Developing Flat Drip Irrigation Pipes Using Bioplastic Materials

Bülent Eker[1], Murat Alkan[2], Ayşegül Akdoğan Eker[3]

[1]Namık Kemal University, Faculty of Agriculture/Tekirdağ-TÜRKİYE

[2]Bursa Metropolitan Municipality, General Directorate BUSKİ / Bursa- TÜRKİYE

[3]Yildiz Technical University, Department of Mechanical Engineering/İstanbul-TÜRKİYE

[1]buekeray@gmail.com; [2]alkan73@gmail.com; [3]akdogan@yildiz.edu.tr

***Abstract*-This study analyzed the use of environmentally friendly, cornstarch based bioplastic raw materials instead of polyethylene based raw material to produce flat drip irrigation pipes, which is the most efficient agricultural irrigation system. Two groups of raw materials were used in the study, low density polyethylene (LDPE) material and cornstarch based biodegradable- poly beta hydroxybutyrate (PHB) raw material. Mixtures are obtained by adding 4 types of PHB raw materials at the ratio of 25%, 30%, 35% and 40% and 5% black masterbatch separately in the form of granules. Test samples were prepared from these mixtures using extrusion film production method. Mechanical tests, shrinking tests and thermal analysis were performed on test samples. Of the raw materials with bioplastic mixture, only the sample obtained from 65% LDPE + 30% PHB + 5% black masterbatch was consistent with the values of commercially available flat drip irrigation pipes with 0.14 mm wall thickness, 443.54 % strain at break, 0.967 g/cm^3 density and 123.36 ℃ melting point. Moreover, raw materials with bioplast additives obtained from the study are suitable for the use as an alternative material in the polyethylene applications used in the fields of agricultural and industry.**

Keywords- Flat Drip Irrigation Pipe; Bioplastic; Polyethylene; Extrusion

I. INTRODUCTION

Plastic applications that are widely used in many fields of engineering, may cause environmental problems, because of the fact that raw material of plastic materials is petroleum. In agricultural lands, which are the most important natural resources, misuse of these types of materials or production of these materials from inappropriate materials would result in irreversible environmental damage. In this context, undesirable results of these types of materials began to be observed in drip irrigation applications. Principal results are break-up of drip irrigation pipes during usage due to mechanical, biologic or sun effects and clogging of the pipes in the system due to low quality of irrigation water. The pipes, which broke up or became useless due to clogged drippers, remain in agricultural land or are collected and discarded in another place.

A drip irrigation system includes pump unit, control unit, main pipe line, manifold pipelines, lateral pipe lines and drippers, respectively [1]. Flat drip irrigation pipes, which are analyzed in the present study, are termed as lateral pipelines [2]. Drippers are placed inside the pipe during the production, at certain distances and dripper pipes fit into the pipe according to the production method and the pipes are then ready for use. These drippers can be round or flat drippers [3].

That flat drip irrigation pipes are produced by adding drip cap inside the pipe at certain distance during pulling of pipe from the mold through extrusion from low density polyethylene (LDPE). Wall thicknesses of the pipes vary between 0.12 mm and 0.60 mm. When polyethylene (PE) which is produced from synthetic polymers produced from petroleum is discarded to the nature, it causes environmental pollution and toxic material accumulation, as it cannot be degraded in the soil for a long time. When they are destroyed by burning, they cause emission of toxic materials into the air. In addition, since they are used in agricultural lands, the damage they give becomes more significant [4].

Polyethylene is manufactured by two main methods which are high and low pressure processes. Low density polyethylene (LDPE) and copolymers are produced by high pressure process, while high density polyethylene and newly developed linear LDPE type are produced with low pressure process [5].

According to [6], LDPE group raw materials no G03-5 and F2-12 are the most commonly used products in the market. Using G03-5 a high quality film production can be made within a wide extrusion conditions. F2-12 is perfect for film production for a general purpose thanks to the combination of its superior optical and mechanical properties.

The results presented in [7] reports that plastics are materials obtained by breaking of monomers C forms with H, O, N and other organic or inorganic elements with simple structure molecule groups and turning them into long and chained structure called polymer. They are not available in nature. Due to the contribution of greenhouse gases emitted from rapidly increasing consumption and processing to global warming, bioplastics and biodegradable plastics gained prominence as an alternative to petro-chemistry based conventional plastics in recent years. For instance, there may be mentioned: (a) Thermoplastic produced from starch; (b) Cellulose based cellulose acetate; (c) PBS (poly-butyrate succinate); (d) PHBV (poly-hydroxybutyrate-co-valerate); (e) PLA (poly-lactic acid); (f) PHA (Poly-beta-hydroxyalkanoates) and (g) PHB (poly-beta-hydroxybutyrate).

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PHB is obtained by fermentation of sugar or starch. Bacillus sp., Pseudomonas sp., Azotobacter sp. are its natural producers; it is synthesized and stored in the form of intracellular store granules. It is a PHA derivative. One ton of PHB is obtained from three tons of substrate. They are biodegradable. In aerobic environment, they transform into CO_2 or water; whereas they transform to CH_4 in anaerobic environment. They degrade in a period ranging from one month to several years.

It was reported that [8] nowadays promising results are obtained from the synthesis of renewable, biocompatible and environmentally friendly plastics like PHB with bacteria and applications in polymer chemistry. Biopolymers produced from renewable sources increase both efficiency and soil conditioning due to their biodegradability and capability of mixing into soil characteristics. The general formula of PHB, is a macromolecular polymer of optically active D(-)-3-hydroxy butyric acid with a methyl group in its lateral chain, which is ($C_4H_6O_2$).

This study is aimed to investigate the use of environmentally friendly bioplastic PHB raw material made of cornstarch instead of PE raw material in production of flat drip irrigation pipes, which is one of the most efficient systems used in agricultural irrigation.

Two groups of raw materials were used to develop raw materials for flat drip irrigation pipe. These raw materials were (i) polyethylene raw material group LDPE and (ii) biodegradable-PHB raw material group BIOPLAST whose principle component is cornstarch. Mixtures were obtained by adding 25%, 30%, 35% and 40%, BIOPLAST into LDPE raw material and 5% black masterbatch separately in the form of granule. Test samples were prepared from these mixtures using extrusion film production method.

Mechanical tests, stress tests, thermal analyses (i.e., DSC analyses and thermal camera shootings), aerobic pool and field tests were performed on test samples. The obtained data were compared with the results of commercially available drip irrigation pipes using statistical methods. Optimum mixture ratios between polyethylene and bioplastic raw materials, which can be used to produce flat drip irrigation pipes, were determined.

II. MATERIAL AND METHOD

LDPE raw materials used in the present study were G03-5 and F2-12. Comparative technical properties according to [6] are tabulated in Table 1.

On the other hand, it should be noted that PHB-BIOPLAST raw materials are BOR-M-501F and BOR-M-502F and considered as masterbatch; whereas BOR-Z-503FM and BOR-Z-703J are considered as resin. Comparative technical properties according to [9] are tabulated in Table 2.

