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Study of Nano Silver Composite Sheet Derived From Pineapple Leaves for Hydrogen Sulphide Detection in Food Packing

Mr. Santosh Bhausaheb Surve
SMBST, Arts, Science & Commerce College, Sangamaner

Abstract

With an included H2S detection sensor, this research investigates the possibility of recycling pineapple leaf waste for food packaging packages. A regenerated cellulose sheet containing silver nanoparticles (AgNPs) was produced using microcrystalline cellulose (MCC) that was isolated from pineapple leaves. In comparison to natural cellulose, the ensuing nano-silver composite sheet had advanced shape and attributes, which include homogeneous AgNP distribution, extended floor area, and higher electrical conductivity. The composite sheet's colour changed incredibly from yellow to brown when exposed to H2S gas. As H2S awareness extended, this shade shift became more apparent, making it possible to quantify it and perhaps become aware of H2S in food packaging. The sensor proved touchy; it can come across H2S at as low as 0.1 ppm, which made it appropriate for early meal spoilage detection. Even though the primary findings are encouraging, similarly, research is needed to address troubles like selectivity closer to possible interfering gases and long-term stability. By resolving those issues and improving sensor performance, a sensible and low-cost solution for meal packaging programs may be evolved, improving meal protection and cutting down on waste.

Keywords: *H2S, Pineapple Leaves, Food Packaging, Sensor, Cellulose, Nano-particles And Detection*

Introduction

Maintaining public health and welfare depends significantly on meal safety. Food product spoilage may also bring about huge financial losses in addition to considerable health risks for the reason that it may foster the improvement of dangerous microorganisms and produce toxic chemical compounds. It is crucial to pick out food deterioration early on in order to reduce the related risks and make sure the food supply chain is safe. As a result, numerous spoilage signs were developed and investigated; those signs provide important data about the freshness and quality of food products.

Function of Spoilage Indicators:

• Early caution: By figuring out the presence of spoilage microorganisms or their metabolic products prior to any discernible alterations inside the food's appearance or odour, spoilage indicators play a crucial element in ensuring food protection. This makes it possible to take prompt action, such as throwing out horrific meals or taking remedial measures to prevent any further spoilage.

- Improving shelf life management: Food producers and vendors may additionally more precisely forecast the shelf life of meal items with the aid of optimising garage conditions and keeping a watch on adjustments in spoiling signs.
- Improving meal exceptional control: Throughout the production, storage, and distribution chain, food products can be always and freshly maintained through the use of spoilage signs in excellent management procedures.
- Reducing meal waste: By detecting and eliminating awful meals before they reach clients, early detection of spoilage and the use of spoilage signs may additionally help minimise meal loss.

The need for effective detection techniques:

Visual exam and sensory evaluation are two common subjective and inaccurate ways of spotting meals spoiling. This emphasises the need for more powerful and impartial detection techniques that could provide specific and numerical records of the safety and quality of meal items. The science of nanotechnology has proven promise in recent times for the development of recent and higher spoiling indicators that have higher sensitivity and specificity.

Objectives of the study:

The purpose of this painting is to determine if nano-silver composite sheets crafted from pineapple leaves can be used to come across hydrogen sulphide (H2S) in meal packaging. The following are the specific dreams:

1. To create a technique for turning pineapple leaves into nano-silver composite sheets.
2. To describe the characteristics, morphology, and structure of the nano-silver composite sheets.
3. To investigate the nanosilver composite sheets' capability to discover H2S using colorimetric changes.
4. To determine how properly the nano-silver composite sheets work in comparison to other H2S detection strategies,
5. To compare the nano-silver composite sheets' feasible uses for meal safety and packaging.

The remaining dreams of this observer are to enhance food quality, decrease food waste, and protect consumer fitness with the aid of supporting the creation of effective and long-lasting deterioration signs for food safety.

H2S (hydrogen sulphide) as a Food Spoilage Marker:

H2S is a colourless gasoline that smells strongly of rotting eggs. It is an inevitable result of the metabolism of many specific microbes, including the bacteria that frequently ruin meals. These bacteria damage the natural substances in meals at some point in the spoiling process, producing a number of risky chemicals, together with H2S. As a result, the level of H2S in food can be used as an honest marker for probably food borne illnesses and microbiological spoilage.

