Investigation of Moisture Transportation Properties of Knitted Fabrics Made From Viscose Vortex Spun Yarns

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Josphat Igadwa Mwasiagi
Moi University

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Salome Kyatuheire, Li Wei, PhD, Josphat Igadwa Mwasiagi, PhD

Donghua University, Song Jiang District, Shanghai, Shanghai CHINA

Correspondence to:
Salome Kyatuheire email: salome.kyatuheire@gmail.com

ABSTRACT

Moisture transportation through fabrics is one of the important parameters which affect clothing comfort. The combination of different factors which include fiber, yarn and fabric structure will yield varying degrees of clothing comfort. This research work concentrated on the use of viscose fibers spun on the vortex spinning system. Six knitted fabric samples were produced and tested for moisture transportation characteristics, which included air and water moisture permeability.

The results indicate that all structures had high wicking levels in the wale than in the course direction. Similarly, all fabrics had poor drying abilities, but good water vapor permeability. There was a good correlation between air permeability and water vapor permeability of the fabrics. This was attributed to the fiber in the yarn not the fabric structure.

INTRODUCTION

The design of fabrics for special applications where moisture transportation is one of the key factors may involve the selection of fiber, yarn, and fabric manufacturing systems. Fabric can be manufactured using knitting, weaving, or nonwoven technologies. Yarn can be manufactured using conventional ring spinning. Advances in research have lead to the commercialization of other yarn manufacturing technologies such as rotor spinning, air jet spinning, friction spinning and vortex spinning. Vortex spinning is a refinement of air jet spinning, which is reported to have several advantages such as higher yarn strength, higher production rate, and lower production cost [1-2]. Vortex yarns are gaining popularity due to the possession of unique properties, which include low hairiness, exceptional pilling and abrasion resistance, quick drying, high moisture absorption, and diffusion properties. These unique properties could enable the use of vortex yarns, when designing fabrics with unique clothing comfort characteristics [3-5]. The low hairiness enables the use of vortex yarns in knitting without waxing while better abrasion resistance of yarns aids better running properties during knitting. While vortex spinning produces yarn of favorable properties at competitive cost, the selection of the fiber used to make the yarn is important. Being among the oldest regenerated cellulosic fibers, viscose fiber is more absorbent when compared to cotton. Therefore it can be used for the production of garments where absorption of perspiration from the human skin is paramount. Hydrophilic fibers like viscose can absorb liquids into the fiber structure thus preventing the spread of liquids, including sweat, along the fabrics. These liquids can be wicked away from the skin through the fabric to the outside where they evaporate, thereby keeping the body cool. Therefore a combination of viscose fiber, which is hydrophilic in nature, vortex spinning, which can be used to manufacture yarn of unique properties, and knitting, a fabric formation system which produces fabric with unique porosity and thickness properties, could produces fabrics with unique moisture transportation properties.

According to Saville [6] moisture can be transmitted through fabrics in two ways; (i) by diffusion and (ii) by wicking. Water diffusion through fabrics could be affected by fabric structure, and the measurement of air flow through fabrics can be used as a guide to the amount of water which can be transmitted through fabrics. A textile assembly that is permeable to air is in most cases permeable to water. However, water permeability should be controlled to ensure that the required clothing comfort is attained. The mechanism of water wicking through a knitted fabric involves the filling up of loops in the fabric with water followed by filling up of the spaces between the fibers in the yarn [7-8]. The air permeability of the fabrics must also be considered, for it will affect the rate at which the moisture is retained or lost by the fabric. The rate of fabric wicking and air permeability is affected by the knit structure, type of fiber (including its chemical and physical properties), fabric mass per unit area (especially for multi-layered fabrics), and knit structure parameters (loop length and loop density) [9-15]. Fabric structures with higher porosity exhibit better wicking characteristics. Using hydrophilic fibers like viscose, will lead to a modification of the water wicking properties. This may lead to a controlled loss of water vapor leading to better clothing comfort. For a multi-layered knitted fabric, the relationship between air and water vapor permeability may not be the same as that of the single layer fabric. The addition of extra fabric layers has a significant effect on the correlation of water vapor and air permeability. Wilbik-Halgas et al [16] reported that in double layered knitted fabric, air permeability is affected by fabric thickness and porosity. The aforementioned factors did not record any significant influence on water vapor permeability. A study of the relationship between selected fabric characteristics (which included wicking) and knitted fabric structure using acrylic knitted fabrics undertaken by Yanilmaz and Kalaoglu [17] revealed that there existed significant difference between the wicking in the course and wale direction. Liang et al [18] studied the drying time of various fabric assemblies and concluded that the drying time during wear is affected by other clothing ensembles of the wearer. Apart from the characteristics of the fabric, water vapor transportation through a textile assembly is greatly influenced by the vapor pressure difference between the skin and the ambient air [19], therefore the environment in which the fabric is going to be used must be considered, when designing fabrics, especially those which are meant to manage water vapor.

