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Study The Effect Of Thermal Treatment On The Mechanical Properties Of Bioplastic Produced By 3d Printer

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Keywords:
ASTM D638- Type 4
Polylactic Acid (PLA)
thermal treatment
3D Printer
tensile test
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ABSTRACT

In this study, it was investigated whether the load strength of bio plastic (PLA) specimens produced in a three-dimensional printer can be increased by applying the temperature and dwell time variables were applied, by performing 9 different experiments. ASTM D638 standard procedure is adopted for evaluating the tensile behaviour of 3D-printed PLA test specimens. It was examined whether there was a change in the material structure and interpretation was made according to the results. Experimental studies primarily started with the production of samples with a 3D printer. In the first three samples, the temperature was kept constant at 100 ℃, then the fourth, fifth and sixth samples were kept under 150° C, The last three samples were kept at 200° C, and the waiting times were adjusted to 25, 50, and 75 minutes, respectively, for samples. Test samples 7, 8 and 9 could not withstand the high temperature, so the tensile test could be performed up to the number 6 sample. In order to investigate the changes in the heat treated samples, the tensile test was applied to the untreated sample and the remaining 6 samples. After testing the samples, yield strength, tensile strength, maximum tensile and modulus of elasticity values were compared. As a result of the test, positive results were observed in yield strength when the untreated sample was compared with the heat treated samples, which shows that the heat treatment has a positive effect on the samples, and also the effect of heat treatment led to an increase elasticity modulus, As per the effect on the bio plastic surface according to the graphs, the specimen roughness was found to vary depending on the temperature because temperature affects in surface roughness. In our attempts, investigations will have performed by Optical microscope analysis, Surface Roughness Measurement, and tensile testing and this will help us to explain properties of the samples and changes likely to occur in the course of the experiments. The aim of this research is improve the mechanical properties of bio plastic by thermal treatment.

دراسة تأثير المعالجة الحرارية على الخصائص الميكانيكية للبلاستيك الحيوي المنتج بواسطة طابعة ثلاثية الأبعاد

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الكلمات المفتاحية:
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اختبار الشد
نمذجة الترسيب المنصهر (FDM).

الملخص

تقيّم في هذه الدراسة ، تم فحص ما إذا كان يمكن زيادة قوة التحمل لعينات البلاستيك الحيوي (PLA) المنتجة في طابعة ثلاثية الأبعاد من خلال تطبيق متغيرات درجة الحرارة ووقت ألانتظار، من خلال إجراء 9 تجارب مختلفة. تم اعتماد الإجراء القياسي ASTM D638 لتقييم سلوك الشد لعينات اختبار PLA المنتجة في طابعة ثلاثية الأبعاد. تم فحص ما إذا كان هناك تغيير في الهيكل الداخلى للبلاستيك وتم إجراء التفسير وفقًا للنتائج. بدأت الدراسات التجريبية بإنتاج عينات باستخدام طابعة ثلاثية الأبعاد. في العينات الثلاث الأولى ، تم الحفاظ على درجة الحرارة ثابتة عند 100 درجة مئوية, ، ثم تم الاحتفاظ بالعينات الرابعة والخامسة والسادسة تحت 150 درجة مئوية, وتم حفظ العينات الثلاثة الأخيرة عند 200 درجة مئوية, وتم تعديل أوقات الانتظار على 25 و 50 و 75 دقيقة على التوالي ، لجميع العينات. عينات الاختبار 7 و 8 و 9 لا يمكنها تحمل درجات الحرارة المرتفعة ، لذلك يمكن إجراء اختبار الشد حتى العينة رقم 6. من أجل فحص التغيرات في العينات

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المعالجة حرارياً ، تم تطبيق اختبار الشد على العينة غير المعالجة والعينات الست المتبقية. بعد اختبار العينات تمت مقارنة مقاومة الخضوع ومقاومة الشد وقيم الشد الأقصى ومعامل المرونة. نتيجة الاختبار لوحظت نتائج ايجابية في مقاومة الخضوع عند مقارنة العينة غير المعالجة مع العينات المعالجة حرارياً ، مما يدل على أن المعالجة الحرارية لها تأثير إيجابي على العينات ، و أدى تأثير المعالجة الحرارية إلى زيادة قوة الخضوع ومعامل المرونة ،. وفقًا للتأثير على سطح البلاستيك الحيوي ، وجد أن خشونة العينة تختلف باختلاف درجة الحرارة ، لأن درجة الحرارة تؤثر على خشونة السطح , في محاولاتنا ، سيتم إجراء التحقيقات عن طريق تحليل المجهر البصري ، وقياس خشونة السطح ، واختبار الشد لتحديد الخصائص الميكانيكية للعينات .الهدف من هذا البحث هو تحسين الخواص الميكانيكية للبلاستيك الحيوي بالمعالجة الحرارية.

1.Introduction

The use of materials produced using 3D printers in individual and commercial areas is increasing day by day due to their important features such as high precision, low labor cost and time saving. For example, gas turbine engine parts, propeller, heat exchangers, dental implants, high performance engine parts etc. [1,2,3]. The production of materials that are very difficult to produce, such as these, has become much easier thanks to 3D printers. Since there is no need for labor and no mold during model production, it has become a sector with an increasing preference rate today. Thanks to professional printers, any desired model can be easily printed, so it does not require being tied to a single working area. Although it is an important feature for professional articles to have high printing precision, this sensitivity also causes high costs [4,5,6].

PLA(Polylactide) is a bio-based, biodegradable and biocompatible polymer which has proved itself to be a promising alternative to petroleum-based polymers. PLA is a high strength and high modulus thermoplastic with good appearance, it has high stiffness and strength, and has better thermal processing. The physical and mechanical properties differ according to the exact type of polymer, heat resistant PLA can withstand temperatures of 110 °C, and the melting temperature can be increased by 40–50 °C. Annealing, adding nucleating agents or forming composites with other materials can all change the mechanical properties of PLA. Thermoplastic processing is an inexpensive way to produce durable plastics. Some processes can extend the life of the plastic and reduce internal stresses caused by manufacturing methods. Furnaces must heat the polymers to a certain degree to impart new properties. The heat softens the ingredients so you can shape or chop them more easily. It also increases the strength of the material and, if necessary, prepares it for further heat treatment. Heat treatment of plastic is necessary during precision machining, bonding and polishing to ensure extreme tolerances are maintained and to prevent cracking. Heat treatment also provides better thermal and mechanical properties. Without this basic heat treatment process, it is nearly impossible to manufacture precision plastic components to precise tolerances [7,8,9].

