

# Research analysis on the physical preservation of Daluang and European paper manuscripts in the Scopus database

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## ABSTRACT

**Background:** The preservation of cultural heritage manuscripts has long been guided by conservation techniques developed for European paper. However, Daluang paper behaves differently from Western paper, raising concerns about the suitability of directly applying European methods to its care. **Purpose:** This study aimed to compare the physical preservation between Daluang manuscripts and European paper manuscripts, for which different methods were used to preserve cultural heritage. **Methods:** A total of 38 peer-reviewed articles were analyzed using a systematic literature review (SLR) from the Scopus database between 2015 – 2025. **Results:** The findings provided evidence on the susceptibility of Daluang manuscripts to fungi and moisture-induced degradation, particularly in tropical countries. In European paper manuscripts, changes in acidity often lead to corrosion. Protection methods for Daluang manuscripts focus on environmental adjustments and preventative measures, whereas European paper requires chemical treatments, such as acid reduction or phytate-based ink protection. **Conclusions:** This study concludes that multilateralism is needed for manuscript preservation, with underpinning principles grounded in conservation science, cultural heritage, and the analytical investigation of materials. More localized research and conservation are urgently needed for endangered collections such as the Daluang manuscripts. **Implications:** These findings imply that conservation implementation must be adapted to the material characteristics, historical trajectories, and environmental contexts of each manuscript, as demonstrated by European and Daluang traditions. In practice, this implies the urgency of developing localized, preventive conservation strategies integrated with digitization to support sustainable preservation and broader access.

**Keywords:** Preservation based on culture; Daluang manuscripts; European paper; Cultural Heritage

## INTRODUCTION

Protecting ancient manuscripts is crucial for securing a nation's cultural heritage. To ensure effective preservation

efforts, it is necessary to understand the specific material characteristics of different traditions, particularly when conservation practices developed for one material are

applied to another (Rachman & Salim, 2018). The state of preservation of extant Daluang manuscripts must be appraised alongside that of European manuscripts, as this will influence the choice of preventive measures. In Indonesia, most preservation methods tend to follow European paper-based preservation procedures without considering that Daluang's physical properties, fiber structure and environmental reactivity differ significantly from those of European papers containing hemp and cotton cellulose (Rachman & Salim, 2018).

Daluang paper is produced from the fibers of the Saéh tree in Sundanese or Glugu in Javanese, both known by their English name Paper Mulberry (*Broussonetia papyrifera*). Daluang paper preserves not only knowledge but also local stories and beliefs reflecting traditional Indonesian culture before European influence. Critically, preserving Daluang writing means safeguarding cultural heritage artefacts while preserving shared memory and cultural understanding (Rachman et al., 2022).

The preservation of indigenous manuscripts, such as the Daluang has implications regarding the diversity and sustainability of cultural heritage on a global scale (Lázaro Ortiz & Jiménez de Madariaga, 2022). However, the current condition of the Daluang manuscripts is poor. Physical damage to many texts is due to age, the humid tropical climate and poor storage facilities. (Rachman & Salim, 2018).

Consequently, a comprehensive comparative understanding of the environment and degradation of Daluang and European paper manuscripts is crucial. Understanding each material's

behavior in response to conservation treatments enables conservators to design more effective treatment strategies. Numerous paper conservation methods have contributed to understanding the preservation and degradation of historical paper in Asian and European manuscripts.

Rachman & Salim (2018) investigated the physical features of the Daluang manuscripts in Cirebon. Furthermore, Rachman et al. (2022) discussed the traditions of functional care in Surakarta. As previously mentioned in research on the Daluang manuscripts and their cultural and historical significance, there is an emphasis on developing preservation methods that account for both material and cultural considerations. These emphases and highlights are substantiated by additional research on European paper manuscripts, as noted by Kralka (2022), which found differences in methodological approaches between Eastern and Western cultures.

Besides these materials and culture-based studies, recent research underscores the need for a systematic approach to evidence synthesis. Wibowo et al.'s (2024) study on the sustainable preservation of Ambonese manuscripts demonstrates how a systematic review of the literature reveals patterns of degradation, preservation challenges, and community-based conservation models. Therefore, this study illustrates how structured review methods can be used to interpret current preservation practices and identify gaps to inform future research.

These developments have demonstrated the increasing importance of systematic and comparative

approaches in manuscript preservation research. The Systematic Literature Review (SLR) offers a means for researchers to systematically and transparently explore and consolidate existing scientific evidence (Siddaway et al., 2019). Nonetheless, despite the adoption of systematic literature reviews in research on manuscript preservation, no systematic review has yet compared the preservation of Daluang manuscripts with that of European paper manuscripts.

Thus, this study aims to review scholarly literature to identify trends in Daluang preservation, investigate the varying physical conditions and reported deterioration of Daluang and European paper manuscripts, and compare their respective preservation and conservation methods. This research will foster a greater understanding of the comparative perspective sought between these two traditions.

## RESEARCH METHODS

The approach used in this study was a systematic literature review (SLR) of peer-reviewed articles published in SCOPUS- indexed journals, following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol. The goal was to examine how research has evolved and pinpoint knowledge gaps (Tlili et al., 2022). SLRs are useful for synthesizing previous work and integrating it into deeper insights and understanding (Torres-Carrion et al., 2018). This process helps generate theory and reveal under-researched topics. Using the SLR method, this study

identified peer-reviewed articles published in the last 5 years, following the PRISMA protocol. The aim was to understand the evolution of research in the research topic area and identify knowledge gaps (Tlili et al., 2022). The SLR summarizes and synthesizes evidence from previous studies and transforms it into knowledge (Torres-Carrion et al., 2018). This study aimed to identify the following:

RQ1: What are the current research trends and the physical conditions or types of deterioration commonly reported in Daluang and European paper manuscripts?

