Afyon Kocatepe Üniversitesi Uluslararası Mühendislik Teknolojileri ve Uygulamalı Bilimler Dergisi

Afyon Kocatepe University International Journal of Engineering Technology and Applied Sciences

AKÜ IJETAS Cilt **6(1)** (2023) Haziran (14-24 s) AKU IJETAS **Vol 6(1)** (2023) June (14-24 pp)

DOI:10.53448/akuumubd.1187051

Araştırma Makalesi / Research Article

e-ISSN 2667-4165 (https://dergipark.org.tr/akuumubd

Akrilik Örme Kumaşlarda Renk Değişimi ve Desen Değişiminin Performans ve Isıl Özelliklerine Etkisinin İncelenmesi

Edanur Turgut[1]*, Züleyha Değirmenci [1] & Muhammed İdris Aktaş [2]

[1] *Gaziantep University, Department of Textile Engineering, Gaziantep/Turkey.*

[2]*Boyar Kimya San. ve Tic. A. Ş. Gaziantep/Turkey.*

e-mail: [1]eda.alpsln@gmail.com ORCID ID:0000-0003-3113-0222, [1] degirmenci@gantep.edu.tr ORCID ID:0000-0002-8669-4968, [2]idris.aktas@gmail.com ORCID ID: 0000-0002-7141-7984.

Receiwed:15.10.2022 ; Accepted: 25.01.2023

Anahtar kelimeler
"Akrilik; Isıl Soğurganlık; Patlama Mukavemeti; Hava Geçirgenliği, İplik Mukavemeti."

Öz

Bu araştırmada kullanılacak numuneler, iplikler 35/2 Nm %100 akrilik olacak şekilde üretilmiştir. İplikler [%40 Akrilik (2.75 dtex), %60 Akrilik (2,2 dtex)] karışım oranlarından oluşmakta ve bu liflere tow boyama işlemi uygulanmıştır. Bu elyaf boyama işleminde 2 grup oluşturularak 2 açık renkli elyaf, 2 orta renkli elyaf, 2 koyu renkli elyaf ve 2 süper koyu boyalı elyaf üretilmiş ve toplam 8 boyalı iplik elde edilmiştir. Elde edilen ipliklerden ribana ve düz örgü kumaşlar üretilmiştir. Elde edilen on altı numune üzerinde kalınlık, hava geçirgenliği, termal direnç, patlama mukavemeti ve iplik mukavemeti testleri yapılarak sıcaklık ve boyama sürelerinin boyama reçetelerine etkisi araştırılmıştır.

Investigation of The Effect of Colour Variation and Pattern Change on Performance and Thermal Properties of Acrylic Knitted Fabrics

Keywords
"Acrylic; Thermal Absorptivity; Bursting Strength; Air Permeability; Yarn Strength."

Abstract

Samples that are going to be used in this research are produced in such a way that the threads are 35/2 Nm 100% acrylic. The yarns consist of [40% Acrylic (2.75 dtex unrelax), 60% Acrylic (2.2 dtex relax pilling)] mixing ratios and tow dyeing process has been applied to these fibers. In this fibre dyeing process, by creating 2 groups, 2 light colored fibers, 2 medium-colored fibers, 2 dark colored fibers and 2 super dark dyed fibers were produced and a total of 8 dyed yarns were obtained. Rib and plain knit fabrics were produced from the yarns obtained. The effects of temperature and dyeing times on dyeing recipes were investigated by performing thickness, air permeability, thermal resistance, bursting strength and yarn strength tests on sixteen samples obtained.

1. Introduction

The textile industry mainly consists of companies covering yarn, knitting, weaving, nonwovens, dyeing and finishing processes. Dyeing and finishing processes are significant in textile enterprises. Dyeing processes have a wide variety of methods. Among these, there are methods that are actively used in many stages such as fiber dyeing, printing dyeing, bobbin dyeing, fabric dyeing. Operations differ in each dyeing method. Among these methods, tow dyeing method, which is among the fiber dyeing methods, is the most common dyeing methods. If considered the tow dyeing (fiber) method, it is a high temperature and high-pressure dyeing method that takes place in large dye boilers, which is a type of dyeing in which tonnage dyeing takes place depending on the demand. There are many things that differ from the temperatures of the dye boilers to the dyeing times.

Dyeing processes and chemicals differ for each fiber type. Each fiber has different dye recipes, and they are processed in different ways. Acrylic fibers, which are among the synthetic fibers, require dyeing because they are colourless (Jiang et al. 2021). Acrylic fiber is one of the most popular synthetic fibers and its annual production was ∼2.2 million tons/year in 2010. [(David and Geoffrey, 1990), (Kamel et al. 2010), (Tiyek and Bozdoğan, 2005)]. Acrylic fiber, which has high strength values, is resistant to abrasion, and has a widespread use in the clothing industry due to its extraordinary physical and chemical properties [(Tiyek and Bozdoğan, 2005), (Sadeghi and Tehrani, 2015)]. Due to the extraordinary properties of acrylic fiber and the demand for this fiber, the demand for acrylic dyeing is also remarkably high.

