American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-9, Issue-1, pp-01-10
www.ajer.org
Research Paper Open Access

# The Influence of Sports Socks Structures on Its Functional Properties

S. A. El Tantawy(1) , R.A.M. Abd El-Hady (2), A. M. M. el Said Qandeel(3)
*(1) Professor of Spinning Technology, Spinning, Weaving & Knitting Department. Faculty of Applied Arts, Helwan University. Egypt.*
*(2) Professor of Engineering & Knitting Technology, Spinning, Weaving & Knitting Department.Faculty of Applied Arts, Helwan University. Egypt.*
*(3) Senior Textile Engineer, Projects Specialist at Industrial Development Authority, Egypt.*
*Corresponding Author: S. A. El Tantawy*

***ABSTRACT:*** *In recent years, the demands of socks have changed with the development in technology and the raised living standards. Therefore, it was necessary to study the possibility to improve the production of weft knitting sports socks to meet the employment needs, climatic changes and achieve the required quality and functional performance properties by controlling the machine adjustment and using different constructions. To achieve the goals of this study, the construction of weft knitting sports socks and the parameters associated with are studied. In the experimental study, two structures (Jersey-Rib) of sports socks were knitted from cotton and regenerated cellulosic bamboo blend with nylon and elastane in different ratios. All socks were knitted on the same hosiery machine by controlling the machine adjustment and using different constructions. results of testing of Calf length sports socks are illustrated and discussed in order to optimize the functional properties of sports socks design.*

***KEYWARDS:*** *Bamboo Fibers, Elastane Yarns, Hosiery Machines Weft Knitted Structures.*

---

Date of Submission: 25-12-2019 Date of acceptance: 03-01-2020

---

## I. INTRODUCTION

Socks is type of cloth manufactured by the knitting technique, it covers the foot and leg complete or partial. There are many types of socks used for casual, sports and medical purposes. Socks make your foot comfortable and warm. Socks are available in various colors, sizes and materials. Raw Material is very important quality and performance factor in Socks [1].

Now a day's high tech circular knitting machines are used having a series of knitting needles in a cylinder formation. The yarn packages are placed on the creel portion and fed according to the pre-designed program through the fed system of machine [2]. The knitting is the primary step in quality process. Sports socks are checked at/ from the knitting machine. Before the knitting process is start it is ensured that the raw material selected is of the desire quality and the yarn fed in the creel portion is according to the pre-define program and pattern of knitting after the few samples prepared the grey socks is inspected to meet the requirement such as size, no of wales & courses heel & foot stretch ribs pattern etc [3].

Quality of raw material and knitting type and construction are the main parameters concern with the comfort and performance. For the manufacturing of sports socks there are number of fibers available and used according to the customer and end use purpose. The Raw material used for sports socks manufacturing are among the following fiber types many type of fiber content / mix blends: Cotton, Coolmax, Merino Wool, Nylon, Acrylic, Polyester, Lycra, Sulcool, Elastic, Ring spun Yarn, Combed Yarn, Melange , Twisted Yarn, Polypropelene, Regenerated yarn and many more [4]. The quality in sports socks can vary depending on many factors. These can be summarized as; the type and properties of the used yarn, knitting conditions and machine properties, finishing method and the used finishing materials and the form giving operation applied on socks [5].

Cotton is a giant of natural fibers and has big market share in textile products, essentially it is the backbone and basic foundation of the world's textile trade and industry, cotton fibers cover the major markets due to attractive properties of cotton natural fiber, these properties can be divided into three parts, one is according to chemical structure, second according to physic structure and the third is using process [6]. According to using process, Cotton fiber has large amorphous portion and this is why the air can be in and out through cotton fiber. So, the fabric made by cotton fiber is quite comfortable to use. Cotton fiber has high absorbency power and this is why this fiber can be died properly and without any harassment. The strength of cotton fiber is quite good. The drape-ability of cotton fiber is awesome. The sewing efficiency on Cotton made fabric is easier and comfortable than other fiber.. Cotton fiber is a versatile fiber which has wide variety of uses [7].

Nylons are one of the most common polymers used as a fiber. Another name for this material is polyamide, Thus due to the characteristic amide groups in the backbone chain [8]. Nylon forms the second most important man made textiles after polyester. Nylon resins are noted for their performance properties including high tensile strength, excellent abrasion, chemical and heat resistance, and low coefficient of friction. Hence they are used in engineering plastics with applications in the automotive industry, electronics and industrial components and films for food packaging, as well as fabric, carpeting, sportswear and recreational equipment. Nylon is blended in with other fabrics to add durability and strength, and dries quickly [9].