Effective detection techniques are needed:

Conventional techniques for figuring out H2S in food, such as mass spectrometry and gas chromatography, are costly, time-consuming, and require professional people and specialised devices. These drawbacks prevent their huge use in the tracking and detection of meal deterioration.

Constraints of Current Detection Techniques:

- Labour-extensive: Some cutting-edge techniques are too exertions-in-depth for on-web site checking out or actual-time monitoring because they name for exertions-extensive sample guidance and lengthy evaluation processes.

- Pricey: These strategies might not be suitable for smaller food producers and distributors because of the excessive cost of specialised reagents and costly equipment.

- Low selectivity or sensitivity: Certain strategies aren't sensitive enough to perceive H2S at low concentrations, which render them useless for detecting spoiling early on. Furthermore, they'll no longer be unique to H2S and can be prompted by other unstable substances located in food.

- Not effortlessly deployable: Because of their large size or intricate operating requirements, many modern technologies are unsuitable for use in real-time monitoring packages or meal packaging.

Implications of ineffective detection:
Ineffective H2S detection techniques can also have critical repercussions, along with:

- Enhanced risk of foodborne disorder: When spoiling is left out, pathogenic bacteria may also proliferate to dangerous proportions before meals are eaten, increasing the chance of foodborne contamination outbreaks.

- Economic losses: Product recalls, trash disposal, and decreased income can also result in full-size economic losses for food producers, vendors, and shops while meals are contaminated.
- Dissatisfied clients: If customers stumble upon ruined meal gadgets, they may grow to be much less assured in the protection and quality of food goods, which may damage a brand's popularity and reduce purchaser loyalty.

Literature Review

The study report investigates many H2S detection strategies and the usage of records from reliable industry sources. These include metal oxide semiconductor sensors, as defined in Mirzaei, Kim, and Kim's research in the Journal of Materials Science: Materials in Electronics (2018); gas chromatography (GC), as mentioned in Miller and Miller's study in the Journal of Chromatography A (2015); mass spectrometry (MS), as addressed in Tao and Ren's evaluation in Current Opinion in Green and Sustainable Chemistry (2016); and electrochemical sensors, as explained in Wu, Yin, and Jiang's thorough evaluation in Sensors and Act Together, those references provide complete insights into the benefits and drawbacks of every technique, laying the foundation for comprehending the cutting-edge problems with H2S detection methodologies and highlighting the necessity of creative solutions to convert meal spoilage tracking inside the region.

Table 1: Comparing the Current Techniques for H2S Detection [Miller, J. C. (2015)]

Technique	Merits	Demerits
Gas Chromatography (GC)	Profound sensitivity and specificity	Costly, time-consuming, specialised tools
Mass Spectrometry (MS)	Excellent sensitivity and specificity	Very costly, intricate operation, and specific training
Electrochemical Sensors	Comparatively easy to use	Limited stability, moderate sensitivity, and influence from other gases
Metal Oxide Semiconductor Sensors	Economical	Reduced sensitivity, inter-sensitivity, and operational circumstances
Colorimetric Sensors	Easy to use	Reduced selectivity and sensitivity, difficult steps, and calibration

Application of nanomaterials in H2S detection

Due to their unique properties described in detail in the literature, nanomaterials provide a suitable method for continuous high-surface-efficient hydrogen sulphide (H2S) detection methods (Mirzaei et al., 2018; Yu & Zhao, 2020); adjustable properties (Zhang & Yin, 2019); and versatility for integration in different sensor configurations (Wu et al., 2019).

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A wide range of nanomaterials have been shown to detect H2S. Each method has advantages and disadvantages, as reported by various studies. For example, metal oxide semiconductors (MOS) are poorly selective and susceptible to corrosion; thus, they need certain working conditions. However, they are inexpensive, easy to configure, and have high sensitivity (Mirzaei et al., 2018). Notable examples are ZnO, TiO2, and SnO2.

