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Research Article

# Evaluation of Air Permeability of Knitted Fabrics at Various Washing Intervals

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**Abstract:** The air permeability of fabrics is one of the most important factors to be considered in making comfortable clothing for consumers. It helps to transport moisture in the form of vapours from the inner skin to the outer environment. This study aims at determining the rate of airflow through the prepared knitted fabrics after various washing intervals. Circular knitted fabrics with 100 % cotton and a blend of cotton and polyester having a ratio of 70 % / 30 % were made by setting different construction parameters. Prepared fabrics were evaluated for their air permeability by following the ASTM D737-1996 test procedure. Then these fabrics were laundered with standard procedure and evaluated after various intervals. It was concluded from the obtained results that construction parameters such as kind of polymer, loop length, hairiness, yarn count, number and size of pores and their distribution play a major role in determining the air permeability of knitted fabrics. Moreover, an increase in washing cycles also reduces the airflow through the fabric.

**Keywords:** Air Permeability, Knitting, Loop Length, Pore Size, Washing

## 1. INTRODUCTION

Knitting is one of the most commonly used fabric construction techniques followed by inter looping of yarns running in the direction of either warp or weft. There are a number of rows made with these loops, each loop is pulled through the previous loop and the process goes on. Knitting can be done flat or circular [1]. Knitted garments are comfortable to wear due to their extensibility in their looped structure which fits easily to the body of the wearer. These garments are preferred by consumers due to their easy-to-care properties. These are light in weight and are more porous as compared to other construction techniques [2]. When a fabric is manufactured, a large area covered by a total volume is air space. The pattern of distribution of airspaces has a great influence on certain properties like protection against air, warmth, breeze, wind, dust or rain, thermal conductivity, absorbency, water or moisture absorption etc. [3].

Natural fibers like cotton are hygroscopic in nature and they allow greater absorbency. They can hold moisture in them. On the other hand, synthetic materials like polyester can hold only a small amount of moisture in them. A combination of both types of fibers can present good results by combining the characteristics of both fibers in a single fabric [4].

Air permeability is one of the functional characteristics of textile materials. It is one of the important parameters to consider while evaluating the comfort of fabrics [5]. Air permeability can be defined as the volume of air measured in mm passed per second from 100 $mm^2$ of a textile material at a water head pressure of 10 mm [6]. It is the ability of a fabric to permeate the air through its structure at a given rate under specific conditions for a given time period. Here porosity plays a major role, and it is well understood by various researchers that there exists a strong statistical relationship between air permeability and the porosity of fabrics [7]. The size, amount and shape of pores in a fabric have a great impact on the air permeability of fabrics. The distribution of pores on a substrate either made of knitting or weaving, gives a prediction about how much air can flow through the pores [8].

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**Table 1.** Construction parameters of knitted fabrics

| Sample Code | Yarn No. (Ne) | Length of Loop (cm) | Course per cm | Wale per cm | Thickness (cm) | Mass (g/m$^2$) |
|---|---|---|---|---|---|---|
| AC-1 | 40 | 0.27 | 25 | 14 | 0.012 | 100.21 |
| AC-2 | 20 | 0.25 | 23 | 12 | 0.013 | 101.01 |
| AB-1 | 40 | 0.24 | 21 | 11 | 0.012 | 105.21 |
| AB-2 | 20 | 0.22 | 19 | 11 | 0.014 | 107.52 |

The evaluation of the air permeability of fabrics is an important aspect to be considered in determining their quality and performance. It helps to identify the intrinsic behaviour of fabrics and must be studied for each manufactured fabric. Different types of construction techniques such as knitting, weaving, felting, napping etc. have a significant effect on the rate of airflow passed through the surface of fabrics. There are multiple factors that can help the manufacturer to alter while making the fabrics in accordance with air permeability; thus providing comfort to the wearer.

Evaluation of the air permeability of knitted fabrics is important to study from commercial and technical points of view. It is the source of physiological comfort to the wearer. As clothing serves as the second skin by protecting the human body from negative external factors. The geometry of textile structure plays an important role in heat transfer between the body and the external environment. Air permeability is the key indicator in this regard. Thus, the thermal properties of raw materials such as fiber and yarn making the textile substrate should be assessed for providing comfort. The main goal of this study was to investigate the rate of airflow through the knitted fabrics after different laundering intervals. A standard test procedure was adopted to measure the rate of airflow through different types of knitted fabrics. Fabrics with different construction parameters were manufactured to note the differences among each tested sample. Results were analyzed statistically through Analysis of Variance (ANOVA).