It is quite difficult to dye 100% acrylic fibers. The reason for this is that the crystalline regions form a tight fiber structure in fibers produced from 100% acrylonitrile and there is no functional group to which the dyestuff can attach. In order to penetrate the dyestuff into the small amount of amorphous region sufficiently, it is necessary to exceed 100 °C. Although it is predicted that the temperature increase in dyeing will increase the speed of the dyeing process, chemical ratios are also important at this point. If the retarder rate is not as high as it should be, it can be clearly seen that it affects the dyeing speed (Sadeghi and Tehrani, 2022). Acrylic fibers are brittle, hard or cannot be dyed with any dye due to the absence of reactive regions, and they are heat-hardening fibers. Often acidic comonomers are added because acrylic fibers are mostly dyed with basic dyes (Tunç, 2012).

When dyeing acrylic fibers, it is necessary to know the properties of dye baths. Dye bath temperatures are especially important at this stage. In the dyebath cooling process, controlled cooling should occur until it drops below average 70°C and the material should be in a still state. Besides, it should not be exceeded above average 120°C. Above this temperature, the fiber becomes shorter and wrinkled. The importance of auxiliary chemicals, pH value, softening chemicals and similar active substances during dyeing is of immense importance in dyeing processes (Saçak, 2007).

The aim of this study is to get to know acrylic fiber closely and to analyze its behavior towards dyeing procedures. The optimization of the dyeing recipes was achieved by evaluating the temperature and time, with particular emphasis on the effects of thermal performance on acrylics.

2. Materials and Methods

2.1. Materials

35/2 Nm 100% Acrylic yarns were used in the samples. This yarn consists of mixtures of [40% Acrylic (2.75 dtex unrelax), 60% Acrylic (2.2 dtex relax pilling)]. In addition, the reason for providing such a mixing ratio in acrylic yarns is to obtain a voluminous yarn structure. High volume yarns are obtained by providing a mixture of relax and unrelax in acrylic yarns. The fiber dyeing of the yarns used in the trials was as follows; By creating 2 groups, 2 colored dyed fibers, 2 medium-colored fibers, 2 dark colored fibers and 2 super dark dyed fibers were produced and a total of 8 dyed threads were obtained. These products are both plain knit, and rib knit. A total of sixteen samples were obtained. The effects of temperature and dyeing times on dyeing recipes were investigated by performing air permeability, thickness, unit weight, bursting test and yarn strength tests on the samples obtained.

2.1.1. Dyeing Chemicals

In auxiliary chemicals, acetic acid (Gr/lt 0.8), leveling (Sasol HK- 250: Gr/lt 0.5), Fiber protective (Migrasit ACM: Gr/lt 0.3), Retarder (it is given according to dye 4 types of chemicals are used.

Softening chemicals are given 3 different softening chemicals: acedic acid (Gr/lt 0.8), Imidazoline (Ak Soft SD-16: 1.5%), Polyethylene Dispersion (Akpol A4: 0.2%).

In acrylic dyeing, the dye ratios vary according to the color tone. In acrylic dyeing, the ratios of auxiliary chemical and softening chemicals recipes were applied as standard in light, medium, dark, and super dark dyeings.

2.1.2. Dyeing Procedure

While auxiliary chemicals and softening chemicals are kept constant in the dyeing process, dyeing temperature and dyeing times may vary according to the lightness and darkness of the color. To give an example of this situation, in acrylic dyeings, the dyeing time can take between 3 and 4 hours in dyeings in which the light color coil dyeing method is used, while it can take an average of 5 hours in tow dyeing methods. The reason for this may vary depending on the amount of yarn or fiber and the tone of the product dyed. In addition to the effect of dyeing in yarn or fiber form on the dyeing time, the duration and temperatures for each of them vary in light, medium, dark and super dark dyeing. As stated during the dyeing process, many factors are calculated, and dyeing is done.

There are some points mentioned in the chart below. At these points, auxiliary chemicals in dyeing are given at the temperature and time at point A. The dyestuff is given at the temperature and time at point B. At point C, softening chemicals are given at temperature and time.

