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Thermogravimetric Analysis of Biocomposites Based on Yucca gloriosa Modified with Organic Compounds

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ABSTRACT

In recent years, much attention has been paid to the efficient use of renewable plant materials in industrial and chemical technologies. At the present stage, the use of agricultural and household waste to obtain expensive industrial products is one of the pressing issues of the consumer market. Like other developing countries, Georgia has the opportunity to use local natural raw materials and commercially unsuitable polymer waste to produce various products with different performance properties. The article reviews thermosgravimetric studies of biomaterials modified with organic silicon and polymer compounds from plant fiber ("Yucca gloriosa"). Several studies of thermal decomposition properties of various biopolymer composites reinforced with natural fibers were conducted. Thermogravimetric analysis (TGA) showed the effect of organic compounds on the thermal stability of the composite material. The modification improved the physical and mechanical properties of the samples.

KEYWORDS: Environmental Protection, Renewable Raw Materials, Recycled Polymers, Biocomposite, Thermogravimetric Analysis

INTRODUCTION

Plant raw materials (biopolymer derivatives) are an inexhaustible renewable resource. Derivatives of sulfur, silicon, nitrogen and other carbohydrates with unique properties (bioavailability and membrane permeability) are widely used in pharmaceutical and food technologies, as well as in medicine. The most common polysaccharide in the plant kingdom is cellulose, which is part of the intercellular matrix of higher plants and serves as a structural material. Provides high mechanical strength and elasticity of plant tissues. The β-configuration of the anomeric carbon of cellulose determines the linear structure of the cellulose macromolecule, which in turn leads to the formation of hydrogen bonds both within the chain and between adjacent chains. This structure of the polymer chain provides high mechanical strength, insolubility in water and chemical inertness, which makes cellulose the best material for building plant cell walls [1-7]. Therefore, it is important to use environmentally friendly and renewable cellulose-containing biomass for the production of composite materials in the industrial sector [8]. The aim of the study is to develop innovative technologies for the production of biocomposite materials from the point of view of environmental safety. The research group obtained a biocomposite material with commercial properties, safe for health (without formaldehyde) using a simple and inexpensive technology (hot pressing method), in which phenolic resins were replaced by a non-toxic polymer material - secondary isotactic polypropylene and high-strength fibers of "Yucca gloria" [9-10]. Thermogravimetric analysis (TGA) methods are used to study polymeric materials and composites. TGA measurements provide valuable information that can be used to select materials for specific end-uses, predict product performance, and improve product quality.

TGA measures the amount and rate (speed) of change of mass of a sample as a function of temperature. The measurements are used to determine the thermal and/or oxidative stability of materials, as well as their composite properties [11]. Knowing the stability temperatures of compounds based on their weight, changes in the temperature dependence is another factor to consider regarding the effectiveness of chemical treatments for the purpose of synergizing the chemical bonding between the natural fiber with polymer matrix or with the synthetic fibers [12].

METHODOLOGY

FTIR spectrometric research was carried out on a SHIMADZU “IRSPIRIT” device. Wavelength 4000-600 cm^{-1}, mode - UATR; The microstructure of the biocomposite was studied using an optical trinocular microscope with a Euromex ME 2665 digital camera.

Thermogravimetric analysis of the developed composite materials was carried out on the TG209F3 "Tarsus" installation under atmospheric air conditions, the temperature rise range was 10 degrees/minute, corundum - α-Al203 was used as a thermally inert substance. Thermal analysis was carried test used to evaluate chemical, physical, and structural changes in a material due to a temperature change.

The physical and mechanical characteristics of the biocomposite developed by the hot pressing method, modified with 40, 60 and 80% polypropylene and treated with tetraethoxysilane from "Yucca gloriosa", were studied. To study the physical and mechanical characteristics of the developed samples,

standard pressure forms of water absorption were used; Heat resistance, dependence of softening on T0 were determined according to "Vika"; The ultimate strength in bending and longitudinal bending, as well as impact toughness were studied.