## 2. MATERIALS AND METHODS

The circular knitted fabrics were manufactured by the following various construction parameters (Table 1). Two types of fibers such as Cotton 100 % and a blend of Polyester / Cotton 70 % / 30 % were used to prepare simple knit fabrics with medium and tight tightness. Each prepared sample was varied in its yarn number, length of the loop, number of courses, number of wales per centimetre, thickness and mass.

All the prepared fabrics were then conditioned prior to testing for 24 hours in a standard testing environment with a temperature of 21 °C ± 1 °C and relative humidity at 65 % ± 2 % by following the ASTM-D 1776 test method [9]. The air permeability of samples was evaluated by following ASTM standard D737 [10]. A test specimen was cut with the help of a template from each group of samples. The size was approximately 6x6 inches [11]. It was ensured that all specimens were free from wrinkles, creases or folds. These were not taken from or near the edge as properties may vary. Each test specimen was placed on the platform of the air permeability tester. The test was performed at a water pressure of 12.7 mm. The specimen was placed on a circular disk in such a way that it overhung from all sides at least one inch. The fabric was clamped tightly with the ring so that it would not shift from its place. The mounting of specimens was done carefully over the orifice to avoid any air leakage due to the cut edges. In order to protect the cut edges and avoid chances of error, a guard ring around each specimen was fixed. It was raised and held between two parallel plates. On the manometer, the dropped pressure read off directly.

All the knitted samples were washed by following instructions given in the standard M6 Monograph of the American Association of Textile Chemists and Colorists [12]. The front-load machine was used with an agitation speed of 45 rpm. The temperature was set at 60 °C for 12 minutes. The 0.1 $gL^{-1}$ standardized AATCC detergent was added in each cycle. Spinning was done at 1300 rpm for further 12 minutes. The samples were then tumble-dried for one and a half hours at the speed of 68 °C. A total of 10 washing cycles were given to the samples. After every 5 cycles, these specimens were labelled and put in a separate packet and assessed for their air permeability at 0 wash, 5 washes and 10 washes.

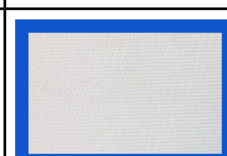
## 3. RESULTS AND DISCUSSION

All the obtained data was assessed through Statistical Package for the Social Sciences (SPSS) and presented in the form of mean values and Standard Deviation. The data was observed on repeated observations at intervals of 0-wash, 5 washes and 10 washes, Analysis of Variance (ANOVA) repeated measurement analysis of variance was used to see the difference made with each washing interval. P-value ≤ 0.05 was taken as significant in determining the results. Data was also depicted through multiple lines charts for better understanding.

It was found that the rate of air permeability of fabrics decreased with the increasing number of washing cycles. The washing and drying of fabrics can affect the rate of airflow passing through these materials. It has been observed that the wear and tear conditions can significantly damage the pores of the fabric structure; the lint may adhere to their surface and restricts the airflow [13]. There is a significant difference between the air permeability of studied fabrics. One of the possible reasons is that single-knit fabrics are composed of a porous structure and this porosity increases air permeability [14]. It has been observed that sample AC-1 and AC-2 has a better rate of air permeability as compared to AB-1 and AB-2. These samples are made with 100% cotton and for this reason, they are associated with hydrophilicity which promotes better air porosity. On the other hand, a fabric made with a combination of cotton and polyester has hydrophobic areas too in its structure that restrict the easy flow of air between the yarns (Table 2). The absorbency of fabrics also affects the air permeability behavior of fabrics. The results are similar to the findings of Guo [11]. It is also observed that the hydrophilicity of cotton fibers makes them swell after absorbing water or any other wet treatment. This swelling brings a change in the dimensional stability and air porosity of fabrics. It also decreases the air passage between component yarns [15].

It was investigated that the size and the total number of pores are the two contributing factors to the air permeability of fabrics. It depicts the phenomenon that the structure of the substrate is very important. As the number of pores increases and the size becomes large, the passage of air will be more to travel through the fabrics [16]. The rate at which air flows through the fabric is largely dependent on its porosity. As porosity increases, the airflow also increases within the fiber and vice

**Table 2.** Air permeability of samples at various washing intervals

| Sample code | Air permeability (cm$^3$/sec/cm$^2$) | | | | | | p-value | Sample photograph |
|---|---|---|---|---|---|---|---|---|
| | 0-wash | | 5-washes | | 10-washes | | | |
| | Mean | SD | Mean | SD | Mean | SD | | |
| AC-1 | 162.21 | 1.21 | 156.32 | 2.15 | 148.25 | 1.25 | 0.00 |  |
| AC-2 | 155.38 | 1.15 | 145.26 | 1.89 | 137.56 | 1.93 | 0.01 |  |
| AB-1 | 121.45 | 1.34 | 111.36 | 1.69 | 102.15 | 1.24 | 0.00 |  |
| AB-2 | 115.35 | 2.10 | 102.53 | 2.12 | 93.54 | 1.55 | 0.01 |  |

versa [17]. A direct relationship can be observed between air permeability and porosity. It has been observed that fabrics with low porosity result in low air permeability through their structures. One of the main reasons for low air permeability was the lesser number of spaces among yarns, especially in the case of coarse materials. The results are similar to the current study in that as the length of the loop increases, the rate of airflow also increases [18].

