# GREEN APPROACH OF CHARRED DOCUMENT PRESERVATION USING SAGO SEEDS AND ITS DECIPHERMENT USING OCR AND VSC TECHNIQUES

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**Abstract:** *Polysaccharides are one of the most abundant natural polymers. The use of a natural polysaccharide in the field of questioned documents, particularly charred documents to stabilize and decipher the invisible content on charred documents, is a novel method. The present study focuses on the application of sago seeds to synthesize sago analog by reaction with glycerol in the presence of an acidic medium and microwave irradiation. The comparative spectral characterization (ATR-FTIR) of pure sago powder and synthesized sago analog confirmed the formation of ether linkages in the sago analog after the reaction. Further, the synthesized sago analog on application over fragile charred documents, charred at 300 °C, provided an appreciable strength to the coated sample in comparison to the non-coated charred sample. The bursting strength tester showed that the bursting strength of coated charred document (Linc Pentonic+75 gsm paper) increased from 0.12 kg/cm2 to 0.19 kg/cm2. Moreover, it deciphered the invisible and unreadable texts over charred documents to a remarkable extent. Additionally, the new optical technique of optical character recognition using Google Lens gave an advanced way of converting deciphered content from images into readable and copiable texts. The analysis of samples under the video spectral comparator (VSC) also showed an appreciably enhanced visibility of texts under flood light and white spotlight at visible range longpass (wavelength). Hence, this study provides an easy, cost-effective, and non-toxic approach to document preservation, decipherment, long storage duration, and future references in a court of law.*

**Keywords:** Forensic document examination, preservation of charred document, evidential document, Sago, OCR, Google Lens, ATR-FTIR, video spectral comparator.

## 1. Introduction

Charred or burnt documents are questioned documents that are likely to contain crucial information and become black and brittle by burning or exposure to excessive heat. Questioned documents are documents whose legitimacy is in dispute. Questioned documents portray a remarkable role in conviction and justification in a court of law [1]. Often, such documents get burned accidentally or deliberately to hide one's wrongful intention or criminal activities. During the burning of documents, one or more papers may or may not get completely burnt due to several external factors, one being limited oxygen supply. Due to the effect of excessive heat, charred documents become extremely fragile and brittle, even curl around the edges. Moreover, the soot, smoke, and carbonized particles turn the writing on charred documents partly or completely invisible. In such states of charred documents, deciphering the writing on them becomes challenging. Therefore, utmost care is needed in handling, preserving, and transporting charred documents from the crime scene to a laboratory for further decipherment.

The process of analyzing and interpreting texts that have been damaged by heat or fire is referred to as

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deciphering charred documents. This specialized area requires expertise in linguistics and chemistry. Charred documents often contain personal records and can hold evidentiary value if recovered from crime scenes. They may also offer valuable insights into ancient cultures and historical events when discovered from archaeological sites or historical archives. However, deciphering them presents challenges, as the heat can cause ink or writing materials to evaporate or fuse with the surface, making the text illegible. To decipher charred documents, experts utilize various techniques such as imaging, chemical analysis, and comparative analysis with known texts. Additionally, their understanding of the document's language, script, and historical context is crucial. Deciphering charred documents is significant as it can provide leads in criminal investigations and reveal new insights into the past that would otherwise remain lost.

The composition of writing inks modifies with time, and before the twentieth century, iron and copper were as tagging agents in writing inks. Different methods were utilized by researchers to decipher text written with such inks. For example, potassium ferrocyanide was used by Blagden (1787) [2], while a photographic plate was incorporated by Davis (1922) to decipher charred documents [3, 4]. Later, calcining method, different light sources like infrared (IR) light, ultraviolet (UV) light, and fluorescent oil were also used [5]. Over the years, advancements were made using chloral hydrate, 5% silver nitrate solution, alcohol-glycerine technique, etc., for burned document decipherment. Over time, the corrosion of iron in pen nibs led to its removal from ink formulations. Modern inks now contain a mixture of pigments, colours, resins, glycerol, alcohol, oils, and fats, devoid of any metals [2]. When these inks undergo combustion, components such as pigments, dyes, alcohol, and resins are consumed, leaving behind oils and fats due to their high boiling points. This residue aids in deciphering writing created through various methods. Nevertheless, the fragile nature of charred documents poses a significant challenge for forensic experts conducting questioned document analysis.

