(REFEREED RESEARCH)

DEVELOPMENT OF DISPOSABLE HYDROPHILIC AND ANTIBACTERIAL POLYPROPYLENE NONWOVEN SHEET

TEK KULLANIMLIK HİDROFİLİK VE ANTİBAKTERİYEL POLİPROPİLEN NONWOVEN ÇARŞAFIN GELİŞTİRİLMESİ

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ABSTRACT

Especially at hospitals, nosocomial infections or the infections of patients are a great concern for the patients, visitors, and healthcare workers. Mortality caused by nosocomial infections is quite high in all over the world. It is reported that 40 % of all nosocomial infections can be prevented. In this study first of all, nosocomial infections and their effect on the human health are disscussed. And then the hospital sheets and their role on the spread of these infections were examined. The main purpose of this study is to develop a new disposable and antibacterial sheet. It was targetted to partially prevent spread of the infections in the hospitals. Because of the cost concerns, the disposable sheet was designed as polypropylene and spun-bond nonwoven. In the experimental section, 3 different polypropylene spun-bond nonwoven fabrics were supplied by General Nonwoven Ltd. Nonwovens were processed into a hydrophilic structure by using atmospheric O2 plasma treatment. Silver based and PHMB based two different antibacterial finishing chemicals were applied to the samples by pad-batch method. Antimicrobial tests and physical tests were applied to the samples according to relevant ISO and ASTM standards for measuring their performance characteristics. Finally experimental results were evaluated using statistical methods and how, and at which level chemical finishing and atmospheric plasma process affects spunbond nonwoven fabric properties were tried to define.

Key Words: Nonwovens, Polipropylene, Oxigen plasma, Antibacterial finishing.

ÖZET

Özellikle hastanelerde, hastane mikrobu ya da hasta enfeksiyonları, hasta, refakatçı ve hastane çalışanları üzerinde önemli bir tehdit oluşturmaktadır. Tüm dünyada hastane enfeksiyonları nedeniyle hayatını kaybeden hastaların sayısı oldukça yüksektir. Halbuki hastane enfeksiyonlarının %40'ının alınacak tedbirlerle önlenebileceği saptanmıştır. Bu çalışmada, ilk önce hastaneden bulaşan enfeksiyonlar ve bunların insan sağlığı üzerindeki etkileri tartışılmıştır. Ardından hastanelerde kullanılmakta olan çarşaflar ve bunların enfeksiyon bulaşmasına olan etkileri irdelenmişirtir. Çalışmamızın temel amacı tek kullanımlık ve antibakteriyel bir çarşaf geliştirmektir. Bu sayede hastanelerde çarşaflar yoluyla yayılacak enfeksiyonların önüne geçilmesi hedeflenmiştir. Üretilecek yapı tek kullanımlık olacağı için maliyeti mümkün olduğunca düşük tutulmaya çalışılmış bu nedenle yapı düşük ağırlıklı nonwoven polipropilen olarak tasarlanmıştır. Deneysel kısımda 3 farklı gramajda spunbond nonwoven polipropilen kumaş General Nonwoven Ltd.'den temin edilmiştir. Kumaşlar atmosferik oksijen plazma yöntemi ile hidrofil hale getirilmiştir. Gümüş ve PHMB antibiyotik esaslı iki farklı antibakteriyel apre emdirme yöntemine göre numunelere uygulanmıştır. Çarşafların performans karakteristiklerini belirlemek üzere fiziksel ve antibakteriyel testler ISO ve ASTM standartlarına göre uygulanmıştır. Son olarak, deneysel sonuçlar istatistiksel yöntemler kullanılarak değerlendirilmiş ve kimyasal terbiye işlemi ve plazma yönteminin nasıl ve hangi seviyede spunbond nonwoven kumaş yapısını etkilediği belirlenmeye çalışılmıştır.

Anahtar Kelimeler: Nonwovenlar, Polipropilen, Oksijen plazma, Antibakteriyel terbiye.

1. INTRODUCTION

The main purpose of our study is to contribute reduction of nosocomial infections by developping a new disposable and antibacterial sheet for hospitals. Nosocomial infections are infections which are a result of treatment in a hospital or a healthcare service unit, but secondary to the patient's original condition. Infections are considered nosocomial if they first appear 48 hours or more after hospital admission or within 30 days after discharge. Nosocomial infections are even more alarming in the 21st century.

In the United States, it has been estimated that as many as one hospital patient in ten acquires a nosocomial infection, or 2 million patients a year. Estimates of the annual cost range from $4.5 billion to $11 billion and up. Nosocomial infections contributed to 88,000 deaths in the U.S. in 1995. One third of nosocomial infections are considered preventable. Ms. magazine reports

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that as many as 92 percent of deaths from hospital infections could be prevented. The most common nosocomial infections are of the urinary tract, surgical site and various pneumonias (1).

