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The Effect of Fabric Structure and Ultrasonic Welding Process on the Performance of the Spunlace Surgical Gowns

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ABSTRACT

This study investigates the effects of fabric properties and ultrasonic welding on the performance of surgical gowns. For this purpose, eight spunlace fabrics with different structural properties were provided. 100% polyester, 100% viscose, and their blends were used as test materials. First, the fabrics' thickness, breaking force, elongation at break, air permeability, drape behavior, and surface friction properties were investigated. Then the fabrics were sewn with the ultrasonic sewing machine. Afterward, the sewn fabrics' seam strength, air permeability, and drape behavior were tested. The results were statistically evaluated. A detailed comparison was made based on the data obtained. The higher the polyester content in the fabric, the higher the fabric strength, seam strength, and air permeability. However, viscose-rich fabrics have a softer feel and are easier to drape compared to polyester fabrics. Moreover, the sewing process leads to a reduction in the air permeability of the fabrics.

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KEYWORDS

Surgical gown, nonwoven fabric, spunlace, ultrasonic welding, seam strength, performance

1. INTRODUCTION

Surgical gowns are the most important part of the surgical clothing system that covers a large part of the body. They have been used for more than a century by doctors and nurses, as protective clothing in the operating room to prevent the transmission of bacteria from patients to surgical staff, thereby reducing the incidence of hospital-acquired infections. In addition to providing protection, it also affects the comfort level of the healthcare personnel and, thus the success of the surgery [1].

The clothing comfort of surgical gowns is an important parameter for the surgical team, which often has to wear the surgical gown for several hours while performing complicated operations in the operating room.

Surgical gowns must have some protective properties. They must be resistant to penetration by blood and other body fluids, depending on their intended use. They should be designed considering liquid repellency, liquid impermeability, air permeability, and similar properties in mind. They should be tear, puncture, and abrasion-resistant. They should not generate dust or flies or allow them to pass through. They should be soft and flexible, lightweight, and should not cause discomfort during use [1]. They should repel liquids but ventilate the surgeon's extreme body heat. And all of this must be achieved in a cost-effective manner [2].

Surgical gowns are classified as "disposable/single-use" or "reusable/multi-use/multiple." Disposable surgical gowns and drapes are usually made from nonwoven alone or in combination with materials that provide greater protection against liquid penetration (e.g., plastic films). Nonwoven fabrics are made from various forms of natural fibers (wood pulp, cotton) and synthetic fibers (polyester, polyolefin) that can be adjusted to desired properties by specific fiber types, bonding processes, and fabric finishes. There are a variety of nonwoven fabrics of all types, including hydroentangled, bonded, stitched, and laminated

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nonwovens, which vary in quality depending on the manufacturer's intended use [3, 4]. Nonwoven fabrics are preferred for surgical gowns due to their low cost, lightweight, durability, breathability, low hairiness, and disposability [5]. Moreover, nonwoven fabrics can prevent almost all possible strike-through of blood and body fluids.

It is well known that cellulose-based garments also provide the best fit on human skin. For this reason, spunlace fabric is the most preferred nonwoven structure due to its softness and surface properties.

Spunlace nonwoven fabric, also known as hydroentangled nonwoven fabric, is produced using high-pressure water jets to entangle loose assemblies of fibers and impart strength to the final nonwoven fabric [6]. The essential steps in the production of hydroentangled spunlace nonwoven fabric include [7]: Formation of the precursor web, web entanglement through water jet application, dewatering, drying of the web, and winding.

Hydroentangled fabrics are often used in medical applications due to their relatively high absorbency. Another important criterion for the large-scale use of hydroentangled fabrics in medical applications is the absence of a binder in the fabric, which allows the fabric to be sterilized at high temperatures [7]. Since no binder is required for its production, it also provides a high degree of softness, a flexible handle, a high drape, and volume. These fabrics exhibit good physical and mechanical properties and are therefore considered a promising alternative fabric for the apparel sector. It is reported that the flexural rigidity and surface properties of spunlace fabrics are superior to those of other nonwovens, while the structural rigidity is comparable to these products. Due to these properties, spunlace fabrics are used as bacteria-proof garments, cleanroom garments, wet wipes, and interlinings [8].

The most common and conventional method of joining these functional garments is sewing with needle and thread. However, conventional seams have small needle holes, and the perforations caused by a conventional seam compromise the integrity and performance of the garment [9]. Ultrasonic sewing is preferred over other conventional sewing methods in the manufacture of nonwoven-based products. The main reason is that the structure of nonwoven fabrics is more suitable for ultrasonic sewing [10].

Ultrasonic is defined as sound waves that cannot be heard by the human ear or at frequencies above about 20 kHz. The ultrasonic bonding mechanism is a physical process that uses mechanical vibrations to soften or melt a thermoplastic material at the joint line [11, 12]. It is an advanced technique for joining synthetic materials and blends to produce continuous and impermeable seams. Fabrics may be 100% synthetic (thermoplastic) or blends with up to 40% natural fiber content [13]. This process can be used to weld materials such as nylon, polyester, polyethylene, polypropylene, urethanes, and polyvinylchloride producing continuous, smooth, durable, and impermeable seams. Welding takes place as a result of the high-frequency mechanical motion of the vibrating horn and compression between the horn and the anvil [14].

