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DEVELOPMENT OF KNITTED FABRIC STRUCTURES WITH HIGH HYGIENIC PERFORMANCE FOR SUMMER KNITWEAR PRODUCED FROM COTTON–FLAX BLENDED YARNS

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Abstract

The paper studies the possibilities of expanding the range of summer knitted garments based on cotton–flax blended yarns. The influence of the flax fibre content in the blend (0, 30, 50 and 70 %) and of the knit structure (single jersey, piqué, pointelle) on hygroscopicity, air permeability, capillarity and water-vapour permeability has been determined. A relationship between loop length and the hygienic properties of the fabric has been established. The results show that the piqué structure made of 50/50 cotton–flax yarn provides the most rational balance between hygienic performance and dimensional stability.

Keywords

polycomponent yarn, cotton–flax blend, knitted fabric, hygroscopicity, air permeability, capillarity, loop length, product range.

РАЗРАБОТКА ТРИКОТАЖНЫХ СТРУКТУР С ВЫСОКИМИ ГИГИЕНИЧЕСКИМИ ПОКАЗАТЕЛЯМИ ДЛЯ ЛЕТНИХ ТРИКОТАЖНЫХ ИЗДЕЛИЙ ИЗ ХЛОПКО-ЛЬНЯНОЙ ПРЯЖИ

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Аннотация. В статье исследованы возможности расширения ассортимента летних трикотажных изделий на основе хлопко-льняных пряж. Определено

влияние доли льняного волокна в смеске (0, 30, 50 и 70 %) и вида трикотажного переплетения (кулирная гладь, пике, ажурное) на гигроскопичность, воздухопроницаемость, капиллярность и паропроницаемость. Установлена зависимость между длиной петли и гигиеническими свойствами полотна. Показано, что переплетение пике из пряжи состава 50/50 обеспечивает наиболее рациональное сочетание гигиенических показателей и формоустойчивости.

Ключевые слова: поликомпонентная пряжа, хлопко-льняная смеска, трикотажное полотно, гигроскопичность, воздухопроницаемость, капиллярность, длина петли, ассортимент.

Introduction

In regions with a hot and dry climate, the main requirement for summer knitwear is to maintain the heat and moisture balance of the body, i.e. to absorb sweat quickly, transport it to the surface and allow it to evaporate. This requirement is determined by the hygroscopicity, capillarity, air permeability and water-vapour permeability of the fabric. At the knitting enterprises of Uzbekistan, most of the product range is made from 100 % cotton yarn. Although cotton yarn is highly hygroscopic, its strong tendency to retain moisture limits its use in light, quick-drying summer garments.

Compared with cotton, flax fibre is distinguished by higher capillarity, higher thermal conductivity and the ability to release moisture quickly. Therefore, spinning yarn from a polycomponent blend of cotton and flax fibres and knitting it into specially selected fabric structures is a promising way to expand the range of summer knitwear. However, the stiffness and limited extensibility of flax fibre cause problems during knitting and impair the dimensional stability of finished garments. It is therefore necessary to select the blend composition and the fabric structure parameters together.

The aim of the study is to substantiate knitted fabric structures with high hygienic performance for summer knitwear made from cotton–flax blended yarns and, on this basis, to develop recommendations for expanding the product range.

Materials and Methods

Blended yarns of four compositions with a linear density of 20 tex were selected as the object of the study: V-1 — 100 % cotton (control), and cotton–flax blends V-2 —

70/30, V-3 — 50/50 and V-4 — 30/70. The main physical and mechanical properties of the yarns are given in Table 1.

Table 1

Physical and mechanical properties of the yarns used in the study

Yarn variant	Composition (cotton/flax), %	Linear density T, tex	Specific breaking load, cN/tex	Elongation at break, %	Unevenness CV, %
V-1	100/0	20	14.8	6.2	12.4
V-2	70/30	20	15.6	5.4	13.1
V-3	50/50	20	16.9	4.7	14.3
V-4	30/70	20	18.2	3.9	15.8

The samples were knitted in three structures on a 14-gauge circular knitting machine: single jersey (N-1), piqué (N-2) and pointelle, an open mesh structure (N-3). The structural parameters of the samples are given in Table 2.