In Italy, in the 2000s, about 6.7 % of hospitalized patients were infected, i.e. between 450,000 and 700,000 patients, which caused between 4,500 and 7,000 deaths. In Switzerland, extrapolations assume about 70,000 hospitalised patients are affected by nosocomial infections (between 2 and 14% of hospitalized patients)

Nonwovens are unique engineered fabrics offering cost effective solutions for an increasingly wide variety of applications. They are engineered to provide specific functions to ensure fitness for purpose. These properties are combined to create the required functionality, while achieving a profitable balance between the expected product life and cost (1).

Nonwovens are defined by INDA, (North America's Association of the Nonwoven Fabrics Industry) as a sheet or web structure bonded together by entangling fiber or filaments mechanically, thermally or chemically. They are engineered to provide specific properties such as: absorbency, liquid repellency, resilience, stretch, softness, strength, flame retardancy, wash ability, cushioning, filtering, bacterial barrier and sterility. In combination with other materials nonwovens provide a spectrum of products with diverse chemical and physical properties. This is reflected in the large variety of industrial, engineering, consumer and health care goods into which nonwoven fabrics are incorporated. The conversion of nonwoven role products into finished products is a further important component step in the process and can also affect final product properties. The one of the nonwoven fabric production technique is spun-bond process. Spun-bond nonwoven fabrics are produced by an integrated process of spinning, attenuation, deposition, bonding, and winding to form rolls. Spun-bond fabrics are produced by depositing extruded, spun filaments onto a collecting belt in a uniform random manner followed by bonding the fibers. The fibers are separated during the web laying process by air jets or electrostatic charges. The collecting surface is usually perforated to prevent the air stream from deflecting and carrying the fibers in an uncontrolled manner (2-4).

Spun-bond fabrics are seen as cost effective compared to other nonwovens. Spun-bonds are widely used in sanitary napkins and to a limited extent in tampons. In the medical sector, certain traditional textile materials are being replaced by spun-bonds (16). Polypropylene fibers are predominant in the nonwovens industry. Some of the reasons for this include low density and specific gravity enabling lightweight fabrics to be produced. They have low glass transition and melting temperature, which is attractive for thermal bonding, inherent hydrophobia that can be modified using fiber finishes and other treatments and they provides fabrics with good bulk and cover, chemical stability, biological degradation resistance (mildew, perspiration), stain and soil release, and good mechanical strength and abrasion resistance. As PP is very hydrophobic material with a very low surface tension, they can be wetted only with liquids with surface tension < 35 mN/m, no water can pass through the PP web without applying a high pressure. This problem can be solved with two different methods. First method is chemical method that PP was made hydrophilic with application of acrylic acid or poly-acrylic acid. The other is Plasma Treatment which is a new challenging method in the textile industry (5-10).

The main purpose of this study is to contribute reduction of infection risks by developping a new disposable, antibacterial, front face hydrophilic and back face hydrophobic, nonwoven fabric. To do so, 100% Polypropylene and spun-bonded nonwoven fabrics were choosen.

2. MATERIAL AND METHOD

2.1. Material

100% Polypropylene spun-bond nonwoven fabrics were produced in three different weights per unit by General Nonwoven Tic.A.S., Gaziantep-Turkey (see table 1). Two different kinds of finishing agents which are silver-based and PHMB (polyhexamethylene biguanide) based were supplied by CHT Tekstil Kimya A.Ş. Bursa-Turkey.

Table 1. PP nonwoven fabric properties

Fiber	Construction	Bonding Method	Fabric Weight (g/m^2)	Supplier Company
%100 Polipropilen	Spun Bonded	Thermal	17	General Nonwoven
%100 Polipropilen	Spun Bonded	Thermal	25	General Nonwoven
%100 Polipropilen	Spun Bonded	Thermal	35	General Nonwoven

2.1.1. Silver-based antibacterial agent

Silver based antimicrobial agent, ISYS – AG, was suplied by CHT company. It is avaliable for all man-made and natural fibers. It contains nanoscaled silver particules. And It is a very strong biosid chemical. It has 3 main effects on the bacteria:

- Destruction of the cell membran
- Deactivation of the cell metabolism
- Destruction of the sell division.

It has a very large spectrum and it is effective on both gram negative and gram pozitive bacteria.The advantages of the chemical are that durable to washing, easy application on the padder, good liquor stability, extremely high antibacterial effect trough nanoscaled silver (11).

