% of ∇E were more than 1. For series one, color changes for mercerization were 0.99, 1.27, 1.22, and 2.2, whereas color changes for the washing process were 0.13, 0.56, and 0.68. For series two, color changes for mercerization were 0.55, 2.1, 1.27, and 3.08, whereas color changes for the washing process were 1.48, 0.84, and 1.4. So, the mercerized samples had larger color change values than washed samples. Color changes between the series due to mercerizing were 0.82, 0.56, 0.54, and 0.73, whereas color changes for washed samples were 0.38, 1.27, 0.18, and 0.49. As the same processed samples with different elastane fabrics were compared in the last comparison, a lower difference in color change has been distinguished.

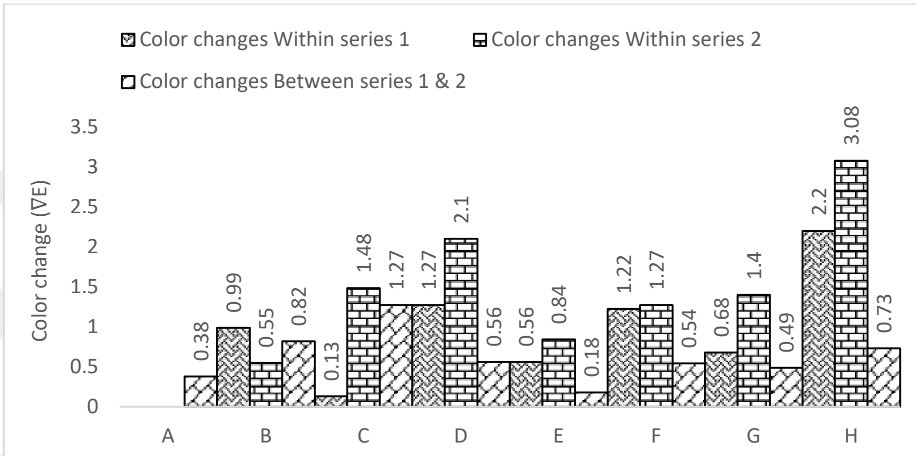


Figure 4.33. Comparison of color changes

4.12. Effect of different washing on color change

4.12.1. Effect of rinse washing

Figure 4.34 and Figure 4.35 depicted the CIElab values obtained after rinse-washing the samples in series 1 & 2. The uppermost line belonged to the letter L, which stood for lightness, followed by the Del E, and last, the line of a* values. The b line was positioned below the baseline because the values of b were negative. Because each sample A, B, C, D, E, F, G, and H was finished with distinct finishing parameters, the del E curve had more ups and downs, implying that the color shift within the series was more prominent. The values in the second series were remarkably like those in the first.

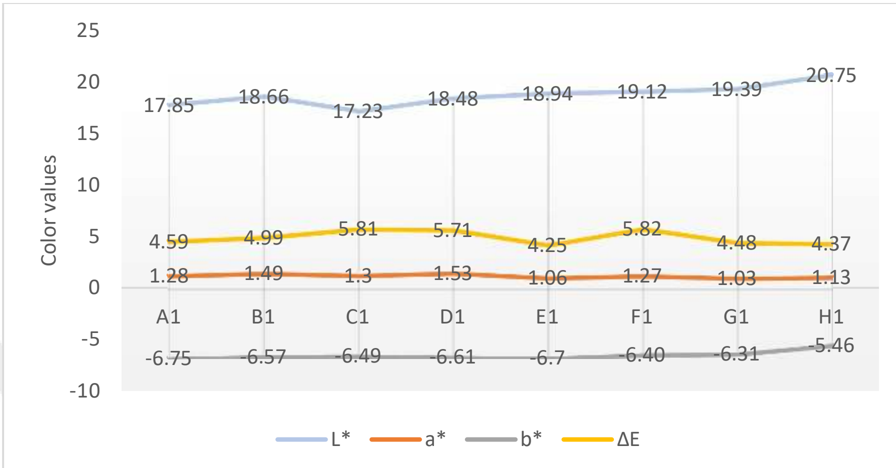


Figure 4.34. Color values after rinse washing for series 1

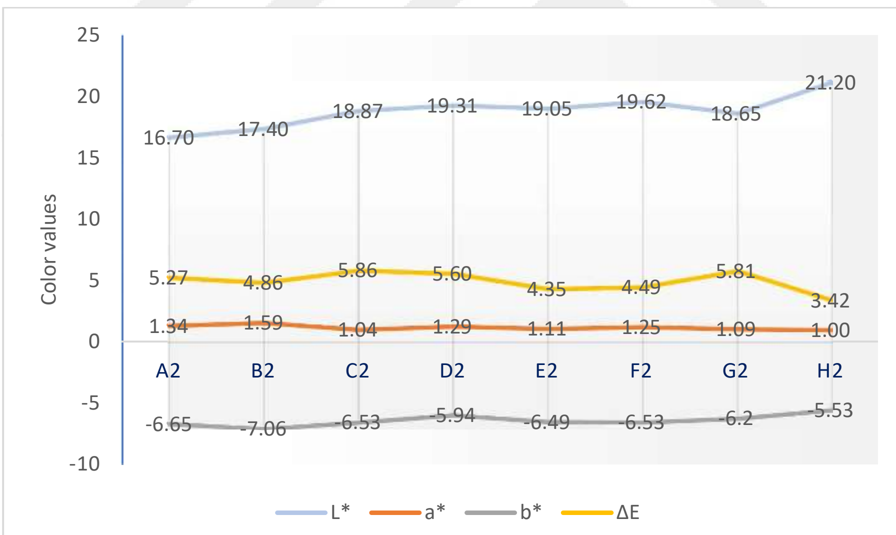


Figure 4.35. Color values after rinse washing for series 2

4.12.2. Effect of enzyme washing

The CIElab values after enzyme washing of the series 1 samples were shown in Figure 4.36 and series 2 samples in Figure 4.37. The shade became bluish as the b values were more negative than the rinse washing values. Lightness and a* values were identical in rinse washing, while del E values were higher in enzyme washing, indicating sample discoloration.

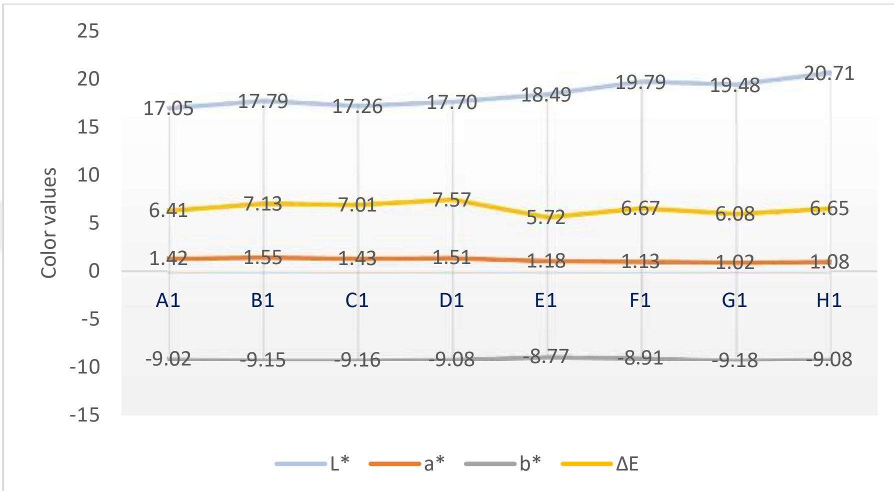


Figure 4.36. Color values after enzyme washing for series 1

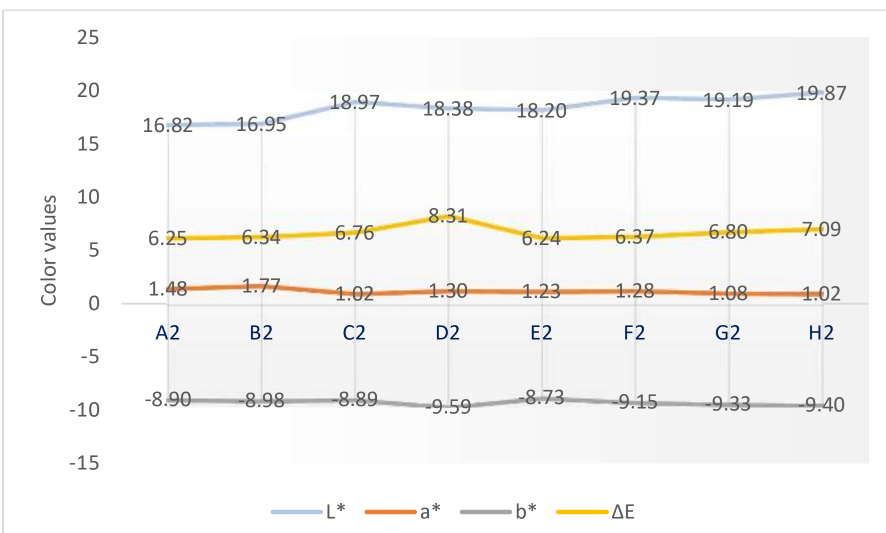


Figure 4.37. Color values after enzyme washing for series 2

4.12.3. Effect of stone washing:

The CIElab values after enzyme washing of the series 1 samples were shown in Figure 4.38 and series 2 samples in Figure 4.39. The shade became more bluish as the b values were more negative than the enzyme washing values. In stone washing, lightness values were increased, resulting in a lighter hue, while a* values were decreased, resulting in a greenish shade. Furthermore, the del E values in stone washing were noticeably higher, indicating that more significant discoloration occurred during the washing process.

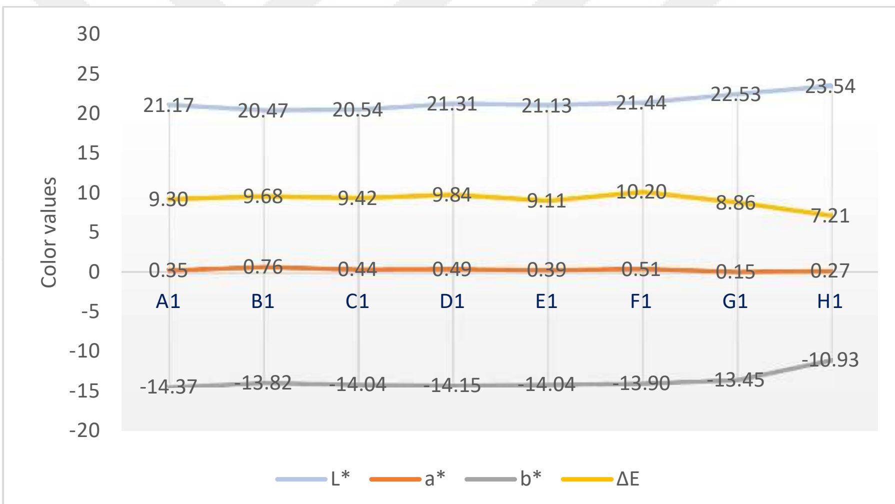


Figure 4.38. Color values after stone washing for series 1

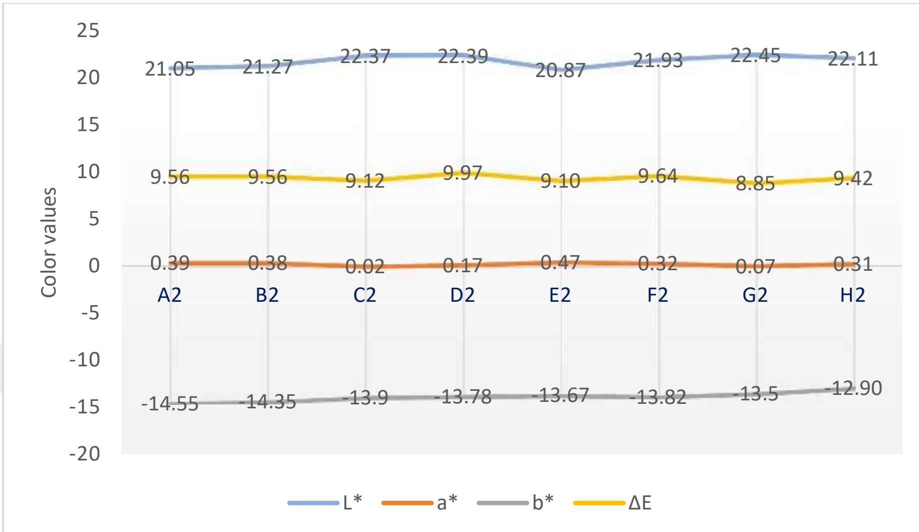


Figure 4.39. Color values after stone washing for series 2

4.12.4. Effect of stone and bleach washing

The CIElab values after stone and bleach washing of the series 1 samples were shown in Figure 4.40 and series 2 samples in Figure 4.41. The shade became more bluish as the b values were more negative than the stone washing values. In stone and bleach washing, lightness values were increased, resulting in a lighter hue, while a* values were further decreased, resulting in a greenish shade. Furthermore, the del E values in stone and bleach washing were slightly increased than stone washing, indicating that more discoloration occurred during this combined washing process.

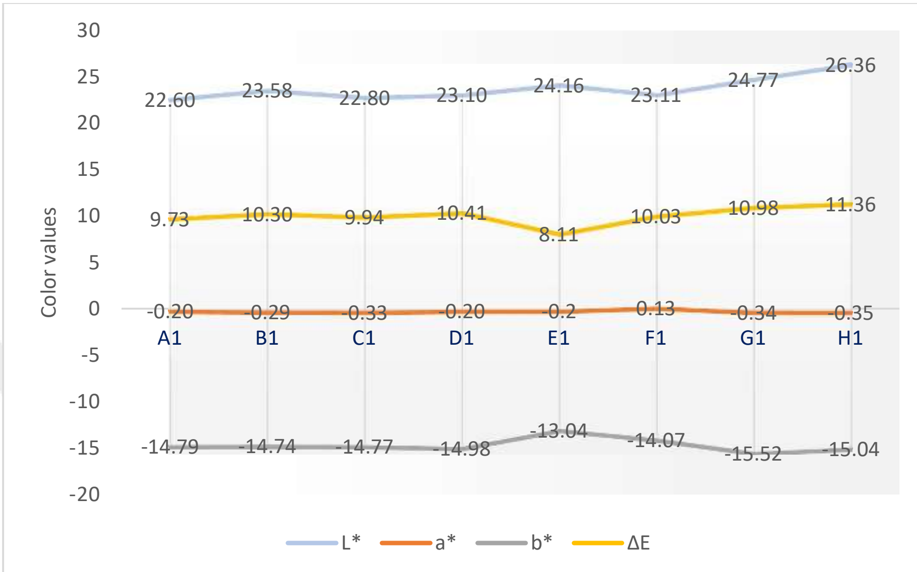


Figure 4.40. Color values after stone and bleach washing for series 1

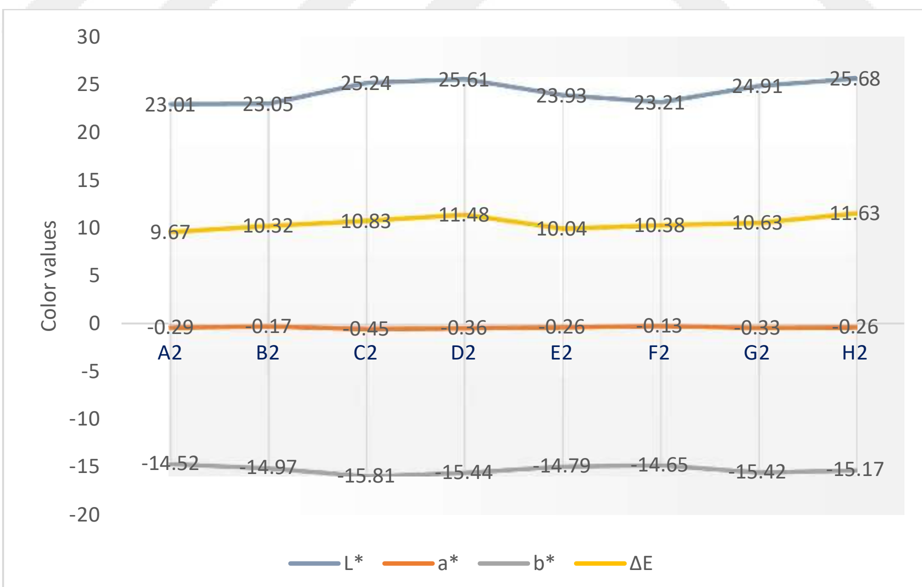


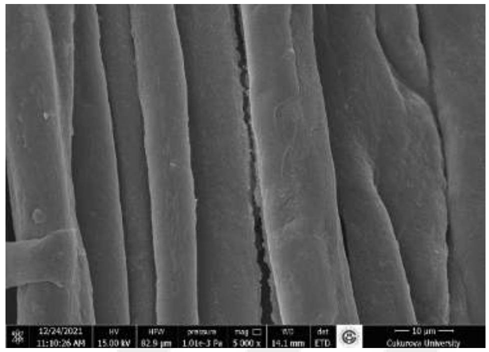
Figure 4.41. Color values after stone and bleach washing for series 2

From Figure 4.34 to Figure 4.41, it can be summarized that the del E, b and L values had an increasing trend as follows: Rinse washing < Enzyme washing < stone washing < stone and bleach washing. After stone and bleach washing, the samples were lighter than the other three washing samples. In addition, the washed samples were blueish in tone due to the negative values of b, and the values were greater in the negative range, indicating that the washing treatments with more abrasive actions rendered the samples more bluesish. The rising trend of del E indicated that the discoloration in denim fabric was done from the outer surface of the yarn. As a result, significant color shifts were seen in subsequent washing processes.

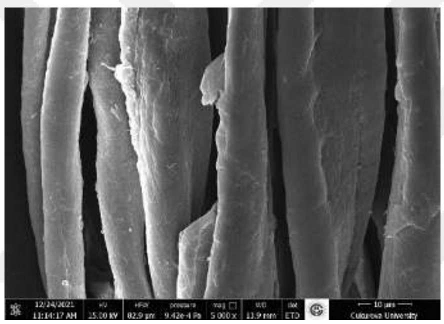
However, in the instance of a, the values showed a downward tendency; Rinse washing > Enzyme washing > stone washing > stone and bleach washing. In addition, it was discovered that washing processes with abrasive action reduced the reddish tones of denim materials.

4.13. SEM image analysis

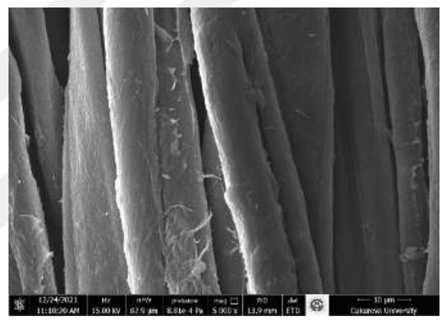
The effect of varied denim washes on the morphology of the denim fabric was studied using SEM. For example, Figure 4.42 depicts SEM images of A1 finished samples, rinse-washed samples, enzyme-washed samples, stone-washed samples, and samples washed with both stones and bleach. Other photographs can be found in the appendix (Figure appx 4.1 and Figure appx 4.16). The fabric was smooth before washing the samples. After rinse washing, the fabric surface of washed samples became cleaner, as if it had been washed normally. Small projecting fibers were eliminated in enzyme washing, resulting in a more lustrous surface. However, after stone washing, a significant mechanical action was performed, resulting in localized color fading and surface damage were seen. Finally, when the cellulose chains disintegrated due to the combined stone and bleach washing, thus damaging the surface of more fibers. The same results were seen in other samples as well.



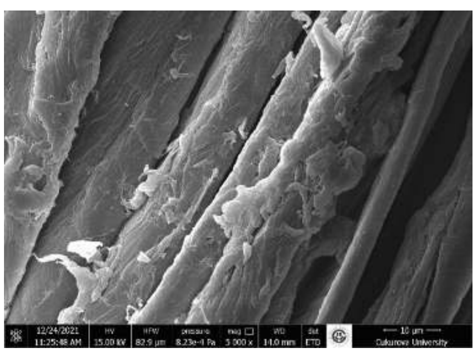
Sample: A1 (Before washing)



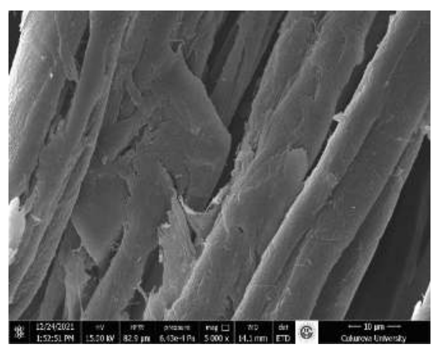
Sample: A1 (Rinse washing)



Sample: A1 (Enzyme washing)



Sample: A1 (Stone washing)



Sample: A1 (Stone & bleach washing)

Figure 4.42. SEM morphology of denim fabrics for sample A1(5000X)

5. CONCLUSION AND RECOMMENDATIONS

The study was aimed to find out the perfect selection of linear density of spandex for weft yarn and the finishing parameters to finish the denim fabrics so that the fabric properties can be optimized. A total of two denim textiles (series 1 and 2) were created in this investigation, employing two different linear densities of elastane core-spun yarn: 78 dtex and 127 dtex, respectively. Aside from that, the fabrics were washed and mercerized at two different temperatures: 120°C and 190°C. In addition, half of the materials were stretched to a 10-centimeter width, resulting in two different width variables. Various tests on denim fabric properties have been carried out. The regression analysis, the independent samples T-test, and the multiple comparison tests were utilized for the statistical analysis. The results obtained in the study can be summarized as follows:

It has been discovered that the weight of the fabrics is reduced by 13-15% due to the finishing processes. In addition, because of stretching at higher temperature (190ºC), the fabric structures became less compact and resulted in a lower weight (GSM). Since the use of higher linear density elastane causes an increase in warp density per unit area, 127 dtex denim has 6% more weight than 78 dtex denim. However, this resulted in 127 dtex denim fabrics having a 5% lower width than 78 dtex denim fabrics. Washed samples have 2% wider width than mercerized ones. In the mercerization process, there was a decrease in the width as a result of the swelling caused by the shrinkage of the cellulose molecules of the weft yarns. A 10% difference in width was detected between the finished and raw fabrics due to the entire finishing process.

While the stretching ability of 127 dtex denim fabric was 5% higher than 78 dtex, the growth value of 78 dtex denim fabric was found to be 8% higher than 127 dtex. The regression model for estimating persistent elongation and stretching was found to be suitable for more than 85 percent of the variances. Due to the presence of elastane, the shrinkage values in the weft direction were 30% higher than in the warp direction. Warp shrinkage of 78 dtex denim fabric looks similar to 127 dtex denim fabric, while weft shrinkage of 78 dtex denim fabric is 11% lower than 127 dtex denim fabric. However, because of the independent T-test, there was no significant difference between the shrinkage averages. Increasing the operating temperature has a significant effect on shrinkage control.

The wefts of the 78 dtex fabric are 18% more resistant to tearing than the 127 dtex fabric. However, since both are produced with the same warp density, there is no significant difference between the warp tear strengths of the two fabrics. In addition, 78 dtex fabric has 8% higher weft way breaking strength, while 127 dtex fabric has 15% higher warp way breaking strength. It was determined that the difference in seam slippage values was not significant.

It has been observed that the air permeability of 78 dtex denim fabric is higher than that of 127 dtex denim fabric. The increase in elastane linear density prevents air permeability by causing a tight fabric structure. As a result, the air permeability rates in the second fabric series are low. It was determined that the stiffness of fabrics made from 78 dtex elastane was 34% lower than 127 dtex elastane fabrics. As the fabrics are softer as a result of mercerization, the washed samples are 15% harder than the mercerized samples.

It was determined that the color tone of the mercerized samples was lighter than the washed samples. In addition, the colors of the finished fabrics without expansion are darker than the expanded ones. Denim fabrics appear reddish and bluish because a* values are positive and b* values are negative. Unexpanded fabrics show more color strengths, while mercerized and expanded fabrics have the lowest values. Since the differences in color intensity are small, it can be said that both series have the same color intensity. The variation in elastane linear density had a very limited effect on the color variation (l, a and b) values between the two fabric series.The fabric was smooth before washing the samples, according to the morphology of the denim fabric determined by SEM examination. The cloth surface of washed samples grew cleaner after rinse washing as if it had been washed normally. Small projecting threads were removed during enzyme washing, resulting in a glossier surface. However, a large mechanical action was conducted following stone cleaning, resulting in localized color fading and surface degradation. Finally, as the cellulose chains fragmented because of the stone and bleach washing, the surface of more fibers was harmed. The same outcomes were observed in other samples.

All the outcomes and conclusions observed in this investigation are consistent with earlier studies without any noteworthy exceptions. In short, the results of the experiments demonstrated the consequences of denim textiles with additional elastane. In this study, only a few tests were conducted to compare two series of fabrics and to determine the best finishing settings. Additional tests for assessing other attributes can be carried out as further investigation. We can recommend other tests such as liquid moisture management qualities, water vapor permeability, fabric drying time measurement, thermal and water vapor resistance, relative hand evaluation, drape, pilling on the fabric's surface lightfastness, etc., for predicting the outcome of the finishing parameters.

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CURRICULUM VITAE

Md Emdad Sarker is a Bangladeshi citizen, currently living in Turkey to pursue his Ph.D. in Textile Engineering at Çukurova University with a fellowship from the Council of Higher Education, Turkey (YÖK) as part of a bilateral agreement with the University Grants Commission of Bangladesh (UGC). He has a bachelor's and a master's degree in Textile Engineering from Bangladesh University of Textiles (BUTEX; formerly known as the College of Textile Technology, affiliated with University of Dhaka). He is working as an Assistant Professor (on study leave) at the Department of Fabric Engineering in BUTEX, Dhaka. He co-authored two books, titled “Textile Dictionary (English to Bengali & English)” and “Practical on Textile Machinery & Machine Controlling Points” He loves visiting and till date he visited several countries, including India, Nepal, Saudi Arabia, Thailand, and Turkey for various purposes. He is highly interested in Quranic Arabic language.