In this study, it was investigated whether the strength of the printed model was changed by changing the temperature and waiting time in the high-grade furnace after the printing process. In order to make a comparison, various tests were carried out on nine different ASTM D638 Type 4 specimens together with the unheated test specimen, the modulus of elasticity, breaking stress, yield stress and maximum stress values were measured separately, these values were compared graphically and the results were interpreted.

2. Material and methods

2.1. Sample making process for tensile sample

Tensile strength, yield strength etc. of 3D models, a number of processes are required in order to measure the properties accurately. Transactions should be prepared meticulously from the very beginning. At the beginning of these steps, the sample to be tested must be printed on a 3D printer.

2.2. Tensile Sample

In order to investigate the effects of temperature applying on the sample, test samples were made of the same type and size of material. Therefore, the ASTM D638 Type 4 sample, which complies with Standards shown in Figure 1, was selected for the tests performed. The samples were stored at room temperature and did not encounter any impact, drop or breakage. The experiment was controlled with sensitive thermometers and there was no deviation in temperature values.

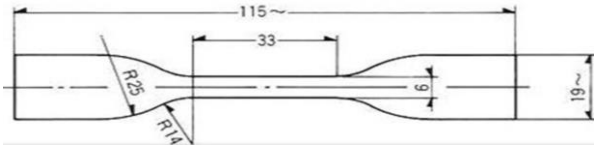


Fig. 1: tensile specimen standard (ASTM D638 Type 4)

Table 1: tensile specimen dimensions

Dimensions	(mm)
Thickness	4
Length of narrow section	33
Width of narrow section	6
Length overall	115
Width overall	19
Fillet radius	14
Outer radius	25

As can be seen in Figure 2, the shape of the specimens is similar to bone since it has larger sized ends. During the tests, the tensile test was applied to nine samples together with the untreated test sample.

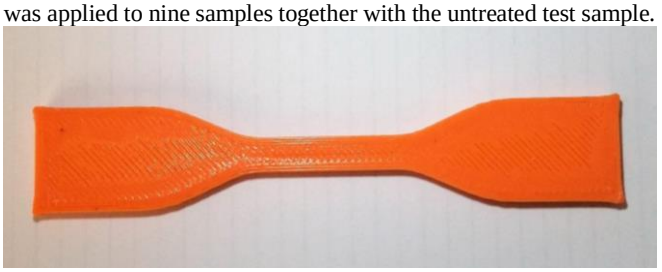


Fig. 2: tensile test specimen dimensions (mm)

In 3D printers, printing accuracy is one of the most important factors affecting output quality. Therefore, the sensitivity of the printer used during the experiment is of great importance. Since the accuracy of the data obtained in the study is of great importance, a high-sensitivity Dream Maker branded printer was preferred (Figure.3).

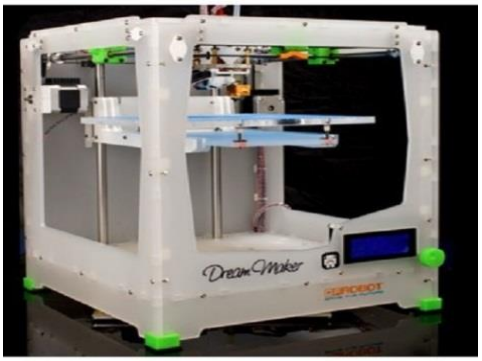


Fig. 3: Dream Maker 3D printer

Samples were printed using the printer shown in Figure.4 and they

were stored in a special area before burn process to prevent them from being affected by moisture and physical damage.

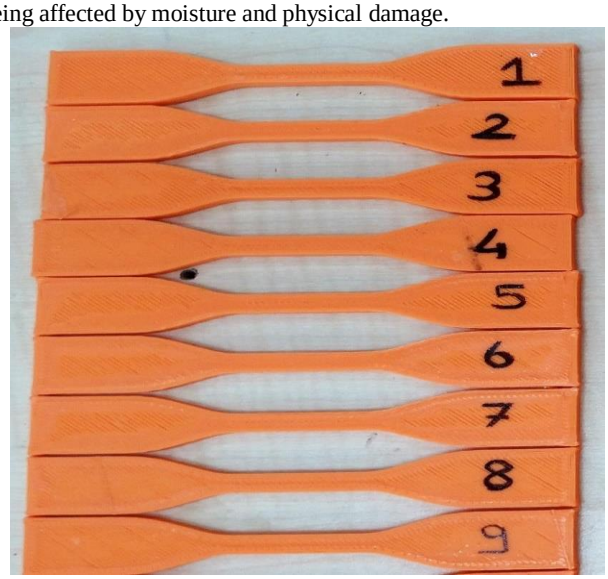


Fig. 4: test samples

In Figure.4, after printing, the numbered tensile samples according to the test order to be made are shown.

2.3. Heating and Temperature Measurement

The samples were Heating at this stage to investigate the effects of temperature and holding time after printing. In order to perform this process properly, the Luxell LX3675 brand oven shown in Figure.5 was used. By using the time adjustment feature, punctuality was ensured during the waiting time, and no missing or excessive waiting was made.

Fig. 5: Luxell LX 3675 oven

During the experiment, the samples were measured by two different degrees in order to avoid any deviation or error in the reading of the temperature value. It can measure sensitively up to 300°C, the degree shown in Figure.6. Since the maximum temperature to be measured in the experiment was 200°C, no problems were encountered during the measurements; the precision of the degree was tested and verified before use.

Fig. 6: The precision grade used in the test phase

Another thermometer, which was used to increase the accuracy of the experiment, was prepared in a laboratory. The samples were tested by Heating of aluminium block with a heat meter inside, shown in Figure.7. Aluminum is a good conductor of heat because it is an element with free conduction electrons. Thus, it can directly measure the temperature value of the samples.