2.1.2. Antibiotic based antibacterial agent

PHMB is the basic compound of Reputex 20. PHMB (polyhexamethylene biguanide) is an oligomer with an average of 12 biguanide per molecule .Because of its activity against Gram-positive and Gram-negative bacteria, fungi, and yeast PHMB antibacterial activity is through the biguanide functional group,which disrupts the bacterial cell membrane (12). It has very strong biosid effect (Fig.1).

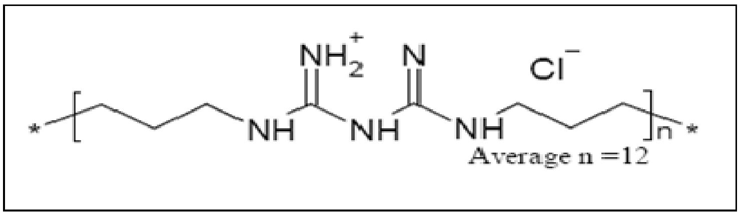

Figure 1. Structure of PHMB

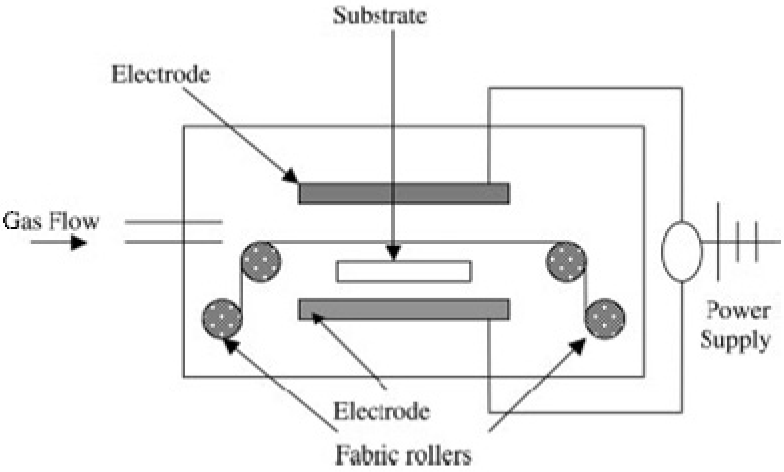

Figure 2. The inner chamber of the atmospheric plasma

2.2. Method

Hydrophobic spunbond nonwoven fabric was processed into a hydrophilic structure by atmospheric plasma treatment for enable application of finishing process. Silver and antibiotic based anti-microbial finishing chemicals were applied to the material by pad-batch method at OZTEK-STAMPA A.Ş., Tekirdağ-Turkey. Anti-microbial test and 9 physical tests including mass/area, tensile strength, tear strength, elongation, thickness, rewet, water vapor permeability, abrasion, stiffness tests are applied to the samples. Finally, experimental results are evaluated, and how and at which level chemical finishing and atmospheric plasma process affects spunbond nonwoven fabric properties are defined.

2.2.1. Hydrophilization of PP through plasma modification

Plasma surface treatments show distinct advantages, because they are able to modify the surface properties of inert materials, sometimes with environment friendly devices. For fabrics, cold plasma treatments require the development of reliable and large systems. Such systems now exist and the use of plasma physics in industrial problems is rapidly increasing. Main advantages of a plasma polymerization methods are: 1) applicability to almost all organic, organo-metallic and heteroatomic organic compounds, 2) modification of surface properties without altering the bulk characteristics, 3) low quantities needed of monomeric compounds making it non energy intensive, and 4) wide applicability to most organic and inorganic structures. Exciting plasma applications include 1) cold plasma discharge synthesis of new polymeric structures, 2) plasma induced polymerization processes, 3) surface grafting of polymers, and 4) surface modification of polymers.

Figure 2 shows that drawing of the inner chamber of the atmospheric plasma facility. Plasma is generated between two electrodes embedded in the dielectric material to form a dielectric barrier discharge.

In our study, cold O_2 plasma modification (13,14) under the atmospheric conditions was applied to the samples. Parameters of the process is shown in Table 2:

Table 2. Plasma modification process parameters

Gas	O_2
Pressure	Atmopheric
Voltage (V)	3500
Machine speed (m/min)	15

Plasma modification is repeated 3 times. The treated fabrics were processed approx 1 min in the plasma machine.

2.2.2. Application of Chemicals

All the finishing formulations and process parameters are shown in the Table 3.

Table 3. Finishing formulations and parameters

	Silver Based Chemical	Antibiotic Based Chemical
Antibacterial Agent (g/l)	2	20
Acetic Acid (g/l)	0,3	-
Total Water (l)	50	50
pH	5– 5.5	7-7,5
Machine Speed (m/min)	20	20
Pressure (Bar)	2,4	2,4
Bath Temperature (°C)	20-25	20-25
Pick Up (%)	40-45	40-45
*Drying Temperature (°C)	150	150
Drying Speed (m/min)	15	15
*Total processing time was 75 seconds. The samples were dryed in the first 45 seconds period. In the last 30 seconds, cross linking of the chemicals were achived.		

