1. Introduction

This thesis describes a scientific study on Sāncipāt manuscript and Hengul-Hāitāl painting traditions of in early and medieval Assam, a state in northeastern India. The thesis also covers an attempt for conservation of Sāncipāt manuscript and restoration of heritage woodcarvings with the Hengul-Hāitāl painting in the traditional way for preservation under ordinary rural conditions.

1.1. Outline of the thesis

In this thesis, a thorough study of Sāncipāt is presented through scientific analysis of its physical, chemical, and mechanical properties, as well as structure and morphology of cellulose and lignin extracted from both old and new Sānci barks. The study encompasses a modified method for preparation of Sāncipāt efficiently. The thesis thoroughly examines the impact of various traditional preservation techniques on both aged and newly created Sāncipāt manuscripts, as well as offers a suggested approach for conserving such manuscripts, along with an evaluation of its effectiveness. In addition to exploring the Hengul-Hāitāl painting tradition, this thesis delves into the scientific aspects of using natural pigments. It also examines how to properly restore heritage woodcarvings using these traditional paints, allowing them to be preserved in rural areas under ordinary conditions without losing their historical significance.

The thesis has been organized into four chapters: Chapter I – Introduction, Chapter II – Materials and Methods, Chapter III – Results and Discussion, and Chapter IV – Conclusions. The first chapter of the thesis provides an overview of the work, delving into the world of ancient and medieval manuscripts. Specifically, it focuses on the Sāncipāt manuscripts of Assam, detailing both the traditional and simplified methods of their preparation, as well as the cellulose and lignin extracted from them. The chapter also emphasizes the importance of manuscript conservation, proposing a customized scientific method for the restoration of dilapidated Sāncipāt manuscripts. Finally, the history of woodcarvings from medieval Assam, particularly the Hengul-Hāitāl painting tradition, is introduced, along with a proposed restoration approach for woodcarvings.

1.2. Manuscripts

A manuscript is a handwritten composition with a rich traditional scientific, historical, or aesthetic value, i.e., manuscripts may be considered a significant source of our historical

and cultural background [1]. 'Manu' means hand, and 'script' means written, which together are known as a manuscript or handwritten manuscript [2]. However, different manuscripts have different compositions. It may be paper, bark, papyrus, cloth, parchment, palm leaf, bamboo sheet, etc., [3]. In earlier times, before the invention of the printing press, all books and documents were written by hand in manuscript form [2]. The style of writing skills is different in different manuscripts. Through this, we can gain insight into the writing techniques utilized in various ancient languages.

1.2.1. History of Manuscripts

There was no printing press or any other high-quality method for writing in the ancient time, so people used different sources of writing bases such as vellum and other parchment types writing base, stone, papyrus, birch bark, palm leaf, *Sāncipāt,* etc., [3-6]. As we delve into history, it becomes evident that manuscripts were commonly created either in scroll or book format. These manuscripts hold immense value in examining the intellectual heritage and traditional knowledge[2,7,8] [9]. Different types of manuscripts are known to be used in different parts of the world [3-5]. The use of papyrus manuscripts in ancient Egypt, the skin of animals in Europe, the use of handmade paper in China, the use of palm leaf in South and Southeast Asian countries as well as the use of various indigenous Bhurja Patra made from bark of *Betula utilis* (Himalayan Birch) which can be found in different parts of India, especially in Kashmir [10-12]. Papyrus was used as the main writing base in ancient Egypt, and both papyrus and animal skins were used in medieval Europe [13,14]. *Sāncipāt*, another type of manuscript made of bark of *Sānci* tree, was limited to Assam where there still exist tens of thousands of such manuscripts with their strength, glaze and ink intact, which are treasures of rich history, literature and cultural heritage of the people of Assam [2,7,15].

1.2.2. Types of ancient and medieval manuscripts

Various writing bases were used for manuscript-writing in different parts of the world, which has a repository of millions of manuscripts [13,14]. There are different ancient and medieval manuscripts are still available which are categorized as given below.

Egypt, Europe and Middle-east: In ancient Egypt, papyrus manuscripts were primary used, while in medieval Europe, both papyrus and animal skins manuscripts were used [7,8,13,14,16]. It is worth noting that papyrus had a significant role in Romanian culture

also [16]. Additionally, goat-skin parchment manuscript was prevalent in Southern Europe, whereas sheepskin manuscripts were commonly found in northern Europe [16].

China: Hand-made paper manuscripts were most extensively used in ancient and medieval China [17,18]. However, bamboo slips were also used as a writing surface in ancient China, as evidenced by historical records [18]. Over 1150 bamboo slips were discovered in the Shuihudi tomb, estimated to have originated from 217 BC [15,19].

India: India possesses more than five million ancient manuscripts, making it the largest repository of manuscript wealth in the world [13,20]. Different types of writing bases were used for manuscript-writing in India [14,15]. Different manuscript bases, namely, Tal Patra (leaves of Palmira and Talipot palm tree), Bhurja Patra (made of bark of Birch tree), *Sāncipāt* (made of bark of *Sānci* tree) and hand-made paper were used as writing bases in different parts of India [14].

1.2.3. Materials used in writing

Various materials were utilized to transcribe manuscripts across different regions of the world, which varied from writing bases to inks during ancient and medieval times, have been described here:

1.2.3.1. Writing base

Throughout ancient and medieval times, a wide range of writing surfaces were utilized for manuscript writing. These included animal skin, paper, papyrus made from Cyperus papyrus, bamboo slips from Bambusa vulgaris, leaves from Palmira and Talipot palm trees, and bark from Birch and Sānci trees, among other materials [21,22].

