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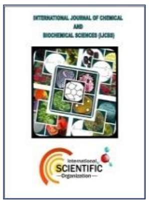

Sago Starch/Polypropylene Blends Reinforced with Compatibilizers: A Promising Strategy for Sustainable Materials with Improved Mechanical Properties

Atri Deo Tripathi[1], Arunkumar D T[2], Rakesh Ashokrao Bhongade[3]

[1]Department Of Chemistry, Teerthanker Mahaveer University, Moradabad, Uttar Pradesh, India, [2]Department of Mechanical Engineering, Faculty of Engineering and Technology, JAIN (Deemed-to-be University), Bangalore, India, and[3]Department of Ayurveda, Sanskriti University, Mathura, Uttar Pradesh, India

Abstract

The Three distinct Compatibilizers, KH-550, KH-570, and glycerine monostearate, were used to treat sago starch (SS). Using an extruder with two screws, blends of treated sago starch and polypropylene (PP) were created. In this work, the mechanical Properties (MP) and thermal characteristics of the polypropylene/sago starch (PP/SS) blends were examined along with the impacts of SS past as well as future treatments and the types and quantities of the Compatibilizers. We discovered that adding more of various types of Compatibilizers enhanced the blends' mechanical properties, and influence strength, including tensile strength (TS), and elongation at break. Among the various types of Compatibilizers, KH-570 had the most enhanced effects, and samples with only 1wt % loading of Compatibilizers showed the greatest improvement in the MP. The thermogravimetric analysis findings show that the inclusion of Compatibilizers did, to some degree, enhance the thermal stability of the PP/SS blends. The inclusion of Compatibilizers increased the sago starch's dispersion in the PP matrix and the sago starch's adherence to the PP matrix, according to scanning electron microscopy (SEM). Among the coupling agents, KH-570 not only had the finest enhanced effects but also continued to function as a plasticizer.

Keywords: Sago starch (SS), polypropylene (PP), thermal properties, biodegradability, mechanical properties (MP), and thermogravimetric analysis (TGA)

Full length article **Corresponding Author*, e-mail:atrideo@rediffmail.com

1. Introduction

Sago starch is a naturally occurring, renewable source of complex carbohydrates with special qualities that make it valuable in a range of applications. SS includes trace quantities of proteins, lipids, and ash, which are inorganic substances like minerals that occur naturally in plant matter. According to the kind of palm from which it is collected as well as the techniques used to extract and prepare the starch, SS might have a different precise composition. White, fine-grained SS is a thickening, stabilizer, and binding agent that is often used in the food industry. In addition, it is used in the production of paper, textiles, adhesives, and other industrial products [1]. Reinforced PP blends are materials that are made of a combination of PP and one or more reinforcing elements. The PP blend's mechanical qualities, such as strength, stiffness, and toughness, may be enhanced by adding the reinforcing elements. Glass fibers, carbon fibers, natural fibers, and mineral fillers like talc or calcium carbonate are some of the reinforcing components utilized in PP blends. To create the final product, the reinforcing elements are often added to the PP blend as fibers or pellets. The mixture is then processed using methods like extrusion, injection molding, or compression molding. In a variety of applications where high strength and durability are needed, including automobile components, packaging materials, home appliances, and construction materials, PP blends reinforced with different elements are frequently employed [2]. Materials made of a combination of SS/PP, and one or more Compatibilizers are known as SS/PP blends reinforced with Compatibilizers. The addition of the Compatibilizers helps the generally immiscible and prone to phase separation SS/PP follow one another better. Compatibilizers may be added to blends to enhance their mechanical qualities and make them more homogenous. SS/PP blends may have their MP significantly improved by the inclusion of Compatibilizers. An efficient method for enhancing the qualities of these materials and making them more appropriate for broader applicability across a range of industries is to use SS/PP blends reinforced with Compatibilizers. The MP of a film is significantly influenced by the processing technique and the length of fibers used in its composition. The MP of the finished items is impacted as a consequence [3].