Elastane (Spandex) was invented in 1937, but is often known by trade names such as Lycra (launched by DuPont in 1958 and now owned by Invista) and Dorlastan [10]. Stretch fibers are readily adopted in sportswear in addressing overall comfort, shape and fit, freedom of movement, support and compression. This material adds a little bit of stretch and allows the sock to fit properly. Usually only a small percentage (2% to 5%) of the sock’s fabric content is made up of these materials. Spandex yarn or Lycra has variable properties which ensure its high utility as the core in elastic core -spun yarn. These include [11]:

- High modulus (power at stretch).
- Fine and very fine yarn counts.
- Capacity to heat set.
- Clear, dull and bright luster's.
- Capacity to dye, if required.

Bamboo is one of the fastest growing plants in the world, growing to maximum height in about three months and reaching maturity in three and four years, spreading rapidly across large areas. Because of the relatively quick growing time and the ability to be grown without fertilizers or pesticides, the fiber source is currently being marketed as an ‘eco-green-sustainable fiber’[12]. Bamboo yarn is soft, durable with moisture-wicking and insulating properties. It also has some antibacterial properties and therefore is odor resisting. Bamboo fiber is currently being used in products such as casual sportswear, base layers, T-shirts, yoga clothing and socks. Bamboo fiber breathes and ventilates exceptionally well because of the hole structure of the fiber. The sports socks are cool even in hot weather. Since bamboo naturally contains anti-bacterial components, the sports socks will always smell fresh and are therefore also suitable for people with allergies. The sports socks feels very soft, are wrinkle free and does not absorb odors. The bamboo used for the production of these sports socks is organically grown [13].

In weft knitting structures, Plain (Single Jersey) is produced by the needles knitting as a single set, drawing the loops away from the technical back and towards the technical face side of the fabric. Plain is the simplest and most economical weft knitted structure to produce and has the maximum covering power. In Rib structure, two sets of needles are operating in between each other so that wales of face stitches and wales of reverse stitches are knitted on each side of the fabric. Single or simple ribs have more than one plain wale but only one rib wale, such as 2×1, 3×1,etc. The extensibility of the fabric widthwise is approximately twice that of single jersey. The lengthwise extensibility is essentially the same as in single jersey [14].

The main goal of this study is to reach the best methods of hosiery machine adjustment for sports socks by using different types and ratios of raw materials (cotton- bamboo- nylon-elstane) with various structures (Jersey-Rib) to achieve the required functional properties.

## II. MATERIALS AND METHDS

In the experimental study, Twelve samples of sports socks were knitted from cotton and regenerated cellulosic bamboo blend with nylon and elastane in different ratios. All socks were knitted on the same hosiery machine by controlling the machine adjustment and using different constructions.

### 2.1. Yarns Specifications
#### 2.1.1. Bamboo Yarns
Table (1) shows the technical specification of used bamboo yarns.

**Table (1) Technical Specification of Used Bamboo Yarns**

| Material Blend % | Bamboo 100% | Standard, Equipment |
|---|---|---|
| Material yarn | 30/1 Bamboo | |
| Count ne | 29.64 | ASTM D 1907-97 |
| Ne CV% | 1.04 | |
| Uster irregularity CV% | 12.4 | ASTM D 1425-96 |
| Imperfections in 1000m | | |
| Thin places (-40) | 69 | ASTM D 1425-96<br>USTER TESTER 3 |
| Thin places (-50) | 1 | |
| Thick places (+35) | 169 | |
| Thick places (+50) | 15 | |
| Neps (+140) | 280 | |
| Neps (+200) | 46 | |
| Neps (+280) | 10 | |
| Hairiness | 5.14 | V 400m/min |
| Strength CN/Tex | 14.71 | ASTM D 2256 97<br>USTER TENSPRAPID 3<br>V 5000m/min |
| Strength CV% | 9.18 | |
| Elongation | 13.88 | |
| Twist /m | 809 | ASTM D 1422-98<br>ZWEIGLE D 312 |
| Twist /inc | 20.54 | |
| Twist factory (ALFA) | 3.75 | |
| Twist CV% | 1.9% | |
| Cone angel | 5° 57´ | |
| Wax | Yes | |
| Test conditions | CONES, 24 HOUR CONDITIONED | TEMP(°C):20.0+/-2.0<br>HR (%): 6.5+/-2.0 |
| | ISO 9001 : 2008<br>Registration No: 12 100 3674 TMS | |