Handmade Paper or Tulāpāt: For nearly 2000 years, Chinese handmade paper has served as the primary medium for transporting calligraphy, paintings, old books, and archives [23]. The inception of papermaking is traced back to China's Eastern Han era (25-220 AD), where Cai Lun, a court official, is widely acknowledged for its invention [24]. It is believed that papermaking came to Korea via a Buddhist monk who had acquired the skill while living in Japan, where it had become a thriving industry by the late 6th century [25]. The best Korean paper is still in use today and is referred to as hanji or dak ji (*Broussonetia papyrifera*). It is made from the paper mulberry tree's inner bark

[25]. During the Mughal era, Kagzipura paper gained popularity for its use in important handwritten documents. Its reputation grew when the Mughals began exporting it to other countries [26]. Tulāpāt, a type of handmade paper, was a frequently used medium for preparing manuscripts in Assam. The Vaishnava Charities, a hagiographic narrative about a religious preacher, provides detailed descriptions of the steps involved in creating Tulāpāt [27]. During medieval times in Assam, Tulāpāt manuscripts were utilized as painting surfaces. Additionally, Tai Ahom's reign in Assam witnessed the use of Tulāpāt manuscripts as writing surfaces for a variety of manuscripts [18]. As mentioned by a noted historian of Assam, Maheswar Neog, the method of producing Tulāpāt comprises of ginning, felting, and pressing of cotton into sheets [18]. Recognizing the significance of paper usage among the Tai people, conservationist Rajatananda Dasgupta emphasizes that the production of Tulāpāt did not involve cotton ginning, felting, or pressing techniques as previously suggested by Neog [28]. Tulāpāt is made using only the pulp from specific tree barks, a process that is unique to Assam and believed to have originated during the Ahom dynasty's reign in the 13th century [18,29]. The art of manuscript writing using Tulāpāt was mainly practiced by Tai-Buddhist communities in Northeast India. The oldest known manuscripts crafted with this technique are the Phung chin and Suktanta Keyompong books, written in the Tai-Ahom language and dating back to 1437 AD. These books hold a remarkable place in the history of manuscript writing [18,30]. For a better understanding of Tulāpāt, we can refer to the eloquent writings of a celebrated local scholar named Chaikhang-Let Gohain from Namphakial village in Dibrugarh, Assam. His description, vividly expressed, provides valuable insights [2].

Papyrus: Papyrus, a popular writing base is a type of reed plant especially grows in certain marshy regions like Egypt. The writing base is taken from the pith of the reed [31]. For preparing papyrus, the slender strips of pith were aligned and layered until they fused together into a cohesive sheet. The final product was then meticulously smoothed through a process of rubbing [31]. In ancient Egypt, papyrus was widely used as a writing material owing to its abundant availability in marshy regions and cost-effectiveness. Its versatility made it a popular choice for a range of purposes, including basket making, sandal crafting, blanket weaving, medicinal applications, incense production, and even boat building. Moreover, Egyptians also utilized papyrus as a fuel source [32,33].

Bhoja Patra or Birch sheet: Bhoja Patra or Birch sheet is also a popular writing base especially found in northern India [7]. The material used for writing is derived from the bark of the Bhoja or Bhurja tree (Betula utilis), which is predominantly found in the Himalayas [7]. The white to brownish hue of this tree's bark is particularly noteworthy. The use of Bhoja Patra or Birch sheets in India saw a decrease with the arrival of handmade paper during the Mughal period [34]. Despite its controversial nature, the use of this tree persists in certain regions of Kashmir, India [34]. Preserving this intricate writing base poses a challenge due to its numerous layers and fragile properties [34].

Tal Patra or Palm leaf: Palm leaves were the most ancient writing medium in the southern region of India and were extensively used in other parts of South and Southeast Asia, such as Nepal, Sri Lanka, Burma, Thailand, Indonesia, and Cambodia [34]. One of the earliest surviving palm leaf manuscripts is a Sanskrit Shaivism treatise from the 9th century, which was discovered in Nepal and is currently preserved at Cambridge University Library [35,36]. Certain varieties of palm trees serve as a writing surface, with a variety of species available for use [11]. The Palmyra palm, also known as Borassus flabellifer, is ideal for dry climates due to its thick and strong fibrous leaves. However, as time passes, the leaves become less flexible and more susceptible to insect attacks. In contrast, the Talipot or fan palm, scientifically called Corypha umbraculifera, offers soft, flexible, and light-colored leaves even after drying. These palms thrive in wet climates and are commonly used for a variety of practical purposes such as writing bases, fans, mats, baskets, umbrellas, and roofing.

Sāncipāt: *Sāncipāt* was a popular manuscript writing-base of early and medieval Assam. Tens of thousands of *Sāncipāt* manuscripts still exist in Assam, some of them centuries old, without losing the glaze in spite of its harsh hot and humid climate [7,15]. Traditionally, *Sāncipāt* was made of bark of *Sānci* tree through an arduous procedure. The first record of *Sāncipāt* manuscript is in Harshacharitam by Banabhatta, a biography of king Harshavardhana (606-647AD) of Kanouj, now in North India [7,8]. Due to its hot and humid climate, Assam is a hub of fungi and insects which feed on cellulosic materials. Interestingly, it is a general observation that the survival ability of properly made *Sāncipāt* manuscript is greater than other types of manuscript found in Assam where fungi andinsects easily destroy manuscripts [7,8]. The preparation of *Sāncipāt* from *Sānci* bark involves repeated smoothening, pressing and drying; partial degumming;

polishing with fatty pulse paste; application of yellowish coating with *Hāitāl* (HgS, Cinnabar) and a border with *Hengul* (As_2S_3, Yellow Orpiment), and punching a hole at the center for tying bundles of *Sāncipāt* which have been reported on several historical and cultural contexts [15,37].

Others (Parchment, bamboo sheet, etc.): Writing on parchment, specifically from sheep, calves, and goats, was a prevalent practice during ancient times. Many civilizations, including the Assyrian people, favored this material for writing [38-40]. To produce parchment writing material, a sequence of steps must be followed. The procedure involves treating animal skin with lime, stretching and removing hair, cleaning thoroughly, and ultimately smoothing the surface [41]. Parchment manuscripts were widely used due to their uniqueness, durability in nature. This writing base was made not only for deluxe manuscript but also used for everyday documents and texts [41]. In ancient China, there was evidence of using bamboo slips as a writing base which were basically found in some ancient tomb [18].

1.2.3.2. Ancient Ink

For countless centuries, ancient cultures have employed different ink types to effectively communicate through written language [42,43]. Understanding ancient ink and color techniques can reveal significant clues about historical enigmas and age-old customs [44,45,46,47]. Different mixture of ingredients viz., dyes, solvents, resins, lubricants, solubilizers, surfactants, particulate matter, fluorescents, etc., made modern ink more complex [45,47]. But carbonaceous materials obtained from wood tar, burnt bone, lamp shoots, pitch or charcoal were used to make ink known as primitive Egyptian ink and Chinese ink [45]. Ink was used in ancient Egypt to write and draw in papyrus at least since the 26^{th} century BC [48]. Different types of ink that were used in ancient and mediaeval times, while some of them are still in use, are mentioned below.

Carbon-based ink: Lampblack or soot and a binding agent like gum Arabic or animal glue were commonly used to make carbon inks [42]. Carbon nanotubes are also utilized to create carbon-based inks [49]. Carbon-based conductive inks are an essential component of the printing industry [50]. Carbon-based inks are a valuable investment due to their exceptional conductivity. They have diverse applications, including energy storage, energy harvesting, electrochemical sensors, and printed heaters [51]. The ink

made from carbon nanotubes is very similar to the electrically conductive ink used in inkjet printers [49].