To address this issue, researchers have explored several approaches for preserving, stabilizing, and interpreting fragile charred documents. One such method involves the application of thin coatings, a technique known as palimpsest imaging [6, 7]. The term palimpsest refers to a manuscript where original writing has been erased or obscured and replaced with new writing. Utilizing coatings like gold or silver, this technique has successfully revealed hidden text in ancient manuscripts, such as the Archimedes Palimpsest, and documents from the Villa of the Papyri. However, the high cost associated with using precious metals and the limited applicability primarily to decipherment rather than preservation present drawbacks. Further, researchers have also used various chemical methods like Polyvinyl acetate (PVA), acetone, ammonia solutions, alkyl-2-cyanoacrylate ester [9, 10]. However, Harrison suggested precautions when using PVA, considering its hindrance under IR and UV light [11, 12]. Challenges with such chemicals often include toxicity, low resistance to weather and moisture, poor resistance to solvents, slow setting speed, and application difficulties. To overcome these shortcomings, a green, non-toxic method using natural polysaccharides or seed mucilage, such as sago seeds, was proposed for charred document stabilization and preservation [13, 14]. This method aims to provide strength, better preservation, and decipherment while being cost-effective, fast, and easy to synthesize and apply [9]. The study has significance in forensic document examination and historical document conservation, allowing preserved charred documents to serve as evidence in legal cases and historical artifacts.

Polysaccharides are natural polymers that can replace non-degradable petroleum-based materials in paper coatings. Starch, a common example, consists of glucose structures forming amylose and amylopectin units [15]. These molecules have hydroxyl groups that bond strongly with paper fibers, improving properties like mechanical strength and barrier properties. By modifying them chemically and adjusting temperature, their properties can be enhanced further. Polysaccharides also allow for the incorporation of functional additives like conductive or antimicrobial agents onto paper surfaces [16]. This study investigates the utilization of natural polysaccharide sago in document coatings to facilitate preservation and decipherment methods. The study involves analyzing the proximate composition and structural differences between pure sago and its modified and synthesized

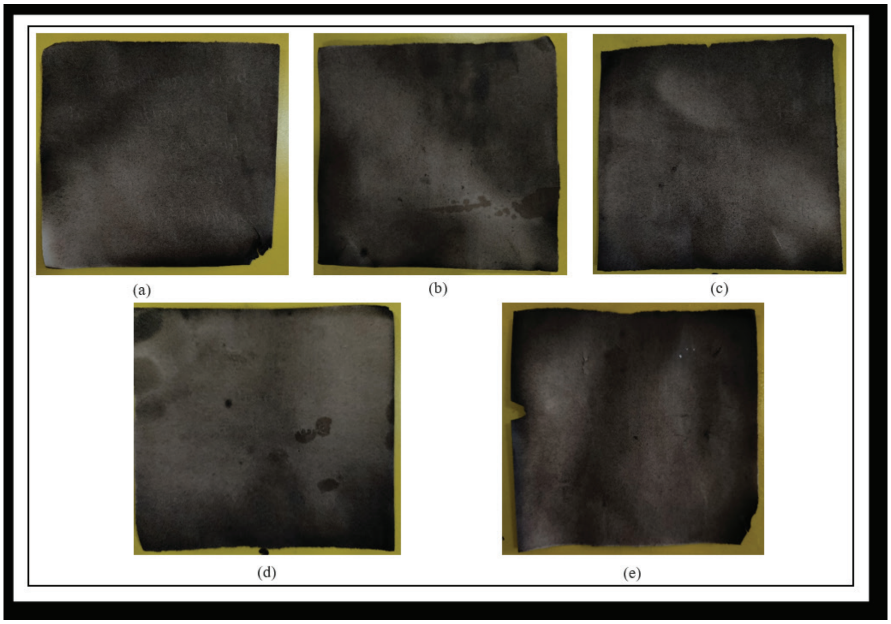

Figure 1: Samples a, b, c, d, and e showing invisible and unreadable texts charred at 300 °C

analog using Attenuated Total Reflectance-Fourier Transform Infrared Spectroscopy (ATR-FTIR) [17-19]. Furthermore, it assesses the mechanical strength of coated charred documents compared to non-coated ones and introduces an advanced decipherment technique using Optical Character Recognition (OCR) via Google Lens (G-lens) [20-22].