Ultrasonic welding has the advantage of low energy consumption, eliminating the costs associated with the needles and threads as in conventional sewing methods. Worldwide usage of welding is still increasing, and its use is expected to grow further due to its economic advantages, as well as environmentally friendly, fast, and clean process conditions. Moreover, variable seam widths and welding of several layers can be achieved and the needle holes in conventional stitched seams are eliminated in the ultrasonic welding method [14].

The mechanical, physical, and comfort properties of spunlace fabrics have been investigated by various researchers. Zhou and Zhang (2012) compared the absorbency rate, water-vapor transmission rate, and diffusion area in a solution of three different polyester/viscose spunlaced nonwoven fabrics [15]. Jain et al. (2019) studied the effect of fiber type, mass per unit area, and the number of cycles on the compressional and recovery behavior of spunlace fabrics [8]. Maiti et al. (2020) investigated the effects of the type of fiber, blend ratio, and process parameters like jet pressure on air permeability, mass per unit area, thickness, liquid absorbency time, liquid absorptive capacity, and tensile strength [16].

The effects of ultrasonic welding parameters on the performance of nonwoven fabrics have been studied by various researchers. Kayar (2014) discussed the ultrasonic seam strength and elongation at the break of thermally bonded nonwoven fabrics. Also, the effects of fiber type, fabric area density, and roller type on the tensile properties of nonwovens were reported [10]. Seram and Cabon (2013) investigated the possibility of constructing different types of seams for apparel using ultrasonic technology [17]. Jevsnik et al. (2017) studied the effects of ultrasonic welding parameters on bond strength, seam, and thickness of the inner part of sports shoes [11]. Boz and Küçük (2021) analyzed the performance of ultrasonic welding in terms of air permeability, water resistance, and bursting strength. For this purpose, nonwoven fabrics with different production methods and masses were compared [18]. Yildiz et al. (2017) investigated the seam tensile properties of ultrasonically bonded nonwoven fabrics and studied the effects of the fabric type, roller type, and sewing speed on the seam tensile properties of the samples [19]. Eryürük et al. (2017) analyzed the bond strength and permeability properties of ultrasonically welded nonwoven fabrics and compare them with traditional sewing techniques [14]. Nguyen et al. (2020) considered the influence of the roller type on the formation of welding joints and their mechanical properties, different roller profiles were designed, fabricated, and tested [20].

This study investigates the effects of fabric properties and ultrasonic welding on the performance of surgical gowns. For this purpose, spunlace fabrics with different materials, blend ratios and masses, commonly used for surgical gowns, are investigated for their mechanical properties and comfort properties before and after ultrasonic welding.

2. MATERIAL AND METHOD

2.1 Material

Eight spunlace fabrics with different materials, blend ratios (100% polyester, 100% viscose, and their blends), and masses, commonly used for manufacturing surgical gowns, were used to investigate the performance, as listed in Table 1.

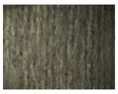
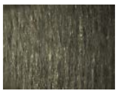
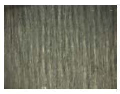
Spunlace nonwoven samples were supplied from Mogul Tekstil. The fabrics were produced from polyester (PES) with a fineness of 1.5 denier and a fiber length of 38 mm, and viscose (CV) with a fineness of 1.5 denier and a fiber length of 38 mm. All specimens were produced in parallel directions and had the same flat pattern.

2.2 Method

Fabrics were sewn using Pfaff 8310 Seamsonic ultrasonic sewing machine (Figure 1a), and ultrasonic sewing was performed using 4 mm pointed engraving roller (Figure 1b). The amplitude and the distance between the horn and the roller were kept constant. The specimens were joined at a speed of 20 dm/min in the machine direction (MD) and cross direction (CD). CD refers to the widthwise of the machine, while MD refers to the lengthwise direction of the produced fabric [21]. The sewn fabric images were given in Figure 2.

As mentioned above, the ultrasonic sewing machine can join fabrics made of 100% synthetics (thermoplastic) or blended fabrics with up to 40% natural fiber content. For this reason, ultrasonic sewing was not applied to fabrics S4, S5, and S6.