RESULTS AND DISCUSSION

The resulting samples (Tab. 1.) are characterized by lightness (in the range from 991 to 1178), high compressive strength (41.2-76.6 MPa) and relatively high impact strength (7-12.5 kJ/m^2). It should be noted here that the impact strength of the resulting composites with mineral fillers based on isotactic polypropylene does not exceed 7.0 kJ/m^2, which confirms that in our case yucca fibers are a reinforcing element. With high filling, the water absorption of materials is 2-5%. Modification of these materials with 5% tetraethoxysilane liquid reduced the rate of water absorption by 1.5-2 times, and the strength properties improved by 10-15%.

Table 1.

№	Composite	Relative density, kg/m^3	Compression strength, Mpa	Impact viscosity, kJ/m^2	Water absorption, %
Samples	PP + YGF 40 wt %	991	66,0	8,8	0,1
2	PP + YGF 60 wt.%	1090	53,5	9,5	2,0
3	PP + YGF 80 wt.%	1175	41,2	7,7	6,5
4	PP + YGF 40 wt.% modified with TEOS 5 wt.%	1010	76,6	12,0	0,1
5	PP + YGF 60 wt.% modified with TEOS 5 wt.%	1054	56,3	12,5	1,2
6	PP + YGF 80 wt.% modified with TEOS 5 wt.%	1170	45,4	8,9	5,1

Table 1. Physical and mechanical properties of the samples PP + YGF 40, 60, 80 wt.% and PP + YGF 40, 60, 80 wt.% modified with TEOS 5 wt.%.

Chemical composition of bioorganic composite materials studied by FTIR spectroscopy (sample 6.). In the FTIR spectrum (cm-1, γ, m.n.), in the 80% modified sample (PP + YGF 80 wt.%) modified with TEOS 5 wt.%, a characteristic absorption band of the OH group can be observed in the region of 3000–3500 cm^{-1}; The absorption band in the region of 2839, 2874 cm^{-1} is characteristic of the valence bond of the –CH_2– group (standing at the C_6 carbon atom); The absorption bond at 2948 cm^{-1} is characteristic of the vinyl group (-CH=CH_2); 1373 cm^{-1} (a mixture of aromatic glasses); 1454 cm^{-1} (-CH_2-propylene); 1620-1680 cm^{-1} (C=C); Due to the substitution of the aromatic group, an overlap has occurred, so the absorption band of the (C=O) group is not visible; 2339 and 2362 cm^{-1} regions show

impurities of aromatic and aliphatic nitriles; In the region of 1161 cm^{-1} a characteristic absorption bond of the (Si – O) bond is observed; 900-1034 cm^{-1} (C-O-C); 700-600 cm^{-1} (Si-C).

Figure 1.