Utilizing the capabilities of a free tool G-Lens, which is an OCR tool renowned for its ability to identify a wide range of information, texts, links, and precise barcodes, as well as perform rapid and straightforward analysis using its comprehensive database [20-23] was employed to analyze and identify deciphered texts from images of charred documents. This process converted the images into a format of text that is readable and copiable. Kumar and Alimohammadi (2023) conducted a study on the effectiveness of G-Lens compared to traditional techniques and its potential to replace them. The findings highlighted the advantages of G-Lens over traditional procedures in enhancing information services, and raising awareness among information professionals and users about its utility as a comprehensive search platform. Additionally, the study emphasized the usefulness of G-Lens for the rapid and accessible dissemination of information [24]. Keeping this in mind, the present study also examines the effectiveness of G-Lens in questioned document examination, particularly for charred and historic documents, representing a novel application within this field.

## 2. Materials and Methods

The study involved the use of Sago seed (Sabudana) purchased from a local general store, glycerol, ethanol, and acetic acid of SRL (Sisco Research Laboratory) grade.

## 3. Sample Preparation

### 3.1. Charred Samples

Charred samples were prepared by writing a random paragraph on white 75 gsm paper (JK copier) with a Linc Pentonic blue ballpoint pen. A total of 10 samples were prepared of 10×10.5 cm. To ensure consistency, the same person wrote on each sample, thus avoiding any influence from varying pen pressures. Subsequently, the prepared document samples were subjected to charring in a muffle furnace, at temperatures ranging from 280-310 °C. Samples charred below 300 °C retained visible written content, while those charred at temperatures above 300 °C began to burn and gradually turned into ashes. Maximum charring with invisible texts was found in samples charred at a temperature of 300 °C(Figure 1), so it was considered for the present research.

Figure 2: Prepared Sago Analog

## 4. Method of Seed Mucilage Extraction and Preservative Preparation

### 4.1. Extraction of Sago Seed Polysaccharide

20 g of Sago (Cycas revoluta) was soaked overnight in 50 ml of distilled water. It was then ground into a fine paste in a domestic grinder and filtered using a fine sieve to remove any unground particles to get mucilage as filtrate.

### 4.2. Synthesis of Sago Seed Analog

To the filtrate, 1 ml of glycerol, 2 ml of ethanol, and 1 ml of acetic acid were added. Thereafter it was subjected to microwave irradiation at temperatures 170 °C, 180 °C, and 190 °C for 5 min., 7 min., and 9 min. to optimize the synthesizing analog as shown in Table 1 and Table 2. During the process, the mixture was stirred using a glass rod until a clear, transparent sago analog was obtained, as shown in Figure 2. The chemical reaction between the reactants is shown in Figure 3.

## 5. Spectral Characterization

The sago, in its pure form ground into powder, along with the synthesized sago analog, underwent ATR-FTIR analysis using a Bruker instrument for spectral characterization. This analysis aimed to identify different band stretching patterns and determine whether new peaks emerged after the reaction between sago starch and glycerol in an acidic environment, as illustrated in Figure 5. The Bruker ATR-FTIR instrument employed a diamond ATR crystal. Before analyzing the samples, a background spectrum was obtained to account for any instrumental or environmental noise, with measurement conditions set within a desired wavenumber range of 4000-400 cm$^{-1}$. Following this, the samples underwent spectral measurements, with the spectrum recorded as percentage transmittance (%T) against wavenumber (cm$^{-1}$). The measurement process was repeated three times to ensure the reproducibility of results.

