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Preparation of nanoparticles incorporated green paper using organic waste

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Abstract

Paper production is one of the major causes of deforestation, around the world this contributes to the rising quantity of greenhouse gases in the atmosphere and, as a result, led to global warming. In this paper, a sustainable solution for the production of paper from tea leaf waste has been reported. Organic waste such as waste tea-leaf, mango seeds, and Indian blackberry seeds are used as an alternative source for paper making. Metal nanoparticles have been incorporated in this paper to enhance the utility. These improved the quality of the synthesized paper by imparting microbial resistance, whiteness, hydrophobicity, and high strength to the synthesized paper. Limonene was also used for increasing the shelf-life of the paper produced. The synthesized paper was produced successfully with all the basic required qualities. Paper produced is cost-effective, writeable, with good tearing strength and shelf-life. The produced paper was kept under observation for one year and it retained the properties for the time. The texture of the paper produced is somewhat like cardboard which can prove to be a good packing paper material, with other uses of a similar kind.

Keywords: Deforestation, sustainable paper, organic waste, hydrophobicity, metal nanoparticles, limonene, eco-friendly.

Introduction

Paper is an essential commodity in all walks of life. Approximately paper manufacture consumes 40% of the world's commercially harvested wood[1]. This results in the loss of biodiversity and creates an imbalance in the natural composition of air. Every year, about 30 million acres of forest are lost, adding to the rising quantity of greenhouse gases in the atmosphere and, as a result, to global warming[1,2]. Biodiversity loss, the replacement of natural or primary woods by tree plantations, the continuous use of gas as bleach, paper recollection systems, and paper exports, which have impacted the livelihoods of paper collectors in poor countries, and excessive demand for transportation within the industry are just a few of the environmental concerns associated with paper production[3].

Pulp and paper industrial waste pollutes the air, water, and land, and discarded paper and poster boards account for around 26% of solid municipal solid waste in lowland areas[3]. The pulp and paper industry consumes a lot of water to produce more products than the other industries. Most pulp mill operators monitor reforestation to ensure an uninterrupted supply of wood[4]. Although paper is reclaimable, not everyone considers recycling. Keeping in mind the sustainability mantra of Reduce, Reuse, and Recycle, efforts are being made in purchasing recycled paper and supporting the paper industry to produce paper in environmentally beneficial ways[5]. However, paper recycling was not sufficient to meet the demands of the paper industry, there is a need to find an alternative solution that wouldn't only be eco-friendly but also be a cost-effective and green method to produce paper[6].

There is a huge wastage of tea leaves in tea-making industries due to incorrect harvesting of the tea leaves. These waste tea leaves are one of the types of agro-waste generated from industries. The organic wastes generated from the households contribute greatly to causing various airborne and water-borne diseases in the population if left untreated, thus it is very important to dispose of this waste in a correct manner. Mostly these wastes are either disposed of in landfills or are burned, both of these procedures are harmful to the environment.

In the present work, we have attempted to search for an eco-friendly way of manufacturing paper. Different types of organic wastes are produced every day, among them are the tea-leaf waste that is the direct plant source material. Usually, the left-out leaves are discarded, being the direct plant source this can be utilized to synthesize paper in a sustainable manner. The organic kitchen wastes that include tea-leaf waste, fruits, and vegetable seeds can be used as the alternative raw material for synthetic paper production[7].

The paper produced with these wastes has both cellulose and fiber contents. The alkaline treatment has been used to treat the organic wastes to provide the paper with the property of high physical strength and to increase the rate of their biodegradation.

Figure-1: Dried tea leaves.

The organic materials used are waste tea leaves (fibrous in nature) [Figure-1], mango seed powder, and crushed Indian blackberry seeds. To lighten the color of the paper calcium carbonate and calcium carbonate nanoparticles were used. The nanoparticle of zinc oxide is also added to provide antibacterial and antifungal properties to the pulp so that the growth of any microbial infection can be avoided[8] [Figure-2].

Figure-2: Nano-particle sample of calcium and zinc respectively.