The fundamental tenets of sustainable materials are to manufacture, utilize, and dispose of materials in a manner that limits their effects on the environment and human health over their entire life cycle. A sustainable future must include sustainable materials because they limit waste, save resources, and lessen the negative effects of human activities on the environment and human health. SS/PP blends with sustainable materials have the potential in reducing the environmental effect of these products and encourage a more sustainable future [4]. The application of natural fiber-reinforced PP is a potential approach for sustainable materials with enhanced MP. PP are synthetic materials produced from renewable resources including sugar, cellulose, or SS. To produce a composite material with superior MP, natural fibers like jute, hemp, or flax may be combined with the PP. These materials have several potential uses, such as packaging, construction materials, and components for automobiles. They may take the place of conventional materials like fiberglass and other petroleum-based polymers, which are bad for the environment. These materials have several potential uses, such as packaging, construction materials, and components for automobiles. The application of natural fiber reinforcements and biodegradable Compatibilizers for SS/PP blends is a viable method for creating sustainable materials with better MP [5]. SS/PP blends strengthened with Compatibilizers are a viable approach for creating sustainable materials with enhanced MP. The mixture may be made more sustainable by using natural or biodegradable fibers and utilizing recycled or biodegradable PP. The adhesion between the SS/PP may be improved by using Compatibilizers like maleic a hydride-grafted PP or epoxidized natural rubber. SS/PP blends reinforced with Compatibilizers are a viable method for creating environmentally friendly materials with enhanced mechanical capabilities, making them a desirable replacement for conventional materials with a negative environmental effect [6]. The study [7] examined the thermal aging that affects the mechanical and morphological characteristics of composites made of virgin PP and acrylonitrile butadiene rubber. The mechanical and morphological characteristics of old and unaged specimens were assessed using a scanning electron microscope and a universal testing machine. The review [8] discussed how biodegradable polymers perform, this increase in demand is related to the expanding environmental concerns about the widespread use of synthetic, non-biodegradable polymeric packaging, namely polyethylene (PE). The need for renewable and biodegradable materials for packaging applications has grown significantly. The study [9] examined the applicability of various degradation settings and describes the behavior of the SS-based film under various degradation conditions. Consumers and academics are attempting to produce biodegradable, secure, and sustainable food packaging materials since non-degradable plastic hurts the environment. The film made of SS is becoming a popular material for food packaging. The paper [10] investigated sago flour was utilized as the source for the 3D printing material and varied amounts of turmeric powder were added. The desire for individualized items has increased recently, and 3D printing is developing as a disruptive technology with the potential to transform the procedures involved in producing food. Given that the color of food products is a crucial factor in determining customer preferences, 4D printing's ability to change the color of 3D-printed objects in reaction to environmental factors is a subject of significant study interest. The study [11] investigated the impact of several plasticizer types. Using a twin-screw extruder, the LDPE was compounded with SS, and then injection molding was done. In contrast to currently available petroleum-based, non-renewable, or pricey polymeric materials, SS-based polymers provide a renewable, affordable alternative. The objective of this work is to create low-density PE degradable SS composites with improved MP. The research [12] evaluated the thermoplastic SS characteristics at different loadings. In the hot-pressing process, TPSS was created using agar in various ratios. Following that, the materials were characterized using SEM, mechanical analysis, differential scanning calorimetry, thermogravimetric analysis, Fourier transform infrared spectroscopy, and moisture absorption assessment. The research [13] determined that SS derived from botanical sources is used to create biodegradable polymers. Using glycerol as a plasticizer, a thermoplastic SS made from potato and cassava SS was successfully created. While employing a melt-mixing process and an injection molding machine to manufacture a PP matrix filled with SS and Compatibilizers, the Compatibilizers was utilized at a concentration of 10% depending on the SS content.

The study [14] examined to learn more about the mechanical and structural SS behaviors of the plasticized SS mix films. Incorporating glycerol or sorbitol at a 33% weight content, cassava and mung bean SS blend films' MP and SS behaviors were investigated. The MP and chemical profiles of the CSMB and MB films were comparatively comparable. The study [15] provided test specimens were created by hot-pressure molding PLA mixtures with varying amounts of wheat SS and MDI at 175°C after being hot-mixed at 180°C. The mixes' MP, fracture microstructure, and water absorption were all studied. TS of pure PLA was 62.7 MPa, while elongation was 6.5%. The mixture containing 45% wheat SS and 0.5 weight percent MDI produced the maximum TS of around 68 MPa with an elongation of about 5.1%. The lowest TS was found in the mix with 20% SS and 0.5wt % MDI, which was at 58 MPa with 5.6% elongation. The purpose of the research was to find a straightforward and efficient method for altering sago starch and to further illustrate the commercial potential of using inexpensive corn SS for the creation of bio-composites with improved MP. In addition to serving as a theoretical basis and practical guide, this would also be very advantageous in terms of applications and environmental preservation.