APPENDICES

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APPENDIX A: STATISTICAL ANALYSIS

Descriptive statistics

Table appx 4.1. Descriptive statistics for physical properties of denim fabrics

Properties	Series	N	Mean	Std. Deviation	Std. Error Mean
GSM reduction	1	40	57.920	20.586	3.255
	2	40	69.329	20.206	3.195
Width increase	1	40	14.579	6.396	1.011
	2	40	15.587	4.568	0.722

Table appx 4.2. Descriptive statistics of Strength properties of denim fabrics

Properties	Series	N	Mean	Std. Deviation	Std. Error Mean
Seam slippage	1	40	38.077	3.186	0.504
	2	40	39.179	3.759	0.594
Warp way breaking strength	1	40	97.169	7.431	1.175
	2	40	114.019	13.646	2.158
Weft way breaking strength	1	40	54.185	2.142	0.339
	2	40	49.873	1.588	0.251
Warp way tearing strength	1	40	6676.002	143.231	22.647
	2	40	6637.342	269.306	42.581
Weft way tearing strength	1	40	5055.300	433.529	68.547
	2	40	4166.925	254.958	40.312

Table appx 4.3. Descriptive statistics of comfort properties of denim fabrics

Properties	Series	N	Mean	Std. Deviation	Std. Error Mean
Stiffness	1	40	866.550	290.698	45.963
	2	40	1284.260	575.787	91.040
Air permeability	1	40	55.475	14.668	2.319
	2	40	43.410	13.716	2.169

Table appx 4.4. Descriptive statistics of dimensional properties of denim fabrics

Properties	**Series**	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
Growth	1	40	3.897	0.454	0.072
	2	40	3.592	0.753	0.119
Stretch	1	40	23.083	7.364	1.164
	2	40	27.402	6.517	1.030
Weft shrinkage	1	40	-10.528	4.492	0.710
	2	40	-11.812	3.392	0.536
Warp shrinkage	1	40	-3.384	0.707	0.112
	2	40	-3.325	0.993	0.157

Independent samples test

Table appx 4.5. Independent samples test for physical properties of denim fabrics

Properties	Equal variances	Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
GSM reduction	Assumed	3.354	0.071	-2.502	78.000	0.014	-11.409	4.561	-20.489	-2.329
	Not assumed			-2.502	77.973	0.014	-11.409	4.561	-20.489	-2.329
Width increase	Assumed	26.713	0.000	-0.811	78.000	0.420	-1.008	1.243	-3.482	1.466
	Not assumed			-0.811	70.566	0.420	-1.008	1.243	-3.486	1.470

Table appx 4.6. Independent samples test for strength properties of denim fabrics

Properties	Equal variances	Levene's Test for Equality of Variances		t-test for Equality of Means					95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Seam slippage	Assumed	7.396	0.008	-1.414	78.000	0.161	-1.102	0.779	-2.653	0.449
	Not assumed			-1.414	75.964	0.161	-1.102	0.779	-2.654	0.450
Warp way breaking strength	Assumed	34.515	0.000	-6.859	78.000	0.000	-16.850	2.457	-21.742	-11.959
	Not assumed			-6.859	60.259	0.000	-16.850	2.457	-21.764	-11.936
Weft way breaking strength	Assumed	1.775	0.187	10.224	78.000	0.000	4.311	0.422	3.472	5.151
	Not assumed			10.224	71.924	0.000	4.311	0.422	3.471	5.152
Warp way tearing strength	Assumed	1.744	0.190	0.802	78.000	0.425	38.660	48.229	-57.356	134.677
	Not assumed			0.802	59.429	0.426	38.660	48.229	-57.831	135.151
Weft way tearing strength	Assumed	8.208	0.005	11.171	78.000	0.000	888.375	79.522	730.058	1046.692
	Not assumed			11.171	63.095	0.000	888.375	79.522	729.467	1047.283

Table appx 4.7. Independent samples test for comfort properties of denim fabrics

Properties	Equal variances	Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Stiffness	Assumed	7.043	0.010	-4.096	78.000	0.000	-417.710	101.985	-620.746	-214.674
	Not assumed			-4.096	57.669	0.000	-417.710	101.985	-621.880	-213.540
Air permeabilty	Assumed	0.287	0.593	3.800	78.000	0.000	12.065	3.175	5.744	18.386
	Not assumed			3.800	77.651	0.000	12.065	3.175	5.743	18.387

Table appx 4.8. Independent samples test for dimensional properties of denim fabrics

Properties	Equal variances	Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Growth	Assumed	3.587	0.062	2.196	78.000	0.031	0.305	0.139	0.029	0.582
	Not assumed			2.196	64.029	0.032	0.305	0.139	0.028	0.583
Stretch	Assumed	7.675	0.007	-2.778	78.000	0.007	-4.319	1.555	-7.414	-1.224
	Not assumed			-2.778	76.866	0.007	-4.319	1.555	-7.415	-1.223
Weft shrinkage	Assumed	25.729	0.000	1.442	78.000	0.153	1.284	0.890	-0.488	3.055
	Not assumed			1.442	72.568	0.154	1.284	0.890	-0.490	3.057
Warp shrinkage	Assumed	5.127	0.026	-0.306	78.000	0.760	-0.059	0.193	-0.443	0.325
	Not assumed			-0.306	70.422	0.760	-0.059	0.193	-0.443	0.325

Multiple comparison analysis

Table appx 4.9. LSD multiple comparison analysis of GSM change in series 1

(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
A1	B1	6.73333*	.80581	.000	5.0919	8.3747
	C1	6.73333*	.80581	.000	5.0919	8.3747
	D1	5.50000*	.80581	.000	3.8586	7.1414
	E1	39.83333*	.80581	.000	38.1919	41.4747
	F1	50.60000*	.80581	.000	48.9586	52.2414
	G1	42.93333*	.80581	.000	41.2919	44.5747
	H1	45.64148*	.80581	.000	44.0001	47.2829
B1	A1	-6.73333*	.80581	.000	-8.3747	-5.0919
	C1	.00000	.80581	1.000	-1.6414	1.6414
	D1	-1.23333	.80581	.136	-2.8747	.4081
	E1	33.10000*	.80581	.000	31.4586	34.7414
	F1	43.86667*	.80581	.000	42.2253	45.5081
	G1	36.20000*	.80581	.000	34.5586	37.8414
	H1	38.90815*	.80581	.000	37.2668	40.5495
C1	A1	-6.73333*	.80581	.000	-8.3747	-5.0919
	B1	.00000	.80581	1.**000**	-1.6414	1.6414
	D1	-1.23333	.80581	.136	-2.8747	.4081
	E1	33.10000*	.80581	.000	31.4586	34.7414
	F1	43.86667*	.80581	.000	42.2253	45.5081
	G1	36.20000*	.80581	.000	34.5586	37.8414
	H1	38.90815*	.80581	.000	37.2668	40.5495
D1	A1	-5.50000*	.80581	.000	-7.1414	-3.8586
	B1	1.23333	.80581	.**136**	-.4081	2.8747
	C1	1.23333	.80581	.**136**	-.4081	2.8747
	E1	34.33333*	.80581	.000	32.6919	35.9747

	F1	45.10000*	.80581	.000	43.4586	46.7414
	G1	37.43333*	.80581	.000	35.7919	39.0747
	H1	40.14148*	.80581	.000	38.5001	41.7829
E1	A1	- 39.83333*	.80581	.000	- 41.4747	- 38.1919
	B1	- 33.10000*	.80581	.000	- 34.7414	- 31.4586
	C1	- 33.10000*	.80581	.000	- 34.7414	- 31.4586
	D1	- 34.33333*	.80581	.000	- 35.9747	- 32.6919
	F1	10.76667*	.80581	.000	9.1253	12.4081
	G1	3.10000*	.80581	.001	1.4586	4.7414
	H1	5.80815*	.80581	.000	4.1668	7.4495
F1	A1	- 50.60000*	.80581	.000	- 52.2414	- 48.9586
	B1	- 43.86667*	.80581	.000	- 45.5081	- 42.2253
	C1	- 43.86667*	.80581	.000	- 45.5081	- 42.2253
	D1	- 45.10000*	.80581	.000	- 46.7414	- 43.4586
	E1	- 10.76667*	.80581	.000	- 12.4081	-9.1253
	G1	-7.66667*	.80581	.000	-9.3081	-6.0253
	H1	-4.95852*	.80581	.000	-6.5999	-3.3171
G1	A1	- 42.93333*	.80581	.000	- 44.5747	- 41.2919
	B1	- 36.20000*	.80581	.000	- 37.8414	- 34.5586
	C1	- 36.20000*	.80581	.000	- 37.8414	- 34.5586

	D1	-37.43333*	.80581	.000	-39.0747	-35.7919
	E1	-3.10000*	.80581	.001	-4.7414	-1.4586
	F1	7.66667*	.80581	.000	6.0253	9.3081
	H1	2.70815*	.80581	.002	1.0668	4.3495
H1	A1	-45.64148*	.80581	.000	-47.2829	-44.0001
	B1	-38.90815*	.80581	.000	-40.5495	-37.2668
	C1	-38.90815*	.80581	.000	-40.5495	-37.2668
	D1	-40.14148*	.80581	.000	-41.7829	-38.5001
	E1	-5.80815*	.80581	.000	-7.4495	-4.1668
	F1	4.95852*	.80581	.000	3.3171	6.5999
	G1	-2.70815*	.80581	.002	-4.3495	-1.0668

Table appx 4.10. LSD multiple comparison analysis of GSM change in series 2

(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
A2	B2	10.30000*	.57489	.000	9.1290	11.4710
	C2	25.00000*	.57489	.000	23.8290	26.1710
	D2	32.26667*	.57489	.000	31.0957	33.4377
	E2	38.73333*	.57489	.000	37.5623	39.9043
	F2	61.30000*	.57489	.000	60.1290	62.4710
	G2	43.20000*	.57489	.000	42.0290	44.3710
	H2	56.96667*	.57489	.000	55.7957	58.1377
B2	A2	-10.30000*	.57489	.000	-11.4710	-9.1290
	C2	14.70000*	.57489	.000	13.5290	15.8710

	D2	21.96667*	.57489	.000	20.7957	23.1377
	E2	28.43333*	.57489	.000	27.2623	29.6043
	F2	51.00000*	.57489	.000	49.8290	52.1710
	G2	32.90000*	.57489	.000	31.7290	34.0710
	H2	46.66667*	.57489	.000	45.4957	47.8377
C2	A2	-25.00000*	.57489	.000	-26.1710	-23.8290
	B2	-14.70000*	.57489	.000	-15.8710	-13.5290
	D2	7.26667*	.57489	.000	6.0957	8.4377
	E2	13.73333*	.57489	.000	12.5623	14.9043
	F2	36.30000*	.57489	.000	35.1290	37.4710
	G2	18.20000*	.57489	.000	17.0290	19.3710
	H2	31.96667*	.57489	.000	30.7957	33.1377
D2	A2	-32.26667*	.57489	.000	-33.4377	-31.0957
	B2	-21.96667*	.57489	.000	-23.1377	-20.7957
	C2	-7.26667*	.57489	.000	-8.4377	-6.0957
	E2	6.46667*	.57489	.000	5.2957	7.6377
	F2	29.03333*	.57489	.000	27.8623	30.2043
	G2	10.93333*	.57489	.000	9.7623	12.1043
	H2	24.70000*	.57489	.000	23.5290	25.8710
E2	A2	-38.73333*	.57489	.000	-39.9043	-37.5623
	B2	-28.43333*	.57489	.000	-29.6043	-27.2623
	C2	-13.73333*	.57489	.000	-14.9043	-12.5623
	D2	-6.46667*	.57489	.000	-7.6377	-5.2957
	F2	22.56667*	.57489	.000	21.3957	23.7377
	G2	4.46667*	.57489	.000	3.2957	5.6377
	H2	18.23333*	.57489	.000	17.0623	19.4043
F2	A2	-61.30000*	.57489	.000	-62.4710	-60.1290
	B2	-51.00000*	.57489	.000	-52.1710	-49.8290
	C2	-36.30000*	.57489	.000	-37.4710	-35.1290
	D2	-29.03333*	.57489	.000	-30.2043	-27.8623
	E2	-22.56667*	.57489	.000	-23.7377	-21.3957
	G2	-18.10000*	.57489	.000	-19.2710	-16.9290

	H2	-4.33333*	.57489	.000	-5.5043	-3.1623
G2	A2	-43.20000*	.57489	.000	-44.3710	-42.0290
	B2	-32.90000*	.57489	.000	-34.0710	-31.7290
	C2	-18.20000*	.57489	.000	-19.3710	-17.0290
	D2	-10.93333*	.57489	.000	-12.1043	-9.7623
	E2	-4.46667*	.57489	.000	-5.6377	-3.2957
	F2	18.10000*	.57489	.000	16.9290	19.2710
	H2	13.76667*	.57489	.000	12.5957	14.9377
H2	A2	-56.96667*	.57489	.000	-58.1377	-55.7957
	B2	-46.66667*	.57489	.000	-47.8377	-45.4957
	C2	-31.96667*	.57489	.000	-33.1377	-30.7957
	D2	-24.70000*	.57489	.000	-25.8710	-23.5290
	E2	-18.23333*	.57489	.000	-19.4043	-17.0623
	F2	4.33333*	.57489	.000	3.1623	5.5043
	G2	-13.76667*	.57489	.000	-14.9377	-12.5957

Table appx 4.11. LSD multiple comparison analysis of Width change in series 1

(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
A1	B1	2.33333*	.39907	.000	1.5205	3.1462
	C1	.23333	.39907	.563	-.5795	1.0462
	D1	2.13333*	.39907	.000	1.3205	2.9462
	E1	12.40000*	.39907	.000	11.5871	13.2129
	F1	15.53333*	.39907	.000	14.7205	16.3462
	G1	11.56667*	.39907	.000	10.7538	12.3795
	H1	14.37037*	.39907	.000	13.5575	15.1832
B1	A1	-2.33333*	.39907	.000	-3.1462	-1.5205
	C1	-2.10000*	.39907	.000	-2.9129	-1.2871
	D1	-.20000	.39907	.620	-1.0129	.6129
	E1	10.06667*	.39907	.000	9.2538	10.8795

	F1	13.20000*	.39907	.000	12.3871	14.0129
	G1	9.23333*	.39907	.000	8.4205	10.0462
	H1	12.03704*	.39907	.000	11.2242	12.8499
C1	A1	-.23333	.39907	.563	-1.0462	.5795
	B1	2.10000*	.39907	.000	1.2871	2.9129
	D1	1.90000*	.39907	.000	1.0871	2.7129
	E1	12.16667*	.39907	.000	11.3538	12.9795
	F1	15.30000*	.39907	.000	14.4871	16.1129
	G1	11.33333*	.39907	.000	10.5205	12.1462
	H1	14.13704*	.39907	.000	13.3242	14.9499
D1	A1	-2.13333*	.39907	.000	-2.9462	-1.3205
	B1	.20000	.39907	.620	-.6129	1.0129
	C1	-1.90000*	.39907	.000	-2.7129	-1.0871
	E1	10.26667*	.39907	.000	9.4538	11.0795
	F1	13.40000*	.39907	.000	12.5871	14.2129
	G1	9.43333*	.39907	.000	8.6205	10.2462
	H1	12.23704*	.39907	.000	11.4242	13.0499
E1	A1	-12.40000*	.39907	.000	-13.2129	-11.5871
	B1	-10.06667*	.39907	.000	-10.8795	-9.2538
	C1	-12.16667*	.39907	.000	-12.9795	-11.3538
	D1	-10.26667*	.39907	.000	-11.0795	-9.4538
	F1	3.13333*	.39907	.000	2.3205	3.9462
	G1	-.83333*	.39907	.045	-1.6462	-.0205
	H1	1.97037*	.39907	.000	1.1575	2.7832
F1	A1	-15.53333*	.39907	.000	-16.3462	-14.7205
	B1	-13.20000*	.39907	.000	-14.0129	-12.3871
	C1	-15.30000*	.39907	.000	-16.1129	-14.4871
	D1	-13.40000*	.39907	.000	-14.2129	-12.5871
	E1	-3.13333*	.39907	.000	-3.9462	-2.3205
	G1	-3.96667*	.39907	.000	-4.7795	-3.1538
	H1	-1.16296*	.39907	.006	-1.9758	-.3501
G1	A1	-11.56667*	.39907	.000	-12.3795	-10.7538

	B1	-9.23333*	.39907	.000	-10.0462	-8.4205
	C1	-11.33333*	.39907	.000	-12.1462	-10.5205
	D1	-9.43333*	.39907	.000	-10.2462	-8.6205
	E1	.83333*	.39907	.045	.0205	1.6462
	F1	3.96667*	.39907	.000	3.1538	4.7795
	H1	2.80370*	.39907	.000	1.9908	3.6166
H1	A1	-14.37037*	.39907	.000	-15.1832	-13.5575
	B1	-12.03704*	.39907	.000	-12.8499	-11.2242
	C1	-14.13704*	.39907	.000	-14.9499	-13.3242
	D1	-12.23704*	.39907	.000	-13.0499	-11.4242
	E1	-1.97037*	.39907	.000	-2.7832	-1.1575
	F1	1.16296*	.39907	.006	.3501	1.9758
	G1	-2.80370*	.39907	.000	-3.6166	-1.9908

Table appx 4.12. LSD multiple comparison analysis of Width change in series 2

(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
A2	B2	1.49333*	.26122	.000	.9613	2.0254
	C2	7.36000*	.26122	.000	6.8279	7.8921
	D2	10.12667*	.26122	.000	9.5946	10.6587
	E2	8.89333*	.26122	.000	8.3613	9.4254
	F2	12.76000*	.26122	.000	12.2279	13.2921
	G2	10.76000*	.26122	.000	10.2279	11.2921
	H2	12.39333*	.26122	.000	11.8613	12.9254
B2	A2	-1.49333*	.26122	.000	-2.0254	-.9613
	C2	5.86667*	.26122	.000	5.3346	6.3987
	D2	8.63333*	.26122	.000	8.1013	9.1654
	E2	7.40000*	.26122	.000	6.8679	7.9321

	F2	11.26667*	.26122	.000	10.7346	11.7987
	G2	9.26667*	.26122	.000	8.7346	9.7987
	H2	10.90000*	.26122	.000	10.3679	11.4321
C2	A2	-7.36000*	.26122	.000	-7.8921	-6.8279
	B2	-5.86667*	.26122	.000	-6.3987	-5.3346
	D2	2.76667*	.26122	.000	2.2346	3.2987
	E2	1.53333*	.26122	.000	1.0013	2.0654
	F2	5.40000*	.26122	.000	4.8679	5.9321
	G2	3.40000*	.26122	.000	2.8679	3.9321
	H2	5.03333*	.26122	.000	4.5013	5.5654
D2	A2	-10.12667*	.26122	.000	-10.6587	-9.5946
	B2	-8.63333*	.26122	.000	-9.1654	-8.1013
	C2	-2.76667*	.26122	.000	-3.2987	-2.2346
	E2	-1.23333*	.26122	.000	-1.7654	-.7013
	F2	2.63333*	.26122	.000	2.1013	3.1654
	G2	.63333*	.26122	.021	.1013	1.1654
	H2	2.26667*	.26122	.000	1.7346	2.7987
E2	A2	-8.89333*	.26122	.000	-9.4254	-8.3613
	B2	-7.40000*	.26122	.000	-7.9321	-6.8679
	C2	-1.53333*	.26122	.000	-2.0654	-1.0013
	D2	1.23333*	.26122	.000	.7013	1.7654
	F2	3.86667*	.26122	.000	3.3346	4.3987
	G2	1.86667*	.26122	.000	1.3346	2.3987
	H2	3.50000*	.26122	.000	2.9679	4.0321
F2	A2	-12.76000*	.26122	.000	-13.2921	-12.2279
	B2	-11.26667*	.26122	.000	-11.7987	-10.7346
	C2	-5.40000*	.26122	.000	-5.9321	-4.8679
	D2	-2.63333*	.26122	.000	-3.1654	-2.1013
	E2	-3.86667*	.26122	.000	-4.3987	-3.3346
	G2	-2.00000*	.26122	.000	-2.5321	-1.4679
	H2	-.36667	.26122	.170	-.8987	.1654
G2	A2	-10.76000*	.26122	.000	-11.2921	-10.2279

	B2	-9.26667*	.26122	.000	-9.7987	-8.7346
	C2	-3.40000*	.26122	.000	-3.9321	-2.8679
	D2	-.63333*	.26122	.021	-1.1654	-.1013
	E2	-1.86667*	.26122	.000	-2.3987	-1.3346
	F2	2.00000*	.26122	.000	1.4679	2.5321
	H2	1.63333*	.26122	.000	1.1013	2.1654
H2	A2	-12.39333*	.26122	.000	-12.9254	-11.8613
	B2	-10.90000*	.26122	.000	-11.4321	-10.3679
	C2	-5.03333*	.26122	.000	-5.5654	-4.5013
	D2	-2.26667*	.26122	.000	-2.7987	-1.7346
	E2	-3.50000*	.26122	.000	-4.0321	-2.9679
	F2	.36667	.26122	.170	-.1654	.8987
	G2	-1.63333*	.26122	.000	-2.1654	-1.1013

Table appx 4.13. LSD multiple comparison analysis of warp way breaking strength in series 1

(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
A1	B1	-0.36667	0.87393	0.678	-2.1468	1.4135
	C1	-2.80000*	0.87393	0.003	-4.5801	-1.0199
	D1	10.66667*	0.87393	0.000	8.8865	12.4468
	E1	3.53333*	0.87393	0.000	1.7532	5.3135
	F1	0.96667	0.87393	0.277	-0.8135	2.7468
	G1	-16.93333*	0.87393	0.000	-18.7135	-15.1532

	H1	-0.95037	0.87393	0.285	-2.7305	0.8298
B1	A1	0.36667	0.87393	0.678	-1.4135	2.1468
	C1	-2.43333*	0.87393	0.009	-4.2135	-0.6532
	D1	11.03333*	0.87393	0.000	9.2532	12.8135
	E1	3.90000*	0.87393	0.000	2.1199	5.6801
	F1	1.33333	0.87393	0.137	-0.4468	3.1135
	G1	-16.56667*	0.87393	0.000	-18.3468	-14.7865
	H1	-0.5837	0.87393	0.509	-2.3638	1.1964
C1	A1	2.80000*	0.87393	0.003	1.0199	4.5801
	B1	2.43333*	0.87393	0.009	0.6532	4.2135
	D1	13.46667*	0.87393	0.000	11.6865	15.2468
	E1	6.33333*	0.87393	0.000	4.5532	8.1135
	F1	3.76667*	0.87393	0.000	1.9865	5.5468
	G1	-14.13333*	0.87393	0.000	-15.9135	-12.3532
	H1	1.84963*	0.87393	0.042	0.0695	3.6298
D1	A1	-10.66667*	0.87393	0.000	-12.4468	-8.8865
	B1	-11.03333*	0.87393	0.000	-12.8135	-9.2532
	C1	-13.46667*	0.87393	0.000	-15.2468	-11.6865

	E1	-7.13333*	0.87393	0.000	-8.9135	-5.3532
	F1	-9.70000*	0.87393	0.000	-11.4801	-7.9199
	G1	-27.60000*	0.87393	0.000	-29.3801	-25.8199
	H1	-11.61704*	0.87393	0.000	-13.3972	-9.8369
E1	A1	-3.53333*	0.87393	0.000	-5.3135	-1.7532
	B1	-3.90000*	0.87393	0.000	-5.6801	-2.1199
	C1	-6.33333*	0.87393	0.000	-8.1135	-4.5532
	D1	7.13333*	0.87393	0.000	5.3532	8.9135
	F1	-2.56667*	0.87393	0.006	-4.3468	-0.7865
	G1	-20.46667*	0.87393	0.000	-22.2468	-18.6865
	H1	-4.48370*	0.87393	0.000	-6.2638	-2.7036
F1	A1	-0.96667	0.87393	0.277	-2.7468	0.8135
	B1	-1.33333	0.87393	0.137	-3.1135	0.4468
	C1	-3.76667*	0.87393	0.000	-5.5468	-1.9865
	D1	9.70000*	0.87393	0.000	7.9199	11.4801
	E1	2.56667*	0.87393	0.006	0.7865	4.3468
	G1	-17.90000*	0.87393	0.000	-19.6801	-16.1199
	H1	-1.91704*	0.87393	0.036	-3.6972	-0.1369

G1	A1	16.93333*	0.87393	0.000	15.1532	18.7135
	B1	16.56667*	0.87393	0.000	14.7865	18.3468
	C1	14.13333*	0.87393	0.000	12.3532	15.9135
	D1	27.60000*	0.87393	0.000	25.8199	29.3801
	E1	20.46667*	0.87393	0.000	18.6865	22.2468
	F1	17.90000*	0.87393	0.000	16.1199	19.6801
	H1	15.98296*	0.87393	0.000	14.2028	17.7631
H1	A1	0.95037	0.87393	0.285	-0.8298	2.7305
	B1	0.5837	0.87393	0.509	-1.1964	2.3638
	C1	-1.84963*	0.87393	0.042	-3.6298	-0.0695
	D1	11.61704*	0.87393	0.000	9.8369	13.3972
	E1	4.48370*	0.87393	0.000	2.7036	6.2638
	F1	1.91704*	0.87393	0.036	0.1369	3.6972
	G1	-15.98296*	0.87393	0.000	-17.7631	-14.2028

Table appx 4.14. LSD multiple comparison analysis of warp way breaking strength in series 2

(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
A2	B2	4.88667*	0.40399	0.000	4.0638	5.7096
	C2	-6.38000*	0.40399	0.000	-7.2029	-5.5571
	D2	-2.24667*	0.40399	0.000	-3.0696	-1.4238
	E2	20.88667*	0.40399	0.000	20.0638	21.7096
	F2	27.52000*	0.40399	0.000	26.6971	28.3429
	G2	31.58667*	0.40399	0.000	30.7638	32.4096
	H2	6.15333*	0.40399	0.000	5.3304	6.9762
B2	A2	-4.88667*	0.40399	0.000	-5.7096	-4.0638
	C2	-11.26667*	0.40399	0.000	-12.0896	-10.4438
	D2	-7.13333*	0.40399	0.000	-7.9562	-6.3104
	E2	16.00000*	0.40399	0.000	15.1771	16.8229
	F2	22.63333*	0.40399	0.000	21.8104	23.4562
	G2	26.70000*	0.40399	0.000	25.8771	27.5229
	H2	1.26667*	0.40399	0.004	0.4438	2.0896
C2	A2	6.38000*	0.40399	0.000	5.5571	7.2029

	B2	11.26667*	0.40399	0.000	10.4438	12.0896
	D2	4.13333*	0.40399	0.000	3.3104	4.9562
	E2	27.26667*	0.40399	0.000	26.4438	28.0896
	F2	33.90000*	0.40399	0.000	33.0771	34.7229
	G2	37.96667*	0.40399	0.000	37.1438	38.7896
	H2	12.53333*	0.40399	0.000	11.7104	13.3562
D2	A2	2.24667*	0.40399	0.000	1.4238	3.0696
	B2	7.13333*	0.40399	0.000	6.3104	7.9562
	C2	-4.13333*	0.40399	0.000	-4.9562	-3.3104
	E2	23.13333*	0.40399	0.000	22.3104	23.9562
	F2	29.76667*	0.40399	0.000	28.9438	30.5896
	G2	33.83333*	0.40399	0.000	33.0104	34.6562
	H2	8.40000*	0.40399	0.000	7.5771	9.2229
E2	A2	-20.88667*	0.40399	0.000	-21.7096	-20.0638
	B2	-16.00000*	0.40399	0.000	-16.8229	-15.1771
	C2	-27.26667*	0.40399	0.000	-28.0896	-26.4438
	D2	-23.13333*	0.40399	0.000	-23.9562	-22.3104
	F2	6.63333*	0.40399	0.000	5.8104	7.4562

	G2	10.70000*	0.40399	0.000	9.8771	11.5229
	H2	-14.73333*	0.40399	0.000	-15.5562	-13.9104
F2	A2	-27.52000*	0.40399	0.000	-28.3429	-26.6971
	B2	-22.63333*	0.40399	0.000	-23.4562	-21.8104
	C2	-33.90000*	0.40399	0.000	-34.7229	-33.0771
	D2	-29.76667*	0.40399	0.000	-30.5896	-28.9438
	E2	-6.63333*	0.40399	0.000	-7.4562	-5.8104
	G2	4.06667*	0.40399	0.000	3.2438	4.8896
	H2	-21.36667*	0.40399	0.000	-22.1896	-20.5438
G2	A2	-31.58667*	0.40399	0.000	-32.4096	-30.7638
	B2	-26.70000*	0.40399	0.000	-27.5229	-25.8771
	C2	-37.96667*	0.40399	0.000	-38.7896	-37.1438
	D2	-33.83333*	0.40399	0.000	-34.6562	-33.0104
	E2	-10.70000*	0.40399	0.000	-11.5229	-9.8771
	F2	-4.06667*	0.40399	0.000	-4.8896	-3.2438
	H2	-25.43333*	0.40399	0.000	-26.2562	-24.6104
H2	A2	-6.15333*	0.40399	0.000	-6.9762	-5.3304
	B2	-1.26667*	0.40399	0.004	-2.0896	-0.4438

	C2	-12.53333*	0.40399	0.000	-13.3562	-11.7104
	D2	-8.40000*	0.40399	0.000	-9.2229	-7.5771
	E2	14.73333*	0.40399	0.000	13.9104	15.5562
	F2	21.36667*	0.40399	0.000	20.5438	22.1896
	G2	25.43333*	0.40399	0.000	24.6104	26.2562