Table 4. The test standarts utilized in the tests

TESTS	STANDARDS
Mass/area (g/m^2)	ASTM D 3776-96
Thickness (mm)	TS 4117 EN ISO 2589
Tensile Strength (N)	TSE EN ISO 13934-1
Tear Strength (N)	TSE EN ISO 13937-1
Elongation (%)	BS 4952
Rewet (time "s",quantity "g")	ERT 151.2-93
Antimicrobial Effect (%)	AATCC 100 (with Staphylocococus Aureus bacteria)
Water Vapor Permeability (g/m^2)	BS 7209
Stiffness (N/m^2)	ASTM D - 3885
Abrasion (revs)	ASTM D - 1388

Test speciments were conditioned at 20 ± 2 ºC and 65 ±2 % RH for 24 h before testing, after conditioning; mass/area, thickness, tear and tensile strength, elongation, rewet, water vapor permeability, abrasion, stiffness and antimicrobial properties of the products have been tested according to relevant ISO and ASTM standards shown at table 4. All samples are examined with ESEM (15). The performance tests were replicated three times for each samples. Once the results were acquired, they were treated statistically.

3. RESULTS AND DISCUSSION

3.1. Evaluation of Mass/Area Test Values

Mass/area tests are carried out according to ASTM D 3776-96 standarts. Obtained results shown in Figure 3 and discussed below:

As it is seen clearly from test results after plasma and anti-microbial finishing treatments, there is a raise at mass/area values of the samples (Figure3). Mainly two reasons verify this situation; one is finishing chemical which fabric takes in, other one is take up both in machine and cross direction of the fabric during drying process so that cause a raise in mass/area values. Moreover another striking point, rising in mass/area values of silver based anti-microbial finish including samples is more than antibiotic based anti-microbial finish including samples. If liquor ratio (approximately 40-45%) is accepted equal for both finishing processes due to chemical's nano-particle structure, this result may be because of high take-up values of silver based anti-microbial finish including material.

3.2. Evaluation of Thickness Test Values

Obtained results shown in figure 4 and discussed below:

It's known that mass/area and thickness values are to some extent proportional eachother. Figure 5 illustrates that relation (R^2=0,53) thickness values are not only factor affecting mass/area values, but also amount of chemical finishing on the material surface and structure porosity of material affect the mass/area values.