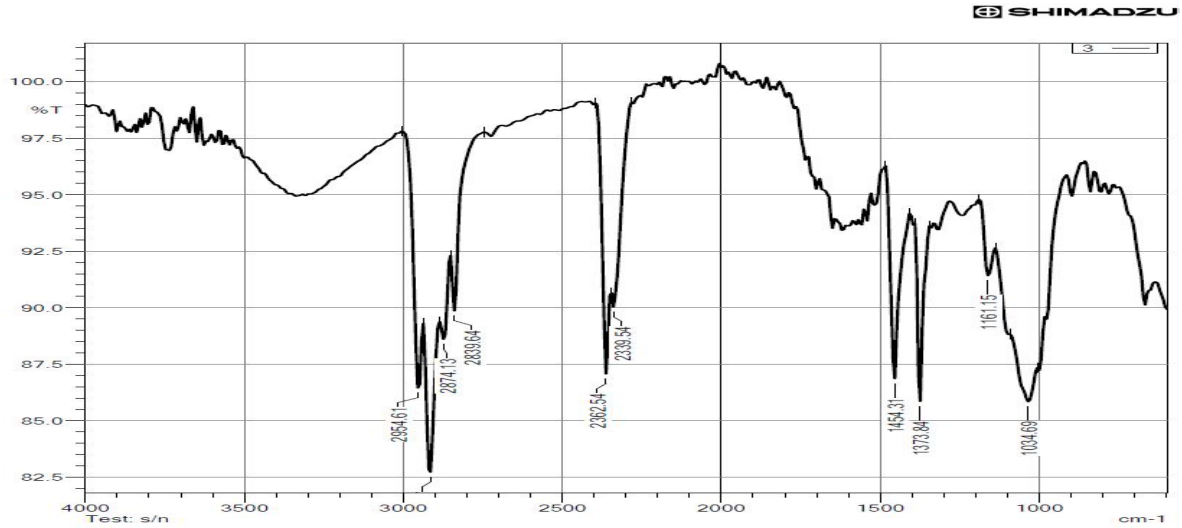


Fig. 1. Sample 6. FTIR spectrum of PP + YGF 80 wt.% modified with TEOS 5 wt.%

Thermal destruction of samples (4.5.6) prepared on the basis of "Yucca slavnaya" was studied by thermogravimetric analysis, which was observed using TG, DTA, DTG curves (Fig. 2-4). For thermogravimetric analysis, the samples were heated from room temperature to 250°C-500°C. The temperature was selected based on the chemical structure of the biopolymer containing "Yucca slavnaya". Since the material is of organic origin, the mass loss of each of them at 500 degrees was approximately >90%.

In the cases of samples 4.5 and 6, the materials exhibit thermal stability up to 250 degrees. Observation of the TG curve clearly shows that the main mass loss occurs between 250 and 350 degrees, which reflects the thermal-oxidative destruction of the material. This point of view is confirmed by the DTA curve, which records the exothermic effect (265, 321 degrees). Meanwhile, the peak of the DTG curve (314 degrees) clearly shows the temperature at which the reaction rate of thermal-oxidative destruction was maximum. In the temperature range from 250 to 425 degrees Celsius, the initial mass loss of sample 6 was approximately 84%. The cases of Sample 4 and Sample 5 were approximately similar to each other, which is explained by the similarity of their composition.

Conditionally by zones: zone I - 25-2500, zone II - 250-3500 and zone III - 350-5000, it can be said that in the second zone the main loss of mass occurs, which on average is 50-65%, at 500 degrees for each of them (example 4.5).) Losses (except for sample 6) amounted to about 95% (table 2.). Example 6 was different: mass loss was 10% up to 250 degrees, which may be due to the removal of volatile substances or moisture. At the same time, the main mass loss is in the range of 250-350 degrees, which is about 41%. In the case of samples 4.5 it is interesting to note that the min. mass loss of samples 4.5 Peak (sample 5. -437.5; and sample 4. -443.3 degrees) is almost the same, the exception is the rapid decrease in mass of sample 6, which is recorded as an exothermic effect, a technical defect is excluded,

most likely, there is some critical temperature at which rapid oxidation of any filler or binder contained in it occurs, or some mass loss event occurs.

Figure 2.