RQ2: What preservation methods are used for Daluang and European paper manuscripts?

This study utilized the SCOPUS database because it covers a wide range of publications in the social sciences and offers high-quality, selected articles.

The citation limitations used in this study were publications from 2015 to 2025, or the last ten years since this study was conducted. The PRISMA protocol used in this study guided the identification, screening, and inclusion of articles. The inclusion criteria were peer-reviewed articles (2015–2025), published in English, and focused on the physical preservation and conservation of paper manuscripts or Daluang. The search process was carried out by entering search keywords, which combined and integrated synonymous vocabulary using Boolean operator search methods such as OR, AND, and NOT. The PRISMA flow diagram is shown in Figure 1.

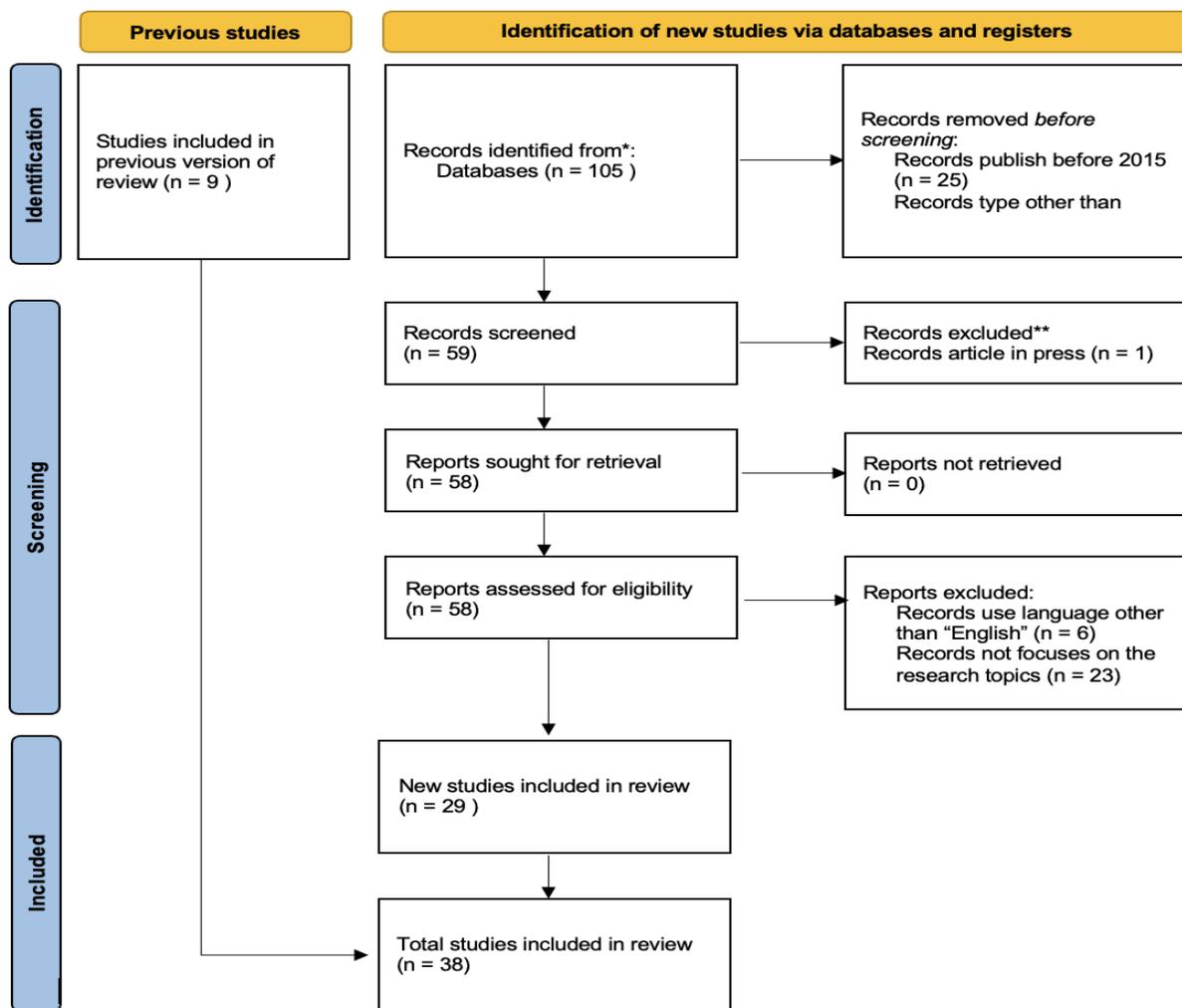


Figure 1. The PRISMA flow diagram

Source: Author's processing based on Scopus (2015–2025)

Figure 1 outlines a transparent and systematic process for identifying and selecting studies for inclusion in this literature review. The nine previous studies included in this review were identified through a systematic search of the SCOPUS database. For this previous search, the keywords "Daluang" OR "Dluwang" were applied across the article title, abstract, and keyword fields. Articles retrieved from these earlier searches formed the foundation for the current review and were combined with newly identified studies from the updated search (2015-2025) to create a more comprehensive analysis.

In the identification phase, the keywords used in this study were

"preservation" AND "conservation" AND "paper manuscript" OR "Daluang" OR "Dluwang in "article title, abstract, and keywords". Initially, 105 records were identified. After removing 25 publications published before 2015 and irrelevant records, we identified 59 records for screening. One publication in the process was excluded at this stage, leaving 58 articles for eligibility assessment. Twenty-nine studies were included in the review, along with 9 from the previous review, for a total of 38.

Regarding the data analysis phase, all eligible articles were carefully examined at the full-text level. A data extraction form was created based on

structured variables, including publication year, research focus, physical conditions, factors causing deterioration, and preservation methods. All extracted data were carefully analyzed using an inductive thematic analysis. Similar codes were grouped into broader themes to identify research trends, determine deterioration patterns, and categorize preservation methods for Daluang and European manuscripts.

