Dokuz Eylül Üniversitesi Mühendislik Fakültesi Fen ve Mühendislik Dergisi
Dokuz Eylul University Faculty of Engineering Journal of Science and Engineering

Basılı/Printed ISSN: 1302-9304. Elektronik/Online ISSN: 2547-958X

# An Experimental Study On Drying Behavior in Digital Printed Fabrics

## Dijital Baskılı Kumaşlarda Kuruma Davranışı Üzerine Deneysel Bir Çalışma

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*Geliş Tarihi / Received: 05.04.2019* *DOI:10.21205/deufmd.2019216320*
*Kabul Tarihi / Accepted: 09.06.2019* *Araştırma Makalesi/Research Article*

*Atıf şekli/ How to cite: ÖZDEMİR, Ş., DOBA-KADEM, F. (2019). An Experimental Study On Drying Behavior In Digital Printed Fabrics. DEUFMD, 21(63), 927-932.*

### Abstract

The human body is known as a thermodynamic system that interacts with the environment. Wetting and drying events are essential factors that affecting the physiological comfort of clothes and depending on many parameters such as fiber type, yarn structure, knitting structure, fabric thickness, or finishing processes etc. For removing the sweat quickly and keep the body dry, knowing wetting and drying behavior of textiles is important in terms of clothing comfort. In this experimental research, cotton and tencel fibers are used which can be known as comfort fibers. By using the yarns produced from these fibers, single jersey knitted fabric surfaces have been formed in the circular knitting machine. The obtained fabrics are colored by digital printing method. Fabrics were tested before and after digital printing because of measuring the effect of digital printing on drying behavior. Interaction of samples with water were analyzed by testing out transfer capillary wetting ability test and drying time determination. It was observed that, the time-dependent rate of drying- thus the mass loss- and transfer capillary wetting ability were consistent with the results found in the literature.

***Keywords:*** *Drying behavior, digital printed, comfort*

### Öz

İnsan vücudu çevre ile etkileşim halinde olan termodinamik bir sistem olarak bilinmektedir. Islanma ve kuruma olayları; lif cinsi, iplik yapısı, örgü yapısı, kumaş kalınlığı, bitim işlemleri gibi birçok parametreye bağlıdır ve fizyolojik giysi konforunu etkileyen çok önemli iki faktördür. Günlük kullanım esnasında, terin vücuttan hızlı bir şekilde uzaklaştırılması ve vücudun kuru kalması için tekstil yüzeylerinin ıslanma ve kuruma davranışlarının bilinmesi giysi konforu açısından önem arz etmektedir. Bu çalışmada hammadde olarak, konfor özelliği sağladığı bilinen pamuk ve tencel lifleri kullanılmıştır. Bu liflerden üretilen iplikler ile yuvarlak örme makinesinde süprem örme kumaş yüzeyleri oluşturulmuştur. Elde edilen kumaşlar dijital baskı yöntemiyle renklendirilmiştir. Numune kumaşlar, dijital baskı işlemi öncesinde ve sonrasında kuruma davranışının nasıl etkilendiğini tespit edebilmek için bazı testlere tabi tutulmuştur. Kuruma davranışı ve transfer kılcal ıslanma kabiliyeti deneysel olarak tespit edilerek numunelerin su ile olan etkileşimi değerlendirilmiştir. Kurumanın zamana bağlı hızının dolayısıyla kütle değişiminin ve transfer kılcal ıslanma kabiliyetinin literatürde var olan sonuçlarla uyumlu olduğu gözlenmiştir.

***Anahtar Kelimeler:*** *Kuruma Davranışı, Dijital Baskı, Konfor*

## 1. Introduction

Fabrics are classified according to their production method. This is shown in Figure 1.

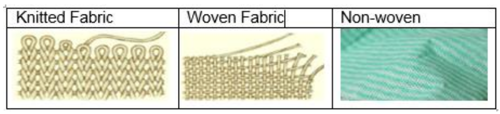


**Figure 1.** Fabrics classifications [1]

Technically, knitting is divided into two main groups (Figure 2). Some of the products obtained by the weft knitting method are; sweaters, vests, jackets, skirts, dresses such as outer garments, undershirts, panties, such as underwear, T-shirts, sweatpants, sweet-shirt, such as combed products, socks, some medical and technical fabrics. Some of the products obtained by warp knitting method are; tulle curtain, lace, swimwear and upholstery fabrics etc. [2].