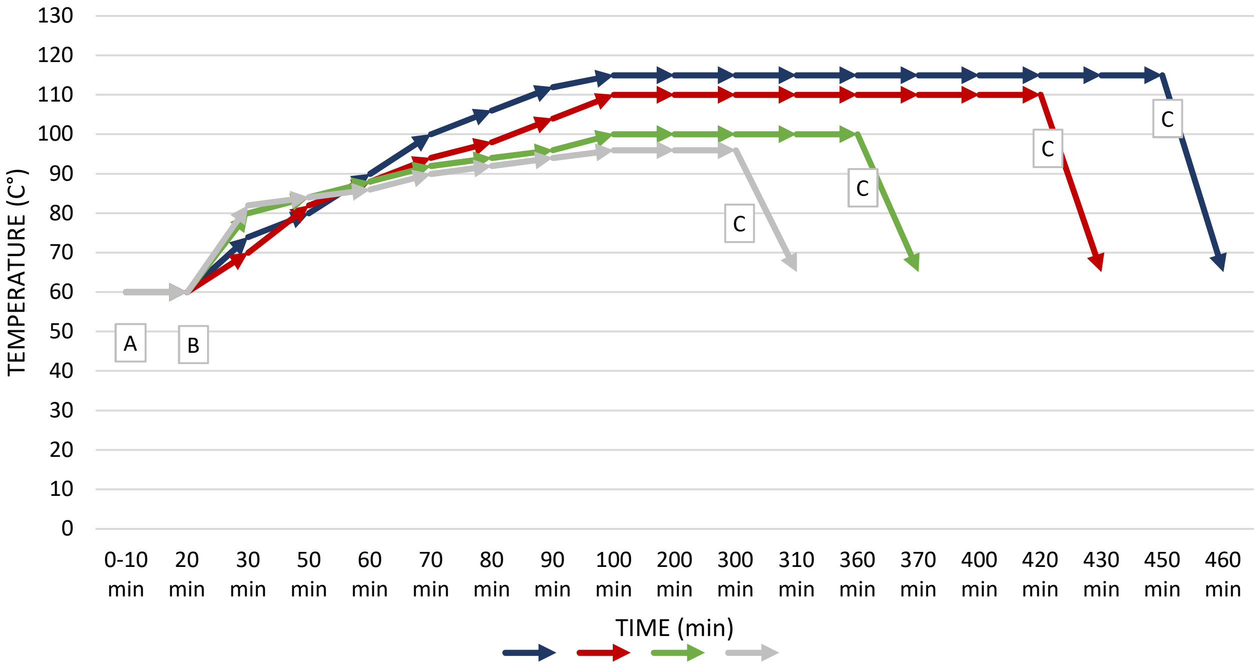

Figure 1. Temperature and time graph in acrylic dyes.

The dyeing start temperature is 60°C for all colors. In acrylic tow dyeing, super dark and dark colors are dyed longer and at higher temperatures than light and medium colors. In other words, it is observed that as the color darkens, the temperature and time increase.

The reason for these high temperatures in super dark dyeing is generally black and navy-blue tones of dark-colored products and it is because these colors have to reach very high temperatures in order to fully absorb the dyes into the fiber.

2.1.3. Knit Fabric

Two types of knitting patterns were used for yarns numbered 35/2. Knitting models are determined as plain knitting and rib. Sample knitting machines were knitted in a manual sample knitting machine with a size of E12 for flat knitting and a manual sample knitting machine with a number of E10 for rib knitting.

2.2. Methods

2.2.1. Yarn Strength

While testing the samples, Jasmes Heal Titan Universal Strength Tester device was used for yarn strength test in accordance with EN ISO 2062 (250 mm 250mm min) standards. The test was carried out by taking 20 measurements for each sample.

2.2.2. Bursting Strength

In bursting tests on samples using a James Heal TruBurst bursting strength tester were determined by the standard of TS 393 EN ISO 13938-2. For the bursting test, 50 cm test material was used and 3 measurements were taken from each fabric sample.

2.2.3. Air Permeability

For the air permeability test, the samples were applied in the M 021A air permeability test device of SDL-Atlas company, based on the TS 391 EN ISO 9237 "Determination of air permeability in textile fabrics" test standard, with a pressure drop of 100 Pa and an area of 20 cm².

2.2.4. Alambeta

The thermal conductivity, thermal absorbance and thermal resistance parameters of the fabrics were determined by measuring with the ALAMBETA tester. Each sample was carried out by taking 3 measurements from the fabric.

2.2.5. Fabric Structural Properties

The samples were tested with the DM 2000 thickness gauge and tested in accordance with ISO 4593 standards. It was tested by taking measurements from 10 different points of each sample. In Table 1, the thickness, unit weight, WPC (number of rod loop/cm) and CPC (number of row loop/cm) values of rib (It is a type of fabric obtained by knitting technique with 2×2 and 1×1 two rows of straight and two rows of reverse loops.) and plain knit fabrics (It is a type of knitting made with a single yarn without creating any pattern) are indicated.

2.2.6. Statistical Analysis

Statistical analyzes were applied to the test results obtained. Test results were analyzed and interpreted with DESIGN EXPERT 13.

Table 1. Fabric structural properties.