Table 2

Structural parameters of the knitted samples (yarn variant V-3)

Sample code	Knit structure	Loop length l, mm	Pw (wales), per 100 mm	Pc (courses), per 100 mm	Areal density, g/m²	Thickness, mm
N-1	Single jersey	3.6	148	122	158	0.62
N-2	Piqué	4.1	132	108	176	0.84
N-3	Pointelle	4.5	118	96	138	0.71

Hygroscopicity and moisture content were determined in accordance with GOST 3816-81, air permeability with GOST 12088-77, areal density with GOST 8845-87, and the numbers of courses and wales with GOST 8846-87. Capillarity was measured as the height to which distilled water rose in 30 minutes. Each property was measured five times and the arithmetic mean was taken; the coefficient of variation did not exceed 5 %. All tests were carried out under standard atmospheric conditions (temperature 20 ± 2 °C, relative humidity 65 ± 2 %).

Results and Discussion

Increasing the proportion of flax fibre in the blend has a direct effect on the hygroscopicity and capillarity of the fabric (Fig. 1). When the flax content was increased from 0 to 70 %, hygroscopicity rose from 7.8 % to 10.3 %, i.e. by 32.1 %, and capillarity from 95 mm to 121 mm, i.e. by 27.4 %. This is explained by the capillary-porous

structure of flax fibre and the activity of the hydroxyl groups in the cellulose macromolecules.

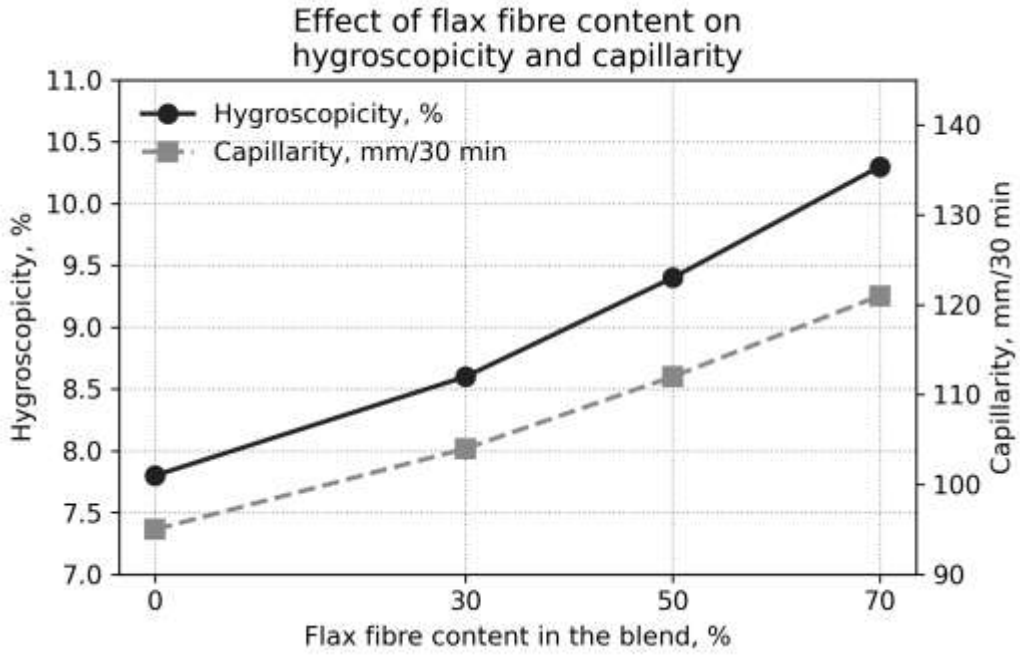

Fig. 1. Effect of flax fibre content on hygroscopicity and capillarity

Air permeability, in contrast, is determined primarily by the knit structure (Fig. 2). With the same raw-material composition, the pointelle structure provides 1.7 times higher air permeability than single jersey. Increasing the flax content of the blend raises air permeability by a further 11–12 % in all structures, which is associated with the widening of the gaps between loops due to the stiffness of flax fibre.