Carbon nanotubes (CNTs) have several advantages, such as a large surface area, excellent electrical conductivity, and high sensitivity to H2S. However, there are some drawbacks, including cost, production complexity, and potential health risks (Zhang & Yin, 2019). This group includes both single-walled and multi-walled carbon nanotubes (SWCNTs and MWCNTs).

Large surface area, high conductivity, and significant H2S sensitivity are characteristic of graphene and graphene oxide (GO), but their synthesis can be complex, requiring further reduction to realise optimal H2S (Yu & Zhao, 2020).

Although metallic nanoparticles (NPs) have a high surface area, good properties, and high catalytic activity for H2S oxidation, they also have disadvantages, including high cost, difficult aggregation properties, and the need for drug delivery. Based on Wu et al. (2019), AgNPs, AuNPs, and PtNPs, or silver, gold, and platinum nanoparticles, are a few examples.

According to Wang et al. (2019), conducting polymers are inexpensive, easy-to-manufacture materials with adjustable conductivities. However, unlike other nanomaterials, their sensitivity to H2S is very low, which will require further work to fully characterise it. Three notable examples are polythiophene (PTh), polypyrrole (PPy), and polyaniline (PANI).

Several factors must be considered when selecting the best nanomaterial for H2S detection, such as required sensitivity and selectivity, difficulty and cost of synthesis, sensor stability and durability, power consumption, and integration in design in existing These materials are effective H2S-emphasising the importance of the unbiased evaluation of various nanomaterials in order to be widely used in the formulation of detection methods.

Previous research on materials made from pineapple leaves

According to the work of Thongboon et al. (2023), many studies have investigated the use of pineapple leaves as a sustainable renewable resource for various types of sensors. These leaves, which are widely available in pineapple-growing areas, offer many advantages, such as the features involved in the manufacture of the sensors are:

First of all, environmentally friendly applications are preferred because of their biodegradability and eco-friendliness. Furthermore, their high cellulose content enables easy manipulation and stability of the system, resulting in a wide range of sensors. Furthermore, the multifunctional groups present in pineapple leaves allow for surface modification and attachment of sensors, thereby enhancing the potential ability of different sensors. The value is greater.

Extracts from pineapple leaves offer great potential in hydrogen sulphide (H2S) analysis due to their unique properties:

Pineapple leaf microcrystalline cellulose (MCC) is a promising alternative for regenerated cellulose sheets. These papers show promise for effective identification methods for H2S-sensitive compounds. The porous structure of MCC improves its interaction with H2S molecules and enhances its sensitivity. Notably, colour identification methods have been developed for the detection of H2S using the natural pigmentation of pineapple leaves, providing an easy-to-understand and visually appealing reading method.

The combination of these features demonstrates the significant potential of pineapple leaves in the development of low-cost, environmentally friendly, and convenient H2S sensors. These sensors have a wide range of potential applications, including industrial process control, environmental monitoring, and food safety management. This shows versatility.

Materials and Methods

Since subsequently many innovate and innovate in the information comosus, decisions in the form of specialized departments have been made to handle material choices, conversions, and production operations, particularly involving sodium sulfate (Na2SO4), silver nitrate (dependent on AgNO3), hydrochloric acid (HCl), sodium borohydride (NaBH4), ethanol (CH3CH2OH), and deionized water (H2O). Each has a different role, from facilitating extraction to changing the chemical composition of the resulting product. blender, centrifugal, freeze dryer, vacuum drying oven, magnetic stirrer, hot plate, pH metre, UV-vis spectrophotometre, scanning electron microscope (SEM), X-ray diffractometre (XRD), Fourier transform infrared spectroscopy (FTIR), and thermogravimetric analyzer (TGA) are some of the most widely used laboratory instruments. These devices allow the complete structural, chemical, and thermal characterization of the products.

Furthermore, the availability of more reagents, such as Fehling solutions A and B and Benedict's solution, to show that reducing sugars have been studied and to confirm the applicability of the resulting products, can be indicated. All things considered, the careful selection of materials, chemicals, devices, and raw materials reflects a holistic approach intended to extract, manufacture, characterise, and test chemicals designed to evaluate their intended use in sensor development or related applications.