Samples	Name of Samples	Fabric Types	Thickness, (mm)	Unit weight, (g/m$^{2)}$	WPC	CPC
Light Color 1	LC1	plain	1,08	196	13	15
		ribana	2,1	341	12	18
Medium Color 1	MC1	plain	0,97	163	13	15
		ribana	2,04	367	13	18
Dark Color 1	DC1	plain	1,05	167	13	15
		ribana	2,01	350	12	19
Super Dark Color 1	SDC1	plain	1,22	167	12	15
		ribana	2,1	367	12	19
Light Color 2	LC2	plain	0,83	183	12	15
		ribana	2,03	338	12	18
Medium Color 2	MC2	plain	0,86	179	12	15
		ribana	2,02	354	12	18
Dark Color 2	DC2	plain	0,93	165	12	15
		ribana	2,02	330	12	19
Super Dark Color 2	SDC2	plain	0,91	181	13	15
		ribana	1,98	355	12	19

3.Result and Discussion

3.1. Yarn Strength

In Figure 2, the yarn endurance test results in the yarn strength test are given.

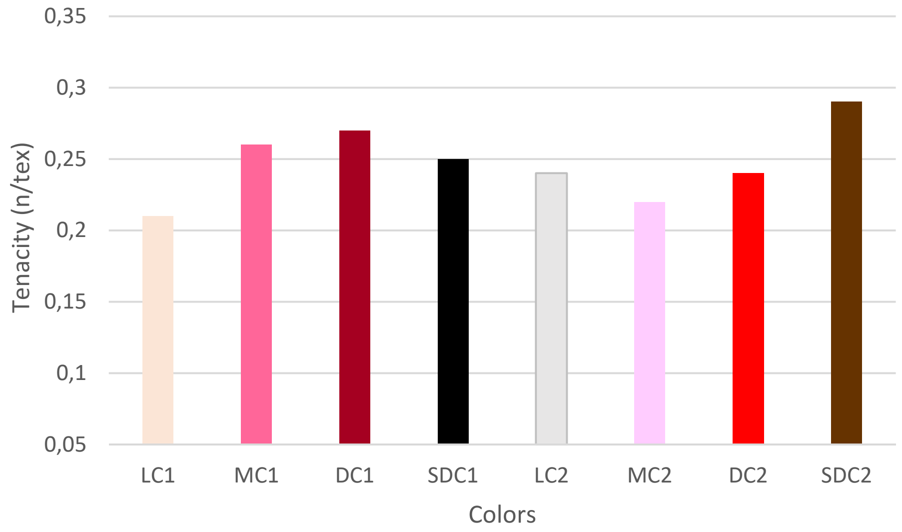

Figure 2. Yarn tenacity test results.

It is observed that the yarn strength test results are close to each other. SDC2 gives better results with slight differences compared to other colors.

In from Figure 3, the yarn extensibility values in the yarn strength test can be seen.

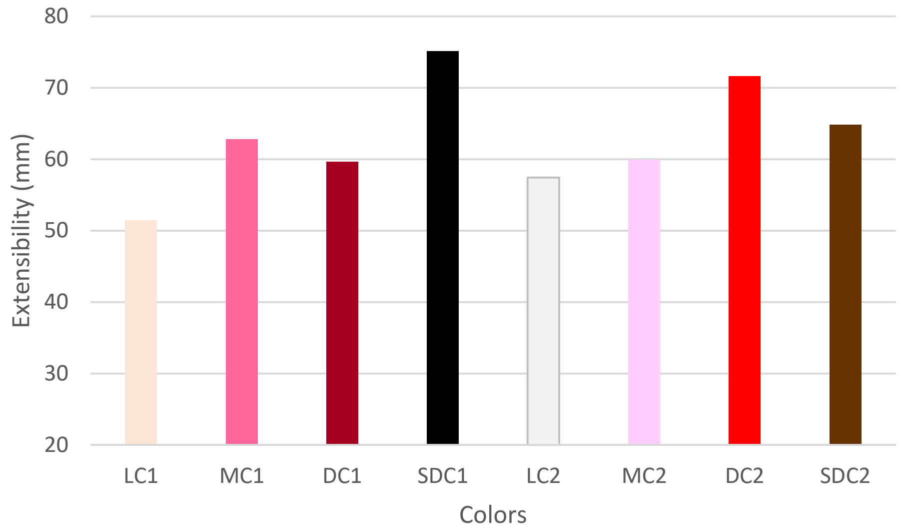

Figure 3. Yarn extensibility test results

When the yarn extensibility values are examined, the highest extensibility is observed in SDC1. It can be observed that the lowest extensibility value is in LC1 color

3.2. Bursting Test

In Figure 4, the bursting strength test results performed for each plain knitted and rib sample are seen.

