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INVESTIGATION OF THE PHYSICAL PROPERTIES OF POLYLACTIC ACID (PLA) BASED MELTBLOWN NONWOVENS FOR AGRICULTURAL APPLICATIONS

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Abstract

In this paper, a preliminary research was conducted to investigate some physical properties of PLA based meltblown nonwovens for agricultural applications. Air permeability, thickness, basis weight, biodegradability and fiber diameter properties of the samples were investigated. PLA based nonwovens that are suitable to be used without damaging the environment were obtained. Such bioplastic nonwovens can be used in various agricultural applications. The samples obtained in this research provided suitable air permeability, thickness and basis weight values for use in agricultural textiles, while being biologically degradable in ecological conditions in natural environments. Bioplastic meltblown nonwoven of 5.8-10.5 µm were obtained in this research.
The results of the research presented in this paper will be used for the selection of a specific agricultural application and thus extensive research will be conducted for product development of the selected product type.

Keywords: Biodegradable polymer, PLA, bioplastic, agricultural textiles, meltblown method, ecological nonwovens.

TARIMSAL UYGULAMALAR İÇİN ERİYİK ÜFLEME (MELTBLOWN) YÖNTEMİYLE ÜRETİLEN POLİLAKTİK ASİT (PLA) ESASLI DOKUSUZ YÜZEYLERİN FİZİKSEL ÖZELLİKLERİNİN İNCELENMESİ

Özet

Bu çalışmada PLA bazlı meltblown dokusuz yüzeylerin tarımsal uygulamalar için fiziksel özelliklerinin araştırılması için bir ön araştırma yapılmıştır. Numunelerin hava geçirgenliği, kalınlık, gramaj, biyobozunurluk ve elyaf çapı özellikleri incelenmiştir. Çevreye zarar vermeden kullanılmaya uygun PLA bazlı dokusuz yüzeyler elde edilmiştir. Bu tür biyoplastik dokusuz yüzeyler çeşitli tarımsal uygulamalarda kullanılabilmektedir. Bu araştırmada elde edilen numuneler doğal ortamlarda ekolojik koşullarda biyolojik olarak parçalanırken, tarım tekstillerinde kullanım için uygun hava geçirgenliği, kalınlık ve gramaj değerleri sağlamıştır. Bu araştırmada 5.8-10.5 µm'lik dokuma olmayan biyoplastik meltblown yüzeyler elde edilmiştir.
Bu makalede sunulan araştırmanın sonuçları, belirli bir tarımsal uygulamanın seçiminde kullanılacak ve böylece seçilen ürün türünde ürün geliştirme için kapsamlı bir araştırma yapılacaktır.

AnahtarKelimeler: Biyobozunur polimer, PLA, biyoplastik, tarım tekstilleri, eriyik üfleme yöntemi, ekolojik dokusuz yüzeyler.

Cite

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1. Introduction

Agrotextile field is a great potential for our country in terms of increase in production efficiency and decrease in cost[1].

Agrotextiles are used in many areas for different purposes such as, packing agricultural products, acceleration of plant growth process, protection the products against UV, disinfection of agricultural areas, inhibition of growth of weeds, control of drainage and erosion for agricultural purpose, protection of animals under bad weather conditions, fishery etc[2].

Increase in the world population and industrialization have brought environmental problems[3]. Petroleum-derived raw materials which last long time for decomposition, are known to emit harmful chemicals and pollute the food chain and also cause reduction of renewable energy in time when the decomposition is started[4]. These raw materials besides the environmental pollution they bring are threat to all living creatures' life. In this context, biodegradable and environmentally harmless polymers are important. Among these bioplastics, polylactic acid (PLA) has gained considerable attention in recent years and its usage rate is rapidly increasing.

In the 1960s, PLA began to be used in the medical field, followed by research on PLA. With the increasing importance of ecological agriculture in recent years, PLA has taken its place in the agricultural sector and continued to be used increasingly.

Bioplastics will offer new potentials for the agricultural industry:

• Agricultural raw materials (renewable resources) play an important role in the production of bioplastics.

• Bioplastic products find significant application areas in agriculture.

• It also finds a completely new and non-food market for agricultural products[4, 5].

Due to these properties, PLA is now also used in applications such as sandbags, weed prevention networks, plant nets and pots. Important features for such applications; it is the process of maintaining structural integrity during use and degradation under soil after use[6].

Sztajnowski et all.'s study was to assess the suitability of spun-bonded PLA nonwovens for agriculture by means of their artificial weathering and to evaluate the effect of calender stabilization parameters on the polymer structural changes and related changes in physical features and mechanical properties. The nonwovens were tested for shrinkage and directional mechanical properties. Test results have shown that these samples are suitable for agricultural applications[7].

Hablotet all. have reported that, two mulches were prepared from polylactic acid (PLA) using spunbond processing, and two via meltblown processing. According to test results, spunbond nonwovens may prove useful as biobased and compostable materials for multi-season mulching, and other long-term agricultural applications, such as for row covers in perennial cropping systems. Meltblown nonwovens may be better suited for more traditional agricultural mulch applications[8].

Feng have investigated that poly(lactic acid) (PLA) melt blown nonwoven disordered mats (MBNDM) at different die-to-collector distances (DCD) and conducted to study the effect of DCD on surface and internal morphology, fiber diameter, alignment degree, apparent contact angle, pore diameter, porosity and stress-strain. Feng have found that fiber diameter, pore diameter, porosity, stress and strain along length direction decrease while alignment degree and apparent contact angle have no obvious change as the increasing of DCD[9].

Hammonds et al. evaluated the surfaces produced by meltblown method with PLA fibers thermally and mechanically. The type of die, air-flow, and die to collector distance (DCD) were determined as variable parameters. They reported that the pore size was between 1.82 and 10.48 micrometers for the microfiber surface and 452 to 818 nanometers for the nanofiber surface. They stated that the tensile modulus and strength of PLA nonwovens increased with air flow in a given DCD, but decreased with increasing DCD for a given air flow. Thermograms obtained from calorimetry have found that microfibers have a larger beta-form crystal composition than nanofiber mats[10].

Zhu et al. in order to improve the properties of PLA meltblown surfaces, PLA / aminated halloysite nanotubes (PLA / A-HNTs) were prepared using PLA / A-HNTs master-batches, compatibilized by dual-monomer glycidyl methacrylate-styrene (St-co-GMA) melt-grafted PLA (PLA-g- (St-co-GMA)). The morphology, crystallization, pore size distribution, filtration performance and mechanical properties of PLA / PLA-g-(St-co-GMA) / A-HNT MBs were characterized. It was concluded that this effect slightly increased the average diameter and pore size of PLA MBs. The A-HNTs increased the crystallinity of PLA MBs, while the crystal forms remained unchanged. Compared to PLA MBs, the tensile strengths of PLA / PLA-g- (St-co-GMA) / A-HNT were increased, but elongation decreased. PLA / PLA-g-(St-co-GMA) / A-HNT MBs were found to be able to achieve higher filtration efficiency than PLA MBs[11].