Table appx 4. 15. LSD multiple comparison analysis of weft way breaking strength in series 1

(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
A1	B1	2.83333*	.24174	.000	2.3409	3.3257
	C1	.36667	.24174	.139	-.1257	.8591
	D1	1.96667*	.24174	.000	1.4743	2.4591
	E1	1.10000*	.24174	.000	.6076	1.5924
	F1	2.73333*	.24174	.000	2.2409	3.2257
	G1	6.76667*	.24174	.000	6.2743	7.2591
	H1	4.35704*	.24174	.000	3.8646	4.8494
B1	A1	-2.83333*	.24174	.000	-3.3257	-2.3409
	C1	-2.46667*	.24174	.000	-2.9591	-1.9743
	D1	-.86667*	.24174	.001	-1.3591	-.3743
	E1	-1.73333*	.24174	.000	-2.2257	-1.2409
	F1	-.10000	.24174	.682	-.5924	.3924
	G1	3.93333*	.24174	.000	3.4409	4.4257
	H1	1.52370*	.24174	.000	1.0313	2.0161
C1	A1	-.36667	.24174	**.139**	-.8591	.1257
	B1	2.46667*	.24174	.000	1.9743	2.9591

	D1	1.60000*	.24174	.000	1.1076	2.0924
	E1	.73333*	.24174	.005	.2409	1.2257
	F1	2.36667*	.24174	.000	1.8743	2.8591
	G1	6.40000*	.24174	.000	5.9076	6.8924
	H1	3.99037*	.24174	.000	3.4980	4.4828
D1	A1	-1.96667*	.24174	.000	-2.4591	-1.4743
	B1	.86667*	.24174	.001	.3743	1.3591
	C1	-1.60000*	.24174	.000	-2.0924	-1.1076
	E1	-.86667*	.24174	.001	-1.3591	-.3743
	F1	.76667*	.24174	.003	.2743	1.2591
	G1	4.80000*	.24174	.000	4.3076	5.2924
	H1	2.39037*	.24174	.000	1.8980	2.8828
E1	A1	-1.10000*	.24174	.000	-1.5924	-.6076
	B1	1.73333*	.24174	.000	1.2409	2.2257
	C1	-.73333*	.24174	.005	-1.2257	-.2409
	D1	.86667*	.24174	.001	.3743	1.3591
	F1	1.63333*	.24174	.000	1.1409	2.1257
	G1	5.66667*	.24174	.000	5.1743	6.1591
	H1	3.25704*	.24174	.000	2.7646	3.7494
F1	A1	-2.73333*	.24174	.000	-3.2257	-2.2409
	B1	.10000	.24174	**.682**	-.3924	.5924
	C1	-2.36667*	.24174	.000	-2.8591	-1.8743
	D1	-.76667*	.24174	.003	-1.2591	-.2743
	E1	-1.63333*	.24174	.000	-2.1257	-1.1409
	G1	4.03333*	.24174	.000	3.5409	4.5257
	H1	1.62370*	.24174	.000	1.1313	2.1161
G1	A1	-6.76667*	.24174	.000	-7.2591	-6.2743
	B1	-3.93333*	.24174	.000	-4.4257	-3.4409
	C1	-6.40000*	.24174	.000	-6.8924	-5.9076
	D1	-4.80000*	.24174	.000	-5.2924	-4.3076
	E1	-5.66667*	.24174	.000	-6.1591	-5.1743
	F1	-4.03333*	.24174	.000	-4.5257	-3.5409

	H1	-2.40963*	.24174	.000	-2.9020	-1.9172
H1	A1	-4.35704*	.24174	.000	-4.8494	-3.8646
	B1	-1.52370*	.24174	.000	-2.0161	-1.0313
	C1	-3.99037*	.24174	.000	-4.4828	-3.4980
	D1	-2.39037*	.24174	.000	-2.8828	-1.8980
	E1	-3.25704*	.24174	.000	-3.7494	-2.7646
	F1	-1.62370*	.24174	.000	-2.1161	-1.1313
	G1	2.40963*	.24174	.000	1.9172	2.9020

Table appx 4.16. LSD multiple comparison analysis of weft way breaking strength in series 2

(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
A2	B2	2.28667*	.30649	.000	1.6624	2.9110
	C2	3.22000*	.30649	.000	2.5957	3.8443
	D2	3.88667*	.30649	.000	3.2624	4.5110
	E2	-.01333	.30649	.966	-.6376	.6110
	F2	3.35333*	.30649	.000	2.7290	3.9776
	G2	2.82000*	.30649	.000	2.1957	3.4443
	H2	4.02000*	.30649	.000	3.3957	4.6443
B2	A2	-2.28667*	.30649	.000	-2.9110	-1.6624
	C2	.93333*	.30649	.005	.3090	1.5576
	D2	1.60000*	.30649	.000	.9757	2.2243
	E2	-2.30000*	.30649	.000	-2.9243	-1.6757
	F2	1.06667*	.30649	.001	.4424	1.6910
	G2	.53333	.30649	.091	-.0910	1.1576
	H2	1.73333*	.30649	.000	1.1090	2.3576
C2	A2	-3.22000*	.30649	.000	-3.8443	-2.5957
	B2	-.93333*	.30649	.005	-1.5576	-.3090
	D2	.66667*	.30649	.037	.0424	1.2910
	E2	-3.23333*	.30649	.000	-3.8576	-2.6090

	F2	.13333	.30649	.666	-.4910	.7576
	G2	-.40000	.30649	.201	-1.0243	.2243
	H2	.80000*	.30649	.014	.1757	1.4243
D2	A2	-3.88667*	.30649	.000	-4.5110	-3.2624
	B2	-1.60000*	.30649	.000	-2.2243	-.9757
	C2	-.66667*	.30649	.037	-1.2910	-.0424
	E2	-3.90000*	.30649	.000	-4.5243	-3.2757
	F2	-.53333	.30649	.091	-1.1576	.0910
	G2	-1.06667*	.30649	.001	-1.6910	-.4424
	H2	.13333	.30649	.666	-.4910	.7576
E2	A2	.01333	.30649	.966	-.6110	.6376
	B2	2.30000*	.30649	.000	1.6757	2.9243
	C2	3.23333*	.30649	.000	2.6090	3.8576
	D2	3.90000*	.30649	.000	3.2757	4.5243
	F2	3.36667*	.30649	.000	2.7424	3.9910
	G2	2.83333*	.30649	.000	2.2090	3.4576
	H2	4.03333*	.30649	.000	3.4090	4.6576
F2	A2	-3.35333*	.30649	.000	-3.9776	-2.7290
	B2	-1.06667*	.30649	.001	-1.6910	-.4424
	C2	-.13333	.30649	.666	-.7576	.4910
	D2	.53333	.30649	.091	-.0910	1.1576
	E2	-3.36667*	.30649	.000	-3.9910	-2.7424
	G2	-.53333	.30649	.091	-1.1576	.0910
	H2	.66667*	.30649	.037	.0424	1.2910
G2	A2	-2.82000*	.30649	.000	-3.4443	-2.1957
	B2	-.53333	.30649	.091	-1.1576	.0910
	C2	.40000	.30649	.201	-.2243	1.0243
	D2	1.06667*	.30649	.001	.4424	1.6910
	E2	-2.83333*	.30649	.000	-3.4576	-2.2090
	F2	.53333	.30649	.091	-.0910	1.1576
	H2	1.20000*	.30649	.000	.5757	1.8243
H2	A2	-4.02000*	.30649	.000	-4.6443	-3.3957

	B2	-1.73333*	.30649	.000	-2.3576	-1.1090
	C2	-.80000*	.30649	.014	-1.4243	-.1757
	D2	-.13333	.30649	.666	-.7576	.4910
	E2	-4.03333*	.30649	.000	-4.6576	-3.4090
	F2	-.66667*	.30649	.037	-1.2910	-.0424
	G2	-1.20000*	.30649	.000	-1.8243	-.5757

Table appx 4.17. LSD multiple comparison analysis of warp way tearing strength in series 1

(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence	
					Lower	Upper
A1	B1	326.33333*	34.8082	0.000	255.4314	397.2353
	C1	28	34.8082	0.427	-42.902	98.902
	D1	284.66667*	34.8082	0.000	213.7647	355.5686
	E1	15.66667	34.8082	0.656	-55.2353	86.5686
	F1	280.66667*	34.8082	0.000	209.7647	351.5686
	G1	66.66667	34.8082	0.064	-4.2353	137.5686
	H1	24.65185	34.8082	0.484	-46.2501	95.5538
B1	A1	-326.33333*	34.8082	0.000	-397.235	-255.431
	C1	-298.33333*	34.8082	0.000	-369.235	-227.431
	D1	-41.6667	34.8082	0.240	-112.569	29.2353
	E1	-310.66667*	34.8082	0.000	-381.569	-239.765
	F1	-45.6667	34.8082	0.199	-116.569	25.2353
	G1	-259.66667*	34.8082	0.000	-330.569	-188.765
	H1	-301.68148*	34.8082	0.000	-372.584	-230.78
C1	A1	-28	34.8082	0.427	-98.902	42.902

	B1	298.33333*	34.8082	0.000	227.4314	369.2353
	D1	256.66667*	34.8082	0.000	185.7647	327.5686
	E1	-12.3333	34.8082	0.725	-83.2353	58.5686
	F1	252.66667*	34.8082	0.000	181.7647	323.5686
	G1	38.66667	34.8082	0.275	-32.2353	109.5686
	H1	-3.34815	34.8082	0.924	-74.2501	67.5538
D1	A1	-284.66667*	34.8082	0.000	-355.569	-213.765
	B1	41.66667	34.8082	0.240	-29.2353	112.5686
	C1	-256.66667*	34.8082	0.000	-327.569	-185.765
	E1	-269.00000*	34.8082	0.000	-339.902	-198.098
	F1	-4	34.8082	0.909	-74.902	66.902
	G1	-218.00000*	34.8082	0.000	-288.902	-147.098
	H1	-260.01481*	34.8082	0.000	-330.917	-189.113
E1	A1	-15.6667	34.8082	0.656	-86.5686	55.2353
	B1	310.66667*	34.8082	0.000	239.7647	381.5686
	C1	12.33333	34.8082	0.725	-58.5686	83.2353
	D1	269.00000*	34.8082	0.000	198.098	339.902
	F1	265.00000*	34.8082	0.000	194.098	335.902
	G1	51	34.8082	0.153	-19.902	121.902
	H1	8.98519	34.8082	0.798	-61.9168	79.8872
F1	A1	-280.66667*	34.8082	0.000	-351.569	-209.765
	B1	45.66667	34.8082	0.199	-25.2353	116.5686
	C1	-252.66667*	34.8082	0.000	-323.569	-181.765
	D1	4	34.8082	0.909	-66.902	74.902

	E1	-265.00000*	34.8082	0.000	-335.902	-194.098
	G1	-214.00000*	34.8082	0.000	-284.902	-143.098
	H1	-256.01481*	34.8082	0.000	-326.917	-185.113
G1	A1	-66.6667	34.8082	0.064	-137.569	4.2353
	B1	259.66667*	34.8082	0.000	188.7647	330.5686
	C1	-38.6667	34.8082	0.275	-109.569	32.2353
	D1	218.00000*	34.8082	0.000	147.098	288.902
	E1	-51	34.8082	0.153	-121.902	19.902
	F1	214.00000*	34.8082	0.000	143.098	284.902
	H1	-42.0148	34.8082	0.236	-112.917	28.8872
H1	A1	-24.6519	34.8082	0.484	-95.5538	46.2501
	B1	301.68148*	34.8082	0.000	230.7795	372.5835
	C1	3.34815	34.8082	0.924	-67.5538	74.2501
	D1	260.01481*	34.8082	0.000	189.1128	330.9168
	E1	-8.98519	34.8082	0.798	-79.8872	61.9168
	F1	256.01481*	34.8082	0.000	185.1128	326.9168
	G1	42.01481	34.8082	0.236	-28.8872	112.9168

Table appx 4.18. LSD multiple comparison analysis of warp way tearing strength in series 2

(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
A2	B2	-29.60000	28.46867	.306	-87.5888	28.3888
	C2	45.40000	28.46867	.121	-12.5888	103.3888
	D2	47.40000	28.46867	.106	-10.5888	105.3888
	E2	-13.60000	28.46867	.636	-71.5888	44.3888
	F2	18.06667	28.46867	.530	-39.9221	76.0554
	G2	60.73333*	28.46867	.041	2.7446	118.7221
	H2	808.06667*	28.46867	.000	750.0779	866.0554
B2	A2	29.60000	28.46867	.306	-28.3888	87.5888
	C2	75.00000*	28.46867	.013	17.0112	132.9888
	D2	77.00000*	28.46867	.011	19.0112	134.9888
	E2	16.00000	28.46867	.578	-41.9888	73.9888
	F2	47.66667	28.46867	.104	-10.3221	105.6554
	G2	90.33333*	28.46867	.003	32.3446	148.3221
	H2	837.66667*	28.46867	.000	779.6779	895.6554
C2	A2	-45.40000	28.46867	.121	-103.3888	12.5888
	B2	-75.00000*	28.46867	.013	-132.9888	-17.0112
	D2	2.00000	28.46867	.944	-55.9888	59.9888
	E2	-59.00000*	28.46867	.046	-116.9888	-1.0112
	F2	-27.33333	28.46867	.344	-85.3221	30.6554
	G2	15.33333	28.46867	.594	-42.6554	73.3221
	H2	762.66667*	28.46867	.000	704.6779	820.6554
D2	A2	-47.40000	28.46867	.106	-105.3888	10.5888
	B2	-77.00000*	28.46867	.011	-134.9888	-19.0112
	C2	-2.00000	28.46867	.944	-59.9888	55.9888
	E2	-61.00000*	28.46867	.040	-118.9888	-3.0112
	F2	-29.33333	28.46867	.311	-87.3221	28.6554
	G2	13.33333	28.46867	.643	-44.6554	71.3221

	H2	760.66667*	28.46867	.000	702.6779	818.6554
E2	A2	13.60000	28.46867	.636	-44.3888	71.5888
	B2	-16.00000	28.46867	.578	-73.9888	41.9888
	C2	59.00000*	28.46867	.046	1.0112	116.9888
	D2	61.00000*	28.46867	.040	3.0112	118.9888
	F2	31.66667	28.46867	.274	-26.3221	89.6554
	G2	74.33333*	28.46867	.014	16.3446	132.3221
	H2	821.66667*	28.46867	.000	763.6779	879.6554
F2	A2	-18.06667	28.46867	.530	-76.0554	39.9221
	B2	-47.66667	28.46867	.104	-105.6554	10.3221
	C2	27.33333	28.46867	.344	-30.6554	85.3221
	D2	29.33333	28.46867	.311	-28.6554	87.3221
	E2	-31.66667	28.46867	.274	-89.6554	26.3221
	G2	42.66667	28.46867	.144	-15.3221	100.6554
	H2	790.00000*	28.46867	.000	732.0112	847.9888
G2	A2	-60.73333*	28.46867	.041	-118.7221	-2.7446
	B2	-90.33333*	28.46867	.003	-148.3221	-32.3446
	C2	-15.33333	28.46867	.594	-73.3221	42.6554
	D2	-13.33333	28.46867	.643	-71.3221	44.6554
	E2	-74.33333*	28.46867	.014	-132.3221	-16.3446
	F2	-42.66667	28.46867	.144	-100.6554	15.3221
	H2	747.33333*	28.46867	.000	689.3446	805.3221
H2	A2	-808.06667*	28.46867	.000	-866.0554	-750.0779
	B2	-837.66667*	28.46867	.000	-895.6554	-779.6779
	C2	-762.66667*	28.46867	.000	-820.6554	-704.6779
	D2	-760.66667*	28.46867	.000	-818.6554	-702.6779
	E2	-821.66667*	28.46867	.000	-879.6554	-763.6779
	F2	-790.00000*	28.46867	.000	-847.9888	-732.0112
	G2	-747.33333*	28.46867	.000	-805.3221	-689.3446

Table appx 4.19. LSD multiple comparison analysis of weft way tearing strength in series 1

(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
A1	B1	-208.00000*	51.81491	.000	-313.5435	-102.4565
	C1	366.33333*	51.81491	.000	260.7898	471.8768
	D1	-289.00000*	51.81491	.000	-394.5435	-183.4565
	E1	421.33333*	51.81491	.000	315.7898	526.8768
	F1	81.00000	51.81491	.128	-24.5435	186.5435
	G1	1142.00000*	51.81491	.000	1036.4565	1247.5435
	H1	251.93333*	51.81491	.000	146.3898	357.4768
B1	A1	208.00000*	51.81491	.000	102.4565	313.5435
	C1	574.33333*	51.81491	.000	468.7898	679.8768
	D1	-81.00000	51.81491	.128	-186.5435	24.5435
	E1	629.33333*	51.81491	.000	523.7898	734.8768
	F1	289.00000*	51.81491	.000	183.4565	394.5435
	G1	1350.00000*	51.81491	.000	1244.4565	1455.5435
	H1	459.93333*	51.81491	.000	354.3898	565.4768
C1	A1	-366.33333*	51.81491	.000	-471.8768	-260.7898
	B1	-574.33333*	51.81491	.000	-679.8768	-468.7898
	D1	-655.33333*	51.81491	.000	-760.8768	-549.7898
	E1	55.00000	51.81491	.296	-50.5435	160.5435
	F1	-285.33333*	51.81491	.000	-390.8768	-179.7898
	G1	775.66667*	51.81491	.000	670.1232	881.2102
	H1	-114.40000*	51.81491	.035	-219.9435	-8.8565
D1	A1	289.00000*	51.81491	.000	183.4565	394.5435
	B1	81.00000	51.81491	.128	-24.5435	186.5435
	C1	655.33333*	51.81491	.000	549.7898	760.8768
	E1	710.33333*	51.81491	.000	604.7898	815.8768
	F1	370.00000*	51.81491	.000	264.4565	475.5435
	G1	1431.00000*	51.81491	.000	1325.4565	1536.5435
	H1	540.93333*	51.81491	.000	435.3898	646.4768

E1	A1	-421.33333*	51.81491	.000	-526.8768	-315.7898
	B1	-629.33333*	51.81491	.000	-734.8768	-523.7898
	C1	-55.00000	51.81491	.296	-160.5435	50.5435
	D1	-710.33333*	51.81491	.000	-815.8768	-604.7898
	F1	-340.33333*	51.81491	.000	-445.8768	-234.7898
	G1	720.66667*	51.81491	.000	615.1232	826.2102
	H1	-169.40000*	51.81491	.003	-274.9435	-63.8565
F1	A1	-81.00000	51.81491	.128	-186.5435	24.5435
	B1	-289.00000*	51.81491	.000	-394.5435	-183.4565
	C1	285.33333*	51.81491	.000	179.7898	390.8768
	D1	-370.00000*	51.81491	.000	-475.5435	-264.4565
	E1	340.33333*	51.81491	.000	234.7898	445.8768
	G1	1061.00000*	51.81491	.000	955.4565	1166.5435
	H1	170.93333*	51.81491	.002	65.3898	276.4768
G1	A1	-1142.00000*	51.81491	.000	-1247.5435	-1036.4565
	B1	-1350.00000*	51.81491	.000	-1455.5435	-1244.4565
	C1	-775.66667*	51.81491	.000	-881.2102	-670.1232
	D1	-1431.00000*	51.81491	.000	-1536.5435	-1325.4565
	E1	-720.66667*	51.81491	.000	-826.2102	-615.1232
	F1	-1061.00000*	51.81491	.000	-1166.5435	-955.4565
	H1	-890.06667*	51.81491	.000	-995.6102	-784.5232
H1	A1	-251.93333*	51.81491	.000	-357.4768	-146.3898
	B1	-459.93333*	51.81491	.000	-565.4768	-354.3898
	C1	114.40000*	51.81491	.035	8.8565	219.9435
	D1	-540.93333*	51.81491	.000	-646.4768	-435.3898
	E1	169.40000*	51.81491	.003	63.8565	274.9435
	F1	-170.93333*	51.81491	.002	-276.4768	-65.3898
	G1	890.06667*	51.81491	.000	784.5232	995.6102

Table appx 4.20. LSD multiple comparison analysis of weft way tearing strength in series 2

(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
A2	B2	-184.93333*	24.15416	.000	-234.1337	-135.7329
	C2	485.06667*	24.15416	.000	435.8663	534.2671
	D2	44.40000	24.15416	.075	-4.8004	93.6004
	E2	164.40000*	24.15416	.000	115.1996	213.6004
	F2	-58.26667*	24.15416	.022	-107.4671	-9.0663
	G2	586.73333*	24.15416	.000	537.5329	635.9337
	H2	70.40000*	24.15416	.006	21.1996	119.6004
B2	A2	184.93333*	24.15416	.000	135.7329	234.1337
	C2	670.00000*	24.15416	.000	620.7996	719.2004
	D2	229.33333*	24.15416	.000	180.1329	278.5337
	E2	349.33333*	24.15416	.000	300.1329	398.5337
	F2	126.66667*	24.15416	.000	77.4663	175.8671
	G2	771.66667*	24.15416	.000	722.4663	820.8671
	H2	255.33333*	24.15416	.000	206.1329	304.5337
C2	A2	-485.06667*	24.15416	.000	-534.2671	-435.8663
	B2	-670.00000*	24.15416	.000	-719.2004	-620.7996
	D2	-440.66667*	24.15416	.000	-489.8671	-391.4663
	E2	-320.66667*	24.15416	.000	-369.8671	-271.4663
	F2	-543.33333*	24.15416	.000	-592.5337	-494.1329
	G2	101.66667*	24.15416	.000	52.4663	150.8671
	H2	-414.66667*	24.15416	.000	-463.8671	-365.4663
D2	A2	-44.40000	24.15416	.075	-93.6004	4.8004
	B2	-229.33333*	24.15416	.000	-278.5337	-180.1329
	C2	440.66667*	24.15416	.000	391.4663	489.8671
	E2	120.00000*	24.15416	.000	70.7996	169.2004
	F2	-102.66667*	24.15416	.000	-151.8671	-53.4663
	G2	542.33333*	24.15416	.000	493.1329	591.5337
	H2	26.00000	24.15416	.290	-23.2004	75.2004

E2	A2	-164.40000*	24.15416	.000	-213.6004	-115.1996
	B2	-349.33333*	24.15416	.000	-398.5337	-300.1329
	C2	320.66667*	24.15416	.000	271.4663	369.8671
	D2	-120.00000*	24.15416	.000	-169.2004	-70.7996
	F2	-222.66667*	24.15416	.000	-271.8671	-173.4663
	G2	422.33333*	24.15416	.000	373.1329	471.5337
	H2	-94.00000*	24.15416	.000	-143.2004	-44.7996
F2	A2	58.26667*	24.15416	.022	9.0663	107.4671
	B2	-126.66667*	24.15416	.000	-175.8671	-77.4663
	C2	543.33333*	24.15416	.000	494.1329	592.5337
	D2	102.66667*	24.15416	.000	53.4663	151.8671
	E2	222.66667*	24.15416	.000	173.4663	271.8671
	G2	645.00000*	24.15416	.000	595.7996	694.2004
	H2	128.66667*	24.15416	.000	79.4663	177.8671
G2	A2	-586.73333*	24.15416	.000	-635.9337	-537.5329
	B2	-771.66667*	24.15416	.000	-820.8671	-722.4663
	C2	-101.66667*	24.15416	.000	-150.8671	-52.4663
	D2	-542.33333*	24.15416	.000	-591.5337	-493.1329
	E2	-422.33333*	24.15416	.000	-471.5337	-373.1329
	F2	-645.00000*	24.15416	.000	-694.2004	-595.7996
	H2	-516.33333*	24.15416	.000	-565.5337	-467.1329
H2	A2	-70.40000*	24.15416	.006	-119.6004	-21.1996
	B2	-255.33333*	24.15416	.000	-304.5337	-206.1329
	C2	414.66667*	24.15416	.000	365.4663	463.8671
	D2	-26.00000	24.15416	.290	-75.2004	23.2004
	E2	94.00000*	24.15416	.000	44.7996	143.2004
	F2	-128.66667*	24.15416	.000	-177.8671	-79.4663
	G2	516.33333*	24.15416	.000	467.1329	565.5337

Table appx 4.21. LSD multiple comparison analysis of seam slippage in series 1

(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence	
					Lower	Upper
A1	B1	3.43333*	0.44143	0.000	2.5342	4.3325
	C1	-3.40000*	0.44143	0.000	-4.2992	-2.5008
	D1	-2.46667*	0.44143	0.000	-3.3658	-1.5675
	E1	-0.66667	0.44143	0.141	-1.5658	0.2325
	F1	-1.96667*	0.44143	0.000	-2.8658	-1.0675
	G1	-8.20667*	0.44143	0.000	-9.1058	-7.3075
	H1	-1.47578*	0.44143	0.002	-2.3749	-0.5766
B1	A1	-3.43333*	0.44143	0.000	-4.3325	-2.5342
	C1	-6.83333*	0.44143	0.000	-7.7325	-5.9342
	D1	-5.90000*	0.44143	0.000	-6.7992	-5.0008
	E1	-4.10000*	0.44143	0.000	-4.9992	-3.2008
	F1	-5.40000*	0.44143	0.000	-6.2992	-4.5008
	G1	-	0.44143	0.000	-	-
	H1	-4.90911*	0.44143	0.000	-5.8083	-4.0099
C1	A1	3.40000*	0.44143	0.000	2.5008	4.2992
	B1	6.83333*	0.44143	0.000	5.9342	7.7325
	D1	.93333*	0.44143	0.042	0.0342	1.8325
	E1	2.73333*	0.44143	0.000	1.8342	3.6325
	F1	1.43333*	0.44143	0.003	0.5342	2.3325
	G1	-4.80667*	0.44143	0.000	-5.7058	-3.9075
	H1	1.92422*	0.44143	0.000	1.0251	2.8234
D1	A1	2.46667*	0.44143	0.000	1.5675	3.3658
	B1	5.90000*	0.44143	0.000	5.0008	6.7992

	C1	-.93333*	0.44143	0.042	-1.8325	-0.0342
	E1	1.80000*	0.44143	0.000	0.9008	2.6992
	F1	0.5	0.44143	0.266	-0.3992	1.3992
	G1	-5.74000*	0.44143	0.000	-6.6392	-4.8408
	H1	.99089*	0.44143	0.032	0.0917	1.8901
E1	A1	0.66667	0.44143	0.141	-0.2325	1.5658
	B1	4.10000*	0.44143	0.000	3.2008	4.9992
	C1	-2.73333*	0.44143	0.000	-3.6325	-1.8342
	D1	-1.80000*	0.44143	0.000	-2.6992	-0.9008
	F1	-1.30000*	0.44143	0.006	-2.1992	-0.4008
	G1	-7.54000*	0.44143	0.000	-8.4392	-6.6408
	H1	-0.80911	0.44143	0.076	-1.7083	0.0901
F1	A1	1.96667*	0.44143	0.000	1.0675	2.8658
	B1	5.40000*	0.44143	0.000	4.5008	6.2992
	C1	-1.43333*	0.44143	0.003	-2.3325	-0.5342
	D1	-0.5	0.44143	0.266	-1.3992	0.3992
	E1	1.30000*	0.44143	0.006	0.4008	2.1992
	G1	-6.24000*	0.44143	0.000	-7.1392	-5.3408
	H1	0.49089	0.44143	0.274	-0.4083	1.3901
G1	A1	8.20667*	0.44143	0.000	7.3075	9.1058
	B1	11.64000*	0.44143	0.000	10.7408	12.5392
	C1	4.80667*	0.44143	0.000	3.9075	5.7058
	D1	5.74000*	0.44143	0.000	4.8408	6.6392
	E1	7.54000*	0.44143	0.000	6.6408	8.4392
	F1	6.24000*	0.44143	0.000	5.3408	7.1392
	H1	6.73089*	0.44143	0.000	5.8317	7.6301