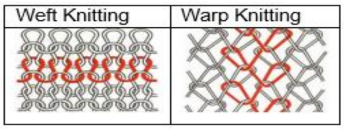


**Figure 2.** Shape of Knits [3]

For the first half of 2018, three main product groups of export increased by between 6,3% and 9,7%. Export of knitted products, which is the most exported product group, increased by 6,3% in January-June 2018 compared to the same period of 2017, reaching 4,5 billion dollars. These values are seen in Table 1 [4].

**Table 1**.Export Values of Knitted Products [4]

Unit: 1000 $

| Product Groups | 2017 January-June | 2018 January-June | Change % |
|---|---|---|---|
| Knitted Products | 4.195.405 | 4.459.075 | 6,3 |
| Woven Products | 2.958.559 | 3.245.000 | 9,7 |
| Made-Up Articles | 949.137 | 1.021.289 | 7,6 |

Source: Exporters Associations Records

Nowadays, fashion trends affect the woven and knitted apparel products. In this context, digital printed products have an important place in the sector in recent years.

The advantages of digital printing can be listed as follows;

*Unit printing costs can be an alternative to conventional printing.

*Print quality is high.

*In conventional methods, pre-print process takes a lot of time and is costly.

*Low meters of fabric can be printed.

*It is environmentally friendly. It saves waste water and energy.

Digital printing applications have different products as textile surface (t-shirt, home textiles, coat etc.) and hard surface (mouse pad, mug, glass, floor covering etc.) applications. In Figure 3, digital printing machine is given which is commonly used in applications and used in this study [5].

**Figure 3.** Digital Transfer Printing Machine [6]

When the literature is examined, it is seen that there are many academic studies about knitting. However, studies on physical properties of printed products have not been found. Examples of some experimental research are given below.

In the study of Oğulata, Doba Kadem and Koç, drying methods and machines used in textile industry are discussed in detail. Content of study, drying machines, conveyor belt dryers and high frequency dryers, which are widely used in textile drying machines, are examined in elaborately [7].

In their study, Mavruz and Oğulata found a linear relationship between air permeability values and yarn count, fabric thickness, stitch frequency and loop length. Supreme structures generally have the highest air permeability values, followed by rib and interlock structures [8].

In Ütebay's study, ink-jet printing on reactive dye-based inks and cotton fabrics investigated the process conditions in which the best results could be obtained in terms of color yield, contour clarity and fastness properties [9].

Onar Çatal et. al. aimed to investigate the effect of rheological properties of pre-treatment thickeners on print quality and color yield. In this study, it was revealed that the rheological properties of the pre-treatment pastes in ink-jet printing have no significant effect on color yield and print quality [10].

The aim of Karakaş is determination of physical and some thermal properties belongs to cotton, polyester and polyamide warp knitting fabrics and evaluation of these results. For this aim, 100% cotton, 100% polyester and 100% polyamid warp knitting fabrics with different constructions were produced. Some selected physical and performance properties of these fabrics were determined experimentaly according to relevant standarts. These properties were listed as weight, fabric thickness, loop frequency, loop yarn length, weave repeat, drying properties of the fabrics and water vapor resistance. Obtained results were interpreted with graphs [11].

Gülşen Bakıcı et. al. investigated the effects of selected construction properties of single jersey fabrics on thickness, air permeability and pilling properties in their study. It is seen that yarn number and loop density have an effect on thickness and air permeability properties. The increase in the stitch density of the fabrics produced with the same number resulted in a decrease in the thickness and air permeability values [12].

In Hajipour and Nateri's research, the effect of weft density on the inkjet printing of polyester was investigated. Lines with different widths were printed in the warp and weft directions, and the print quality was evaluated as the line width. The obtained result showed that the weft density affected the line width and the print quality decreased with an increased weft density. The investigation of the relation between the print quality and the vertical wicking shows a very poor relation [13].

## 2. Material and Method

In this study, single jersey knitted fabrics which produced from 100% tencel and 100% cotton raw materials were colored with digital printing, after that, air permeability and bursting strength tests applied to both samples before and after printing.

Yarn quality properties of samples are given in table 2.