The purpose of this study was the production of nonwovens to be used as agricultural textiles that are harmless to the environment and agricultural products, also without creating pollution after their usage and without the need to collect, self-destructive surfaces. Therefore, in this study, 72 different bioplastic nonwoven samples were produced by using meltblown method and PLA raw material and then, some physical properties (air permeability, thickness, weight), biodegradability and fiber diameter of the samples were investigated.

1.1. Polylactic acid (PLA)

Polylactic acid (PLA), a repeating unit of lactic acid, is a polymer entering the group of aliphatic polyesters. One of the most important characteristics is that it is a biodegradable and compostable thermoplastic polymer produced from starch rich vegetable sources such as corn, sugar cane and wheat.

The lactide monomer forming the polylactic acid can be produced by carbohydrate fermentation or chemical synthesis. Today lactic acids are produced by fermentation. PLA polymer is made by ring opening polymerization mechanism. By this method, high molecular weight PLA is obtained[12, 13].

General Features of PLA are as follows:

PLA is synthesized from renewable sources.

PLA is a 100% biodegradable polymer. In nature, it disappears spontaneously in a short period of time such as 0-2 years.

PLA is an ecological polymer that can decompose in nature without any danger and does not contaminate the soil during its degredation.

The degradation of the PLA in nature takes place in 2 steps:

1- High molecular weight (Mn> 4000) chains are hydrolyzed to low molecular weight oligomers (the reaction continues by accelerating with the addition of acid or alcali and the effect of temperature and humidity).

2- When Mn<4000, the microorganisms in the environment continue to deteriorate by releasing smaller molecular weight compounds such as carbon dioxide, water and humus[13].

1.2. Meltblowing Method

The meltblown technique for producing nonwoven products has been forecasted in recent years as one of the fastest-growing in the nonwovens industry. With the current expansion and interest, a strong and bright future is forecasted for this technology. The scope and utility of this technology will increase and meltblowing will become a major technique in nonwoven technology.

The most common and current definition used for the meltblown method is that, it is a one-step process and also an innovative surface forming method by the way of the thermoplastic raw material is melted in the extruder and self-bonded by spraying the microfibers onto the cylinder from nozzle with high-speed air flow.

Polymer material being melted in the extruder is sprayed through the nozzle holes with high speed hot air flow and the micro-size fibers are cooled and solidified as they move towards the collection cylinder. The solidified fibers form a randomly oriented nonwoven surface in the collection cylinder. Due to the turbulence created by the air flow, the fibers are placed highly complex. Usually a vacuum placed in the collector retracts hot air[14]. Figure 1 shows the schematic representation of the meltblown method.

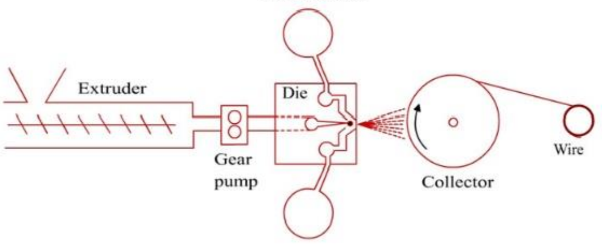


Figure 1. Schematic representation of the meltblown method[15]

The various advantages of the meltblown method are as follows:

It is considered the most practical way to obtain a surface with less than one micron fiber.

It is a continuous process.

The area required for production is much less than the other methods.

The textile surface is produced in one step from the raw material which is taken as granule, powder or chips[14, 15].

In meltblown process; air temperature, die temperature, die to collector distance(DCD), collector drum speed, output(melt feed rate), air volume are changeable machine parameters.

2. Material and Method

In this study, 72 different nonwoven samples were produced by using meltblown method. PLA which has 70-85 g/10 min (210°C) melt index, was used as raw material to produce the samples. PLA is a material that rapidly absorbs moisture in the environment. This leads to degradation of the polymer chains during melting and to deterioration in mechanical properties with loss of molecular weight. For this reason, PLA granules were dried at 80 ° C for 4 hours before processing. Subsequently, surfaces were obtained by melt blown method. The meltblown production parameters are given in table 1.

Table 1.Meltblown Production Parameters

Meltblown Production Setting	Die hole diameter 0.009 inches	Die hole diameter 0.007 inches
Extruder zone 1 temperature(°F)	335	400
Extruder zone 2 temperature(°F)	385	450
Extruder zone 3 temperature(°F)	445	470
Die temperature(°F)	495	450
Air temperature(°F)	525	480

Various production parameters namely, output(melt feed rate), DCD, collector drum speed and die hole diameter were changed during the production of the samples. Production was realized with 4 different outputs(%50, 60, 70, 80), 3 DCDs (40, 50, 60cm), 3 collector drum speeds (5, 10, 15ft/min) and 2 die hole diameters(D1: 0.009 inches, D2: 0.007 inches). The experimental plan is given in table 2.

Table 2. Experimental plan of samples

Sample no (Die hole diameter .009inches)	Sample no (Die hole diameter .007inches)	Output (melt feed rate) (%)	DCD (cm)	Collector Drum Speed (ft/min)
1-1	2-1	50	40	5
1-2	2-2	50	40	10
1-3	2-3	50	40	15
1-4	2-4	50	50	5

1-5	2-5	50	50	10
1-6	2-6	50	50	15
1-7	2-7	50	60	5
1-8	2-8	50	60	10
1-9	2-9	50	60	15
1-10	2-10	60	40	5
1-11	2-11	60	40	10
1-12	2-12	60	40	15
1-13	2-13	60	50	5
1-14	2-14	60	50	10
1-15	2-15	60	50	15
1-16	2-16	60	60	5
1-17	2-17	60	60	10
1-18	2-18	60	60	15
1-19	2-19	70	40	5
1-20	2-20	70	40	10
1-21	2-21	70	40	15
1-22	2-22	70	50	5
1-23	2-23	70	50	10
1-24	2-24	70	50	15
1-25	2-25	70	60	5
1-26	2-26	70	60	10
1-27	2-27	70	60	15
1-28	2-28	80	40	5
1-29	2-29	80	40	10
1-30	2-30	80	40	15
1-31	2-31	80	50	5
1-32	2-32	80	50	10
1-33	2-33	80	50	15
1-34	2-34	80	60	5
1-35	2-35	80	60	10
1-36	2-36	80	60	15

Some physical properties (air permeability, thickness and basis weight), biodegradability, fiber diameter of samples were tested and the results were evaluated statistically. The names and the standards of the tests applied to the samples are given at table 3.

Table 3. Tests and standards

TEST	STANDARD
Air Permeability	TS 391 EN ISO 9237
Thickness	TS 7128 EN ISO 5084
Basis Weight	TS EN ISO 29073-1
Fiber Diameter	TS 1186

3. Results and Discussions

Thickness, basis weight and air permeability properties of all samples were tested and biodegradability, fiber diameter were investigated for the selected samples. The results were evaluated statistically.

3.1. Thickness Test Results

Thickness measurement of the samples was measured with a Digital Thickness Gauge M034A thickness device under a pressure of 200 Pa in an area of 20 cm^2 and results were obtained in millimeters. The measurement standard is TS 7128 EN ISO 5084. The results were determined by the mean value obtained by taking ten measurements from each sample.