2. Experimental

2.1 *Materials*

Commercial PP had been drained out at 80 degrees Celsius for 8 hours before use. The area's low-cost corn starch (CST) was sourced, it had been dried by baking it in a vacuum oven at 80 degrees Celsius regards to 72 hours before usage. GMS were offered and “methacryloxy propyl trimethoxyl silane” was produced. An additional substance was purchased against retailers, and appropriate usage.

2.2 *Sample Preparation*

The following is the method used to hydrolyze KH-550. Alcohol and distilled water were used to create the solvent. The mixture contains 20 weight percent KH-550, 72 weight percent unchanging ethyl alcohol, and 8 weight percent purified water. In further specifics, 20 grams of KH-550 were first dispersed in 72 grams of 100% ethanol for 10 min while being stirred at room temperature. At a flow rate of .2 mL/minute, 8 g of purified water was subsequently added to the mixture before the process were complete, the resulting interaction, was the substance we employed in our tests. The KH570 weight percent represents the average KH-570 weight percentage.

Blending and Surface Modification: PP and CST were blended in a high-speed mixer at room temperature for 6 minutes at a rotary speed of 200 rpm. At loadings of 0.3, 0.5, 0.7, 1.0, 1.2, and 1.5wt%, six levels of each of the three kinds of Compatibilizers were utilized, along with a set quantity of CST. In further detail, a given quantity of PP was added to a rapid-fire mixer, along with a specific quantity of CST, which was sprayed into the mixer for 15 minutes while being rotated at an acceleration of 60 rpm, and a specific quantity of the diluted KH-570 or KH-550 solution. The mixture was then combined at a 500 rpm rotary speed. Finally, upon drying, the adjusted mix was produced. The aforementioned steps were used to create the improved blend using GMS, which was then applied straight to the mixer.

2.3 *Formation of the PP/sago starch Composites*

A twin-screw extruder was used to melt-blend the resulting mixtures. 160 ºC, 185 ºC, 190 ºC, 200ºC, and 195ºC, with a 60 rpm speed of the screw, were the temperature settings employed through mixing the provide in the container area through area 2, area 3, and area 4 to the nozzle. The mixtures were extruded using a several-hole blade, and the extrudates was afterward fuel inside a granulator where they were transformed into granules. Before we investigated the granules, they were dried at 80 ºC, for 6 hours.

2.4 *Characterization*

STA 449C equipment was used to do the measurements, which included heating the sample at a speed of 10ºC/min from the outside temperature to 600ºC according to nitrogen. 10mg to 15mg worth of samples were used. SEM pictures were acquired on a JEOL JSM-6700F scanning electron microscope was used to capture the pictures, and a 15kV acceleration voltage was used. Gold was sputter-coated onto the fracture surfaces before the inspection.

2.5 *Analyzing the MP*

According to conventional processes as described in GB/T1040-1992 and GB/T1043-1993, the contents of the extruded were injection-molded into specified experiment forms. Tensile tests were performed at a speed of fifty millimeters per minute using a standard testing device according to GB/T1040-1992. For calculating the strength of impact, a graded phase impacting device by GB/T1040-1993 was used. Test cases were set up for testing by keeping it 25 degrees Celsius and fifty percent relative humidity for a few days. Each test was placed under the same conditions. Each of the outcomes was computed using the usual quantities of the 7 cases.

3. Results and Discussions

3.1 *Effects of Different Modifying Agent Types and Contents on the MP of Composites*

The weight distributions of CST/PP in this trial were set at 30% along with 70%. Due to their weak interfacial adhesion strength, the characteristics of PE or PP/SS blends often dropped dramatically. The findings of the investigation into the impact of various Compatibilizers and various additional quantities on the blends are shown in Figures 1 to 3. The TS of each sample rose noticeably as the quantity of modifying agent increased in comparison to the sample without the addition of Compatibilizers, as shown in Figure 1. It suggested that these compatible substances improved the tensile characteristics. When the changing agent level was 1wt%, the TS had reached its highest and 13% greater than it was for blends without Compatibilizers. For notched specimens, Izod impact evaluations were carried out at ambient temperature. Figure 2 displays the CST filler-PP composites' Izod impact properties after being produced with different Compatibilizers. The distinct compatibilizers utilized across the blended affected the Izod impact strengths similarly to how they affected TS. The blend samples that only had a 1wt% loading of Compatibilizers showed a rise in their final strengths, according to our research. In comparison to the mix without Compatibilizers, with a 1wt% of KH-570, KH-550, and GMS, the Izod notched Influence quantities increased by around 16%, 22%, and 26%. Figure 3 demonstrates that both the lengthening at dissolve and the TS followed an equivalent trend. The degree to which the MP of mixes improved also showed significant disparities, we discovered. KH-570, KH-550, also GMS were used in that sequence, going from good to bad, suggesting that KH-570 was the superior Compatibilized out of the three. This may be the consequence of the altering agents' various structural variations. The compatibility between PP and CST might be further enhanced according to the concept of dissolving in the same material composition.