Table 1. Properties of spunlace fabrics

	S1	*S2*	*S3*	*S4*	*S5*	*S6*	*S7*	*S8*
Material	100% PES	70% PES - 30% CV	50% PES - 50% CV	30% PES - 70% CV	100% CV	100% CV	100% PES	100% PES
Fabric weight (g/m²)	50	50	50	50	50	70	70	100
Thickness (mm)	37,20	49,00	37,60	40,80	36,00	41,80	49,80	63,60
Microscopic images (machine direction)[a]								
Microscopic images (cross direction)[a]								

Note: [a] Images of the fabrics were taken at 6.4× magnification using a Leica light microscope

Figure 1. (a) Pfaff 8310 Seamsonic Ultrasonic Sewing Machine, (b) The roller

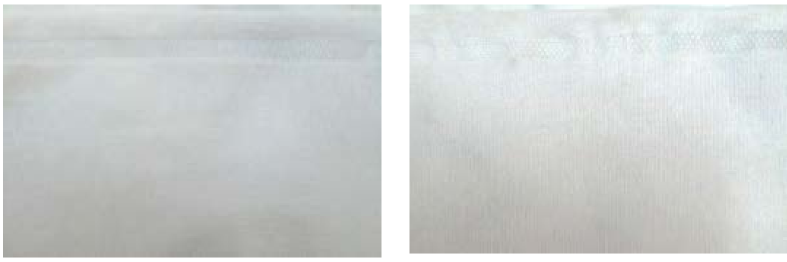


Figure 2. The images of sewn samples (S7) (a) parallel to MD, (b) vertical to MD

The thickness, breaking strength, air permeability, drape behavior, and surface friction properties of the unsewn fabrics and the seam strength, air permeability, and drape behavior of the sewn fabrics were tested. The specimens with and without seams were conditioned for 24 hours under standard atmosphere conditions (20°C ± 2°C temperature, 65% ± 4% RH) before testing.

The thickness values were measured with the SDL ATLAS Digital Thickness Gauge according to TS 7128 EN ISO 5084 standard. Breaking force and elongation at break tests were performed using a Zwick Roell ZO10 tensile tester in accordance with the standard TS EN ISO 13934-1. The test speed was 100 mm/min, and the gauge length was 20 mm. Specimens were tested in the machine and the cross directions for each fabric type. Seam strength tests were performed in accordance with the standard ISO 13935-2 using a Zwick Z010 tester. The fabrics were cut to a size of 350×100 mm, then folded and ultrasonically bonded from 1 cm of the fabric edge. The speed of the instrument was set at 50 mm/min. Air permeability was measured using the FX3300 tester according to TS EN ISO 9237 standard. The air pressure during the tests was 100 Pa, and the test area was 20 cm^2. Ten measurements were taken for each specimen.

The fabric drapability test was performed using the Cusick Drape Tester according to TS EN ISO 9073-9. In the drape test, a circular specimen is held concentrically between two smaller horizontal discs and allowed to fold under its weight. A light is shined from underneath the specimen, and the shadow cast by the fabric is observed [22]. The draped image of the mounted fabric sample is captured by a digital camera mounted above the drape meter. The captured image is transferred to a computer, and the area is calculated in pixel values by the software. The drape coefficient was calculated according to Equation (1). Three measurements were taken for each specimen. The air permeability and drape coefficient of the specimens with seams were measured, as shown in Figure 3.

The surface friction properties of the investigated fabrics were measured using the FricTorq instrument with three repetitions and indicated as “friction coefficient (μkin)”. Frictorq is based on a method for measuring the coefficient of friction of the fabrics using a rotational principle and thus measures the torque [23-25].

The statistical software SPSS was used to analyze the test results. ANOVA and Student-Newman-Keuls tests were performed to determine whether the effect of material type, blend ratio, and weight on the measured properties was statistically significant at the 95% confidence level (p<0,05).

3. RESULTS AND DISCUSSION

The statistical results in terms of p-values are shown in Table 2. For the Student-Newman-Keuls test, the mean values are indicated by letters. All values marked with the same letter are not significantly different (“a” represents the lowest value and “f” the highest value).

$$Drape\ Coefficient\ (\%) = \frac{Area\ under\ the\ draped\ sample - Area\ of\ supported\ disk}{Area\ of\ the\ specimen - Area\ of\ supported\ disk} x\,100 \qquad (1)$$

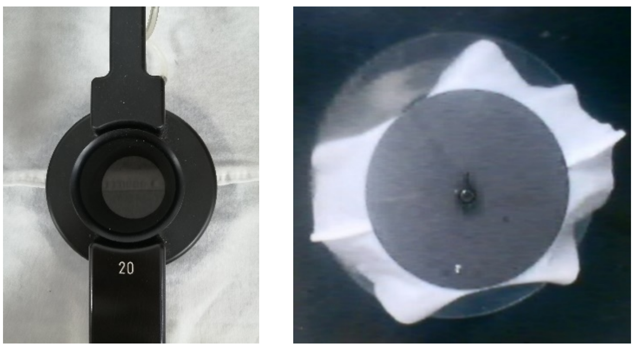


Figure 3. The measurement of welded specimens (a) The air permeability measurement (b) The drape coefficient measurement

