INVESTIGATION OF STRUCTURAL AND PERFORMANCE PROPERTIES OF HEMP-CONTAINING KNITTED FABRICS WITH DIFFERENT COMPOSITIONS

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ABSTRACT

The growing relevance of sustainable materials has increased the importance of hemp-containing products obtained from natural fibers. When the raw materials used in the garment industry are examined, it is observed that the market share of hemp-containing fibers is low in percentage. Researching the production techniques and methods of fabrics to be obtained from hemp fiber and adapting them to the use of clothing will contribute significantly to the development of the hemp product range. It is aimed that these fabrics to be developed will pass tests in accordance with end-consumer standards. In this study, structural and performance properties of hemp fiber were examined and alternatives were produced instead of conventional methods for a sustainable world. In line with the sustainability strategy, there are advantages of hemp fibers in terms of water consumption, environmental impact compared to cotton fiber. Within the scope, studies were carried out to develop single jersey knitted fabrics by hemp- containing at different compositions such as 70 % cotton/ 30 %hemp, 80 % cotton/ 20 %hemp and 90 % cotton/ 10 %hemp, %100 cotton fabric having the similar structural properties was taken as a control sample. As a result, prototype tests were performed considering the structural and performance properties of the developed fabrics.

KEYWORDS

Textile Ecology; Sustainability; Hemp Fiber; Cotton Fiber; Knitting; Water Consumption.

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INTRODUCTION

The textile and apparel industry, which is one of the most important requirements of people, should continue its activities by considering human and environmental health and, accordingly, sustainable development. The concept of “textile ecology” is important to ensure sustainability in the textile industry. In this context, hemp, a biodegradable fiber, has come to the fore again [1].

Due to its many environmentally friendly features, the use of hemp fiber in sustainable textile design and production also allows it to be evaluated within the scope of slow and ecological fashion. There are many studies conducted on reusing hemp fibers by recycling them with chemical methods, and this shows its sustainability. Hemp is a more environmentally friendly, economical and sustainable type of raw material compared to similar raw materials [2].

Hemp is an industrial plant which has an annual, herbaceous and multi-use potential in the cannabis. Cannabis is a woody annual plant from the Cannabaceae family. Today, there are two subspecies of hemp. These are; Cannabis sativa and Cannabis indica. The type that is important for industrial applications and used in fiber production is Cannabis sativa. [3].

Since it does not demand much water, it contributes to the protection of water resources. It produces a high amount of oxygen and does not require pesticides and fertilization as it does not have any agricultural pests. Hemp acts as a carbon sink due to CO_2 absorption, and it has been revealed that hemp plants help maintain strong soil structure, protecting them against landslides due to their roots located at a depth of about 1 meter underneath. According to the related literature, compared to cotton cultivation, it was determined that the water footprint of industrial hemp (2719 l/kg) is less than 1/3 of the water footprint of cotton (10000 l/kg) [4].

On the other hand, it has been observed that 60% of hemp is returned to the soil as a nutrient when dried in the field. In this context, literature research has shown that the environmental impact of hemp raw materials is low and can be an important resource in

ensuring sustainability in the textile industry. Looking at the physical structure of hemp fiber, hemp fiber has a hollow structure. It has a large lumen and this lumen constitutes approximately 1/2 - 1/3 of the total cross-sectional area. It is larger than ramie, flax, and cotton. Since there are many hydrophilic molecules that can easily combine water molecules, hemp fiber has good moisture absorption with a commercial moisture value of 10.8%. It also has a much higher moisture holding capacity than cotton fiber with a commercial moisture value of 8.5%. Hemp fiber with a polygonal cross-section has a hollow structure with a lot of air inside, which can increase insulation. At the same time, it effectively prevents the formation of anaerobic bacteria. Hemp fiber can block up to 90% of ultraviolet sunlight without any treatment, and this is because of its high lignin content, which can absorb ultraviolet light [5-7].