The thickness measurements of the samples were performed and test results can be seen in figure 2 and 3.

One-way between group multivariate test, was applied to determine to see the effects of output(melt feed rate), DCD and collector drum speed on thickness results.

The results of the thickness analysis have shown that, output(melt feed rate) has a statistically significant effect on thickness. For 0.009 inches diameter, the difference between the thickness values obtained from different outputs(melt feed rate) appears to be very large. The size of the effect was calculated by eta squared(eta squared = .330). Whereas for 0.007 inches diameter, the difference appears to be moderate (eta squared = .070). Post-hoc comparisons have been done using the Student-Newman-Keuls test. As the output(melt feed rate) increased, the thickness increased, since the polymer fed at unit time increases with increasing output(melt feed rate). This effect is observed more clearly in the die hole diameter 0.009 inches. The results the statistical analysis showing the effects of output on thickness according can be seen at table 4 and figure 4.

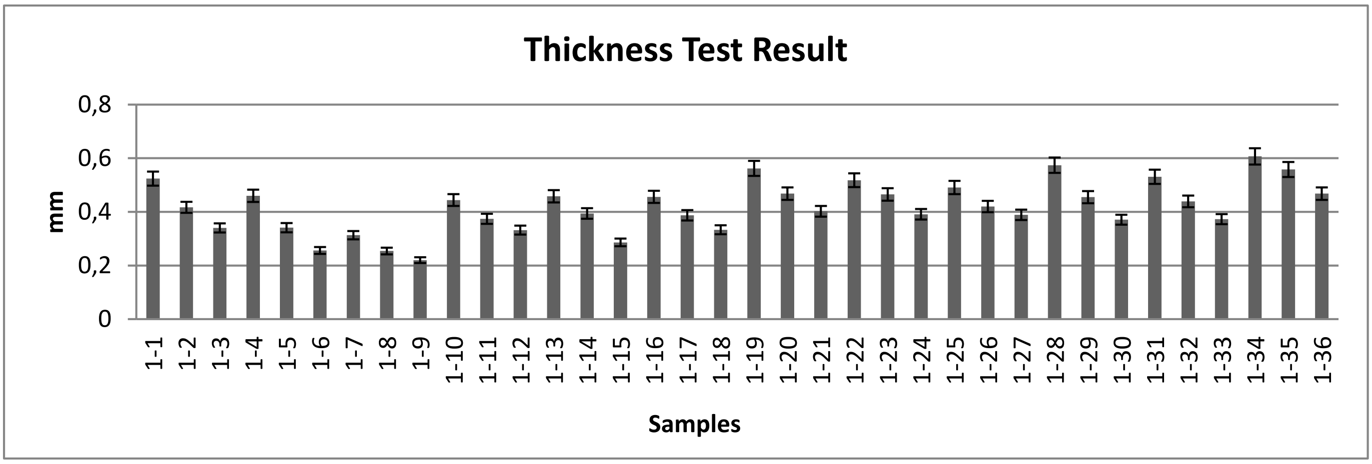


Figure 2. Thickness test results for die hole diameter 0.009inches

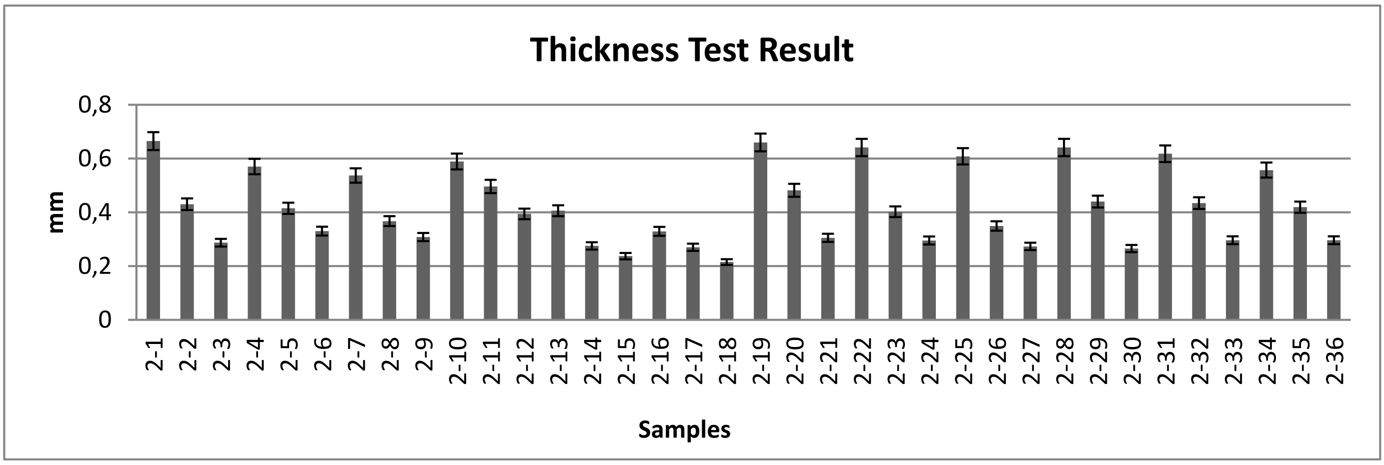


Figure 3. Thickness test results for die hole diameter 0.007inches

Table 4. Effect of output on thickness

Output (%)	0.009 inches diameter			
	Mean	Std. Dev.	F	p
50	.347	.099	58.472	.000
60	.385	.062		
70	.456	.063		
80	.486	.086		
	0.007 inches diameter			
50	.434	.127	8.989	.000
60	.357	.121		
70	.446	.148		
80	.441	.134		

Significant for p <0.05.

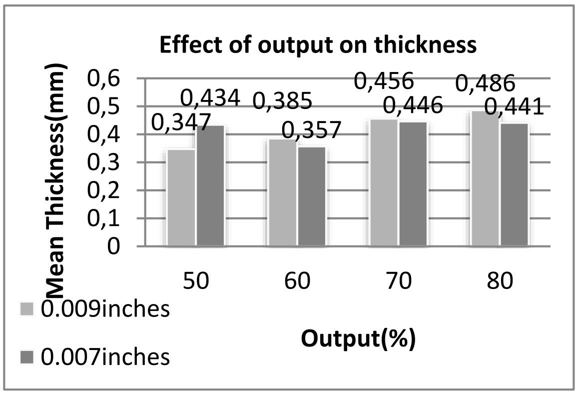


Figure 4. Change of thickness with output

The effect of DCD on thickness was found to be statistically significant. For 0.009 inches diameter, the difference between the thickness values obtained from different DCD appears to be small. The size of the effect was calculated by eta squared (eta squared = .021).The difference appears to be moderate (eta squared = .080) for 0.007 inches diameter. Post-hoc comparisons have been done using the Student-Newman-Keuls test. For both diameters, the thickness decreased with the increase in DCD from 40 to 60. The reason for this is the increase in the distance the fibers take in unit time. The results of the statistical analysis showing the effect of change in thickness with DCD can be seen at table 5 and figure 5.