Table 2. Statistical analysis results

Parameters		p-value	Value	Parameters		p-value	Value
Breaking force - MD	S5	0,000*	53,7597 a	**Breaking force - CD**	S5	0,000*	15,3800 a
	S4		69,6367 ab		S4		17,0633 a
	S3		84,7433 b		S3		20,1100 a
	S2		85,6467 b		S2		27,2733 b
	S6		120,9567 c		S6		32,0667 bc
	S1		152,5900 d		S7		36,1967 c
	S7		219,6333 e		S1		38,2600 c
	S8		513,0867 f		S8		76,8200 d
Elongation at break - MD	5	0,000*	15,5867 a	**Elongation at break - CD**	6	0,000*	54,7633 a
	6		18,3100 a		4		57,3000 a
	4		22,0167 b		5		58,0867 a
	8		26,1700 c		3		84,3300 b
	3		27,3633 c		2		85,8067 b
	2		35,8200 d		8		90,6200 bc
	1		44,2567 e		7		102,1200 c
	7		46,3633 e		1		104,1733 c
Air permeability - fabric	8	0,000*	715,20 a	**Drape coefficient**	4	0,000*	22,9699 a
	6		751,80 a		5		23,5526 a
	7		1174,00 b		3		32,4105 b
	5		1464,00 c		2		34,2138 bc
	4		1668,00 d		1		34,8256 bc
	3		1742,00 d		6		35,4638 bc
	1		1840,00 e		7		36,4096 c
	2		1990,00 f		8		46,6210 d
Drape coefficient – sewn parallel to MD	3	0,000*	34,88 a	**Drape coefficient - sewn parallel to CD**	3	0,000*	27,80 a
	2		36,06 ab		2		29,89 b
	1		37,70 b		1		30,09 b
	7		38,04 b		7		31,30 b
	8		47,90 c		8		42,24 c
Seam strength – sewn parallel to MD	3	0,000*	22,5100 a	**Seam strength - sewn parallel to CD**	3	0,000*	26,9900 a
	2		30,6167 b		2		45,1600 b
	1		45,1500 c		1		56,3200 c
	7		59,7267 d		7		99,8900 d
	8		114,7467 e		8		142,7400 e
Coefficient of friction	6	0,000*	0,3834 a	**Air permeability - sewn samples**	8	0,000*	514,40 a
	4		0,4190 ab		7		992,80 b
	5		0,4209 ab		3		1224,00 c
	8		0,4455 b		2		1306,00 c
	3		0,4998 c		1		1450,00 d
	7		0,5055 c	*Statistically significant (p<0,05).			
	2		0,5264 c				
	1		0,5355 c				

3.1 Breaking Force and Elongation at Break

The average breaking force values against the blend ratio in the machine and the cross directions of the fabric specimens are shown in Figure 4.

The breaking force of MD is always higher than that of CD for all samples, and the difference between the values is statistically significant (p=0,000). It agrees with earlier work by other researchers [26-28]. This is because the fabrics are composed of staple fibers and the fibers are aligned in MD so because of less number of fibers in the cross direction region, the developed fabric exhibited lower tensile strength in CD [29]. Also, Zhao et al. (2020) found that this is a typical effect caused by the carding process, in which most of the fibers are laid parallel at MD [30].

Moreover, it is also noticeable that the fabric strength increases in both directions as the blend ratio of polyester fibers increases in the range of 0 to 100%. On the contrary, as the proportion of viscose fibers increases, the fabric strength decreases. This is due to the higher breaking strength of polyester fibers compared to viscose fibers used in sample preparation.

The effects of the blend ratio on the elongation at break are shown in Figure 5. The figure clearly shows that the elongation at break is higher for CD than for MD, and the difference between the values is statistically significant (p=0,000). Since the webs were laid in parallel, the low elongation in MD and the higher elongation in CD are due to the predominant orientation of the MD fiber segment orientations in the parallel-laid web [31]. The figure also shows that the elongation at break increases with increasing polyester fiber content in both directions.

The effects of fabric weight on the breaking force and elongation at break are shown in Figures 6 and 7.

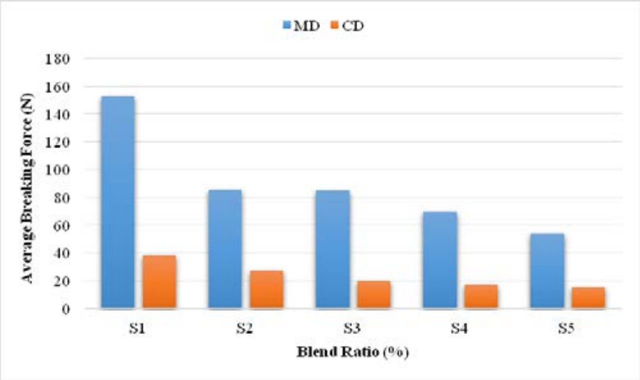


Figure 4. Effect of blend ratio on breaking force in machine and cross directions