The length of the loop also influences the air permeability of fabrics. The effect of structural indicators in the form of loop length was determined and it was found that an increase in the length of the loop in knitted fabrics, makes an increase in the porosity which results in greater permeability to air [3]. This concept is well understood by the fact that as the loop length increases, the spacings between course and wales are also increased, thus the size of the pores enlarges and helps in easy airflow [16]. It is well observed from the findings that the loop length is greater for a sample AC-1 and thus its air permeability is also higher followed by AC-2, AB-1 and AB-2 as shown in Figure 1.

It is also investigated from the results that an increase in laundering cycles, leads to a decrease in air permeability of all specimens. One of the possible reasons of low air permeability is the buildup of lint due to rubbing during laundering cycles. Abrasion caused by washing procedures causes the fibers to accumulate on the surface of fabric and cover the air spaces among yarns. Thus, it restricts the air flow to pass through them [19-20]. P-value less than 0.05 also suggests the same that there is a significant difference in the air permeability of fabrics after each washing interval.

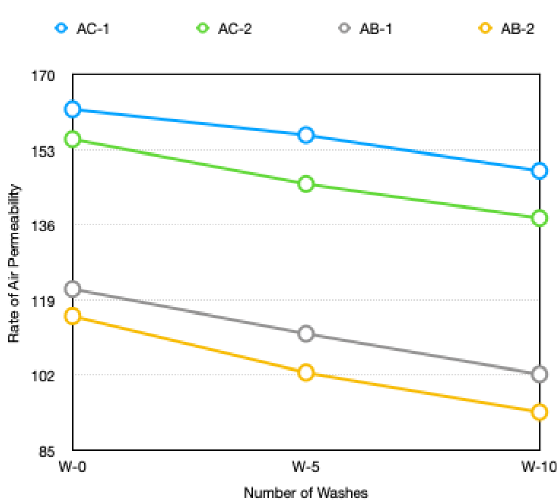



**Fig. 1.** Air permeability of fabrics

The Fineness of the yarn is another important factor to consider while evaluating the air permeability of fabrics. The finer the fiber, the greater the porosity. It may be due to the reduction in fabric mass because due to increased fineness. On the other hand, coarse yarns reduce the air spaces among yarns and lead towards reduced air porosity and air permeability [21]. Moreover, fine yarns do not prone to yarn hairiness and it has been observed by many researchers that low hairiness also increases the rate of airflow in the fabrics. In fact, hairiness fills up the space among yarns on the substrate and restricts the airflow to pass through them [22]. Thinner fabrics also facilitate the airflow through them. Fine fibers with less hairiness help the air to pass through them with ease [23]. It was also observed by [24] that non-washed samples had the highest rate of air permeability in fabrics. Single-layered fabrics are more permeable to air as compared to double-knit or layered fabrics. It has been observed that double-knit fabrics have more thickness thus restricting the passage of airflow [25]. The air permeability of knitted fabric was affected by certain factors such as its structure, yarn number, thickness, mass and density [26]. It has been investigated that as the yarn becomes smoother and finer, the air permeability increases due to the smaller number of yarns across the structure. It was due to the reason that the pores of the yarns among loops were opened and allowed the air to pass through them [27].

## 4. CONCLUSION

It was concluded from the findings that construction parameters in knitted fabrics have a significant effect on the air permeability of finished products. The rate of airflow decreased with an increase in washing cycles. It was found that thickness, yarn number and length of the loop were the most important determinants of air permeability through the knitted fabrics. Fabrics permeable to air provide comfort to the wearer. This study was limited to laboratory experiments; other follow-up studies can lead to measuring the comfort level of the wearer through wear trials. Moreover, future studies can be conducted to determine the rate of flow through woven and non-woven fabrics manufactured with different construction parameters. A comprehensive comparison between various construction techniques can be made against air permeability through these materials. The findings can be served as a helpful tool in designing and manufacturing comfortable clothing products. It can provide a framework for establishing new guidelines for knitted products in relation to their air permeability and porosity.

## 5. CONFLICT OF INTEREST

The authors declare no conflict of interest.

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