#### 2.1.2. Cotton Yarns
Table (2) shows the technical specification of used cotton yarns.

**Table (2) Technical Specification of Used Cotton Yarns**

| Material Blend % | Cotton 100% | Standard, Equipment |
|---|---|---|
| Material yarn | 30/1 Cotton | |
| Count ne | 29.76 | ASTM D 1907-97 |
| Ne CV% | 1.35 | |
| Uster irregularity CV% | 9.50 | ASTM D 1425-96 |
| Imperfections in 1000m | | |
| Thin places (-40) | 56 | ASTM D 1425-96<br>USTER TESTER 3 |
| Thin places (-50) | 0 | |
| Thick places (+35) | 168 | |
| Thick places (+50) | 16 | |
| Neps (+200) | 28 | |
| Neps (+200) | 37 | |
| Neps (+280) | 8 | |
| Hairiness | 6.70 | V 400m/min |
| Strength CN/Tex | 14.71 | ASTM D 2256 97<br>USTER TENSPRAPID 3<br>V 5000m/min |
| Strength CV% | 9.18 | |
| Elongation % | 4.60 | |
| Elongation CV% | 8.50 | |
| Twist /m | 756 | ASTM D 1422-98<br>ZWEIGLE D 312 |
| Twist /inc | 19.08 | |
| Twist factory (ALFA) | 3.75 | |
| Twist CV% | 1.8% | |
| Cone angel | 5° 57´ | |
| Wax | Yes | |
| Test conditions | CONES,24HOUR CONDITIONED | TEMP(°C):20.0+/-2.0<br>HR (%): 6.5+/-2.0 |
| | ISO 9001 : 2008<br>Registration No: 12 100 3674 TMS | |

### 2.1.3. Nylon Yarns
Table (3) shows the technical specification of used nylon yarns.

**Table (3) Technical Specification of Used Nylon Yarns**

| | |
|---|---|
| **Material Blend %** | 100% polyamide |
| **Yarn Count** | 70/1 Dtex polyamide |
| **Dtex Various %** | 0.6 |
| **Tensile strength CN/dtex** | 4.3 |
| **Tensile strength CV %** | 3.5 |
| **Extension at Break %** | 22.4 |
| **Extension at Break CV %** | 4.2 |
| **Oil Content %** | 2.4 |
| **Tenacity (CN)** | 3.80 |
| **Deviation of denier (Dtex)** | ±1.5 |
| **Variation of elongation (CV %)** | 4.5 |

### 2.1.4. Elastane (Lycra)
Table (4) shows the technical specification of used elastane (Lycra) yarns.

**Table (4) Technical Specification of Used Elastane (Lycra) Yarns**

| **Material Blend %** | **100 % Lycra** | **100 % Lycra** |
|---|---|---|
| **Yarn Count** | 40 Dtex | 70 Dtex |
| **Tenacity (CN)** | 36.4 | 63.8 |
| **Deviation of denier (Dtex)** | ±6.0 | ±6.5 |
| **Elongation (%)** | 590 | 610 |
| **Stress at elongation 300%** | 8.0 | 11.0 |
| **Elastic recovery at elongation 300%** | 95 | 95 |
| **Boiling water shrinkage (%)** | 12 | 11 |
| **Oil content (%)** | 3.0-7.0 | 3.0-7.0 |

### 2.2. Sports Socks Design and manufacturing
Regarding to theoretical modeling, it is assumed that various fabric structures demonstrate different mechanical and functional properties. This matter is base of sample preparation and plan of experiments. Twelve Calf length weft knitted sports socks samples were produced using two different structures with various raw materials in the same hosiery machine. Table (5) shows the hosiery machine specification that used to produce sports socks samples under study while Table (6) shows the sports socks samples specification.

**Table (5) The Hosiery Machine Specification**

| | |
|---|---|
| **Company** | Lonati |
| **Machine's type** | Single |
| **Machine's Model** | GL 615 S |
| **Made in** | Italy via Francesco Lonati |
| **Year of made** | 2013 |
| **Serial. No** | 14275 |
| **Construction** | Plain or terry |
| **Machine gauge (Needle / Inch)** | 14 |
| **Needle Thickness** | 0.70 – 0.60 MM |
| **Cylinder diameter (Inch)** | 3 3/4″ |
| **Needle number** | 168 |
| **Machine Dimension** | 94.5*103.3*180 CM |
| **Machine weight** | 230 KG |
| **Number of feeders** | 1 |