H1	A1	1.47578*	0.44143	0.002	0.5766	2.3749
	B1	4.90911*	0.44143	0.000	4.0099	5.8083
	C1	-1.92422*	0.44143	0.000	-2.8234	-1.0251
	D1	-.99089*	0.44143	0.032	-1.8901	-0.0917
	E1	0.80911	0.44143	0.076	-0.0901	1.7083
	F1	-0.49089	0.44143	0.274	-1.3901	0.4083
	G1	-6.73089*	0.44143	0.000	-7.6301	-5.8317

Table appx 4.22. LSD multiple comparison analysis of seam slippage in series 2

(I)	**(J)**	**Mean Difference**	**Std. Error**	**Sig.**	**95% Confidence**	
					Lower	Upper
A2	B2	.85333*	0.17261	0.000	0.5017	1.2049
	C2	-6.28333*	0.17261	0.000	-6.6349	-5.9317
	D2	-7.45667*	0.17261	0.000	-7.8083	-7.1051
	E2	2.85333*	0.17261	0.000	2.5017	3.2049
	F2	1.72000*	0.17261	0.000	1.3684	2.0716
	G2	.98667*	0.17261	0.000	0.6351	1.3383
	H2	-4.34333*	0.17261	0.000	-4.6949	-3.9917
B2	A2	-.85333*	0.17261	0.000	-1.2049	-0.5017
	C2	-7.13667*	0.17261	0.000	-7.4883	-6.7851
	D2	-8.31000*	0.17261	0.000	-8.6616	-7.9584
	E2	2.00000*	0.17261	0.000	1.6484	2.3516
	F2	.86667*	0.17261	0.000	0.5151	1.2183
	G2	0.13333	0.17261	0.446	-0.2183	0.4849
	H2	-5.19667*	0.17261	0.000	-5.5483	-4.8451
C2	A2	6.28333*	0.17261	0.000	5.9317	6.6349
	B2	7.13667*	0.17261	0.000	6.7851	7.4883
	D2	-1.17333*	0.17261	0.000	-1.5249	-0.8217
	E2	9.13667*	0.17261	0.000	8.7851	9.4883

	F2	8.00333*	0.17261	0.000	7.6517	8.3549
	G2	7.27000*	0.17261	0.000	6.9184	7.6216
	H2	1.94000*	0.17261	0.000	1.5884	2.2916
D2	A2	7.45667*	0.17261	0.000	7.1051	7.8083
	B2	8.31000*	0.17261	0.000	7.9584	8.6616
	C2	1.17333*	0.17261	0.000	0.8217	1.5249
	E2	10.31000*	0.17261	0.000	9.9584	10.6616
	F2	9.17667*	0.17261	0.000	8.8251	9.5283
	G2	8.44333*	0.17261	0.000	8.0917	8.7949
	H2	3.11333*	0.17261	0.000	2.7617	3.4649
E2	A2	-2.85333*	0.17261	0.000	-3.2049	-2.5017
	B2	-2.00000*	0.17261	0.000	-2.3516	-1.6484
	C2	-9.13667*	0.17261	0.000	-9.4883	-8.7851
	D2	-10.31000*	0.17261	0.000	-10.6616	-9.9584
	F2	-1.13333*	0.17261	0.000	-1.4849	-0.7817
	G2	-1.86667*	0.17261	0.000	-2.2183	-1.5151
	H2	-7.19667*	0.17261	0.000	-7.5483	-6.8451
F2	A2	-1.72000*	0.17261	0.000	-2.0716	-1.3684
	B2	-.86667*	0.17261	0.000	-1.2183	-0.5151
	C2	-8.00333*	0.17261	0.000	-8.3549	-7.6517
	D2	-9.17667*	0.17261	0.000	-9.5283	-8.8251
	E2	1.13333*	0.17261	0.000	0.7817	1.4849
	G2	-.73333*	0.17261	0.000	-1.0849	-0.3817
	H2	-6.06333*	0.17261	0.000	-6.4149	-5.7117
G2	A2	-.98667*	0.17261	0.000	-1.3383	-0.6351
	B2	-0.13333	0.17261	0.446	-0.4849	0.2183
	C2	-7.27000*	0.17261	0.000	-7.6216	-6.9184
	D2	-8.44333*	0.17261	0.000	-8.7949	-8.0917
	E2	1.86667*	0.17261	0.000	1.5151	2.2183
	F2	.73333*	0.17261	0.000	0.3817	1.0849
	H2	-5.33000*	0.17261	0.000	-5.6816	-4.9784

H2	A2	4.34333*	0.17261	0.000	3.9917	4.6949
	B2	5.19667*	0.17261	0.000	4.8451	5.5483
	C2	-1.94000*	0.17261	0.000	-2.2916	-1.5884
	D2	-3.11333*	0.17261	0.000	-3.4649	-2.7617
	E2	7.19667*	0.17261	0.000	6.8451	7.5483
	F2	6.06333*	0.17261	0.000	5.7117	6.4149
	G2	5.33000*	0.17261	0.000	4.9784	5.6816

Table appx 4.23. LSD multiple comparison analysis of air permeability in series 1

(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
A1	B1	26.92298*	4.30135	0.000	18.1614	35.6845
	C1	-4.58893	4.30135	0.294	-13.3505	4.1726
	D1	33.15491*	4.30135	0.000	24.3934	41.9165
	E1	30.57279*	4.30135	0.000	21.8112	39.3343
	F1	26.43827*	4.30135	0.000	17.6767	35.1998
	G1	22.50516*	4.30135	0.000	13.7436	31.2667
	H1	20.10715*	4.30135	0.000	11.3456	28.8687
B1	A1	-26.92298*	4.30135	0.000	-35.6845	-18.1614
	C1	-31.51192*	4.30135	0.000	-40.2735	-22.7504
	D1	6.23193	4.30135	0.157	-2.5296	14.9935
	E1	3.64981	4.30135	0.402	-5.1117	12.4114
	F1	-0.48471	4.30135	0.911	-9.2463	8.2768
	G1	-4.41783	4.30135	0.312	-13.1794	4.3437
	H1	-6.81583	4.30135	0.123	-15.5774	1.9457
C1	A1	4.58893	4.30135	0.294	-4.1726	13.3505
	B1	31.51192*	4.30135	0.000	22.7504	40.2735
	D1	37.74384*	4.30135	0.000	28.9823	46.5054
	E1	35.16172*	4.30135	0.000	26.4002	43.9233

	F1	31.02721*	4.30135	0.000	22.2657	39.7888
	G1	27.09409*	4.30135	0.000	18.3325	35.8556
	H1	24.69609*	4.30135	0.000	15.9345	33.4576
D1	A1	-33.15491*	4.30135	0.000	-41.9165	-24.3934
	B1	-6.23193	4.30135	0.157	-14.9935	2.5296
	C1	-37.74384*	4.30135	0.000	-46.5054	-28.9823
	E1	-2.58212	4.30135	0.553	-11.3437	6.1794
	F1	-6.71663	4.30135	0.128	-15.4782	2.0449
	G1	-10.64975*	4.30135	0.019	-19.4113	-1.8882
	H1	-13.04776*	4.30135	0.005	-21.8093	-4.2862
E1	A1	-30.57279*	4.30135	0.000	-39.3343	-21.8112
	B1	-3.64981	4.30135	0.402	-12.4114	5.1117
	C1	-35.16172*	4.30135	0.000	-43.9233	-26.4002
	D1	2.58212	4.30135	0.553	-6.1794	11.3437
	F1	-4.13451	4.30135	0.344	-12.8961	4.627
	G1	-8.06763	4.30135	0.07	-16.8292	0.6939
	H1	-10.46563*	4.30135	0.021	-19.2272	-1.7041
F1	A1	-26.43827*	4.30135	0.000	-35.1998	-17.6767
	B1	0.48471	4.30135	0.911	-8.2768	9.2463
	C1	-31.02721*	4.30135	0.000	-39.7888	-22.2657
	D1	6.71663	4.30135	0.128	-2.0449	15.4782
	E1	4.13451	4.30135	0.344	-4.627	12.8961
	G1	-3.93312	4.30135	0.367	-12.6947	4.8284
	H1	-6.33112	4.30135	0.151	-15.0927	2.4304
G1	A1	-22.50516*	4.30135	0.000	-31.2667	-13.7436
	B1	4.41783	4.30135	0.312	-4.3437	13.1794
	C1	-27.09409*	4.30135	0.000	-35.8556	-18.3325
	D1	10.64975*	4.30135	0.019	1.8882	19.4113
	E1	8.06763	4.30135	0.070	-0.6939	16.8292
	F1	3.93312	4.30135	0.367	-4.8284	12.6947
	H1	-2.398	4.30135	0.581	-11.1596	6.3636
H1	A1	-20.10715*	4.30135	0.000	-28.8687	-11.3456

	B1	6.81583	4.30135	0.123	-1.9457	15.5774
	C1	-24.69609*	4.30135	0.000	-33.4576	-15.9345
	D1	13.04776*	4.30135	0.005	4.2862	21.8093
	E1	10.46563*	4.30135	0.021	1.7041	19.2272
	F1	6.33112	4.30135	0.151	-2.4304	15.0927
	G1	2.398	4.30135	0.581	-6.3636	11.1596

Table appx 4.24. LSD multiple comparison analysis of air permeability in series 2

(I)	**(J)**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**	**95% Confidence Interval**	
					Lower	Upper
A2	B2	22.09923*	2.66824	0.000	16.6642	27.5343
	C2	-14.12490*	2.66824	0.000	-19.5599	-8.6899
	D2	24.82444*	2.66824	0.000	19.3894	30.2595
	E2	20.62482*	2.66824	0.000	15.1898	26.0598
	F2	21.72516*	2.66824	0.000	16.2901	27.1602
	G2	22.27914*	2.66824	0.000	16.8441	27.7142
	H2	17.55304*	2.66824	0.000	12.118	22.9881
B2	A2	-22.09923*	2.66824	0.000	-27.5343	-16.6642
	C2	-36.22413*	2.66824	0.000	-41.6592	-30.7891
	D2	2.72521	2.66824	0.315	-2.7098	8.1602
	E2	-1.47441	2.66824	0.584	-6.9094	3.9606
	F2	-0.37407	2.66824	0.889	-5.8091	5.061
	G2	0.17991	2.66824	0.947	-5.2551	5.6149
	H2	-4.54619	2.66824	0.098	-9.9812	0.8888
C2	A2	14.12490*	2.66824	0.000	8.6899	19.5599
	B2	36.22413*	2.66824	0.000	30.7891	41.6592
	D2	38.94934*	2.66824	0.000	33.5143	44.3844
	E2	34.74972*	2.66824	0.000	29.3147	40.1847
	F2	35.85006*	2.66824	0.000	30.415	41.2851
	G2	36.40404*	2.66824	0.000	30.969	41.8391
	H2	31.67794*	2.66824	0.000	26.2429	37.113

D2	A2	-24.82444*	2.66824	0.000	-30.2595	-19.3894
	B2	-2.72521	2.66824	0.315	-8.1602	2.7098
	C2	-38.94934*	2.66824	0.000	-44.3844	-33.5143
	E2	-4.19962	2.66824	0.125	-9.6346	1.2354
	F2	-3.09928	2.66824	0.254	-8.5343	2.3357
	G2	-2.5453	2.66824	0.347	-7.9803	2.8897
	H2	-7.27140*	2.66824	0.010	-12.7064	-1.8364
E2	A2	-20.62482*	2.66824	0.000	-26.0598	-15.1898
	B2	1.47441	2.66824	0.584	-3.9606	6.9094
	C2	-34.74972*	2.66824	0.000	-40.1847	-29.3147
	D2	4.19962	2.66824	0.125	-1.2354	9.6346
	F2	1.10034	2.66824	0.683	-4.3347	6.5354
	G2	1.65432	2.66824	0.540	-3.7807	7.0893
	H2	-3.07178	2.66824	0.258	-8.5068	2.3632
F2	A2	-21.72516*	2.66824	0.000	-27.1602	-16.2901
	B2	0.37407	2.66824	0.889	-5.061	5.8091
	C2	-35.85006*	2.66824	0.000	-41.2851	-30.415
	D2	3.09928	2.66824	0.254	-2.3357	8.5343
	E2	-1.10034	2.66824	0.683	-6.5354	4.3347
	G2	0.55398	2.66824	0.837	-4.881	5.989
	H2	-4.17212	2.66824	0.128	-9.6071	1.2629
G2	A2	-22.27914*	2.66824	0.000	-27.7142	-16.8441
	B2	-0.17991	2.66824	0.947	-5.6149	5.2551
	C2	-36.40404*	2.66824	0.000	-41.8391	-30.969
	D2	2.5453	2.66824	0.347	-2.8897	7.9803
	E2	-1.65432	2.66824	0.540	-7.0893	3.7807
	F2	-0.55398	2.66824	0.837	-5.989	4.881
	H2	-4.7261	2.66824	0.086	-10.1611	0.7089
H2	A2	-17.55304*	2.66824	0.000	-22.9881	-12.118
	B2	4.54619	2.66824	0.098	-0.8888	9.9812
	C2	-31.67794*	2.66824	0.000	-37.113	-26.2429

	D2	7.27140*	2.66824	0.010	1.8364	12.7064
	E2	3.07178	2.66824	0.258	-2.3632	8.5068
	F2	4.17212	2.66824	0.128	-1.2629	9.6071
	G2	4.7261	2.66824	0.086	-0.7089	10.1611

Table appx 4.25. LSD multiple comparison analysis of stiffness in series 1

(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
A1	B1	-120.88604	136.19165	0.381	-398.2993	156.5273
	C1	-351.31791*	136.19165	0.015	-628.7312	-73.9046
	D1	-188.24405	136.19165	0.176	-465.6574	89.1693
	E1	-113.57459	136.19165	0.411	-390.9879	163.8387
	F1	151.92377	136.19165	0.273	-125.4895	429.3371
	G1	168.56120	136.19165	0.225	-108.8521	445.9745
	H1	354.58286*	136.19165	0.014	77.1695	631.9962
B1	A1	120.88604	136.19165	0.381	-156.5273	398.2993
	C1	-230.43188	136.19165	0.100	-507.8452	46.9814
	D1	-67.35802	136.19165	0.624	-344.7713	210.0553
	E1	7.31144	136.19165	0.958	-270.1019	284.7248
	F1	272.80981	136.19165	0.054	-4.6035	550.2231
	G1	289.44724*	136.19165	0.041	12.0339	566.8606
	H1	475.46889*	136.19165	0.001	198.0556	752.8822
C1	A1	351.31791*	136.19165	0.015	73.9046	628.7312
	B1	230.43188	136.19165	0.100	-46.9814	507.8452
	D1	163.07386	136.19165	0.240	-114.3395	440.4872
	E1	237.74332	136.19165	0.090	-39.6700	515.1566
	F1	503.24169*	136.19165	0.001	225.8284	780.6550
	G1	519.87912*	136.19165	0.001	242.4658	797.2924
	H1	705.90077*	136.19165	0.000	428.4875	983.3141
D1	A1	188.24405	136.19165	0.176	-89.1693	465.6574
	B1	67.35802	136.19165	0.624	-210.0553	344.7713
	C1	-163.07386	136.19165	0.240	-440.4872	114.3395
	E1	74.66946	136.19165	0.587	-202.7439	352.0828
	F1	340.16783*	136.19165	0.018	62.7545	617.5811
	G1	356.80526*	136.19165	0.013	79.3919	634.2186
	H1	542.82691*	136.19165	0.000	265.4136	820.2402

E1	A1	113.57459	136.19165	0.411	-163.8387	390.9879
	B1	-7.31144	136.19165	0.958	-284.7248	270.1019
	C1	-237.74332	136.19165	0.090	-515.1566	39.6700
	D1	-74.66946	136.19165	0.587	-352.0828	202.7439
	F1	265.49837	136.19165	0.060	-11.9149	542.9117
	G1	282.13580*	136.19165	0.046	4.7225	559.5491
	H1	468.15745*	136.19165	0.002	190.7441	745.5708
F1	A1	-151.92377	136.19165	0.273	-429.3371	125.4895
	B1	-272.80981	136.19165	0.054	-550.2231	4.6035
	C1	-503.24169*	136.19165	0.001	-780.6550	-225.8284
	D1	-340.16783*	136.19165	0.018	-617.5811	-62.7545
	E1	-265.49837	136.19165	0.060	-542.9117	11.9149
	G1	16.63743	136.19165	0.904	-260.7759	294.0507
	H1	202.65909	136.19165	0.147	-74.7542	480.0724
G1	A1	-168.56120	136.19165	0.225	-445.9745	108.8521
	B1	-289.44724*	136.19165	0.041	-566.8606	-12.0339
	C1	-519.87912*	136.19165	0.001	-797.2924	-242.4658
	D1	-356.80526*	136.19165	0.013	-634.2186	-79.3919
	E1	-282.13580*	136.19165	0.046	-559.5491	-4.7225
	F1	-16.63743	136.19165	0.904	-294.0507	260.7759
	H1	186.02165	136.19165	0.181	-91.3917	463.4350
H1	A1	-354.58286*	136.19165	0.014	-631.9962	-77.1695
	B1	-475.46889*	136.19165	0.001	-752.8822	-198.0556
	C1	-705.90077*	136.19165	0.000	-983.3141	-428.4875
	D1	-542.82691*	136.19165	0.000	-820.2402	-265.4136
	E1	-468.15745*	136.19165	0.002	-745.5708	-190.7441
	F1	-202.65909	136.19165	0.147	-480.0724	74.7542
	G1	-186.02165	136.19165	0.181	-463.4350	91.3917

Table appx 4.26. LSD multiple comparison analysis of stiffness in series 2

(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
A2	B2	466.57198*	197.31085	.024	64.6629	868.4810
	C2	1109.63773*	197.31085	.000	707.7287	1511.5468
	D2	1263.72228*	197.31085	.000	861.8132	1665.6313
	E2	1095.79126*	197.31085	.000	693.8822	1497.7003
	F2	1211.31386*	197.31085	.000	809.4048	1613.2229
	G2	1295.80936*	197.31085	.000	893.9003	1697.7184
	H2	1676.28194*	197.31085	.000	1274.3729	2078.1910
B2	A2	-466.57198*	197.31085	.024	-868.4810	-64.6629
	C2	643.06575*	197.31085	.003	241.1567	1044.9748
	D2	797.15030*	197.31085	.000	395.2412	1199.0594
	E2	629.21928*	197.31085	.003	227.3102	1031.1283
	F2	744.74188*	197.31085	.001	342.8328	1146.6509
	G2	829.23738*	197.31085	.000	427.3283	1231.1464
	H2	1209.70996*	197.31085	.000	807.8009	1611.6190
C2	A2	-1109.63773*	197.31085	.000	-1511.5468	-707.7287
	B2	-643.06575*	197.31085	.003	-1044.9748	-241.1567
	D2	154.08455	197.31085	.441	-247.8245	555.9936
	E2	-13.84647	197.31085	.944	-415.7555	388.0626
	F2	101.67613	197.31085	.610	-300.2329	503.5852
	G2	186.17163	197.31085	.352	-215.7374	588.0807
	H2	566.64421*	197.31085	.007	164.7352	968.5533
D2	A2	-1263.72228*	197.31085	.000	-1665.6313	-861.8132
	B2	-797.15030*	197.31085	.000	-1199.0594	-395.2412
	C2	-154.08455	197.31085	.441	-555.9936	247.8245
	E2	-167.93102	197.31085	.401	-569.8401	233.9780
	F2	-52.40842	197.31085	.792	-454.3175	349.5006
	G2	32.08708	197.31085	.872	-369.8220	433.9961
	H2	412.55966*	197.31085	.045	10.6506	814.4687

E2	A2	-1095.79126*	197.31085	.000	-1497.7003	-693.8822
	B2	-629.21928*	197.31085	.003	-1031.1283	-227.3102
	C2	13.84647	197.31085	.944	-388.0626	415.7555
	D2	167.93102	197.31085	.401	-233.9780	569.8401
	F2	115.52260	197.31085	.562	-286.3865	517.4317
	G2	200.01810	197.31085	.318	-201.8910	601.9272
	H2	580.49068*	197.31085	.006	178.5816	982.3997
F2	A2	-1211.31386*	197.31085	.000	-1613.2229	-809.4048
	B2	-744.74188*	197.31085	.001	-1146.6509	-342.8328
	C2	-101.67613	197.31085	.610	-503.5852	300.2329
	D2	52.40842	197.31085	.792	-349.5006	454.3175
	E2	-115.52260	197.31085	.562	-517.4317	286.3865
	G2	84.49550	197.31085	.671	-317.4136	486.4046
	H2	464.96808*	197.31085	.025	63.0590	866.8771
G2	A2	-1295.80936*	197.31085	.000	-1697.7184	-893.9003
	B2	-829.23738*	197.31085	.000	-1231.1464	-427.3283
	C2	-186.17163	197.31085	.352	-588.0807	215.7374
	D2	-32.08708	197.31085	.872	-433.9961	369.8220
	E2	-200.01810	197.31085	.318	-601.9272	201.8910
	F2	-84.49550	197.31085	.671	-486.4046	317.4136
	H2	380.47259	197.31085	.063	-21.4365	782.3816
H2	A2	-1676.28194*	197.31085	.000	-2078.1910	-1274.3729
	B2	-1209.70996*	197.31085	.000	-1611.6190	-807.8009
	C2	-566.64421*	197.31085	.007	-968.5533	-164.7352
	D2	-412.55966*	197.31085	.045	-814.4687	-10.6506
	E2	-580.49068*	197.31085	.006	-982.3997	-178.5816
	F2	-464.96808*	197.31085	.025	-866.8771	-63.0590
	G2	-380.47259	197.31085	.063	-782.3816	21.4365

Table appx 4.27. LSD multiple comparison analysis of growth in series 1

(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
A1	B1	-.40000*	.10915	.001	-.6223	-.1777
	C1	-.73333*	.10915	.000	-.9557	-.5110
	D1	-.86667*	.10915	.000	-1.0890	-.6443
	E1	.06667	.10915	.546	-.1557	.2890
	F1	-.06667	.10915	.546	-.2890	.1557
	G1	-.73333*	.10915	.000	-.9557	-.5110
	H1	.35704*	.10915	.003	.1347	.5794
B1	A1	.40000*	.10915	.001	.1777	.6223
	C1	-.33333*	.10915	.005	-.5557	-.1110
	D1	-.46667*	.10915	.000	-.6890	-.2443
	E1	.46667*	.10915	.000	.2443	.6890
	F1	.33333*	.10915	.005	.1110	.5557
	G1	-.33333*	.10915	.005	-.5557	-.1110
	H1	.75704*	.10915	.000	.5347	.9794
C1	A1	.73333*	.10915	.000	.5110	.9557
	B1	.33333*	.10915	.005	.1110	.5557
	D1	-.13333	.10915	.231	-.3557	.0890
	E1	.80000*	.10915	.000	.5777	1.0223
	F1	.66667*	.10915	.000	.4443	.8890
	G1	.00000	.10915	1.000	-.2223	.2223
	H1	1.09037*	.10915	.000	.8680	1.3127
D1	A1	.86667*	.10915	.000	.6443	1.0890
	B1	.46667*	.10915	.000	.2443	.6890
	C1	.13333	.10915	.231	-.0890	.3557
	E1	.93333*	.10915	.000	.7110	1.1557
	F1	.80000*	.10915	.000	.5777	1.0223
	G1	.13333	.10915	.231	-.0890	.3557
	H1	1.22370*	.10915	.000	1.0014	1.4460

E1	A1	-.06667	.10915	.546	-.2890	.1557
	B1	-.46667*	.10915	.000	-.6890	-.2443
	C1	-.80000*	.10915	.000	-1.0223	-.5777
	D1	-.93333*	.10915	.000	-1.1557	-.7110
	F1	-.13333	.10915	.231	-.3557	.0890
	G1	-.80000*	.10915	.000	-1.0223	-.5777
	H1	.29037*	.10915	.012	.0680	.5127
F1	A1	.06667	.10915	.546	-.1557	.2890
	B1	-.33333*	.10915	.005	-.5557	-.1110
	C1	-.66667*	.10915	.000	-.8890	-.4443
	D1	-.80000*	.10915	.000	-1.0223	-.5777
	E1	.13333	.10915	.231	-.0890	.3557
	G1	-.66667*	.10915	.000	-.8890	-.4443
	H1	.42370*	.10915	.000	.2014	.6460
G1	A1	.73333*	.10915	.000	.5110	.9557
	B1	.33333*	.10915	.005	.1110	.5557
	C1	.00000	.10915	1.000	-.2223	.2223
	D1	-.13333	.10915	.231	-.3557	.0890
	E1	.80000*	.10915	.000	.5777	1.0223
	F1	.66667*	.10915	.000	.4443	.8890
	H1	1.09037*	.10915	.000	.8680	1.3127
H1	A1	-.35704*	.10915	.003	-.5794	-.1347
	B1	-.75704*	.10915	.000	-.9794	-.5347
	C1	-1.09037*	.10915	.000	-1.3127	-.8680
	D1	-1.22370*	.10915	.000	-1.4460	-1.0014
	E1	-.29037*	.10915	.012	-.5127	-.0680
	F1	-.42370*	.10915	.000	-.6460	-.2014
	G1	-1.09037*	.10915	.000	-1.3127	-.8680

Table appx 4.28. LSD multiple comparison analysis of growth in series 2

(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
A2	B2	-.60000*	.08991	.000	-.7831	-.4169
	C2	-2.60000*	.08991	.000	-2.7831	-2.4169
	D2	-1.40000*	.08991	.000	-1.5831	-1.2169
	E2	-1.00000*	.08991	.000	-1.1831	-.8169
	F2	-.53333*	.08991	.000	-.7165	-.3502
	G2	-.60000*	.08991	.000	-.7831	-.4169
	H2	-1.20000*	.08991	.000	-1.3831	-1.0169
B2	A2	.60000*	.08991	.000	.4169	.7831
	C2	-2.00000*	.08991	.000	-2.1831	-1.8169
	D2	-.80000*	.08991	.000	-.9831	-.6169
	E2	-.40000*	.08991	.000	-.5831	-.2169
	F2	.06667	.08991	.464	-.1165	.2498
	G2	.00000	.08991	1.000	-.1831	.1831
	H2	-.60000*	.08991	.000	-.7831	-.4169
C2	A2	2.60000*	.08991	.000	2.4169	2.7831
	B2	2.00000*	.08991	.000	1.8169	2.1831
	D2	1.20000*	.08991	.000	1.0169	1.3831
	E2	1.60000*	.08991	.000	1.4169	1.7831
	F2	2.06667*	.08991	.000	1.8835	2.2498
	G2	2.00000*	.08991	.000	1.8169	2.1831
	H2	1.40000*	.08991	.000	1.2169	1.5831
D2	A2	1.40000*	.08991	.000	1.2169	1.5831
	B2	.80000*	.08991	.000	.6169	.9831
	C2	-1.20000*	.08991	.000	-1.3831	-1.0169
	E2	.40000*	.08991	.000	.2169	.5831
	F2	.86667*	.08991	.000	.6835	1.0498
	G2	.80000*	.08991	.000	.6169	.9831
	H2	.20000*	.08991	.033	.0169	.3831
E2	A2	1.00000*	.08991	.000	.8169	1.1831