Table 5. Effect of DCD on thickness

DCD (cm)	0.009 inches diameter			
	Mean	Std. Dev.	F	p
40	.438	.083	3.926	.021
50	.409	.085		
60	.408	.114		
	0.007 inches diameter			
40	.471	.141	394.699	.000
50	.409	.132		
60	.377	.123		

Significant for p <0.05.

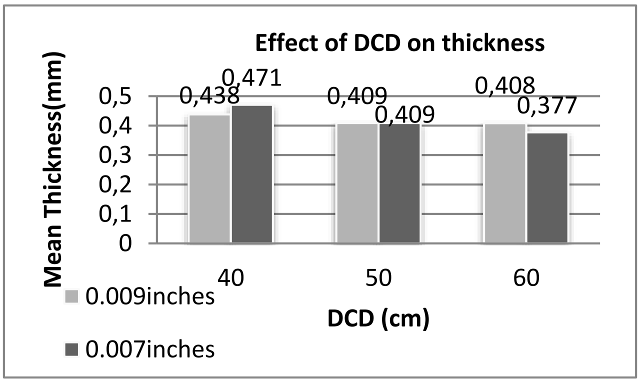


Figure 5. Change of thickness with DCD

A statistically significant relation between collector drum speed and thickness was seen. For both diameters, the difference between the collector drum speed ratios was found to be very large. The size of the effects were calculated with eta squared (eta squared for 0.009 inches = .396, eta squared for 0.007 inches = .687).Post-hoc comparisons have been done using the Student-Newman-Keuls test. As the collector drum speed increased, the thickness decreased. The decrease in thickness was due to the decrease in the amount of fiber collected on the unit time as the collector accelerates. The results of the statistical analysis showing the effect of change in thickness with collector drum speed can be seen at table 6 and figure 6.

Table 6. Effect of collector drum speed on thickness

Collec. Speed (ft/min)	0.009 inches diameter			
	Mean	Std. Dev.	F	p
5	.495	.079	116.990	.000
10	.414	.076		
15	.347	.069		
	0.007 inches diameter			
5	.568	.102	394.699	.000
10	.398	.072		
15	.292	.047		

Significant for p <0.05.

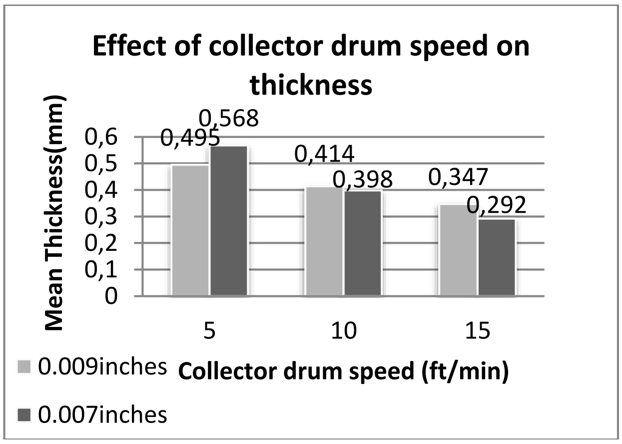


Figure 6. Change of thickness with collector drum speed

3.2. Basis Weight Results

Weight is expressed as the value in grams of an area of 100 cm^2. Five samples of 10cmx10cm dimensions were weighed on the precision scale and the average weight of the samples was calculated. The test standard for weight measurement is TS EN ISO 29073-1.

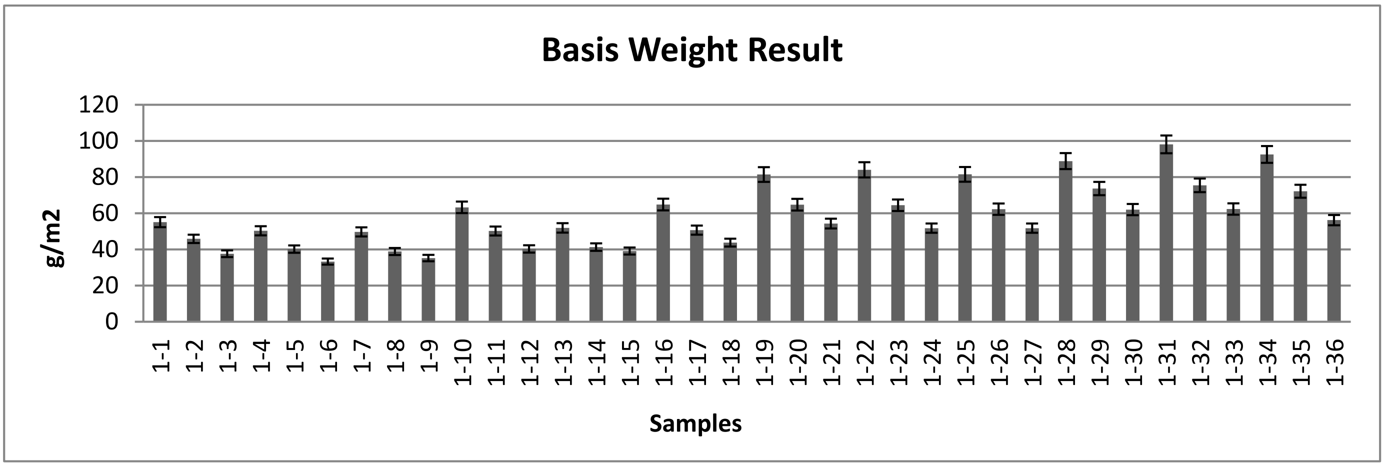
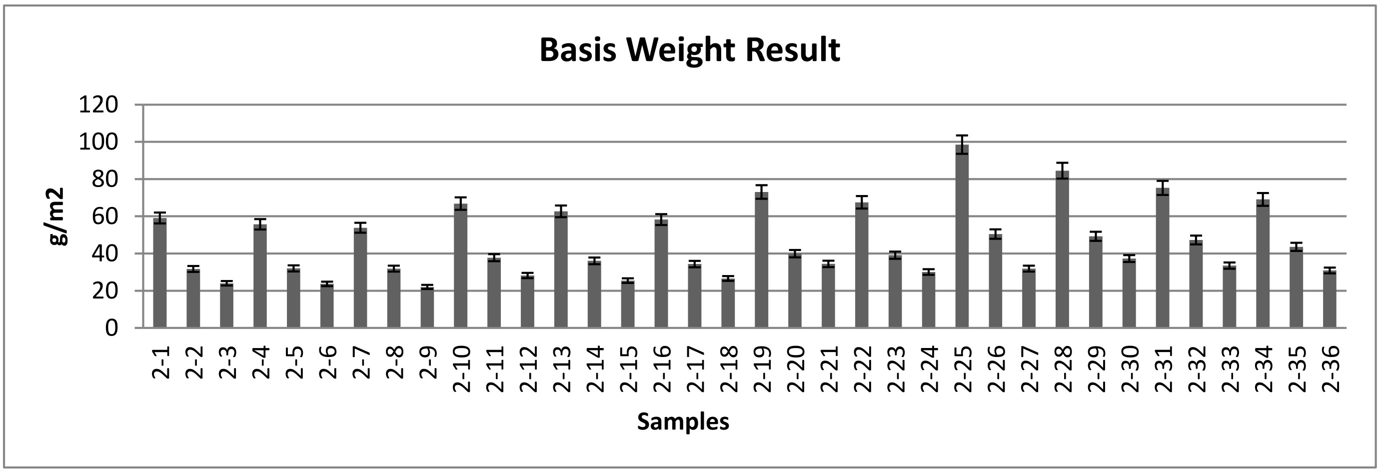