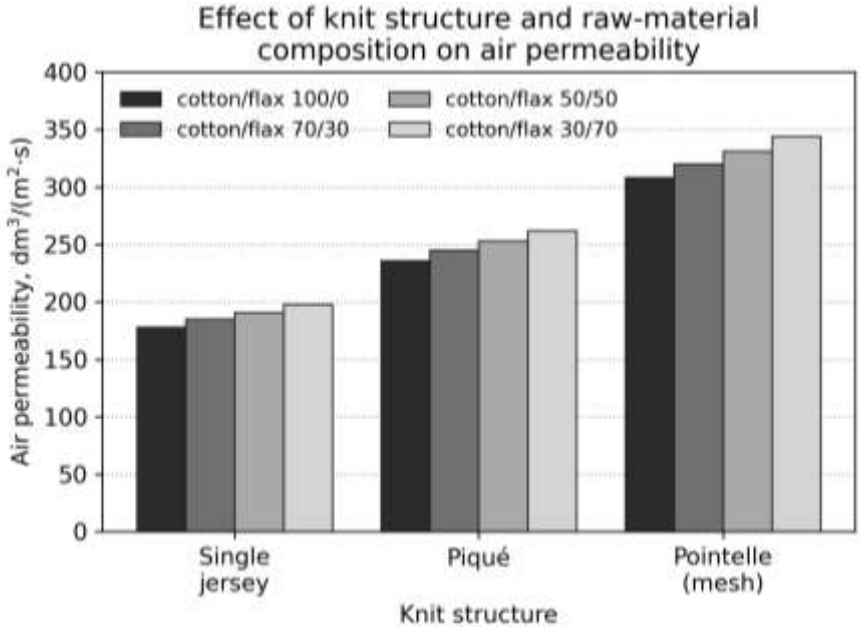

Fig. 2. Effect of knit structure and raw-material composition on air permeability

The main controllable parameter of the knit structure is loop length. Fig. 3 shows the effect of loop length on air permeability and areal density for a single jersey sample made from 50/50 yarn. When the loop length is increased from 3.2 mm to 4.4 mm, air permeability rises from 152 to 258 dm³/(m²·s), i.e. by 69.7 %, while areal density decreases from 172 to 136 g/m², i.e. by 20.9 %. Both relationships are linear within the range studied (coefficient of determination $R^2 > 0.98$).

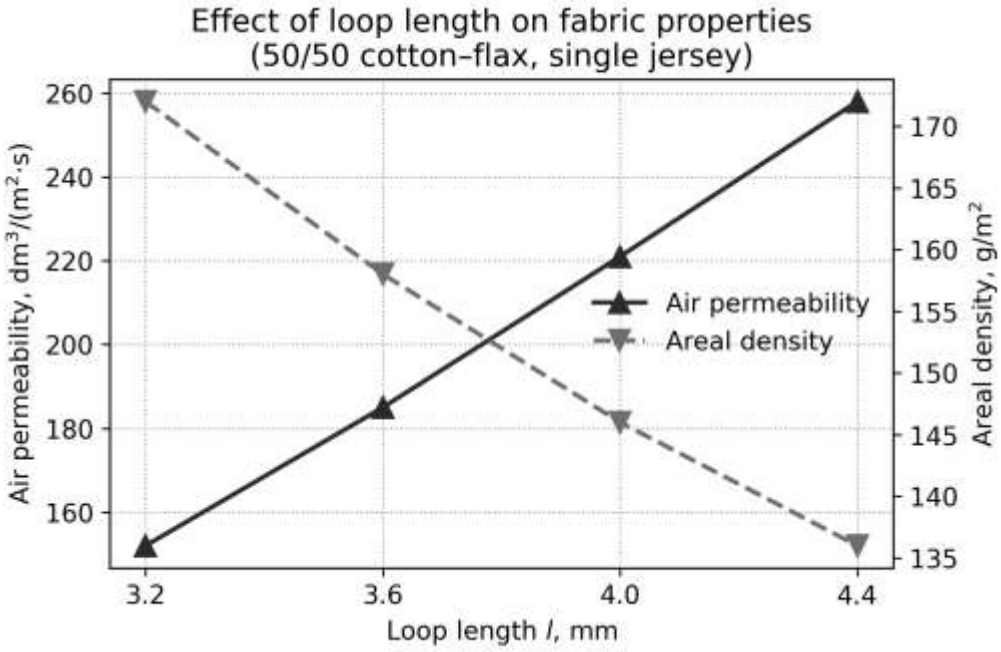

Fig. 3. Effect of loop length on fabric properties

However, loop length cannot be increased indefinitely: at values above 4.4 mm, the dimensional stability of the fabric deteriorates sharply and shrinkage after washing exceeds 7 %. Therefore, 3.9–4.2 mm was adopted as the optimal loop length range for summer garments.