	B2	.40000*	.08991	.000	.2169	.5831
	C2	-1.60000*	.08991	.000	-1.7831	-1.4169
	D2	-.40000*	.08991	.000	-.5831	-.2169
	F2	.46667*	.08991	.000	.2835	.6498
	G2	.40000*	.08991	.000	.2169	.5831
	H2	-.20000*	.08991	.033	-.3831	-.0169
F2	A2	.53333*	.08991	.000	.3502	.7165
	B2	-.06667	.08991	.464	-.2498	.1165
	C2	-2.06667*	.08991	.000	-2.2498	-1.8835
	D2	-.86667*	.08991	.000	-1.0498	-.6835
	E2	-.46667*	.08991	.000	-.6498	-.2835
	G2	-.06667	.08991	.464	-.2498	.1165
	H2	-.66667*	.08991	.000	-.8498	-.4835
G2	A2	.60000*	.08991	.000	.4169	.7831
	B2	.00000	.08991	1.000	-.1831	.1831
	C2	-2.00000*	.08991	.000	-2.1831	-1.8169
	D2	-.80000*	.08991	.000	-.9831	-.6169
	E2	-.40000*	.08991	.000	-.5831	-.2169
	F2	.06667	.08991	.464	-.1165	.2498
	H2	-.60000*	.08991	.000	-.7831	-.4169
H2	A2	1.20000*	.08991	.000	1.0169	1.3831
	B2	.60000*	.08991	.000	.4169	.7831
	C2	-1.40000*	.08991	.000	-1.5831	-1.2169
	D2	-.20000*	.08991	.033	-.3831	-.0169
	E2	.20000*	.08991	.033	.0169	.3831
	F2	.66667*	.08991	.000	.4835	.8498
	G2	.60000*	.08991	.000	.4169	.7831

Table appx 4.29. LSD multiple comparison analysis of stretch in series 1

(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
A1	B1	-3.60000*	.25892	.000	-4.1274	-3.0726
	C1	.13333	.25892	.610	-.3941	.6607
	D1	-3.00000*	.25892	.000	-3.5274	-2.4726
	E1	11.80000*	.25892	.000	11.2726	12.3274
	F1	12.20000*	.25892	.000	11.6726	12.7274
	G1	12.46667*	.25892	.000	11.9393	12.9941
	H1	14.13926*	.25892	.000	13.6118	14.6667
B1	A1	3.60000*	.25892	.000	3.0726	4.1274
	C1	3.73333*	.25892	.000	3.2059	4.2607
	D1	.60000*	.25892	.027	.0726	1.1274
	E1	15.40000*	.25892	.000	14.8726	15.9274
	F1	15.80000*	.25892	.000	15.2726	16.3274
	G1	16.06667*	.25892	.000	15.5393	16.5941
	H1	17.73926*	.25892	.000	17.2118	18.2667
C1	A1	-.13333	.25892	.610	-.6607	.3941
	B1	-3.73333*	.25892	.000	-4.2607	-3.2059
	D1	-3.13333*	.25892	.000	-3.6607	-2.6059
	E1	11.66667*	.25892	.000	11.1393	12.1941
	F1	12.06667*	.25892	.000	11.5393	12.5941
	G1	12.33333*	.25892	.000	11.8059	12.8607
	H1	14.00593*	.25892	.000	13.4785	14.5333
D1	A1	3.00000*	.25892	.000	2.4726	3.5274
	B1	-.60000*	.25892	.027	-1.1274	-.0726
	C1	3.13333*	.25892	.000	2.6059	3.6607
	E1	14.80000*	.25892	.000	14.2726	15.3274
	F1	15.20000*	.25892	.000	14.6726	15.7274
	G1	15.46667*	.25892	.000	14.9393	15.9941
	H1	17.13926*	.25892	.000	16.6118	17.6667

E1	A1	-11.80000*	.25892	.000	-12.3274	-11.2726
	B1	-15.40000*	.25892	.000	-15.9274	-14.8726
	C1	-11.66667*	.25892	.000	-12.1941	-11.1393
	D1	-14.80000*	.25892	.000	-15.3274	-14.2726
	F1	.40000	.25892	.132	-.1274	.9274
	G1	.66667*	.25892	.015	.1393	1.1941
	H1	2.33926*	.25892	.000	1.8118	2.8667
F1	A1	-12.20000*	.25892	.000	-12.7274	-11.6726
	B1	-15.80000*	.25892	.000	-16.3274	-15.2726
	C1	-12.06667*	.25892	.000	-12.5941	-11.5393
	D1	-15.20000*	.25892	.000	-15.7274	-14.6726
	E1	-.40000	.25892	.132	-.9274	.1274
	G1	.26667	.25892	.311	-.2607	.7941
	H1	1.93926*	.25892	.000	1.4118	2.4667
G1	A1	-12.46667*	.25892	.000	-12.9941	-11.9393
	B1	-16.06667*	.25892	.000	-16.5941	-15.5393
	C1	-12.33333*	.25892	.000	-12.8607	-11.8059
	D1	-15.46667*	.25892	.000	-15.9941	-14.9393
	E1	-.66667*	.25892	.015	-1.1941	-.1393
	F1	-.26667	.25892	.311	-.7941	.2607
	H1	1.67259*	.25892	.000	1.1452	2.2000
H1	A1	-14.13926*	.25892	.000	-14.6667	-13.6118
	B1	-17.73926*	.25892	.000	-18.2667	-17.2118
	C1	-14.00593*	.25892	.000	-14.5333	-13.4785
	D1	-17.13926*	.25892	.000	-17.6667	-16.6118
	E1	-2.33926*	.25892	.000	-2.8667	-1.8118
	F1	-1.93926*	.25892	.000	-2.4667	-1.4118
	G1	-1.67259*	.25892	.000	-2.2000	-1.1452

Table appx 4.30. LSD multiple comparison analysis of stretch in series 2

(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
A2	B2	-.72000*	.28856	.018	-1.3078	-.1322
	C2	8.01333*	.28856	.000	7.4256	8.6011
	D2	11.94667*	.28856	.000	11.3589	12.5344
	E2	13.14667*	.28856	.000	12.5589	13.7344
	F2	14.68000*	.28856	.000	14.0922	15.2678
	G2	14.54667*	.28856	.000	13.9589	15.1344
	H2	17.41333*	.28856	.000	16.8256	18.0011
B2	A2	.72000*	.28856	.018	.1322	1.3078
	C2	8.73333*	.28856	.000	8.1456	9.3211
	D2	12.66667*	.28856	.000	12.0789	13.2544
	E2	13.86667*	.28856	.000	13.2789	14.4544
	F2	15.40000*	.28856	.000	14.8122	15.9878
	G2	15.26667*	.28856	.000	14.6789	15.8544
	H2	18.13333*	.28856	.000	17.5456	18.7211
C2	A2	-8.01333*	.28856	.000	-8.6011	-7.4256
	B2	-8.73333*	.28856	.000	-9.3211	-8.1456
	D2	3.93333*	.28856	.000	3.3456	4.5211
	E2	5.13333*	.28856	.000	4.5456	5.7211
	F2	6.66667*	.28856	.000	6.0789	7.2544
	G2	6.53333*	.28856	.000	5.9456	7.1211
	H2	9.40000*	.28856	.000	8.8122	9.9878
D2	A2	-11.94667*	.28856	.000	-12.5344	-11.3589
	B2	-12.66667*	.28856	.000	-13.2544	-12.0789
	C2	-3.93333*	.28856	.000	-4.5211	-3.3456
	E2	1.20000*	.28856	.000	.6122	1.7878
	F2	2.73333*	.28856	.000	2.1456	3.3211
	G2	2.60000*	.28856	.000	2.0122	3.1878
	H2	5.46667*	.28856	.000	4.8789	6.0544
E2	A2	-13.14667*	.28856	.000	-13.7344	-12.5589

	B2	-13.86667*	.28856	.000	-14.4544	-13.2789
	C2	-5.13333*	.28856	.000	-5.7211	-4.5456
	D2	-1.20000*	.28856	.000	-1.7878	-.6122
	F2	1.53333*	.28856	.000	.9456	2.1211
	G2	1.40000*	.28856	.000	.8122	1.9878
	H2	4.26667*	.28856	.000	3.6789	4.8544
F2	A2	-14.68000*	.28856	.000	-15.2678	-14.0922
	B2	-15.40000*	.28856	.000	-15.9878	-14.8122
	C2	-6.66667*	.28856	.000	-7.2544	-6.0789
	D2	-2.73333*	.28856	.000	-3.3211	-2.1456
	E2	-1.53333*	.28856	.000	-2.1211	-.9456
	G2	-.13333	.28856	.647	-.7211	.4544
	H2	2.73333*	.28856	.000	2.1456	3.3211
G2	A2	-14.54667*	.28856	.000	-15.1344	-13.9589
	B2	-15.26667*	.28856	.000	-15.8544	-14.6789
	C2	-6.53333*	.28856	.000	-7.1211	-5.9456
	D2	-2.60000*	.28856	.000	-3.1878	-2.0122
	E2	-1.40000*	.28856	.000	-1.9878	-.8122
	F2	.13333	.28856	.647	-.4544	.7211
	H2	2.86667*	.28856	.000	2.2789	3.4544
H2	A2	-17.41333*	.28856	.000	-18.0011	-16.8256
	B2	-18.13333*	.28856	.000	-18.7211	-17.5456
	C2	-9.40000*	.28856	.000	-9.9878	-8.8122
	D2	-5.46667*	.28856	.000	-6.0544	-4.8789
	E2	-4.26667*	.28856	.000	-4.8544	-3.6789
	F2	-2.73333*	.28856	.000	-3.3211	-2.1456
	G2	-2.86667*	.28856	.000	-3.4544	-2.2789

Table appx 4.31. LSD multiple comparison analysis of warp shrinkage in series 1

(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
A1	B1	-.63200*	0.08661	0.000	-0.8084	-0.4556
	C1	-1.13200*	0.08661	0.000	-1.3084	-0.9556
	D1	-.76400*	0.08661	0.000	-0.9404	-0.5876
	E1	-.43200*	0.08661	0.000	-0.6084	-0.2556
	F1	-.56400*	0.08661	0.000	-0.7404	-0.3876
	G1	1.16800*	0.08661	0.000	0.9916	1.3444
	H1	.36800*	0.08661	0.000	0.1916	0.5444
B1	A1	.63200*	0.08661	0.000	0.4556	0.8084
	C1	-.50000*	0.08661	0.000	-0.6764	-0.3236
	D1	-0.132	0.08661	0.137	-0.3084	0.0444
	E1	.20000*	0.08661	0.028	0.0236	0.3764
	F1	0.068	0.08661	0.438	-0.1084	0.2444
	G1	1.80000*	0.08661	0.000	1.6236	1.9764
	H1	1.00000*	0.08661	0.000	0.8236	1.1764
C1	A1	1.13200*	0.08661	0.000	0.9556	1.3084
	B1	.50000*	0.08661	0.000	0.3236	0.6764
	D1	.36800*	0.08661	0.000	0.1916	0.5444
	E1	.70000*	0.08661	0.000	0.5236	0.8764
	F1	.56800*	0.08661	0.000	0.3916	0.7444
	G1	2.30000*	0.08661	0.000	2.1236	2.4764
	H1	1.50000*	0.08661	0.000	1.3236	1.6764
D1	A1	.76400*	0.08661	0.000	0.5876	0.9404
	B1	0.132	0.08661	0.137	-0.0444	0.3084
	C1	-.36800*	0.08661	0.000	-0.5444	-0.1916
	E1	.33200*	0.08661	0.001	0.1556	0.5084
	F1	.20000*	0.08661	0.028	0.0236	0.3764
	G1	1.93200*	0.08661	0.000	1.7556	2.1084
	H1	1.13200*	0.08661	0.000	0.9556	1.3084

E1	A1	.43200*	0.08661	0.000	0.2556	0.6084
	B1	-.20000*	0.08661	0.028	-0.3764	-0.0236
	C1	-.70000*	0.08661	0.000	-0.8764	-0.5236
	D1	-.33200*	0.08661	0.001	-0.5084	-0.1556
	F1	-0.132	0.08661	0.137	-0.3084	0.0444
	G1	1.60000*	0.08661	0.000	1.4236	1.7764
	H1	.80000*	0.08661	0.000	0.6236	0.9764
F1	A1	.56400*	0.08661	0.000	0.3876	0.7404
	B1	-0.068	0.08661	0.438	-0.2444	0.1084
	C1	-.56800*	0.08661	0.000	-0.7444	-0.3916
	D1	-.20000*	0.08661	0.028	-0.3764	-0.0236
	E1	0.132	0.08661	0.137	-0.0444	0.3084
	G1	1.73200*	0.08661	0.000	1.5556	1.9084
	H1	.93200*	0.08661	0.000	0.7556	1.1084
G1	A1	-1.16800*	0.08661	0.000	-1.3444	-0.9916
	B1	-1.80000*	0.08661	0.000	-1.9764	-1.6236
	C1	-2.30000*	0.08661	0.000	-2.4764	-2.1236
	D1	-1.93200*	0.08661	0.000	-2.1084	-1.7556
	E1	-1.60000*	0.08661	0.000	-1.7764	-1.4236
	F1	-1.73200*	0.08661	0.000	-1.9084	-1.5556
	H1	-.80000*	0.08661	0.000	-0.9764	-0.6236
H1	A1	-.36800*	0.08661	0.000	-0.5444	-0.1916
	B1	-1.00000*	0.08661	0.000	-1.1764	-0.8236
	C1	-1.50000*	0.08661	0.000	-1.6764	-1.3236
	D1	-1.13200*	0.08661	0.000	-1.3084	-0.9556
	E1	-.80000*	0.08661	0.000	-0.9764	-0.6236
	F1	-.93200*	0.08661	0.000	-1.1084	-0.7556
	G1	.80000*	0.08661	0.000	0.6236	0.9764

Table appx 4.32. LSD multiple comparison analysis of warp shrinkage in series 2

(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
A2	B2	-1.66800*	0.09704	0.000	-1.8657	-1.4703
	C2	1.10000*	0.09704	0.000	0.9023	1.2977
	D2	-.56800*	0.09704	0.000	-0.7657	-0.3703
	E2	-1.53200*	0.09704	0.000	-1.7297	-1.3343
	F2	-2.06800*	0.09704	0.000	-2.2657	-1.8703
	G2	-.20000*	0.09704	0.048	-0.3977	-0.0023
	H2	-.46800*	0.09704	0.000	-0.6657	-0.2703
B2	A2	1.66800*	0.09704	0.000	1.4703	1.8657
	C2	2.76800*	0.09704	0.000	2.5703	2.9657
	D2	1.10000*	0.09704	0.000	0.9023	1.2977
	E2	0.136	0.09704	0.171	-0.0617	0.3337
	F2	-.40000*	0.09704	0.000	-0.5977	-0.2023
	G2	1.46800*	0.09704	0.000	1.2703	1.6657
	H2	1.20000*	0.09704	0.000	1.0023	1.3977
C2	A2	-1.10000*	0.09704	0.000	-1.2977	-0.9023
	B2	-2.76800*	0.09704	0.000	-2.9657	-2.5703
	D2	-1.66800*	0.09704	0.000	-1.8657	-1.4703
	E2	-2.63200*	0.09704	0.000	-2.8297	-2.4343
	F2	-3.16800*	0.09704	0.000	-3.3657	-2.9703
	G2	-1.30000*	0.09704	0.000	-1.4977	-1.1023
	H2	-1.56800*	0.09704	0.000	-1.7657	-1.3703
D2	A2	.56800*	0.09704	0.000	0.3703	0.7657
	B2	-1.10000*	0.09704	0.000	-1.2977	-0.9023
	C2	1.66800*	0.09704	0.000	1.4703	1.8657
	E2	-.96400*	0.09704	0.000	-1.1617	-0.7663
	F2	-1.50000*	0.09704	0.000	-1.6977	-1.3023
	G2	.36800*	0.09704	0.001	0.1703	0.5657
	H2	0.1	0.09704	0.311	-0.0977	0.2977

E2	A2	1.53200*	0.09704	0.000	1.3343	1.7297
	B2	-0.136	0.09704	0.171	-0.3337	0.0617
	C2	2.63200*	0.09704	0.000	2.4343	2.8297
	D2	.96400*	0.09704	0.000	0.7663	1.1617
	F2	-.53600*	0.09704	0.000	-0.7337	-0.3383
	G2	1.33200*	0.09704	0.000	1.1343	1.5297
	H2	1.06400*	0.09704	0.000	0.8663	1.2617
F2	A2	2.06800*	0.09704	0.000	1.8703	2.2657
	B2	.40000*	0.09704	0.000	0.2023	0.5977
	C2	3.16800*	0.09704	0.000	2.9703	3.3657
	D2	1.50000*	0.09704	0.000	1.3023	1.6977
	E2	.53600*	0.09704	0.000	0.3383	0.7337
	G2	1.86800*	0.09704	0.000	1.6703	2.0657
	H2	1.60000*	0.09704	0.000	1.4023	1.7977
G2	A2	.20000*	0.09704	0.048	0.0023	0.3977
	B2	-1.46800*	0.09704	0.000	-1.6657	-1.2703
	C2	1.30000*	0.09704	0.000	1.1023	1.4977
	D2	-.36800*	0.09704	0.001	-0.5657	-0.1703
	E2	-1.33200*	0.09704	0.000	-1.5297	-1.1343
	F2	-1.86800*	0.09704	0.000	-2.0657	-1.6703
	H2	-.26800*	0.09704	0.009	-0.4657	-0.0703
H2	A2	.46800*	0.09704	0.000	0.2703	0.6657
	B2	-1.20000*	0.09704	0.000	-1.3977	-1.0023
	C2	1.56800*	0.09704	0.000	1.3703	1.7657
	D2	-0.1	0.09704	0.311	-0.2977	0.0977
	E2	-1.06400*	0.09704	0.000	-1.2617	-0.8663
	F2	-1.60000*	0.09704	0.000	-1.7977	-1.4023
	G2	.26800*	0.09704	0.009	0.0703	0.4657

Table appx 4.33. LSD multiple comparison analysis of weft shrinkage in series 1

(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
A1	B1	-1.13333*	0.17395	0.000	-1.4877	-0.779
	C1	-0.26667	0.17395	0.135	-0.621	0.0877
	D1	-.93333*	0.17395	0.000	-1.2877	-0.579
	E1	-8.76667*	0.17395	0.000	-9.121	-8.4123
	F1	-10.03333*	0.17395	0.000	-10.3877	-9.679
	G1	-8.56667*	0.17395	0.000	-8.921	-8.2123
	H1	-10.07481*	0.17395	0.000	-10.4291	-9.7205
B1	A1	1.13333*	0.17395	0.000	0.779	1.4877
	C1	.86667*	0.17395	0.000	0.5123	1.221
	D1	0.2	0.17395	0.259	-0.1543	0.5543
	E1	-7.63333*	0.17395	0.000	-7.9877	-7.279
	F1	-8.90000*	0.17395	0.000	-9.2543	-8.5457
	G1	-7.43333*	0.17395	0.000	-7.7877	-7.079
	H1	-8.94148*	0.17395	0.000	-9.2958	-8.5872
C1	A1	0.26667	0.17395	0.135	-0.0877	0.621
	B1	-.86667*	0.17395	0.000	-1.221	-0.5123
	D1	-.66667*	0.17395	0.001	-1.021	-0.3123
	E1	-8.50000*	0.17395	0.000	-8.8543	-8.1457
	F1	-9.76667*	0.17395	0.000	-10.121	-9.4123
	G1	-8.30000*	0.17395	0.000	-8.6543	-7.9457
	H1	-9.80815*	0.17395	0.000	-10.1625	-9.4538
D1	A1	.93333*	0.17395	0.000	0.579	1.2877
	B1	-0.2	0.17395	0.259	-0.5543	0.1543
	C1	.66667*	0.17395	0.001	0.3123	1.021
	E1	-7.83333*	0.17395	0.000	-8.1877	-7.479
	F1	-9.10000*	0.17395	0.000	-9.4543	-8.7457
	G1	-7.63333*	0.17395	0.000	-7.9877	-7.279
	H1	-9.14148*	0.17395	0.000	-9.4958	-8.7872
E1	A1	8.76667*	0.17395	0.000	8.4123	9.121
	B1	7.63333*	0.17395	0.000	7.279	7.9877
	C1	8.50000*	0.17395	0.000	8.1457	8.8543
	D1	7.83333*	0.17395	0.000	7.479	8.1877
	F1	-1.26667*	0.17395	0.000	-1.621	-0.9123
	G1	0.2	0.17395	0.259	-0.1543	0.5543

	H1	-1.30815*	0.17395	0.000	-1.6625	-0.9538
F1	A1	10.03333*	0.17395	0.000	9.679	10.3877
	B1	8.90000*	0.17395	0.000	8.5457	9.2543
	C1	9.76667*	0.17395	0.000	9.4123	10.121
	D1	9.10000*	0.17395	0.000	8.7457	9.4543
	E1	1.26667*	0.17395	0.000	0.9123	1.621
	G1	1.46667*	0.17395	0.000	1.1123	1.821
	H1	-0.04148	0.17395	0.813	-0.3958	0.3128
G1	A1	8.56667*	0.17395	0.000	8.2123	8.921
	B1	7.43333*	0.17395	0.000	7.079	7.7877
	C1	8.30000*	0.17395	0.000	7.9457	8.6543
	D1	7.63333*	0.17395	0.000	7.279	7.9877
	E1	-0.2	0.17395	0.259	-0.5543	0.1543
	F1	-1.46667*	0.17395	0.000	-1.821	-1.1123
	H1	-1.50815*	0.17395	0.000	-1.8625	-1.1538
H1	A1	10.07481*	0.17395	0.000	9.7205	10.4291
	B1	8.94148*	0.17395	0.000	8.5872	9.2958
	C1	9.80815*	0.17395	0.000	9.4538	10.1625
	D1	9.14148*	0.17395	0.000	8.7872	9.4958
	E1	1.30815*	0.17395	0.000	0.9538	1.6625
	F1	0.04148	0.17395	0.813	-0.3128	0.3958
	G1	1.50815*	0.17395	0.000	1.1538	1.8625

Table appx 4.34. LSD multiple comparison analysis of weft shrinkage in series 2

(I)	(J)	Mean Difference	Std. Error	Sig.	95% Confidence	
					Lower	Upper
A2	B2	-.36000*	0.10609	0.002	-0.5761	-0.1439
	C2	-5.29333*	0.10609	0.000	-5.5094	-5.0772
	D2	-6.79333*	0.10609	0.000	-7.0094	-6.5772
	E2	-5.92667*	0.10609	0.000	-6.1428	-5.7106
	F2	-9.16000*	0.10609	0.000	-9.3761	-8.9439
	G2	-7.92667*	0.10609	0.000	-8.1428	-7.7106
	H2	-8.92667*	0.10609	0.000	-9.1428	-8.7106
B2	A2	.36000*	0.10609	0.002	0.1439	0.5761
	C2	-4.93333*	0.10609	0.000	-5.1494	-4.7172
	D2	-6.43333*	0.10609	0.000	-6.6494	-6.2172
	E2	-5.56667*	0.10609	0.000	-5.7828	-5.3506
	F2	-8.80000*	0.10609	0.000	-9.0161	-8.5839
	G2	-7.56667*	0.10609	0.000	-7.7828	-7.3506
	H2	-8.56667*	0.10609	0.000	-8.7828	-8.3506
C2	A2	5.29333*	0.10609	0.000	5.0772	5.5094
	B2	4.93333*	0.10609	0.000	4.7172	5.1494
	D2	-1.50000*	0.10609	0.000	-1.7161	-1.2839
	E2	-.63333*	0.10609	0.000	-0.8494	-0.4172
	F2	-3.86667*	0.10609	0.000	-4.0828	-3.6506
	G2	-2.63333*	0.10609	0.000	-2.8494	-2.4172
	H2	-3.63333*	0.10609	0.000	-3.8494	-3.4172
D2	A2	6.79333*	0.10609	0.000	6.5772	7.0094
	B2	6.43333*	0.10609	0.000	6.2172	6.6494
	C2	1.50000*	0.10609	0.000	1.2839	1.7161
	E2	.86667*	0.10609	0.000	0.6506	1.0828
	F2	-2.36667*	0.10609	0.000	-2.5828	-2.1506
	G2	-1.13333*	0.10609	0.000	-1.3494	-0.9172
	H2	-2.13333*	0.10609	0.000	-2.3494	-1.9172

E2	A2	5.92667*	0.10609	0.000	5.7106	6.1428
	B2	5.56667*	0.10609	0.000	5.3506	5.7828
	C2	.63333*	0.10609	0.000	0.4172	0.8494
	D2	-.86667*	0.10609	0.000	-1.0828	-0.6506
	F2	-3.23333*	0.10609	0.000	-3.4494	-3.0172
	G2	-2.00000*	0.10609	0.000	-2.2161	-1.7839
	H2	-3.00000*	0.10609	0.000	-3.2161	-2.7839
F2	A2	9.16000*	0.10609	0.000	8.9439	9.3761
	B2	8.80000*	0.10609	0.000	8.5839	9.0161
	C2	3.86667*	0.10609	0.000	3.6506	4.0828
	D2	2.36667*	0.10609	0.000	2.1506	2.5828
	E2	3.23333*	0.10609	0.000	3.0172	3.4494
	G2	1.23333*	0.10609	0.000	1.0172	1.4494
	H2	.23333*	0.10609	0.035	0.0172	0.4494
G2	A2	7.92667*	0.10609	0.000	7.7106	8.1428
	B2	7.56667*	0.10609	0.000	7.3506	7.7828
	C2	2.63333*	0.10609	0.000	2.4172	2.8494
	D2	1.13333*	0.10609	0.000	0.9172	1.3494
	E2	2.00000*	0.10609	0.000	1.7839	2.2161
	F2	-1.23333*	0.10609	0.000	-1.4494	-1.0172
	H2	-1.00000*	0.10609	0.000	-1.2161	-0.7839
H2	A2	8.92667*	0.10609	0.000	8.7106	9.1428
	B2	8.56667*	0.10609	0.000	8.3506	8.7828
	C2	3.63333*	0.10609	0.000	3.4172	3.8494
	D2	2.13333*	0.10609	0.000	1.9172	2.3494
	E2	3.00000*	0.10609	0.000	2.7839	3.2161
	F2	-.23333*	0.10609	0.035	-0.4494	-0.0172
	G2	1.00000*	0.10609	0.000	0.7839	1.2161

Regression analysis

The regression analysis was done to find the effect of washing and mercerization on the fabric properties individually.