Figure 7. Basis weight results for die hole diameter



0.009inches

Figure 8. Basis weight results for die hole diameter 0.007inches

The basis weight measurements of the samples were performed and test results can be seen in figure 7 and 8. One-way between group multivariate test, was applied to determine to see the effects of output(melt feed rate), DCD and collector drum speed on basis weight results. The results of the thickness analysis have shown that, output(melt feed rate) has a statistically significant effect on basis weight. For both diameters, the difference between outputs(melt feed rate) was large. The size of the effects were calculated by eta squared (eta squared for 0.009 inches = .580, eta squared for 0.007 inches = .120).This effect was observed more clearly in the die hole diameter 0.009 inches. Post-hoc comparisons have been done using the Student-Newman-Keuls test. This result indicated that as output from50 to 80 increased, the basis weight increased. This was due to an increase in the amount of polymer per unit area. As the output increases from 50 to 80, the amount of polymer sprayed increases, which leads to an increase in thickness. The results of statistical analysis showing the change in basis weight with output of the can be seen at table 7 and figure 9.

Table 7. Effect of output(melt feed rate) on basis weight

Output (%)	0.009 inches diameter			
	Mean	Std. Dev.	F	p
50	42.88	7.26	163.940	.000
60	49.46	9.16		
70	66.23	12.40		
80	75.69	14.16		
	0.007 inches diameter			
50	37.01	14.07	16.241	.000
60	41.77	15.42		
70	51.67	22.12		
80	52.36	18.41		

Significant for p <0.05.

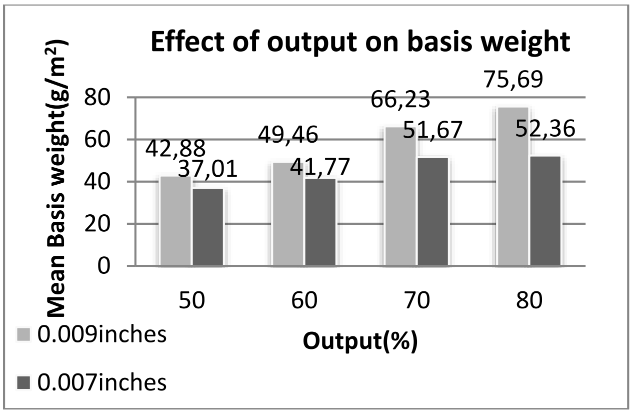


Figure 9. Change of basis weight with output

For the samples which produced 0.009 inches and 0.007 inches die hole diameter, DCD did not have a statistically significant effect on basis weight since the polymer per unit area did not change. Can be seen at table 8.

Table 8. Effect of DCD on basis weight

0.009 inches diameter	0.007 inches diameter
F (2, 357) = .480, p = .619	F (2, 357) = .804, p = .448

There was a statistically significant relation between collector drum speed and basis weight. For both diameters, the difference between the collector drum speed ratios was very large. The size of the effect was calculated by eta squared (eta squared for 0.009 inches = .356, eta squared for 0.007 inches = .795).Post-hoc comparisons have been done using the Student-Newman-Keuls test. As the collector drum speed increased, the basis weight decreased. This decrease in basis weight was due to the decrease in the amount of fiber collected on the unit time as the collector accelerates. The results of the statistical analysis showing the effects of collector drum speed on basis weight can be seen at table 9 and figure 10.

Table 9. Effect of collector drum speed on basis weight

Collec. Speed (ft/min)	0.009 inches diameter			
	Mean	Std. Dev.	F	p
5	71.78	17.82	98.908	.000
10	56.55	13.69		
15	47.12	10.35		
	0.007 inches diameter			
5	68.68	12.45	691.385	.000
10	39.43	6.62		
15	28.99	4.64		

Significant for p <0.05.

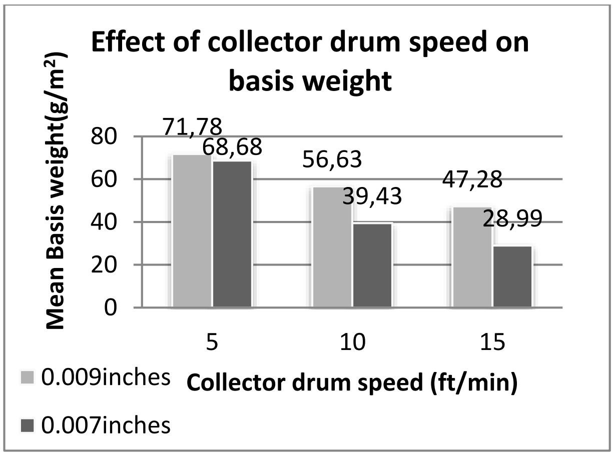


Figure 10. Change of basis weight with collector drum speed

3.3. Air Permeability Test Results

The air permeability of the samples was obtained with the Test Instruments FX 3300 digital air permeability tester by measuring the proportion of air perpendicular between the two sides of the fabric under a pressure of 100 Pa from a 20 m² area. The measurement results are l / m² / s and the measurement standard is TS 391 EN ISO 9237. The results were determined by the mean value obtained by taking ten measurements from each sample. The air permeability measurements of the samples were performed and test results can be seen in figure 11 and 12.

One-way between group multivariate test, was applied to determine the effects ofoutput(melt feed rate), DCD, collector drum speed and fiber diameter on air permeability results.

According to the results of the analysis, output(melt feed rate) has a statistically significant effect on air permeability.For the samples which were produced with 0.009 inches and 0.007 inches die hole diameter, the differences between the outputs(melt feed rate)respectively were moderate(eta squared = .05) and large(eta squared = .135) respectively. The size of the effect was calculated by eta squared. Post-hoc comparisons have been done using the Student-Newman-Keuls test. As the output(melt feed rate)increased, the air permeability decreased. The increased in output from 50 to 80 caused the amount of polymer sprayed to increase, thus the amount of air passing through the surface was reduced. The results of the statistical analysis showing effect output on air permeability can be seen at table 10 and figure 13.