TABLE 1 PROPERTIES OF LDPE/G03-5 AND F2-12 RAW MATERIALS

Properties and Data			**LDPE G03-5**	**LDPE F2-12**
Testing Item	**Method**	**Unit**	**Value**	**Value**
Melt Flow Rate (MFR) (190 ℃ / 2160 g)	ASTM D-1238	g/10 min	0.23 - 0.37	2.0 - 3.5
Density,23 ℃	ASTM D-1505	g/ cm3	0.919 - 0.923	0.918 - 0.922
Film Quality	ALKATHENE 36	-	T	A
Swelling Ratio	ALKT-7	-	1.41	
Ash	ALKT-509	%wt	-	0.16
Haze	ASTM D-1003	%	9.3	6.7
Gloss	ASTM D-2457	-	57	70
Melt Point (DSC)	ASTM E-794	℃		110
Shore D Hardness	ASTM D-1706	-		44

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TABLE 2 PROPERTIES OF PHB-BIOPLAST/BOR-M-501F, BOR-M-502F, BOR-Z-503FM, BOR-Z-703J RAW MATERIALS

Properties and Data			**BOR-M-501F**	**BOR-M-502F**	**BOR-Z-503FM**	**BOR-Z-703J**
Testing Item	**Standard**	**Unit**	**Result**	**Result**	**Result**	**Result**
Appearance	Q/320113SSD001- 2002		Light Yellow	Light Yellow	Light Yellow	Light Yellow
Density	GB 1033	g/ cm3	1.05 – 1.15	1.05 – 1.15	0.98 – 1.10	0.98 – 1.10
Moisture Content	Q/320113SSD001- 2002	%	0.50 – 1.20	0.50 – 1.20	0.50 – 1.20	0.30 – 1.20
Melt Flow Index	GB3682	g/10 min	0– 2	0 – 2	2 – 5	2 - 5
Tensile strength	GB 1040	MPa	≥15	≥15	≥ 20	≥20
Breaking Elongation	GB 1040	%	≥300	≥300	≥ 50	≥50
Bio Substances Content	Q/320113SSSD001- 2002	%	≥70	≥70	≥ 7 0	≥70
n-hexane Extracts	GB/T5009.58	%	≤4.0	≤4.0	≤ 4.0	≤4.0
Rockwell Hardness	GB9342	R Standard	R gauge	R gauge	-	50
Softening Point	GB/1633	℃	>65	>65	> 85	>85
Degradation rate in100days	ISO14855:2000 OK-BIOBASED	%	*	*	*	> 46
*= The degradation rate in 100 days is up to the adding ratio of it.						
The data for tensile strength and elongation refer to that of finished film products.						

Pipes with a wall thickness of 0.15 mm produced by two different firms were used for the test samples produced from flat drip irrigation pipe.

Test samples were produced by mixing different ratios of BIOPLAST masterbatch, resin and black masterbatch into G03-5 and F2-12 raw materials. Mixtures were obtained by changing the ratios 25%, 30%, 35% and 40% to find maximum mixture ratio in LDPE. Extrusion machine and film layer forming the method were used as sample production technique.

Due to their high cornstarch content, biodegradable raw materials easily absorb humidity and water loss is the case during processing. The raw materials were stored in a dry place and let to cure for 24 hours before production of a film layer to avoid water loss. At the stage of film production, using extrusion machine, screw extruder L/D ratio was kept at 28:1 and blow-up ratio was kept at minimum 1:3 to achieve maximum production yield and optimum film quality. Regional processing temperatures of the machine were 165 ℃, 170 ℃, 175 ℃ and 180 ℃, respectively.

Test samples in accordance with ISO 37 TYPE 2 standard were prepared before conducting tests, and analyses were performed on two commercially available different brands of flat drip irrigation pipe materials and six materials, successfully produced under various mixtures ratios.

Wall thickness, density, hardness and stress test measurement studies on the test samples were performed in laboratory environment at 23 ℃ ± 2 ℃ and moisture value of: 50 Rh ± 5 Rh with 3 replications.

Stress tests performed on test samples were conducted using INSTRON Stress Device with a sensitivity of 0.1 N/0.01 mm, speed of 500 mm/min and 5.00 kN load in accordance with ISO 37.

Stress at peak, displacement at break, % strain at break, load at break, stress at 0.2% yield, Young’s modulus and energy to break point were determined.

Differential scanning calorimetry (DSC) test set up was used to determine thermal properties of the samples. The plastic material general standard ISO 11357 was taken into consideration during the analyses. The samples were prepared at weights varying from 4.7 mg to 5.5 mg. Thermal property analyses were conducted on the samples using DSC device at 50 ℃ to 230 ℃ and at a rate of change of 10 ℃/min. Endothermic and exothermic properties of the samples were analyzed. In addition, melting temperature, crystallization temperatures, reaction initiation and end points, area and delta H values were identified

Temperature changes at the surface of the material were measured by FLIR P640 brand thermal camera to determine temperature storage abilities on material surface of the samples.

The studies to investigate biological degradability properties of the samples were conducted in aerobic pools of Bursa West Wastewater Treatment Plant with a design flow rate of 240000 m3/day and in field environment by keeping 3 test samples for 1000 hours. Change between initial and final weights and physical losses of the samples were determined.

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Test and analyses were performed on 6 materials produced at varying mixture ratios and on 2 different commercially available flat drip irrigation pipe materials in 3 replications. Test and experiment results of the 8 different test samples were grouped by "Tukey LS Means Differences": a statistical analysis test method using JMP7 program.

III. RESULTS AND DISCUSSION

Bioplast ratios were changed to 25%, 30%, 35% or 40% to find the maximum mixture ratios of biodegradable raw materials in LDPE. On the prepared mixtures, the codes of the ones with successful extrusion film blowing procedure and the codes and raw material ratios of 8 different samples obtained from commercially available flat drip irrigation pipes are presented in Table 3. Test samples prepared from the samples are presented in Fig. 1.

TABLE 3 RAW MATERIAL MIXTURE OF SUCCESSFULLY PRODUCED SAMPLES

Raw Material Mixture Of The Samples								
	alus01	**alus02**	**alus03**	**alus04**	**alus05**	**alus06**	**alus07**	**alus08**
Low Intensity Polyethylene	**70%**	**70%**	**65%**	**65%**	**95%**	**95%**	**B Firm Flat Drip Irrigation Pipe**	**C Firm Flat Drip Irrigation Pipe**
	F2-12	**F2-12**	**F2-12**	**F2-12**	**G03-5**	**F2-12**		
Masterbatch	**5%**	**5%**	**5%**	**5%**	**5%**	**5%**		
	Black	**Black**	**Black**	**Black**	**Black**	**Black**		
Biodegradable Plastic	**25%**	**25%**	**30%**	**30%**				
	MASTERBATCH **BOR-M-501F**	MASTERBATCH **BOR-M-502F**	RESIN **BOR-Z-503FM**	RESIN **BOR-Z-703J**				