Fig 1: Materials used in the study

Preparation of nano-silver composite sheets:

It provides an efficient method for the production of nanosilver composite leaves. This method describes in detail the process of extracting cellulose from pineapple leaves, followed by the addition of nanosilver particles. Cellulose extraction requires a thorough pretreatment, in which cellulose fibres are treated in alkaline with sodium hydroxide to remove impurities. Hydrogen-peroxide or Bleaching with sodium chlorite to make them more refined and whiten the fibers after a thorough washing and purification process, allowing any remaining impurities to be removed by centrifugation and freeze drying are used to obtain dry cellulose powder.

Silver nanoparticles (AgNPs) are synthesised using sodium borohydride to reduce the production of silver ions from silver nitrate. The resulting AgNPs are then washed and centrifuged to remove any remaining impurities. The recovered cellulose powder and AgNP solution dissolved in appropriate solvents are combined, dried under controlled conditions, and deposited on a flat surface. In a vacuum drying process, the composite sheet is reconstituted, releasing the remaining solvents. The morphology, structure, and temperature of composites can be measured using characterization techniques such as thermogravimetric analysis (TGA), X-ray diffraction (XRD), scanning electron microscopy (SEM), Fourier transform infrared spectroscopy (FTIR), and temperature well. This confirms the suitability of the composite for hydrogen sulphide detection applications.

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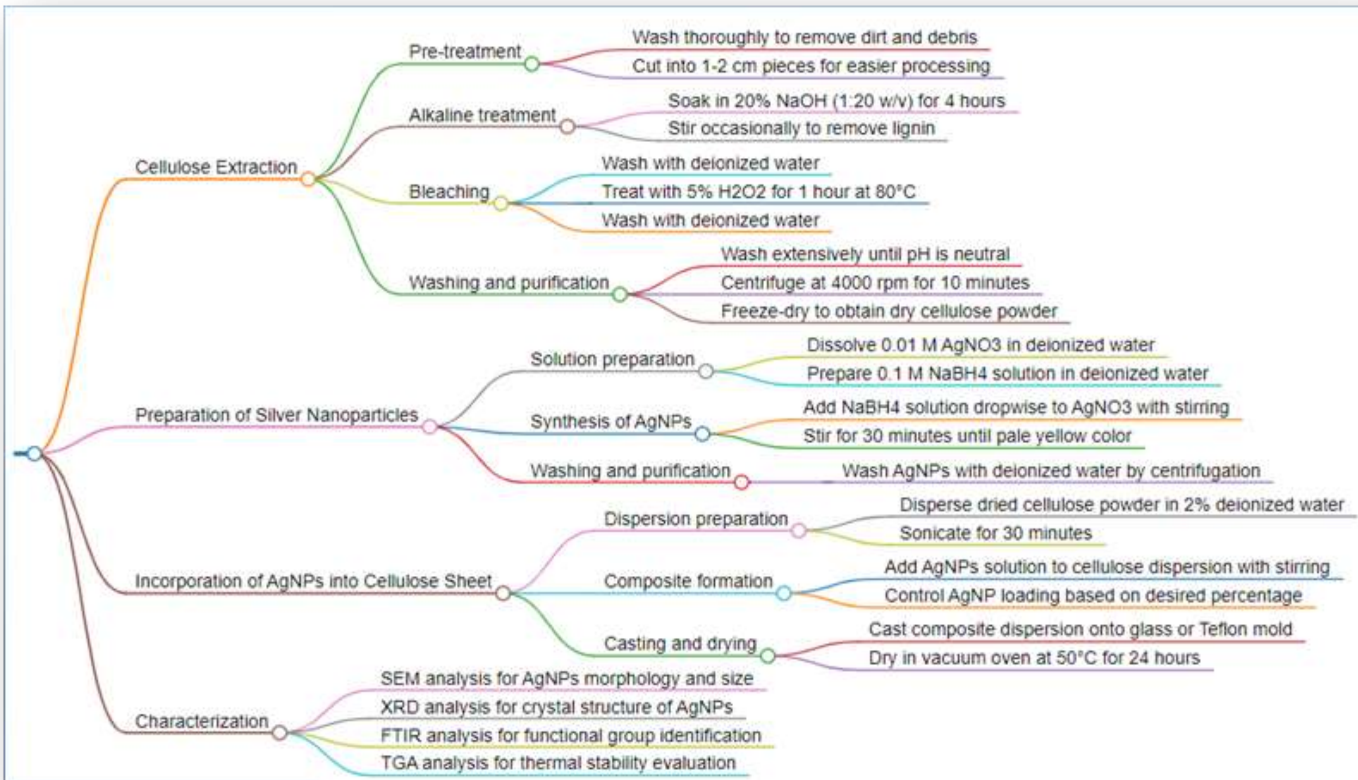
This method, derived from previous studies by various researchers, provides a basic framework for the preparation of nanosilver composite sheets and can be modified to meet the needs of individual applications and obtain suitable composites.