## RESULTS AND DISCUSSION

Thirty-eight papers were identified for synthesis through a literature search in Scopus. These papers highlight the spectrum of scholarly activity focused on the Daluang manuscript and on European paper-based materials, including conservation strategies, digitization initiatives, and historical and cultural contexts. Research trends in the preservation of Daluang manuscripts and European paper-based manuscripts are shown in Figure 2.

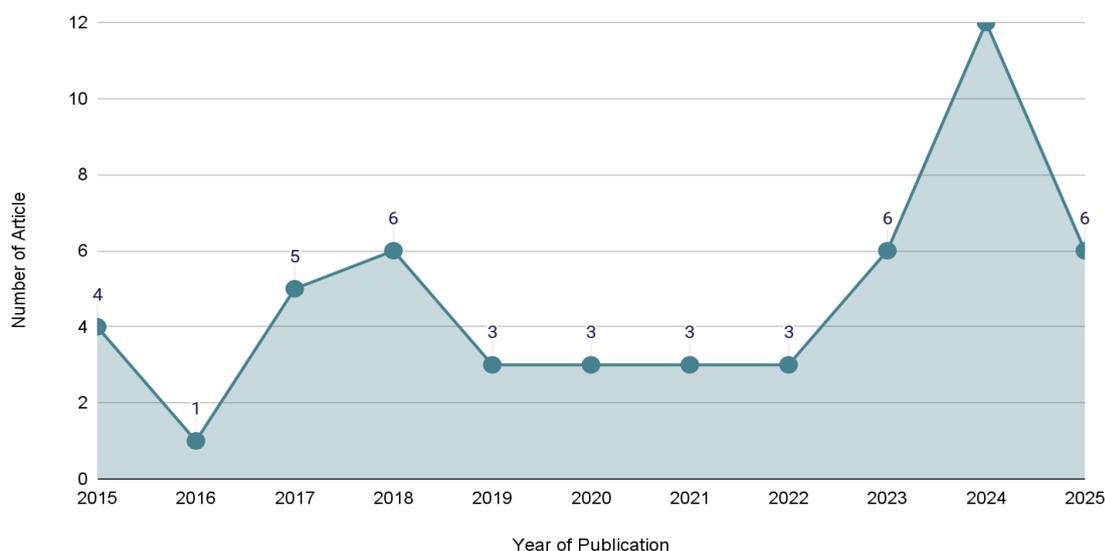


Figure 2. Number of articles published per year (2015–2025)  
Source: Author's processing based on Scopus (2015–2025)

Figure 2 reflects the dynamics of academic interest between 2015 and 2025. Early 2015 saw a lukewarm start, which then declined significantly in 2016. Interest in the movement grew and peaked locally in 2018 before tapering off. There was a prolonged period of stagnation followed from 2019 to 2022. Revival commenced in 2023 and peaked in 2024. While output slightly dropped in 2025, it remained above the levels reached during the previous stagnant years, suggesting a resurgence and potential increase in

academic interest in this niche of cultural heritage preservation.

Figure 3 shows a network map of keywords according to SCOPUS-indexed publications from 2015 to 2025. Links between nodes represent the co-occurrence of these terms in similar contexts, and the size of each node conveys their frequency. The words are grouped into color clusters that indicate the content's themes. The red cluster highlights keywords such as preservation, conservation, manuscripts, palm-leaf



Table 1  
Selected journal on the preservation of Daluang manuscript

Code	Author	Year	Cite
A1	Oetari et al.	2016	46
A2	Sukmawati et al.	2015	13
A3	Lintang et al.	2021	7
A4	Rachman & Salim	2018	6
A5	Padarik et al.	2016	6
A6	Daneshgar	2021	2
A7	Rachman et al.	2022	1
A8	Salim et al.	2021	1
A9	Che Omar & Arifin	2023	0

Source: Author's processing based on Scopus (2015–2025)

Based on the cluster visualization of co-occurring terms in the uploaded network map, the focus of contemporary research on the preservation of Daluang Manuscripts can be primarily construed into three distinct thematic clusters, as shown in Figure 4. Cluster 1, colored red, falls in the material degradation and microbial biodeterioration category. This cluster includes terms such as carboxymethyl cellulose (CMC), microcrystalline cellulose (MC), cellulolytic, fungi, deterioration, and xerophile. These collocated terms direct the research trajectory, with an emphasis on the chemical and biological mechanisms that cause degradation in manuscripts, particularly through microbial agents such as fungi and cellulolytic (cellulose-destructing) activity. It is also common in studies in this cluster to examine how environmental conditions, particularly in humid and xerophilic environments, trigger biodeterioration and how additives such as CMC and MC contribute to paper durability or conservation measures. This reflects the conservation science of European manuscripts, which is closely related to hard materials, microbiology, and

stabilization approaches through chemical treatment protocols and restoration science.

Cluster 2, highlighted in green, relates to the cultural background and significance of the Daluang Manuscripts. None of the above search terms yielded any other results. Other keywords included Cirebon, Daluang manuscript, Indonesia and manuscript preservation. From this, the second focus of interest is not the conservation of Daluang manuscripts in a more general sense but rather the preservation of the area or its cultural value. This examines the material aspects of manuscript conservation and how it can be used to preserve Indonesia's cultural heritage, particularly in Cirebon, where Daluang manuscripts have been produced for hundreds of years. Another aspect of this research area, namely the conservation of the heritage, itself, should be socially acceptable, locally-borne and consistent with the local knowledge system on how Daluang was made and used.