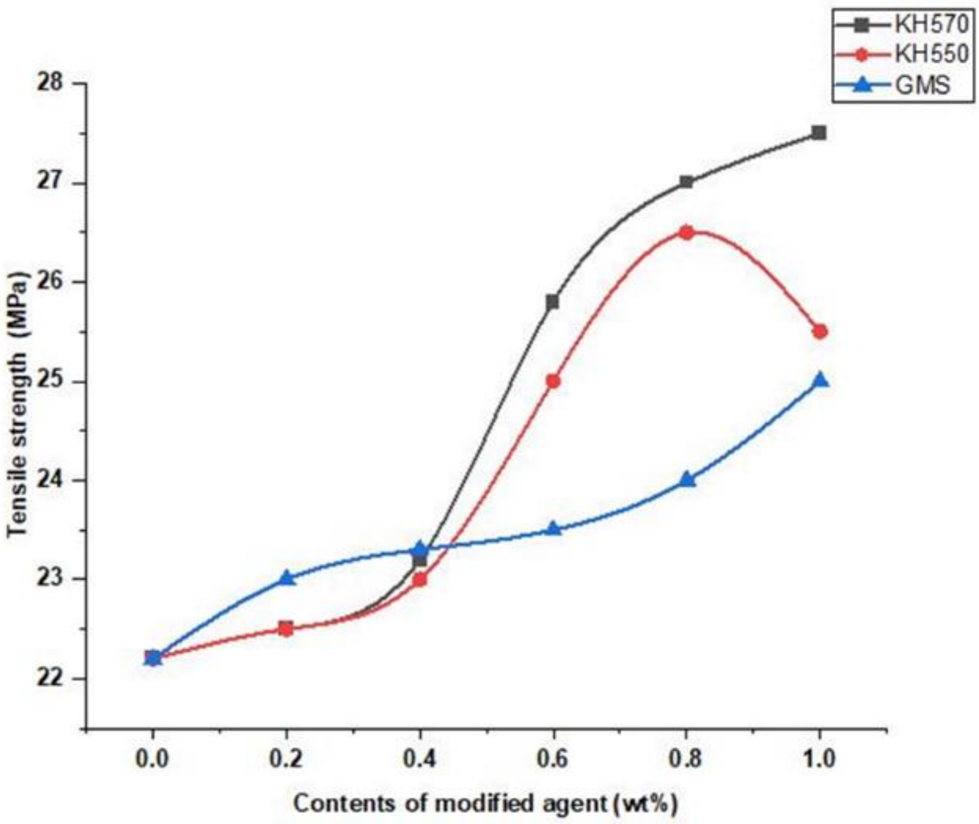

Figure 1: Effects of various Compatibilizers types and quantities on TS

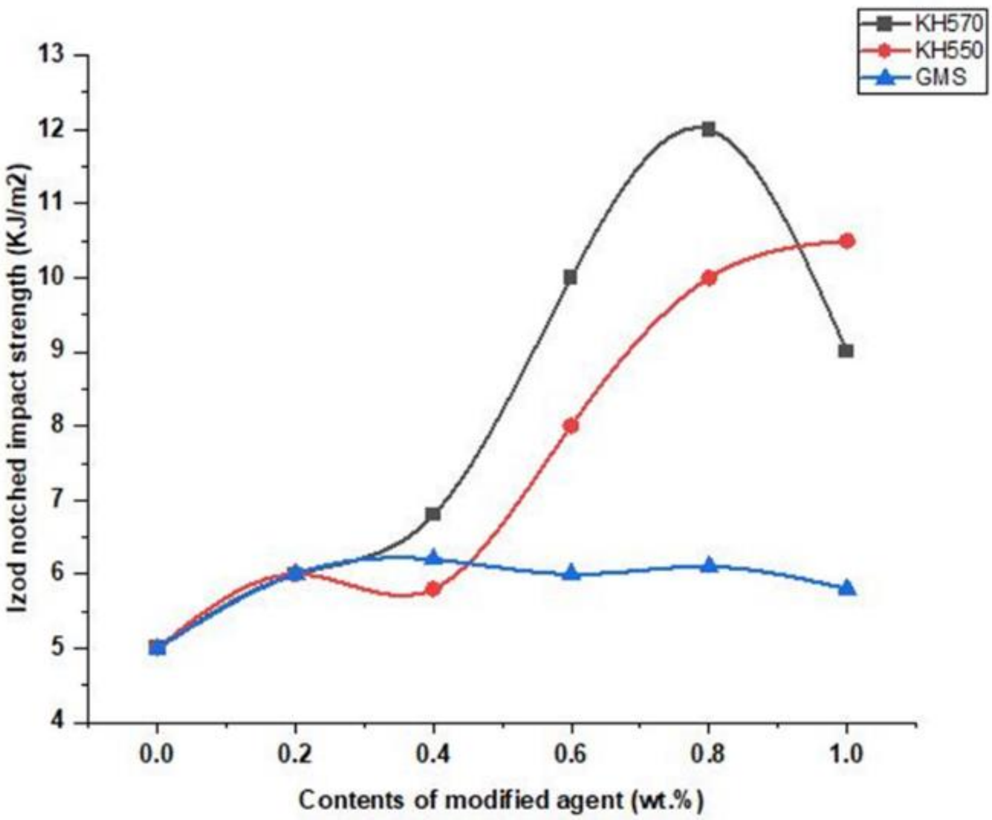

Figure 2: Effects of various Compatibilizers