Characterization of sorghum biomass as a filler for polymer composites

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Introduction

The subject of the research was to identify the possibility of using sorghum biomass as a filler for polymer composites. The material was obtained from Polish crops. Initial preparation consisted of separating individual morphological parts of plants (stems, leaves and grains), than drying, grinding and fractional division. A dimensional analysis using a microscope was performed for the material. For use in the composite materials fraction <0.25 mm was selected. In order to select appropriate polymer matrices, the composition of the raw material was tested, including the content of lignin, cellulose and hemicellulose and functional groups by Fourier Transform Infrared Spectroscopy (FTIR). Resistance to thermal degradation and the processing potential were tested using thermogravimetry (TGA). Based on these results, an initial selection of matrices was made.

Materials

Sorghum

Stems

Leaves

Grains

Testing methods

- The content of main compounds of Sorgo such as cellulose, lignin and extractives (ethanol, 1% NaOH) were performed with using: Seifert's method (cellulose); Klason method (lignin insoluble in 72% sulphuric acid - Tappi method (T 222)); content of extractives soluble in ethanol (T 204); content of substances soluble in 1% NaOH (hemicelluloses) (T 212)

- The thermal properties of the materials were determined by thermogravimetry (TGA) in nitrogen and air atmospheres, in the temperature range from 30 to 900°C and a heating rate of 10°C/min (Netzsch TG 209 F1 apparatus). Samples of 10 mg were tested in ceramic vessels. The following values were determined: temperature at which mass loss was 5% and 10% (T5%, T10%), residual mass at 900°C (W%) and maximum thermal degradation temperatures from derived thermogravimetric graphs (DTG).
- Fourier transform infrared spectroscopy (FTIR) was carried out using the Jasco FT/IR-4600 apparatus in attenuated total reflectance (ATR) mode with 64 scans at a resolution of 4 cm^{-1} in the wavenumber range of 4000 - 400 cm^{-1}.

Acknowledgement

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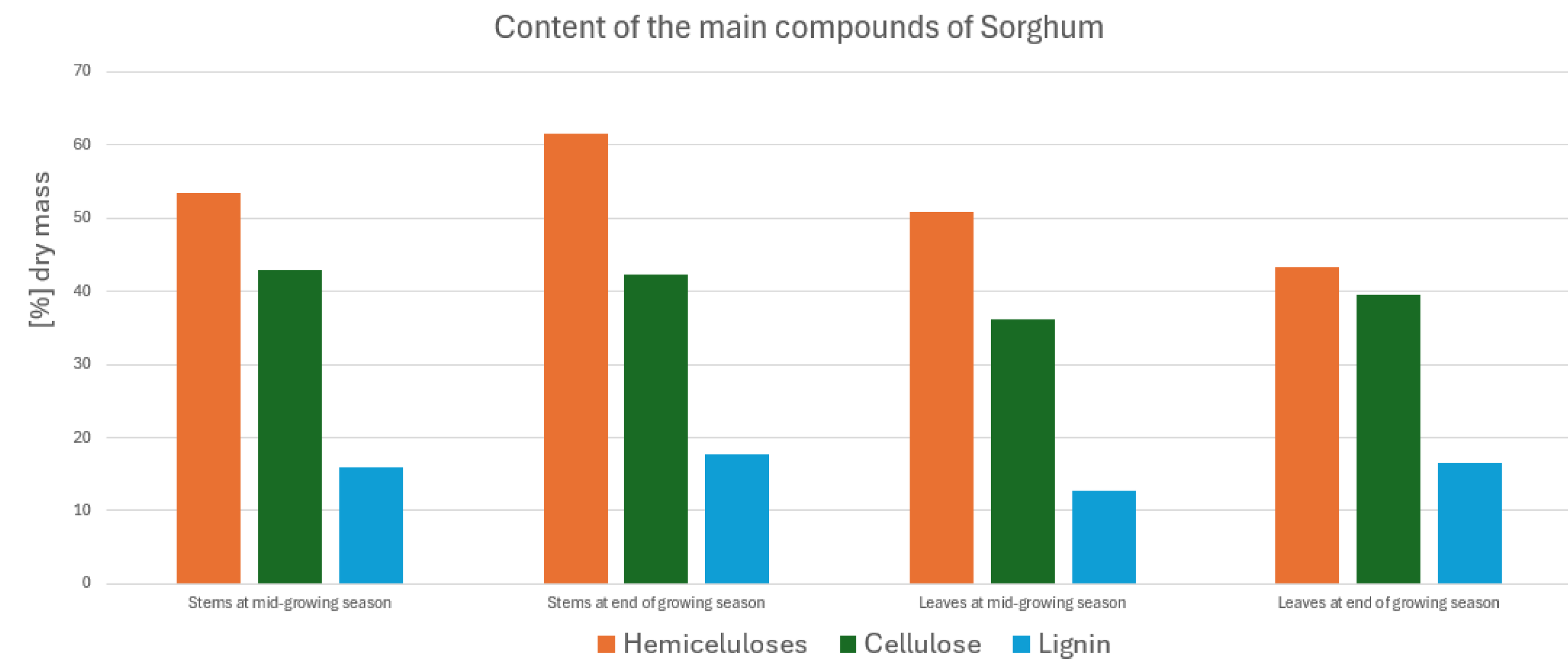
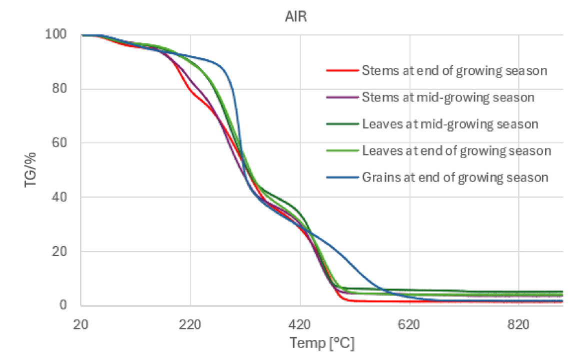
DOKTORAT WDROŻENIOWY