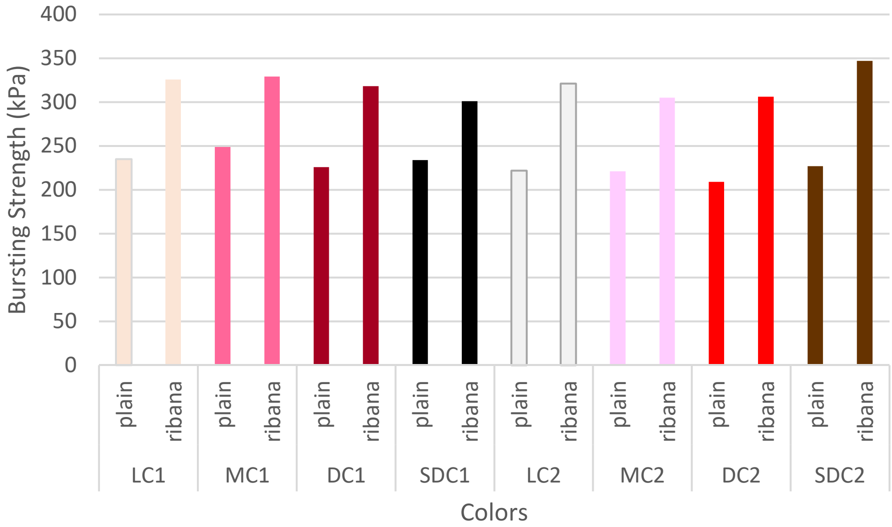

Figure 4. Bursting strength test results.

According to Figure 4, color variations is not decisive on bursting strength while pattern is highly effective. Additionally, it is thought that ribana is stronger than plain fabrics which are lighter and thinner than the ribana ones according to Figure 4.

3.3. Air Permability

In Figure 5, air permeability test values for rib and plain knit fabrics can be observed.

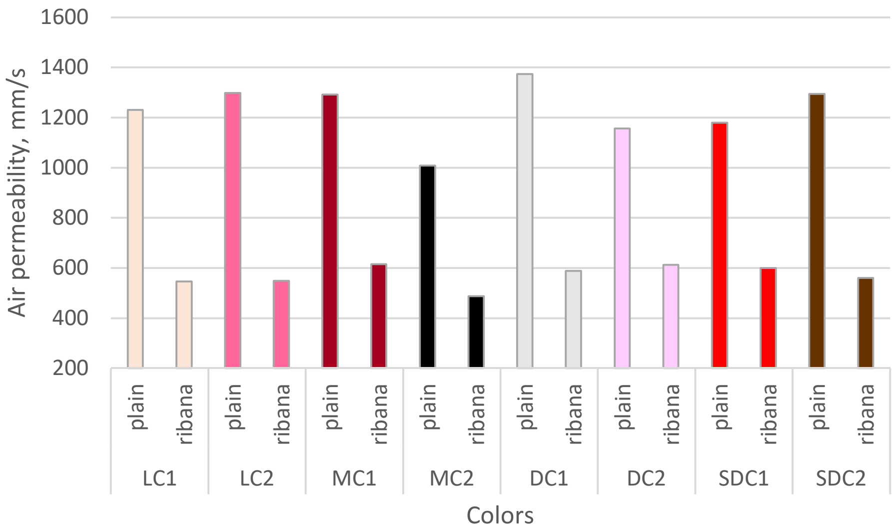

Figure 5. Air permability test results.

When looking at Figure 5, it can be observed that the knitting pattern is an effective parameter on air permeability, while it is observed that color variation has no effect on air permeability. When plain fabrics are examined in themselves, it is observed that the highest air permeability value is in the LC2, and the lowest air permeability is in the color SDC1. When the rib fabrics are examined within themselves, their air permeability results are close to each other.

In the air permeability test, a significant difference is observed between plain, and rib knit fabrics in general. The reason for this is that as the thickness of the knitted fabrics increases due to the structural differences of the fabric, it is observed that it becomes difficult for the air to pass over the fabric. Therefore, it is seen that the air permeability values are higher because plain fabrics have a thinner and more hollow structure than rib knit fabrics. (Türksoy, Üstüntağ ve Çarkıt, 2017)

3.4. Thermal Conductivity, Thermal Absorptivity and Thermal Resistance

Thermal conductivity test results are given in Figure 6.

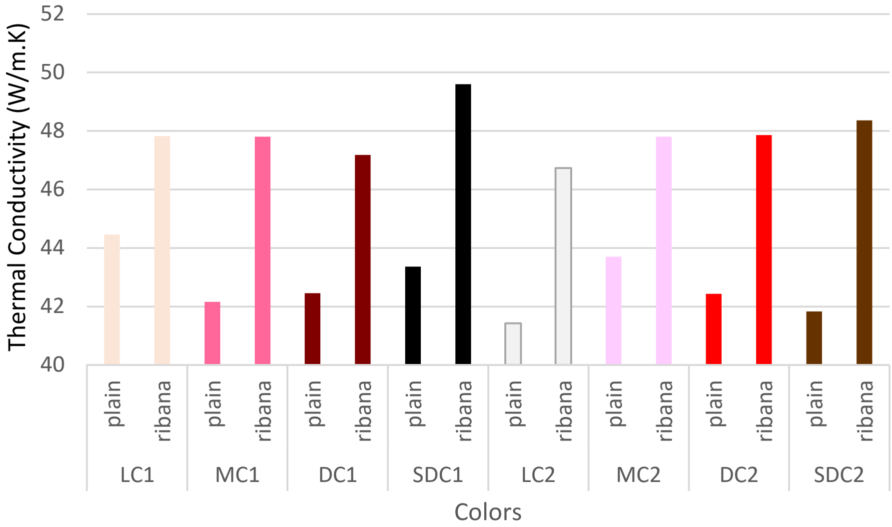

Figure 6. Thermal conductivity test results.