Table appx 4.35. Regression model summary for washing in series 1 fabrics

Dependent variable	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df 1	df 2	Sig. F Change
warp shrinkage	.572[a]	0.327	0.247	0.74976	0.327	4.123	2	17	0.035
weft shrinkage	.999[a]	0.997	0.997	0.25114	0.997	2886.345	2	17	0.000
Growth	.916[a]	0.839	0.820	0.18240	0.839	44.253	2	17	0.000
Stretch	.998[a]	0.997	0.997	0.36371	0.997	2754.689	2	17	0.000
GSM change	.998[a]	0.995	0.995	1.43462	0.995	1784.930	2	17	0.000
Warp way breaking strength	.821[a]	0.674	0.635	4.82359	0.674	17.560	2	17	0.000
Weft way breaking strength	.868[a]	0.753	0.724	1.49442	0.753	25.929	2	17	0.000
Warp way tearing strength	.444[a]	0.197	0.103	52.46507	0.197	2.087	2	17	0.155
Weft way tearing strength	.974[a]	0.948	0.942	102.16983	0.948	156.532	2	17	0.000
Width change	.996[a]	0.992	0.991	0.57269	0.992	1074.078	2	17	0.000
Seam slippage	.940[a]	0.884	0.870	1.20224	0.884	64.707	2	17	0.000
Stiffness	.348[a]	0.121	0.018	301.09515	0.121	1.171	2	17	0.334
Air permeability	.920[a]	0.847	0.829	6.79840	0.847	47.136	2	17	0.000

Table appx 4.36. Regression model summary for mercerizing in series 1 fabrics

Dependent variable	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
warp shrinkage	.770[a]	0.592	0.545	0.32435	0.592	12.357	2	17	0.000
weft shrinkage	.998[a]	0.996	0.995	0.31564	0.996	2042.137	2	17	0.000
Growth	.829[a]	0.687	0.650	0.28534	0.687	18.625	2	17	0.000
Stretch	.998[a]	0.996	0.995	0.57966	0.996	2030.205	2	17	0.000
GSM change	.997[a]	0.994	0.994	1.72876	0.994	1483.909	2	17	0.000
Warp way breaking strength	.686[a]	0.471	0.409	3.95073	0.471	7.563	2	17	0.004
Weft way breaking strength	.657[a]	0.432	0.365	0.75046	0.432	6.458	2	17	0.008
Warp way tearing strength	.823[a]	0.678	0.640	79.78928	0.678	17.873	2	17	0.000
Weft way tearing strength	.872[a]	0.761	0.733	126.86339	0.761	27.062	2	17	0.000
Width change	.994[a]	0.988	0.987	0.75717	0.988	707.409	2	17	0.000
Seam slippage	.700[a]	0.489	0.429	1.93264	0.489	8.149	2	17	0.003
Stiffness	.784[a]	0.615	0.569	177.46225	0.615	13.566	2	17	0.000
Air permeability	.449[a]	0.202	0.108	7.30362	0.202	2.146	2	17	0.148

a. Predictors: (Constant), Width opening, Stretching temperature

Table appx 4.37. Regression model summary for washing in series 2 fabrics

Dependent variable	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
warp shrinkage	.986[a]	0.971	0.968	0.17388	0.971	288.073	2	17	0.000
weft shrinkage	.958[a]	0.918	0.908	0.91409	0.918	94.597	2	17	0.000
Growth	.621[a]	0.386	0.313	0.82711	0.386	5.335	2	17	0.016
Stretch	.954[a]	0.910	0.900	1.85723	0.910	86.233	2	17	0.000
GSM change	.951[a]	0.905	0.894	5.63888	0.905	80.780	2	17	0.000
Warp way breaking strength	.960[a]	0.922	0.912	4.66536	0.922	99.997	2	17	0.000
Weft way breaking strength	.960[a]	0.921	0.912	0.48151	0.921	99.236	2	17	0.000
Warp way tearing strength	.622[a]	0.387	0.315	40.84712	0.387	5.371	2	17	0.016
Weft way tearing strength	.991[a]	0.982	0.980	35.01082	0.982	455.925	2	17	0.000
Width change	.938[a]	0.880	0.866	1.54119	0.880	62.166	2	17	0.000
Seam slippage	.943[a]	0.889	0.876	1.24421	0.889	68.192	2	17	0.000
Stiffness	.757[a]	0.573	0.523	428.79228	0.573	11.417	2	17	0.001
Air permeability	.944[a]	0.891	0.878	5.53510	0.891	69.519	2	17	0.000

Table appx 4.38. Regression model summary for mercerizing in series 2 fabrics

Dependent variable	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
warp shrinkage	.968a	0.937	0.930	0.19085	0.937	126.631	2	17	0.000
weft shrinkage	.883a	0.780	0.754	1.81187	0.780	30.076	2	17	0.000
Growth	.952a	0.906	0.895	0.13036	0.906	81.731	2	17	0.000
Stretch	.933a	0.870	0.854	2.72280	0.870	56.701	2	17	0.000
GSM change	.947a	0.896	0.884	7.18465	0.896	73.149	2	17	0.000
Warp way breaking strength	.946a	0.895	0.882	3.91779	0.895	72.289	2	17	0.000
Weft way breaking strength	.793a	0.629	0.585	0.53407	0.629	14.413	2	17	0.000
Warp way tearing strength	.850a	0.723	0.690	198.96506	0.723	22.184	2	17	0.000
Weft way tearing strength	.902a	0.813	0.791	50.53977	0.813	37.063	2	17	0.000
Width change	.867a	0.751	0.722	2.47398	0.751	25.681	2	17	0.000
Seam slippage	.988a	0.976	0.973	0.63056	0.976	349.640	2	17	0.000
Stiffness	.871a	0.759	0.731	261.33695	0.759	26.834	2	17	0.000
Air permeability	.391a	0.153	0.053	4.96708	0.153	1.534	2	17	0.244

Table appx 4.39.Regression coefficients of warp shrinkage due to washing and mercerizing of Series 1 & Series 2

Process Parameters	Variables	B	SE	β	t	p	95% CI	
Washing (Series 1)	(Constant)	-1.348	0.779		-1.729	0.102	-2.992	0.297
	ST	-0.013	0.005	-0.554	-2.786	0.013	-0.023	-0.003
	WO	-0.023	0.034	-0.139	-0.698	0.495	-0.094	0.047
Mercerizing (Series 1)	(Constant)	-1.705	0.337		-5.058	0.000	-2.417	-0.994
	ST	-0.009	0.002	-0.64	-4.136	0.001	-0.013	-0.004
	WO	-0.04	0.015	-0.427	-2.758	0.013	-0.071	-0.009
Washing (Series 2)	(Constant)	-6.369	0.181		-35.239	0.000	-6.751	-5.988
	ST	0.02	0.001	0.748	18.21	0.000	0.018	0.023
	WO	-0.122	0.008	-0.642	-15.638	0.000	-0.138	-0.105
Mercerizing (Series 2)	(Constant)	-2.464	0.198		-12.42	0.000	-2.883	-2.046
	ST	0.002	0.001	0.107	1.757	0.097	0	0.005
	WO	-0.135	0.009	-0.962	-15.817	0.000	-0.153	-0.117

Table appx 4.40. Regression coefficients of weft shrinkage due to washing and mercerizing of Series 1 & Series 2

Process Parameters	Variables	B	SE	β	t	p	95% CI	
Washing (Series 1)	(Constant)	-30.012	0.261		-114.958	0.000	-30.563	-29.461
	ST	0.122	0.002	0.999	75.978	0.000	0.119	0.125
	WO	0.003	0.011	0.004	0.297	0.770	-0.02	0.027
Mercerizing (Series 1)	(Constant)	-29.891	0.328		-91.101	0.000	-30.583	-29.199
	ST	0.129	0.002	0.998	63.906	0.000	0.125	0.133
	WO	-0.008	0.014	-0.009	-0.561	0.582	-0.038	0.022
Washing (Series 2)	(Constant)	-23.874	0.95		-25.124	0.000	-25.879	-21.869
	ST	0.061	0.006	0.729	10.47	0.000	0.049	0.073
	WO	0.365	0.041	0.621	8.921	0.000	0.278	0.451
Mercerizing (Series 2)	(Constant)	-24.705	1.883		-13.117	0.000	-28.679	-20.731
	ST	0.078	0.012	0.768	6.747	0.000	0.054	0.103
	WO	0.31	0.081	0.436	3.826	0.001	0.139	0.481

Table appx 4.41. Regression coefficients of stretch due to washing and mercerizing of Series 1 & Series 2

Process Parameters	Variables	B	SE	β	t	p	95% CI	
Washing (Series 1)	(Constant)	49.420	0.380		130.710	0.000	48.620	50.220
	ST	-0.170	0.000	-1.000	-74.180	0.000	-0.180	-0.170
	WO	-0.040	0.020	-0.030	-2.460	0.025	-0.070	-0.010
Mercerizing (Series 1)	(Constant)	60.770	0.600		100.850	0.000	59.500	62.040
	ST	-0.240	0.000	-1.000	-63.530	0.000	-0.240	-0.230
	WO	-0.130	0.030	-0.080	-4.900	0.000	-0.180	-0.070
Washing (Series 2)	(Constant)	52.500	1.930		27.190	0.000	48.420	56.570
	ST	-0.140	0.010	-0.860	-11.850	0.000	-0.170	-0.120
	WO	-0.470	0.080	-0.410	-5.670	0.000	-0.650	-0.300
Mercerizing (Series 2)	(Constant)	53.400	2.830		18.870	0.000	47.430	59.370
	ST	-0.150	0.020	-0.750	-8.570	0.000	-0.190	-0.110
	WO	-0.770	0.120	-0.550	-6.320	0.000	-1.030	-0.510

Table appx 4.42. Regression coefficients of GSM change due to washing and mercerizing of Series 1 & Series 2

Process Parameters	Variables	B	SE	β	t	p	95% CI	
Washing (Series 1)	(Constant)	146.930	1.490		98.520	0.000	143.780	150.080
	ST	-0.540	0.010	-0.990	-59.260	0.000	-0.560	-0.520
	WO	-0.490	0.060	-0.130	-7.660	0.000	-0.630	-0.360
Mercerizing (Series 1)	(Constant)	147.010	1.800		81.800	0.000	143.220	150.800
	ST	-0.600	0.010	-0.990	-54.330	0.000	-0.620	-0.580
	WO	0.310	0.080	0.070	4.000	0.001	0.150	0.470
Washing (Series 2)	(Constant)	146.470	5.860		24.990	0.000	134.100	158.830
	ST	-0.410	0.040	-0.850	-11.290	0.000	-0.480	-0.330
	WO	-1.470	0.250	-0.440	-5.840	0.000	-2.010	-0.940
Mercerizing (Series 2)	(Constant)	150.810	7.470		20.190	0.000	135.050	166.570
	ST	-0.540	0.050	-0.920	-11.780	0.000	-0.640	-0.440

	WO	-0.880	0.320	-0.220	-2.740	0.014	-1.560	-0.200

Table appx 4.43. Regression coefficients of warp breaking strength due to washing and mercerizing of Series 1 & Series 2

Process Parameters	Variables	B	SE	β	t	p	95% CI	
Washing (Series 1)	(Constant)	82.93	5.01		16.54	0.000	72.35	93.51
	ST	0.08	0.03	0.34	2.46	0.025	0.01	0.14
	WO	1.16	0.22	0.75	5.39	0.000	0.71	1.62
Mercerizing (Series 1)	(Constant)	84.75	4.11		20.64	0.000	76.08	93.41
	ST	0.07	0.03	0.51	2.91	0.010	0.02	0.13
	WO	-0.46	0.18	-0.46	-2.58	0.019	-0.83	-0.08
Washing (Series 2)	(Constant)	179.04	4.85		36.92	0.000	168.80	189.27
	ST	-0.42	0.03	-0.96	-14.10	0.000	-0.48	-0.36
	WO	-0.22	0.21	-0.07	-1.04	0.315	-0.66	0.22
Mercerizing (Series 2)	(Constant)	142.48	4.07		34.98	0.000	133.88	151.07
	ST	-0.22	0.03	-0.70	-8.86	0.000	-0.27	-0.17
	WO	1.43	0.18	0.64	8.13	0.000	1.06	1.80

Table appx 4.44. Regression coefficients weft breaking strength due to washing and mercerizing of Series 1 & Series 2

Process Parameters	Variables	B	SE	β	t	p	95% CI	
Washing (Series 1)	(Constant)	64.45	1.55		41.49	0.000	61.18	67.73
	ST	-0.05	0.01	-0.68	-5.61	0.000	-0.07	-0.03
	WO	-0.30	0.07	-0.54	-4.51	0.000	-0.44	-0.16
Mercerizing (Series 1)	(Constant)	56.45	0.78		72.36	0.000	54.81	58.10
	ST	-0.02	0.01	-0.62	-3.41	0.003	-0.03	-0.01
	WO	-0.04	0.03	-0.21	-1.13	0.275	-0.11	0.03
Washing (Series 2)	(Constant)	51.87	0.50		103.63	0.000	50.81	52.93
	ST	0.00	0.00	0.07	0.96	0.351	0.00	0.01
	WO	-0.30	0.02	-0.96	-14.06	0.000	-0.35	-0.26
Mercerizing (Series 2)	(Constant)	50.83	0.56		91.55	0.000	49.66	52.00
	ST	-0.01	0.00	-0.37	-2.51	0.022	-0.02	0.00

	WO	-0.11	0.02	-0.70	-4.75	0.000	-0.16	-0.06

Table appx 4.45. Regression coefficients of warp way tearing strength due to washing and mercerizing of Series 1 & Series 2

Process Parameters	Variables	B	SE	β	t	p	95% CI	
Washing (Series 1)	(Constant)	6856.660	54.540		125.720	0.000	6741.590	6971.720
	ST	-0.390	0.340	-0.250	-1.160	0.263	-1.100	0.320
	WO	-3.950	2.350	-0.370	-1.680	0.111	-8.900	1.000
Mercerizing (Series 1)	(Constant)	6162.400	82.940		74.300	0.000	5987.410	6337.400
	ST	2.180	0.510	0.590	4.280	0.001	1.110	3.260
	WO	14.880	3.570	0.570	4.170	0.001	7.360	22.410
Washing (Series 2)	(Constant)	6763.120	42.460		159.280	0.000	6673.530	6852.710
	ST	-0.010	0.260	-0.010	-0.050	0.963	-0.560	0.540
	WO	-5.990	1.830	-0.620	-3.280	0.004	-9.840	-2.130
Mercerizing (Series 2)	(Constant)	7655.110	206.830		37.010	0.000	7218.740	8091.480
	ST	-5.770	1.270	-0.580	-4.540	0.000	-8.460	-3.090
	WO	-43.350	8.900	-0.620	-4.870	0.000	-62.120	-24.580

Table appx 4.46. Regression coefficients of weft way tearing strength due to washing and mercerizing of Series 1 & Series 2

Process Parameters	Variables	B	SE	β	t	p	95% CI	
Washing (Series 1)	(Constant)	6390.58	106.21		60.17	0.000	6166.50	6614.66
	ST	-8.55	0.65	-0.72	-13.10	0.000	-9.93	-7.17
	WO	-54.35	4.57	-0.66	-11.90	0.000	-63.99	-44.71
Mercerizing (Series 1)	(Constant)	6258.36	131.88		47.46	0.000	5980.12	6536.59
	ST	-5.93	0.81	-0.87	-7.31	0.000	-7.64	-4.22
	WO	-4.50	5.67	-0.09	-0.79	0.439	-16.47	7.47
Washing (Series 2)	(Constant)	4517.77	36.40		124.13	0.000	4440.99	4594.56
	ST	-1.90	0.22	-0.28	-8.50	0.000	-2.37	-1.43
	WO	-45.37	1.57	-0.95	-28.98	0.000	-48.67	-42.07
	(Constant)	4596.02	52.54		87.48	0.000	4485.18	4706.87

Mercerizing (Series 2)	ST	-1.09	0.32	-0.35	-3.38	0.004	-1.77	-0.41
	WO	-17.90	2.26	-0.83	-7.92	0.000	-22.67	-13.13

Table appx 4.47. Regression coefficients of width change due to washing and mercerizing of Series 1 & Series 2

Process Parameters	Variables	B	SE	β	t	p	95% CI	
Washing (Series 1)	(Constant)	41.98	0.60		70.51	0.000	40.72	43.23
	ST	-0.17	0.00	-1.00	-46.33	0.000	-0.18	-0.16
	WO	0.03	0.03	0.03	1.17	0.258	-0.02	0.08
Mercerizing (Series 1)	(Constant)	41.13	0.79		52.25	0.000	39.47	42.79
	ST	-0.18	0.01	-0.99	-37.56	0.000	-0.19	-0.17
	WO	0.07	0.03	0.05	2.01	0.060	0.00	0.14
Washing (Series 2)	(Constant)	32.72	1.60		20.43	0.000	29.34	36.10
	ST	-0.09	0.01	-0.75	-8.92	0.000	-0.11	-0.07
	WO	-0.46	0.07	-0.56	-6.69	0.000	-0.61	-0.32
Mercerizing (Series 2)	(Constant)	31.42	2.57		12.22	0.000	25.99	36.84
	ST	-0.10	0.02	-0.74	-6.12	0.000	-0.13	-0.06
	WO	-0.41	0.11	-0.45	-3.74	0.002	-0.65	-0.18

Table appx 4.48. Regression coefficients of seam slippage due to washing and mercerizing of Series 1 & Series 2

Process Parameters	Variables	B	SE	β	t	p	95% CI	
Washing (Series 1)	(Constant)	30.51	1.25		24.41	0.000	27.87	33.14
	ST	0.04	0.01	0.42	5.09	0.000	0.02	0.06
	WO	0.55	0.05	0.84	10.17	0.000	0.43	0.66
Mercerizing (Series 1)	(Constant)	30.62	2.01		15.24	0.000	26.38	34.86
	ST	0.03	0.01	0.44	2.55	0.021	0.01	0.06
	WO	0.27	0.09	0.54	3.13	0.006	0.09	0.45
Washing (Series 2)	(Constant)	47.50	1.29		36.73	0.000	44.77	50.23
	ST	-0.07	0.01	-0.74	-9.10	0.000	-0.09	-0.06
	WO	0.41	0.06	0.59	7.32	0.000	0.29	0.53
	(Constant)	40.84	0.66		62.30	0.000	39.46	42.22

Mercerizing (Series 2)	ST	-0.03	0.00	-0.26	-7.06	0.000	-0.04	-0.02
	WO	0.72	0.03	0.95	25.49	0.000	0.66	0.78

Table appx 4.49. Regression coefficients of stiffness due to washing and mercerizing of Series 1 & Series 2

Process Parameters	Variables	B	SE	β	t	p	95% CI	
Washing (Series 1)	(Constant)	1360.81	313.00		4.35	0.000	700.44	2021.17
	ST	-2.90	1.92	-0.34	-1.51	0.150	-6.96	1.16
	WO	3.46	13.47	0.06	0.26	0.800	-24.95	31.87
Mercerizing (Series 1)	(Constant)	1741.69	184.48		9.44	0.000	1352.48	2130.90
	ST	-5.83	1.13	-0.77	-5.14	0.000	-8.22	-3.43
	WO	-6.77	7.94	-0.13	-0.85	0.406	-23.51	9.98
Washing (Series 2)	(Constant)	3170.57	445.74		7.11	0.000	2230.14	4111.00
	ST	-9.16	2.74	-0.53	-3.34	0.004	-14.94	-3.38
	WO	-65.48	19.18	-0.54	-3.42	0.003	-105.94	-25.03
Mercerizing (Series 2)	(Constant)	2741.51	271.67		10.09	0.000	2168.34	3314.67
	ST	-8.27	1.67	-0.59	-4.95	0.000	-11.79	-4.74
	WO	-63.11	11.69	-0.64	-5.40	0.000	-87.76	-38.45

Table appx 4.50. Regression coefficients of air permeability due to washing and mercerizing of Series 1 & Series 2

Process Parameters	Variables	B	SE	β	t	p	95% CI	
Washing (Series 1)	(Constant)	123.42	7.07		17.46	0.000	108.51	138.33
	ST	-0.41	0.04	-0.90	-9.48	0.000	-0.50	-0.32
	WO	0.63	0.30	0.20	2.08	0.053	-0.01	1.27
Mercerizing (Series 1)	(Constant)	33.20	7.59		4.37	0.000	17.18	49.22
	ST	0.10	0.05	0.45	2.07	0.054	0.00	0.20
	WO	0.01	0.33	0.00	0.02	0.988	-0.68	0.69
Washing (Series 2)	(Constant)	110.61	5.75		19.22	0.000	98.47	122.75
	ST	-0.41	0.04	-0.92	-11.52	0.000	-0.48	-0.33
	WO	0.62	0.25	0.20	2.52	0.022	0.10	1.15
	(Constant)	27.41	5.16		5.31	0.000	16.51	38.30

Mercerizing (Series 2)	ST	0.06	0.03	0.38	1.72	0.103	-0.01	0.12
	WO	0.07	0.22	0.07	0.33	0.749	-0.40	0.54

APPENDIX B: COLOR MEASUREMENT

Table appx 4.51. Measured CIELab values of Series 1 sample

Sample	Color values					
	L*	a*	b*	C*	h	K/S
A1	22.77	1.03	-4.94	5.05	281.82	13.26
B1	23.70	1.03	-4.61	4.73	282.53	12.18
C1	22.83	1.10	-4.85	4.98	282.79	13.18
D1	23.99	1.00	-4.59	4.69	282.26	11.87
E1	23.23	1.01	-4.63	4.74	282.28	12.64
F1	23.81	0.98	-4.29	4.40	282.91	12.01
G1	23.41	0.95	-4.75	4.84	281.26	12.53
H1	24.62	0.91	-3.76	3.86	283.57	11.16

Table appx 4.52. Measured CIELab values of Series 2 samples

Samples	Color values					
	L*	a*	b*	C*	h	K/S
A2	22.60	1.05	-5.28	5.38	281.26	9.59
B2	22.94	1.18	-4.86	5.01	283.65	12.98
C2	24.05	0.84	-5.09	5.16	279.41	12.01
D2	24.41	0.98	-4.22	4.33	283.09	11.43
E2	23.29	1.05	-4.80	4.91	282.39	12.64
F2	23.29	1.10	-4.21	4.35	284.66	12.46
G2	23.89	0.85	-4.78	4.85	280.10	12.07
H2	25.32	0.73	-3.86	3.92	280.75	10.62

Table appx 4.53. Color differences of series 1 samples

Sample	Color differences					
	ΔL*	Δa*	Δb*	ΔC*	Δh	ΔE
A1	Reference sample					
B1	0.93	0.00	0.33	-0.32	0.06	0.99
C1	0.06	0.07	0.09	-0.07	0.08	0.13
D1	1.22	-0.03	0.35	-0.36	0.04	1.27
E1	0.46	-0.02	0.31	-0.31	0.04	0.56
F1	1.04	-0.05	0.65	-0.65	0.09	1.22
G1	0.64	-0.08	0.19	-0.21	0.05	0.68
H1	1.85	-0.12	1.18	-1.19	0.14	2.20

Table appx 4.54. Color differences of series 2 samples

Sample	Color differences					
	ΔL*	Δa*	Δb*	ΔC*	Δh	ΔE
A2	Reference sample					
B2	0.34	0.13	0.42	-0.37	0.22	0.55
C2	1.45	-0.21	0.19	-0.22	0.17	1.48
D2	1.81	-0.07	1.06	-1.05	0.15	2.10
E2	0.69	0.00	0.48	-0.47	0.10	0.84
F2	0.69	0.05	1.07	-1.03	0.29	1.27
G2	1.29	-0.20	0.50	-0.53	0.10	1.40
H2	2.72	-0.32	1.42	-1.46	0.04	3.08

Table appx 4.55. Color differences between two series

Sample	Color differences between two series					
	ΔL*	Δa*	Δb*	ΔC*	Δh	ΔE
	Series 1 samples have been considered as references					
A	-0.17	0.02	-0.34	0.34	0.05	0.38
B	-0.76	0.16	-0.25	0.28	0.09	0.82
C	1.22	-0.26	-0.24	0.19	0.30	1.27
D	0.41	-0.02	0.37	-0.37	0.07	0.56
E	0.06	0.05	-0.17	0.17	0.01	0.18
F	-0.52	0.12	0.08	-0.05	0.13	0.54
G	0.48	-0.09	-0.03	-0.02	0.10	0.49
H	0.70	-0.18	-0.10	0.06	0.19	0.73

Table appx 4.56. Color values of A1 samples due to washing

Samples	Color values of A1 samples due to washing					
	L*	a*	b*	C*	h	K/S
Before wash	22.14	0.98	-5.14	5.23	280.76	13.26
Rinse wash	17.85	1.28	-6.75	6.87	280.73	21.23
Enzyme wash	17.05	1.42	-9.02	9.13	278.95	24.26
Stone wash	21.17	0.35	-14.37	14.37	271.41	20.20
Stone and bleach wash	22.60	-0.20	-14.79	14.79	269.22	18.32

Table appx 4.57. Color differences between the A1 samples

Samples	Color differences					
	ΔL*	Δa*	Δb*	ΔC*	Δh	ΔE
Before wash	Reference sample					
Rinse wash	-4.28	0.30	-1.60	1.63	0.00	4.59
Enzyme wash	-5.08	0.44	-3.88	3.90	0.22	6.41
Stone wash	-0.97	-0.62	-0.92	9.14	1.41	9.30

Stone and bleach wash	0.46	-1.18	-9.65	9.56	1.77	9.73

Table appx 4.58. Color values of B1 samples due to washing

Samples	Color values of B1 samples due to washing					
	L*	a*	b*	C*	h	K/S
Before wash	23.18	0.93	-4.52	4.62	281.58	12.18
Rinse wash	18.66	1.49	-6.57	6.74	282.77	19.42
Enzyme wash	17.79	1.55	-9.15	9.28	279.59	22.48
Stone wash	20.47	0.76	-13.82	13.84	273.16	20.75
Stone and bleach wash	23.58	-0.29	-14.74	14.74	268.87	16.68

Table appx 4.59. Color differences between the B1 samples

Samples	Color differences between the B1 samples					
	ΔL*	Δa*	Δb*	ΔC*	Δh	ΔE
Before wash	Reference sample					
Rinse wash	-4.51	0.56	-2.05	2.12	0.12	4.99
Enzyme wash	-5.39	0.62	-4.63	4.67	0.23	7.13
Stone wash	-2.70	-0.16	-9.29	9.22	1.17	9.68
Stone and bleach wash	0.40	-1.22	-10.22	10.12	1.83	10.30

Table appx 4.60. Color values of C1 samples due to washing

Samples	Color values of C1 samples due to washing					
	L*	a*	b*	C*	h	K/S
Before wash	22.81	0.92	-4.91	5.00	280.57	13.18
Rinse wash	17.23	1.30	-6.49	6.62	281.35	22.38
Enzyme wash	17.26	1.43	-9.16	9.27	278.89	23.76
Stone wash	20.54	0.44	-14.04	14.05	271.80	21.04
Stone and bleach wash	22.80	-0.33	-14.77	14.77	268.73	18.02

Table appx 4.61. Color differences between the C1 samples

Samples	Color differences between the C1 samples					
	ΔL*	Δa*	Δb*	ΔC*	Δh	ΔE
Before wash	Reference sample					
Rinse wash	-5.58	0.39	-1.58	1.63	0.08	5.81
Enzyme wash	-5.45	0.52	-4.25	4.28	0.19	7.01
Stone wash	-2.27	-0.48	-9.127	9.05	1.28	9.42
Stone and bleach wash	-0.01	-1.24	-9.86	9.77	1.77	9.94

Table appx 4.62. Color values of D1 samples due to washing

Samples	Color values of D1 samples due to washing					
	L*	a*	b*	C*	h	K/S
Before wash	23.80	0.90	-4.65	4.74	280.93	11.87
Rinse wash	18.48	1.53	-6.61	6.79	283.04	19.76
Enzyme wash	17.70	1.51	-9.08	9.21	279.45	22.71
Stone wash	21.31	0.49	-14.15	14.16	272.00	19.50
Stone and bleach wash	23.10	-0.20	-14.98	14.98	269.22	17.53

Table appx 4.63. Color differences between the D1 samples

Samples	Color differences between the D1 samples					
	ΔL*	Δa*	Δb*	ΔC*	Δh	ΔE
Before wash	Reference sample					
Rinse wash	-5.32	0.63	-1.96	2.05	0.21	5.71
Enzyme wash	-6.11	0.61	-4.43	4.47	0.17	7.57
Stone wash	-2.50	-0.40	-9.51	9.43	1.27	9.84
Stone and bleach wash	-0.70	-1.10	-10.33	10.25	1.72	10.41

Table appx 4.64. Color values of E1 samples due to washing

Samples	Color values of E1 samples due to washing					
	L*	a*	b*	C*	h	K/S
Before wash	22.89	0.98	-5.12	5.21	280.87	12.64
Rinse wash	18.94	1.06	-6.7	6.78	278.98	19.34
Enzyme wash	18.49	1.18	-8.77	8.85	277.65	21.14
Stone wash	21.13	0.39	-14.04	14.04	271.58	19.93
Stone and bleach wash	24.16	-0.2	-13.04	13.04	269.11	14.94

Table appx 4.65. Color differences between the E1 samples

Samples	Color differences between the E1 samples					
	ΔL*	Δa*	Δb*	ΔC*	Δh	ΔE
Before wash	Reference sample					
Rinse wash	-3.94	0.08	-1.58	1.57	0.20	4.25
Enzyme wash	-4.40	0.19	-3.65	3.64	0.38	5.72
Stone wash	-1.76	-0.59	-8.91	8.83	1.39	9.11
Stone and bleach wash	1.27	-1.19	-7.92	7.83	1.69	8.11