| Tracks | Cylinder | 1 |
|---|---|---|
| | Dial | 2 |
| Max speed | RPM | 350 |

**Table (6) The Sports Socks Samples Specification**

| Sample No. | Elastane count (Dtex) | Structure | | Bamboo 85% Nylon 4% Elastane 11% | Cotton 85% Nylon 4% Elastane 11% | Bamboo 81% Nylon 4% Elastane 15% | Cotton 81% Nylon 4% Elastane 15% | Bamboo 43% Cotton 42% Nylon 4% Elastane 11% | Bamboo 41% Cotton 40% Nylon 4% Elastane 15% |
|---|---|---|---|---|---|---|---|---|---|
| | | Jersey | Rib | | | | | | |
| 1. | 40 | | | | | | | | |
| 2. | | | | | | | | | |
| 3. | 40 | | | | | | | | |
| 4. | | | | | | | | | |
| 5. | 70 | | | | | | | | |
| 6. | | | | | | | | | |
| 7. | 70 | | | | | | | | |
| 8. | | | | | | | | | |
| 9. | 40 | | | | | | | | |
| 10. | | | | | | | | | |
| 11. | 70 | | | | | | | | |
| 12. | | | | | | | | | |

**2.3. Measurements of Manufactured Samples**

Several tests were carried out in order to evaluate the functional performance properties anti-microbial behavior. of produces sports socks, these tests include mechanical and physical properties tests.

**2.3.1. Weight Test**

This test was carried out by using Mettler H 30 apparatus according to the D3776 / D3776M - 09a..

**2.3.2. Thickness Test**

The thickness samples were measured by the Teclock tester under a pressure 0.2 kg f/cm2 according to the D1777- 96(2011) e1.

**2.3.3. Air Permeability Test**

This test was carried out for all samples, according to the ASTM D737 - 04(2012).

**2.3.4. Spray Test**

This test was carried out for all samples, according to the ISO 4920 and BS EN 24920.

**2.3.5. Bursting Strength Test**

This test was carried out for all samples by using the strip method according to the ASTM D3786 / D3786M – 13.

**2.3.6. Fabric Weariness or Abrasion Tester**

This test was carried out for all samples, according to the ASTM D3884 - 09(2017).

**2.3.7. Pilling Resistance Test**

This test was carried out for all samples, according to the ASTEM D4970/D4970M-16e3.

**2.3.8. Determination The growth rate of bacteria (E. coli and S. aureus) and fungi (T. Viridae and A. niger) Test**

This test was carried out for all samples, according to the ATCC Method 147-2004.

## III. RESULTS AND DISCUSSION

A knitted structure consists of interlacing loops and properties of these fabrics depending on the relationships and production methods of these loops. Therefore investigating the characteristics of weft knitted fabrics by structure is useful when designing fabrics for sports socks. Twelve samples of Calf length sports socks in different weft knitted structures (Jersey, Rib) were produced in hosiery weft knitting machine according to the research plan to determine the best specification.

### 3.1. The Effect of Sports Socks Structure on Fabric Weight

Figure (1) shows the effect of jersey and rib knit structures samples on fabric weight.

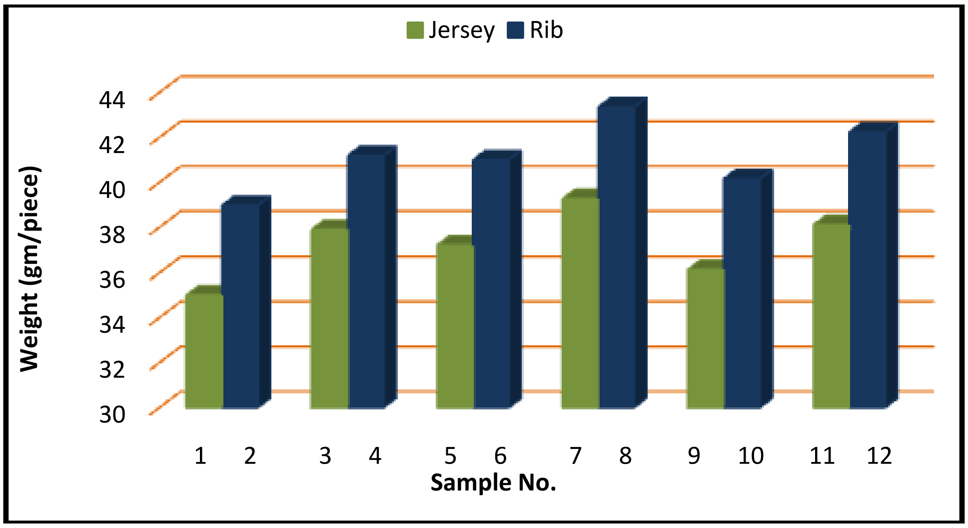


**Fig. (1) The Relationship between Sports Socks Structure and Fabric Weight (gm/piece)**

As shown in Figure (1), it is cleared that; there is difference in the weight values according to the construction of experimental samples. Rib structure recorded higher weights values compared to jersey structures due to that the rib fabrics which are knitted in two needle series (cylinder/dial in circular in circular knitting machines) have two series of courses in two surfaces. In these kinds of knitted fabrics the loops are connected together in two directions of both courses. Therefore, it seems rib structure can present higher weight values in comparison with plain ones.