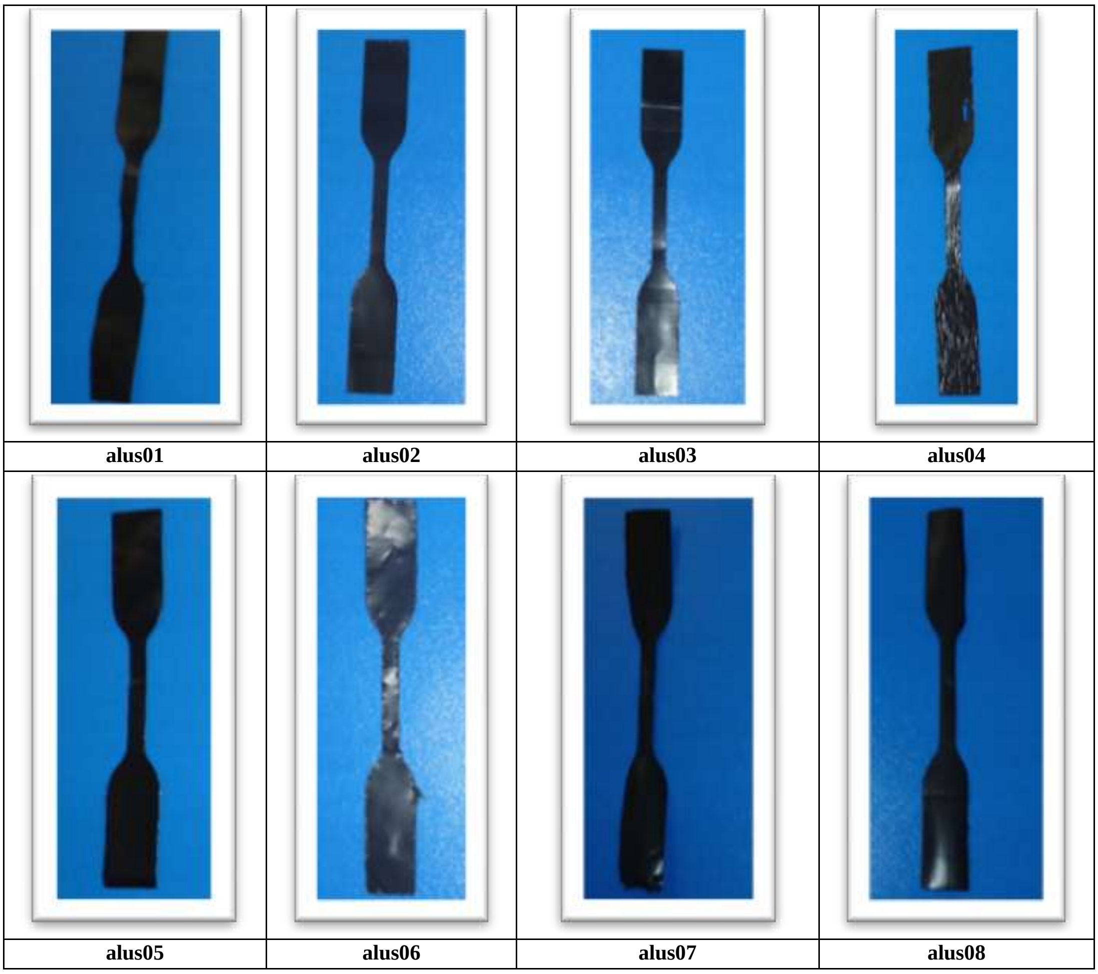

Fig. 1 Test Samples

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Grouping results of wall thickness, weight, density and hardness data of test samples according to LS Means Differences Tukey HSD statistical analysis method are presented in Table 4.

TABLE 4 WALL THICKNESS, WEIGHT, DENSITY AND HARDNESS RESULTS LS MEANS DIFFERENCES TUKEY HSD DATA

Test Samples	Wall Thickness (mm)		Weight (g)		Density (g/cm^3)		Hardness (Shore D)	
alus01	0.0933	C	0.0792	C	0.9693	A	30.0000	A
alus02	0.0700	CD	0.0649	CD	0.9873	A	25.0000	B
alus03	0.1400	B	0.1206	B	0.9670	A	23.0000	C
alus04	0.4067	A	0.1605	A	0.9137	B	22.0000	D
alus05	0.0467	D	0.0456	D	0.9243	B	25.0000	B
alus06	0.0733	CD	0.0676	C	0.9750	A	30.0000	A
alus07	0.1700	B	0.1445	A	0.9363	B	25.0000	B
alus08	0.1733	B	0.1415	AB	0.9380	B	25.0000	B

Wall thickness, weight and density mean values of test samples are shown in Fig. 2.

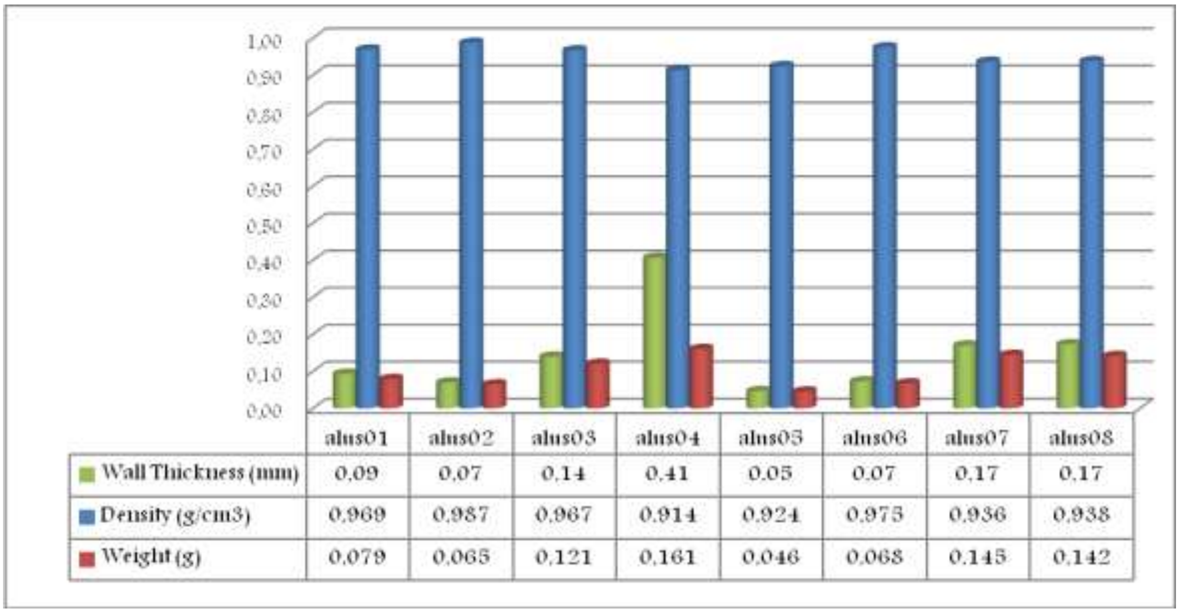

Fig. 2 Comparative Graphs of Pipe Wall Thickness, Density and Weight Values of Test Samples

Based on the stress test results of test samples, the grouping results of stress at peak, displacement at break, % strain at break, load at break, stress at 0.2% yield, Young's modulus and energy to break point data according to LSMeans Differences Tukey HSD statistical analysis method are tabulated in Table 5 and plotted in Fig. 3.