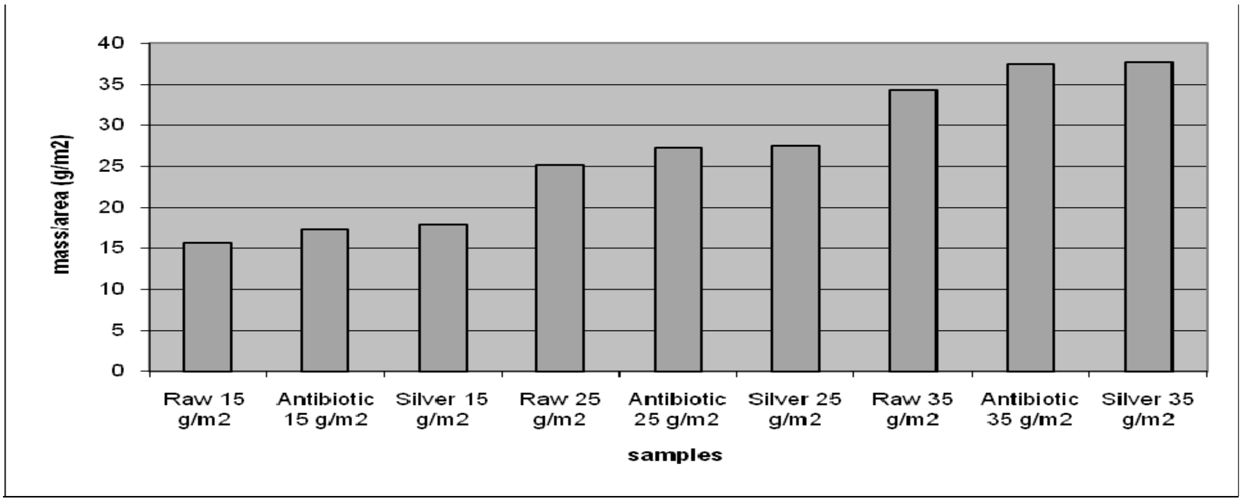

Figure 3. Effect of anti-microbial finishes on the fabric mass

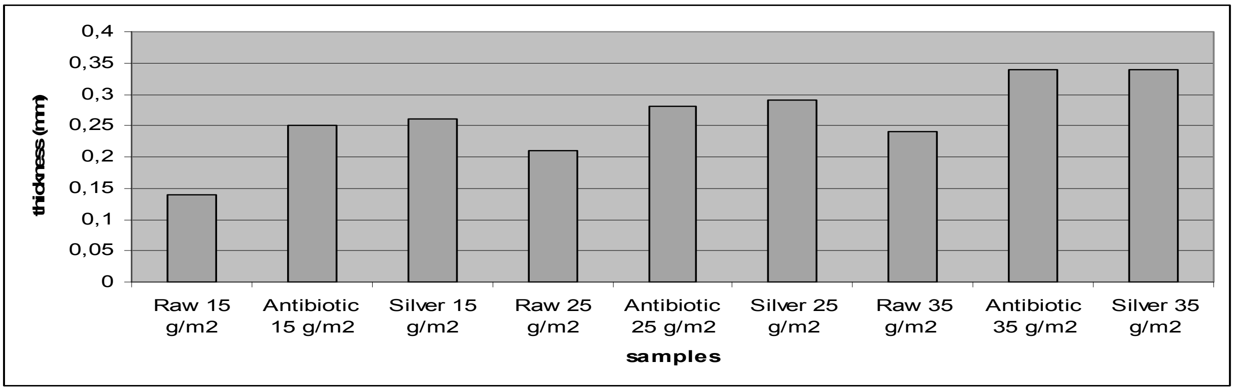

Figure 4. Thickness variation of the samples after anti-microbial test

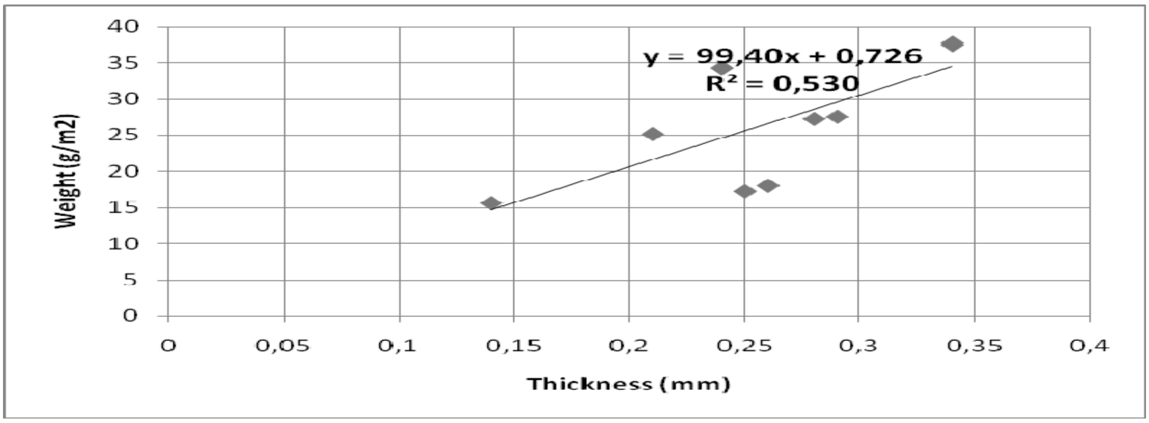

Figure 5: Thickness/weight corelation

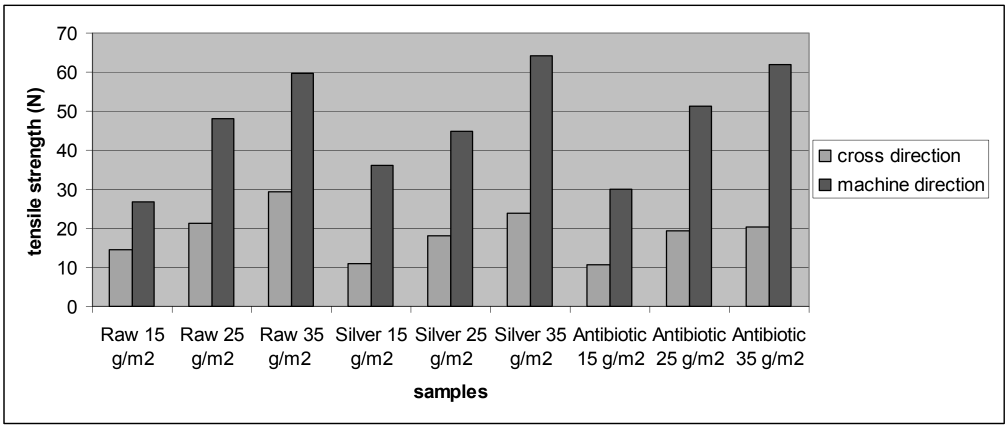

Figure 6. Tensile strength test values

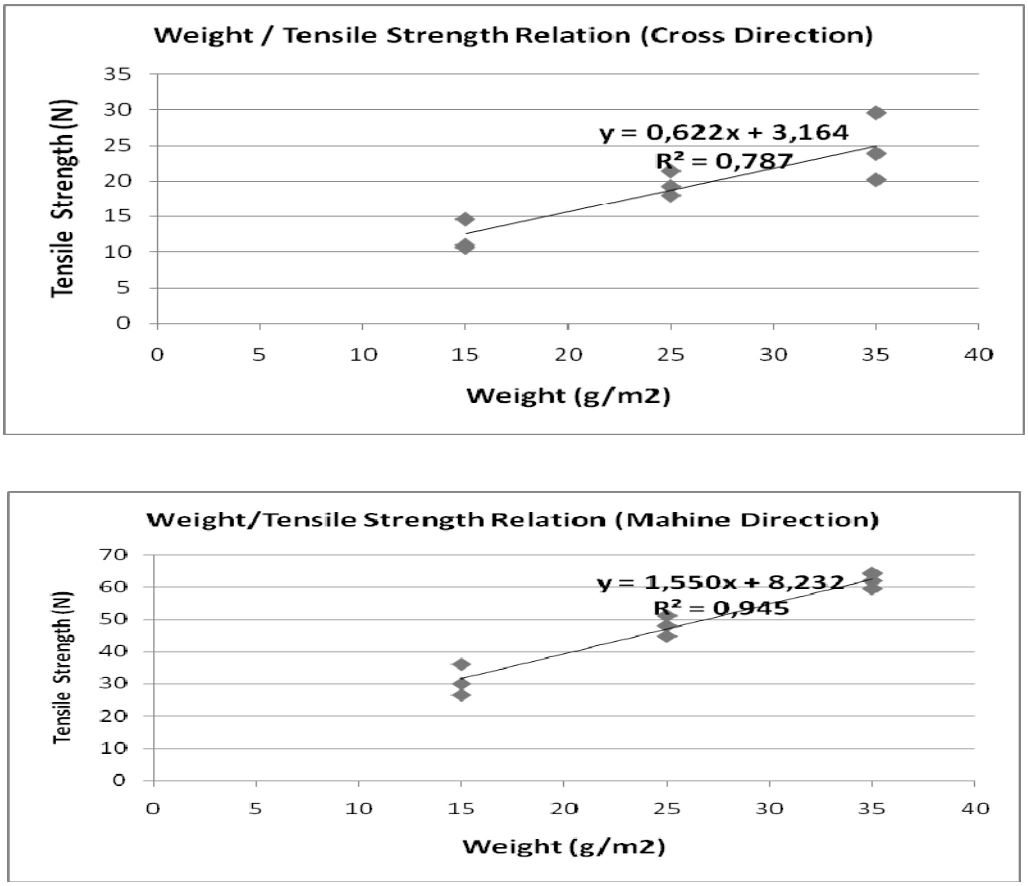

Figure 7. Weight/tensile strength relation

3.3. Evaluation of Tensile Strength Test Values

It can be seen from figure 6, both type of anti-microbial finish applications caused that tensile strengths of the sample were decreased at cross direction whereas generally increased at machine direction. It should be taken into consideration during plasma modification and pad-batch process, the samples were exposed to stress trough out machine direction. According to the test results obtained from both finishing applicated samples, tensile strength values were close to eachother.

Especially samples with low mass/area values have higher mass/area and tensile strength correlation was inevitable. Other remarkable point is that the correlation is more strong at machine direction (fig.7).

3.4. Evaluation of Tear Strength Test Values

According to the tear strength values from figure 8, a significant change wasn't observed at tensile strength values after finishing treatment. Furthermore high tear strength values are desired at all garment types. However, generally tear strength test method is applied to the woven fabrics.