Fig. 7: Aluminum-based digital thermometer

2.4. Tensile Test

Tensile testing is one of the most basic and common types of mechanical testing, tensile tests determine how strong a material is and how long it can stretch. Tensile tests are typically performed on electromechanical or universal test instruments, are simple to perform and are fully standardized, figure 8 shows the tensile device where the tensile test was performed. Produced composite samples were pulled at a tensile speed of 1 mm/min in SHIMADZU AG-IS brand 50 kN capacity tensile test device. After the test, the stress-strain diagrams, tensile strength, yield strength and elongation values of the samples were obtained automatically from the computer-controlled TRAPEZIUM program (Figure 8), the samples produced from material were subjected to the tensile test after process, in order to detect the changes in properties of material [10,11].

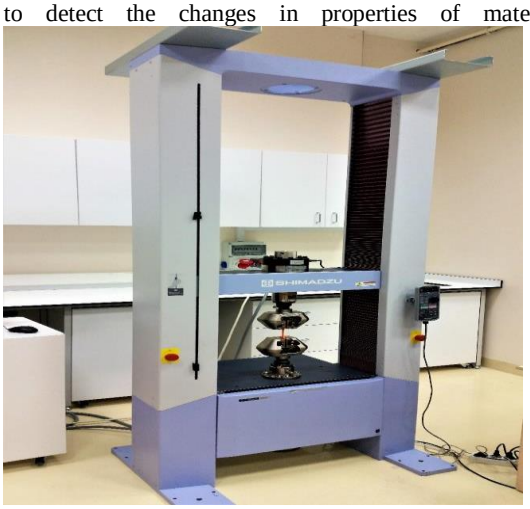


Fig. 8: Tensile Test machine (Shimadzu model)

2.5. Surface roughness measurement

The surface roughness measurements were conducted to identify the kind of interaction between the material and the surroundings as well as to predict the mechanical performance, ideal roughness, and surface qualities in material, Texture in the lab controlled by the computer, software for measurement of surface roughness for 3D which driven by a computer, these estimates were carried out using software for the centre-line average (CLA) and Roughness average (Ra), this method using a surface profilometer with a contact stylus, and this method is accurate and effective (Figure 9), when analyzing surface finish, other factors were also determined through the comparison of all the peaks and valleys with the mean line [12,13].

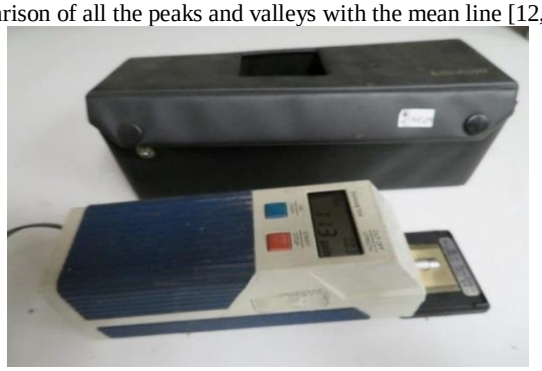


Fig. 9: Surface roughness measurement Machine

2.6. The Optical microscope

The Microscopes are tools used to enlarge images of small objects so as they can be studied without any confusion. Microstructure investigations of bio plastic (PLA) specimens used in the experiments were made using Nikon SMZ745T model optical microscope. The optical microscope has a millimetre table with a sensitivity of 0.01 mm, which can move in the X and Y directions. Optical microscope has a 0.67-5X zoom magnification and a working distance of 115mm. With the use of extra optical lenses, it can magnify up to 3.35-300X, and these images can be examined and analyzed by using the Clemex Captiva 6.0 computer software (Figure 10) [14,15].

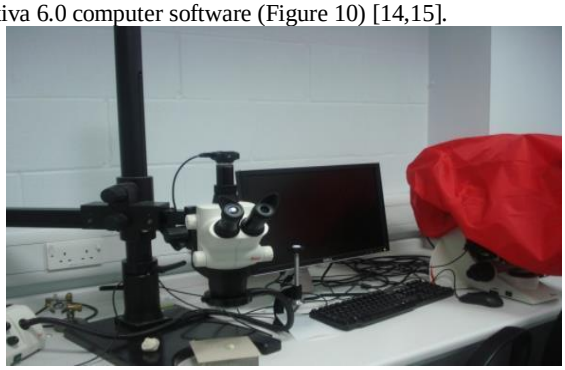


Fig. 10: The optical microscope in the lab

3. Results and Discussion

3.1. Effect of Temperature on Strength

With this test method, the tensile properties of untreated plastic samples are tested under pretreatment, temperature, humidity and test machine speed conditions. The same tests are performed on the treated samples and the results are compared. Due to the effect of temperature, the samples become stronger or deteriorate in their structures after the changes they undergo in the molecular structure. Therefore,

The temperature should be adjusted appropriately for each filament type and damage should be prevented. As the temperature increased, the ties gradually stretch. After reaching the maximum level, the part starts to melt and differences occur in the main model.

Within the scope of the study, the positive or negative effects of the heat treatment application on the tensile strength of the produced material were examined. In addition, the most suitable working range was determined by comparing the changes in the elasticity modulus, yield strength and breaking strength values of the samples. Using the FDM 3D printer, nine tensile specimens were produced in the same models. In order for the test to be successful, the materials were Heating at different temperatures and waiting times. It has been revealed that the temperature and waiting time highly affect the properties of the samples.

Heating process was started by first measuring the temperature of the furnace with precise degrees and bringing it to the desired value. When the desired temperature value was reached, the samples were prepared and placed in the oven on greaseproof paper to avoid any surface contact. As seen in figure 11, the samples were heated in triplicate [18,19,20].

Fig. 11: Baking process of samples

The samples were heating at different temperatures and times, respectively, as shown in Table 2. After the first 25 minutes, the first sample, the second sample at the 50th minute, and the third sample at the 75th minute were taken from the oven and placed in an insulated container. Then, after the temperature setting of the furnace was fixed at 200°C, the processes were continued by applying the same holding time for samples 4,5 and 6.