TABLE 5 STRESS TEST RESULTS LS MEANS DIFFERENCES TUKEY HSD DATA

Test Samples	Stress at Peak (MPa)		Displacement at Break (mm)		(%) Strain at Break		Load at Break (kN)		Stress at 0.2 % yield (MPa)		Young's Modulus (MPa)		Energy to Break Point (J)	
alus01	12.6273	C	74.1883	AB	122.8667	C	0.0027	B	5.0807	D	161.0247	BCD	0.3150	CD
alus02	10.5483	C	38.6387	C	183.1950	C	0.0023	B	5.3027	D	113.7510	D	0.1097	E
alus03	9.6007	C	88.7087	A	443.5420	A	0.0027	B	5.0470	D	125.3063	D	0.4327	C
alus04	8.4643	C	27.8890	C	139.4450	C	0.0047	B	4.9717	D	135.4560	CD	0.1953	DE
alus05	23.1900	B	43.5510	BC	274.7927	B	0.0030	B	8.0297	BC	119.2697	D	0.1620	DE
alus06	19.4440	B	41.5837	C	161.2500	C	0.0020	B	10.1077	AB	298.8607	A	0.2780	CDE
alus07	32.3067	A	88.0003	A	462.7750	A	0.0150	A	11.7383	A	208.2553	BC	1.5030	B
alus08	31.6723	A	98.8300	A	497.9160	A	0.0180	A	11.8967	A	220.8723	AB	1.7700	A

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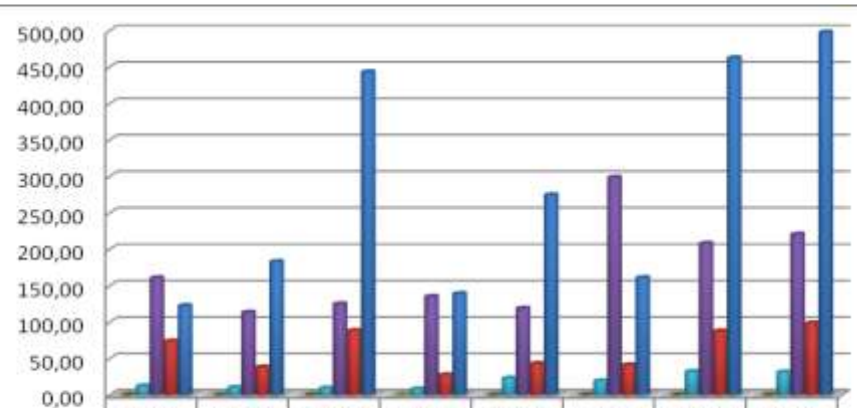
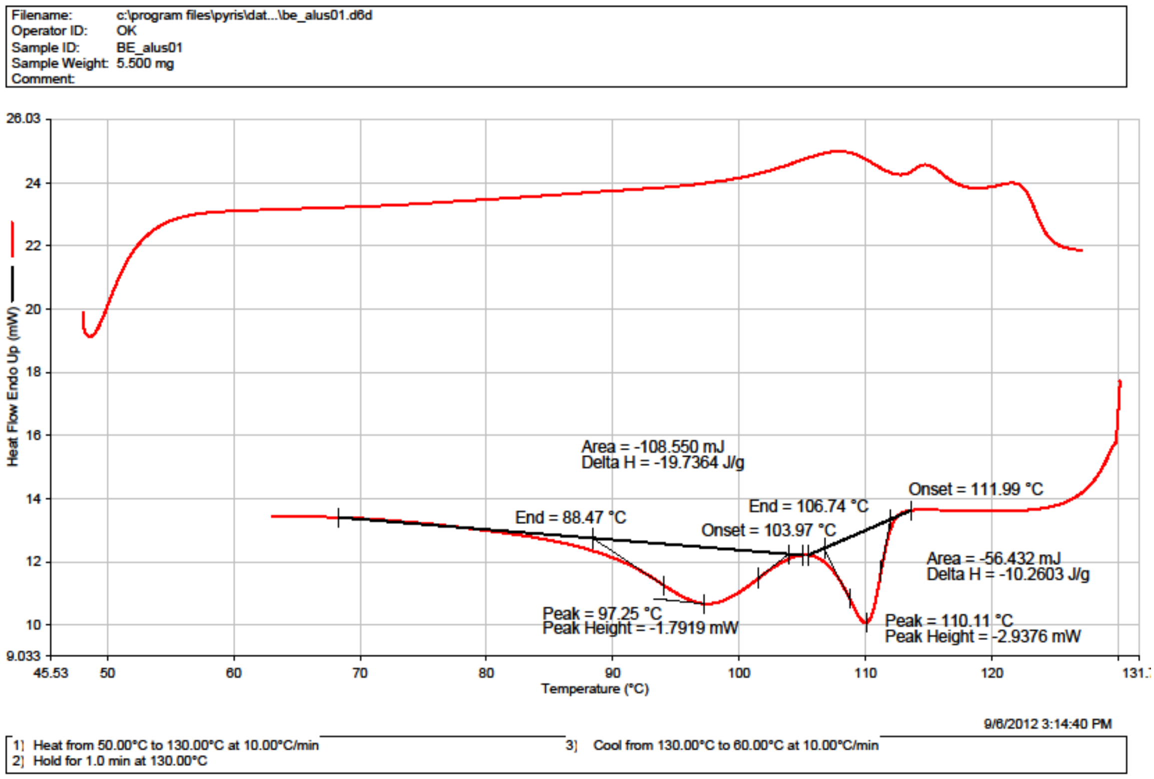


	alus01	alus02	alus03	alus04	alus05	alus06	alus07	alus08
Wall Thickness (mm)	0.09	0.07	0.14	0.41	0.05	0.07	0.17	0.17
Stress at Peak (MPa)	12.63	10.55	9.60	8.46	23.19	19.44	32.51	31.67
Young's Modulus (Mpa)	161.02	113.75	125.31	135.46	119.27	298.86	208.26	220.87
Displacement at Break (mm)	74.19	38.64	88.71	27.89	43.55	41.58	88.00	98.83
(%) Strain at Break	122.87	183.20	443.54	139.45	274.79	161.25	462.78	497.92

Fig. 3 Comparative Graphs of Stress Test Results of Test Samples

Thermal property analysis results on test samples using DSC device are presented in Figs. 4-7.