### 3.2. The Effect of Sports Socks Structure on Fabric Thickness

Figure (2) shows the effect of jersey and rib knit structure samples on fabric thickness.

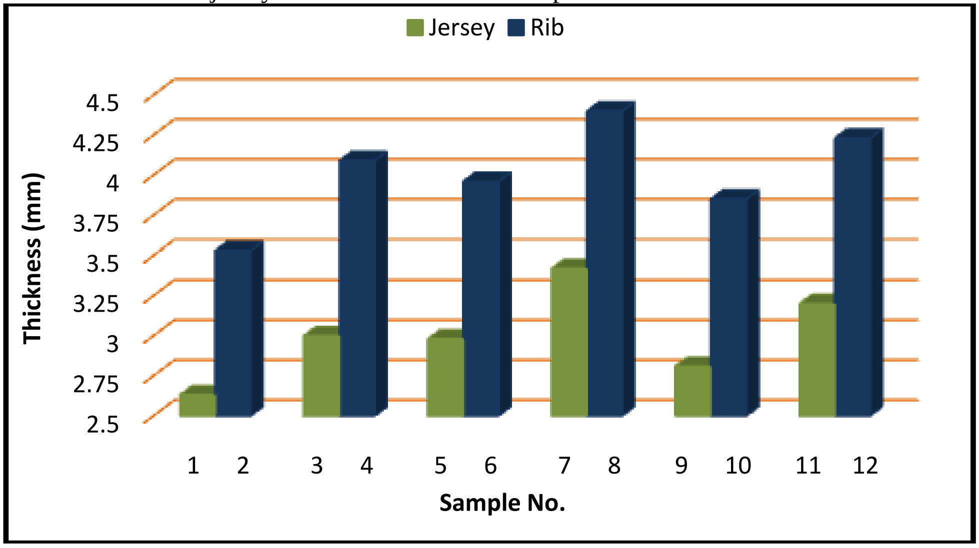


**Fig. (2) The Relationship between Sports Socks Structure and Fabric Thickness (mm)**

As shown in Figure (2), it is cleared that; there is difference in the thickness values according to the construction of experimental samples. Rib structure recorded higher thickness values compared to jersey structure because it was produced by two sets of needles being alternately set or gated between each other and it is theoretically twice the thickness and half the width of an equivalent Plain fabric.

### 3.3. The Effect of Sports Socks Structure on Fabric Air Permeability

Figure (3) shows the effect of jersey and rib knit structure samples on fabric Air permeability property ($cm^3/cm^2$. sec).

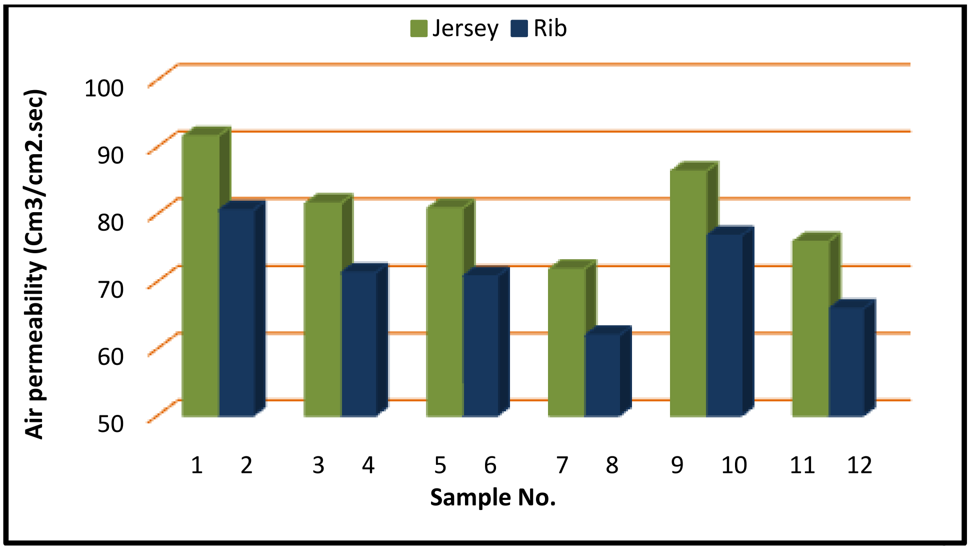


**Fig. (3) The Relationship between Sports Socks Structure and fabric Air Permeability ($cm^3/cm^2$. sec)**

As shown in Figure (3),it is observed that, There is difference in the air permeability values according to the construction of experimental samples. The results indicate that rib structure has lower air permeability values than jersey structure. The existence of this decline is most probably a consequence of the thicker structure of rib fabric, where the transportation of air through a thick fabric will be difficult while the open structure of jersey fabric gives the ability to the air to pass through fabric without any obstacles due to the lower thickness of the fabric compared to rib structure.