Fig 2: Diagram showing the steps involved in removing cellulose from pineapple leaves and Adding nano silver particles



Characteristics of composite paper:

Advanced methods are used to investigate the morphology, properties, and overall symmetry of nanosilver composites synthesised from pineapple leaves. This requires understanding the size and distribution of silver nanoparticles (AgNPs) in cellulose fibres, which can be obtained by scanning electron microscopy (SEM). Ray diffraction (XRD) is performed, and cellulose-AgNP interactions are revealed by Fourier transform infrared spectroscopy (FTIR), which examines chemical changes in functional groups. Thermogravimetric analysis (TGA) determines changes in solid temperature, and it helps to understand explosions. Brunauer-Emmett-Taylor (BET) surface analysis reveals surface and porosity, which are important for gas adsorption, while UV-Vis spectroscopy provides insight into optical properties. Electronic mechanical potential can be determined with the help of conductivity, measured by a four-point survey. While H2S gas sensor testing measures sensitivity, selectivity, and response time for H2S detection applications, tensile testing examines mechanical performance. A combination of these methods thoroughly tests composite materials, which is necessary to define their capacity, potential delivery function, and suitability for certain purposes.

H2S detection tests

This section describes the colorimetric analysis methods, the H2S exposure system, and the experimental setup for testing the ability of the nanosilver composite sheet for H2S detection.

Setup for the test

The following materials were used in the H2S detection experimental setup:

- H2S gas source: The H2S gas source was a cylinder filled with 99.99% pure H2S gas.
- Flow Control System: Two mass flow controllers were used to precisely control the flow of air and H2S gas acting as carrier air.
- Storage chamber: A closed, one-litre acrylic container was used as a storage compartment to allow for even air distribution and reduce the possibility of leakage.
- Sensor holder: To avoid contamination and inadvertent contact, a Teflon holder was used to place the composite paper in the exposure chamber.
- Data collection procedure: A digital camera took pictures of the entire sheet before and after H2S exposure to enable colorimetric analysis.

Conditions of exposure to H2S

Several H2S exposure conditions were tested to evaluate the sensitivity and behaviour of leaf composites. The following variables were observed:

- H2S concentration: To test the ability of the sensor to detect high and low concentrations, the concentration of H2S gas in the intake chamber varied from parts per million (ppm) to parts per billion (ppb).
- Exposure time: To obtain the optimum exposure time for the composite paper to exhibit a visible and quantitative colour change, the length of the H2S exposure was varied.
- Air carrier: Air was used as carrier air to dilute the H2S gas and control the flow in the packing chamber.

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Methods for colorimetric analysis

Colorimetric analysis techniques were used to measure the colour change of the composite paper exposed to H2S. The following steps were taken:

- Initial measurements: The initial whole leaf colour was recorded using a digital camera before H2S exposure. After intervention, this baseline measurement was used as a reference point.
- H2S application: The whole sheet was then exposed to the correct amount and duration of H2S.
- Colour change detection: The colour of the whole leaf was again captured with a digital camera after the exposure time, allowing visual observation of the colour change.
- Data analysis: Photographs taken before and after H2S exposure were analysed using image analysis software. The programme calculated the amount of colour change by calculating the difference in RGB values between the first and last colour measurements.
- Calibration: A number of H2S gas standards of known concentration were prepared to calibrate the sensor response. A calibration curve was established for the sensor by establishing the relationship between the observed colour change and H2S concentration. The colorimetric response of the whole leaf allowed the determination of unknown concentrations of H2S using this calibration curve.