While considering water transportation properties for knitted fabric, it is important to consider the effect of the washing process (laundering), since knitted fabric are normally affected (structurally) after washing [20]. When dealing with knitted fabrics made from viscose fibers, the issue of the washing process becomes even more important, since viscose knitted fabrics has been reported to undergo structural changes after the washing process [21].

The aim of this work was to study the behavior of viscose fiber on the moisture management properties of fabrics from vortex spun yarns. The effect of fabric laundering on selected water transportation characteristics was also examined. This study is expected to add to the pool of knowledge in fabric design, especially for fabrics which are expected to offer special water vapor management properties.

MATERIALS AND METHODS

The yarns used in this research were produced from viscose staple fibres with a staple length of 38 mm. The fibres were carded on a carding machine followed by three stages of drawing. The drawn fibres were finally converted into yarn of nominal count 37 Tex on a vortex spinning machine at a production speed of 370m/min. The yarns produced were tested in the yarn testing laboratories under standard testing conditions. Yarn unevenness was measured on a YG133B/M yarn irregularity analyser at a speed of 400 m/min in accordance to ASTM D1425-96 test method. Hairiness values were measured using a YG172 hairiness tester at a speed of 30 m/min according to the ASTM D5647.

Six different structures were knitted on a flat V bed knitting machine. The structures were single jersey (SJ), rib 1x1 (R1), rib 2x2 (R2), full cardigan (FC), half cardigan (HC), and Milano rib (MR). After knitting, fabrics were subjected to dry relaxation in a standard room condition of a temperature of 21±2^{o}C and relative humidity of 65± 2% RH. The fabric dimensions which included wales/cm, courses/cm, stitch density, loop length, weight (g/cm^2) and fabric thickness were determined. Fabric thickness was measured using a Shirley thickness meter. Given that knitted fabrics have been reported to undergo structure modification after washing (laundering), the fabric samples were divided into two sets; before laundering and after laundering. The after laundering samples were treated to a one laundry cycle in a domestic washing machine. They were then dried and preconditioned in standard testing conditions for 48 hours before testing. The experiments carried out to study the moisture characteristics of the knitted samples were water wicking, air permeability, drying time, and evaporation rate.

Wicking tests were performed on the course and wale sample strips following the AATC TM 197-2011 standards. The diagrammatic representation of the equipment used is shown in *Figure 1*. Fabric strips 250 mm long and 30 mm wide were hung vertically in a bath containing distilled water and wet dye. The level to which water had risen was measured after every five minutes for a total of 30 minutes. Drying tests were carried out on specimens of 20x20 cm, which were weighted using an electronic balance. Water equivalent to 30% of the fabric dry weight was used to wet the fabrics and their weight was taken at an interval of 5mins to ascertain the Water Evaporation rate. This is in line with the test for quick drying capability of fabrics contained in ASTM D 4935-99 standards.

Water vapor permeability tests were conducted according to GB/T 12704.1-2009 standards. Fabrics samples stretched over Calcium chloride anhydrous were heated in a thermo-hygrostat for 30 min, their weight taken, and then steamed for 1hr and the final weight taken to assess water vapor permeability.

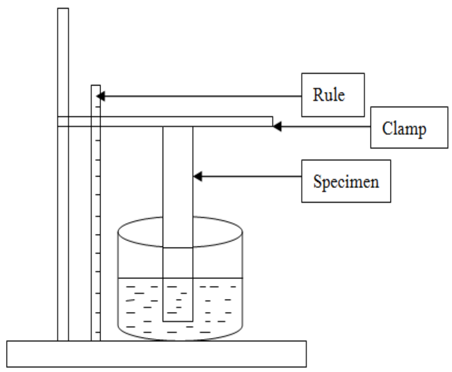

FIGURE 1. Diagrammatic representation of the fabric wicking test apparatus.