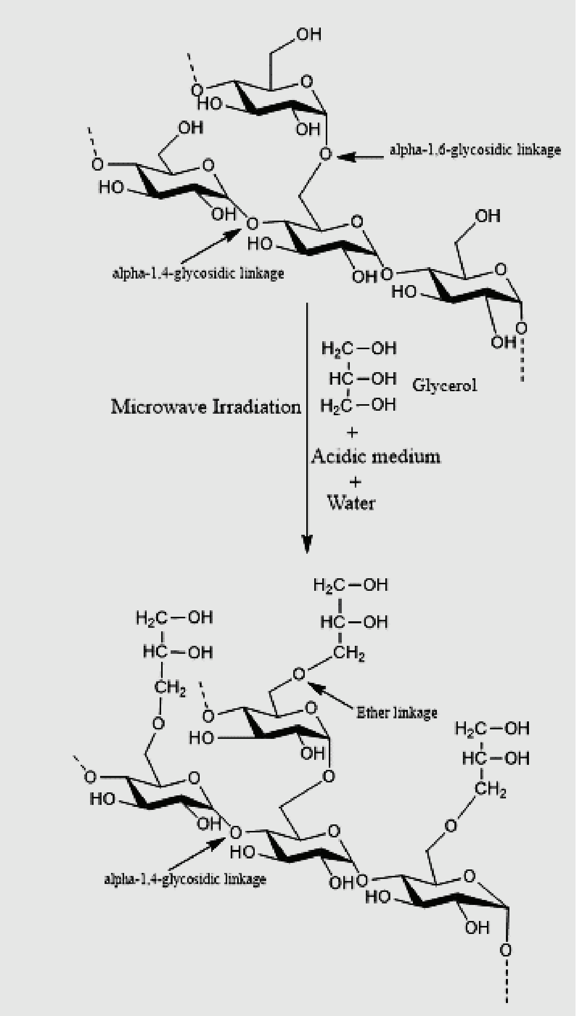

Figure 3: Etherification of amylopectin molecule of sago starch and glycerol in an acidic medium: Reproduced from open access article [31].

| S. No. | Duration (min.) | Observation |
|---|---|---|
| 1. | 5 | Low viscosity, not appropriate for coating |
| 2. | 7 | Optimum consistency and viscosity, appropriate for coating |
| 3. | 9 | High viscosity with white flakes, not appropriate for coating |

Table 1: Effect of Reaction Temperature on the Synthesis of Sago Analog.Reaction Duration: 7 min.

| S. No. | Temperature (°C) | Observation |
|---|---|---|
| 1. | 170 | Low viscosity, not appropriate for coating |
| 2. | 180 | Optimum consistency and viscosity, appropriate for coating |
| 3. | 190 | High viscosity, flaky appearance, not appropriate for coating |

Table 2: Effect of Reaction Duration on the Synthesis of Sago Analog.Reaction Temperature: 180 °Cmin.

## 6. Application of Sago Analog

The sago analog, once prepared, was carefully applied onto five charred samples using finger-wearing gloves, ensuring a smooth and evenly coated layer for preservation. Another set of five charred samples was kept aside for comparison purposes, focusing on their physical properties, particularly the strength, and the visibility of texts before and after coating application.

## 7. Optical Character Recognition (OCR)

After applying the synthesized sago analog, an image was captured using a OnePlus Nord CE 5G mobile camera.Subsequently, OCR software, specifically G-Lens was utilized to analyze the image. Google Lens, an easily accessible OCR tool, employs an algorithm to search and analyze captured images, converting them into readable and copiable text format [20].

## 8. Video Spectral Comparator (VSC)

The coated charred sample was then subjected to analysis using an advanced optical technique known as the Video Spectral Comparator (VSC). This device incorporates various light sources, such as floodlight, white spot light, and among others. The coated samples were placed in a visualization chamber, and different light sources with varied wavelengths were applied to assess the maximum visibility of the deciphered texts.

## 9. Strength Test of Coated and Non-coated Charred Samples

### 9.1. Paper Folding Test

After the coated charred samples were thoroughly dried, they underwent an initial assessment of their strength compared to non-coated charred samples through a paper folding test. This test involved folding the paper edge from one side and observing the tearing interval upon folding. Initially, the edges of the non-coated charred sample were folded along the sides, and then the same procedure was repeated with samples coated using the sago analog. This test aimed to approximate the increase in strength achieved by coating the samples with the sago analog for extended preservation.