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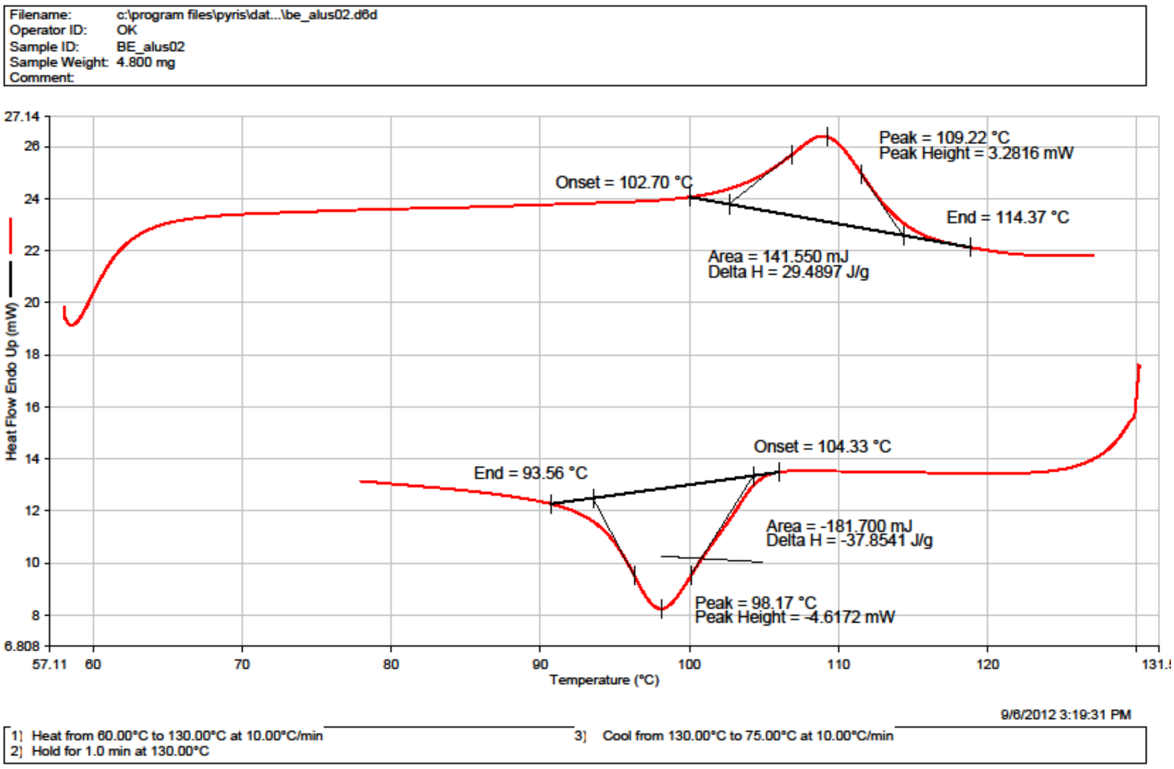
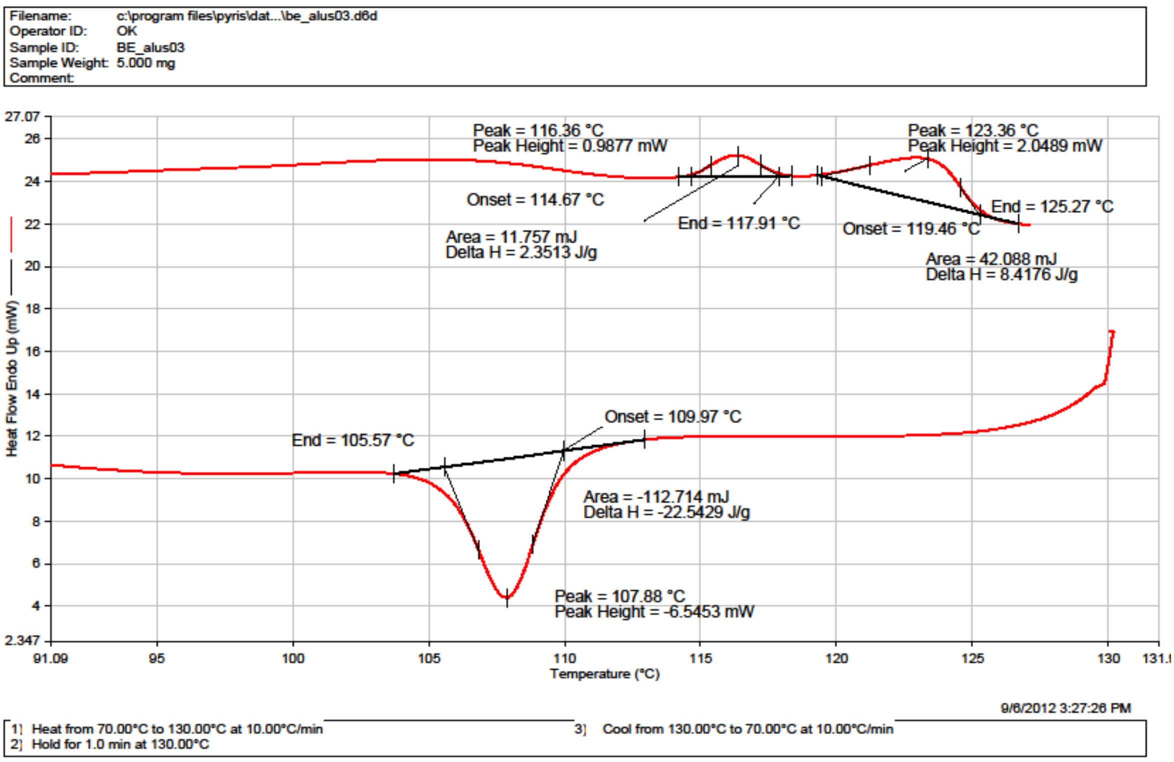