Iron gall ink: Iron gall ink, also known as iron gallotannate, has been one of the most widely used inks throughout the history of western civilization [45,52]. From the middle ages until the 20th century, this ink was widely used [45]. Due to their acidic nature, iron gall inks have been shown to accelerate the deterioration of numerous historical artifacts and papers [52]. This ink requires a very stable environment without any humidity [53]. When the humidity levels are increased during the production of iron gall ink, several acids like formic acid, acetic acid, and furan derivatives can form. These acids have the potential to damage cellulosic paper and create artifacts [54]. The impact of acidic iron gall ink deterioration depends on the quality of the writing surface. The degradation of different papers due to iron gall ink is influenced by factors like the width of the ink lines, the pH level, and the thickness of the paper [52].

Māhi: Old Assamese manuscripts were written with a special herbal ink called *Māhi* [51]. This ink, which is entirely different from iron gall ink, was created by combining the fruit-pulp of Hilikha (*Terminalia chebula*), Amlakhi (*Emblica officinalis*) and Bhomora (*Terminalia belerica*); the bark of Hilikha, Bhomora, mango (*Magnifera indica*), Jamuk (*Eugenia jambolana*), Bahat (monkey jack, *Artocarpus lakoocha*); and the whole herb of Keharaj (*Eclipta alba*), Bar Manimuni (*Centella asiatica*) and Saru Manimuni (*Hydrocoryl rotundifolia*) and many more herbal materials [15,45]. The neutral pH characters make completely different Māhi ink from the European iron gall ink [45,55]. The neutral pH of Māhi ink indicates the acid free nature as well as the non-corrosiveness nature of Māhi ink [15,45,55]. This unique type of ink has also antifungal and antibacterial properties [45]. The use of Māhi ink on a unique type of lignocellulosic writing base known as *Sāncipāt* make more protective against the hot and harsh humid climate of Assam [2,45,55,56]. There are lots of centuries old *Sāncipāt* manuscripts written with Māhi ink still existing in Assam which are still compatible for reading [15,51].

1.2.4. Sāncipāt Manuscript writing

A unique type of writing base, *Sāncipāt* was a popular manuscript writing-base of early and medieval Assam [7,15]. These manuscripts were made of the bark of *Sānci* tree

(*Aquilaria malaccensis*) through an arduous procedure was extensively used in early and medieval Assam, located in the Brahmaputra valley surrounded by the Himalayas and other mountain ranges, and characterized by a hot and humid climate. Tens of thousands of *Sāncipāt* manuscripts still exist in Assam, some of them centuries old, without losing the glaze in spite of harsh hot and humid climate [7,18]. The first record of *Sāncipāt* manuscript is found in *Harshacharitam* by Banabhatta, a biography of king Harshavardhaba (606-647 AD) of Kanouj, now in North India [7,18,37]. It is mentioned in the biography that some special gifts were sent to *Harshavardhaba* by king *Kumar Bhaskaravarman* (595-650 A.D.) of Kamrupa, now in Assam, among which, was a collection of manuscripts. The manuscripts, containing literature of high standard, were made of *Sāncipāt* with a reddish yellow color of *Hāitāl*, a mineral pigment also known as yellow orpiment. On the other hand, the descriptions of Banabhatta and notes of *Hiuen Tsiang*, a Chinese pilgrim who visited Kamrupa on invitation of the king, clearly reflects the presence of a conducive atmosphere in Kamrupa for practice of knowledge and literature for a long period under the royal patronage of king *Bhaskaravarman* and his predecessors [15,57]. Thus, this unique tradition of writing and illustrating *Sāncipāt* manuscript with Māhi started by 7th century which continued till the early 20th century [17,58]. This tradition is now almost extinct in the face of modernization and introduction of modern paper and printing technology.

1.2.4.1. Preparation of Sāncipāt

Sānci tree: *Sānci* tree also known as Agar tree (*Aquilaria malaccensis*) is found mainly in Asian country like India, Bangladesh, Sri Lanka, Malaysia etc. *Sānci* tree is grown in large scale in Assam. There are two types of *Sānci* tree namely Bholā Sānci and Jatiya Sānci. The bark of Bholā Sānci is preferred for making *Sāncipāt* since the bark of Bholā Sānci is smoother than that of Jatiya Sānci [15,59].

The traditional method of preparation of *Sāncipāt*: There are several documents on preparation of *Sāncipāt* found in the literature. I have adopted the widely accepted procedure reported by a noted Historian, E. Gait in his book ‘A History of Assam’ for preparation of *Sāncipāt* [60]. The arduous recipe involves of pealing of bark of *Sānci* tree, cutting into size, drying, cleaning, partially degumming, smoothening, application of fatty

pulse as primer coating, application of a thin coating of *Hāitāl* and boarder with *Hengul* before writing with *Māhi*, an herbal ink of early Assam [2,45,55,56]. The key steps of the traditional arduous procedure including the writing tools are given below:

(a) 15-20 years old *Sānci* tree with about 20-25 inches in girth is selected (Figure. 1.1).

(b) A bark strip of about 5-18 feet length and about 3-27 inches width above 4 feet from the ground is removed from the tree (Figure. 1.1).

(c) The strip is rolled inside out and is dried in the sunlight for 10-12 days [61] (Figure. 1.1). Some practitioners used to smoke the rolls. Then the strip is put under water for few days to soften.

(d) Next, the outer side is rubbed with a coarse hard substance, called *Jhao* [15], to remove the outermost scaly layer of the bark. *Jhao* is made by fixing sand or coarse glass powder on an iron rod or burning a paste of a 1:2 clay and sand [62]. Sometimes, the outermost scaly layer of the bark is removed using a sharp knife before removing the bark from the tree [15].

(e) Then bark is exposed to dampen under dew for overnight before the softer outer layer, called *nikari*, of the bark is removed carefully.

(f) The bark strip is cut into convenient pieces of 9-27 inches long and 3-18 inches wide.

(g) Pieces are soaked in cold water and degummed partially by rubbing. Further partial degumming of the strip is done by boiling in water in a large water bath. *Kanibih* seeds (*Crotton triglium*), leaves of *Chalkunwari* (Aloe-vera, *Aloe barbadensis*) and/or Tutia is added to the water bath to impart paste-resistance of *Sāncipāt* [63,64] (Figure. 1.2).