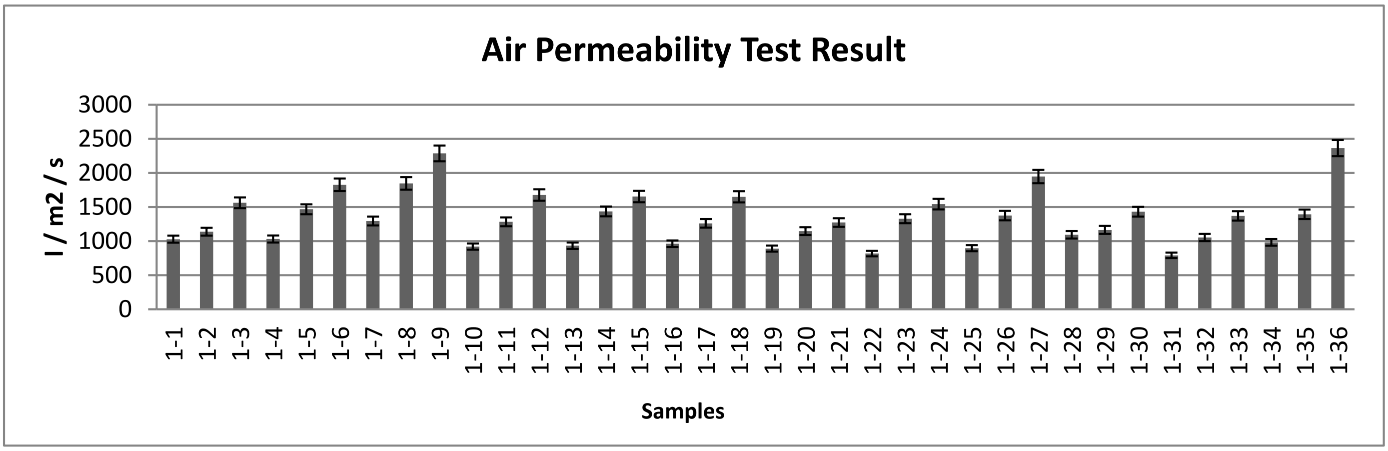


Figure 11. Air permeability test results for die hole diameter 0.009inches

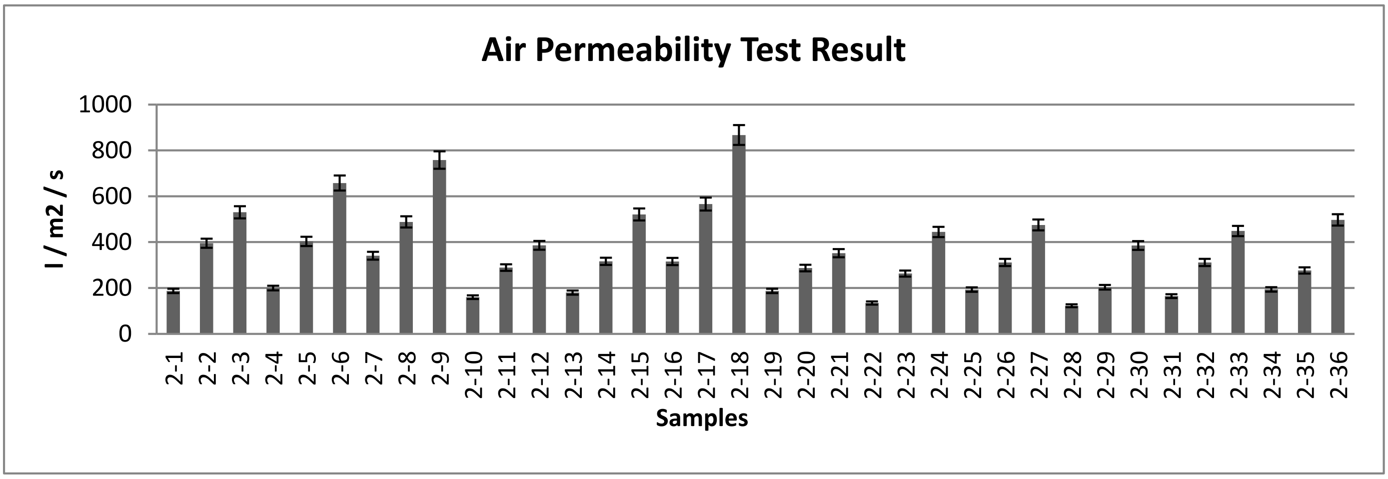


Figure 12. Air permeability test results for die hole diameter 0.007inches

Table 10. Effect of output(melt feed rate) on air permeability

Output (%)	0.009 inches diameter			
	Mean	Std. Dev.	F	p
50	1498.38	433.68	6.991	.000
60	1308.69	323.45		
70	1246.61	368.45		
80	1294.00	451.99		
	0.007 inches diameter			
50	439.92	188.31	18.566	.000
60	400.04	215.71		
70	294.03	116.25		
80	289.18	127.42		

Significant for p <0.05.

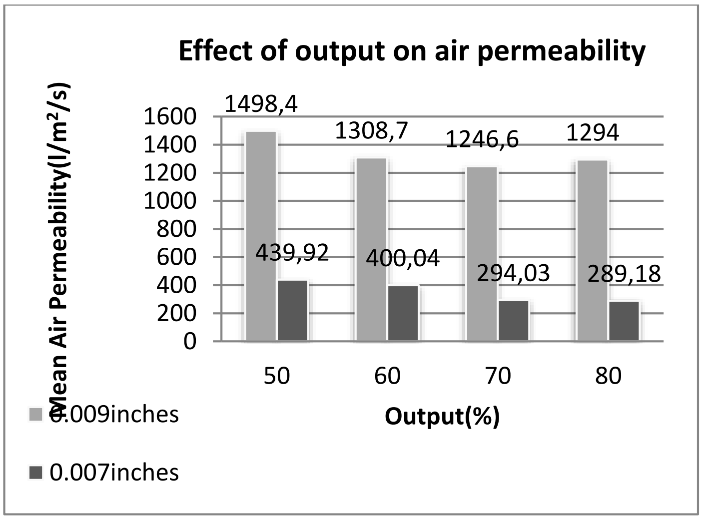


Figure 13. Change of air permeability with output

The effect of DCD was found to be statistically significant on air permeability. For both diameters, the difference between the air permeability values obtained from different outputs(melt feed rate) appeared to be large. The size of the effect was calculated by eta squared (eta squared for 0.009 inches = .106, eta squared for 0.007 inches = .123). Post-hoc comparisons have been done using the Student-Newman-Keuls test. The increase in

DCD from 40 to 60 caused the air permeability to increase. Since the DCD increased, the amount of polymer which was collected on the surface decreased, allowing more air to pass to the other side of the surface. The results of the statistical analysis can be seen at table 11 and figure 14.

Table 11. Effect of DCD to air permeability

DCD (cm)	0.009 inches diameter			
	Mean	Std. Dev.	F	p
40	1217.57	226.34	21.224	.000
50	1271.22	340.98		
60	1521.98	510.54		
	0.007 inches diameter			
40	290.31	121.90	24.959	.000
50	336.94	158.58		
60	440.13	211.61		

Significant for p <0.05.