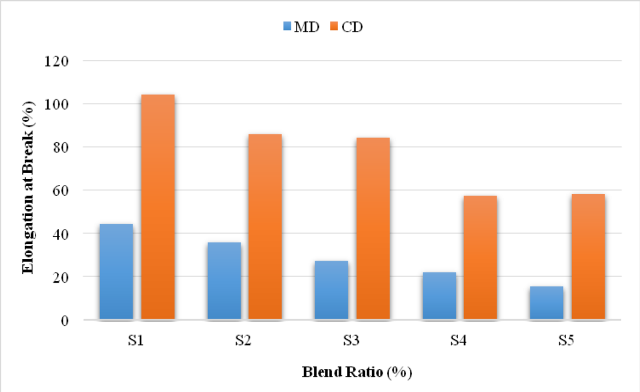


Figure 5. Effect of blend ratio on elongation at break in machine and cross directions

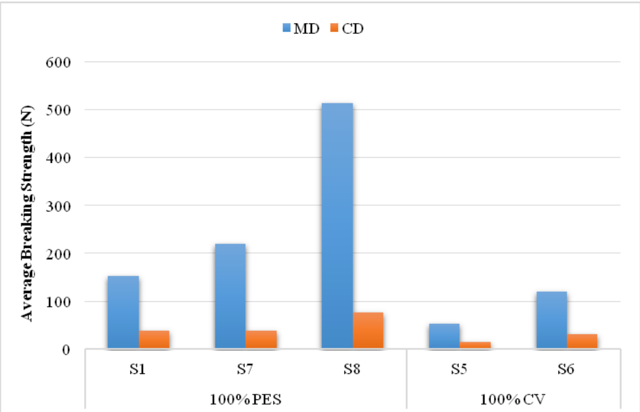


Figure 6. Effect of fabric weight on breaking force in machine and cross directions

Figure 6 shows that the breaking force values increase with increasing fabric weight for both fiber types. Polyester-containing fabrics have higher values than viscose-containing fabrics for the same weight. Moreover, the breaking force values in MD are always higher than those of CD for all samples, as explained above.

As shown in Figure 7, the elongation at break in MD increases as the weight increases from 50 to 70 g/m^2. However, as it increases further from 70 to 100 g/m^2, it begins to decrease. For CD, the elongation at break decreases with increasing weight.

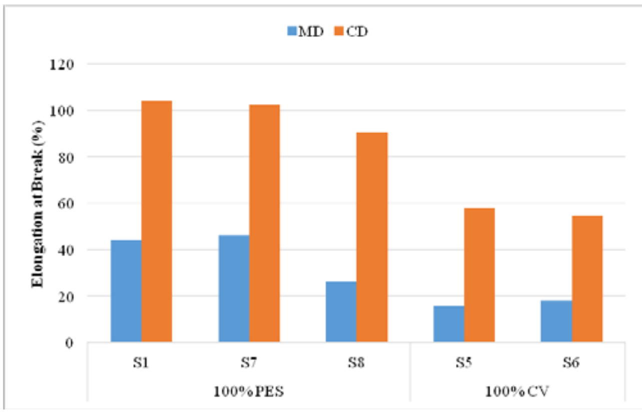


Figure 7. Effect of fabric weight on elongation at break in machine and cross directions

3.2 Seam Strength

The average seam strength values in the machine and the cross directions of the fabric samples are shown in Figure 8.

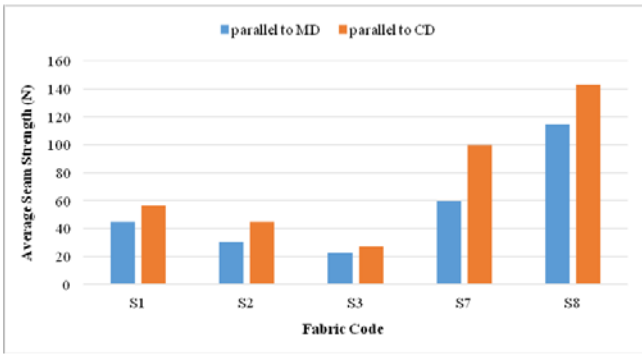


Figure 8. Effects of blend ratio and fabric weight on seam strength

As shown in Figure 8, the highest seam strength value is measured at S8 and the lowest at S3 in both directions. The analysis shows that there is a statistically significant difference between the seam strength of fabrics. The seam strength of fabrics increases as the ratio of polyester in a blend increases, indicating that polyester-rich fabrics have a more durable structure than viscose-rich fabrics. It can also be noted that seam strength is directly proportional to the fabric weight in both directions. That is, the heavier the fabric, the greater the seam strength. A higher fabric weight provides more resistance to seam breakage, resulting in higher seam strength.

In general, seam strength is higher for specimens sewn parallel to the cross direction than for specimens sewn parallel to the machine direction. The term seam parallel to the machine and cross directions refers to the condition that the seam is formed in the corresponding direction and the load is applied perpendicular to the seam line. The extensibility of nonwoven fabrics is lower in the MD and higher in the CD. Since the extensibility is higher in the

CD, the seam zone reaches the elongation limit in a shorter time and results in lower strength values.