In the thermal conductivity test results in Figure 6, it is observed that the highest thermal conductivity is in SDC1 and the lowest thermal conductivity is in LC2 among rib fabrics. It has been obtained that the highest thermal conductivity in plain fabrics is in LC1, unlike rib fabrics, and the lowest thermal conductivity is in LC2.

Rib and plain fabrics should not be compared with each other in thermal conductivity, thermal absorbency, or thermal resistance tests. Because the void structure ratio or density ratios in plain fabric are not the same as rib fabric, it is necessary to compare these fabrics within themselves. (Uyanık ve Kaynak, 2018)

Thermal absorptivity test results are given in Figure 7.

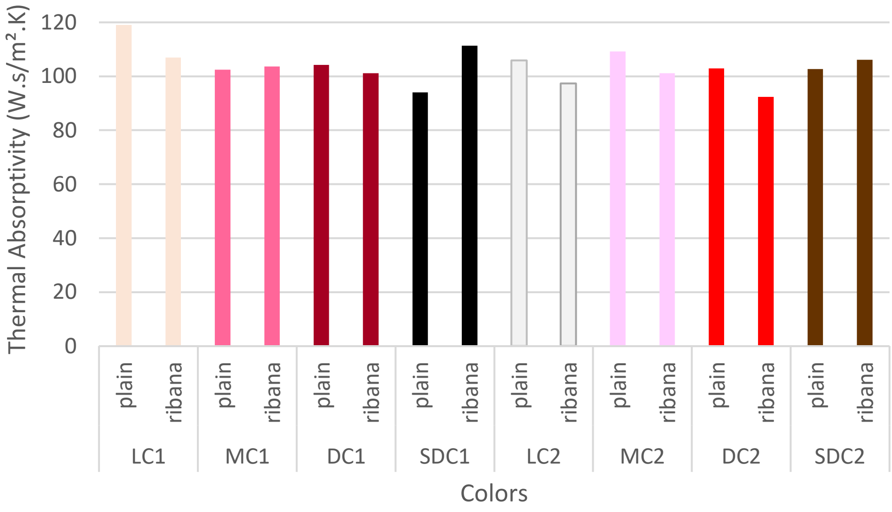

Figure 7. Thermal absorptivity test results.

When the thermal absorptivity test results are examined, it is observed that the highest thermal absorptivity value is in LC1 plain and SDC1 rib fabric is in the second place. It was concluded that the color and knitting pattern did not have effect on the thermal absorptivity.

The results show that even though the changes (thickness, weight, stitch density) caused by dyeing on the structural properties of the fabrics cause change on the thermal absorbance of the fabric, since the specific heat values of all fabrics are between 1.46-2.16 J/g-°C and the thermal conductivity is between 0.187-0.209 W/m-K. thermal results were close to each other.

Thermal resistance test results can be seen in Figure 8.

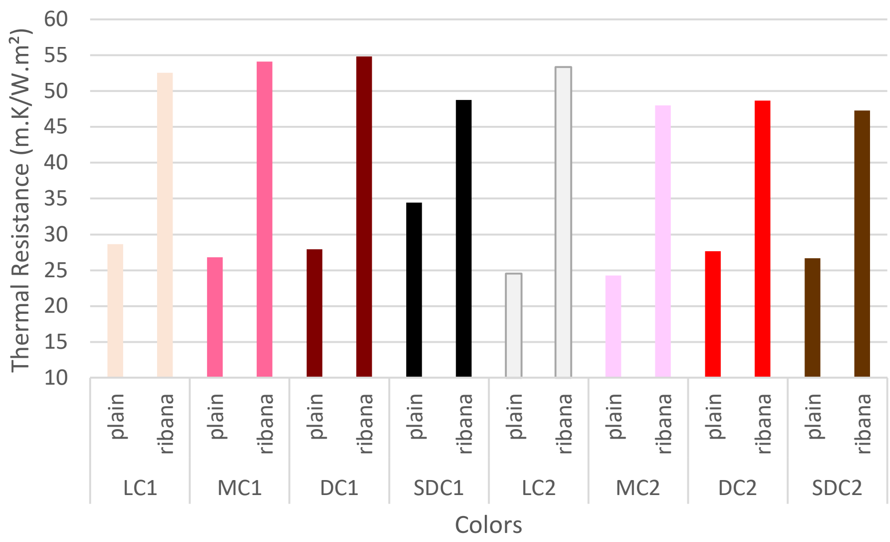

Figure 8. Thermal resistance test results.