Cluster 3, highlighted in blue, relates to regional history and local manuscript traditions. This cluster includes Banyumas, the Dluwang manuscript, and

Kepangeranan Banyumas, signifying research aimed at exploring local or regional manuscript traditions and historical-political contexts such as the Kepangeranan (principality). This line of

research addresses the need to understand the provenance, uses, and ceremonial functions of Daluang manuscripts within different cultural settings in Java.

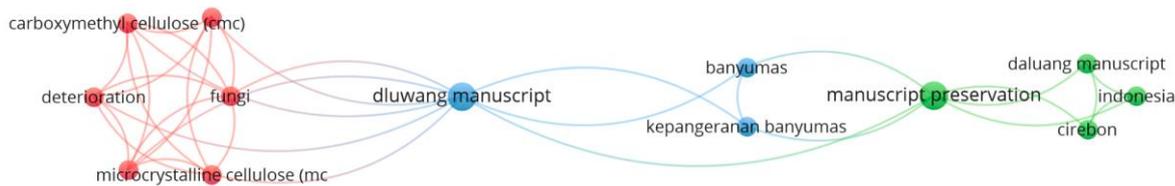


Figure 4. Research clusters on Daluang Manuscript Preservation

Source: Author's processing based on Scopus (2015–2025)

Daluang manuscripts are made from the bark of *Broussonetia papyrifera* (paper mulberry) tree, a plant native to Southeast Asia. As detailed in Table 2, Daluang manuscripts are thick, rough, and durable supporting ink retention and long-term preservation in tropical climates. Unlike European papers, especially those produced from the 19th century onward, which are more fragile with smoother surfaces and are prone to brittleness and deterioration from acids and ink corrosion, these bark sheets are fibrous, alkaline, and durable (Rachman et al., 2022; Sukmawati et al., 2015). The bark sheets are composed of long cellulose fibers, which add strength and resistance to acidity and biological attack (Oetari et al., 2016; Rachman, 2020) The manually process of making Daluang does not involve chemical additives, thus providing a stable base and bark for long-term writing. Observations of various Indonesian manuscript collections confirm that Daluang-based documents can remain legible and usable for several centuries (Salim et al., 2021).

On the other hand, post-19th-century European paper manuscripts are generally composed of wood pulp and are highly lignin-rich, making them more acidic and

susceptible to deterioration (Abdel-Maksoud et al., 2024; Hajji et al., 2015). Older European papers, composed from linen and cotton rags, were more stable but were later replaced by pulp-based mass-produced papers (Barkeshli et al., 2024). The presence of acidic binders in modern paper leads to brittleness, especially under changing environmental conditions (Yu et al., 2023). Consequently, many 19th and 20th-century European manuscripts now require deacidification or chemical reinforcement to avoid total disintegration.

Daluang is widely regarded for its high physical durability, thanks to the tightly woven, long plant fibers produced by its manufacturing process. The sheets exhibit significant tear and degradation resistance even after prolonged exposure to tropical conditions. Often found stacked or folded, these manuscripts remain flexible and strong due to the alkaline and organic nature of the sheets (Rachman et al., 2022). Moreover, a large number of well-preserved Daluang manuscripts in local museums or ancient archives, such as those in Surakarta and Banyumas, exhibit minimal loss of content and structural damage (Rachman, 2020).

Table 2

Physical conditions of Daluang and European manuscript paper

Physical Condition	Daluang Manuscript	European Paper Manuscript
Base material	Made from <i>Broussonetia papyrifera</i> (paper mulberry), which is naturally fibrous, strong, and durable. (A33, A31, A30, A36, A37)	Typically composed of wood pulp or cotton rags; more acidic and less stable over time, especially from the 19th century. (A10, A4, A19, A27)
Durability	Highly durable due to thick, intertwined plant fibers; resists tearing and aging under tropical conditions. (A33, A36, A5)	More fragile, especially with age; often becomes brittle and discolored. (A10, A18, A3)
Texture & surface	Rough and fibrous surface, which helps ink retention but also provides space for fungal growth. (A33, A36)	Smooth surface, good for writing, but more susceptible to damage from friction and folding. (A10, A3, A29)
Climate vulnerability	Relatively stable in tropical humidity but vulnerable in closed or unventilated storage spaces. (A5, A36, A32)	Highly sensitive to humidity fluctuations; requires strict environmental control to avoid deterioration. (A22, A21, A10, A3)

Source: Author's processing based on Scopus (2015–2025)

On the other hand, European paper manuscripts tend to be more sensitive to defects such as brittleness, yellowing, and cracking with age (Hajji et al., 2015; Salah, 2018). The high acid content and short wood pulp fibers in wood pulp paper can largely explain this sensitivity. In addition, high-grade rag paper also shows signs of degradation when stored under unfavorable conditions or handled carelessly. Studies report that older manuscripts typically exhibit corner damage, brittle edges, and flaking surfaces, especially visible along fold lines and binding edges (Collado-Montero & Espejo-Arias, 2015). Therefore, the conservation process for European manuscripts typically includes procedures such as re-backing, humidification, or lamination.

Daluang material also exhibits a rough and very gritty texture due to its organic, raw fiber composition. Its gritty texture is very useful in preserving ancient inks, especially the carbon-based

types, which bind well with minimal bleeding (Rachman et al., 2022; Rachman & Salim, 2018). To some extent, this texture tends to trap dust particles and airborne bio-pollutants, thereby providing conducive conditions for fungal growth. Importantly, species such as *Penicillium* and *Aspergillus* have been found embedded in the surfaces of ancient Daluang manuscripts preserved in highly humid environments (Oetari et al., 2016).

European paper, in contrast, typically has a smoother, more even finish due to industrial pressing and sizing techniques (Hajji et al., 2015). This smooth surface facilitates fine handwriting and legible ink, and the paper can be used for both print and cursive writing. The smoother finish, however, also makes the paper more fragile, and it can wear from folding or rubbing. In addition, corrosion from the type of ink commonly used in European manuscripts, such as iron gall ink, often penetrates the smooth paper and causes physical degradation in the

areas where the text resides (Collado-Montero & Espejo-Arias, 2015; Duh et al., 2018).