Fig. 4 Thermal Property Graphs of alus01 and alus02 Samples obtained with DSC



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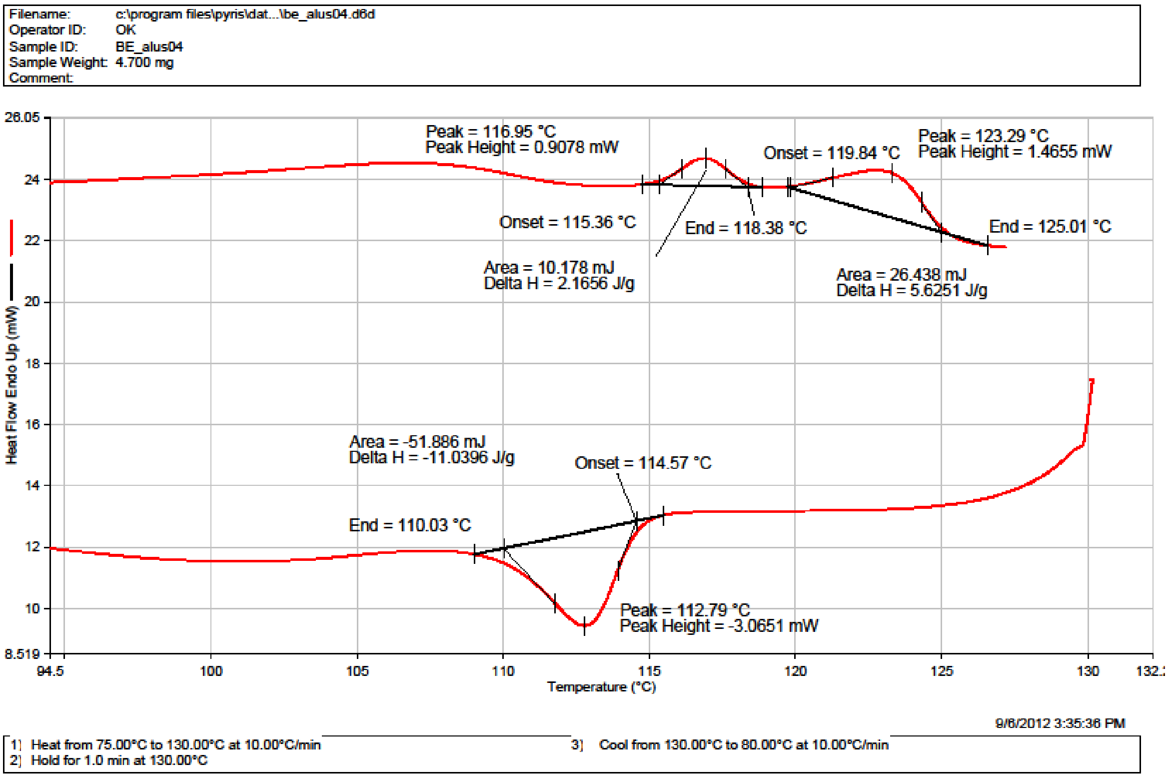
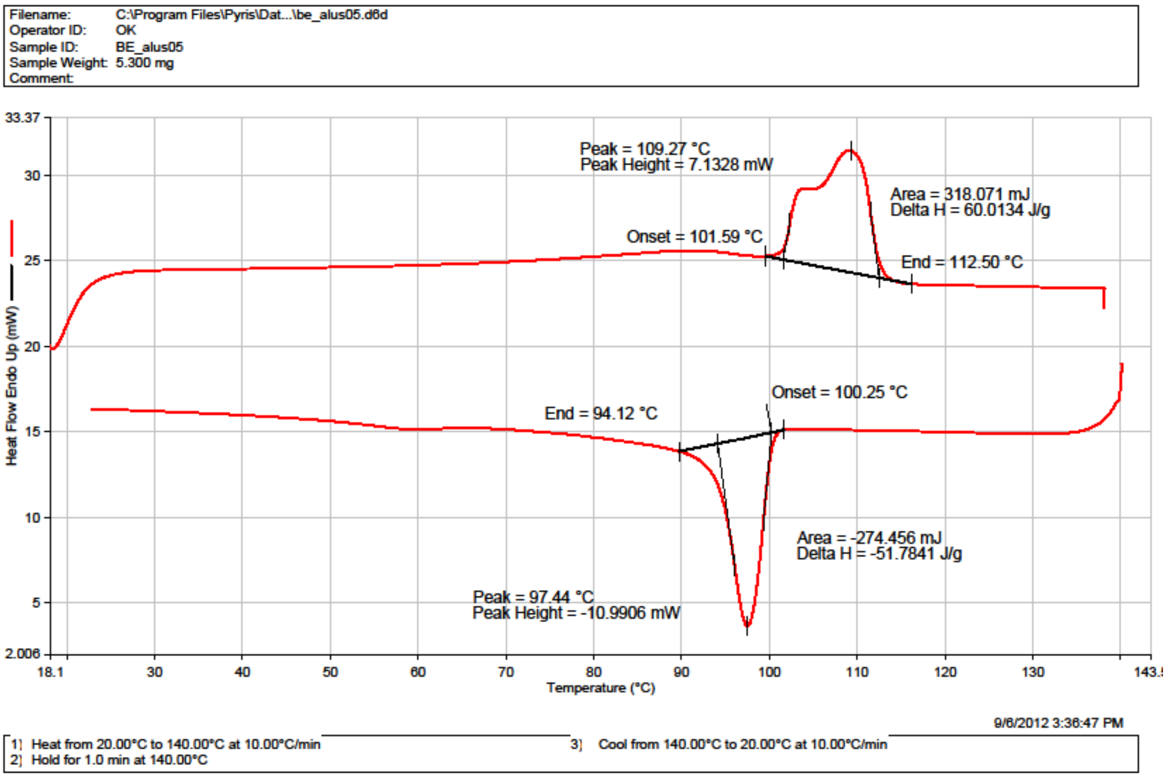


Fig. 5 Thermal Property Graphs of alus03 and alus04 samples obtained with DSC



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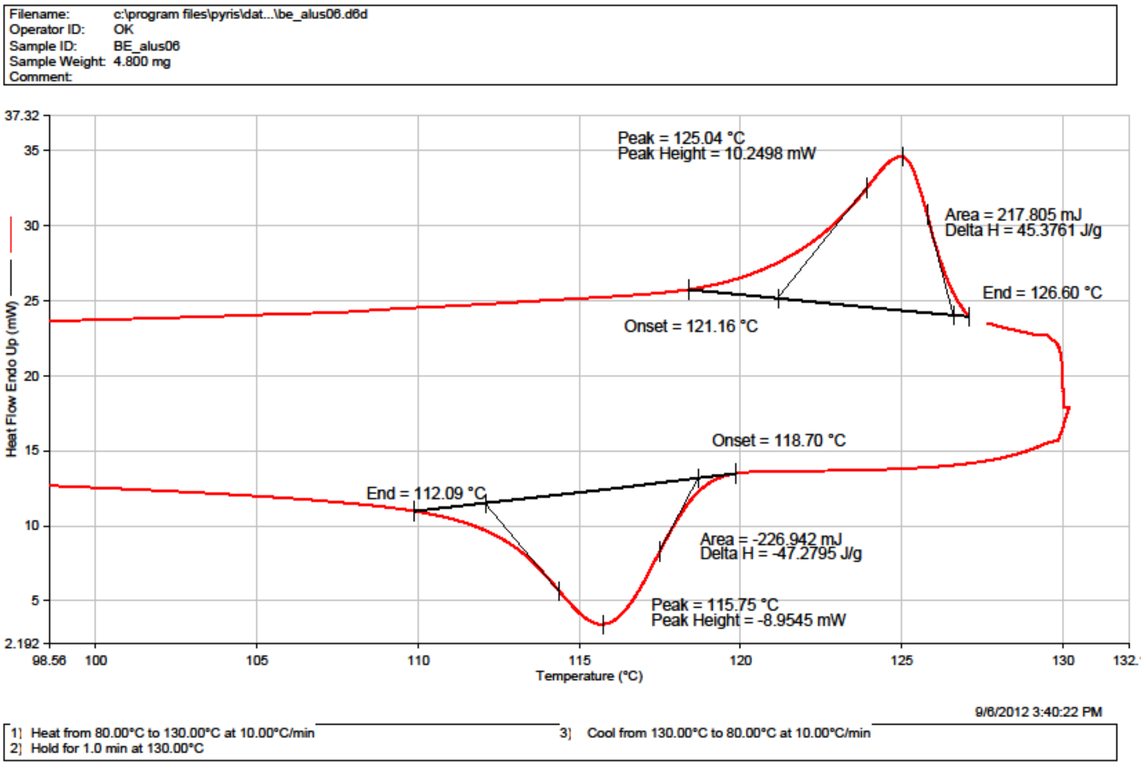
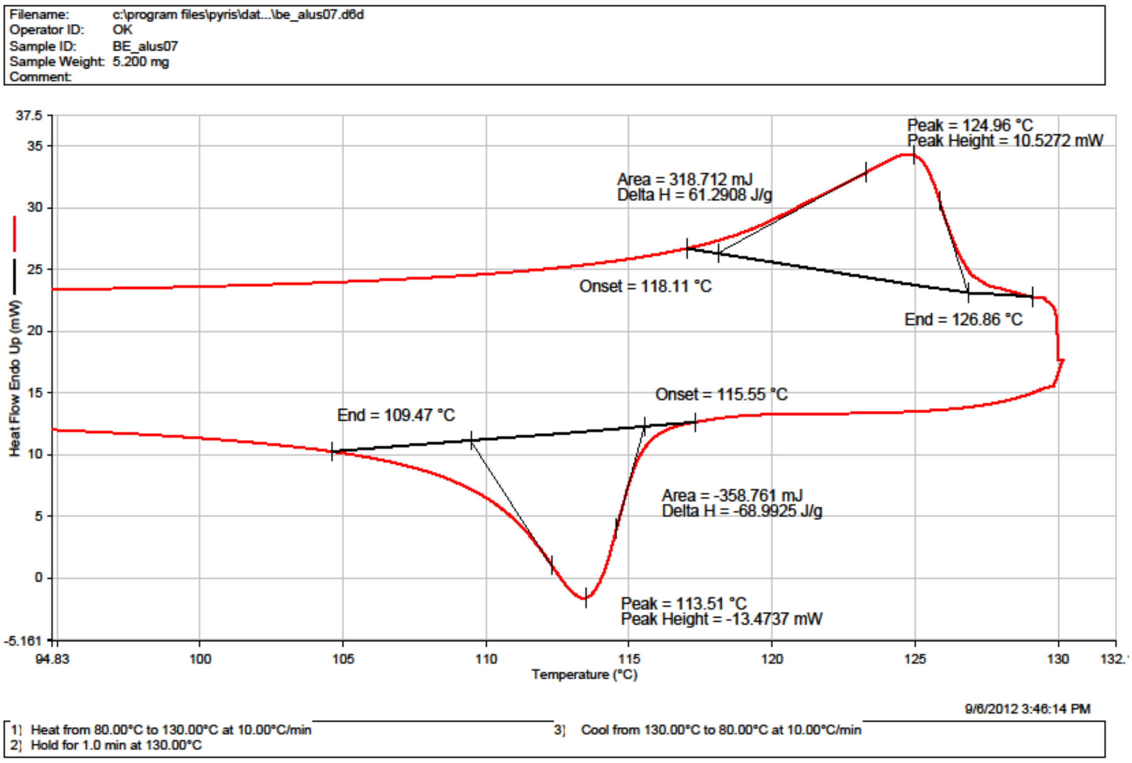