3.3 Air Permeability

Air permeability is a measure of the airflow that can be maintained through a material at a specified pressure. It provides information about the breathability and comfort of the fabric [32]. The effects of blend ratio and fabric weight on the air permeability of unsewn samples are shown in Figures 9 and 10.

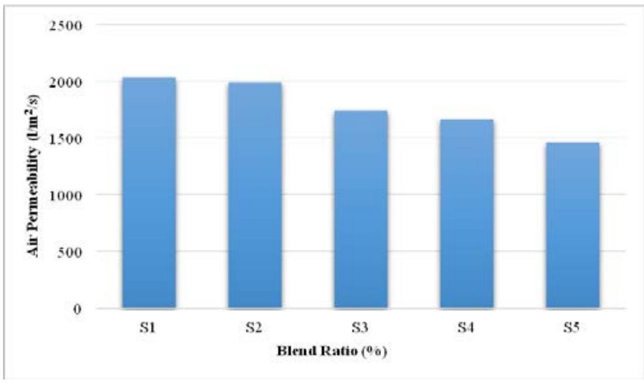


Figure 9. Effect of blend ratio on air permeability of unsewn samples

Increasing the polyester content leads to an increase in the air permeability of spunlace samples, while the trend is reversed for viscose-rich fabrics. Polyester-containing fabrics have higher values than those with viscose for the same weight (Figure 9). This phenomenon can be attributed to the crimp factor of the fibers, as found by Maiti et al. (2021). It can be concluded that polyester fibers with higher crimp, compared to 100% viscose fibers, result in more voluminous webs, thus increasing air permeability [33]. Moreover, due to the high bending rigidity and low packing density of polyester, viscose-rich fabrics also have a more compact structure than polyester fabrics with the same density [34].

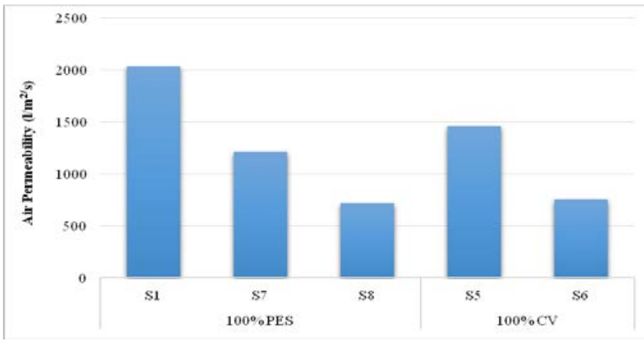


Figure 10. Effect of fabric weight on air permeability of unsewn samples

As shown in Figure 10, the air permeability of polyester or viscose nonwoven fabrics decreases with increasing weight. As the weight increases, the number of pores increases with the number of fibers, while the pore size decreases. A higher number of fibers leads to an increase in thickness. Higher fabric thickness and the greater number of fibers per unit area provide more resistance to airflow, which in turn leads to a decrease in air permeability as the weight of the fabric increases [34-36]. As noted by Zhao et al. (2020), when the weight of the spunlace fabric decreases, the fiber web is thinner, and the pores between the fibers are larger, resulting in high air permeability [37]. This is also consistent with the results of Midha and Mukhopadhyay (2005), and Maduna (2018) [38-39]. As a result, lower air permeability with higher fabric weight makes the garment uncomfortable [36].

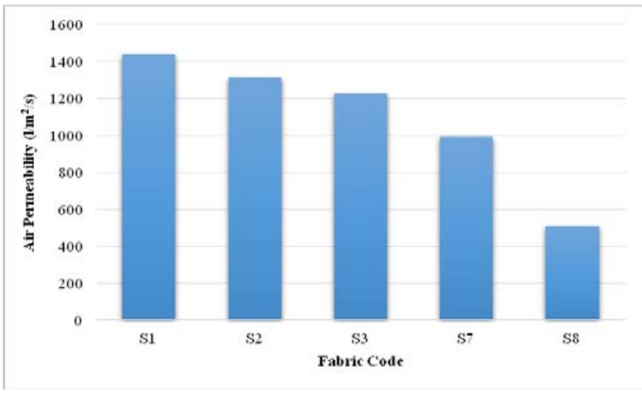


Figure 11. Effects of blend ratio and fabric weigth on air permeability of sewn samples

According to Figures 9-11, the comparison of the sewn and unsewn samples shows that ultrasonic sewing has a significant effect on the air permeability values and reduces the air permeability of the samples compared to the unsewn samples, as indicated by Daukantiene and Vadeike (2018) [40]. The reason for this is the increase in fabric thickness in the seam area. As mentioned in the literature, air permeability decreases with increasing thickness, weight, and fabric density. Thus, the ultrasonic sewing method increases the thickness of the seam area, resulting in lower air permeability.

3.4 Drape Behavior

Drape is an important component of the esthetic appearance of a garment and plays a critical role in the comfort and fit of the garment [11]. Drape behavior is determined by the drape coefficient. The drape coefficient is the ratio between the projected area of the fabric sample and its undraped area, from which the area of the supporting disk is derived. The higher the drape coefficient, the lower the drapeability of the fabric and the stiffer the fabric [41, 42].