As seen in Table 3, Daluang manuscripts, especially in tropical conditions, are thick and porous, allowing them to resist high humidity without immediate deterioration. Traditional storage methods, such as open shelving and ventilated boxes, also play a role, as air circulation discouraged mold growth. However, Daluang manuscripts are susceptible to fungal growth when stored in closed or damp environments, particularly along folds and edges (Lintang et al., 2021). Case studies of libraries in Java demonstrate the significance of air circulation and periodic checking as preventive measures against microbial infestations.

The composition of European paper manuscripts is highly reactive to changes in humidity and temperature, which must be strictly controlled to maintain stability and avoid decomposition. Paper made from wood pulp is particularly prone to wrinkling, brittleness, and mold growth in high-humidity conditions (Moretti et al., 2024). Conservation standards suggest maintaining constant temperature and humidity, providing clean, filtered air, and protecting against ultraviolet (UV) radiation to avoid chemical and biological decay (Cerchiara et al., 2018). Manuscripts not maintained to these standards will experience foxing, ink bleeding and warping (rarely observed types of degradation in properly distributed Daluang) (Collado-Montero & Espejo-Arias, 2015; Hajji et al., 2015). Daluang manuscripts are also susceptible to fungal attack, particularly in humid conditions where ventilation may be inadequate.

Such conditions provide a favorable environment for fungi and yeasts, especially in closed boxes/wooden rooms without ventilation (Oetari et al., 2016; Salim et al., 2021).

Studies on the presence of microorganisms have identified species that directly attacked the Daluang manuscripts in the Surakarta collection, particularly, older manuscripts folded and stored as bundles, including *Aspergillus* and *Candida*. (Lintang et al., 2021; Rachman, 2020). Fungal infections of European paper may also pose a threat, although the risk is generally limited to post-flood storage environments or water-damaged materials. Fungi, such as *Penicillium* and *Trichoderma*, are capable of growing on European cellulose paper at relative humidity (RH) >65%, as is the case with untreated wood pulp paper made in the 19th century (Cerchiara et al., 2018; Hajji et al., 2015).

It has been reported that cellulose-degrading fungi may cause discoloration, brittleness, or even perforation of paper and in water-damaged cases, may require immediate treatment for libraries (Collado-Montero & Espejo-Arias, 2015; Moretti et al., 2024). Insect damage in Daluang manuscripts is rare, as the fiber structure produced by traditional pounding methods is dense and compact. Booklice and silverfish (*Lepisma saccharina*) can occasionally be found in neglected stored items, attacking starchy materials used for binding or ink (Oetari et al., 2016; Rachman & Salim, 2018). Although Daluang is bark-bound, small boreholes and edge nibbling have been occasionally recorded in long-unopened manuscripts (Rachman et al., 2022).

Table 3

## Deterioration of Daluang and European paper manuscripts

Deterioration	Daluang Manuscript	European Paper Manuscript
Fungal contamination	Frequently affected by mold and yeast, especially in areas with poor air circulation and high humidity. (A30, A32, A34, A26, A28)	Commonly colonized by cellulose-digesting fungi when exposed to moisture, especially after flooding or poor storage. (A21, A28, A19)
Pest damage	Less susceptible due to compact fiber structure, though some insect activity such as silverfish may still be observed. (A33, A36)	Vulnerable to insects such as silverfish, termites, and booklice in unsealed storage conditions. (A10, A18)
Ink corrosion	Risk of fading or ink migration due to organic-based ink reacting with plant fibers. (A30, A33)	Serious corrosion, especially with iron gall ink, leading to paper cracking and disintegration. (A2, A9, A24, A29)
Mechanical wear	Prone to fraying at edges and folding lines due to frequent handling or improper storage. (A36, A33, A37)	Shows spine stress, leaf detachment, and tearing from binding pressure and material brittleness. (A3, A27, A11)

Source: Author's processing based on Scopus (2015–2025)

European paper, however, is more palatable to bugs in hot, wet, unsealed conditions. Insects such as silverfish, termites and booklice cause significant damage as by feeding on paper fibers and binding adhesive used, creating tunnels through the pages or consuming the covers (Hajji et al., 2015; Salah, 2018). Several historical records and current appraisals indicate that inadequate pest control and the high-sugar organic glues used in European bindings also heighten the risk of pest infestations in archival and library collections (Abdel-Maksoud et al., 2024; Collado-Montero & Espejo-Arias, 2015).

Ink deterioration in Daluang manuscripts is primarily caused by a reaction between organic inks made from plant or mineral mixtures and the fibrous plant surface that serves as the writing medium. Over time, this can lead to color fading, ink migration, or even surface abrasion, particularly in areas exposed to

sunlight and frequent contact (Rachman et al., 2022; Rachman & Salim, 2018). The alkaline nature of Daluang mitigates this reaction to some extent; however, ink formulations containing metallic content can still be a potential threat (Salim et al., 2021).

European manuscripts are confronted with a more serious problem of ink corrosion due to the widespread use of iron gall ink throughout history. Acid oxidation during cellulose degradation leads to fast cracking and perforation followed by the loss of text lines (Duh et al., 2018; Yu et al., 2023). This paper destruction mechanism is not only damaging but also further reduces the durability and legibility of manuscripts, especially those in volumes where ink degradation is accelerated by pressure (Collado-Montero & Espejo-Arias, 2015; Hajji et al., 2015).