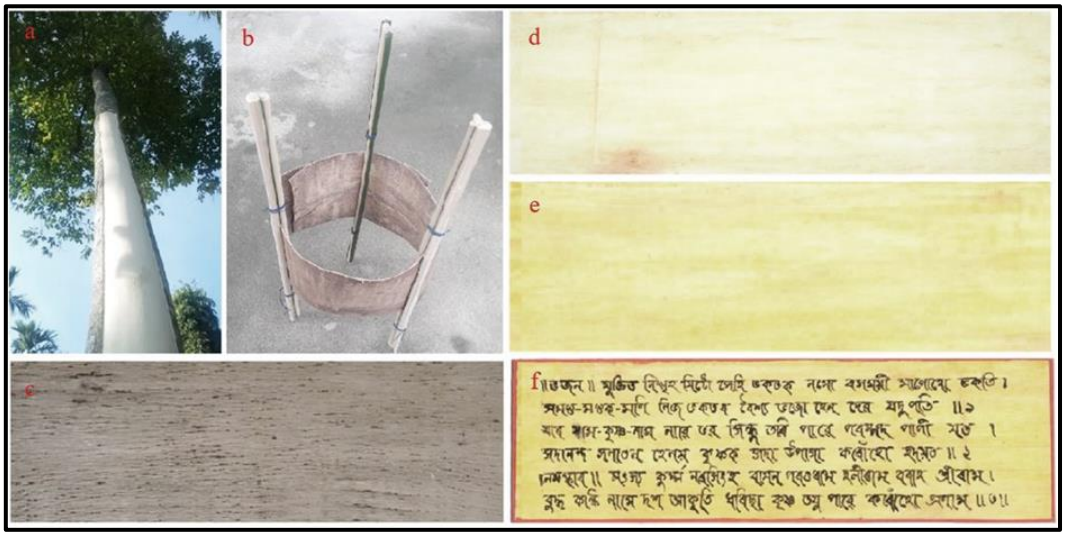


Figure. 1.1: (a) A Bholā *Sānci* tree after removal of bark, (b) *Sānci* bark strip rolled inside out for drying, (c) *Sānci* bark after degumming, (d) after fatty pulse polishing, (e) after application of *Hāitāl* and (f) after drawing boarder with *Hengul* and writing with Māhi.

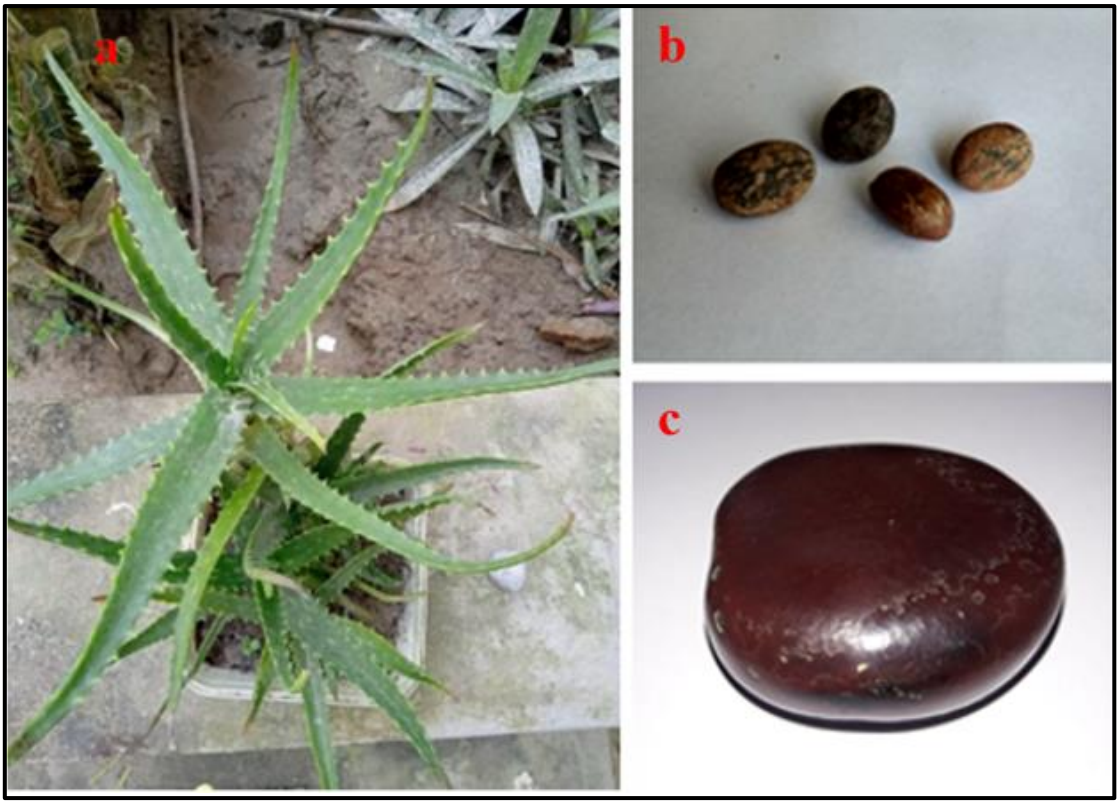


Figure. 1.2: (a) A Chalkuwari plant, (b) some Konibih seeds and (c) a Ghila.

(h) Both the surfaces of the strip are again scrapped with a small knife [15]. They are then dried in the sun for about half an hour. While drying, care is taken by applying uniform weight to avoid cracking, shrinking, or kinking of the strip. These are again smoothened by rubbing with a *Ghila* or a conch-shell (Figure. 1.2).

(i) Next, a thin coat of a fine paste of a skinned fatty pulse, called *Matimah* (*Phaseolus radiatus*), is applied on the strip to fill up any cracks or wrinkles on the surface of the strip and then sundried (Figure. 1.1).

(j) The dry strips are then again smoothened by rubbing with a *Ghila* or a conch-shell.

(k) Then a thin coating of yellow *Hāitāl* pigment is applied on both sides of the strip (Figure. 1.3). For this, the paint is prepared by mixing powdered *Hāitāl* in water using an herbal gum obtained from fruit of *Bel* (Stone apple), *Ou Tenga* (Elephant apple) or *Dhekia* (Fiddlehead fern). The pieces are again sundried and smoothened with a *Ghila* or conch-shell [15].

(l) A red boarder of about 1 cm width of red *Hengul* pigment is also applied along the boundaries on both sides of the strip (Figure. 1.1).