Table 2: Temperature - Waiting Time values according to the test order

Experiment Number	temperature (°C)	Waiting Time (min)
1	100	25
2	100	50
3	100	75
4	150	25
5	150	50
6	150	75
7	200	25
8	200	50
9	200	75

Depending on the type of filament used during the processes, the 7,8 and 9th samples, which were kept at 200°C, melted within 25 minutes (figure 12), since the samples could not withstand high temperatures. For this reason, in the experiments carried out to increase the strength of the part produced using PLA Plus model filament, it was concluded that the temperature value of 200°C is not suitable for use. Tensile test; Due to the melting of the 7, 8 and 9 samples, it could only be applied to the first six heat-treated samples and the untreated trial sample.

Fig. 12: Samples melted at 200 °C

The aim of the study is to investigate the positive or negative effects of heat treatment on the strength of the specimen. Therefore, along with the 6 treated samples, an untreated trial sample was also taken to the tensile test. After the ASTM D638 Type 4 samples were heated, the changes in the material structure were analyzed by applying a tensile force at a deformation rate of 1mm/min with the tensile test device in Laboratory.

A mutual tensile force was applied to the produced samples (figure 13).

Fig. 13: tensile tester

In order to perform the tensile test, the t (thickness), w (width), and l (Height) values of each sample must be measured one by one. Table 3 shows the t, w, l values of the samples before the tensile test [21,22,23].

Table 3: Width, thickness and Height values of samples

samples Number	w: Width (mm)	t: Thickness (mm)	l: Height (mm)
1	6.52	4.63	63.70
2	6.40	4.46	62.50
3	6.45	4.41	64.35
4	6.48	4.42	63.86
5	6.46	4.35	63.15
6	6.47	4.46	63.55
Non-Heat-Treated sample	6.37	4.27	65.04

The test measuring device used converted the applied tensile force, per cent elongation, stress and strain values into an excel file in detail until the samples broke. The obtained excel data were transferred to the stress and strain graph and the yield strength, tensile strength, maximum stress, and modulus of elasticity values were calculated on this graph.

3.2. Results of Surface Roughness Measurement

In the lab, we measure points for the surface of bio plastic material, the process to measure surface roughness was carried out with a stylus-type instrument in order to examine the texture, and this method is accurate and effective.

The results are commonly obtained from the graphs; however, in lab settings, these calculations are conducted by the computer. The Graphs show us how to measure many points for surface of bio plastic material.

There were Parameters for this method.

Description of Parameters

- Ry Maximum roughness depth
- Rq RMS of roughness average
- Ra Roughness average
- Rz (DIN) Mean peak-to-valley height
- Rp Maximum peak height
- Rt Vertical height between max/min
- Rz (ISO) Ten point height
- Rmax Maximum peak-to-valley height

Rq is calculated by taking the root mean square the series of measurements of deviations from the centreline.

Rz: the average of the five highest and the five deepest valleys within the sampling.

For Surface Roughness we look at amplitudes of peaks, if the graph is in straight line this meaning the surface is smooth but in these graphs we can see amplitudes of peaks is big and this meaning the surface is roughness

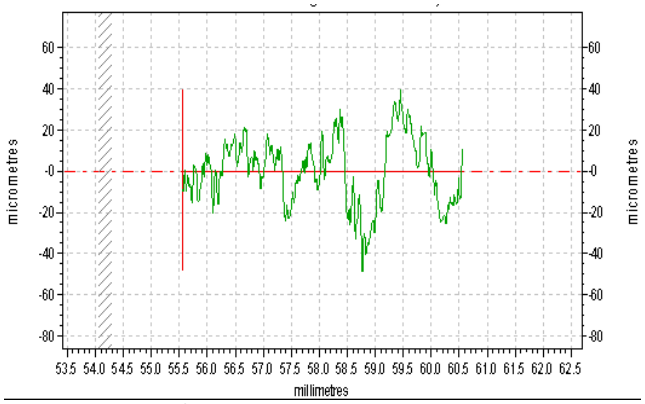


Fig. 14: Surface Roughness at Non-Heat-Treated sample
Ra 13.2657 µm Rp1max 38.4216 µm Rv1max 47.6301 µm
Rt 87.2563 µm Rp 31.4790 µm Rv 35.3858 µm
Rz (DIN) 66.8768 µm RS 119.45 µm RSm 767.83 µm

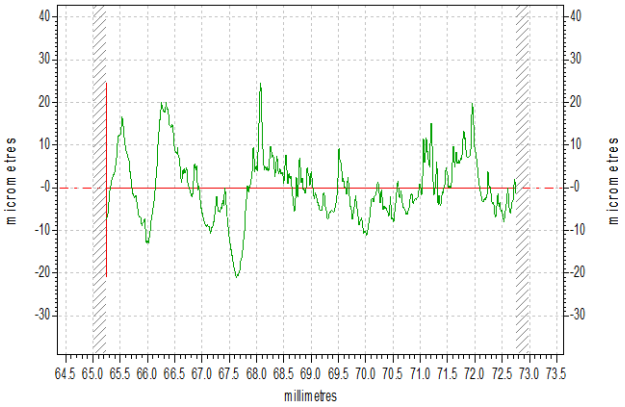


Fig. 15: Surface Roughness at 100 °C and 75 minutes

Ra 5.9037 µm Rp1max 24.6259 µm Rv1max 21.0662 µm
Rt 45.6921 µm Rp 21.4586 µm Rv 14.1782 µm
Rz (DIN) 35.6368 µm RS 181.38 µm RSm 929.53 µm

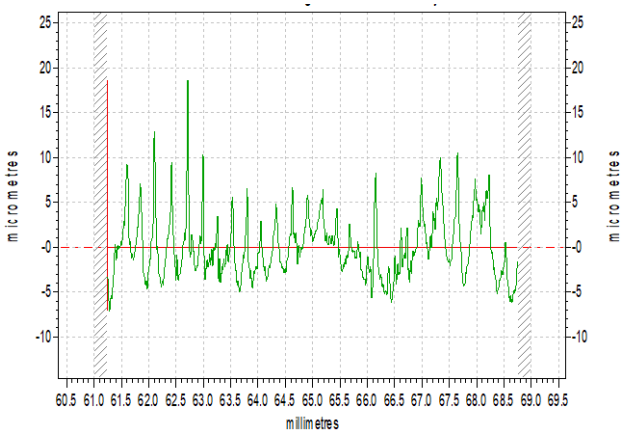


Fig. 16: Surface Roughness at 150 °C and 75 minutes

Ra 2.7036 µm Rp1max 18.6368 µm Rv1max 7.1169 µm
Rt 25.7537 µm Rp 12.4779 µm Rv 6.3295 µm
Rz(DIN) 18.8074 µm RS 155.18 µm RSm 346.60 µm