**Table 2.** Yarn properties

| Material | Ne | U% | CVm% | Thick -40% | Thin +50% | Nep +200% | H | Rkm (kgf*Nm) | B-force (gF) | Elongation % |
|---|---|---|---|---|---|---|---|---|---|---|
| Cotton | 23,79 | 8,94 | 11,27 | 9,50 | 5,50 | 9,50 | 7,94 | 15,43 | 383,1 | 6,90 |
| Tencel | 23,62 | 8,36 | 10,57 | 10 | 4,50 | 14,50 | 6,64 | 28,90 | 722,70 | 11,37 |

The needle diagram of single jersey knitted fabrics is shown in figure 4.

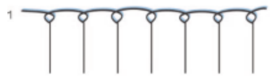


**Figure 4.** Needle diagram of single jersey fabrics

Knitting machine properties that samples were produced are shown in Table 3.

**Table 3.** Knitting machine properties

| Machine/Model | Pus (Diameter)(mm) | Fayn | Needle(Total Number) |
|---|---|---|---|
| Mayer & Cie | 762 | 18 | 1680 |

After knitting, specified simple pattern was applied by digital printing method to fabrics. Fabrics were tested before and after digital printing because of measuring the effect of digital printing. Interaction of samples with water were analyzed by testing out transfer capillary wetting ability test and drying time determination.

Drying behavior test is one of the most important test used to describe comfort properties of fabrics. The test is as follows: 3 sub-samples from different locations of the fabrics were soaked in distilled water for 1 minute. The absorbed water was measured with precision scales. To determine the time-dependent drying behavior, the samples were placed in the dryer at 105°C and weighed every 2 minutes to measure the amount of weight they had lost [14, 15,].

On the other hand, there is no standard test method for measuring transfer capillary wetting. In that, the working principles of transfer capillary wetting are known, a device has been prepared in order to compare the fabrics which differ in transfer capillary wetting ability.

The lower rubber layer provides isolation of the system from environmental influences. The top rubber layer, provides an optimum pressure (approximately 16kg / m) and acting as a cover prevents water vapor from escaping from the system as much as possible. 3 pairs (i.e. 6 pieces) of each of the samples were cut to 10cmx10 cm. One specimen of sample pair was kept in distilled water for a few minutes, then rubbed to remove excess surface water and after being weighed on the electronic scale, properly placed on the lower rubber layer as a wet layer. The other specimen of sample pair was placed on top of the wet layer. Then the top rubber layer was covered on specimens. The appearance of the system is similar to a sandwich. The masses of both the wet layer and the sample were weighed and recorded at 5. 10. 15. 20. 25. and 30. Minutes [17].

## 3. Results

Test results for analyzing the effect of digital printing on fabric properties are given in this section. In tables, C means cotton, T means Tencel, B means before printing, A means after printing. The fabric coding is done in this way.

Thickness and weight results of fabrics are given in Table 4.

**Table 4.** Determination of weight and thickness

| | | Weight($g/m^2$) | | | | | Thickness(mm) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | Ort. | St. Dev. | 1 | 2 | 3 | Mean | St. Dev. |
| C | B | 114,39 | 115,62 | 111,20 | 113,74 | 1,86 | 0,41 | 0,41 | 0,42 | 0,4133 | 0,004714 |
| | A | 109,78 | 108,41 | 105,23 | 107,80 | 1,91 | 0,39 | 0,40 | 0,39 | 0,3933 | |
| T | B | 100,29 | 99,2 | 100,22 | 99,87 | 0,54 | 0,38 | 0,38 | 0,37 | 0,3766 | |
| | A | 95,15 | 94,50 | 97,23 | 95,63 | 1,16 | 0,36 | 0,35 | 0,36 | 0,3566 | |

The following table shows the frequency properties of fabrics based on TSE - TS EN 14971 Standard [18]. After printing process, it's seen that either wale density or course density decreased.