(m) Finally, a small round hole of about 5 mm diameter is punched at the center of the strip and a red boundary is drawn around the hole with *Hengul*. The *Sāncipāt* is now ready for manuscript writing and illustration.

Figure. 1.3: A thin coating of yellow *Hāitāl* pigment is applied on both sides of the strip (top and bottom). Both sides of the folio look identical.

1.2.4.2. Pigments and herbal materials used in the preparation of Sāncipāt

Diverse herbal and mineral materials including mineral and herbal pigments were used to prepare Sāncipāt manuscripts in medieval Assam. The following is a comprehensive list of these materials.

Tutia: Tutia also commonly known as blue vitriol or copper sulphate penta hydrate used as a degumming agent for *Sāncipāt* Preparation. These ingredients are added during the boiling with a belief that they make the *Sāncipāt* paste-resistant [15,59,65]. This is an inorganic compound which chemical formula is $CuSO_4.nH_2O$ [n=1 to 7] and also have antifungal, antibacterial and insecticidal properties [7,66].

Chal Kunwari: During the boiling of *Sāncipāt*, leaves of Chal Kunwari are also added with a belief that they make *Sāncipāt* paste-resistant [15,64,65]. *Aloe barbadensis* is a

sharp succulent plant which has many medicinal properties and has been used since ancient times to cure various wounds, burns and various skin diseases [67]. Chal Kunwari plant is found in abundance throughout Asia, Europe, America, and Africa, with around 150 different types recorded [68].

Kanibih seeds: Kanibih seed, also referred to as Cotton Triglium, is a well-known ingredient utilized in the making of *Sāncipāt,* which is comparable to Tutia and Chal Kunwari [15,59,65,68]. There are more than 1200 different species with large genus Croton which belonging to the family Euphorbiaceae signifies the verities of Chal Kunwari [69,70]. About 2200 years ago, there was evidence of using this plant as a medical herb in China [71]. This seed is traditionally used as a purgative for the treatment of gastrointestinal and intestinal disorders [72].

Ghila: In the traditional process of *Sāncipāt* preparation, Ghila, a hard seed of fruit with red colour of *Borghila* (*Entada scandens*) is used for smoothening the dry strips of *Sāncipāt* by rubbing [15]. The use of this hard seed of fruits are very popular in different places. The Karbi tribes of Assam and Oceanic group of tribes like Onges and great Andamanese often consumed the boiled seeds of Ghila [73-76]. Excepts these tribes; Garo, Naga and Kanikkars of Assam, Tamil Nadu and Kerela used this for eating by soaking and boiling the hard seed [73-76]. However, a half ripened Ghila seed were used as a substitute of coffee in South America [73,77]. These seeds also have some medicinal properties. There is evidence of using the paste of Ghila seeds for curing the inflammatory glandular swelling [77]. These seeds are widely used in India for remediation of different health threat like contraception, snakebites and aphrodisiac [73,75] and some people in India also used the powder of this seeds as a natural shampoo for hair washing [73,75].

***Hengul-Hāitāl*:** On the final stage of preparation of *Sāncipāt,* a thin coat of a particular citron yellow pigment, namely, *Hāitāl* (*Haritala, orpiment*), was applied [12,15]. Due to its bright yellow colour in nature it is called orpiment [78]. From the Latin word '*auripigmentum*' the name orpiment was originated which is also meant that 'gold pigment'[78] . From the chemistry background this yellow orpiment is known as diarsenic trisulphite (As_2S_3), a naturally occurring highly stable crystalline compound. Due to presence of S3- ions, Haital is look like yellow in nature [7,79]. When an acidic

solution of arsenic trioxide (As_2O_3) is passed through hydrogen sulphide, it precipitates a citron yellow flocculent mass [2,78]. *Hengul (cinnabar)* is also a naturally occurring stable crystalline solid pigments with intense red color, very popular in ancient times because of their beautiful bright colors [80-82] For the decoration of boarder of *Sāncipāt* sometimes used this bright red pigment [7,15]. This solid pigment *Hengul* contains some amount of mercury sulphide compounds (HgS). This red pigment is also known as red vermillion, was abundant in China but was also found in India [83].

1.2.5. Cellulose and lignin extracted from Sāncipāt

Plant stiffness, flexibility and strength depends on the amount of cellulose and lignin present in the plant cell walls [84-86]. Cellulose and lignin, being the main constituents in plant cell walls, have been identified to play a vital role in the conservation of different manuscripts made from Papyrus, Birch bark, Tālpātra, Sāncipāt, etc. Unfortunately, hardly any scientific data is available regarding cellulose and lignin of *Sāncipāt*.

Cellulose: The most prevent organic polymer, cellulose is made up of 3000 or more glucose units and is the main molecule in the cell walls of higher plants. Cellulose is also an important component of the wood, paper, textile, lumber, and renewable biofuel sectors [87]. Due to its ecofriendly, biocompatible, and renewable qualities, demand for it is steadily growing. The chemical formula for this substance is $(C_6H_{10}O_5)_n$, where 'n' is the degree of polymerization and indicates the quantity of glucose groups [88]. Wood, cotton fibers, and the stalks of annual plants like wheat and bamboo are some of the major sources of cellulose [87]. However, cellulose is mostly found in the cell walls of wood, where it is known as 'hemicelluloses,' along with lignin, pectin, and polysaccharides. From a structural standpoint, cellulose is a linear syndiotactic homopolymer (same repeating monomer unit in which the pendant groups are arranged in a regular alternating pattern) made up of a linear chain of several hundred to many thousands of β (1→4) linked glucopyranose unit bears three hydroxyl groups that impart properties like hydrophilicity, chirality, biodegradability, etc. [89] Intermolecular Van Der Waals forces and the multiple hydroxyl groups' capacity to form strong hydrogen bonds with oxygen atoms on the same or nearby chains are what hold the chains tightly together side by side and give rise to additional properties like high tensile strength, micro fibrillated structure, hierarchical organization (crystalline and amorphous fractions), and highly cohesive nature [90].

Figure. 1.4 [91] depicts the chemical structure of cellulose, which is generated through condensation polymerization and consists of monomers linked together by glycosidic oxygen bridges. The repeating unit of this natural polymer is cellobiose, a dimer of glucose whose degree of polymerization varies depending on the sources. Cellulose can be classified into several categories based on the sources and placement of hydrogen bonds between and within strands. Structure I_α and I_β, cellulose generated by bacteria and algae is richer in I_α. While higher plants cellulose mostly consists of I_β. In regenerated cellulose fibers, cellulose is present as cellulose II [88].