In the thermal resistance results, it was obtained that the highest thermal resistance in plain fabrics was SDC1, while the lowest thermal resistance was in MC2. In rib fabrics, it is observed that the highest thermal resistance is in DC1 color and the lowest thermal resistance is in SDC2.

The thermal transmittance value of acrylic fibers is 200 mW/m*K and the thermal transmittance value of still air is known as 25 mW/m*K. There is an inverse relationship between thermal transmittance and thermal absorptivity. In addition, as the fabrics get thicker, the air in the fabric also increases. Therefore, the thermal permeability of the air in the pores of the stitch causes a decrease in the thermal absorption values of the fabrics. As is known, the specific heat value of acrylic fiber is (1.46-2.16 J/g-°C). Higher thermal permeability, specific heat, and lower thickness of fabrics result in lower thermal absorption. (Değirmenci and Çelik, 2016)

4. Statistical Analyses

Statistical analyses of the study is carried out by Design Expert 13.0 package programme. And one way ANOVA test results are presented in Table 2. Pattern and color variations are the dependent variables and bursting strength, air permeability, thermal absorptivity, thermal resistance, thermal conductivity, thickness, unit weight and stitch density are the responses. According to this table if the P-values less than 0,0500 indicate model terms are significant. In this case This parameter is a significant model term. Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model.

Table 2. Statistical analyses.

	Source	Sum of Squares	df	Mean Square	F-value	p-value	
Bursting strength	**Model**	35066,25	8	4383,28	36,37	< 0.0001	Significant
	Pattern	33306,25	1	33306,25	276,32	< 0.0001	Significant
	Colour	1760,00	7	251,43	2,09	0,1765	Not significant
Air permeability	**Model**	1,805E+06	8	2,256E+05	45,37	< 0.0001	Not significant
	Pattern	1,736E+06	1	1,736E+06	349,14	< 0.0001	Significant
	Colour	68584,44	7	9797,78	1,97	0,1955	Not significant
Thermal absorptivity	**Model**	291,28	8	36,41	0,7676	0,6430	Not significant
	Pattern	25,83	1	25,83	0,5446	0,4845	Not significant
	Colour	265,45	7	37,92	0,7995	0,6124	Not significant
Thermal resistance	**Model**	2231,33	8	278,92	25,42	0,0002	Significant
	Pattern	2172,73	1	2172,73	197,99	< 0.0001	Significant
	Colour	58,60	7	8,37	0,7629	0,6349	Not significant
Thermal conductivity	**Model**	115,15	8	14,39	25,55	0,0002	Significant
	Pattern	106,76	1	106,76	189,50	< 0.0001	Significant
	Colour	8,39	7	1,20	2,13	0,1703	Not significant
Thickness	**Model**	4,55	8	0,5694	106,87	< 0.0001	Significant
	Pattern	4,46	1	4,46	837,64	< 0.0001	Significant
	Colour	0,0921	7	0,0132	2,47	0,1278	Not significant
Unit weight	**Model**	1,234E+05	8	15422,75	73,67	< 0.0001	Significant
	Pattern	1,227E+05	1	1,227E+05	585,99	< 0.0001	Significant
	Colour	706,94	7	100,99	0,4824	0,8215	Not significant
Stitch density	**Model**	5940,00	8	742,50	19,41	0,0004	Significant
	Pattern	5402,25	1	5402,25	141,24	< 0.0001	Significant
	Colour	537,75	7	76,82	2,01	0,1889	Not significant

According to Table 5 except thermal absorptivity pattern is a significant model term on all responses while colour is not a significant factor. Consequently, it is concluded that color is not a selective parameter on air permeability, thermal conductivity, bursting strength and structural parameters of knitted sample fabrics wheras pattern is effective on these properties.

4.1.Optimization

In this study by using Design Expert statistical software optimization is applied. Used yans in this study are generally used in winter season. According to the seasonal preferences constraints are determined and given in Table 3.

The importance level of the criterias are selected as five for the parameters determined as maximum or minumum others are selected as three for the parameters determined as in range.

Table3. Constraints of the samples according to winter season

Name	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
Pattern	is in range	Level 1 of A	Level 2 of A	1	1	3
Color	is in range	Level 1 of B	Level 8 of B	1	1	3
Bursting strength	maximize	209	347	1	1	5
Air permeability	minimize	488	1373	1	1	5
Thermal absorptivity	minimize	92,33	119	1	1	5
Thermal resistance	maximize	24,26	54,8	1	1	5
Thermal conductivity	minimize	41,43	49,6	1	1	5
Thickness	maximize	0,83	2,1	1	1	5
Unit weight	is in range	163	367	1	1	3
Stitch density	is in range	180	234	1	1	3

Table *4.* Solution of the optimization constraints.