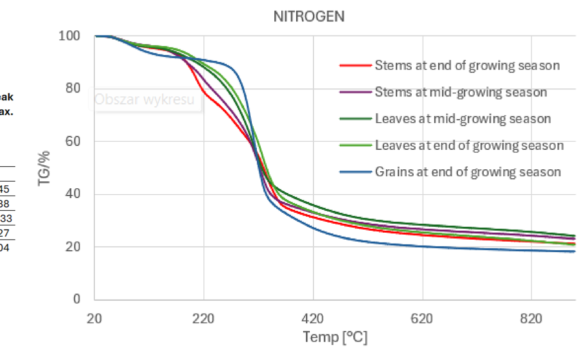
Test results



In sorghum stems there is a higher content of hemicelluloses, which additionally increases with the maturation of the plant, in the case of leaves the content decreases towards the end of the vegetation period. In leaves, with the progress of vegetation, the amount of cellulose increases, which in stems remains at the same level. The content of lignin in both types of material increases with the progress of vegetation.



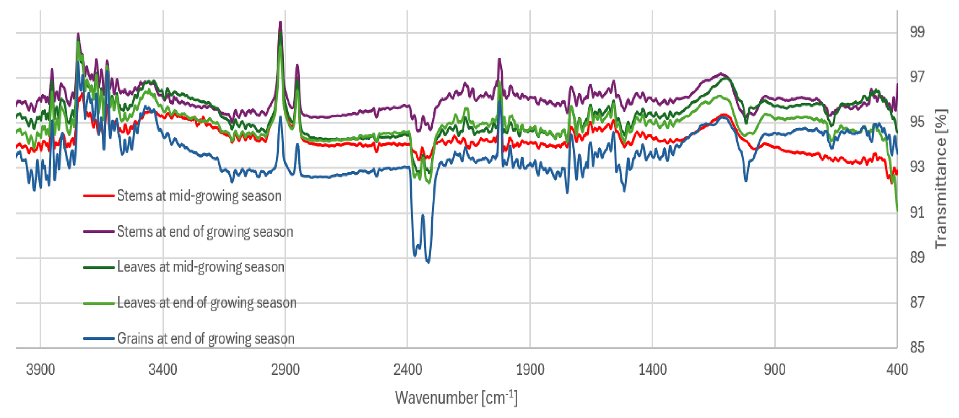
Name	T10% (°C)	Residual Mass (%)	DTG Peak (°C)/ max. rate (%/min)	T10% (°C)	Residual Mass (%)	DTG Peak (°C)/ max. rate (%/min)
	nitrogen			air		
Leaves at mid-growing season	205,489	24,3483	313,9/6,1	220,649	5,36606	293,0/5,45
Stems at mid-growing season	187,989	22,9904	217,2/2,58	190,649	3,72394	288,8/4,88
Grains at end of growing season	240,989	18,3347	312,5/11,51	258,649	1,65385	310,4/16,33
Leaves at end of growing season	214,489	21,0397	326,9/6,48	218,649	4,12104	248,1/2,27
Stems at end of growing season	188,489	21,4091	332,4/5,28	188,149	1,46699	328,2/4,04



Both in air and nitrogen, the material from the stems decomposes faster than the material from the leaves, in both cases the leaves decompose slower at the end of the growing season and the stems at mid-growing season. Cellulose decomposes in the range of 300-400°C.

Hemicellulose decomposes in the range of 220-315°C. Lignin decomposes in the range of 150-900°C. These ranges are reflected in the above graphs, the material from the stems contains the most hemicelluloses and cellulose, therefore the decomposition is more rapid in the temperature range up to 400°C. Above this limit, the course of decomposition of the materials from leaves and stems is similar, the decomposition of lignin is visible, which in the air atmosphere occurs much more rapidly in the first phase than in the nitrogen atmosphere.

In the case of material from grains, the decomposition is slower due to the content of fatty acids. At 300°C, their rapid decomposition occurs, after this phase we observe a mild decomposition of cellulose and lignin.



FTIR studies with the assumed parameters did not show significant differences between the spectra obtained for materials from stems and leaves. However, differences were visible for the grains sample, which occurred in the ranges: 1670-1710 cm^{-1} (C=O stretching), 2850-2930 cm^{-1} (C-H stretching), about 1110 cm^{-1} (C-O stretching), about 900 cm^{-1} (C=C vibrations) and 2500-3300 cm^{-1} (OH stretching) and confirmed the content of fatty acids.

Results and Conclusion

Analysis of the thermal decomposition of sorghum materials for plastics processing at higher temperatures clearly indicates the use of sorghum leaf material as an additive, which will have a lower tendency to degrade. However, the stem material can still be used at lower processing temperatures. At the highest processing temperatures, the grain material will work best as a filler. In terms of the chemical composition of the samples, the stem material will work well when combined with polar matrices such as thermoplastic starch or polylactic acid (PLA), while the leaf material will be best for strongly hydrophobic matrices such as polypropylene. The grain material will be suitable for matrices of different polarity due to its fatty acid content.

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