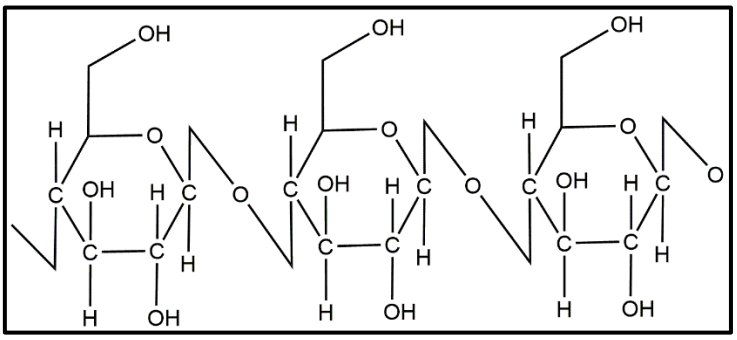
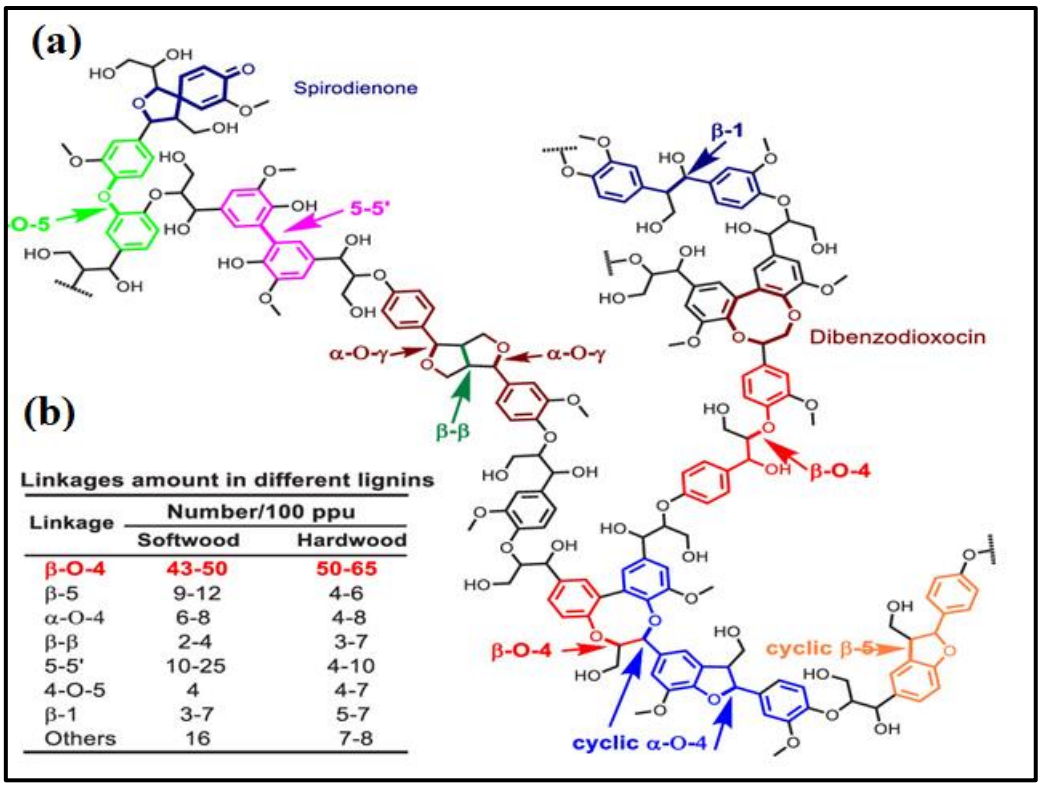


Figure. 1.4: Schematic representation of the structure of cellulose

For a considerable period of time, cellulose has been put to use in a variety of applications, including building materials, paper, textiles, and clothing. Its origin lies in the utilization of wood and plant fibers as an energy source. However, cellulose comes with certain drawbacks, such as its tendency to adsorb significant amounts of water, its inclination to form aggregates during processing, and its incompatibility with hydrophobic polymers. As a result, their employment in different applications depends on the extraction method and the sources employed.

Lignin: Lignin, being the second most abundant biopolymer after cellulose, has a very complicated structure in nature [92] (Figure. 1.5). Depending on the distinctive characteristics of lignin, softwood lignin is composed of mainly guaiacyl (G) units whereas hardwood lignin contains both guaiacyl (G) and syringyl (S) units in different ratios [86,92,93]. Sometimes, a small amount of *p*-hydroxyphenyl propane units associated with *p*-coumaryl alcohol are found in both soft and hard wood lignin's [92,93] . Though many researchers have extensively studied the structure of lignin but till date, no proper structural evidence have been reported to confirm the above [86,94]. Functional groups like methoxyl, phenolic and aliphatic hydroxyl containing different types of

linkages are responsible for making the structure of lignin very complex [86]. The schematic diagram of the lignin structure is given in the figure below [91]. A few common linkages found in the lignin molecule are β-O-4 ether linkages followed by other types of ether and C-C linkages like α-O-4, β-5, 5–5, 4-O-5, β-1, and β- βĩ [86,95]. However, majority part of the lignin molecule contains hydrophilic as well as hydrophobic functional moieties which turns it into a very suitable biomacromolecule for various applications [96,97]. lignin plays a very important role in the transportation of water, minerals and nutrients in the plant in addition to protecting the plant from attack by micro-organisms [86].



Linkage	Number/100 ppu	
	Softwood	Hardwood
β-O-4	43-50	50-65
β-5	9-12	4-6
α-O-4	6-8	4-8
β-β	2-4	3-7
5-5'	10-25	4-10
4-O-5	4	4-7
β-1	3-7	5-7
Others	16	7-8

Figure. 1.5: (a) Representative lignin structure and typical linkages. (C) Approximate linkages abundance in softwood/hardwood. Reproduced with permission from ref [86]. Copyright 2023 ACS.

1.2.6. Conservation of Manuscripts

1.2.6.1. Different process

There are different conservative processes already developed for conservation of different types of old manuscripts made from paper, papyrus, Birch sheet, parchment etc. Before

the starting of conservation process documentation of manuscripts is very important. In order to properly document conservation efforts, it is essential to take photographs before and after the process is complete. Additionally, arranging the sheets in a chronological order based on their historical significance is also important [98]. Some selected methods of conservation are mentioned below,

Method used for paper conservation: Different popular steps for conservation of papers are:

(a) Intervention before Preparation: Prior to the conservation of paper manuscripts in this process, some nondestructive methods like pH measurement, UV-visible spectroscopy, p-XRD, XRF etc. analytical technique are used for characterization, documentation and conservation of the current condition of the artefact and treatment planning of paper manuscript [99,100].

