Wood polymer composites (WPC) surround us in many products, mainly for construction usage, like decking boards. The introduction of wood-originated fillers into a polymer matrix decreases the environmental impact, reduces the cost of the final products compared to counterparts made of pure polymer and extends lifetime compared to natural wood. The growing awareness about climate change and changes in legislation encourage society to choose products made from more sustainable materials. In the polymer industry, the common practice to achieve this is replacing goods prepared with petrochemical compounds from renewable resources, such as adding natural plant-based fillers. To enhance even more the sustainability of wood polymer composites, virgin wood dust or fibers may be replaced by waste materials from the agri-food industry generated during the processing of plants, vegetables, and fruits, such as peels, pomace, and nonedible parts of plants. The proposed aim of this study focuses on the additional use of plant-based materials, which are rich in phytochemicals, revealing superior antioxidant activity. Introducing those fillers will act in the polymer as a stabilizing agent, allowing for the substitution of synthetic stabilizers, which may reveal potential negative environmental impact. Polyolefins are highly vulnerable to thermo-oxidative degradation. The melt processing and exposure to external factors, such as UV light radiation, can lead to the degradation of unstabilized polyethylene, the most often used polymer for the manufacturing of WPC. Unfortunately, using plant-based fillers is limited due to weak interactions between filler and the matrix, causing a reduction of mechanical performance and lifespan of WPC products compared to unmodified polymers. The reduced interaction at the phase boundaries is caused by the chemical composition of the polyethylene, a non-polar material, and polar natural filler in this project. To improve interactions between the matrix and fillers, the polarity of the natural fillers has to be decreased. Several chemical modification methods can achieve this; the chemical agents react with a natural filler to decrease their hydrophilic nature.

The unanalyzed scientific problem concerns how chemical treatment influences the antioxidant compounds found in plants with their possible extraction.

This project will focus on three different chemical treatments with various mechanisms to achieve increased hydrophobicity of biomass: alkaline treatment, silanization, and permanganate treatment. The main components of biomass, which are cellulose, hemicellulose, and lignin, are vulnerable to the above-mentioned chemical reagent, and performing chemical modifications of plant-based materials causes changes in the lignocellulosic structure. In addition, they react with the hydroxyl groups found in biomass constituents. The three mentioned chemical treatment methods convey a lot of possible threats to the overall antioxidant properties of plant-based fillers. Changes in lignocellulosic structure can lead to delignification (lignin removal) and, related to it, a decrease in antioxidant potential since lignin is an amorphous polymer with antioxidant properties. The high reactivity with the hydroxyl groups can also lead to undesirable interactions with antioxidant compounds, which have a great number of them and are strongly connected to their antioxidant activity. All of those modifications are performed in water or acetone, which are common solvents for the extraction of low-molecular compounds, so the extraction of antioxidant compounds may occur during modification.

This research will answer questions regarding the extraction of those compounds during chemical treatment and introduce the most efficient way to modify plant-based fillers to increase their interactions with the polymer matrix while maintaining antioxidant properties. The proposed research plan involves the modification of three biomass wastes: chestnut shell, wheat bran, and black tea after brewing. During the project, the biomass waste fillers will be thoroughly investigated regarding their antioxidant properties before and after treatment. The evaluation of prepared composites will allow us to assess the simultaneous investigation of the stabilization effect and to identify the interactions between the matrix and modified fillers. A key aspect of the project is the quantitative and qualitative characterization of the migration of phytochemicals, which contribute to enhanced stabilization, from waste biomass fillers into the polymer matrix.

The combination of achieved research results will allow the preparation of guidelines for modifying plant-based fillers to obtain a simultaneous component of self-stabilizing polymer composites with favorable mechanical properties.