Table appx 4.66. Color values of F1 samples due to washing

Samples	Color values of F1 samples due to washing					
	L*	a*	b*	C*	h	K/S
Before wash	24.48	0.91	-4.17	4.27	282.28	12.01
Rinse wash	19.12	1.27	-6.40	6.52	281.27	18.70
Enzyme wash	19.79	1.13	-8.91	8.98	277.21	18.85
Stone wash	21.44	0.51	-13.90	13.91	272.10	19.17
Stone and bleach wash	23.11	0.13	-14.07	14.07	270.53	16.74

Table appx 4.67. Color differences between the F1 samples

Samples	Color differences between the F1 samples					
	ΔL*	Δa*	Δb*	ΔC*	Δh	ΔE
Before wash	Reference sample					
Rinse wash	-5.36	0.37	-2.23	2.25	0.09	5.82
Enzyme wash	-4.69	0.22	-4.74	4.71	0.55	6.67
Stone wash	-3.04	-0.40	-9.73	9.64	1.37	10.20
Stone and bleach wash	-1.37	-0.78	-9.90	9.80	1.59	10.03

Table appx 4.68. Color values of G1 samples due to washing

Samples	Color values of G1 samples due to washing					
	L*	a*	b*	C*	h	K/S
Before wash	23.56	0.86	-4.68	4.75	280.41	12.53
Rinse wash	19.39	1.03	-6.31	6.4	279.26	18.39
Enzyme wash	19.48	1.02	-9.18	9.23	276.37	19.59
Stone wash	22.53	0.15	-13.45	13.45	270.66	17.33
Stone and bleach wash	24.77	-0.34	-15.52	15.53	268.74	15.3

Table appx 4.69. Color differences between the G1 samples

Samples	Color differences between the G1 samples					
	ΔL*	Δa*	Δb*	ΔC*	Δh	ΔE
Before wash	Reference sample					
Rinse wash	-4.17	0.17	-1.64	1.64	0.11	4.48
Enzyme wash	-4.10	0.16	-4.50	4.48	0.47	6.08
Stone wash	-1.03	-0.71	-8.78	8.70	1.36	8.86
Stone and bleach wash	1.21	-1.20	-10.85	10.77	1.75	10.98

Table appx 4.70. Color values of H1 samples due to washing

Samples	Color values of H1 samples due to washing					
	L*	a*	b*	C*	h	K/S
Before wash	24.79	0.77	-3.84	3.92	281.27	11.16
Rinse wash	20.75	1.13	-5.46	5.58	281.7	15.85
Enzyme wash	20.71	1.08	-9.08	9.14	276.76	17.4
Stone wash	23.54	0.27	-10.93	10.93	271.41	14.84
Stone and bleach wash	26.36	-0.35	-15.04	15.04	268.67	13.14

Table appx 4.71. Color differences between the H1 samples

Samples	Color differences between the H1 samples					
	ΔL*	Δa*	Δb*	ΔC*	Δh	ΔE
Before wash	Reference sample					
Rinse wash	-4.04	0.36	-1.62	1.66	0.04	4.37
Enzyme wash	-4.08	0.31	-5.24	5.23	0.471	6.65
Stone wash	-1.25	-0.5	-7.1	7.01	1.12	7.21
Stone and bleach wash	1.57	-1.12	-11.2	11.12	1.69	11.36

Table appx 4.72. Color values of A2 samples due to washing

Samples	Color values of A2 samples due to washing					
	L*	a*	b*	C*	h	K/S
Before wash	21.70	0.96	-5.02	5.11	280.83	9.59
Rinse wash	16.70	1.34	-6.65	6.78	281.38	23.64
Enzyme wash	16.82	1.48	-8.90	9.02	279.47	24.78
Stone wash	21.05	0.39	-14.55	14.55	271.54	20.47
Stone and bleach wash	23.01	-0.29	-14.52	14.52	268.84	17.53

Table appx 4.73. Color differences between the A2 samples

Samples	Color differences between the A2 samples					
	ΔL*	Δa*	Δb*	ΔC*	Δh	ΔE
Before wash	Reference sample					
Rinse wash	-5.00	0.38	-1.63	1.67	0.06	5.27
Enzyme wash	-4.88	0.52	-3.88	3.91	0.16	6.25
Stone wash	-0.65	-0.57	-9.53	9.44	1.40	9.56
Stone and bleach wash	1.31	-1.25	-9.50	9.41	1.80	9.67

Table appx 4.74. Color values of B2 samples due to washing

Samples	Color values of B2 samples due to washing					
	L*	a*	b*	C*	h	K/S
Before wash	21.70	1.15	.4.83	4.96	283.41	12.98
Rinse wash	17.40	1.59	-7.06	7.23	282.72	22.05
Enzyme wash	16.95	1.77	-8.98	9.15	281.18	24.26
Stone wash	21.27	0.38	-14.35	14.35	271.52	19.93
Stone and bleach wash	23.05	-0.17	-14.97	14.97	269.33	17.60

Table appx 4.75. Color differences between the B2 samples

Samples	Color differences between the B2 samples					
	ΔL*	Δa*	Δb*	ΔC*	Δh	ΔE
Before wash	Reference sample					
Rinse wash	-4.30	0.44	-2.23	2.27	0.07	4.86
Enzyme wash	-4.75	0.62	-4.15	4.19	0.26	6.34
Stone wash	-0.42	-0.77	-9.52	9.40	1.75	9.56
Stone and bleach wash	1.35	-1.32	-10.15	10.01	2.11	10.32

Table appx 4.76. Color values of C2 samples due to washing

Samples	Color values of C2 samples due to washing					
	L*	a*	b*	C*	h	K/S
Before wash	24.53	0.67	-5.06	5.11	277.53	12.01
Rinse wash	18.87	1.04	-6.53	6.61	279.08	19.42
Enzyme wash	18.97	1.02	-8.89	8.95	276.56	20.38
Stone wash	22.37	0.02	-13.9	13.9	270.08	17.88
Stone and bleach wash	25.24	-0.45	-15.81	15.81	268.38	14.94

Table appx 4.77. Color differences between the C2 samples

Samples	Color differences between the C2 samples					
	ΔL*	Δa*	Δb*	ΔC*	Δh	ΔE
Before wash	Reference sample					
Rinse wash	-5.66	0.37	-1.47	1.51	0.16	5.86
Enzyme wash	-5.56	0.35	-3.83	3.85	0.11	6.76
Stone wash	-2.16	-0.65	-8.84	8.80	1.09	9.12
Stone and bleach wash	0.70	-1.12	-10.75	10.71	1.43	10.83

Table appx 4.78. Color values of D2 samples due to washing

Samples	Color values of D2 samples due to washing					
	L*	a*	b*	C*	h	K/S
Before wash	24.56	0.79	-4.07	4.14	280.97	11.43
Rinse wash	19.31	1.29	-5.94	6.08	282.30	18.17
Enzyme wash	18.38	1.30	-9.59	9.67	277.71	21.74
Stone wash	22.39	0.17	-13.78	13.78	270.72	17.74
Stone and bleach wash	25.61	-0.36	-15.44	15.44	268.65	14.26

Table appx 4.79. Color differences between the D2 samples

Samples	Color differences between the D2 samples					
	ΔL*	Δa*	Δb*	ΔC*	Δh	ΔE
Before wash	Reference sample					
Rinse wash	-5.25	0.51	-1.87	1.93	0.12	5.60
Enzyme wash	-6.19	0.51	-5.52	5.53	0.36	8.31
Stone wash	-2.18	-0.62	-9.71	9.63	1.35	9.97
Stone and bleach wash	1.04	-1.15	-11.37	11.30	1.72	11.48

Table appx 4.80. Color values of E2 samples due to washing

Samples	Color values of E2 samples due to washing					
	L*	a*	b*	C*	h	K/S
Before wash	23.08	0.91	-4.85	4.94	280.62	12.64
Rinse wash	19.05	1.11	-6.49	6.68	279.75	18.93
Enzyme wash	18.20	1.23	-8.73	8.81	278.01	21.74
Stone wash	20.87	0.47	-13.67	13.68	271.96	20.20
Stone and bleach wash	23.93	-0.26	-14.79	14.79	268.98	16.20

Table appx 4.81. Color differences between the E2 samples

Samples	Color differences between the E2 samples					
	ΔL*	Δa*	Δb*	ΔC*	Δh	ΔE
Before wash	Reference sample					
Rinse wash	-4.02	0.20	-1.64	1.65	0.09	4.35
Enzyme wash	-4.88	0.32	-3.87	3.87	0.30	6.24
Stone wash	-2.21	-0.44	-8.82	8.74	1.24	9.10
Stone and bleach wash	0.85	-1.17	-9.94	9.86	1.73	10.04

Table appx 4.82. Color values of F2 samples due to washing

Samples	Color values of F2 samples due to washing					
	L*	a*	b*	C*	h	K/S
Before wash	23.52	0.91	-4.33	4.42	281.86	12.46
Rinse wash	19.62	1.25	-6.53	6.65	280.80	17.88
Enzyme wash	19.37	1.28	-9.15	9.24	277.96	12.35
Stone wash	21.93	0.32	-13.82	13.82	271.33	18.39
Stone and bleach wash	23.21	-0.13	-14.65	14.65	269.50	17.06

Table appx 4.83. Color differences between the F2 samples

Samples	Color differences between the F2 samples					
	ΔL*	Δa*	Δb*	ΔC*	Δh	ΔE
Before wash	Reference sample					
Rinse wash	-3.90	0.39	-2.21	2.23	0.10	4.49
Enzyme wash	-4.15	0.37	-4.82	4.82	0.44	6.37
Stone wash	-1.59	-0.59	-9.49	9.40	1.43	9.64
Stone and bleach wash	-0.31	-1.04	-10.32	10.23	1.73	10.38

Table appx 4.84. Color values of G2 samples due to washing

Samples	Color values of G2 samples due to washing					
	L*	a*	b*	C*	h	K/S
Before wash	24.28	0.62	-4.86	4.9	277.27	12.07
Rinse wash	18.65	1.09	-6.2	6.29	279.94	19.5
Enzyme wash	19.19	1.08	-9.33	9.39	276.61	20.2
Stone wash	22.45	0.07	-13.5	13.5	270.31	17.46
Stone and bleach wash	24.91	-0.33	-15.42	15.43	268.76	15.14

Table appx 4.85. Color differences between the G2 samples

Samples	Color differences between the G2 samples					
	ΔL*	Δa*	Δb*	ΔC*	Δh	ΔE
Before wash	Reference sample					
Rinse wash	-5.64	0.47	-1.39	1.40	0.26	5.81
Enzyme wash	-5.10	0.46	-4.47	4.50	0.08	6.80
Stone wash	-1.83	-0.55	-8.64	8.60	0.99	8.85
Stone and bleach wash	0.63	-0.95	-10.56	10.53	1.29	10.63

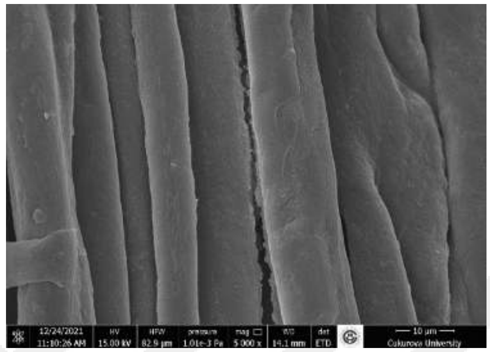
Table appx 4.86. Color values of H2 samples due to washing

Samples	Color values of H2 samples due to washing					
	L*	a*	b*	C*	h	K/S
Before wash	24.09	0.79	-3.70	3.79	282.12	10.62
Rinse wash	21.20	1.00	-5.53	5.62	280.20	15.36
Enzyme wash	19.87	1.02	-9.40	9.45	276.18	19.01
Stone wash	22.11	0.31	-12.90	12.90	271.37	17.53
Stone and bleach wash	25.68	-0.26	-15.17	15.18	269.00	13.94

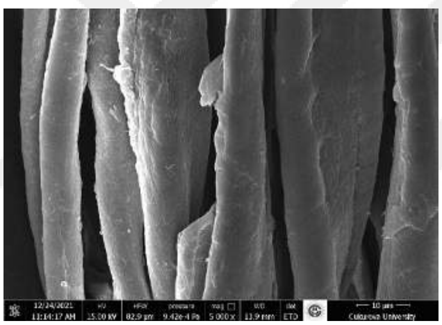
Table appx 4.87. Color differences between the H2 samples

Samples	Color differences between the H2 samples					
	ΔL*	**Δa***	**Δb***	**ΔC***	**Δh**	**ΔE**
Before wash	Reference sample					
Rinse wash	-2.89	0.20	-1.83	1.83	0.15	3.42
Enzyme wash	-4.22	0.22	-5.70	5.70	0.62	7.09
Stone wash	-1.98	-0.50	-9.20	9.12	1.31	9.42
Stone and bleach wash	1.59	-1.06	-11.47	11.39	1.73	11.63

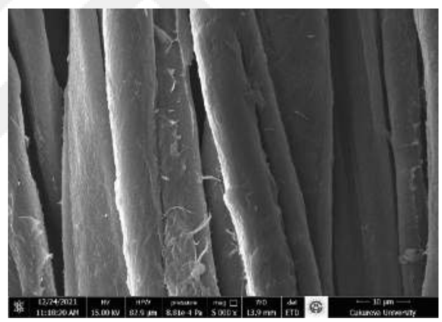
APPENDIX C: SEM IMAGE ANALYSIS



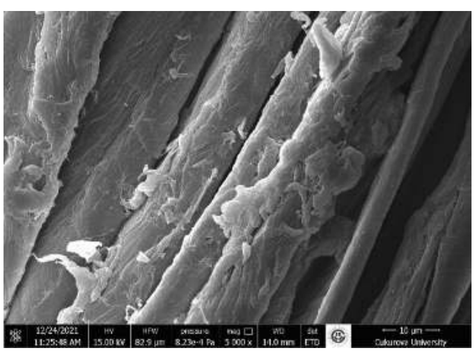
Sample: A1 (Before washing)



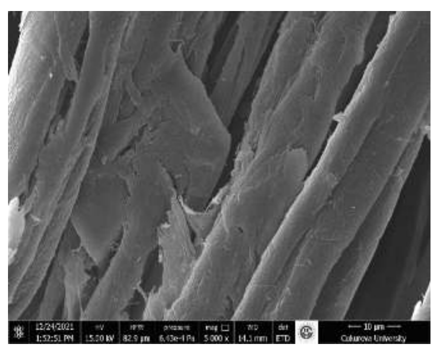
Sample: A1 (Rinse washing)



Sample: A1 (Enzyme washing)

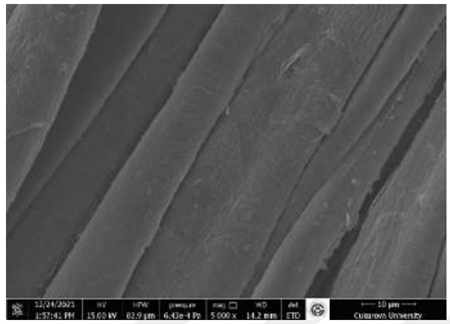


Sample: A1 (Stone washing)

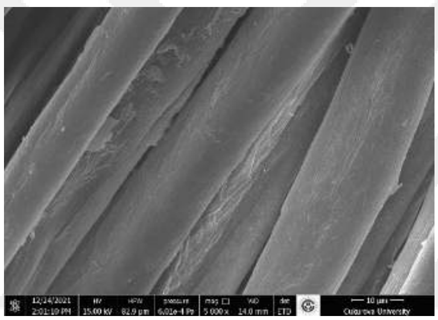


Sample: A1 (Stone & bleach washing)

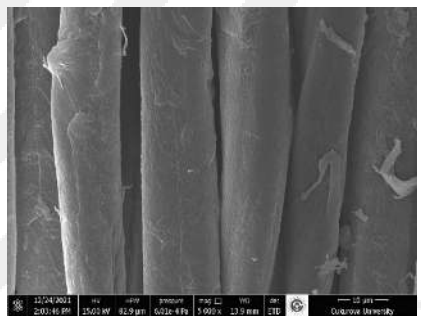
Figure appx 4.1. SEM morphology of A1 denim fabrics (5000X)



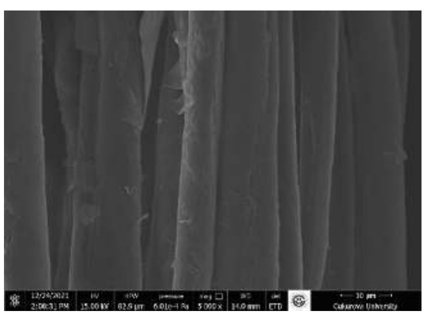
Sample: B1 (Before washing)



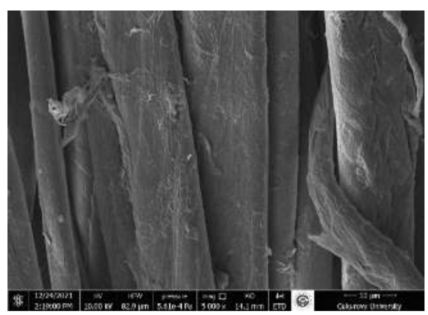
Sample: B1 (Rinse washing)



Sample: B1 (Enzyme washing)

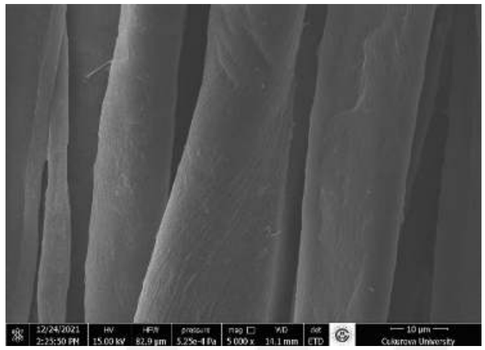


Sample: B1 (Stone washing)

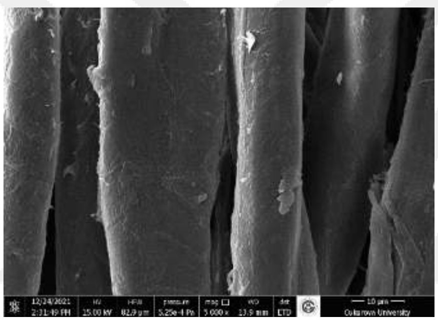


Sample: B1 (Stone & bleach washing)

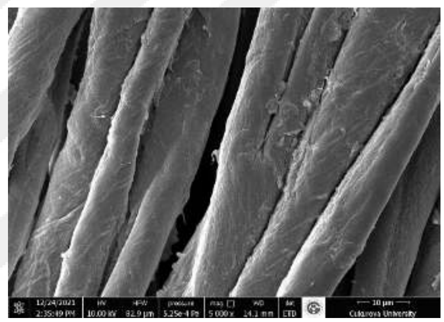
Figure appx 4.2. SEM morphology of B1 denim fabrics (5000X)



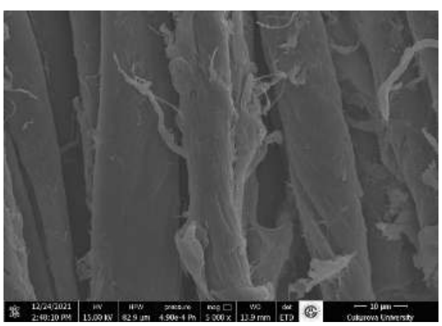
Sample: C1 (Before washing)



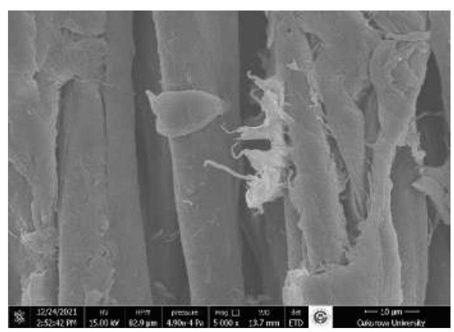
Sample: C1 (Rinse washing)



Sample: C1 (Enzyme washing)

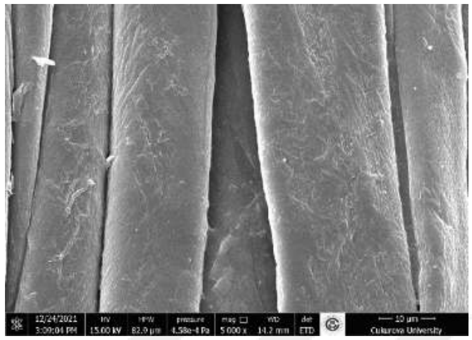


Sample: C1 (Stone washing)

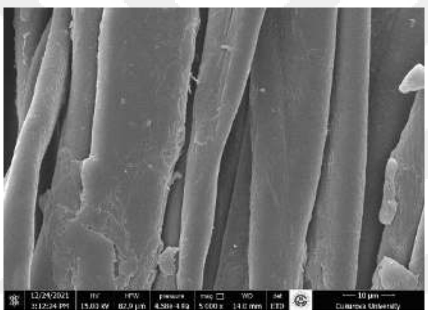


Sample: C1 (Stone & bleach washing)

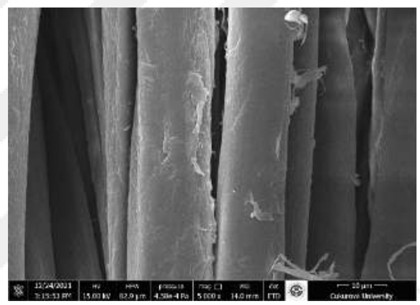
Figure appx 4.3. SEM morphology of C1 denim fabrics (5000X))



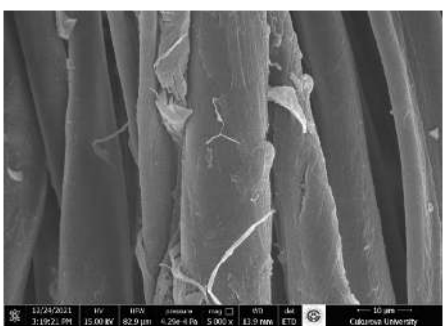
Sample: D1 (Before washing)



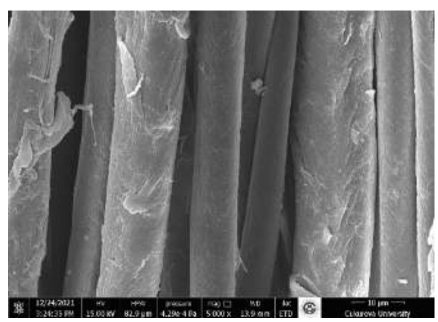
Sample: D1 (Rinse washing)



Sample: D1 (Enzyme washing)

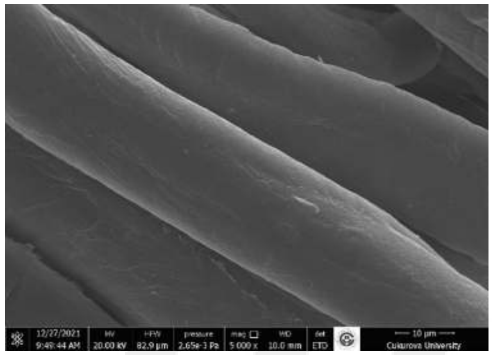


Sample: D1 (Stone washing)

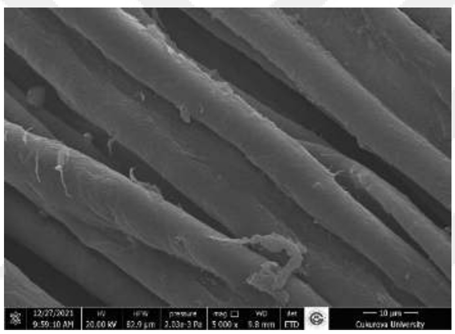


Sample: D1 (Stone & bleach washing)

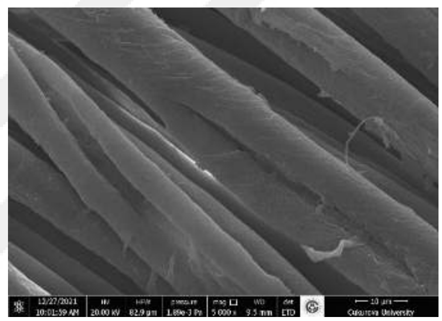
Figure appx 4.4. SEM morphology of D1 denim fabrics (5000X)



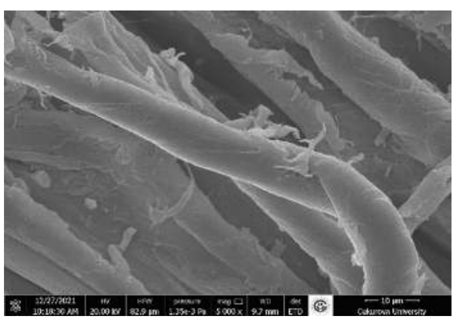
Sample: E1 (Before washing)



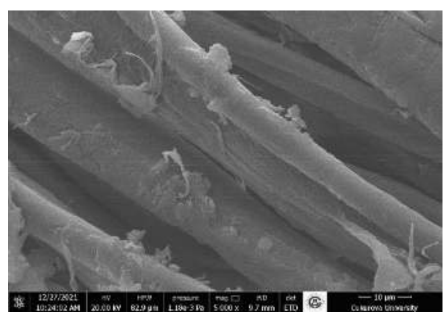
Sample: E1 (Rinse washing)



Sample: E1 (Enzyme washing)

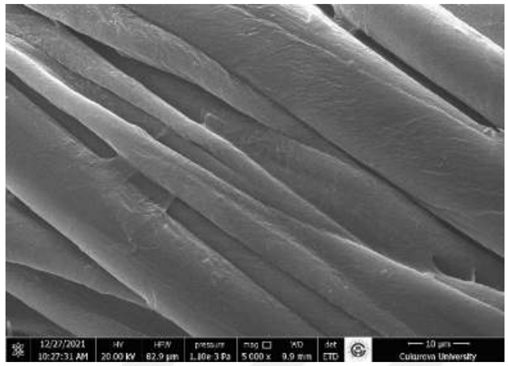


Sample: E1 (Stone washing)

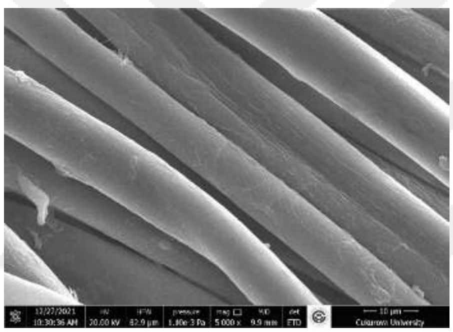


Sample: E1 (Stone & bleach washing)

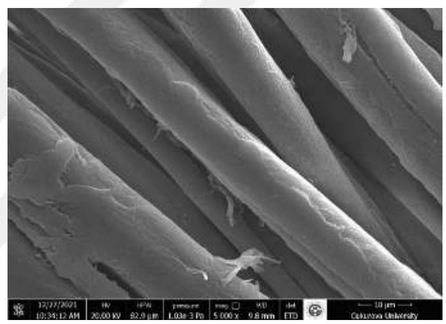
Figure appx 4.5. SEM morphology of E1 denim fabrics (5000X)



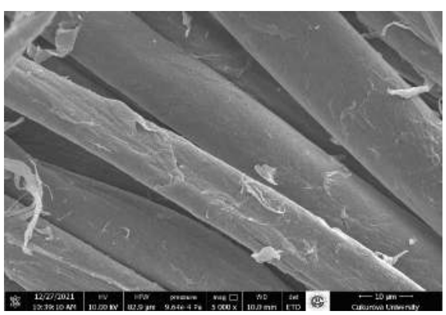
Sample: F1 (Before washing)