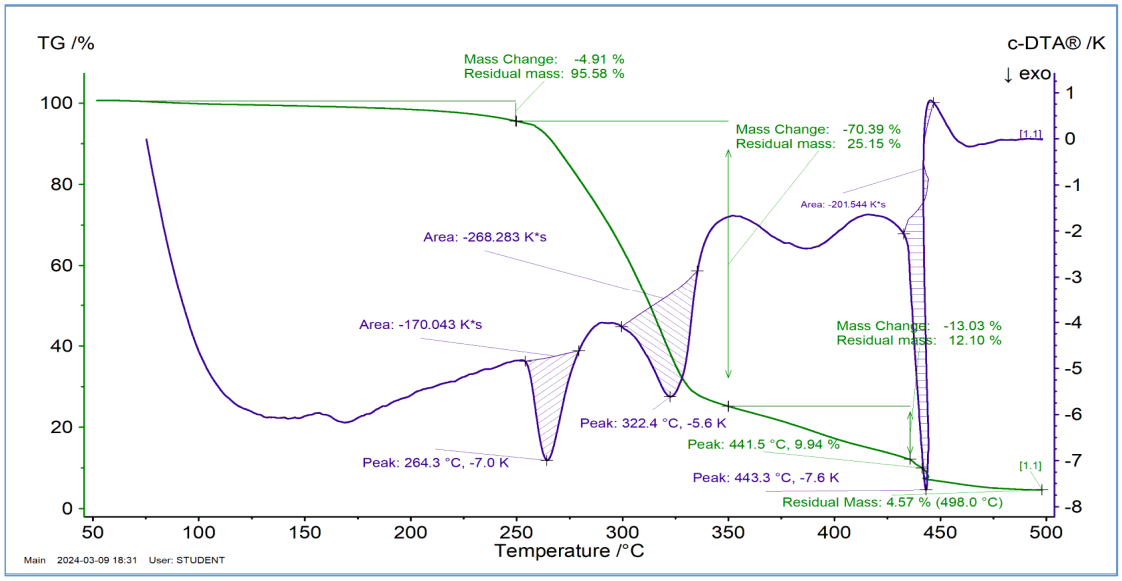
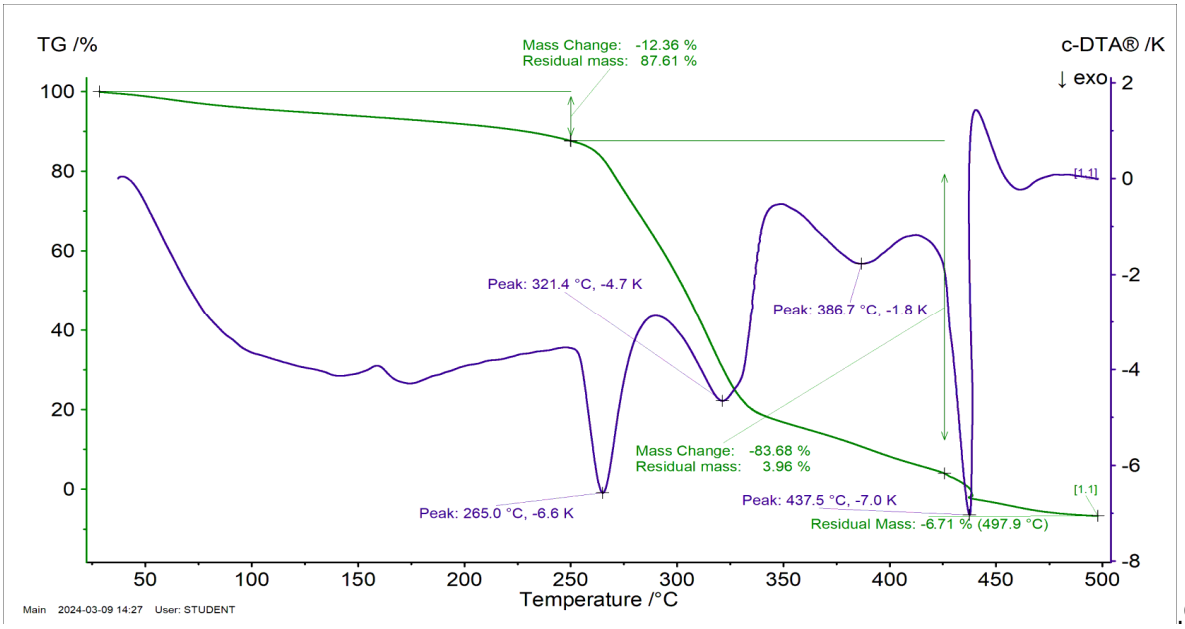


Fig. 2. Sample 4. PP + YGF 40 wt.% modified with TEOS 5 wt.%

Figure 3.

Fig. 3. Sample 5. PP + YGF 60 wt



.%

modified with TEOS 5 wt.%

Figure 4.