The effects of blend ratio and fabric weight on the drape behavior of unsewn samples are shown in Figures 12 and 13.

As shown in Figure 12, the drape coefficient of the fabrics increased with the increase in the ratio of polyester in a blend, indicating that polyester-rich fabrics have a stiffer structure than viscose-rich fabrics. This can be explained by the high bending rigidity of polyester fibers compared to viscose fibers.

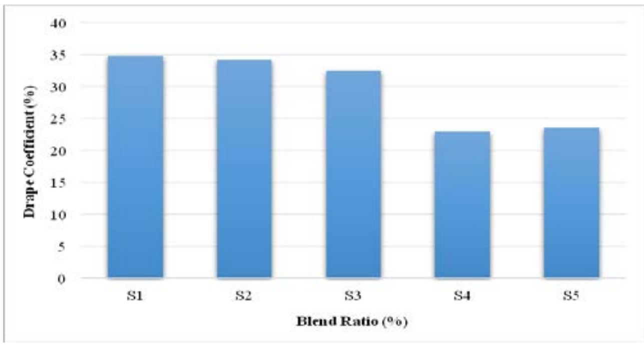


Figure 12. Effect of blend ratio on drape coefficient of unsewn samples

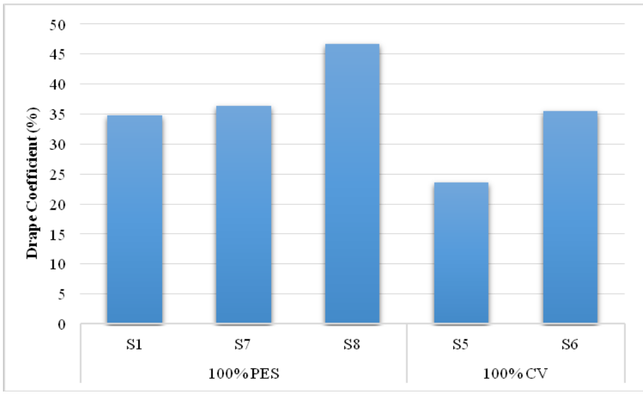


Figure 13. Effect of fabric weight on drape coefficient of unsewn samples

As shown in Figure 13, the drape coefficient value of polyester and viscose nonwoven fabrics increases with increasing weight. This is due to the rise in fabric tightness, as stated by Eryürük et al. (2019) [43].

To investigate the effects of sewing and sewing direction, the fabric samples were sewn parallel and perpendicular to the machine direction. The effects of blend ratio and fabric weight on the drape coefficient of the sewn pieces are shown in Figure 14. Also, Figure 15 shows the comparison between drape coefficients of draped samples with and without seams.

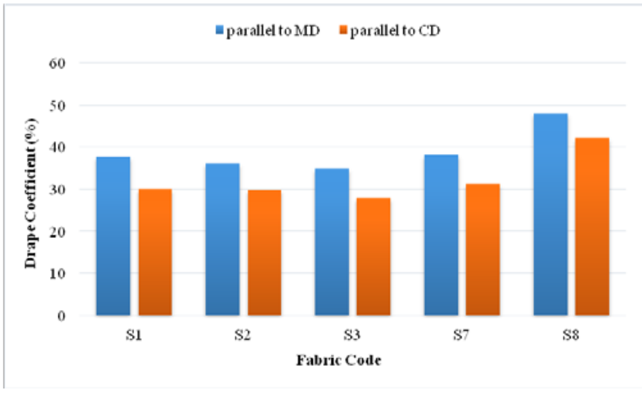
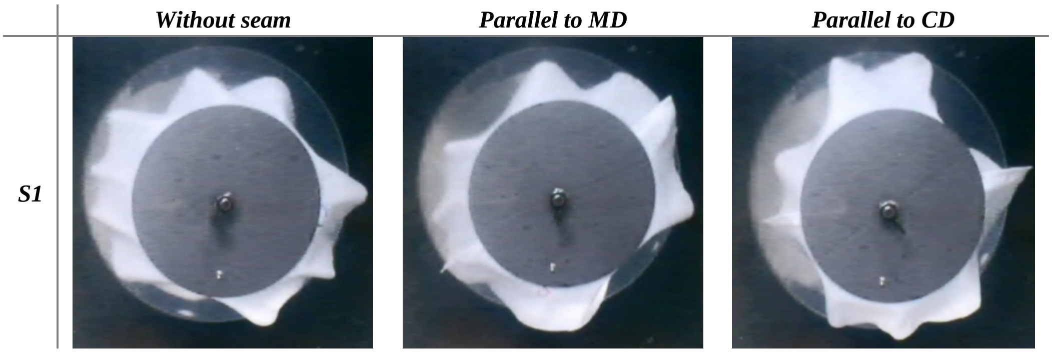


Figure 14. Effects of blend ratio and fabric weight on drape coefficient of sewn samples

While the highest drape coefficient results were obtained for the seams parallel to MD, the values for the unsewn fabrics were lower than MD and above CD. A sewn fabric is not a single piece of fabric but consists of two joined pieces of the same fabric. Due to the greater mass concentration in the seam area, sewing leads to an increase in fabric stiffness [11, 44]. As a result, sewing operations increase the drape coefficient of fabrics. This means that sewing operations lead to a reduction in the drape of fabrics.