### 3.4. The Effect of Sports Socks Structure on Fabric Absorption (l/sec)

Figure (4) shows the effect of jersey and rib knit structure samples on fabric absorption property (l/sec).

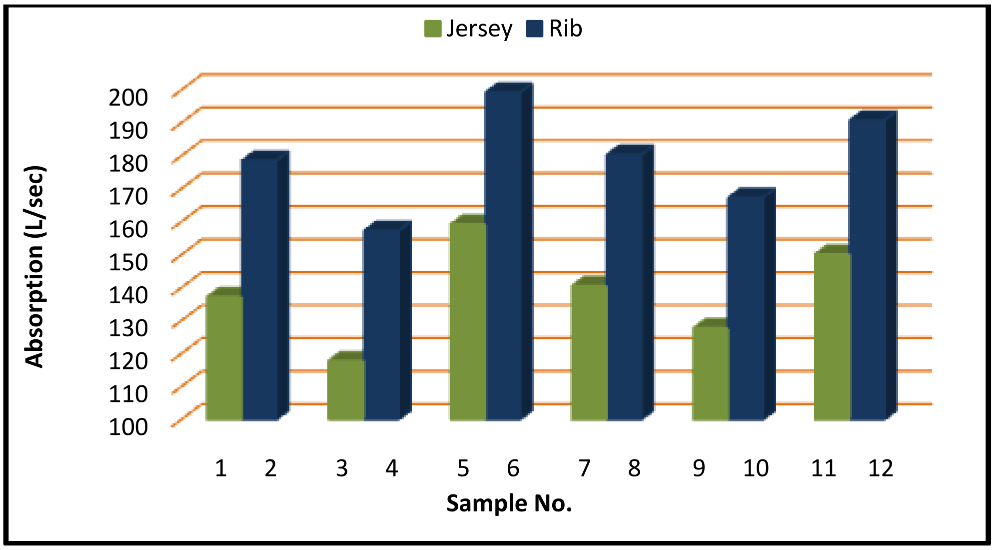


**Fig. (4) The Relationship between Sports Socks Structure and Fabric Absorption (l/sec)**

As shown in Figure (4), it is cleared that; the wick ability rate of rib structure makes it to have the higher water absorption amount compared with jersey structure. Rib can take up the water with higher amount and allow less air passage. These findings indicate that the rib socks can absorb a lot of sweat, perspiration moves fast from skin to outside and as a result user can feel dry and more comfort. Furthermore, Rib structure demonstrated the highest water up-take capacity and very high initial wicking rate. This performance is most likely due to the structures capability to act like a capillary system, rapidly removing and transporting water through the structure.

### 3.5. The Effect of Sports Socks Structure on Fabric Bursting Strength

Figure (5) shows the effect of jersey and rib knit structure samples on fabric bursting strength property (Kpa).