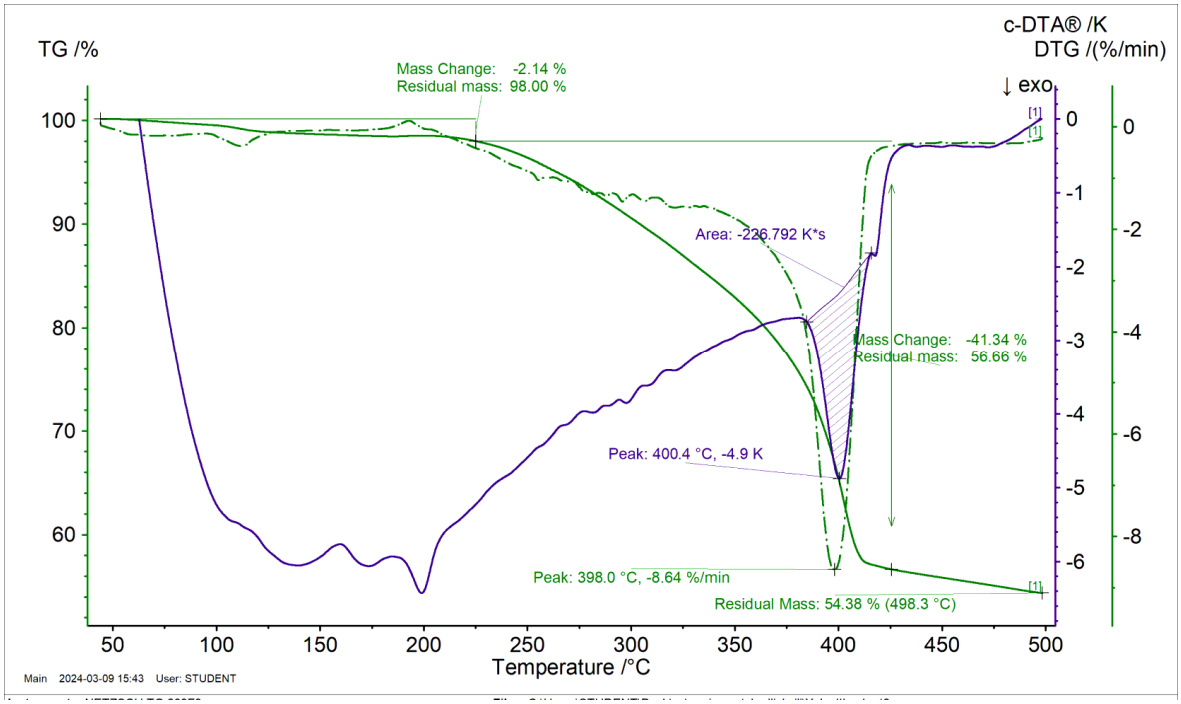


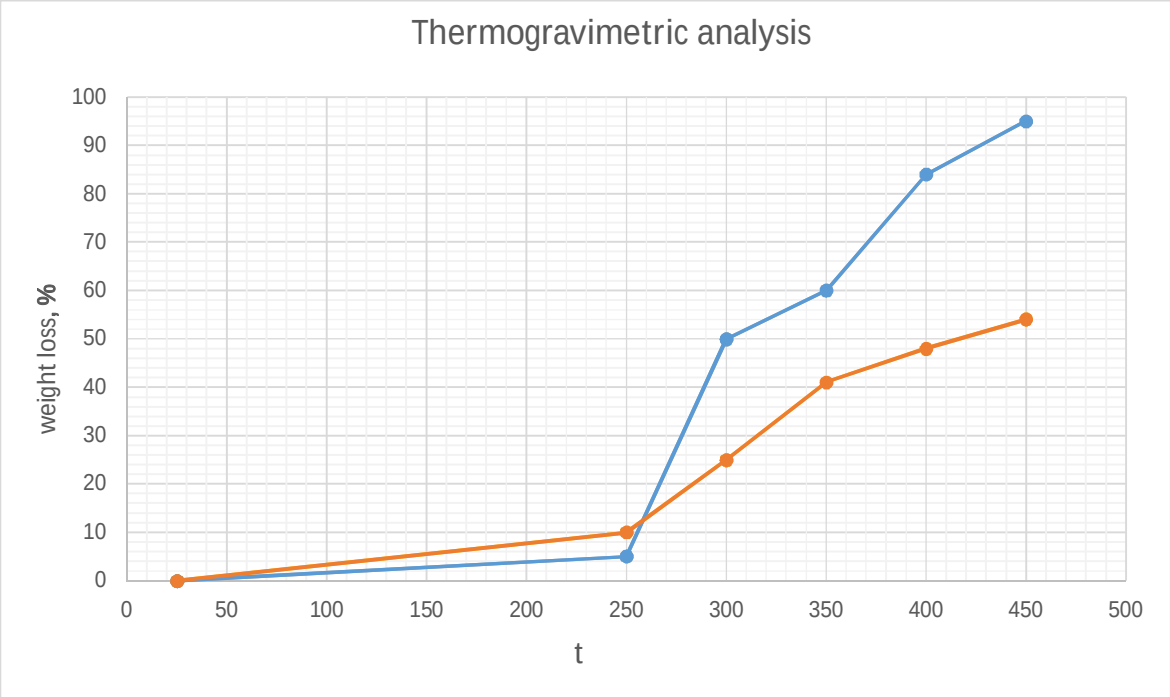
Fig. 4. Sample 6. PP + YGF 80 wt.% modified with TEOS 5 wt.%