**Table 5.** Physical qualities of fabrics

| Before digital printed | | | | | | | |
|---|---|---|---|---|---|---|---|
| Sample | Wale Density (wale/cm) | | | | | Mean | St. Dev. |
| Cotton | 10,24 | 10,24 | 10,24 | 10,24 | 10,04 | 10,20 | 0,08 |
| Tencel | 8,66 | 8,46 | 9,25 | 9,45 | 9,65 | 9,09 | 0,46 |
| Sample | Course Density (course/cm) | | | | | Mean | St. Dev. |
| Cotton | 11,81 | 12,01 | 12,20 | 12,20 | 12,60 | 12,17 | 0,26 |
| Tencel | 11,81 | 11,42 | 11,61 | 11,81 | 11,81 | 11,69 | 0,16 |
| After digital printed | | | | | | | |
| Sample | Wale Density (wale/cm) | | | | | Mean | St. Dev. |
| Cotton | 9,84 | 9,45 | 9,25 | 9,06 | 9,84 | 9,49 | 0,31 |
| Tencel | 9,06 | 8,66 | 8,66 | 8,66 | 9,06 | 8,82 | 0,19 |
| Sample | Course Density (course/cm) | | | | | Mean | St. Dev. |
| Cotton | 12,20 | 11,81 | 12,20 | 11,81 | 12,20 | 12,05 | 0,19 |
| Tencel | 11,42 | 11,81 | 11,81 | 11,42 | 11,81 | 11,65 | 0,19 |

A decrease in fabric weight was observed due to the decrease in frequency after digital printing.

In Table 6, transfer capillary wetting results of fabrics were shared. These results are the amount of dry specimen's weight which has been wetted by wet specimen of sample pair.

**Table 6.** Wetting quantities of dry specimens

| Wetting quantities of dry specimens (g) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 5' | 10' | 15' | 20' | 25' | 30' |
| Cotton | B | 1.374 | 1.408 | 1.422 | 1.435 | 1.441 | 1.451 |
| | A | 1.355 | 1.361 | 1.375 | 1.386 | 1.392 | 1.396 |
| Tencel | B | 1.709 | 1.852 | 1.901 | 1.925 | 1.929 | 1.922 |
| | A | 2.07 | 2.14 | 2.143 | 2.134 | 2.116 | 2.095 |

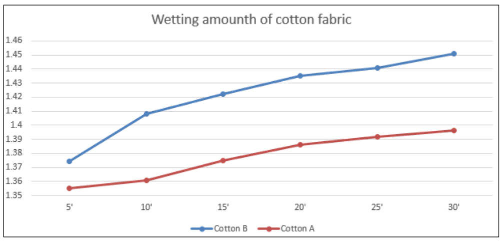


**Figure 5.** Wetting amount of dry cotton fabrics

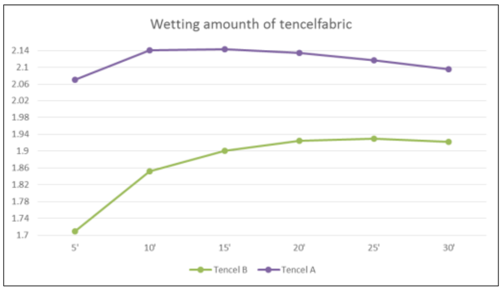


**Figure 6.** Wetting amount of dry tencel fabrics

According to the results, tencel and cotton exhibited different behaviors because of the fact that their fiber structures. As, tencel was more absorbent than cotton, the wetting occured more rapid. So tencel fabrics have reached an earlier equilibrium. Wetting continued in cotton for the first 30 minutes.

The time-dependent drying behavior of fabrics measured and total weight loss are given in Table 7.

When the table and graphics were examined, it was seen that the drying behaviors of both fabrics were similar. Fabrics from both raw materials have lost weight before and after printing.

The water evaporates from the fabrics as the drying process takes place. In Table 8, amount of water evaporating from fabrics was given.

While the drying process is taking place, the weight of the fabrics decreases and correlatively, the amount of evaporating water increases.