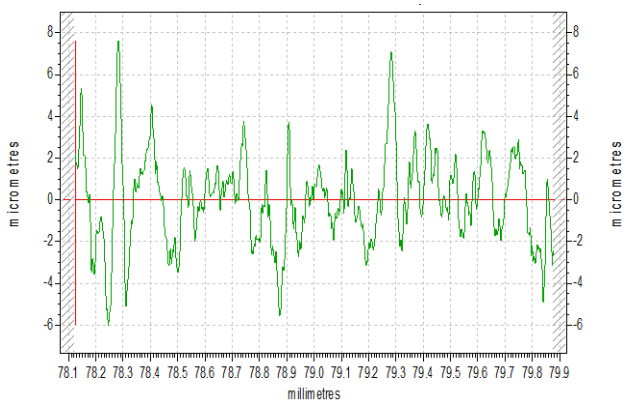


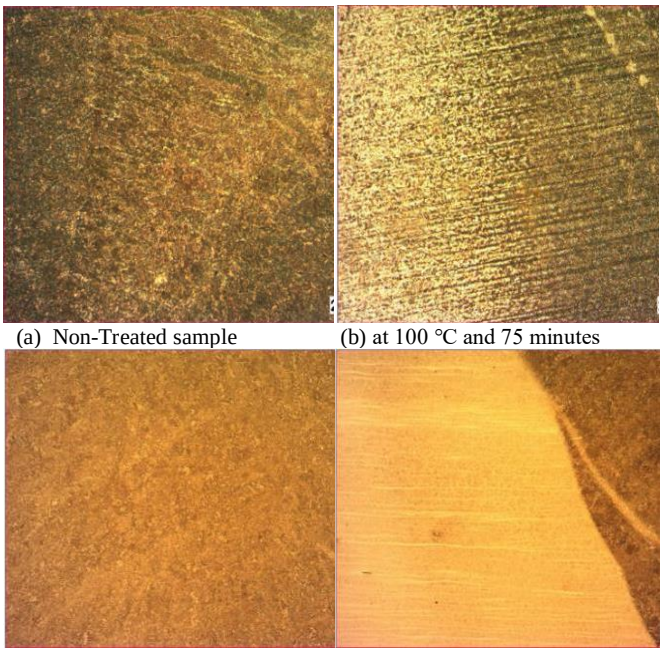
Fig. 17: Surface Roughness at 200 ℃ and 75 minutes

Ra 1.6553 µm Rp1max 7.6113 µmRv1max 5.9984 µm
Rt 13.6097 µm Rp 4.7968 µm Rv 4.3602 µm
Rz (DIN) 9.1570 µm RS 35.59 µm RSm 109.37 µm

3.3. Results of Optical microscope

In Figure 18 (a), (b), optical microscope images of the samples. After the process, a change in the grain structure was observed after thermal treatment effect on the surface area. The structure affected by the process on the surface was printed more compared to the interior and the homogeneity of the structure deteriorated. It was noted that the striking distributions in the interior structure intertwined and the distinctive structures began to disappear,

In figure 18 (c), (d), after increase the heat, the thickness of the deformed region increased with the increase of the effect of process. It is seen that the grains are oriented from one side to the other after process of treatment, although process-induced deformation is observed in the surface line, it has been observed surface deformation process.



(a) Non-Treated sample (b) at 100 ℃ and 75 minutes

(c)at 150 ℃ and 75 minutes (d) at 200 ℃ and 75 minutes

Fig. 18: optical microscopy images

3.4. Tensile Test Results

Tensile test data should be converted to stress-strain graph in order to find values such as yield strength, tensile strength, and modulus of elasticity of the samples.

The following steps have been implemented to carry out these operations:

• The stress and strain values obtained from the tensile test for each sample were made graphically in the excel file.

• From the stress findings, the highest value between the beginning and the end was determined, and the maximum stress was found and this value was added to the graph.

• A point was determined on the line running from the beginning to the apex and the stress value of that point was found. The equation of the line is obtained from the intersection points by combining the found stress value and the initial stress values in Table 3. The modulus of elasticity was found with the coefficient at the beginning of x value in the line equation. The yield strength was found from y value in the coordinates of the intersection point.

• A separate graph has been prepared for yield strength, maximum tensile and modulus of elasticity values. The data from the samples are included in this chart and made available for interpretation of the results (figure 19). In Table 4, the tensile test results of the samples are given in MPa.

Table 4: Tensile test results of samples

	Yield Value	Tensile Value	Modulus of Elasticity
Untreated Sample	23.84 MPa	47.197 MPa	30.542 MPa
1	23.19 MPa	40.706 MPa	30.561 MPa
2	24.56 MPa	42.961 MPa	32.44 MPa
3	25.75 MPa	42.274 MPa	32.465 MPa
4	27.57 MPa	41.66 MPa	29.15 MPa
5	22.36 MPa	41.124 MPa	35.691 MPa
6	22.14 MPa	42.638 MPa	34.007 MPa

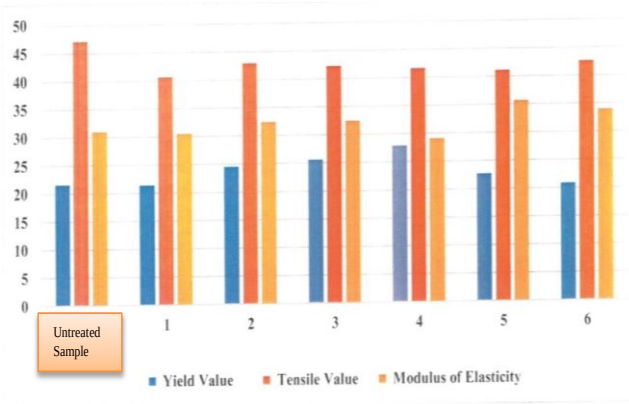


Fig. 19: Collective comparison of test results

The red line corresponding to the stress value of 40.706 MPa in the tensile test graph of sample number 1 shows the maximum stress. This value shows the magnitude of the resistance of the material at the moment of rupture. The yellow line shows the line formed from the point where the elastic deformation turns into plastic. Yield strength and modulus of elasticity are found by this line. It shows the yield strength of 23.19 MPa and the modulus of elasticity of 30.561 MPa. The maximum rupture value was found to be 3.72 MPa. (Figure 20).