types and compositions on the Izod notched impact strength

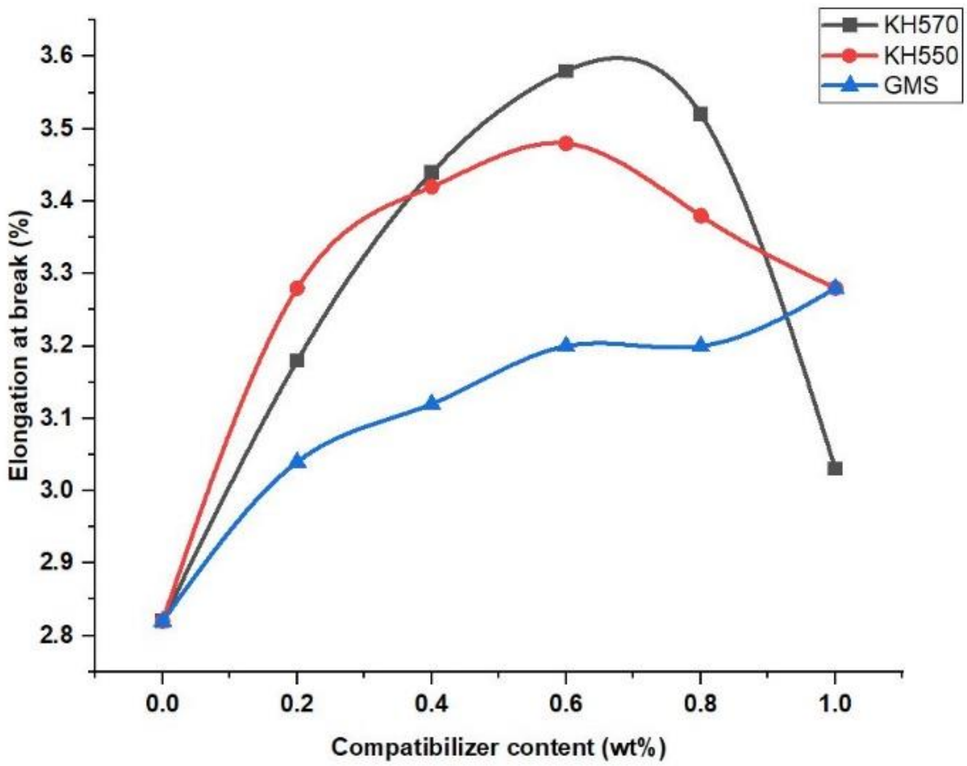

Figure 3: Effects of various Compatibilizers types and substances on the length at break