Air permeability was measured using the numerical air permeability tester YG461E according to ASTM D 737. A differential pressure of 100 Pa/mmH_2O, permeation rate of 50 and a nozzle diameter of 6, 10 and 12 depending on the fabric density were used.

Analysis of variance (ANOVA) was performed to determine the statistical significance of any difference seen in the properties of various structures.

For tests where fabrics were tested before and after laundry, paired t-tests were performed to get the significance of the laundering process on the fabric properties. Levene's test was also used to ascertain the homogeneity of means.

RESULTS AND DISCUSSIONS

The Characteristics of The Yarn and Fabric Samples

The yarn and fabrics samples were measured according to the procedures discussed in the material and methods sections. The results are given in *Table I* and *Table II.* According to the results the full cardigan (FC) samples were thicker than all the other samples, while the single jersey samples were the thinnest.

TABLE I. Vortex yarn characteristics.

Yarn property	Values
CV of yarn count, %	10
U%	8.0
Thin places (-50%) per km	0
Thin places (-30%)per km	123
Thick places (+50%)per km	1
Neps (+200%) per km	51
Hairiness index	0.13

TABLE II. Dimensional characteristics of the fabrics samples.

Fabric code	SJ	R1	R2	FC	HC	MR
Wales per cm	5	5	5	3	3	5
Courses per cm	8	7	10	6	6	10
Stitch density (CW/cm^2)	36.8	35.8	47.0	18.8	17.7	47.0
Loop length (mm)	0.7	1.3	1.3	1.1	1.3	0.8
Weight (g/$cm^{2)}$	0.03	0.04	0.04	0.04	0.04	0.05
Thickness (mm)	1.1	1.8	2	2.5	2.3	2.1

The Effect of Fabric Structure and Laundering Process on Fabric Wicking

The wicking experiments were performed for the fabrics, before and after laundering. The wale-wise results are given in *Figures 2 and 3.* From *Figure 2*, full cardigan (FC) has the highest wicking rate and rib 1x1 (R1) has the lowest. The rate of wicking as seen in the *Figure 2* was rapid in the first five minutes. Beyond this, wicking continued to rise but at a significantly lower rate. This is the same for the fabrics given in *Figure 3.* As explained by Zhuang et al [8], the initial rapid wicking rate followed by a slower wicking rate could be due to gravitational forces that interfered with the capillary rise of the liquids through the fabric since the wicking test was done using fabrics hanged in a vertical direction. Benltoufa et al [7] explained the aforementioned wicking phenomena in fabric wicking to be as a result of rapid absorption of water in the macro structure followed by a slower transmission of water through the micro structure of the fabric. This phenomenon could enable the fabric to be able to control water transportation in fabric in a manner that could lead to better clothing comfort.

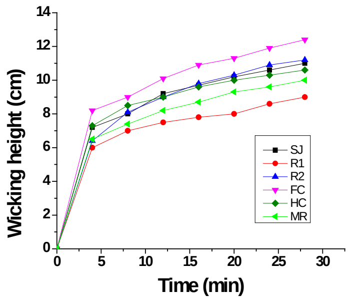

FIGURE 2. Fabric wicking in the wale-wise direction before laundrying.

Upon laundering, all fabric samples displayed narrower inter-fabric differences (*Figure 3*). This may be an indication of a positive correlation between laundering and wicking. From *Figures 2 and 3,* it can be seen that all samples showed a difference in the wicking property after laundering. A paired t-test indicated a significant difference between the fabrics wicking ability before and after laundry. Levene's test for equality of means of the wicking height at the end point (30 mins) also indicated a significant differnce for the wicking heights before and after laundering.

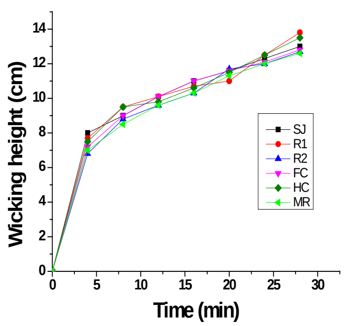

FIGURE 3. Fabric wicking in the wale-wise direction after laundrying.

The course-wise wicking behavior of fabrics as shown in *Figure 4*, showed a similar trend of wicking order as displayed before laundry by the wale-wise direction. The similar wicking trends for both course-wise and wale-wise directions before laundering may point to the fact that fabric structure could be a major factor affecting wicking.