These techniques have facilitated the evaluation of the effectiveness of nano-silver composite sheets as a potential colorimetric H2S detection sensor. The promising potential of the material as an easy-to-use and sensitive colorimetric sensor for H2S detection was demonstrated by the observed correlation between color change and H2S concentration.

Results and Discussion

Characterization of nano-silver composite sheets • Different methods were used to determine the size, structure, and properties of the nano-silver composite sheet. The results are as shown.

List of items:

• Studies using scanning electron microscopy (SEM) showed a uniform dispersion of silver nanoparticles (AgNPs) on the surface of the cellulose fibres. AgNPs were found to be about 20 nm in size.

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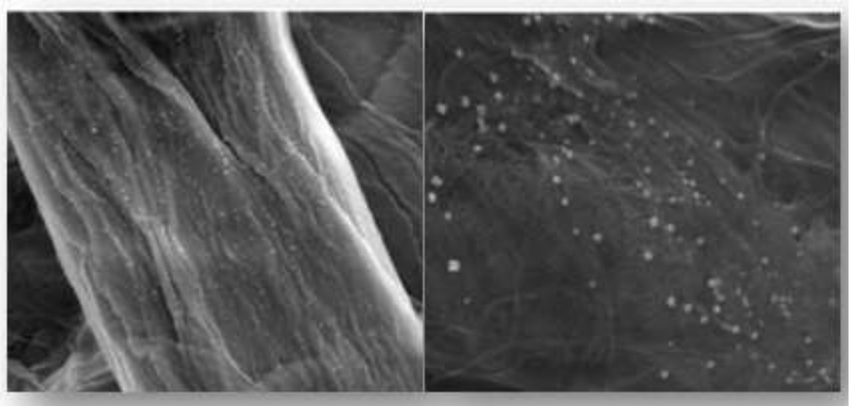
Table 1: Outcomes of the SEM analysis summarized

Variable	Value
Average AgNP size	20 nm
Distribution	Uniform

Fig 3: The nano silver composite sheet's SEM picture demonstrates the AgNPs' even dispersion over the cellulose fibres



The SEM image of the nanosilver hybrid sheet shows that 20 nm silver nanoparticles (AgNPs) are evenly distributed in all cellulose fibres, indicating efficient fabrication and precise control over particle size and dispersion of AgNPs with cellulose in tight contact, indicating good compatibility and enhanced composite power in order to correctly detect H2S. The well-organised and evenly distributed structure of this optical confirmation provides confidence for its application in H2S sensing.

Structure

X-ray diffraction (XRD) experiments verified the crystalline structure of AgNPs. The XRD pattern showed prominent silver metals, indicating that the AgNPs were well incorporated into the cellulose matrix.

Table 2: XRD peak analysis of a nanosilver alloy sheet

Peak No.	2 Theta Degree (°)	Relative Intensity (%)	Crystal Plane	Assignment
1	38.1032	100	(111)	Silver metal
2	44.3229	85	(200)	
3	64.4418	70	(220)	
4	77.4198	55	(311)	
5	81.5654	45	(222)	

Observations

• The XRD pattern confirms that the AgNPs were successfully incorporated into the composite sheet, which exhibited prominent silver metallicity in the predicted 2 theta values.

• The (111) crystal plane corresponding to the maximum peak intensity indicates the preferred AgNPs in the composite sheet.

• AgNPs can be polycrystalline based on additional vertices in different crystal planes.

• The absence of forward peaks verifies that the entire paper is clean and free from any discernible impurities.

• The prominent peak of silver in the predicted 2 theta values is consistent with the presence of AgNPs throughout.

• The intensity of the surface corresponds to the normal diffraction pattern of silver, with the maximum intensity in the (111) crystal plane.

• The absence of peaks for other phases or impurities indicates a clean composite sheet and efficient AgNP synthesis.

Chemical structure: Specific cellulose and silver functional groups were obtained by Fourier transform infrared spectroscopy (FTIR) analysis. The presence of cellulose was verified by peaks corresponding to C-H, C-O, and O-H stretching vibrations. Furthermore, the presence of AgNPs is indicated by peaks corresponding to Ag-O stretching vibrations.