S7

Figure 15. The comparison between drape coefficients of draped samples with and without seams

Moreover, the drape coefficient of the samples sewn parallel to MD is higher than the drape coefficient of the fabrics sewn parallel to CD. This is because the fibers are more aligned and more tightly entangled in the machine direction. This restricts the movement of fibers in the machine direction, resulting in a higher drape coefficient in this direction.

3.5 Coefficient of Friction

The physical properties of fabrics directly affect the handling properties of the garments made from them. Therefore, fabrics with a lower coefficient of kinetic friction have better handling properties [45]. The coefficient of friction results against the blend ratio is shown in Figure 16.

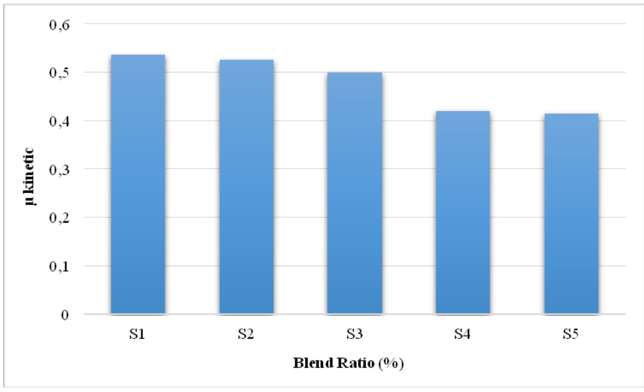


Figure 16. Effect of blend ratio on coefficient of kinetic friction

According to the test results shown in Figure 16, the kinetic friction coefficients of blended fabrics with higher viscose content are lower than those of fabrics with higher polyester fiber content. It can be concluded that viscose fabrics have a softer handle when compared to polyester fabrics.

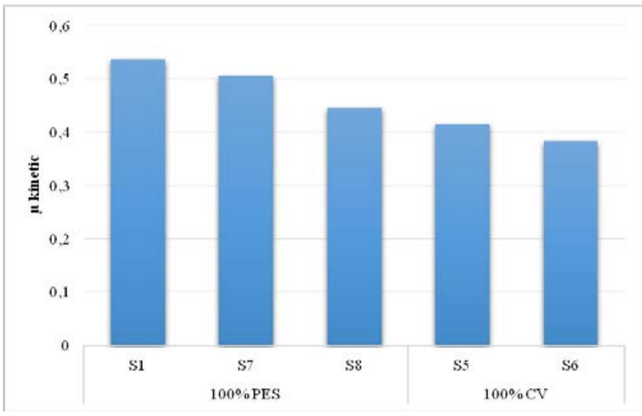


Figure 17. Effect of fabric weight on coefficient of kinetic friction

As can be seen from Figure 17, it is found that the coefficient of friction values decreases with increasing weight. As stated by Babaarslan and Avcioglu Kalebek, this can be explained by the fact that the fibers are not uniformly distributed in the low-weight specimens [46]. The test results show that, with increasing weight, the fiber orientation of the nonwovens becomes more stable, and nonwoven fabrics with a more stable structure have a lower coefficient of friction. This result shows that viscose-containing fabrics and heavier fabrics have smoother surfaces and provide a softer feel.

4. CONCLUSION

This study investigates the effects of fabric properties and ultrasonic welding on the performance of disposable surgical gowns. For this purpose, eight spunlace fabrics with different structural properties (material and weight) were provided. First, the thickness, breaking force, elongation at break, air permeability, drape behavior, and surface friction properties of the fabrics were investigated. Then the fabrics were sewn with the ultrasonic sewing machine and the seam strength, air permeability, and drape behavior of the sewn fabrics were tested. The main results of these analyses are summarized below.

- Specimens cut in the machine direction are significantly stronger and less extensible than specimens cut in the cross direction because of the predominance of fiber orientation in that direction.

- The fabric strength and the seam strength increase in both directions as the blend ratio of polyester fibers and the weight of the fabric increase.
- The higher the polyester content in the fabric, the higher the fabric strength, seam strength, and air permeability. However, polyester-rich fabrics have a stiffer structure than viscose-rich fabrics, and viscose-rich fabrics have a softer handle and are more drapeable compared to polyester-rich fabrics.
- Sewing operations result in a reduction in air permeability of fabrics as fabric thickness increases in the seam area.
- Heavier fabrics are stronger, more durable, have a smoother surface, and provide a softer feel. Nevertheless, their air permeability values are lower, which can worsen the comfort properties.
- It is recommended to use heavy polyester fabrics in areas where strength is more important, and viscose-containing fabrics in areas where handling is important.

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