### 9.2. Bursting Strength Determination

To determine the bursting strength, both the coated and non-coated charred samples were tested using a Pacorr Digital Bursting Strength Tester. The

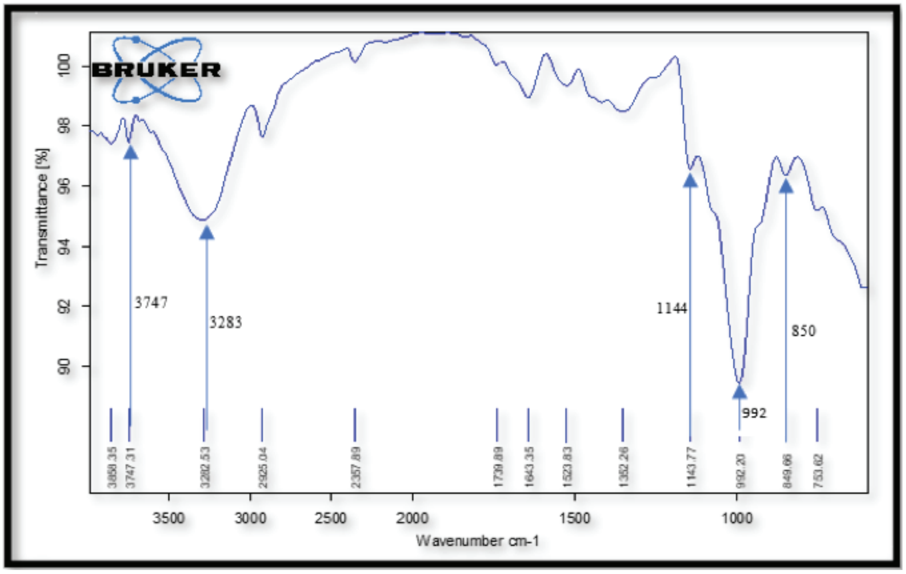

Figure 4: ATR-FTIR spectra of Pure Sago powder.

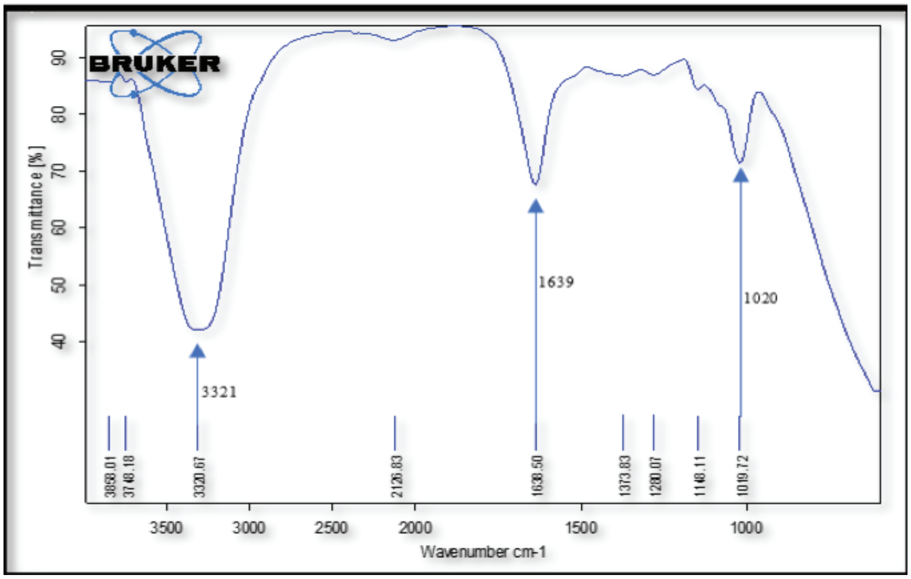

**Figure 5:** ATR-FTIR of synthesized Sago Analog.

non-coated charred sample was placed on the frame of the tester, and a plunger was then used to apply force gradually to the sample material until rupture occurred. The bursting strength tester recorded the force exerted by the plunger at the point of sample rupture, providing quantitative data on the strength properties of the documents. The same procedure was repeated for the coated charred samples after preservation with the sago analog.