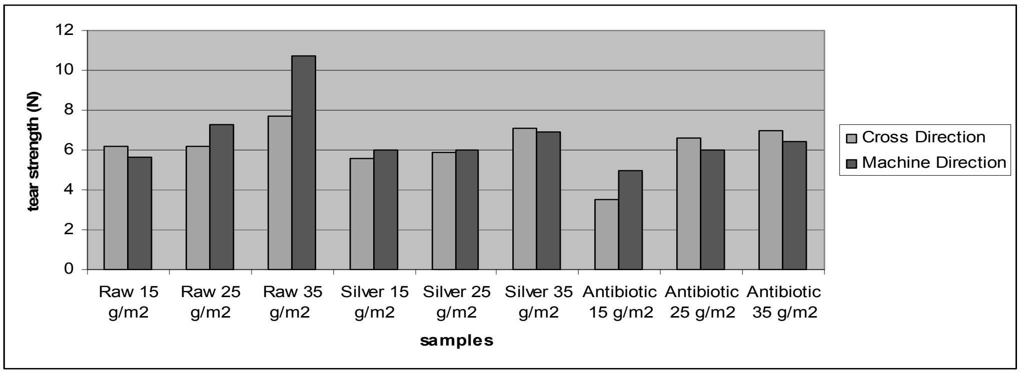

Figure 8. Tear strength test values

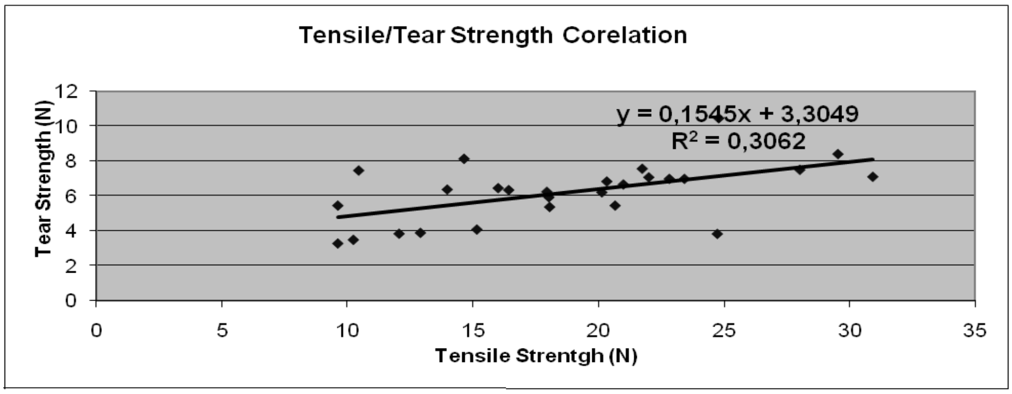

Figure 9. Tensile/tear strength corelation

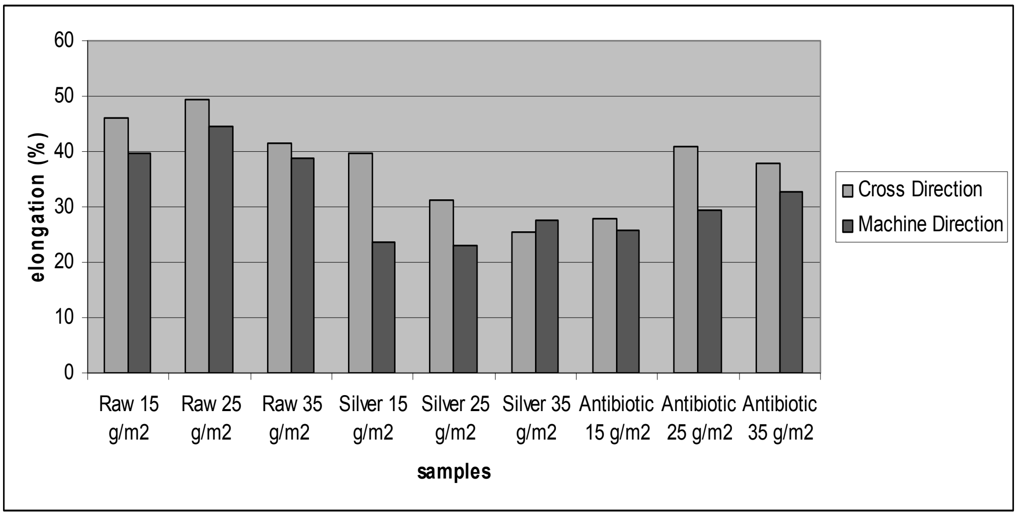

Figure 10. Elongation test values

Tear strength is related with the structure of fabric. Finishing processes can be reduced tear strength resistance. Correlation is weak as well as there is a direct proportion between tear and tensile strength (fig.9). This is because of the tear strength is more about the structure of the fabric. However it's not an important disadvantage for disposable fabrics.

3.5. Evaluation of Elongation Test Values

Figure 10 shows that the either machine direction or cross direction of the nonwoven fabrics have significant decreases in elongation properties after plasma modification and pad-batch process cause tension on the fabrics. Thus, the tension on the fabrics obviously shows itself as lack of elongation. Besides, the lack of elongation on machine direction is the much more than cross direction.