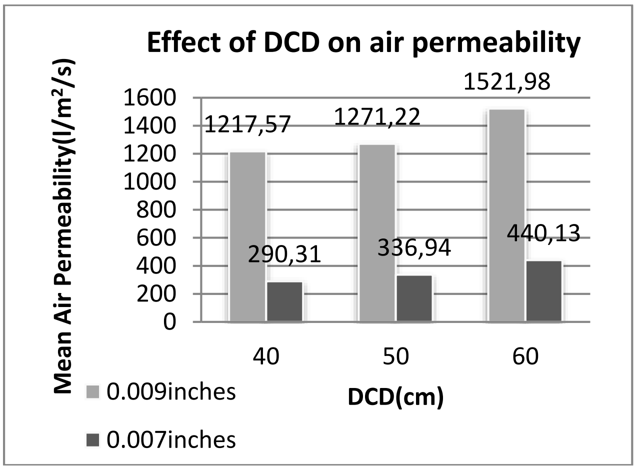


Figure 14. Change of air permeability with DCD

There was a statistically significant relation between collector drum speed and air permeability. For both diameters, the differences between collector drum speed ratios were very large. The size of the effect was calculated by eta squared (eta squared for 0.009 inches = .559, eta squared for 0.007 inches = .566).Post-hoc comparisons have been done using the Student-Newman-Keuls test. This result indicated that as the collector drum speed increased, the amount of polymer sprayed onto the surface decreased and thus the air permeability increased. The results of the statistical analysis can be seen at table 12 and figure 15.

Table 12. Effect of collector drum speed on air permeability

Collec. Speed (ft/min)	0.009 inches diameter			
	Mean	Std. Dev.	F	p
5	970.27	172.02	226.675	.000
10	1324.85	244.43		
15	1715.64	362.53		
	0.007 inches diameter			
5	198.13	68.83	233.124	.000
10	342.45	104.87		
15	526.80	161.78		

Significant for p <0.05.

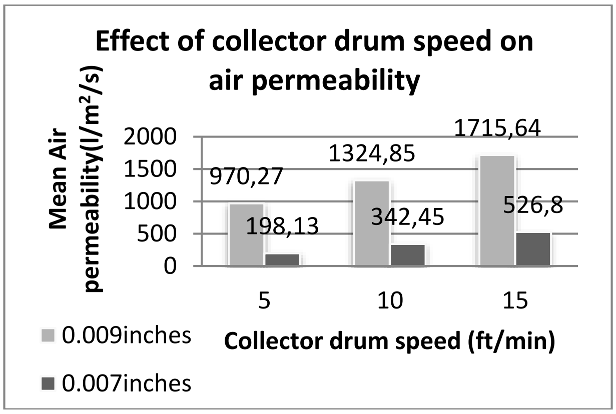


Figure 15. Change of air permeability with collector drum speed

Apart from output, DCD and collector drum speed, air permeability was affected from thickness, basis weight and fiber diameter. As the thickness and basis weight value of the samples increased, the air permeability value decreased.

The fiber diameter changes with the change in the diameter of the die. In these samples, the size and distribution of pores on the surface varied with the change in the diameter of the die. As the fiber diameter decreased, the surface area increased, which reduced the air permeability. Therefore, the air permeability value of the samples produced with the 0.007 inch die hole diameter were lower than that produced with 0.009 inch die hole diameter.

3.4. Biodegradability Test Results

Three samples per die hole diameter were selected to determine biodegradability. These samples, in the size of 20cmx30cm, were buried in 6 different pots and periodically watered and left under the sun for 3 months. The samples were removed from the pots at the half and end of the 3 months, namely 6th and 12th weeks and their weight loss was calculated. Figure 16 shows the photos of the samples which were buried in the pots.

Figure 16. The samples buried for biodegradability test

For the calculation of the first weight loss, the samples were removed from the soil after 6 weeks and weight loss was measured. The samples were again buried in the soil and continued to be irrigated periodically. At the end of the 12 weeks, the weight loss was examined again. The results of the first and second weight loss can be seen at table 13 and figure 17.

Table 13. Results of biodegradability test

Sample No	1.% weight loss after 6 weeks	2.% weight loss after 12 weeks
1-3	5,5	18,85
1-6	20,62	33,76
1-9	14,48	27,35
2-4	4,76	16,5
2-5	9,20	27,7
2-6	8,20	30,35

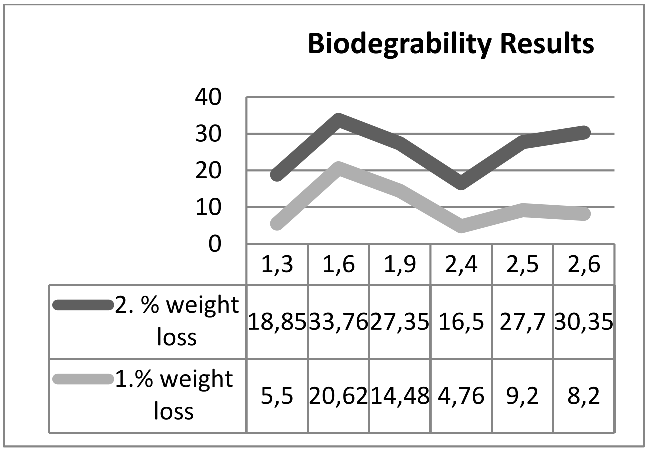


Figure 17.Results of biodegradability test

Results of the biodegradability test have shown that, nonwoven surfaces produced from PLA polymer were able to disappear spontaneously in nature. That is why it has been widely used in the field of agricultural textiles.
For the first measurement, among the samples which were produced with the die hole diameter 0.009inches, 3 samples with the same output (melt feed rate) and collector drum speed values were selected in order to examine the effect of DCD. A best biodegradation value was obtained from the samples produced with 50 cm DCD.
Among the samples produced with the die hole diameter 0.007inches, 3 samples with the same output(melt feed rate) and DCD values were selected in order to examine the effect of collector speed.
According to the results of the measurement, the best biodegradability effect was obtained from the samples produced with10 m/min collector drum speed.
In the second measurement results, it was seen that the samples produced by die hole diameter 0.009inches were similar to first measurement and that the degradation percentage in the samples produced with die hole diameter 0.007inches increased in the samples produced with collector speed of 15 m/min.
One-way between group multivariate test, was applied to determine to see the effects of DCD, collector drum speed, thickness and basis weight on biodegradability results.

The results of the biodegradability analysis have shown that, DCD, collector drum speed, thickness and basis weight have a statistically significant effect on biodegradability. The results of the statistical analysis can be seen at table 14.

Table 14. Effect of statistical analysis to biodegradability

	0.009 inches diameter		0.007 inches diameter	
	F	Sig. (p)	F	Sig. (p)
DCD	8.214	.001	9.728	.000
Collector drum speed	9.610	.000	23.971	.000
Thickness	110.168	.000	6.422	.000
Basis weight	6.571	.000	35.196	.000

Significant for $p < 0.05$.

As the amount of polymer sprayed to the unit area increased, the thickness and basis weight increased and this caused to decrease the biodegradability.

3.5. Fiber Diameter

Fibre diameter of meltblown nonwovens plays a critical role in some physical properties of the meltblown nonwovens, as it determines the surface area, which is a very important parameter for applications. In this study, fiber diameters were measured by light microscope according to TS 1186 standard. The mean value was calculated by taking fifty measurements from each sampleand it was seen that bioplastic meltblown nonwovens with fibre diameter of 5.8-10.5 µm were achieved. Figure 18and 19 shows the fibre diameter properties of bioplastic meltblown nonwovens.