## 10. Results and Discussion

Table 1 and 2 shows that the appropriate consistency of sago analog was achieved at 180 °C microwaved for 7 min. This is because, at this temperature, the analog exhibited the highest level of transparency, allowing for easy visualization of the coated documents (Figure 6). The viscosity of the synthesized analog was also in the appropriate range (12 cps), ensuring smooth and consistent application on charred documents.

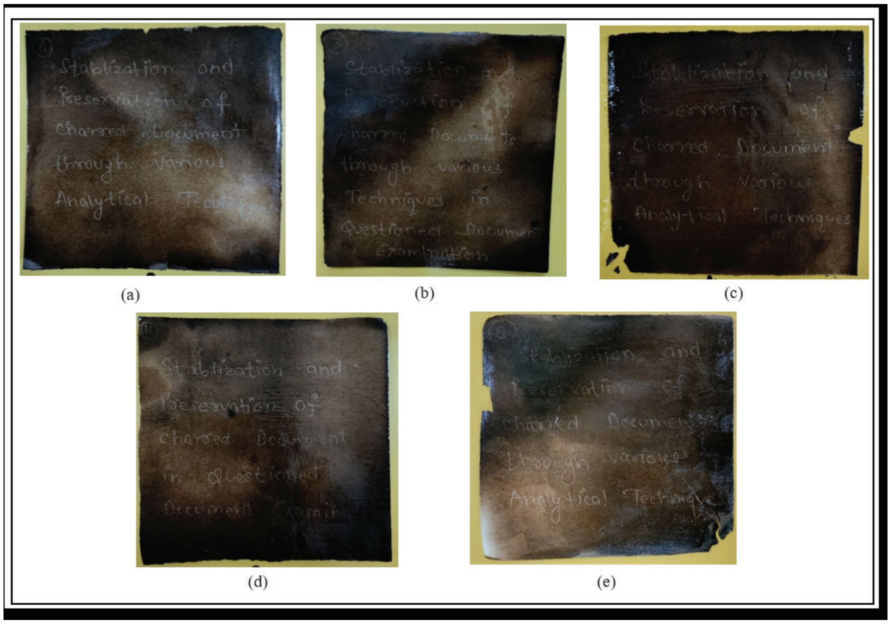

Figure 6: Coated and preserved charred samples a, b, c, d, and e showing deciphered, i.e., visible and readable texts.

Furthermore, the prepared sago analog was white, clear, and mucus-like in colour and texture which was found appropriate for coating and preserving charred documents.

The analysis of pure sago powder and the prepared sago analog, shown in Figure 4 and Figure 5, reveals distinct ATR-FTIR spectra characteristics. The ATR-FTIR spectrum of pure sago indicates the presence of α-1,4-glycosidic linkage at 1144 cm$^{-1}$ [25], as well as α-1,6-glycosidic linkage at 992 and 850 cm$^{-1}$ [26], representing the skeletal mode of the amylopectin sago starch ring. Additionally, significant -C-OH stretching of the primary and secondary alcoholic groups is observed at 3747 cm$^{-1}$ and 3283 cm$^{-1}$, respectively. Conversely, the spectrum of the sago analog (Figure 4) exhibits a distinct spectral peak between 1300-1000 cm$^{-1}$ [27], particularly at 1020 cm$^{-1}$, indicating potential etherification reactions between starch and glycerol. This suggests the formation of ether (C-O-C) linkage between the primary -OH and terminal -OH groups of the glycerol molecule in the synthesized sago analog [17, 28]. However, the difference in spectra, or the ether peak at 1020 cm$^{-1}$ in Figure 4, appears minimal due to partial etherification occurring during the condensation reaction between sago starch and a glycerol molecule.

In incidents involving fire, documents exposed to high temperatures experience dehydration, resulting in fragility and weakness. The loss of written content and the darkening of documents caused by intense heat and smoke pose considerable challenges during the process of deciphering documents. When the sago analog was utilized, it was noted that under typical daylight conditions, the text became visible to the naked eye across most parts of the charred document, as demonstrated in Figure 6. In contrast, in some areas, the text was only slightly visible under oblique lighting, whereas before the application of the sago analog, it was invisible both to the naked eye and under oblique lighting in daylight conditions, as shown in Figure 1. This improvement may be attributed to the removal of carbon particles from the ink of the previously invisible text upon application of the sago analog onto the charred documents, thereby rendering the text legible.