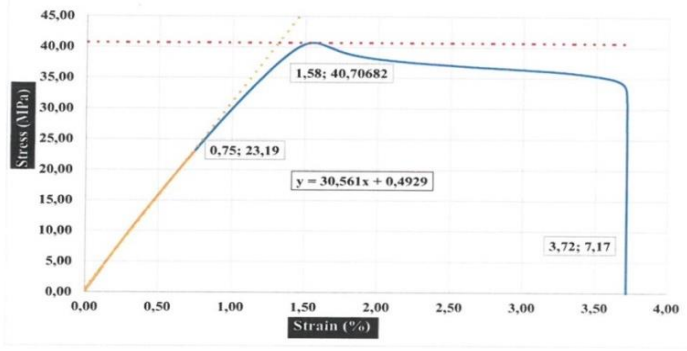


Fig. 20: Tensile test chart of sample No. 1

In the tensile test graph of sample number 2, the yield value was measured as 24.56 MPa and the modulus of elasticity was 32.44 MPa. The maximum stress is 42.961 MPa and the breaking value is 3.32 MPa. There was an increase in the maximum breaking point value compared to sample number 1. It took longer for the

sample to transition from the elastic region to the plastic region, so the material entered the permanent deterioration stage after a longer period of time (figure 21).

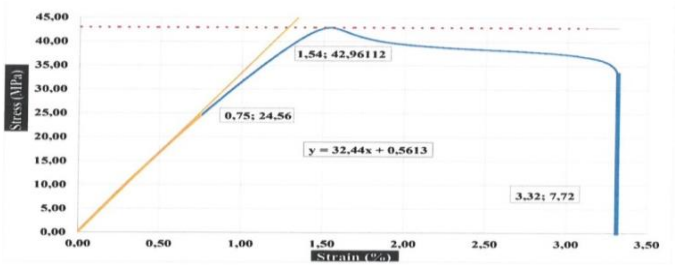


Fig. 21: Tensile test chart of sample No. 2

In the tensile test graph of sample number 3, the maximum rupture was measured as 3.41 MPa and the stress values were measured as 42.274 MPa. The effect of the waiting time did not cause a clear change compared to the first two samples. The modulus of elasticity was found to be 32.465 MPa and yield values were found to be 25.75 MPa (figure 22).

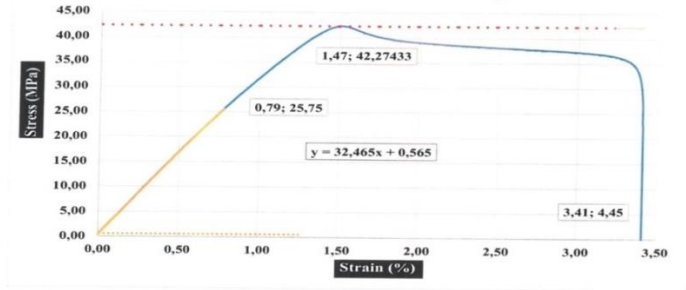


Fig. 22: Tensile test chart of sample No. 3

According to the data obtained from the tensile test graph of sample number 4, the yield value was measured as 27.57 MPa, the modulus of elasticity 29.15 MPa, the maximum stress as 41.66 MPa and the breaking value as 4.66 MPa. The maximum yield and rupture value belongs to the 4th sample. It was found that the transition period to the plastic zone took the longest and the physical rupture process was the last to occur (figure 23).

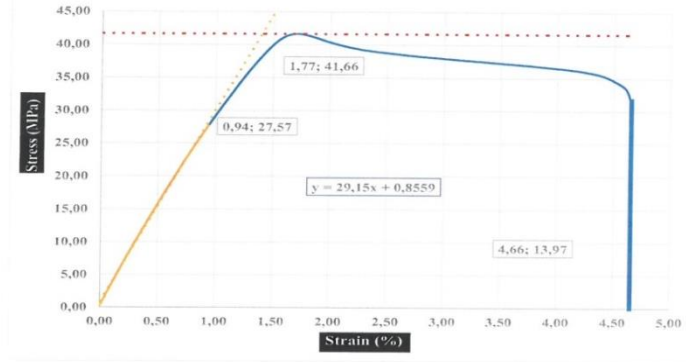


Fig. 23: Tensile test chart of sample No. 4

According to the data taken from sample 5, the yield value was 22.36 MPa, the modulus of elasticity was 35.691MPa, the maximum stress was 41.124 MPa and the breaking value was 1.72MPa. Except for sample number 4, the elastic modulus, which shows a regular increase, is the highest value in the 5th sample (figure 24).

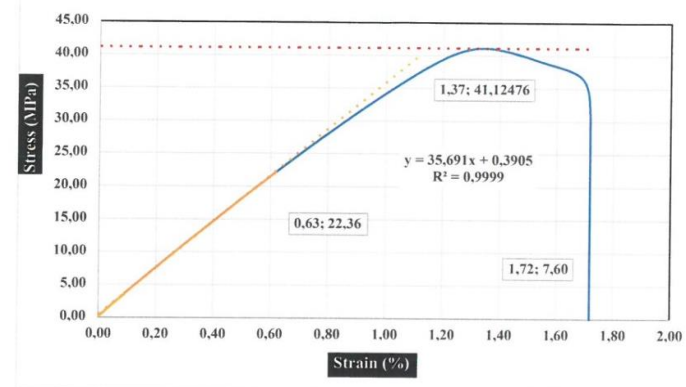


Fig. 24: Tensile test chart of sample No. 5

According to the data results of sample number 6, the yield value was measured as 22.14 MPa, the breaking value was 1.76 MPa, the maximum tensile value was 42.638 MPa and the modulus of elasticity was 34.007 MPa (figure 25).