Figure 5 demonstrates that laundered fabrics have higher wicking heights compared to those not laundered. This may be due to the fact that laundered fabrics have shorter loop lengths which make the fabrics tight. It can also be seen from the graph that the order of wicking capability changes after laundering. Similarly, the wicking heights in the course wise direction is lower than wale-wise direction for both cases that is before and after laundry. This can be attributed to the fact that the wales act as capillaries through which water is wicked vertically.

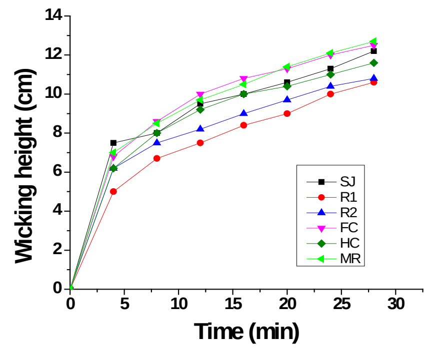

FIGURE 4. Course-wise fabric wicking before laundering.

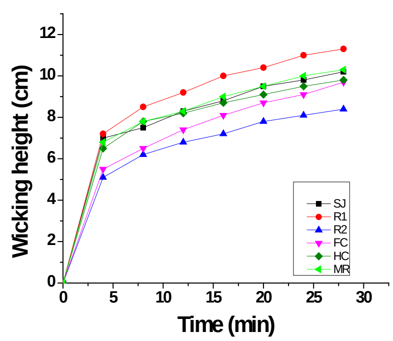

FIGURE 5. Course-wise fabric wicking after laundering

The Effect of Fabric Structure and Laundering Process on Air permeability

The air permeability results are given in *Figure 6*. As portrayed in *Figure 6*, all fabric samples tested showed decreased air permeability characteristic after laundering. This could be a result of fabric shrinkage which reduces fabric porosity.

Considering the six samples single jersey (SJ) exhibited the highest air permeability value while the lowest values were recorded by the half cardigan (HC) and the full cardigan (FC) samples. These results indicated that air permeability was negatively correlated to fabric thickness, which is in total agreement with Wilbik-Halgas [16] results.

To explore the air permeability of the knitted fabrics further, the samples were laundered and the effect of the laundering process on air permeability examined.

The results indicated a comparatively different trend where the laundered Milano (MR) and single jersey (SJ) allowed less air to pass through. Fabric washing is therefore critical when dealing with knitted fabrics.

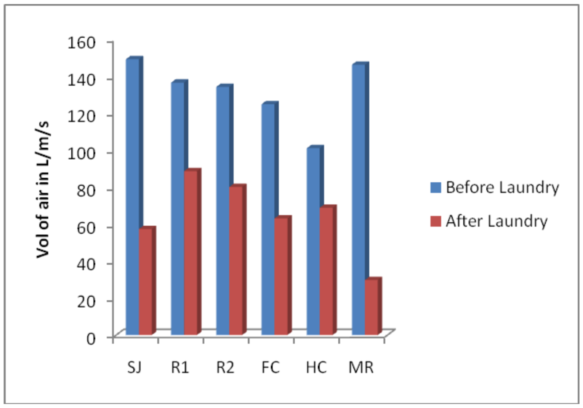

FIGURE 6. Effect of Knit structure on fabric air permeability

The laundering process could have caused structural changes to the samples. Given that viscose fiber is hydrophilic, there could be possibilities structural changes due to fiber moisture absorption and desorption hysteresis.

The Effect of Fabric Structure and Laundering Process on Water Vapor Permeability

The results of the water vapor permeability experiments performed in this research are given in *Figure 7*. A paired t-test was performed on the results and it showed that there existed a significant difference in the water permeability values of the different structures before and after laundry. This is a pointer that laundering processes have a crucial impact on fabric water vapor permeability. In addition, ANOVA tests indicated a statistically significant difference in the permeability values of the different structures.