Limonene is a colourless liquid aliphatic hydrocarbon found in citrus fruit peel oil. It has the chemical formula C10H16 and is a cyclic monoterpene. It's typically found in the rinds of citrus fruits including grapefruit, lemon, lime, and, especially, oranges. In fact, limonene accounts for 98 percent (by weight) of the essential oil extracted from orange peel. This was extracted from the peels of lemon and orange and was added to the paper for its antimicrobial properties[9,10,11].

Methodology

Production of Pulp using organic waste: Organic kitchen waste (dried powdered Indian blackberry and mango seeds 10g and 40g dried powdered tea leaves) were immersed in 500 ml of 1M sodium hydroxide solution and heated at 50 to 60°C with constant stirring and after the solution volume reduced to 50%, 50ml of the phosphate buffer of pH 7 was added. It was heated for another 2hr, keeping the temperature between 40 to 50°C. Then set it aside to cool down, and left undisturbed overnight, covered with a filter paper at room temperature.

The next day, the pulp was filtered out, which had developed in the beaker and the supernatant was discarded. The pulp was rinsed with distilled water until all traces of NaOH were washed off. The pulp was left undisturbed for approximately 5 to 6h [Figure-3].

Figure-3: Unwashed pulp sample.

Synthesis of calcium carbonate nanoparticles: 1M Calcium chloride and 1M Sodium carbonate were prepared and each solution was stirred on a magnetic stirrer for 15 min. At 40°C, both solutions were combined and agitated for 1 hour. This led to the production of white precipitate in the solution. This solution was cooled and left undisturbed for 5 to 6h. The supernatant and the precipitate formed were separated by filtration using a suction pump. The translucent supernatant contains calcium carbonate nanoparticles. Spectral analysis of the supernatant confirms the presence of nanoparticles. The precipitate obtained was also used as a dyeing agent into the pulp[12].

Zinc oxide nanoparticle synthesis: 1M zinc acetate and 1M sodium hydroxide solution were mixed and stirred for 30 min on a magnetic stirrer. At 35°C, 100ml of ethanol was added to the solution, which was then agitated for another 1 hour. The prepared solution was left at room temperature for 24h for ethanol evaporation. Spectral analysis of the solution confirmed the presence of zinc oxide[13,14].

Synthesis of paper: The pulp was washed thoroughly with distilled water and excess water was squeezed out. To the prepared pulp 15ml of zinc oxide nanoparticle solution and 15 ml of calcium carbonate nanoparticles were added respectively and were stirred vigorously. To this calcium carbonate precipitate prepared during the synthesis of calcium carbonate nanoparticles was added. Now the mixture was divided into two beakers, beakers A and B. To beaker A, limonene oil and lemon juice were added that act as an antimicrobial agent and have bleaching properties. To beaker B, grated lemon zest and lemon juice were introduced which added similar properties to it. All the constituents were mixed on a magnetic stirrer at room temperature and left undisturbed for 24h. The pulp was separated from the supernatant and was spread as thin as possible on a flat base tray and on a Petri plate with a flat base and was placed inside a clean contaminant-free oven at 35 to 38°C for 24 to 30h unless the moisture evaporated completely. Completely dried and light color paper was obtained. The characterization of the prepared paper was done.

Results and discussions

The nanoparticles were characterized by spectrophotometry[15]. The zinc oxide nanoparticle synthesized by the sol-gel method shows an absorbance peak at 380nm, and calcium carbonate nanoparticles synthesized by the precipitation method show an absorbance peak at 540nm (Figure-4). Hence confirms the presence of nanoparticles in the solution.