Fig. 6 Thermal Property Graphs of alus05 and alus06 samples obtained with DSC



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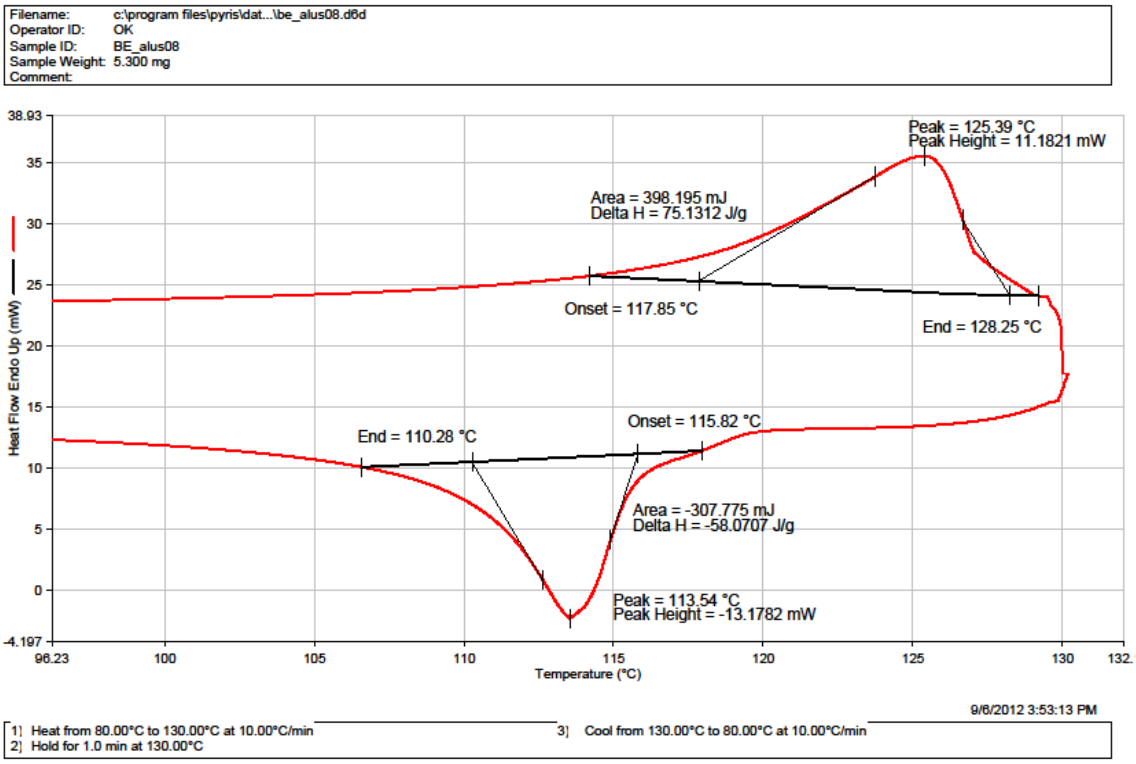
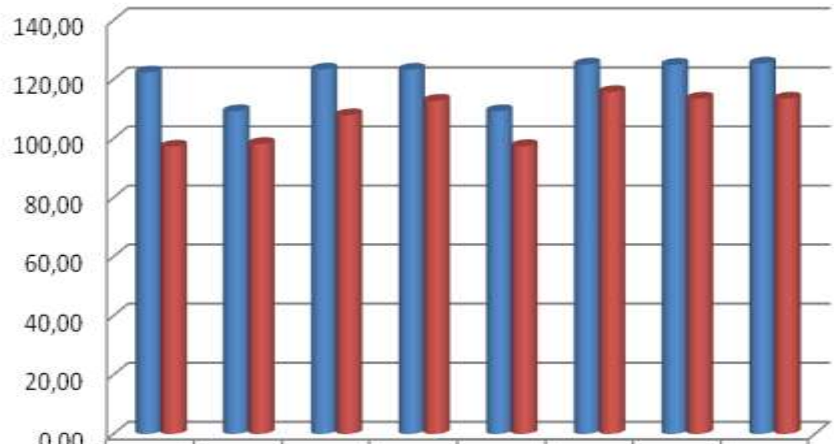


Fig. 7 Thermal Property Graphs of alus07 and alus08 samples obtained with DSC

Comparisons of melting and crystallization temperatures of test samples determined by DSC analysis are presented in Fig. 8.



	alus01	alus02	alus03	alus04	alus05	alus06	alus07	alus08
Melting Temperature (°C)	122,36	109,22	123,36	123,29	109,27	125,04	124,96	125,39
Crystallization Temperature(°C)	97,25	98,17	107,88	112,79	97,44	115,75	113,51	113,54

Fig. 8 Melting and Crystallization Comparison Graphs of Test Samples Obtained by DSC

Spot1, Max. and Min. color change temperature points representing temperature storage values of test samples on material surface are presented in Table 6.

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TABLE 6 COLOR CHANGE TEMPERATURES OF TEST SAMPLES

	Spot1 (℃)	**Max. (℃)**	**Min. (℃)**
alus01	26.3	27.5	24.9
alus02	25.6	26.5	24.7
alus03	26.4	30.3	24.5
alus04	26.1	28.6	24.3
alus05	26.5	29.1	24.1
alus06	26.5	27.6	24.2
alus07	25.5	27.0	24.0
alus08	26.3	31.1	24.3

Mean % weight change results in test samples that are kept at aerobic pool and field for 1000 hours are presented in Table 7.