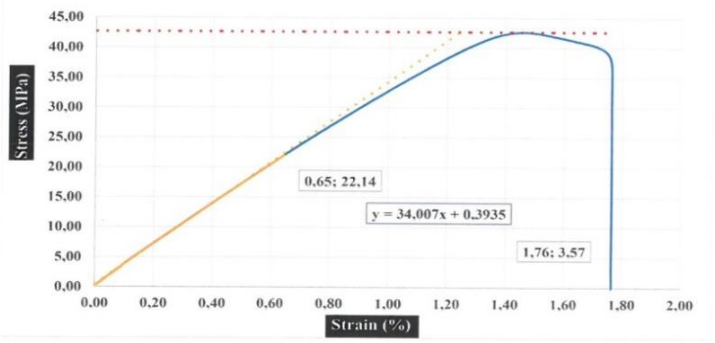


Fig. 25: Tensile test chart of sample No. 6

According to the tensile test results of the untreated test sample, the yield value was measured as 25.74 MPa, the rupture value as 3.31 MPa, the modulus of elasticity as 30.542 MPa and the maximum stress value as 47.20 MPa (figure 26).

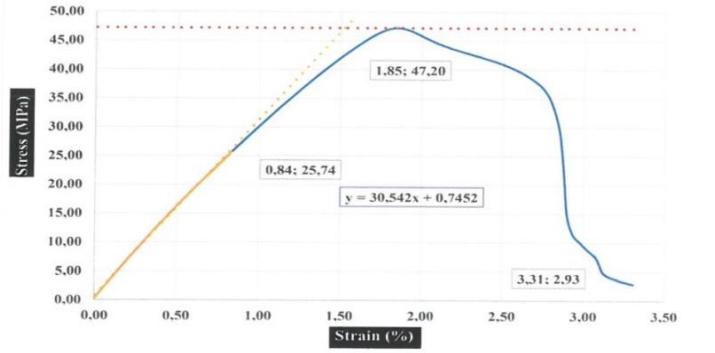


Fig. 26: Tensile test chart of untreated sample

4. Discussion

In this section, the data obtained from Surface Roughness Measurement were compared for all samples, also optical microscope images analysis for thermal treatment process.

As per the effect on the bio plastic surface according to the graphs, the specimen roughness was found to vary depending on the temperature, because temperature affects in reduce surface roughness. For instance, at the first point, the surface roughness at the first point was 5.90 µm, at the second point, 2.70 µm and at the third point 1.65, and at Non-Heat-Treated sample 13.26 µm.

It can be concluded that burns by thermal treatment on the surface of bio plastic need to improving the surface quality and this is because strength of the surface is low. The type of bonding is an essential factor that influences the physical, mechanical and aesthetics of the substance. The surface roughness model is based on mechanical analysis, and hardness and surface deformation depend on the type of material. Surface roughness is useful in determining the quality of the bond of the polymer with other materials. A composite is a kind of engineered material that consists of particular fillers in a soft matrix.

Optical microscope analysis was performed to determine the phase change, grain size change and layer differences of such structures. After analysis, different structures draw attention from the surface to the interior in general terms.

The optical images, it showed the presence of a nebula structure on the surface with limited detailed characterization, this structure is deformed and ultra-fine-grained. However, as the processing conditions get heavier, the effect on the surface gets heavier, the deformation effective layer thickness deepens considerably and it is thought that it may have an effect in terms of mechanical properties. It was observed that the thickness of both nanocrystalline and deformation-affected, oriented fine-grained layers increased significantly as the processing conditions increased.

In this section, the data obtained from the tensile test were compared with the untreated test sample, and according to the results obtained, the increase and decrease in the yield strength, breaking strength, maximum tensile and modulus of elasticity values obtained from the

tensile test results of the material were examined.

4.1. Change in Yield Strength

In this region where permanent deformation begins to occur, the yield value should be as high as possible in order for the material to be restored after being under load for a long time. As seen in Table 5, the highest yield value is 25 minutes at 150°C. It belongs to sample number 4, which is kept waiting. Compared to the non-thermal sample, the increase in the flow resistance increased the ability of the material to return to its old form by 7.1 %. When looking at the table in general, the test process applied up to the fourth sample had a positive effect on the yield strength of the samples, while increasing the holding time at 150°C at a constant temperature led to a decrease in the yield value. (Figure 27)

Table 5: Comparison of yield values of samples

	Yield Value
Untreated Sample	25.74 MPa
1	23.19 MPa
2	24.56 MPa
3	25.75 MPa
4	27.57 MPa
5	22.36 MPa
6	22.14 MPa
Max	27.57 MPa
Min	22.14 MPa
Average	24.261 MPa

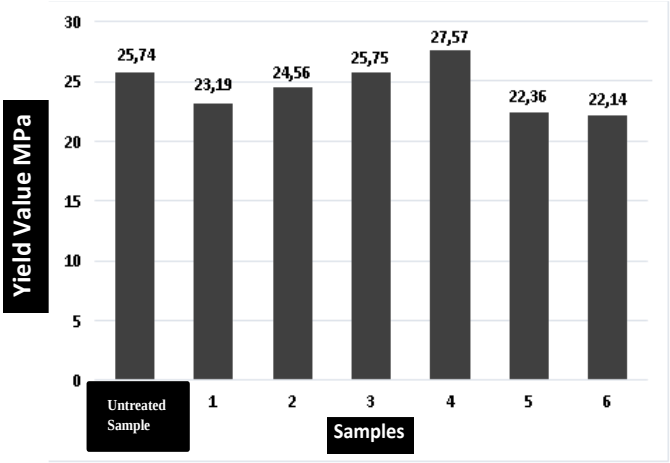


Fig. 27: Yield strength values of samples

4.2. Change in Maximum Stress

The maximum tensile strength showed a decreasing trend in all heat-treated samples, as seen in figure 28. Since there is no linear increase or decrease, it is not known which of the temperature and holding time variables has a negative effect. As can be seen in Table 6, the average stress value of all samples is calculated as 41.894 MPA, and this value is very low compared to the non-thermal sample.