Following the application, the texts became instantly visible, and the samples were then photographed. The captured images of deciphered texts underwent a preliminary decipherment process using OCR through G-Lens to assess their readability level by converting the images into text. The method gave a promising result as it was observed that the


“Stablization and P... Analytical Techra”

विभिन्न विश्लेषणात्मक तकनीक के ...

(a)

“Stablization aun Pr ...ent Examination”

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(c)

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(d)

“Stablization and P...echnique Teching”

स्थिरीकरण और prese esservati...

(e)

Figure 7: Figures a, b, c, d, and e showing OCR read texts through Google lens.

G-Lens recognized the maximum words of a coated charred image in Figure 7a, 7c, and 7d and converted it into readable and copiable texts as “Stabilization and Preservation of Charred Documents through various Analytical Techniques”. However, only a few words and characters were not recognized by G-Lens (e.g., ‘of’ in Figure 7b and ‘of’ and ‘various’ in Figure 7e), even if they were visible through the naked eye. This may be due to the low intensity of the visibility of texts or due to the lighting and angle of the camera with the paper surface while capturing the image.

Furthermore, the advanced instrumental technique using a Video Spectral Comparator (VSC), revealed that the texts which were faintly deciphered through the application of sago analog became significantly more visible under different light sources and wavelengths. As depicted in Figure 8, the faintly visible texts, such as ‘preservation’, ‘and’, ‘of’, ‘document’ in Figure 8b, and a few previously invisible texts, became more prominently visible under white spot light within the visible range, and white balance settings of 134 (R) and 888 (B). Similarly, other texts shown in Figures 8a, 8c, 8d, and 8e, also became remarkably visible under flood light and white spot light within the visible range.

Additionally, it was noted that the sago substitute exhibited notably brief drying and setting times, typically lasting between 10 to 15 minutes after being applied to charred specimens. Once dried, this sago alternative created a protective layer over the charred document, resembling a polish that smoothed the surface and reduced the fragility and brittleness of the document by initiating a rehydration process. Additionally, the application of this protective polysaccharide layer of sago increased the mechanical resilience of the charred samples. This was confirmed through general observations of thickness and folding tests conducted on both coated and uncoated charred samples. Non-coated charred samples exhibited extreme fragility due to dehydration under high temperatures, breaking easily upon slight folding along the edges. Conversely, coated charred samples with the sago analog displayed increased flexibility and stability, withstanding bending and folding along the edges without breaking as rapidly as non-coated samples. This indicates that the preservation and stabilization of charred samples with the sago analog resulted in rehydration, rendering them more flexible and stable, thereby enhancing their strength.

Moreover, a quantitative examination was conducted to assess the stability and strength improvement of coated charred samples. Utilizing a digital bursting strength tester, it was observed that the bursting strength of 75 gsm non-coated charred samples averaged 0.12 kg/cm$^2$ ± standard deviation. In contrast, stabilized and coated charred samples exhibited an increased bursting strength, measuring 0.19 kg/cm$^2$, as depicted in Figure 9. This augmentation in strength is likely attributable to the penetration and absorption of the sago analog into the

(a) (b) (c)

(d) (e)

Figure 8: Visualization of coated charred documents under Video Spectral Comparator having enhanced deciphered texts.

charred paper substrate. Consequently, this reinforces the charred layer, leading to an overall enhancement in its strength.

## 11. Conclusion

The current study demonstrates a novel approach utilizing sago seeds, a natural polysaccharide, for charred documents preservation and decipherment, offering an easy, non-toxic, sustainable, and cost-effective method. The accessibility of sago seeds contributes to the cost-effectiveness of this approach. Additionally, the use of microwave irradiation for synthesizing the product streamlines the process, making it convenient, rapid, environmentally friendly, and non-laborious. The application of the synthesized sago analog for charred document preservation and decipherment is promising, as it effectively reveals previously invisible text and remains legible to the naked eye upon application. Furthermore, employing the widely available optical recognition tool, Google Lens, through a mobile camera yields commendable