Daluang scripts are sturdy; however, mechanical damages to the

edges and folding lines is common in high-use manuscripts. The rolling or stacking of unwrapped manuscripts without interleaving has resulted in fraying, creasing, and surface fiber loss in the majority of collections (Rachman, 2020; Rachman & Salim, 2018). In addition, the surface will degrade over time due to oils and abrasion caused by repeated contact with ungloved hands (Salim et al., 2021). In addition, European paper manuscripts are highly susceptible to mechanical damage, including spine stress, loose leaves, and tears, both due to the brittle nature of old paper and as a consequence of taut binding. The stiffening of wood pulp paper with aging makes it susceptible to fold and hinge-related damage (Collado-Montero & Espejo-Arias, 2015; Hajji et al., 2015). Cracking along creases and marginal text loss in bound volumes are caused by mechanical pressure exerted when opening the spine (Abdel-Maksoud et al., 2024; Salah, 2018).

As shown in Table 4, Daluang manuscripts are preserved by wrapping them in cloth and storing them in wooden boxes or cabinets, which are typically held in private collections and local cultural institutions. Lacking environmental controls, these storage solutions also fail to regulate humidity and temperature, which can lead to degradation (Rachman & Salim, 2018; Salim et al., 2021). In most cases, storage is intended for ritualistic or cultural purposes rather than long-term preservation; manuscripts are often

stored in stacks without interleaving sheets or support (Oetari et al., 2016; Rachman, 2020). However, European paper manuscripts, especially in libraries and archives over the past two centuries, have been stored in wooden cabinets or open shelves.

As preservation consciousness increased, especially from the late 20th century onward, many institutions have shifted to acid-free enclosures, buffered folders and molded supports to reduce physical handling damage (Duh et al., 2018; Hajji et al., 2015). Best practice guidelines now consider not only the stability of library and archival materials but also the physical orientation (e.g., horizontal or vertical) to reduce stress on the spine and edges of the paper (Collado-Montero & Espejo-Arias, 2015).

Environmental control is still in its infancy in most Daluang manuscript repositories. Many small archives or local libraries lack consistent access to Heating, Ventilation, and Air Conditioning (HVAC) systems or dehumidifiers. Despite this, there is growing awareness and some institutions in Indonesia have implemented some degree of Relative Humidity (RH) monitoring and temperature control, especially for high-value or research-priority collections (Rachman et al., 2022; Salim et al., 2021). The literature reports that Daluang is generally stable at RH values of about 55–65%, yet the emergence of mold becomes more frequent above 70% (Lintang et al., 2021; Rachman, 2020).

Table 4

Preservation methods for Daluang and European paper manuscripts

Preservation Methods	Daluang Manuscript	European Paper Manuscript
Traditional storage	Commonly stored wrapped in cloth or in wooden boxes, often without environmental regulations. (A20, A5, A33, A36)	Previously stored in shelves and wooden cases; now typically stored in acid-free boxes with proper support. (A1, A10, A18)
Environmental control	Limited implementation; growing awareness in institutions to implement RH and temperature controls. (A22, A36, A32)	Advanced environmental systems in many archives, with HVAC and monitoring to control degradation. (A22, A21, A6)
Pest management	Use of natural repellents (e.g., herbal) and physical inspection; less standardized. (A36, A26, A28)	Integrated Pest Management (IPM) systems include monitoring traps and sanitation protocols. (A21, A26, A28)
Fungus monitoring	Increasing biological studies to identify fungal species and apply targeted treatments. (A30, A32, A34, A36)	Routine monitoring with spore sampling and lab diagnostics, especially post-disasters. (A28, A19)
Digital preservation	Digitization efforts are increasing in universities and local libraries to enhance access and safety. (A14, A15, A16, A25)	Well-established digitization projects are led by national libraries and cultural institutions. (A12, A14, A15, A25)

Source: Author's processing based on Scopus (2015–2025)

In contrast, European archives tend to have much better environmental controls. Modern preservation standards require stable RH (typically around 45–55%) and temperature (18–22°C), which are maintained using HVAC systems with sensors and automatic alerts (Collado-Montero & Espejo-Arias, 2015; Hajji et al., 2015). Environmental controls include air-treatment mechanisms that filter airborne pollutants and dust, which might affect the papers over time in luxury facilities (Abdel-Maksoud et al., 2024; Salah, 2018). Such a system is crucial for libraries with iron gall ink collections, which are highly responsive to humidity fluctuations. Management of Daluang manuscript infestations is generally unsystematic and involves traditional preservation methods. Several caretakers use natural repellents (e.g., dried cloves, neem leaves or

camphor) and believe they are effective against silverfish or booklice (Rachman & Salim, 2018; Salim et al., 2021). Physical inspections are conducted manually, and local infestations manually controlled and are not systemically monitored. However, some institutions are adopting a more systematic approach to address documented pest damage as a preservation issue (Oetari et al., 2016; Rachman et al., 2022).

It was purely coincidental that all tested suspects were negative, while the paper collections in the European collections were protected by Integrated Pest Management (IPM) programs, including environmental prevention, regular inspections, and pest trapping systems. These programs frequently involve sticky traps, pheromone lures and data on the position of pest activity

hotspots (Collado-Montero & Espejo-Arias, 2015; Hajji et al., 2015). Moreover, the IPM program includes a regular sanitation schedule and isolation zones for new acquisitions or suspected infested specimens thereby minimizing the risk of damage when applied to large archival collections (Abdel-Maksoud et al., 2024; Salah, 2018). Since then, fungus monitoring has become a main concern for Daluang manuscript custodians. Several recent reports have described biological studies identifying fungal species active on Daluang surfaces using microscopic observations and molecular methods (Lintang et al., 2021; Oetari et al., 2016). These studies contribute to the knowledge base, which can be used to improve the management of infected vines through directed treatments such as controlled fumigation and antifungicide applications.