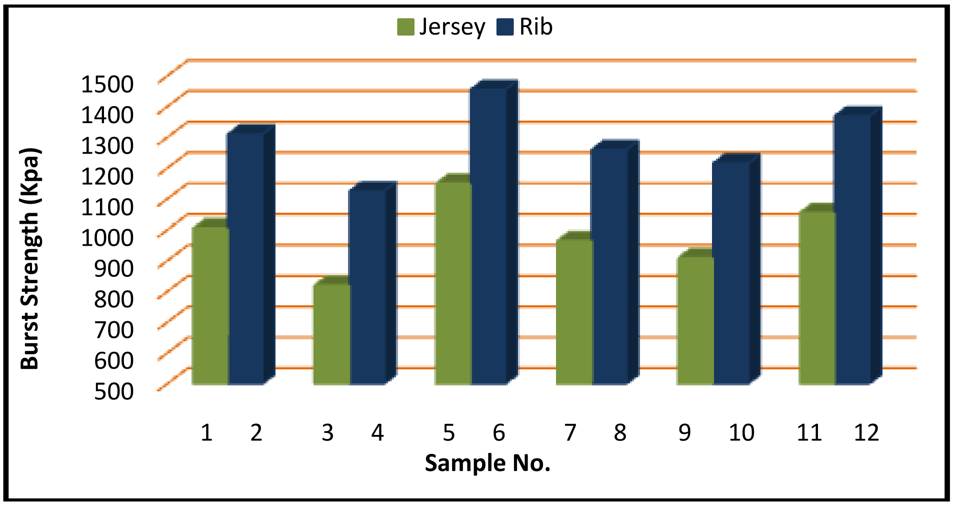


**Fig. (5) The Relationship between Sports Socks Structure and Fabric Bursting Strength (Kpa)**

As shown in Figure (5), it is observed that, there is difference in the bursting strength values according to the construction of experimental samples. In these kinds of knitted fabrics the loops are connected together in two directions of both courses. Therefore, it seems rib fabrics can present better bursting strength properties in comparison with plain ones.

### 3.6. The Effect of Sports Socks Structure on Fabric Abrasion Resistance

Weariness or abrasion resistance is expressed as the decrease in weight percent after abrasion (100 cycles).
Lose in weight (%) = [(original weight – weight after abrasion)/ original weight x 100

Figure (6) shows the effect of jersey and rib knit structure samples on fabric abrasion resistance property.

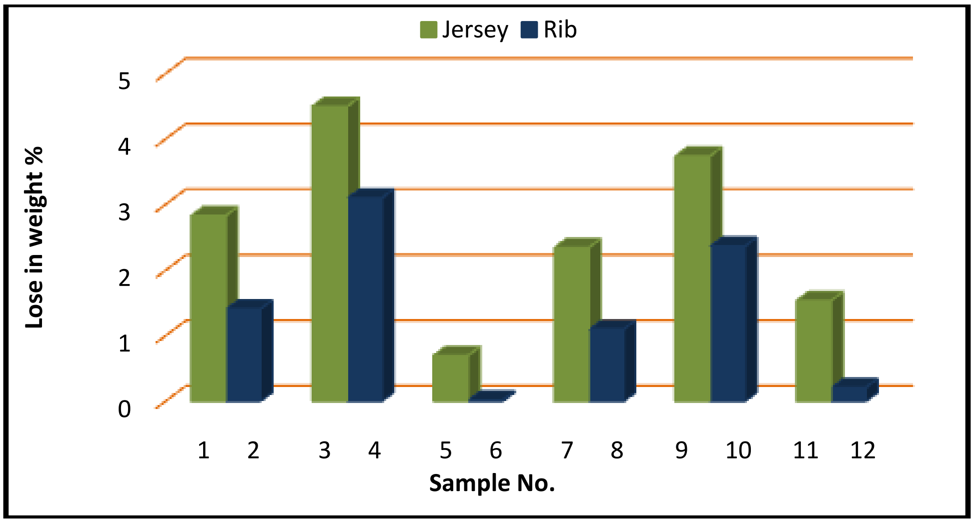


**Fig. (6) The Relationship between Sports Socks Structure and Fabric Abrasion Resistance**

**(The Lose in weight %)**

As illustrated in Figure (6), the results for abrasion resistance revealed that; the effect of knit structure is highly significant in produced fabrics. Because of the different structural properties of the fabric samples chosen, the results indicate that Rib structure causes better abrasion resistance property (less lose in fabric weight % after abrasion) than jersey structure by using the same other manufacturing parameters because Rib structure is more stable, thicker and voluminous structure.

### 3.7. The Effect of Sports Socks Structure on Fabric Pilling

Pilling is a condition that arises in wear due to the formation of little 'pills' of entangled fiber clinging to the fabric surface giving it an unsightly appearance. Pills are formed by a rubbing action on loose fibers which are present on the fabric surface. The more usual way of evaluation is to access the pilling subjectively by comparing it with a written scale of severity. Most scales are divided into five grades and run from grade 5, no pilling, to grade 1, very severe pilling. Several aspects affecting fabric pilling include fiber properties, yarn structure, fabric tightness, finishing and dyeing processes. Figure (7) shows the effect of jersey and rib knit structure samples on fabric pilling resistance test property.