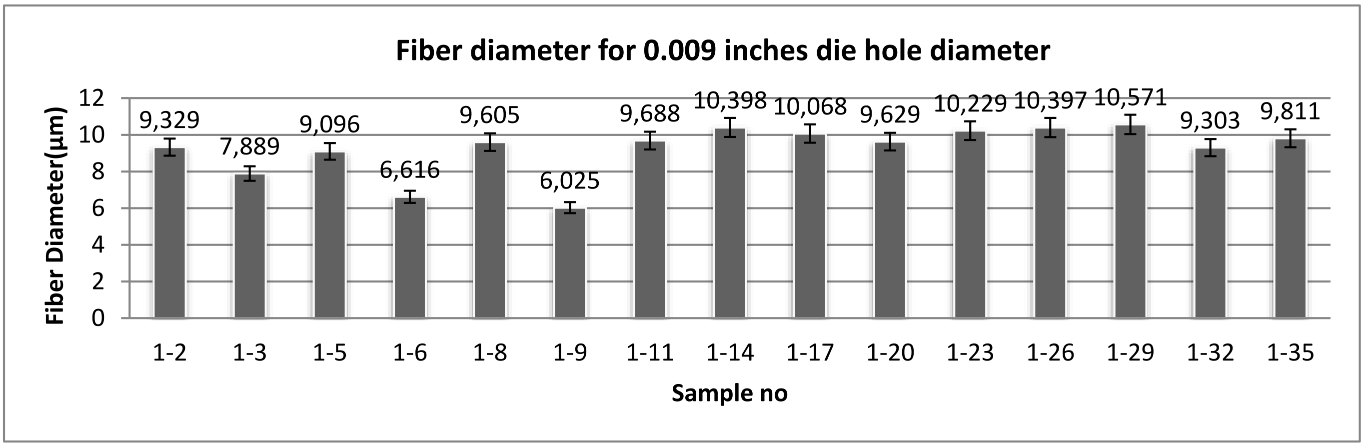


Figure 18. Fibre diameter for 0.009 inches die hole diameter

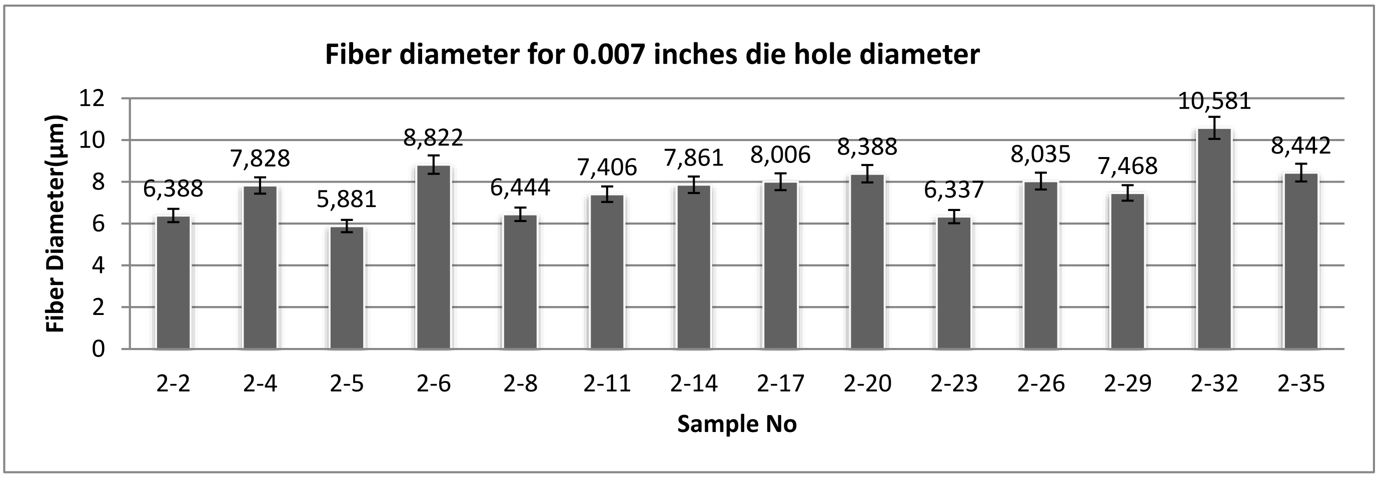


Figure 19. Fibre diameter for 0.007 inches die hole diameter

Correlation analysis was applied to determine the effects of die hole diameter on fiber diameter. The results of the correlation analysis can be seen at table 15.

Table 15. Effect of correlation analysis to die hole diameter on fiber diameter

	Fibre diameter x Die hole diameter
Pearson Correlation	.527**
Sig. (2- tailed)	.000
N	290

**. Correlation is significant at the 0.01 level (2-tailed).

4. Conclusion

One of the most important problems in the Turkish agriculture sector is to minimize product losses before and after harvesting, to increase productivity in production and to reduce costs. For this purpose, agricultural technical textiles offer significant potential for our country. The increasing share of agricultural textiles is the nonwoven surfaces.

Nonwovens can be produced in a short time and at a more affordable cost since it does not contain the stages such as yarn preparation, warp preparation, finishing process and so on. In recent years, the importance of biodegradability in the production of nonwovens with the use of mostly petroleum-derived raw materials has started to be used in the self-destructing raw materials in nature. Many of the synthetic fibers and polymers are very slowly degraded even when they are embedded in bioactive soils for 30 years. However, biodegradable fibers and polymers begin to degrade for a period of 1 month.

In this study, some physical properties (air permeability, thickness, and basis weight), biodegradability and fiber diameter of nonwoven samples produced with PLA were investigated. These bioplastic meltblown nonwoven fabrics have been found to have a diameter fiber diameter of 5.8-10.5 µm.

According to the test results, thickness was strongly related to basis weight and it was also found out that air permeability decreased with increasing thickness and basis weight.

As the amount of polymer sprayed increased with increasing output, the thickness and weight increased and the air permeability decreased. However, the increase of DCD and collector speed decreased the amount of polymer sprayed to the unit area per unit time.

The air permeability increased with decreasing thickness and basis weight.
The samples provided suitable air permeability, thickness and basis weight values for use in agricultural textiles.
In addition, the samples are biologically degradable in ecological conditions in natural environments.
According to the 1st and 2nd measurement results, in the samples produced with die hole diameter 0.009inches, the best biodegradation was also observed with samples produced with 50 cm DCD.
According to the 1st measurement results, in the samples produced with die hole diameter 0.007inches, the best biodegradation was observed in the sample produced with10 m/min collector drum speed. According to the 2nd measurement results, increment of the degradation percent age in the samples produced with collector drum speed of 15 m/min was observed. Results of the biodegradability test have shown that, nonwoven surfaces produced from PLA polymer were able to disappear easily in nature.
This paper presents the results of a preliminary research conducted on the physical properties of PLA based meltblown nonwovens. Basing on the results obtained from this study, a specific agricultural application will be selected and a more detailed research will be conducted for the development of selected product.

5. Acknowledgements

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