Within the scope, the development studies with a composition of 70 % cotton/ 30 %hemp, 80 % cotton/ 20 %hemp and 90 % cotton/ 10 %hemp single jersey knitted fabrics in navy blue color with Ne number 20/1 were carried out. These fabrics were compared to %100 cotton fabric with similar properties. The mass per unit area value of the cotton fabric is 175 g/m^2 and the width is 185 cm. Procurement studies were carried out to determine the fabric formulation and content. Since hemp fiber is limited, the duration of the studies has been extended. Fabric development studies were carried out with another supplier.

Defects in raw material production due to the pandemic and the fact that hemp yarn quality is not suitable for knitting made prototype development studies difficult. Since hemp is seen as the cotton fiber of the future, TYH Tekstil attaches importance to the use of hemp- containing yarns. Therefore, despite the failures, the studies continued. As a result, structural and performance tests such as pilling, fastness, fiber analysis (quantitative/microscopic count- qualitative method) and bursting strength were made on the developed fabrics and comparisons were made between both fabrics.

EXPERIMENTAL

Materials

Single jersey knitted fabrics with Ne 20/1 yarn counts in different weights and compositions from natural fibers were used in this study. The structural parameters of the fabric samples used in this study are listed in Table 1.

Table 1. Properties of TYH fabrics.

Properties of Fabrics	Fabric-1	Fabric-2	Fabric-3	Fabric-4
Raw Material	100% cotton	90 % Cotton 10 %Hemp	80 % Cotton 20 %Hemp	70 % Cotton 30 %Hemp
Type Knitting	Single jersey			
Unit Weight (gr/m^2)	175	170	170	160
Yarn Count (Ne)	20/1			
Color	Navy Blue- 654-860.qtx			

Table 2. Tests and Standards.

Test	Standard
Washing Fastness (Gyrowash)	ISO 105 C06 AIS
Rubbing Fastness (Dry-Wet)	EN ISO 105 – X12
Water Fastness	EN ISO 105 – E01
Perspiration Fastness	EN ISO 105 – E05
pH	ISO 3071 – 1980
ICI Pilling Box	ISO 12945 – 1
Pilling Martin Dale	EN ISO 12947
Fiber Analysis (quantitative/microscopic count)	AATCC 20 A
Fiber Analysis (qualitative method)	TS 4739:1986 (Metot:1)
Bursting Strength	ISO 13938-2:2019

Methods

To ensure compatibility between fabrics, first of all, the structural properties of the developed fabrics were evaluated. Washing fastness, rubbing fastness (dry and wet), water fastness, perspiration fastness, pH tests, pilling test with ICI Pilling Box and Pilling Martin Dale were performed. In addition, fiber analysis (quantitative/microscopic count- qualitative method), bursting strength test was determined. Test sample fabrics were adjusted according to standard conditions before test and analyzes (21 ± 1 °C, 65 ± 2% relative humidity).

In this study, these tests applied to the fabrics have been conducted in accordance with certain standards. Tests and related standards are given in Table 2.

Hemp-containing yarns could not be knitted due to the strength problem. Both yarns created bursting images during knitting. Yarn repair works were started by checking the strength, pilling and fastness values of the fabrics and improving the production conditions of the yarns. It has been observed that the working performance is low during knitting due to waiting after fixation with yarns. The fixation is a process performed to provide yarn relaxation and proper working form.

The drier the environment in the waiting conditions of the yarn, the shorter the deterioration of this form. If the standard weather conditions (closed warehouses out of the sun) are provided, it is not affected by the waiting period. When the incoming yarns were examined, it was observed that they were subject to the post-shipment transfer process and the yarn was very dry. This situation directly affects the breaking and working performance. Double fixation was applied for improvement studies. It has been tried to improve the working performances by re-transferring-fixing the yarns.