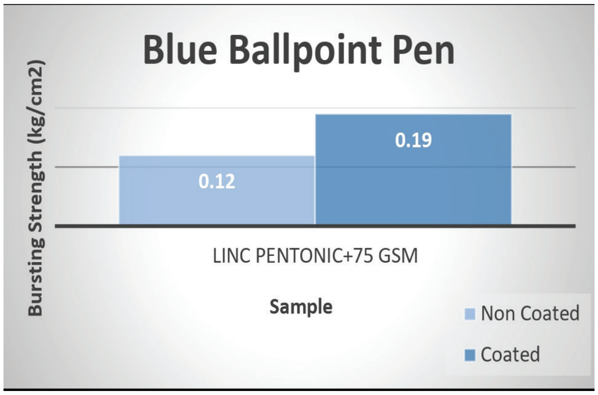

Figure 9: Illustrates the increase in Bursting Strength between Non-Coated and Coated charred documents.

results in character recognition, surpassing 95%, without the need for sophisticated equipment. The use of Google Lens for deciphering charred documents provides reliable textual evidence suitable for presentation in legal proceedings. Moreover, the enhanced bursting strength observed in the preserved and coated charred samples imparts sufficient stability compared to the fragile, brittle, and hard-to-handle non-coated charred samples. Therefore, based on these findings, it is evident that this research holds significant potential for stabilizing, preserving, and deciphering charred documents. It can contribute valuable insights to the field of forensic document analysis, aiding professionals in the preservation and decipherment of charred documents. Additionally, the findings suggest the potential use of charred documents as evidence, even after exposure to high temperatures, utilizing a non-toxic, environmentally safe material, natural polysaccharide, instead of synthetic polymers.

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# DETERMINATION OF THE AGE OF GEL PEN INKS ON HANDWRITTEN DOCUMENTS USING GAS CHROMATOGRAPHY-MASS SPECTROMETRY AND CHEMOMETRICS

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**Abstract / Overview:**
**Background:** *The accurate determination of age of ink used in the documents related to forensic cases is often submitted to forensic document examiners. Determining the age of ink refers to assessing the most probable time when the ink was used to write on paper. It may become tedious due to the great variety of writing inks available in the market and due to the complexity of chemical processes that occur over time after the deposition of the ink onto the paper. Limited work is available concerning non-ballpoint pen inks. Thus, the study addressed the determination of the age of the writings made using gel pens of 4 different coloured inks by studying their volatile components by employing GC-MS. The effects of the storage conditions and different substrates (paper) on the aging of ink were also assessed.* **Results:** *More than 70% drop in the peak area was observed initially, which increased with time and the fall was more or less stable up to 60 days, after which the peaks disappeared. Slight effect of the type of substrate and storage condition was observed. The results were backed with Karl Pearson's correlation method suggesting comparability between the samples stored in closed and open storage conditions.*
**Conclusion:** *GC-MS is suitable for studying the solvent components of gel pen inks for the determination of the age of ink. The methodology used in this study provided reliable results for writings stored for up to 75 days.*

**Keywords:** Documents, questioned documents, determination of the age of the ink, determination of the age of documents, dating of pen inks, dating of documents, gel pen inks, gas chromatography-mass spectroscopy, the effect of substrate, likelihood ratio.

## 1. Introduction

The constituents of ink are divided into three categories: vehicles, colorants, and additives. A vehicle acts as a carrier and provides a medium for the colorant to flow, and is volatile. Acolorant is mainly dye or pigment, which is used to provide color to the ink. Additives contribute towards viscosity, adhesion, rheological properties, etc. (1). The inks used in pens are broadly classified into ballpoint pen and non-ballpoint pen ink. These inks can also be classified into water-based or oil-based inks. The inks used in ballpoint pens are oil-based, and those in non-ballpoint pens are water-based, which include gel, fountain, pilot, fibre tip pens, etc. (2).

The determination of the age of the ink has been discussed based on the static profile, that is, the evaluation of the properties that do not change with time, and the dynamic profile, that is,the evaluation of the changes that occur in the different components with time (3). Ink has been considered a solution of a volatile solvent and a non-volatile solute present in a vertical container open at one end (for example, a pen cartridge). After the ink gets deposited onto the paper, various physical and chemical changes occur, such as colorant degradation, solvent evaporation,

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