European manuscript conservation protocols regularly include routine fungal monitoring, particularly after flooding, water leaks, or air conditioning failures. Procedures such as surface sampling, spore counting, and laboratory culture analysis are used to detect microbial risks before visible symptoms appear (Collado-Montero & Espejo-Arias, 2015; Hajji et al., 2015). Several national libraries use airborne spore traps during high-risk seasons or in high-risk regions, and link fungal presence to climate-control data to optimize settings (Abdel-Maksoud et al., 2024).

As spore emerge, Daluang manuscripts are increasingly being digitally preserved, with digitization projects spearheaded by universities. Institutes including Universitas Indonesia, Universitas Gadjah Mada have scanned hundreds of pages for research, teaching

and disaster recovery (Rachman et al., 2022; Salim et al., 2021). Yet challenges persist in funding, resolution standards and metadata management, with most projects still working on a grant or volunteer basis (Rachman, 2020; Rachman & Salim, 2018)

National and international digitization programs have supported the preservation of European manuscript. Europeana and the British Library's Endangered Archives Programme have used OCR software and digital asset management systems to digitize collections using high-resolution scanners (Duh et al., 2018; Yu et al., 2023). Such actions not only guarantee the long-term availability of documents, but also limit their physical use and handling. Given their fragility, this latter aspect substantially increases their lifespan (Collado-Montero & Espejo-Arias, 2015; Salah, 2018). Theoretically, the present study highlights a multilateral perspective on manuscript preservation that encompasses conservation science, cultural heritage and material studies. The unique features of the European and Daluang paper manuscript collections support the idea that preservation should not be based on a general 'one-size-fits-all' approach, but rather should stem from the material, historical and environmental context of each document.

Furthermore, recognizing local materials such as the Daluang manuscripts in academic discussion contributes to decolonizing the preservation framework and 'encourages a global perspective on heritage' that accommodates local knowledge systems and traditional conservation treatments. Pragmatically, the research findings underscore the

urgency of localized yet standardized conservation treatments, particularly for Daluang manuscripts stored in underfunded repositories. Institutions need to strengthen environmental monitoring, pest control and biological diagnostics, and incorporate community knowledge into preventive conservation strategies. Moreover, the growing shift toward digitization must be leveraged to protect vulnerable collections and expand access for scholars and the general public. Investment in appropriate digitization infrastructure, along with relevant training and outreach support is needed to underpin the emergency survival of primary manuscript traditions like these, and their long-term sustainability.

## CONCLUSION

This study has examined 38 scholarly articles to analyze research trends, reported physical conditions, and preservation methods associated with Daluang and European paper manuscripts. This study suggests appropriate preservation treatment for Daluang and European manuscripts. While sophisticated chemical-based conservation technologies and environmental guidelines have been developed to assist Europeans in preserving their manuscripts, Daluang manuscripts require locally context-sensitive strategies that prioritize a culturally respectful approach and preventive conservation. The results of this study demonstrate that manuscript preservation is not merely a technical issue, but also culturally and contextually fraught. Introducing traditional materials like Daluang into global academic discussions involves a 'decolonizing'

epistemology that recognizes local knowledge, local practice and the social function of objects in repositories. It is recommended that further research be expanded to develop a set of standardized, flexible conservation methods tailored to the Daluang's unique structure. This study reaffirms the urgency of promoting Daluang manuscript conservation through capacity building and local studies. Nevertheless, the continued need for further empirical investigations specifically in tropical Southeast Asia, suggests that the physical and scientific understanding of biodeterioration, abrasion, and ink corrosion on Daluang remains limited. To protect this heritage, training local conservators, adopting integrated conservation policies and encouraging comparative studies of adaptive preservation techniques are crucial. Similarly, digital curation should be extended with effective metadata and access systems to minimize physical handling.

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## AUTHOR CONTRIBUTIONS

TAS: Conceptualization, Writing - original draft, Formal analysis, Writing - review & editing. AFA: Data curation, Writing - review & editing. MKJAS: Supervision, resources.

## CONFLICT OF INTEREST

The author(s) declare no conflict of interest.

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## DATA AVAILABILITY

The 38 selected Scopus-indexed articles generated during the development of this study have been deposited in a Google Sheet, and it is accessible at <https://bit.ly/49k07Av>.

## REFERENCES

- Abdel-Maksoud, G., Omar, S., Hamed, A., & Hassan, R. (2024). Analytical techniques for condition assessment of leather binding of a historical manuscript from El-AzharAl-Sharif Library. *Egyptian Journal of Chemistry*, 0(0), 0–0. <https://doi.org/10.21608/ejchem.2024.252533.8936>
- Barkeshli, M., Stephen, I., Shevchuk, I., & Soltani, M. (2024). Characteristics of sizing materials used in Persian medieval manuscripts: Physical, optical, spectral imaging, and fungicidal properties. *Studies in Conservation*, 69(7), 519–536. <https://doi.org/10.1080/00393630.2024.2342647>
- Cerchiara, T., Palermo, A. M., Esposito, G., & Chidichimo, G. (2018). Effects of microwave heating for the conservation of paper artworks contaminated with aspergillus versicolor. *Cellulose*, 25(3), 2063–2074. <https://doi.org/10.1007/s10570-018-1687-5>
- Collado-Montero, F. J., & Espejo-Arias, T. (2015). A Colorimetric characterization and assessment of the chromatic deterioration of the medieval manuscript registro notarial de torres in the Archives of the Royal Chancellery in Granada, Spain. *Restaurator. International Journal for the Preservation of Library and Archival Material*, 36(2), 121–145. <https://doi.org/10.1515/res-2014-0008>
- Duh, J., Krstić, D., Desnica, V., & Fazinić, S. (2018). Non-destructive study of iron gall inks in manuscripts. *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms*, 417, 96–99. <https://doi.org/10.1016/j.nimb.2017.08.033>
- Hajji, L., Boukir, A., Assouik, J., Lakhari, H., Kerbal, A., Doumenq, P., Mille, G., & De Carvalho, M. L. (2015). Conservation of Moroccan manuscript papers aged 150, 200 and 800 years: Analysis by infrared spectroscopy (ATR-FTIR), X-ray diffraction (XRD), and scanning electron microscopy energy dispersive spectrometry (SEM-EDS). *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, 136, 1038–1046. <https://doi.org/10.1016/j.saa.2014.09.127>
- Kralka, P. (2022). Conserving paper: reflections on cultures of conservation in Europe and East Asia. *Journal of the Institute of Conservation*, 45(2), 135–146. <https://doi.org/10.1080/19455224.2022.2068634>
- Lázaro Ortiz, S., & Jiménez de Madariaga, C. (2022). The UNESCO convention for the safeguarding of the intangible cultural heritage: A critical analysis. *International Journal of Cultural Policy*, 28(3), 327–341.