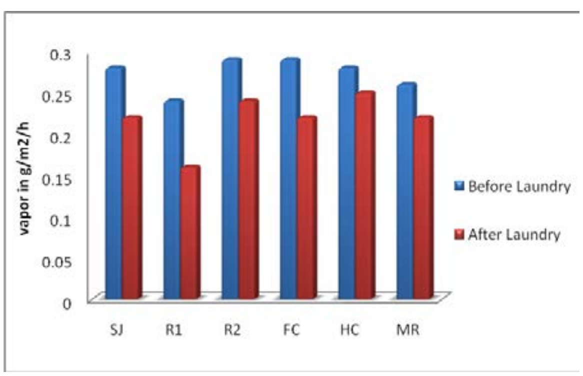

FIGURE 7. Effect of knit structure on fabric Water vapor permeability.

The trend of the water vapor permeability did not show a correlation with fabric thickness as reported by Prahsarn et al [22] whose samples were made from polyester an hydrophobic fiber. The samples in this study were made of viscose, an hydrophilic fiber. There could be a possibility that the type of fiber (viscose) and/or the type of knit structures spun could have contributed to this unexpected result.

The Effect of Fabric Structure on Evaporation Rate and Drying time

To study the fabric ability to lose water, the evaporation rate and the drying time experiments were undertaken.

The drying properties of the fabrics samples as shown in *Figure 8*, indicated that the half cardigan (HC) and full cardigan (FC) samples have poorer drying properties. This could be due to the fact that they were comparatively thicker than the other samples as shown in *Table II*. The Rib 1x1 (R1) sample was among the thinner samples, so it was not surprising, when it recorded one of the best drying characteristic. The behavior of the single jersey (SJ) sample was however unexpected. Generally higher drying ability corresponds to lower fabric thickness.

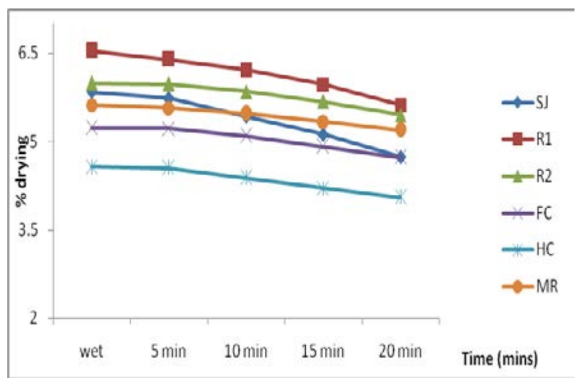

FIGURE 8. Effect of change of knit structure on the fabric drying time.

The results of fabric evaporation rate experiments are given in *Figure 9*, which showed that the Single Jersey (SJ) and the rib 1x1 (R1) samples had the highest evaporation rate. The Full cardigan (FC), rib 2x2 (R2) and the Milano rib (MR) samples showed the lowest evaporation. The evaporation results conform to the generally accepted results that water vapor evaporation rate is negatively correlated to fabric thickness [17].

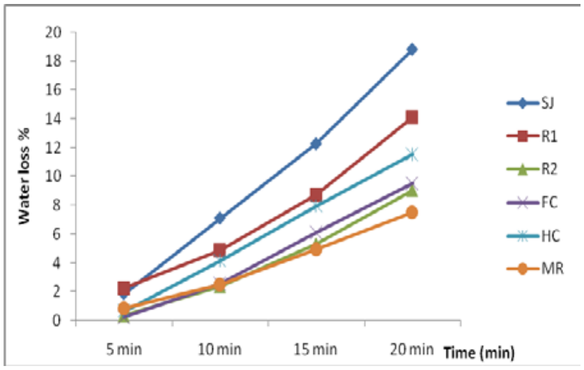

FIGURE 9. Effect of knit structure on water evaporation rate.

CONCLUSION

This research investigated the moisture transportation properties of knitted fabrics made from vortex yarns for six knit structures (single jersey, rib 1x1, rib 2x2, full cardigan, half cardigan and milano rib).

The results obtained in this research indicate that water wicking properties, air permeability, water vapor permeability, evaporation rate, and drying time were affected by the type of knit structure. It was also established that the laundering process altered the above mentioned properties of the knitted samples tested. Air permeability and water evaporation rate for the knitted fabric samples showed negative correlation with fabric thickness. Air and water permeability showed a significant decrease when the samples were subjected to laundering.

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AUTHORS' ADDRESSES
Salome Kyatuheire
Li Wei, PhD
Josphat Igadwa Mwasiagi, PhD
Donghua University
2999 North Renmin Road
Song Jiang District
Shanghai, Shanghai 201620
CHINA