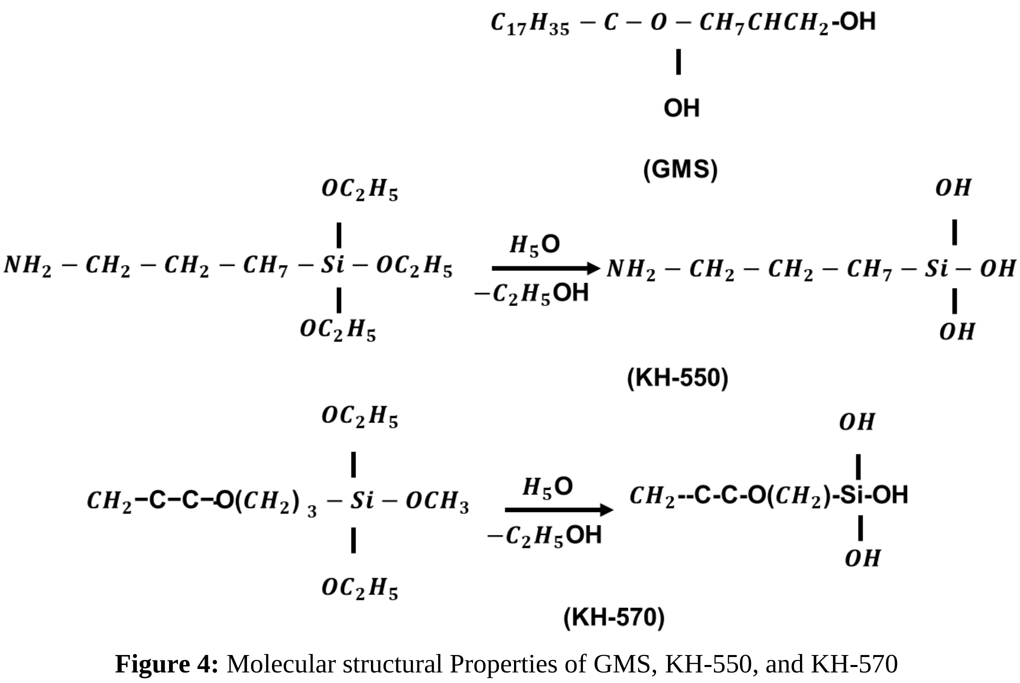

Figure 4: Molecular structural Properties of GMS, KH-550, and KH-570

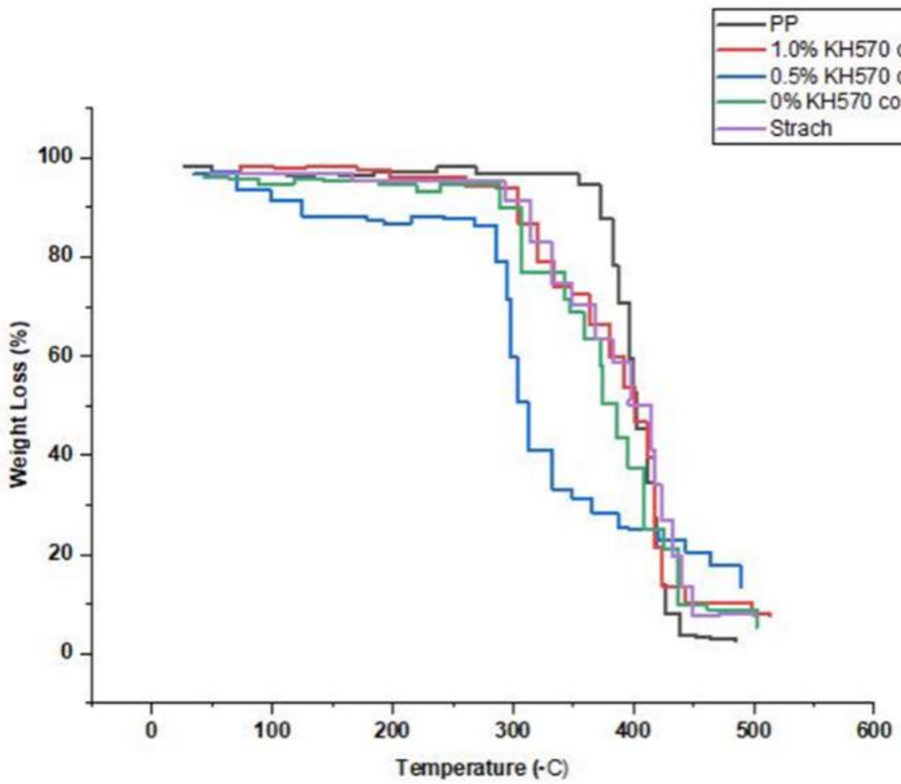

Figure 5: TGA curves for various KH-570 concentrations in PP, starch, and PP/CST composites