Table 3

Hygienic properties of the samples (yarn variant V-3)

Sample	Hygroscopicity, %	Air permeability, dm³/(m²·s)	Capillarity, mm/30 min	Water-vapour permeability, mg/(cm²·s)	Dimensional change, %
N-1 (single jersey)	9.4	191	112	5.8	–4.6
N-2 (piqué)	9.7	253	118	6.4	–3.2
N-3 (pointelle)	10.1	331	124	7.1	–6.8

Based on the data in Table 3, the indicators were normalised and a comprehensive hygienic assessment of the structures was made (Fig. 4). Although the pointelle structure leads in hygienic performance, it showed the lowest dimensional stability. The piqué structure showed balanced results for all five indicators.

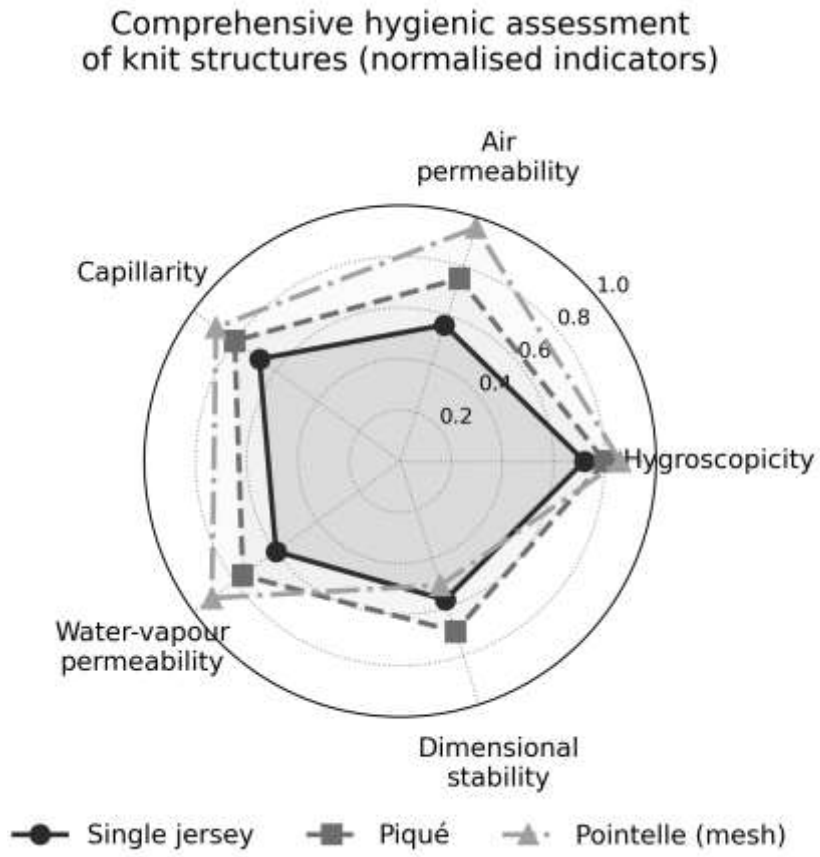

Fig. 4. Comprehensive hygienic assessment of the knit structures

Conclusions

1. Increasing the flax fibre content of the cotton–flax blend to 70 % raises the hygroscopicity of the fabric by 32.1 % and its capillarity by 27.4 %, but reduces the elongation at break of the yarn from 6.2 % to 3.9 % and increases the risk of yarn breakage during knitting.

2. The knit structure has a stronger effect on air permeability than the raw-material composition: changing the structure changes this indicator by a factor of 1.7, whereas changing the composition changes it by only 11–12 %.

3. The optimal loop length range for summer knitwear is 3.9–4.2 mm; within this range the hygienic performance is high and the dimensional change after washing does not exceed 4 %.

4. According to the comprehensive assessment, piqué fabric knitted from 50/50 cotton–flax yarn is recommended for expanding the range of summer T-shirts, polo shirts and light shirts, while the pointelle structure is suitable for garments that require maximum breathability.

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