**Table 7.** Temporal mass change of fabrics

| | COTTON | | TENCEL | |
|---|---|---|---|---|
| | Before Print | After Print | Before Print | After Print |
| 0' | 0.920 | 0.860 | 1.331 | 1.197 |
| 2' | 0.884 | 0.806 | 1.295 | 1.154 |
| 4' | 0.853 | 0.763 | 1.272 | 1.130 |
| 6' | 0.830 | 0.728 | 1.253 | 1.097 |
| 8' | 0.806 | 0.698 | 1.233 | 1.069 |
| 10' | 0.777 | 0.674 | 1.208 | 1.051 |
| 12' | 0.752 | 0.656 | 1.182 | 1.034 |
| 14' | 0.733 | 0.634 | 1.156 | 1.014 |
| 16' | 0.709 | 0.611 | 1.129 | 0.996 |
| 18' | 0.692 | 0.586 | 1.101 | 0.980 |
| 20' | 0.670 | 0.564 | 1.069 | 0.962 |
| 22' | 0.650 | 0.531 | 1.042 | 0.937 |
| 24' | 0.628 | 0.509 | 1.018 | 0.915 |
| 26' | 0.604 | 0.489 | 0.992 | 0.896 |
| 28' | 0.584 | 0.467 | 0.968 | 0.880 |
| 30' | 0.564 | 0.442 | 0.940 | 0.860 |
| 32' | 0.542 | 0.423 | 0.916 | 0.845 |
| 34' | 0.523 | 0.403 | 0.889 | 0.827 |
| 36' | 0.499 | 0.377 | 0.862 | 0.807 |
| 38' | 0.473 | 0.356 | 0.834 | 0.792 |
| 40' | 0.451 | 0.332 | 0.815 | 0.772 |

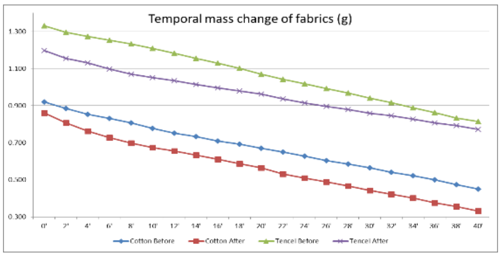


**Figure 7.** Temporal mass change of fabrics

**Table 8.** Amount of water evaporating from fabrics

| | COTTON | | TENCEL | |
|---|---|---|---|---|
| | BEFORE | AFTER | BEFORE | AFTER |
| 0' | 0.000 | 0.000 | 0.000 | 0.000 |
| 2' | 0.036 | 0.114 | 0.036 | 0.043 |
| 4' | 0.067 | 0.157 | 0.059 | 0.067 |
| 6' | 0.090 | 0.192 | 0.078 | 0.100 |
| 8' | 0.114 | 0.222 | 0.098 | 0.128 |
| 10' | 0.143 | 0.246 | 0.123 | 0.146 |
| 12' | 0.168 | 0.264 | 0.149 | 0.163 |
| 14' | 0.187 | 0.286 | 0.175 | 0.183 |
| 16' | 0.211 | 0.309 | 0.202 | 0.201 |
| 18' | 0.228 | 0.334 | 0.230 | 0.217 |
| 20' | 0.250 | 0.356 | 0.262 | 0.235 |
| 22' | 0.270 | 0.389 | 0.289 | 0.260 |
| 24' | 0.292 | 0.411 | 0.313 | 0.282 |
| 26' | 0.316 | 0.431 | 0.339 | 0.301 |
| 28' | 0.336 | 0.453 | 0.363 | 0.317 |
| 30' | 0.356 | 0.478 | 0.391 | 0.337 |
| 32' | 0.378 | 0.497 | 0.415 | 0.352 |
| 34' | 0.397 | 0.517 | 0.442 | 0.370 |
| 36' | 0.421 | 0.543 | 0.469 | 0.390 |
| 38' | 0.447 | 0.564 | 0.497 | 0.405 |
| 40' | 0.469 | 0.588 | 0.516 | 0.425 |

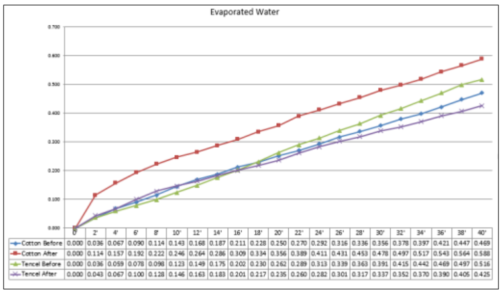


**Figure 8.** Water evaporating from fabrics

## 4. Discussion and Conclusion

After the results are analyzed, the following inferences could be made:

- After the printing, the time-dependent water loss increased in cotton and decreased in the tencel. This is due to the differences in the structural properties of tencel and cotton.

- Transfer capillary wetting continued in cotton after 30 minutes. Tencel had reached almost close results quickly.

Suggestions;

- Fabrics can be produced by using other raw materials.

- The parameters of the digital printing process can also be effective on the comfort characteristics. They can change.

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