In actuality, not all active groups took part in the process of forming chemical bonds. Multiple instances show that the chain length was both disproportionately long as well as short from the perspective of the coupling/modifying component. In decreasing order of molecular chain length, the command was GMS, KH-570, and KH-550. Simply from this perspective, KH-570 was the ideal suitable Compatibilizers when comparing the chain lengths of the three Compatibilizers. In other words, the sample containing KH-570 had the greatest overall MP and the highest enhanced effects for improved effects. The blend's morphologies also demonstrated this propensity. Figure 4 demonstrate thehydrolyzedKH-550 $[-\mathrm{OH}$ (3), $-NH_2$ (1)] hydrolyzed$\mathrm{KH}-570[-\mathrm{OH}$ (3), $-\mathrm{COO}-$ (1)] and $\mathrm{GMS}[-\mathrm{OH}(2)$, $-\mathrm{COO}-$ (1)] in turn. The molecule of KH-570 also contained $\mathrm{C{=}C}$bonds, were comparable to the remaining$\mathrm{C{=}C}$bonds in PP.

In comparison to the mix without Compatibilizers, the elongation at break values at 1wt% of KH-570, KH550, and GMS, clearly increased by roughly 120%, 100%, and 30%. These findings show that the addition of Compatibilizers to blends was helpful for the enhancement of the MP of the blends. When utilized maleic anhydride-grafted PP in Compatibilizers for blends of high levels of density PE-tapioca SS and "ethylene-co-acrylic" acid copolymer, for example, Compatibilizers over mixtures of low-density PE-CST and low-density PE-potato SS, they found that the results followed a similar trend. In general, the degree of load transmission between the matrix and changed elements had a significant impact on the MP of the hybrids. Given the same PP and CST and identical content circumstances, excellent dispersion and improved interfacial adhesion were crucial components of our study system. They found that increased compatible forces caused TS; Izod notched impact strength, and elongation at fracture to increase.

3.2 *Thermogravimetric Analysis (TGA)*

The intrinsic properties of the materials and connections among each about particles have an impact on a polymerized substance's thermal sustainability. Because KH-570 an best suggested modifying agent into aforementioned study and because the other two modifying agents have a similar tendency, provisional findings of PP/CST mix with various KH-570 contents in this report. Figure 5 displays the TGA forms of SS, PP, and PP/SS mixtures at various KH-570 levels. The normal signs of PP deterioration. Over 345ºC, the breakdown of PP began. The pure/original SS has two stages of weight loss (WL). Vaporization of fluid caused initial WL, which was about 10%, in the temporal range below 145ºC. The WL rate then stayed nearly constant throughout the temperature range of 145 to around 266ºC, indicating that the SS framework was unaltered. At a temperature of 266ºC, the SS began to oxidize, degrade, or decompose, and this is when the second mass loss began. The mixes had three different phases for WL, though. The initial mass loss in the 100ºC to 175ºC range of temperatures showed the deprotonation of humidity. Thermal dissolution of PP and the thermal degradation/disintegration a leftover SS led to the third mass loss, which began at 327ºC. The thermal WL about the PP/CST blends were discovered as well to be equivalent to pure SS/PP, much smaller compared to pure CST, and just slightly higher than pure PP. However, discovered certain variations in the rate of thermal WL were by carefully analyzing the different TGA curves are PP/SS mixes. In the temperature range from 100ºC to roughly 266ºC, discovered the WL of blends by addressed SS was a little improve with grew substance of KH-570; this trend stood up as very obvious above 266ºC as compared to without Compatibilizers; that indicated the incorporation of KH-570 had been helpful to improve an thermal stability every PP/SS composite materials. That resulted from the enhancement of the interfacial adhesion and dispersion among PP/SS.

4. Conclusions

There are three distinct Compatibilizers, KH-570, KH-550, and GMS, were used to treat CST before a twin-screw extruder was used to create PP/CST mixes. The outcomes of several Compatibilizers and their compositions of MP and thermal characteristics about PP/CST blends were studied into the present article. Discovered that adding to and growing amounts of the Compatibilizers, substantially enhanced the MP of the blends due to an increase in the TS, stress propagation, and bonding at the interface among the matrix polymer and the filler. The samples with only a 1wt% injection of compatible substances produced the greatest increase in MP. KH-570 and KH-570550, and GMS were the compounds that revealed the best effects, going from excellent to bad in turn. The TGA tests revealed that, as opposed to the compatibilized mix, the effects of different Compatibilizers and their content of them MP also thermal characteristics of the PP/CST blend were studied in the present article. Infrared weight loss of PP/CST blends was more significant than every pure CST and inferior to that of pure PP, placing them among the two purses. The SEM result demonstrates the addition of the Compatibilizers to the blend solution improved CST and PP's interface adhesion and dispersal. Regarding bonding employees, KH-570 not only exhibited the most improved properties but also continued to function as a plasticizer. It thinks the outcome will direct the creation of biodegradable polymers.