3.6. Evaluation of Rewet Test Values

This test method is applied according to Strike Through (s) ERT 150.2-93, Rewet (g) ERT 151.2-93 and Run-off (%) ERT 152.1-02 standards. The test was performed according to instructions below:

1. Selected 3 products for testing.
2. Prepared the product so it lies flat, folded under the front and back wing flaps, leaving product target area flat and in contact with test surface area.
3. Measured out a volume of test solution for the product being tested with a graduated cylinder and transfer the solution to the separator funnel.
4. Centered the dosing tube over the target zone. The target zone is at the notch in the center of the crotch area.
5. Delivered the test solution into the tube by fully opening the stopcock on the funnel or starting the metering pump.
6. Started the timer when fluid starts to flow from the funnel or pump.

When test results at Table 5 were examined, it's seen that raw materials have totally hydrophobic structure except thin spun-bond nonwoven surface. This is because of non-homogeneous fiber distribution properties of spun-bond nonwoven materials. Plasma modified and finishing treated fabrics rewet time shorter than raw material. This shows effect of plasma modifications to improve hydrophilic structure can be seen more clearly.

Moreover rewet time also increased depending on mass/area and thickness ratio values. Silver based anti-microbial finishing chemical contain fabric's rewet time longer than antibiotic based one. This proves our previous high mass/area and thickness values of silver based one comparing with antibiotic one.

Table 5. Rewet test results

Sample	Rewet time (s)				Wetting Quantity (g)			
	1	2	3	Ave.	1	2	3	Ave.
Raw 15 g/m^2	3,53	4,4	3,85	3,93	0,34	0,26	0,15	0,05
Raw 25 g/m^2	62,1	23,44	30,9	38,81	0	0	0	0,00
Raw 35 g/m^2	164,35	154,32	151,07	156,58	0	0	0	0,00
Silver 15 g/m^2	183,25	127,35	45,42	118,67	0,08	0,13	0,1	0,10
Silver 25 g/m^2	10,23	5,92	9,19	8,45	0,1	0,09	0,09	0,09
Silver 35 g/m^2	46,84	44,35	26,57	39,25	0,08	0,12	0,07	0,09
Antibiotic 15 g/m^2	8,51	4,12	5,44	6,02	0,08	0,08	0,09	0,08
Antibiotic 25 g/m^2	17,47	21,89	14,69	18,02	0,09	0,08	0,07	0,08
Antibiotic 35 g/m^2	21,07	21,26	15,9	19,41	0,08	0,08	0,08	0,08

3.7. Evaluation of Abrasion Test Values

As shown in the figure 11, the fabrics which have same mass/area values, have same abrasion resistance. Because of fabric with high mass/area values taking much more finishing material, finishing treatments decrease abrasion resistance. As a result the samples with high mass/area values have a lower abrasion resistance.

3.8. Evalution of Anti-microbial Test Values

This test method is applied according to AATCC 100 standards with S. Aureus bacteria at ECHOTEX laboratories in Istanbul.

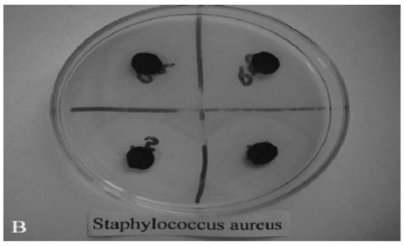

Figure 12. Anti-microbial test with Staphylococcus Aureus

Effect of chemicals used in high bactericide level has shown it clearly. Both types of finished fabrics are passed successfully from anti-microbial test (99%). Thus bacteria reproduction was prevented on the fabric surface.

Table 6. Anti-microbial test results

	Reducing number of Bacteria after 24h (%)	
Chemicals	Finished Fabric	Raw Fabric
ISYS- AG (Silver Based)	99,9	0
Reputex-20 (Antibiotic Based)	99,9	0

4. CONCLUSIONS

According to the applied tests results both types of finished fabrics are passed successfully from anti-microbial test. Thus bacteria reproduction is prevented on the fabric surface. Finally results are interpreted finishing treatment with silver exhibit generally better results in many of physical tests such as rewet, water vapor permeability, stiffness. Although the other some tests results related with silver application change a little bit in undesirable way or not change, they are not crucial disadvantages for disposable fabrics. In addition this final material is designed for use in hygiene required places like hospitals, clinics, hotels, laboratories, nursery, restaurants and beauty centers as sheet, slipper, pinafore or table cloth.

Ongoing Project

As a future work, The unique disposable bed sheet is considered as three layers which are laminated to each other by hot-melt technique. First layer is antimicrobial, front face hydrophilic, back face hydrophobic, 100% PP nonwoven upper layer,middle layer is 100% CV nonwoven medium layer which has high liiquid absorption capacity, and last layer is fully hydrophob 100% PP nonwoven bottom layer which prevents leakage. EVA (Ethylenevinylacetate) based net formed hot-melt material which bonds three layers.

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