(b) Disinfection/sterilization and Disinfestation: Various methods such as disinfection, sterilization, and disinfestation are employed to effectively protect paper artifacts against different biological agents. In general disinfestation are used to entails the extermination the insects and rodents while to eliminate different types of fungi and bacteria, disinfection or sterilization are used [101].

(c) Dry or surface cleaning: In this procedure dust, dirt and other foreign materials should be removed from the surface of the old paper for different aesthetic reasons. Since dirt may be transferred by water into the paper matrix and may become fixed, hence dry cleaning must precede aqueous treatments [102]. Some of the specific commercial products like special sponges, dust absorbing materials (e.g. Absorene) etc. have been developed for the surface cleaning of paper [100].

(d) Wet cleaning: In this conservative step one should follow three different cleaning process like washing by water or organic solvent, enzyme treatment and bleaching to preserve and restoration of paper manuscripts [103]. To remove different impurities like microorganism metabolism, atmospheric pollution, different acidic impurities; deionized water and different organic solvent like 30-50% ethanol or isopropanol mixture, N-methyl-2-pyrrolidone are used [100,104-107]. To avoid chlorine, different transition metal, Ca, Mg hardness; deionized water used [100,104]. However, enzyme treatment is used for the removal of organic adhesive residues [108]. For the enzyme treatment one should maintain the pH and temperature [109]. Bleaching is performed

for the removal of the overall discoloration or of disfiguring stains under the utmost care [108].

(e) Chemical stabilization: Chemical stabilization is regarded as one of the most significant conservation interventions concerning the long-term preservation of paper. It is one of the most effective chemical stabilization strategies for paper [108]. Deacidification of paper neutralizes existing acids and prevents future acidity development by depositing alkaline substances [108,110]. Sometimes the technology based on nanoparticles are also used to deacidification of paper [108]. In the nanotechnology-based conservation process calcium and magnesium hydroxide nanoparticles are dispersed in alcohols for the deacidification of paper which give promising results in now a day [111,112] [113,114].

(f) Paper repairs: Japanese paper or paper pulp can be a reliable solution for conserving and restoring damaged paper. The success of this approach hinges on the severity and nature of the damage, as well as the repair tools at hand [113].

(g) Consolidation/strengthening: In this process of paper preservation lamination can takes place. After lamination weak, mouldily and brittle paper can be reinforced by pasting on one or both sides thin Japanese paper with methyl cellulose paste [114].

Method used for papyrus conservation: Some of the already proven methods are used to conservation and restoration of papyrus manuscripts are given below,

(a) Cleaning: Prior to commencing the cleaning procedure on papyrus, it is imperative to verify the efficacy of the water and other cleansing agents on the ink. The appropriate method for cleaning papyrus involves the use of a soft brush and a rubber air bulb to carefully eliminate any loose particles from the surface. In this process 40% water and 60% ethyl alcohol was used with cotton swab without effecting the carbon ink of the papyrus surface [115].

(b) Removal of gelatin support: In this step acid free blotting paper with warm water is used to removal of sticky parts of Papyrus. Papyrus was sandwiched between the two pieces of blotting paper for drying. For a more efficient removal of Papyrus parts with tweezers, it is necessary to soften and swell the gelatin sheet for a duration of five minutes under a light weight [115].

(c) Bridging: In this step remoistenable tissue which is made from Kozo-Shi Haini Tengujo 1 (5.8 g/m2) and a 50:50 mixture of carboxy methyl cellulose and Shofu wheat starch paste is used to support the weak areas with Papyrus strips. The paste

was archives by using small amount of water to reactive the adhesive. Remoistenable tape paper was chosen to avoid discoloration and irreversibility problems [115-117].

(d) Mounting: This is the last step of the conservation of Papyrus. In this step Papyrus was stored on passe-partout from acid free canson (Gravure 270 g/m2) which was in between two glass sheets. Thus, both sides of the papyrus are viewed. The use of passe-partout reduces the pressure from glass-sheets [115,116]. The final papyrus sheets were enclosed with plastic slide binder bar and placed under the Tyvek envelope to protect from dust, abrasion and pollutants to keep in storage [115].

Method used for palm leaf manuscripts conservation: There are two common palm leaf manuscripts are available in libraries, one is Tala Patra and other is Sritala patra. First one is thick and coarse which is written on by a metallic stylus using charcoal dust for distinct writing. The second types of palm leaf are thin, flexible like paper and written on by carbon ink with a reed pen. All these leaves are easily attackable by insects. The leaves are brittle and fragile due to prolonged fluctuation of relative humidity, temperature and also due to the loose of their natural oil. Citronella oil is applied to both sides of palm leaf manuscripts to maintain their flexibility and repel insects. In case of damage, repairs are easily made by using Favicol and additional palm leaf pieces. To provide even more protection, the manuscript can be strengthened with Chiffon lamination or encapsulated in polyester film [11,98,118].

Method used for birch bark conservation: This type of bark is an inner layer of Birch tree composed of several layers with natural gum and woody knots. Due to the presence of salted salicylic acid, insects do not attack on it. However, this type of bark has also been natural strain for which it cannot be bleached. But after a considerable time, the adhesive properties of the Birch sheet are loose, and the layers get separated. 2-3% CMC paste, or thin Maida (flour) paste is used by a fine brush to fix the separated layers. Once joining the separated layers, it may be lubricated by using citronella oil on both sides of the Birch bark manuscripts and then encapsulated by using polyester films for easy handling [11,98,118].

Pastedown: Pastedown is a method of making the last page of a book with a double size paper, one part of which serves as the first free page as opposed to the cover of the book. In this way, the first page serves as the title page and the page of the last should informs

about the details of the pages of the book. This process imparts an immense strength to the book.

1.2.6.2. Sāncipāt conservation

Importance: In the absence of any proper scientific preventive and curative conservation techniques for *Sāncipāt* manuscripts, some of the manuscripts have been wearing out slowly. Some manuscripts were traditionally stored in exposure to smoke above cooking stove of firewood to keep away from humidity and pastes [119-121], which is no longer in practice now as firewood has been replaced by smokeless cooking gas. Very few people use some rudimentary traditional conservative treatments like sprinkling water extract of neem (*Azaradicta Indica*) leaf followed by drying in sunlight once in a year [15,18]. On the other hand, some *Sāncipāt* manuscripts are being conserved unscientifically using chemicals like isopropyl alcohol, ammonia and thymol [122,123] which may rather be harmful to *Sāncipāt* as the material source, structure and composition of *Sāncipāt* greatly differs from paper and both lignin and cellulosic fibers are affected by some common chemicals used in chemical preservation [7,124]. The authors have witnessed a large number of *Sāncipāt* manuscripts where black stains are bloated from the edges of the margins of folios and from a central puncture, *Nābhi,* made for tying the folios, due to application of chemicals. Thus, a scientific study on conservation of *Sāncipāt* manuscripts is very important.