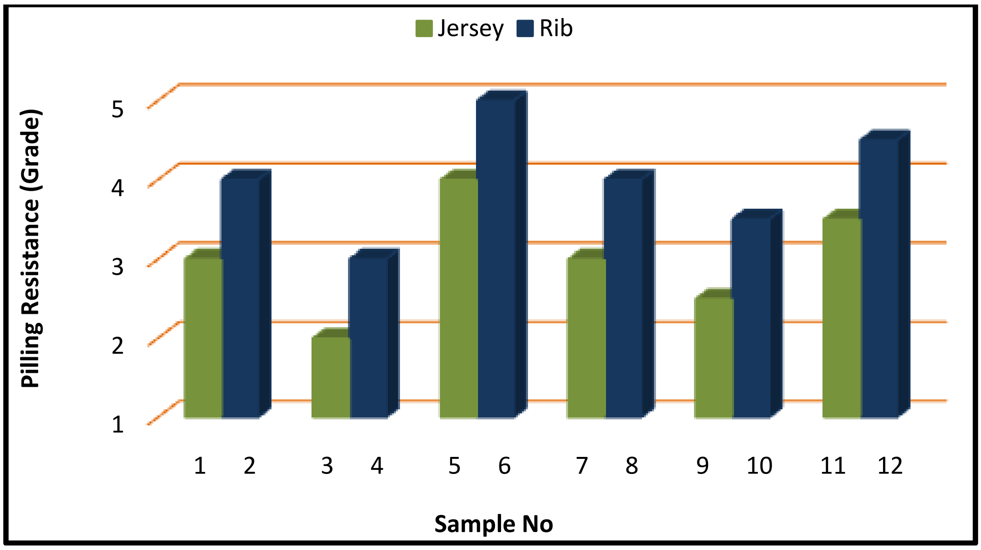


**Fig. (7) The Relationship between Sports Socks Structure and Fabric Pilling Resistance (grade)**

As shown in Figure (7), it is cleared that, there is difference in pilling resistance values according to the construction of experimental samples. Rib structure recorded the best pilling resistance values compared to jersey structure due to that the rib fabrics which are knitted in two needle series have two series of courses in two surfaces. Therefore, it becomes more tight structure which causes better pilling resistance.

## IV. CONCLUSIONS

A knitted structure consists of interlacing loops and properties of these fabrics depending on the relationships and production methods of these loops. Therefore investigating the characteristics of weft knitted fabrics by structure is useful when designing fabrics for sports socks. It is cleared that; there is difference in the functional properties according to the construction of experimental samples. Rib structure recorded higher weight, thickness, absorption, bursting strength, abrasion and pilling resistance values compared to jersey structures due to that the rib fabrics which are knitted in two needle series (cylinder/dial in circular in circular knitting machines) have two series of courses in two surfaces. In these kinds of knitted fabrics the loops are connected together in two directions of both courses. Therefore, it seems rib fabrics can present higher values in comparison with plain ones. The results indicate that rib structure has lower air permeability values than jersey structure. The existence of this decline is most probably a consequence of the thicker structure of rib fabric, where the transportation of air through a thick fabric will be difficult while the open structure of jersey fabric gives the ability to the air to pass through fabric without any obstacles due to the lower thickness of the fabric compared to rib structure. These findings are an important tool in the design of healthy comfortable sports socks.

## REFERENCES


[1]. Smith J, Pitts N. "Selecting socks". w.ohioline.osu.edu/hygfact/5000/5544.html.(2009).
[2]. Sadhan Chandraray. " Fundamentals and advances in knitting technology". Woodhead publishing limited. (2011).
[3]. David J Spence, Knitting Technology. "A comprehensive handbook and practical guide", Third edition, Woodhead Publishing Limited, Cambridge, England, (2001).
[4]. Önder E, Candan C. "Çorap Kalite Özellikleri, Çorap Kalite El Kitabı", Çorap SanayicileriDerneği. (2005).
[5]. R Shisho. " Textile in Sports", Woodhead Publishing Limited. (2005).
[6]. "Fibers; Vegetable", Wiley. (2006).
[7]. Riello, Giorgio. "Cotton: The Fabric that Made the Modern World". (2013).
[8]. Clark, Jim. "Polyamides". Chemguide. (2015).
[9]. "Nylons (Polyamide)". British Plastics Federation. (2017).
[10]. J. Hu, J.Lu., "Recent Developments in Elastic Fibers and Yarns for Sportswear", Elsevier BV. (2015).
[11]. Cay M Kielty, Michael J Sherratt & Adrian Shuttlewo rth C, "Elastic fibers". J Cell Sci , 115, (2002).
[12]. Saravanan K, Prakash C. " Bamboo fibres & their application in textiles". Indian Text J. (2007).
[13]. Erdumlu N., Ozipek B. "Investigation of Regenerated Bamboo Fibre and Yarn Characteristics." FIBRES & TEXTILES in Eastern Europe, Vol. 16, No. 4. (2008).
[14]. Iyer , Mammel & Schäch, "Circular knitting : technology, process, structures, yarns, quality". Third edition, Bamberg : Meisenbach, 2004.


S. A. El Tantawy. "The Influence of Sports Socks Structures on Its Functional Properties"
*American Journal of Engineering Research (AJER)*, vol. 9(01), 2020, pp 01-10