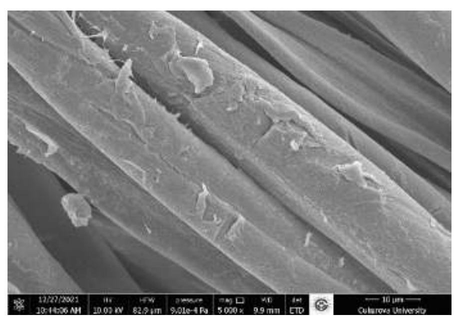
Sample: F1 (Rinse washing)



Sample: F1 (Enzyme washing)

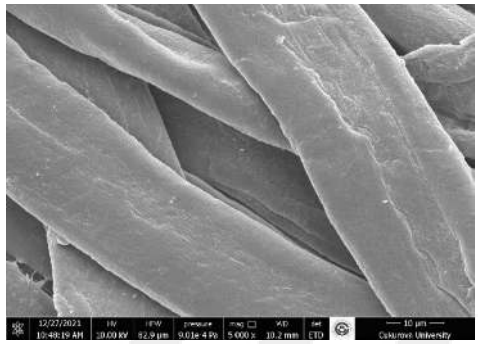


Sample: F1 (Stone washing)

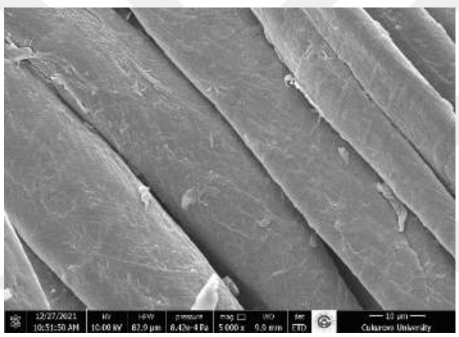


Sample: F1 (Stone & bleach washing)

Figure appx 4.6. SEM morphology of F1 denim fabrics (5000X)

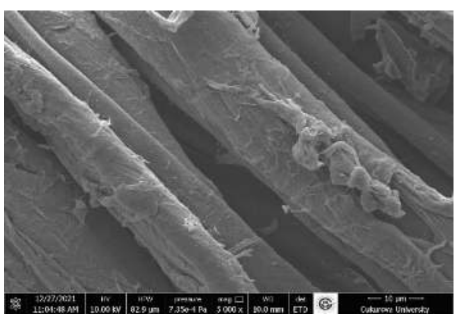


Sample: G1 (Before washing)

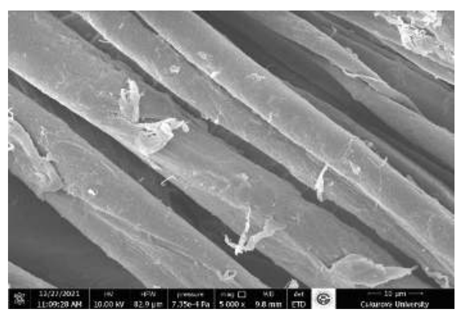


Sample: G1 (Rinse washing)

Sample: G1 (Enzyme washing)

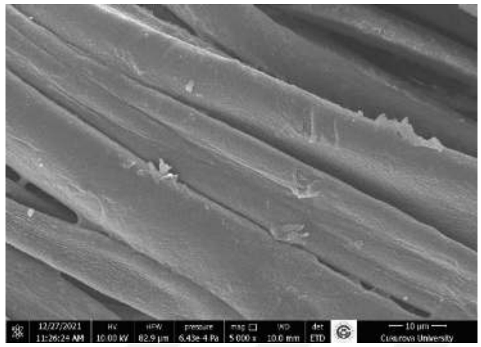


Sample: G1 (Stone washing)

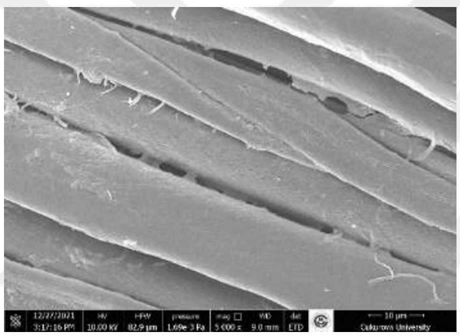


Sample: G1 (Stone & bleach washing)

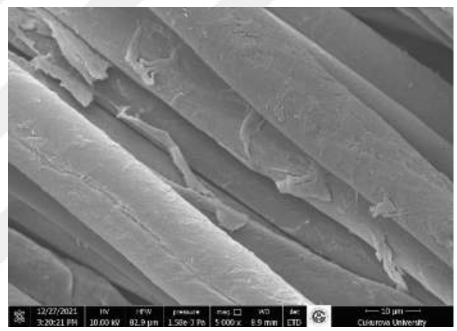
Figure appx 4.7. SEM morphology of G1 denim fabrics (5000X)



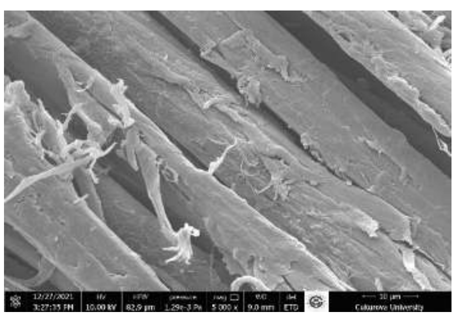
Sample: H1 (Before washing)



Sample: H1 (Rinse washing)



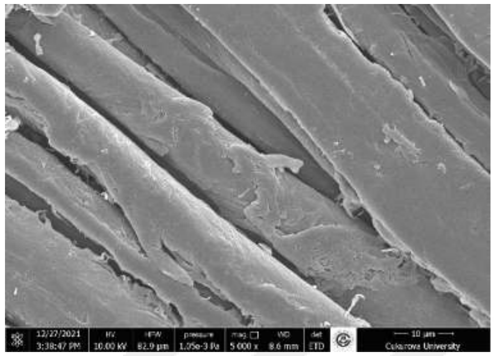
Sample: H1 (Enzyme washing)



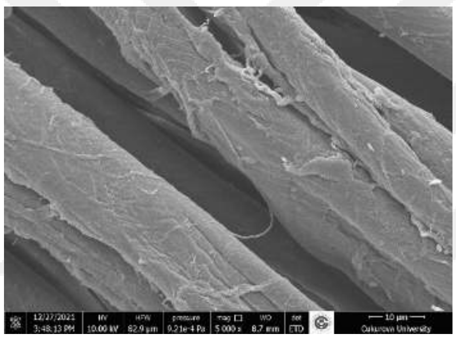
Sample: H1 (Stone washing)

Sample: H1 (Stone & bleach washing)

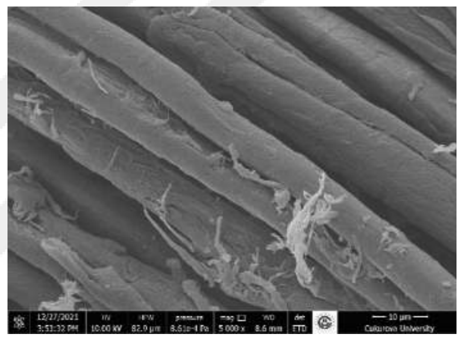
Figure appx 4.8. SEM morphology of H1 denim fabrics (5000X)



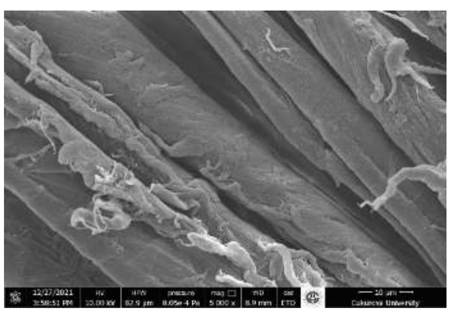
Sample: A2 (Before washing)



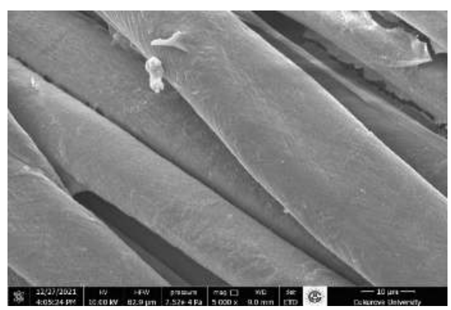
Sample: A2 (Rinse washing)



Sample: A2 (Enzyme washing)

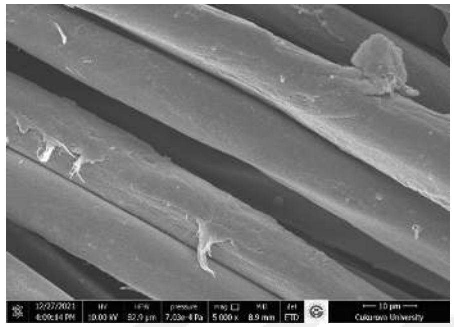


Sample: A2 (Stone washing)

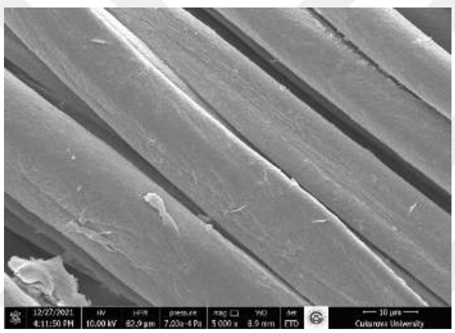


Sample: A2 (Stone & bleach washing)

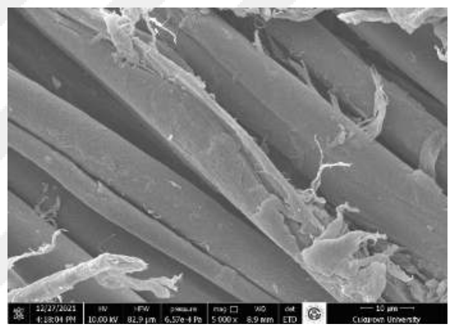
Figure appx 4.9. SEM morphology of A2 denim fabrics (5000X)



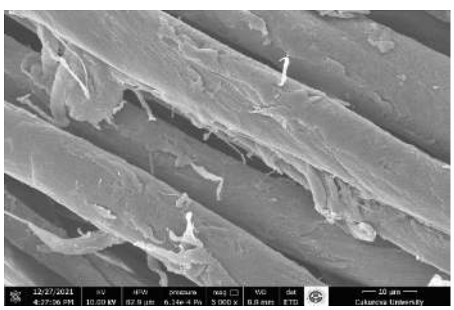
Sample: B2 (Before washing)



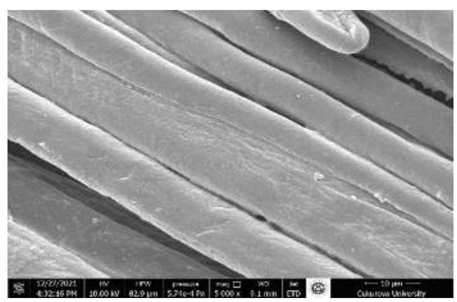
Sample: B2 (Rinse washing)



Sample: B2 (Enzyme washing)

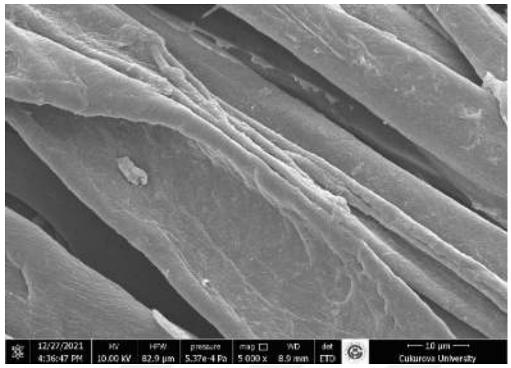


Sample: B2 (Stone washing)

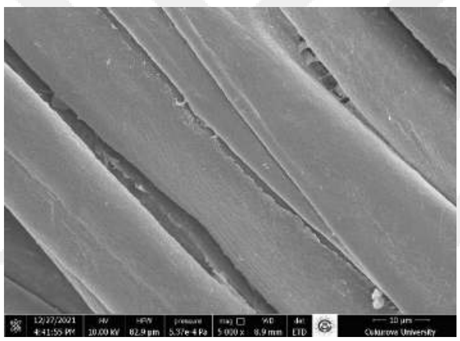


Sample: B2 (Stone & bleach washing)

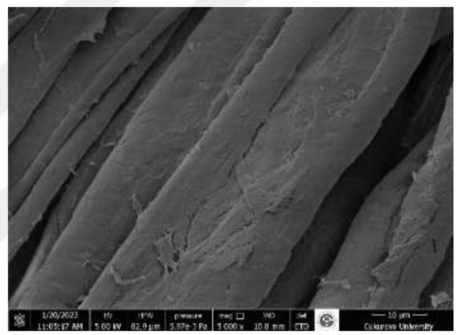
Figure appx 4.10. SEM morphology of B2 denim fabrics (5000X)



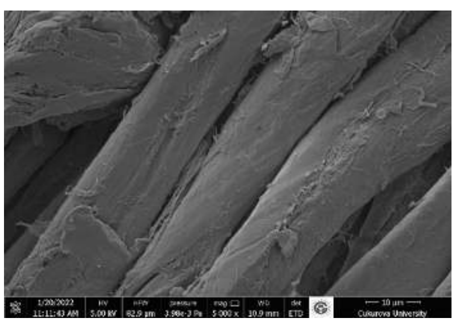
Sample: C2 (Before washing)



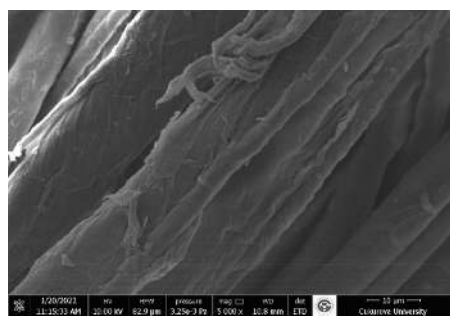
Sample: C2 (Rinse washing)



Sample: C2 (Enzyme washing)

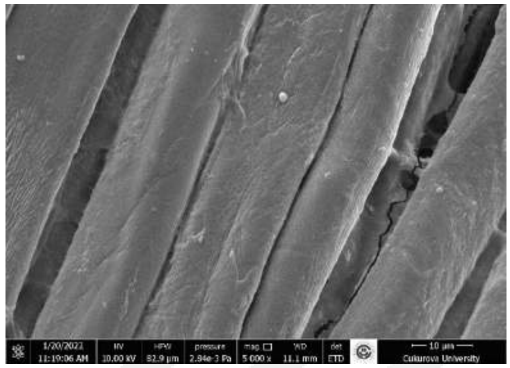


Sample: C2 (Stone washing)

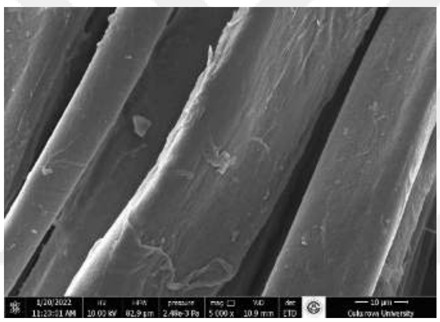


Sample: C2 (Stone & bleach washing)

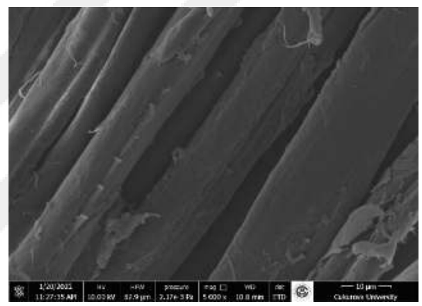
Figure appx 4.11. SEM morphology of C2 denim fabrics (5000X)



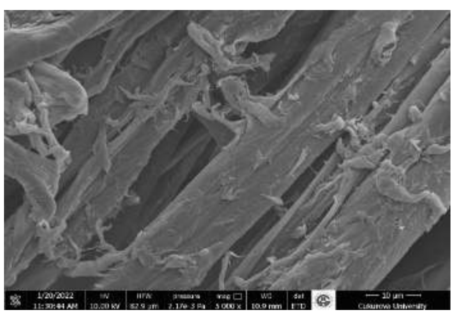
Sample: D2 (Before washing)



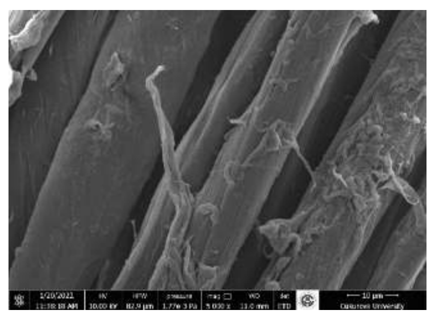
Sample: D2 (Rinse washing)



Sample: D2 (Enzyme washing)

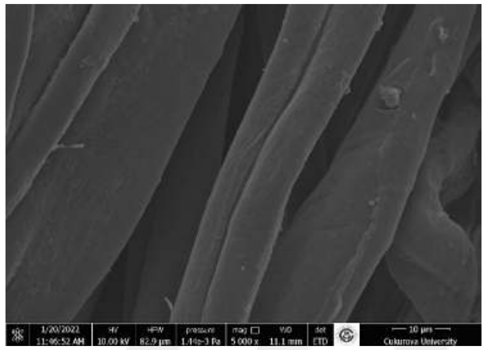


Sample: D2 (Stone washing)

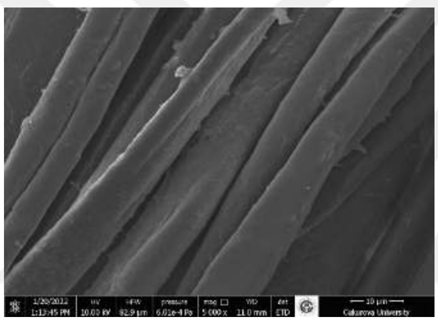


Sample: D2 (Stone & bleach washing)

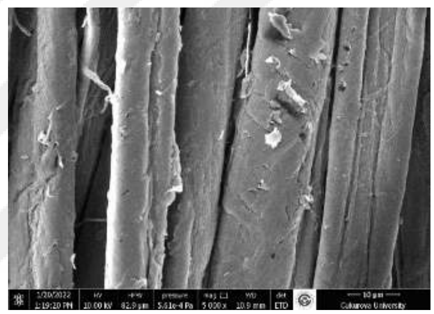
Figure appx 4.12. SEM morphology of D2 denim fabrics (5000X)



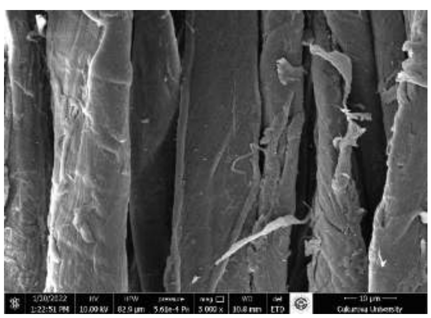
Sample: E2 (Before washing)



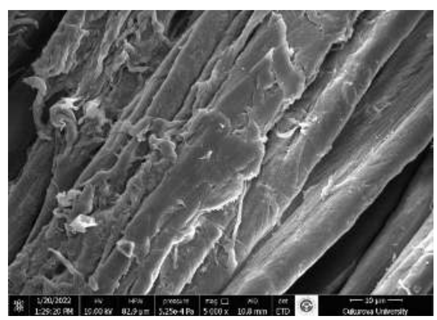
Sample: E2 (Rinse washing)



Sample: E2 (Enzyme washing)

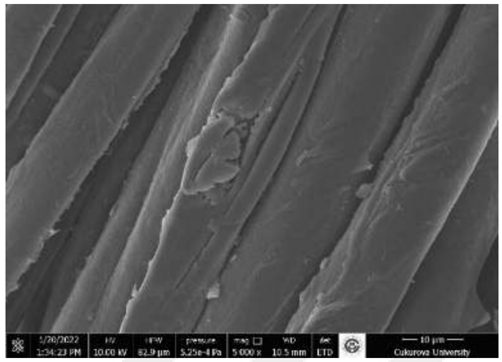


Sample: E2 (Stone washing)

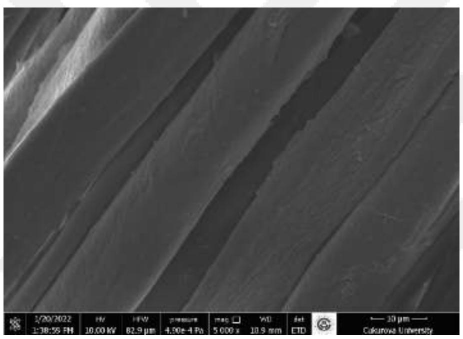


Sample: E2 (Stone & bleach washing)

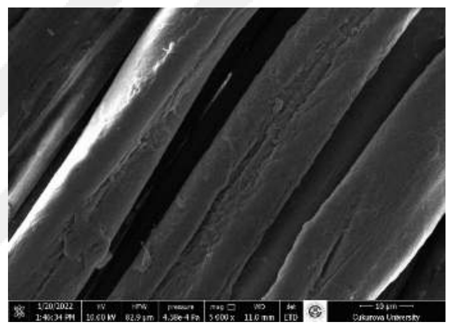
Figure appx 4.13. SEM morphology of E2 denim fabrics (5000X)



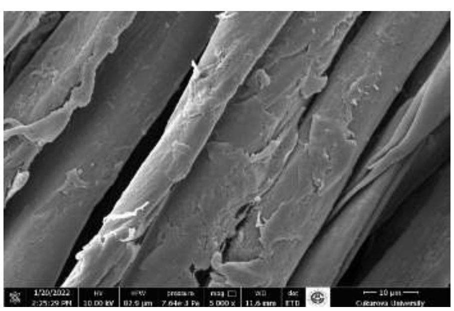
Sample: F2 (Before washing)



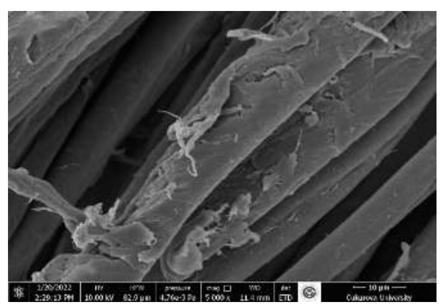
Sample: F2 (Rinse washing)



Sample: F2 (Enzyme washing)

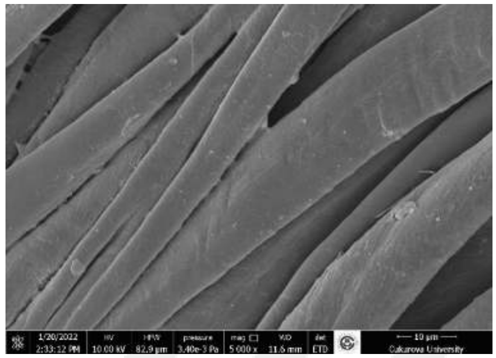


Sample: F2 (Stone washing)

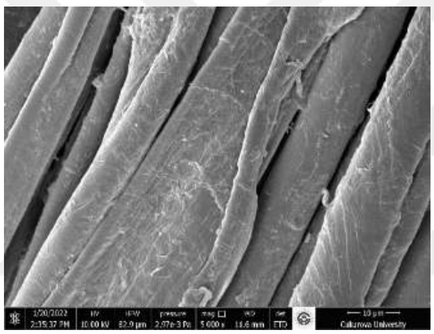


Sample: F2 (Stone & bleach washing)

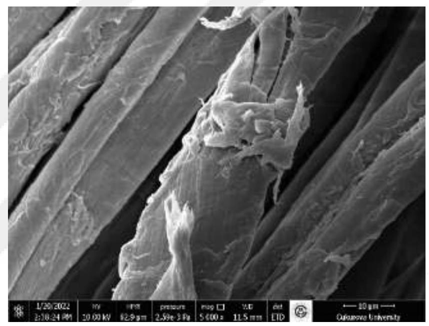
Figure appx 4.14. SEM morphology of F2 denim fabrics (5000X)



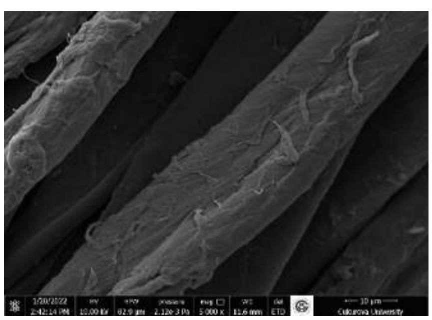
Sample: G2 (Before washing)



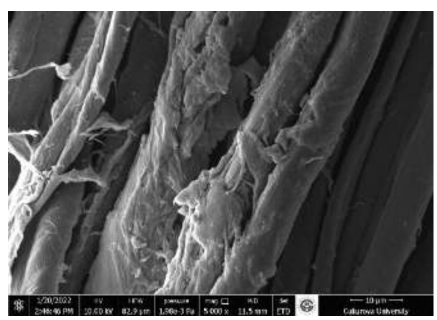
Sample: G2 (Rinse washing)



Sample: G2 (Enzyme washing)

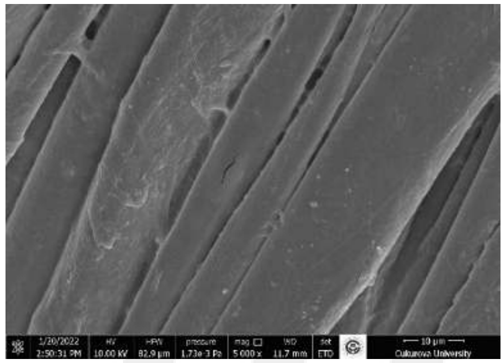


Sample: G2 (Stone washing)

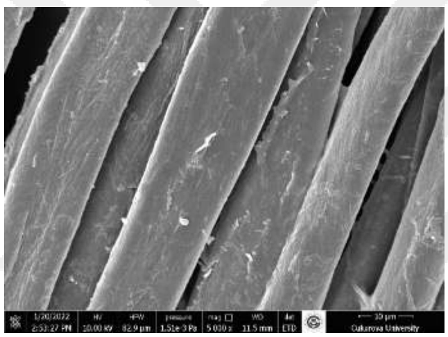


Sample: G2 (Stone & bleach washing)

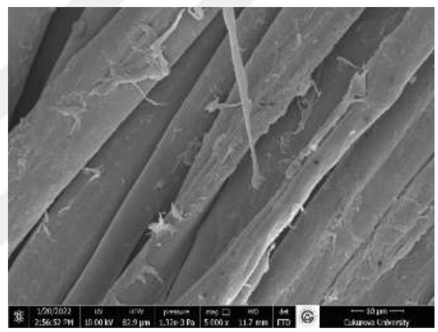
Figure appx 4.15. SEM morphology of G2 denim fabrics (5000X)



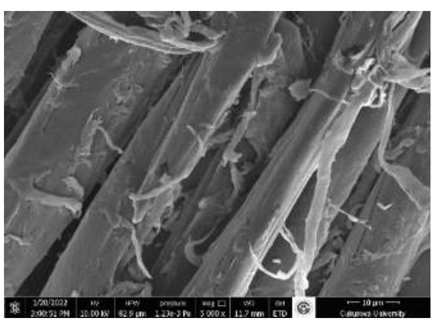
Sample: H2 (Before washing)



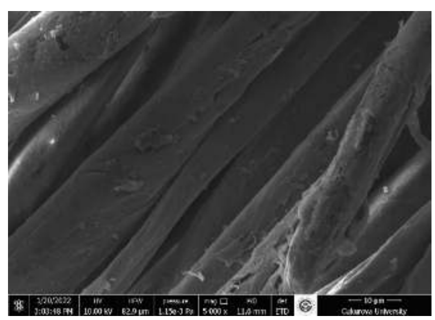
Sample: H2 (Rinse washing)



Sample: H2 (Enzyme washing)



Sample: H2 (Stone washing)



Sample: H2 (Stone & bleach washing)

Figure appx 4.16. SEM morphology of H2 denim fabrics (5000X)