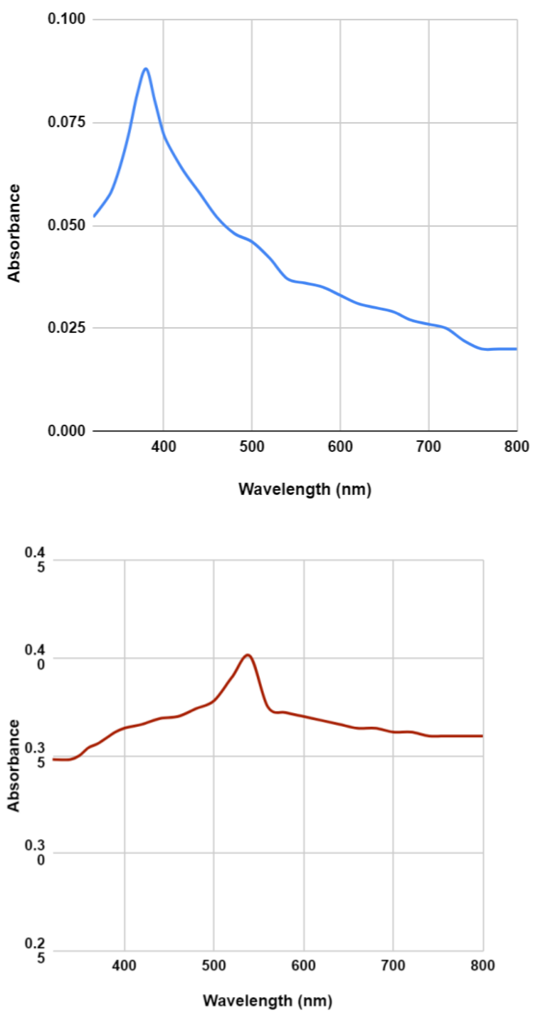

Figure-4: Spectrophotometric analysis of (a) zinc oxide and (b) calcium carbonate nanoparticles.

Properties of the synthesized paper: **Colour of paper:** The color of the paper is lightened to a great extent by the action of calcium carbonate nanoparticles and calcium carbonate precipitate since calcium has the property of whitening. Also, lemon juice has been utilized for its well-known bleaching property to lighten the color of the paper synthesized. Effect of $CaCO_3$ nano-particles**:** The color of the organic pulp used is whitened to a greater extent due to the presence of calcium carbonate nanoparticles as a whitening agent and calcium carbonate as a dyeing agent (Figure-5).

Figure-5: The color of the paper is lightened due to the presence of $CaCO_3$ nanoparticles.

Figure-6: Sample A [Limonene oil was added].

Figure-7: Sample B [Lemon zest was added].

Sample A- limonene oil and lemon juice acts as a bleaching and antimicrobial agent	Sample B - a light yellow tinge is imparted to the paper due to citrus peel

Antimicrobial Property of the synthesized paper (Durability): Limonene oil extracted from citrus fruit peels was introduced to the paper, which has added antimicrobial properties to the paper. Also, zinc oxide nanoparticles were added that have antibacterial and antifungal properties. The synthesized paper was kept under observation for more than a year and no microbial infection or other degradation was observed. Hence it proved to be quite durable in terms of storage. None of the issues was faced regarding any microbial growth as the antimicrobial agents were added beforehand in the process.

The thickness of paper: The thickness of the paper produced is approximately 1 mm measured using a vernier caliper (Figure-8). The paper is securely bonded, and ripping it is difficult without a violent act of tearing it. The paper has quite high tearing strength.

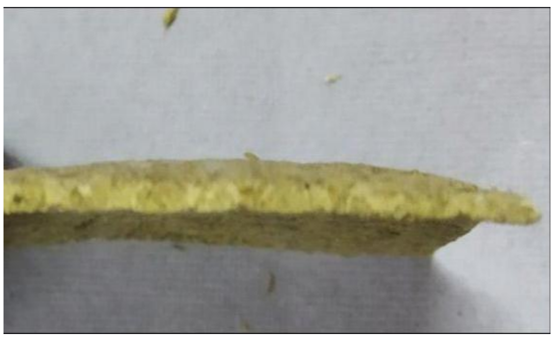

Figure-8: Thickness of paper (final sample) approx 1mm.

Texture: The texture of the paper is similar to that of cardboard produced by processing waste papers in industries. The color and texture are similar to the filter papers used in the laboratory (Figure-9). The paper has a similar texture to that of materials used for packaging. However, the finer paper can be created using appropriate machinery.