Number	Pattern	Color	Bursting	Air permeability	Thermal absorptivity	Thermal resistance	Thermal conductivity	Thickness	Unit weight	Stitch density	Desirability	
1	Ribana	SDC2	317,125	651,063	100,324	50,583	46,663	1,958	348,063	216,375	0,714	Selected

Table 4 shows that ribana pattern and SDC2 sample is the best fabric type for winter season with 0,714 desired value.

5.Conclusion

As a result of this study when examining the effect of color difference and pattern change on the performance and thermal properties of acrylic knitted fabrics, the colors preferred by people according to seasonal differences are different. This is because dark colors store the heat they absorb from the sun. In this study, it was investigated whether this theorem gives a result in direct proportion to the thermal comfort properties, but it was found that the variations in colors did not cause a significant effect on both thermal properties and air permeability. The strength results also confirm the thermal comfort results. Serious differences are observed between rib and plain fabric in the bursting test, because the flexibility due to the double needle bed causes more elongation in the stitches and this elongation increases the bursting strength of the fabrics, but the color change does not have a significant effect on the bursting strength. When the air permeability of the fabrics is considered, the closed air and space structure inside the loops of the rib fabric is more than the plain fabric. Therefore, due to the structural differences in terms of low thickness, unit height and static air inside the ribana fabric, the air permeability of the plain fabric is higher than the air permeability of the rib fabric. On the other hand, color differences between samples had no significant effect and air permeability static analyzes corrected the tested results. Therefore, it has been decided that the pattern is a more effective parameter than the color on the performance of the fabric produced from the same raw material. Within 16 samples the most convenient sample is selected as ribana and SDC2 one with 0,714 desired value according to determined constraints which are important for winter season.

Acknowledgments
The writers would like to express their sincere thanks to BOYAR KİMYA SAN. VE TİC. A.Ş/Gaziantep for supplying of the yarns and the samples. This study was done with the project supported by Gaziantep University/Gaziantep.

6.References

Sadeghi-Kiakhani, M., & Tehrani-Bagha, A. R. (2016). Retarding action of poly(amidoamine) dendrimers and cationic gemini surfactants in acrylic dyeing. *Dyes and Pigments, 125, 323–330*. https://doi.org/10.1016/j.dyepig.2015.10.037.

Jiang, H., Guo, G., Chen, W., & Cui, Z. (2021). Reactive dyeing of synthetic fibers employing dyes containing a diazirine moiety. *Dyes and Pigments, 194, 109555*. https://doi.org/10.1016/j.dyepig.2021.109555.

R. David, H. Geoffrey. (1990). The Chemistry and Application of Dyes*, New York and London*.

M.M. Kamel, H.M. Helmy, H.M. Mashaly, H.H. Kafafy. (2010). Ultrasonic assisted dye-ing: dyeing of acrylic fabrics C.I. Astrazon Basic Red 5BL 200%, *UltrasonicsSonochem*. 17 92–97.

Sadeghi-Kiakhani, M., & Tehrani-Bagha, A. R. (2015). Cationic ester-containing Gemini surfactants as retarders in acrylic dyeing. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, 479, 52–59. https://doi.org/10.1016/j.colsurfa.2015.03.030

Uyanık S. & Kaynak H. 2018. Pamuklu/Elastan Süprem Kumaşlarda Fiziksel, Boyutsal ve Görünüm Özellikleri. *Journal of Textiles and Engineer*. Cilt (Vol): 25 Sayı (No): 110. https://doi.org/10.7216/130075992018251100 7.

Saçak M., 2007. *Lif ve Elyaf Kimyası*.Cilt(Vol): 2. 978- 975-8640-26-3.

Türksoy H., S. Üstüntağ and G. Çarkıt. 2017. Thermal Comfort Properties of Fabrics Knitted from Bamboo/Cotton Blended Yarns. *Dokuz Eylul University-Faculty of Engineering Journal of Science and Engineering*, Volume 19, Issue 56, May 2017. DOI: 10.21205/deufmd.2017195649.

Değirmenci, Z. and N. Celik. 2016. Investigation of Thermal Comfort Properties of Jeggings Manufactured by the Use of Knitted Denim-Like Fabrics. *Journal of Testing and Evaluation*, Vol. 44, No. 1, pp. 268– 279, doi:10.1520/JTE20140165. ISSN 0090-3973.

Yavaşcaoğlu A., Eren R. and Süle G. 2018. Effects of Usage Acrylic Yarn on Thermal Comfort and Moisture Management Properties of Woven Shirting Fabrics. *Tekstil Ve Konfeksiyon* 28(2).

TİYEK, İ., & Bozdoğan, F. (2005). Akrilik lif üretiminde koagülasyon banyosunun önemi. *Pamukkale Üniversitesi Mühendislik Bilimleri Dergisi*, 11(3), 319-323.

Tunç, S. (2012). Meta aramid kumaşın boyanması, haslık yönünden elyaf boyalı meta-aramid kumaşlarla karşılaştırılması (Master's thesis, Namık Kemal Üniversite