Table 6: Comparison of Tensile Values of Samples

	Tensile Value
Untreated Sample	47.197 MPa
1	40.7068 MPa
2	42.9611 MPa
3	42.2743 MPa
4	41.66 MPa
5	41.124 MPa
6	42.638 MPa
Max	47.197 MPa
Min	40.7068 MPa
Average	41.894 MPa

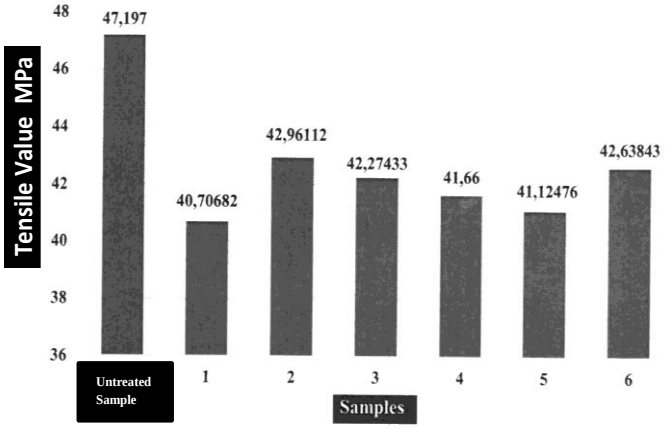


Fig. 28: Tensile strength values of samples

4.3. Chang in Modulus of Elasticity

The modulus of elasticity reached the highest level with a value of 35.691 MPa in sample 5, which was kept at 150°C for 50 minutes. An increase of 15.06% was observed in the elasticity value of the material when compared to the unheated test sample. When the data in Table 7 was examined in general, an average elasticity value of 32.385 MPa was not observed in the elasticity modules of the samples (figure 29).

Table 7: Comparison of the modulus of elasticity values

	Modulus of Elasticity
Untreated Sample	30,542 MPa
1	30,561 MPa
2	32,44 MPa
3	32,465 MPa
4	29,15 MPa
5	35,691 MPa
6	34,007 MPa
Max	35,691 MPa
Min	29,15 MPa
Average	32,385 MPa

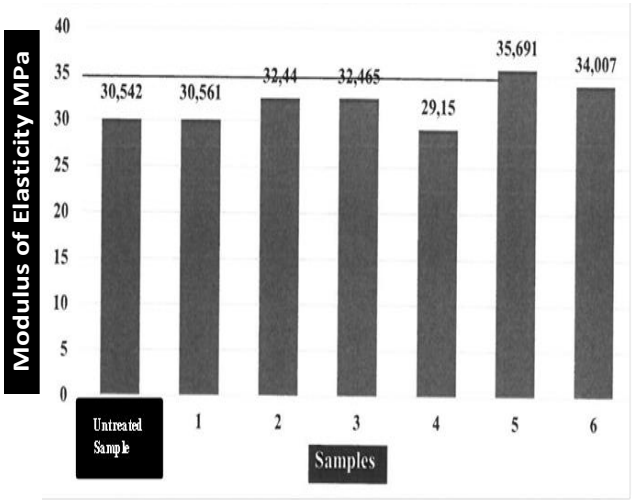


Fig. 29: Modulus of elasticity values of samples

5. Conclusion

With the help of 3D printers, which have been developing since the early 1980s and increasing in popularity every day, it has become very easy to produce any model and examine its data. The use of FDM technology is quite high compared to other production methods. 3D printer technology will be more suitable for individual use thanks to the developments in technology in the future.

Apart from the cost of 3D printers to be widely used in daily life, models that require high accuracy and robustness cost much more to manufacture. The effects of temperature and holding time are a study to reduce cost and to obtain high strength. In this study, the results of the tensile test after heat treatment of the samples, which were kept between 100°C and 200°C for 25, 50 and 75 minutes were compared

with the results of the untreated test sample. With the effect of temperature, the molecules of the samples come closer to each other, thus creating a strong bond in the samples, it was tried to increase the strength and it was expected that the samples would get high results from the tensile test.

Only nine samples were selected to take into account the design requirements, and the best and optimal temperatures for bioplastics were chosen with appropriate timing, because in low grades, there is no noticeable modification in the plastic properties, and in intermediate grades, the change will be slow, in increasing the temperatures of the samples, the plastic will melt. Test samples could not withstand the high temperature, so the tensile test could be performed for a few samples. Taking into account the quality of the results.

As a result of the test, positive results were observed in yield strength when the untreated sample was compared with the heat treated samples, the highest increase was achieved in sample number 4 with a value of 27.57 MPa. The test had a negative effect on the tensile strength and the highest value was observed in the untreated sample with 47.197 MPa. The increase in the modulus of elasticity is in sample number five with a value of 35.691 MPa, which shows that the heat treatment has a positive effect on the samples. As a result of the experiments, the effect of heat treatment led to an increase in yield strength and elasticity modulus, and as per the effect on the bio plastic surface according to the graphs, the specimen roughness was found to vary depending on the temperature, because temperature affects in surface roughness, and the surface roughness at the first point 5.90 µm, at the second point, 2.70 µm and at the third point 1.65, and at Non-Heat-Treated sample 13.26 µm, and this was evident from measurements of the surface roughness of bioplastics (PLA) for some points at high temperatures.

According to the results obtained, the data in the graphs were compared with the average flow value and thermal processing sample values of 5.75 % in the flow strength in general. When the same is calculated for elasticity module, there is a 6.06 %recovery. The greatest change caused by the temperature effect was measured in tensile strength with a decrease of 11.24%. Looking at the results of the other six samples compared with the untreated test sample, it was seen that the temperature and holding time variables were expected to increase the yield strength, modulus of elasticity, maximum stress and maximum rupture values of the samples, but generally decreased. As a result of the processes, it was concluded that the effect of temperature and holding time reduces the tensile strength of the materials.

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