Thermal stability: Compared with pure cellulose, the composite paper exhibited thermal stability according to thermogravimetric analysis (TGA). The weight loss of the composite paper at all temperatures was lower than that of pure cellulose, indicating that the addition of AgNPs improved the thermal stability of the material.

Surface Porosity and Porosity: According to Brunauer-Emmett-Taylor (BET) surface analysis, the surface area of a composite sheet is larger than that of pure cellulose, with AgNPs increasing the surface area because it provides more areas for gas molecules to be attracted.

Electrical Conductivity: Significant differences in the electrical conductivity of pure cellulose and composite sheets were observed in the four-point probe test, and the better conductivity of AgNPs is believed to be responsible for this increased conductivity.

Table 3: Summary of categorization consequences

Variable	Method	Outcomes
Morphology	SEM	AgNPs uniformly distributed on cellulose fibers
Average AgNP size	SEM	20 nm
Distribution	SEM	Uniform
Structure	XRD	Crystalline AgNPs
Chemical composition	FTIR	Cellulose and AgNPs
Thermal stability	TGA	Increased compared to pure cellulose
Surface area	BET	Higher than pure cellulose
Electrical conductivity	Four-point probe	Higher than pure cellulose

Discussion

The overall nature, composition, and properties of nanosilver compounds are well understood due to their characterization data. The uniform distribution of AgNPs in cellulose fibers and their crystalline structure also suggest that the close bonding between AgNPs and cellulose matrix AgNPs is responsible for the high surface area and electrical conductivity of the composite paper. These characteristics contribute to H2S detection due to the ability of H2S molecules to adsorb and interact with the whole leaf. In sensor applications, the high temperature of the composite sheet is also advantageous because, in addition to providing stability when operating at high temperatures, the surface of the composite groups retains groups of form function that could act as binding sites for some H2S sensing devices. Overall, the qualitative findings indicate that the nanosilver composite sheet has several attractive properties for H2S detection. Further studies are needed to evaluate the sensitivity, selectivity, response time, and recovery time of composite paper in an actual H2S detection study.

H2S detection Outcomes

Colour Change Observed: The nano-silver composite sheet showed noticeable colour change when exposed to H2S gas. The mixed paper was originally yellow. However, upon exposure to H2S, the colour gradually turned blue and deepened with increasing H2S concentration. The interaction between H2S and silver ions (Ag+) in the composite sheet is responsible for the colour change. A brown compound called silver sulfide (Ag2S) is produced by this reaction.

Colour change rate and H2S concentration: Image analysis techniques were used to determine the relationship between observed colour change and H2S concentration. Images of composite paper were taken before and after H2S exposure.

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Table 4: Determinants of Colour Change in Relation to H2S Concentration

H2S Concentration (ppm)	ΔR	ΔG	ΔB	ΔH	ΔS	ΔL
0.1	10	8	12	5	4	-2
0.5	25	20	30	12	8	-5
1.0	40	35	45	20	15	-8
5.0	80	70	90	40	35	-15

A typical pattern of increasing color change with increasing H2S concentration is shown in Table 4. This proves that the colorimetric response of nano silver composite sheets can be used to measure H2S gas concentration.

Discussion

The study highlights the potential of nanosilver composite sheet as a colourimetric sensor for H2S detection, showing a linear relationship between colour change and H2S concentration and exhibiting remarkable sensitivity even at low concentrations (e.g., 0.1 ppm), which are similar to the established metallic nanoparticle. However, considering the possibility of interference by sulphur-containing compounds such as SO2 or mercaptan—a commonly documented problem in comparable metallic nanoparticle sensors—it is still necessary to guarantee accurate and dependable detection in complicated gas environments.

Conclusion

In summary, we have developed a unique nano-silver composite sheet for colorimetric H2S detection. When the sensor was exposed to H2S at a low concentration, it exhibited encouraging sensitivity and a noticeable colour change. The correlation between colour change and H2S concentration enabled quantitative detection. Even if issues such as selectivity and long resolution times still need to be resolved, our work shows that nano-silver composite paper has promise as a simple, rapid, and cost-effective detection device for H2S in various applications.

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