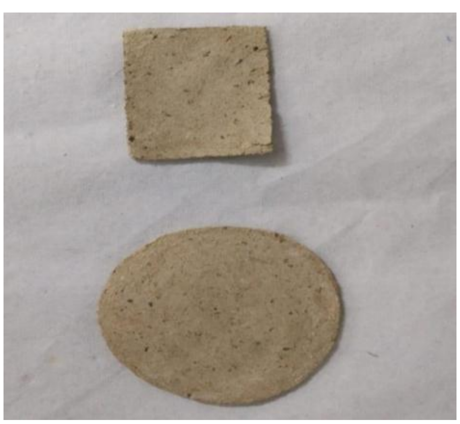

Figure-9: Produced paper is placed on a filter paper.

Usage: It can be used for packaging purposes as well, similar to cardboards (Figure-11). It is appropriate for writing (Figure-10). The pen ink was absorbed properly by the “synthesized paper”.

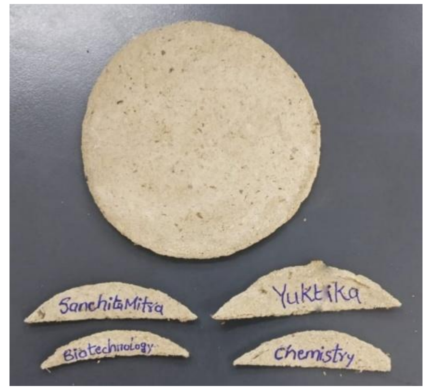

Figure-10: Paper produced is suitable for writing.

Figure-11: Quality of paper (resembles the cardboard produced by machine).

Weight of the paper: The synthesized paper was weighed on a weighing balance and it was observed that from 50g of powdered organic waste, approximately 5g of paper was produced (Figure-12).

Figure-12: Weighing the synthesized paper.

Comparison with industrial paper: The paper produced can be roughly compared to the cardboard produced in industries with high-tech machines. In comparison with the white paper prepared with the wood pulp the paper withstand properties like the ability to write on it, color is also fair enough, the tearing strength is almost the same (Figure-13).

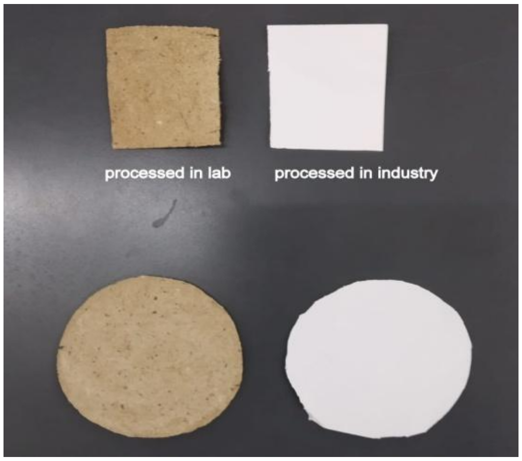

Figure-13: A fair comparison between papers.

Finally, after all the work we have performed we come up with a good quality writeable paper with a lighter color, and the thickness of the final sample produced is 1mm. The synthetic paper produced is prepared using kitchen organic waste as an alternative raw material for producing the paper in a sustainable manner.

Conclusion

From the above research work conducted, it is concluded that kitchen waste is a great alternative raw material that can be used to produce paper in a sustainable manner, that otherwise goes into waste[16]. It can be used as an eco-friendly way of producing paper and further research can be conducted to lighten the color of the paper produced and to increase its low tear index, double-fold resistance, burst index, etc. The organic waste generated from the households has high cellulose and fiber content which was effectively utilized for the green paper synthesis process. The produced synthetic paper was found to be stable for more than 1 year under testing. to increase the durability. Calcium and zinc nanoparticle incorporation was found to enhance the quality of the paper produced. The zinc oxide nanoparticles enhance the antimicrobial property of the paper and calcium carbonate nanoparticles lighten its color to a great extent. Thus, kitchen trash can be used to create eco-friendly, cost-effective, and sustainable paper using a green approach with low waste generation. The paper generated is biodegradable in nature and may be readily recycled using a similar method.

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