References

[1] A. Zarski, K. Bajer, &J. Kapuśniak. (2021). Review of the most important methods of improving the processing properties of starch toward non-food applications. *Polymers*, *13*(5), 832.

[2] M. K. Ab Wahab, H. S. Mohamad, E. Jayamani, H. Ismail, I. Wnuk, A. Przybył, P. Postawa. (2021). Effect of sago starch modifications on polystyrene/thermoplastic starch blends. *Materials*, *14*(11), 2867.

[3] L. García-Guzmán, G. Cabrera-Barjas, C. G.Soria-Hernández, J. Castaño, A. Y. Guadarrama-Lezama, S. Rodríguez Llamazares. (2022). Progress in starch-based materials for food packaging applications. *Polysaccharides*, *3*(1), 136-177.

[4] D. A. Tanjung, N. Jamarun, S. Arief, H. Aziz, A. H.Ritonga, B. Isfa. (2021). Improving mechanical and physical properties on thermoplastic sago starch blends with the addition of polypropylene. *development*, *14*(4), 2451-2458.

[5] R. K. Malviya, R. K. Singh, R. Purohit, R. Sinha. (2020). Natural fibre reinforced composite materials: Environmentally better life cycle assessment–A case study. *Materials Today: Proceedings*, *26*, 3157-3160.

[6] H. T. N. Kuan, M. Y. Tan, Y. Shen, M. Y. Yahya. (2021). Mechanical properties of particulate organic natural filler-reinforced polymer composite: A review. *Composites and Advanced Materials*, *30*, 26349833211007502.

[7] N. S. Othman, R.Santiagoo, W. A. Mustafa, M. Zainal, A. A. Ghani, A. M. Anas. (2019). Thermal Aging Effect on the Mechanical and Morphological Properties of Polypropylene/Virgin Acrylonitrile Butadiene Rubber/Sago composites. *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences*, *63*(2), 174-180.

[8] Y. Zhong, P. Godwin, Y. Jin, H. Xiao. (2020). Biodegradable polymers and green-based antimicrobial packaging materials: A mini-review. *Advanced Industrial and Engineering Polymer Research*, *3*(1), 27-35.

[9] C. Y. Su, D. Li, L. J. Wang, Y. Wang. (2022). Biodegradation behavior and digestive properties of starch-based film for food packaging–a review. *Critical Reviews in Food Science and Nutrition*, 1-23.

[10] S. Shanthamma, R. Preethi, J. A. Moses, C. Anandharamakrishnan. (2021). 4D printing of sago starch with turmeric blends: A study on pH-triggered spontaneous color transformation. ACS Food Science & Technology, 1(4), 669-679.

[11] S. Kormin, F. Kormin, M. D. H. Beg. (2019). Effect of plasticizer on physical and mechanical properties of ldpe/sago starch blend. In *Journal of Physics: Conference Series* (Vol. 1150, No. 1, p. 012032). IOP Publishing.

[12] N. H. Taharuddin, R. Jumaidin, R. A. Ilyas, Z. H. Kamaruddin, M. R. Mansor, F. A. Md Yusof, M. N. F. Norrrahim. (2022). Effect of agar on the mechanical, thermal, and moisture absorption properties of thermoplastic sago starch composites. Materials, 15(24), 8954.

[13] H. C. Obasi, F. C. Egeolu, O. D. Oparaji. (2015). Comparative analysis of the tensile and biodegradable performances of some selected modified starch filled polypropylene blends. *Am. J. Chem. Mater. Sci*, *2*(2), 6-13.

[14] H. P. N. Vu, N. Lumdubwong. (2016). Starch behaviors and mechanical properties of starch blend films with different plasticizers. *Carbohydrate polymers, 154,* 112-120.

[15] H. Wang, X. Sun, P. Seib. (2002). Mechanical properties of poly (lactic acid) and wheat starch blends with methylenediphenyl diisocyanate. *Journal of applied polymer science*, 84(6), 1257-1262.