RESULTS AND DISCUSSION

Fastness is a color strength of textile product to withstand the factors encountered during both its production and use. It is a major quality feature in dyed textile products. Knowing the fastness of the textile material is important for the preparation of care labels [8]. Thus, washing fastness, rubbing fastness (dry and wet), water fastness, perspiration fastness and pH tests were applied. Table 3 shows the results of these testing. These tests were carried out in the company's laboratory. As can be seen from Table 3, it was determined that the developed knitted fabrics presented good fastness results. Test results were evaluated according to the company's acceptance value and customer criteria.

In addition, the pilling problem, one of the important problems in textile, disturbing both the producer and the consumer and also affecting the fabric quality. Test devices and methods used together with the factors affecting pilling are also very important in terms of evaluating the pilling performance of fabrics [9]. In this context, as a fabric pilling analysis, Martin Dale test according to EN ISO 12947 standard and ICI Pilling Box test according to ISO 12945-1 standard were performed on the developed knitted fabrics as seen in Table 3. Martin Dale test results were determined as 3/4 and 4, ICI Pilling Box test as 4. These results have been accepted as valid according to standards.

Table 3. Structural Tests of the fabrics and results.

Physical Test	Fabric-1	Fabric-2	Fabric-3	Fabric-4
Washing Fastness	4/5	4/5	4/5	4
Dry Rubbing Fastness	4/5	4	4/5	4/5
Wet Rubbing Fastness	3/4	4	4	4
Water Fastness	4/5	4	4	3/4
Perspiration Fastness	4/5	4	4/5	4
pH	6.8	6.9	6.9	6.8
ICI Pilling Box	4	4	4	3/4
Pilling Martin Dale	4	3/4	4	3

Table 4. Performance tests of the fabrics and results.

Performance Test	Fabric-1	Fabric-2	Fabric-3	Fabric-4
Bursting Strength, (kPa)	603.3	489.2	525.95	460.05
Distance To Burst, (mm)	16.1	10.6	10.8	10.5

In the literature, effect of the parameters, affecting the evenness also mechanical and structural properties of blended yarns with different hemp compositions, and the regression equation between blending ratio and yarn mechanical property was investigated. Based on this equation, blended yarns were produced in different compositions by using polyester, hemp and cotton fibers in the experiment. When the results were examined, it was observed that the unevenness of the hemp blended yarn increased as the hemp fiber ratio in the yarn increased. Since hemp fiber has longer fiber length, higher initial modulus, irregular fiber cross-section and greater surface friction than polyester and cotton, in addition to its stiffness, its distribution in the yarn is greatly affected by the content. Due to its mechanical properties, hemp fiber is affected by its distribution in the yarn. It has been found that, due to their smooth surface and low holding force, they are easy to slide from each other, although they have high strength when stretched. It has also been observed that when hemp fiber is blended with polyester and cotton in specific rate, the adhesive strength increases again under the effect of twisting [7, 10].

Bursting strength test were performed in the relevant parts of the product as a performance test. In this context, the performance tests of the fabrics are presented in Table 4.

Examining the test results, the rigid structure of the hemp fiber improves the strength of the fabric up to a certain point, and when that point is exceeded, hemp fibers begin to fall out. Thus, it reduces strength and more fiber fall out occurred in the Fabric-4 (70 % Cotton/ 30 %Hemp) compared to others. In the test results, it was observed that the Fabric-3 (80 % Cotton/ 20 %Hemp) gave ideal results close to cotton. In terms of structural properties, the Fabric-3 (80 % Cotton/ 20 %Hemp) gave better results than other hemp blended fabrics. This fabric can be an alternative fabric to cotton fibers. The optical microscope images of hemp and cotton fibers are shown in Figure 1.