Table 2.

Samples	Thermogravimetric analysis %							
	I zone		II zone		III zone			IV zone
	25-250⁰C	250-270⁰C	250-350⁰C		400-498⁰C			
	TG	DTA	TG	DTA	TG	DTA	DTG	DTA
sample 4. PP+YGF 40 wt.% **modified with** TEOS 5 wt.%	**Mass Change** -4.91% **Residual Mass** 95.58%	**Peak** 264.3⁰C **Area** -170.043k*s	**Mass Change** -70.39 % **Residual Mass** 25.15%	**Peak** 322.4⁰C **Area** -268.283 k*s	**Residual Mass** -4.57% (498.0⁰C)	**Peak** 443.3⁰C, -7.6k **Area** -201.544 k*s		**Peak** 386.7⁰ C, -1.8K
sample 5. PP + YGF 60 wt.% **modified with** TEOS 5 wt.%	**Mass Change** -12.36% **Residual Mass** 87.6%	**Peak** 265.0⁰C, -6.6K	**Mass Change** -83.68% **Residual Mass** 3.96%	**Peak** 321.4⁰C, -4.7K	**Residual Mass** -6.71% (497.9⁰C)	**Peak** 386.7⁰C, -1.8K		**Peak** 437.5⁰ C -7.0K
sample 6. PP + YGF 80 wt.% **modified with** TEOS 5 wt.%	**Mass Change** -2.14% **Residual Mass** 98.00%		**Mass Change** -41.34% **Residual Mass** 56.66%		**Residual Mass** 54.38% (498.3⁰C)	**Peak** 400.4⁰C, -4.9K **Area** -226.792 k*s	**Peak** 386.7⁰C -1.8K	

Table 2. of the samples 4,5,6 (PP + YGF 40, 60, 80 wt.% modified with TEOS 5 wt.%)
Mass loss depending on temperature

Scheme 1.



Scheme 1. Of the samples 4,5,6 (PP + YGF 40, 60, 80 wt.% modified with TEOS 5 wt.%) Graphical analysis

CONCLUSION

The article discusses the technologies for processing renewable plant raw materials and secondary polymer products in order to obtain thermoplastic and thermosetting samples manufactured using new, simple and inexpensive technologies - for use in industrial production (construction, furniture, home design). New bio composite materials free from formaldehyde have been obtained - based on renewable plant raw materials and recycled polymers - with improved physical and mechanical properties, high environmental friendliness and simple production technology, meeting modern and international requirements for similar materials. The modification of organic compounds improved the physical and mechanical characteristics of the developed biomaterial. The polymer matrix decomposes in between the range of 300 and 500 °C. Either for structural or non-structural applications, other potential strategies for the thermal stability improvement for composite structures with chemically treated natural fiber-reinforced polymer composites are hybridizing with synthetic fibers. Thermogravimetric analysis (TGA) revealed the influence of chemical compounds on the thermal stability of bioorganic composite materials.

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