TABLE 7 AEROBIC POOL AND FIELD TESTS % WEIGHT CHANGE MEAN RESULTS OF TEST SAMPLES

Test Samples	**% Weight Change (Wait for 1000 Hours)**	
	Aerobic Pool	**Field**
alus01	-0.00237%	-0.00097%
alus02	-0.00123%	-0.00137%
alus03	-0.00117%	-0.00283%
alus04	-0.00113%	-0.00107%
alus05	0%	0%
alus06	0%	0%
alus07	0%	0%
alus08	0%	0%

This study used two groups of raw materials which were low density polyethylene raw material group LDPE (G03-5 and F2-12) and biodegradable PHB raw material group BIOPLAST whose main component is cornstarch (Masterbatch: BOR-M-501F, BOR-M-502F, Resin: BOR-Z-503FM and BOR-Z-703J).

Four types of BIOPLAST raw materials at the ratios of 25%, 30%, 35% and 40% and 5% black masterbatch were mixed in LDPE G03-5 raw material separately in the form of granules. Film production could not be done in extrusion device using the obtained mixture. The reason is that melting temperatures, melt flow rate and density values of G03-5 and BIOPLAST raw materials did not match during extrusion process. Fish eyes, non-melting grains, ballooning instability and blocking were observed during processing in film layers. Therefore, film extrusion failed.

In LDPE-F212/BIOPLAST mixtures in granular form, the mixture with masterbatch bioplastic contents up to 25% by weight and the mixtures with resin bioplastic contents up to 30% by weight can be successfully processed with blow-up film extrusion method.

Of the obtained mixtures, mixtures ratios of the samples successfully processed in film blowing extruder device and sample codes are:

- alus01= 70% F2-12 + 25% BOR-M-501F + 5% Black Masterbatch,
- alus02= 70% F2-12 + 25% BOR-M-502F + 5% Black Masterbatch,
- alus03= 65% F2-12 + 30% BOR-Z-503FM + 5% Black Masterbatch and
- alus04= 65% F2-12 + 30% BOR-Z-703J + 5% Black Masterbatch mixtures, respectively.

Where, alus05 and alus06 film layers were produced from pure LDPE G03-5 and LDPE F2-12 with no BIOPLAST content to compare bioplastic mixture products in test and analyses. In addition, samples of flat drip irrigation pipe materials from 2 commercially available firms were used in the study under alus07 and alus08 codes for comparison.

At the stage of film production using extrusion machine, screw extruder L/D ratio was kept at 28:1 and blow up ratio was kept at minimum 1:3 to achieve maximum production yield and optimum film quality. Regional processing temperatures of the machine were 165 ℃, 170 ℃, 175 ℃ and 180 ℃, respectively.

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Mean pipe wall thickness of the bioplastic mixture samples successfully produced were alus01= 0.09 mm, alus02=0.07 mm, alus03=0.14 mm and alus04=0.41 mm. This indicates that resin mixtures with BOR-Z-503FM and BOR-Z-703J can reach higher pipe wall thickness. Wall thickness of the commercially available flat drip irrigation pipes were 0.17 mm for both alus07 and alus08. These values and the one published in technical catalogue (wall thickness=0.15 mm) of the firms specified by [10] did not match.

Mean densities of the bioplastic mixture samples were alus01=0.969 g/cm3, alus02=0.987 g/cm3, alus03=0.967 g/cm3 and alus04=0.914 g/cm3. Comparison of these values with the mean density of LDPE raw material of 0.921 g/cm3 [6], mean density value of BIOPLAST masterbatch raw materials of 1.10 g/cm3 and mean density values of BIOPLAST resin raw materials of 1.04 g/cm3 [9] revealed that the densities of alus01, alus02 and alus03 samples increased compared to those of LDPE, which is due to the bioplastic raw material ratio.

Among bioplastic mixture samples, the hardness of alus01 was observed to have the highest value with 30 shore D. It was observed that bioplastic masterbatch additive increased the hardness of the mixture more than the bioplastic resin additive did.

Stress test results performed on the samples showed that the stress at peak of the samples with BIOPLAST additive (alus01=12.63 MPa, alus02=10.55 MPa, alus03=9.60 MPa and alus04=8.46 MPa) reduced by half compared to that of the samples produced from LDPE with no additives. It was observed that bioplastic additives had a negative impact on the stress at peak.

Among bioplastic samples, % strain amount of only alus03 was obtained as 443.54 and reached the value of commercially available flat drip irrigation pipes (alus07=462.78 and alus08=497.92).

Young’s modulus values of the samples with BIOPLAST additives were lower than those of the AYPE with no additives and those of commercially available flat drip irrigation pipes. Bioplastic additives decreased Young’s modulus.

According to DSC analyses of the samples with BIOPLAST additives, alus03 sample had the highest melting peak point temperature (123.36 ℃). It is consistent with the melting temperature limits of polyethylenes, which are 105 ℃ and 130 ℃ [11]. In addition, it is highly consistent with those of alus07 (124.96 ℃) and alus08 (125.39 ℃) which are the materials of commercially available flat drip irrigation pipes. On the other hand, crystallization peak point was 107.88 ℃ for alus03, which is similar to the values of alus07 (113.51 ℃) and alus08 (113.54 ℃).

Temperature storage abilities of material surface of the samples were determined. These values were comparable. Effect of bioplastic additives was almost negligible on temperature storage abilities. The value of 26.4 ℃ for alus03 sample was similar to those of alus07 (25.5 ℃) and alus08 (26.3 ℃).

Of the samples, kept in aerobic pool for 100 hours to measure biodegradability properties, weight loss measured in alus01 and alus02 with bioplastic additives were 0.00237% and 0.00123%, respectively. The alus03 with bioplastic additives had a weight loss of 0.00117% while alus04 had a weight loss of 0.00113%. Furthermore, no color or softness change was observed in the samples. However, it was observed that when compared to bioplastic masterbatches, bioplastic resins can remain without degrading for longer periods. Theoretically, no biodegradation is expected in other samples produced from LDPE. This was shown in test results.

The 1000-hour waiting test on soil surface, which is the field of use of flat drip irrigation pipes, revealed no weight loss in all samples with bioplastic additives. No degradation was observed in the samples during losses. These weight losses were alus01=0.00097%, alus02=0.00137%, alus03=0.00283% and alus04=0.00107%. The highest percentage weight loss was seen in mixture code alus03. No loss occurred in samples produced from LDPE.

IV. CONCLUSION

Test and experimental results performed on the samples were analyzed using “LSMeans Differences Tukey” statistical analysis method conducted by using JMP7 Program. The relationships between the samples were determined and the samples were grouped. Comparison of the samples with BIOPLAST additives showed that the best results were obtained from samples alus03 and alus04 with resin additives. Comparison of all samples revealed that alus03 sample with bioplastic resin additive reached the properties of alus07 and alus08 which are commercially available flat drip irrigation pipes.

Based on the tests, analyses and statistical interpretations, it was showed that alus03 is the best bioplastic mixture; it contains 65% F2-12, 30% BOR-Z-503FM and 5% Black Masterbatch raw materials. Therefore, the sample alus03 can be considered as an alternative raw material in the production of flat drip irrigation pipes, and the preliminary data required to start a prototype flat drip irrigation pipe using alus03 raw material was obtained in this study.

In addition, products (alus01, alus02, alus03 and alus04) with bioplastic additives, can be used as alternative material in agriculture and industrial application sectors. They can be used to produce mulch films and seedling bags in agriculture, and further to that, they can be used as packages, bags and litter bags.

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