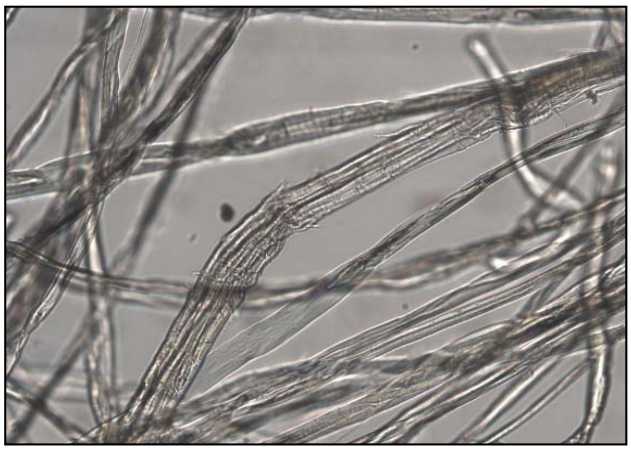

Figure 1. Structure of cotton/hemp fibers

The fibers in the middle in the image are hemp fibers, as seen in the Figure 1. Under a microscope a cotton fiber looks like a twisted ribbon or a collapsed and twisted ribbon or a collapsed and twisted tube. These twists are called convolutions [11]. Hemp has more twisted ribbon than cotton fiber.

During the growth phase of the plant, there is no change in the number of fibers, but the length of the fiber's increases. In the hemp plant, the fiber thickness increases from the stem down. The fiber lengths are determined by the distance between the ribbon. The glossy hemp fibers are yellow-brown, and the cross-section of the fiber is polygonal [7, 12].

CONCLUSIONS

The fact that the products obtained from synthetic fibers are petroleum-based increase the CO_2 emission and carbon footprint. Natural fibers are mostly preferred in clothing products used in our daily lives. On the other hand, hemp fibers have become an alternative to cotton since the cultivation process of cotton fibers, which is the most preferred natural fiber, includes abundant irrigation and pesticide and chemical fertilizer applications that cause many health problems. For this purpose, TYH Tekstil has given importance to research and development studies in this field, considering hemp fibers as the cotton of the future.

Many problems have been encountered in hemp fiber, from the fiber stage to the fabric stage. Despite all the problems, fabrics have been developed. Studies were carried out to develop single jersey knitted fabrics from blending raw materials containing hemp at different composition such as 70 % cotton/ 30 %hemp, 80 % cotton/ 20 %hemp and 90 % cotton/ 10 %hemp, %100 cotton fabric having the similar structural properties was taken as a control sample. The structural and performance properties of the fabrics developed in the test results are evaluated. Results show that compared to other hemp-containing knitted fabrics, 80% cotton/ 20% hemp blended knitted fabric was considered more suitable for use in knitting. Consequently, this study reveals that composition is not the decisive factor, although it is commonly assumed that the strength reduces as the hemp ratio increase. The rigid structure of the hemp fiber improves the strength of the fabric up to a certain point, and when that point is exceeded, hemp fibers begin to fall out. Thus, it reduces strength and more fiber fall out occurred in the Fabric-4 (70 % Cotton/ 30 %Hemp) compared to others.

Hemp fiber is very popular nowadays due to the rising of environmental concerns. This popularity depends on its ecological properties and superior daily usage performance. This paper gives

information about hemp fiber properties and its advantages. The aim of this paper is to highlight the importance of hemp-containing textiles for today's world textile market. As a suggestion, in the light of this study, experiments can be made on different fabric compositions to find the rate at which fiber fall out starts. Factors affecting the fall out can be determined and studies can be carried out to solve this problem. As a result, its use can be spread by increasing the hemp mixture to the highest possible rate. It's observed that defects are related to strength properties according to performance test in this study. TYH Tekstil Istanbul R&D Center is open to cooperate for innovative studies and suggestions.

Acknowledgements: *This study is conducting in an apparel company's R&D Center as an R&D project. This work would not have been possible without his endless support of dear Mr. Mehmet Kaya, the director of TYH Tekstil A.Ş. We are especially indebted to him and TYH Tekstil. We would also like to show my gratitude to all of those with whom We have had the pleasure to work during this study and other related projects.*

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