- <https://doi.org/10.1080/10286632.2021.1941914>
- Lintang, W., Susetyo-Salim, T., Oetari, A., & Sjamsuridzal, W. (2021). Isolation and characterization of fungi from deteriorated old manuscripts from Banyumas, collection of Library of Universitas Indonesia. *IOP Conference Series: Earth and Environmental Science*, 948(1), 012031. <https://doi.org/10.1088/1755-1315/948/1/012031>
- Moretti, E., Sciarpi, F., Proietti, M. G., & Fiore, M. (2024). A multidisciplinary approach to the evaluation of air quality and thermo-hygrometric conditions for the conservation of heritage manuscripts and printed materials in historic buildings: A case study of the Sala del Dottorato of the University of Perugia as a model for heritage preservation and occupants' comfort. *Applied Sciences*, 14(12), 5356. <https://doi.org/10.3390/app14125356>
- Oetari, A., Susetyo-Salim, T., Sjamsuridzal, W., Suherman, E. A., Monica, M., Wongso, R., Fitri, R., Nurlaili, D. G., Ayu, D. C., & Teja, T. P. (2016). Occurrence of fungi on deteriorated old dluwang manuscripts from Indonesia. *International Biodeterioration & Biodegradation*, 114, 94–103. <https://doi.org/10.1016/j.ibiod.2016.05.025>
- Rachman, M. A. (2020). The manuscript collection values of Radya Pustaka Museum, Surakarta, Indonesia. *Library Philosophy and Practice*, 3922, 1–16. <https://digitalcommons.unl.edu/libphilprac/3922>
- Rachman, Y. B., & Salim, T. A. (2018). Daluang manuscripts from Cirebon, Indonesia: History, manufacture and deterioration phenomena. *Restaurator. International Journal for the Preservation of Library and Archival Material*, 39(1), 71–84. <https://doi.org/10.1515/res-2017-0014>
- Rachman, Y. B., Salim, T. A., Rachman, M. A., & Ratnasari, W. (2022). Dluwang manuscripts from Royal Surakarta, Indonesia: Deterioration phenomena and care practices. *Studies in Conservation*, 67(5), 289–301. <https://doi.org/10.1080/00393630.2021.1923284>
- Salah, T. A. (2018). Investigation and restoration of a 17th century ad manuscript at Al-Azhar library in Egypt. *International Journal of Conservation Science*, 9(1), 117–126. [https://ijcs.ro/volume\\_9.html](https://ijcs.ro/volume_9.html)
- Salim, T. A., Rachman, Y. B., & Shuhidan, S. M. (2021). Kepangeranan Banyumas Dluwang manuscripts collection: An initial assessment initial assessment Kepangeranan Banyumas Dluwang manuscripts collection: An Initial Assessment. *Library Philosophy and Practice*, 5722. <https://digitalcommons.unl.edu/libphilprac>
- Siddaway, A. P., Wood, A. M., & Hedges, L. V. (2019). How to do a systematic review: A best practice guide for conducting and reporting narrative reviews, meta-analyses, and meta-syntheses. *Annual Review of Psychology*, 70(1), 747–770. <https://doi.org/10.1146/annurev-psych-010418-102803>
- Sukmawati, D., Oetari, A., Hendrayanti, D., Atria, M., & Sjamsuridzal, W.

- (2015). Identification of phylloplane yeasts from paper mulberry (*Broussonetia papyrifera* (L.) L'Hér. ex Vent.) in Java, Indonesia. *Malaysian Journal of Microbiology*. <https://doi.org/10.21161/mjm.68114>
- Tlili, A., Altinay, F., Huang, R., Altinay, Z., Olivier, J., Mishra, S., Jemni, M., & Burgos, D. (2022). Are we there yet? a systematic literature review of open educational resources in Africa: A combined content and bibliometric analysis. *PLOS ONE*, *17*(1), e0262615. <https://doi.org/10.1371/journal.pone.0262615>
- Torres-Carrion, P. V., Gonzalez-Gonzalez, C. S., Aciar, S., & Rodriguez-Morales, G. (2018). Methodology for systematic literature review applied to engineering and education. *2018 IEEE Global Engineering Education Conference (EDUCON)*, 1364–1373. <https://doi.org/10.1109/EDUCON.2018.8363388>
- Wibowo, S. F., Alfida, Fuad, K., Ma'Rifat, D. F., Zuhrah, F., & Warnis. (2024). Preservation as a shared responsibility: Collaboration for the sustainable preservation of Ambon manuscripts. *Preservation, Digital Technology and Culture*, *53*(2), 91–106. <https://doi.org/10.1515/pdte-2024-0014>
- Yu, C., Zhang, M., Wang, Y., Chen, S., & Li, M. (2023). Treatment of a severely damaged paper manuscript of the Tang Dynasty unearthed from the Western Regions. *Restaurator. International Journal for the Preservation of Library and Archival Material*, *44*(1), 33–52. <https://doi.org/10.1515/res-2022-0017>