For conservation of *Sāncipāt* manuscripts one also needs to note that only a small fraction of these manuscripts is housed in well-maintained museums or libraries. Most of the manuscripts are at a large number of vaisnavite monasteries and villages in ordinary rooms where there is no possibility of providing passive environment for microbes and restrictions to insects using sealed air-conditioning. It is also necessary to repair and restore partially damaged manuscripts. Some *Sāncipāt* manuscripts, which were not prepared through proper recipe, are being damaged by fungus and insects (Figure. 1.6). On the other hand, there continues traditions of reading *Sāncipāt* manuscripts daily at some of the monasteries and occasionally at some villages making conservation with passive environment impractical and rather needing a method of restoration cum conservation of the manuscripts (Figure. 1.7) for preserving them in ordinary condition for use for reading.

Proposed Method: A method, based on the traditional method of preparation of *Sāncipāt*, has been proposed for restoration and conservation of the unique writing base

of *Sāncipāt* without using any chemicals like isopropyl alcohol. The proposed method uses only the fungus and insect repellant pigments of *Hāitāl* and *Hengul* with *Bael* gum as done traditionally during preparation of *Sāncipāt*. As water is used in preparation of both *Sāncipāt* and *Mahī,* we have chosen to apply *Hāitāl* and *Hengul* with water and *Bael* gum, of course, drying the *Sāncipāt* as quickly as possible after that. We have also chosen to apply a *La*-coating on the *Sāncipāt* finally as is done traditionally during preparation of *Sāncipāt* manuscript.

Figure. 1.6: (a) Two folios coated with yellow *Hāitāl* and still in good condition of a manuscript, Kirtan Ghosha, copied in 1753 AD (Saka 1675), and preserved at home of

Shri Jagat Duwaria, Mohkina village, Majuli, and (b) the last folio of the same manuscripts not coated with *Hāitāl*, has been damaged considerably needing restoration.

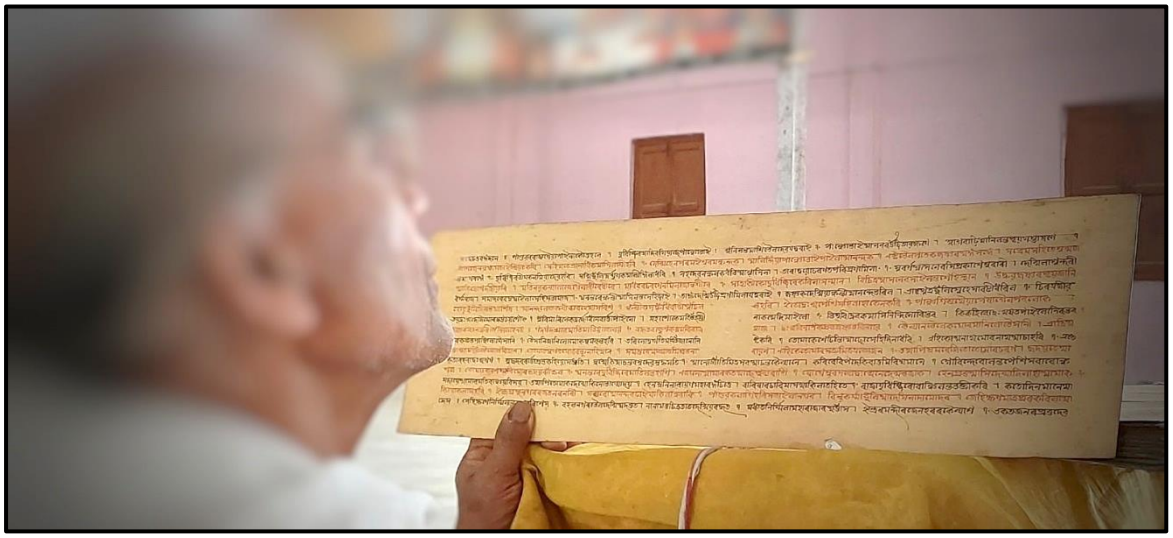


Figure. 1.7. A monk reads a *Sāncipāt* folio with coated with *Hāitāl* but without lac coating at Auniati Satra, Majuli holding by his hand. This *Sāncipāt* manuscript was written with commercial red and black ink.

The proposed customized method of conservation of *Sāncipāt* manuscript, based on its traditional method of preparation is described below.

(a) Physical cleaning: Both surfaces of the Sāncipāt folio is to be cleaned physically, first by soft rubbing with a clean cotton cloth and then rubbing the dirt from the open spaces with a small clean rubber and a soft brush without touching or affecting the writing and miniature paintings. Neither any solvent, organic and water, nor any chemical is used in the cleaning.

(b) Mending: Next, any broken or torn portion of *Sāncipāt* is to be mended by pasting of fresh thin piece of *Sāncipāt* using the natural traditional Bael gum without any additional water (Figure. 1.8). The sides of the pasted piece of *Sāncipāt* can be smoothened using a blade. A hot-air oven and mild hot-pressing, with a light iron in cotton mode putting a white cotton cloth between the *Sānci* bark and the iron, may be used in order to aid adhesion and drying instead of drying under the sun in the traditional method (Figure. 1.8) [11,121]. A short-cut method of the traditional arduous method of preparation of *Sāncipāt* can be used to prepare fresh *Sāncipāt.* A 10-15-year-old, instead of a 20-25-year-old traditionally chosen, *Sānci* tree gives a thin *Sānci* bark which is suitable for mending. The *Sānci* bark is cleaned and cut into convenient pieces in traditional way and then partially degummed by boiling in

presence of Tutia for an hour instead of soaking in water overnight in presence of Tutia. The pieces are then dried partially using hot-air oven and mild hot-pressing using an iron. A thin *Mātimāh* (fatty pulse) paste is then applied on the piece to smoothen the surface by filling any wrinkles or hair cracks present. It's then dried again using hot-air oven and mild hot-pressing. Next, a thin coating of *Hāitāl* is applied on the piece followed by drying and smoothening by hot-pressing to get a thin *Sāncipāt* ready for using in mending.

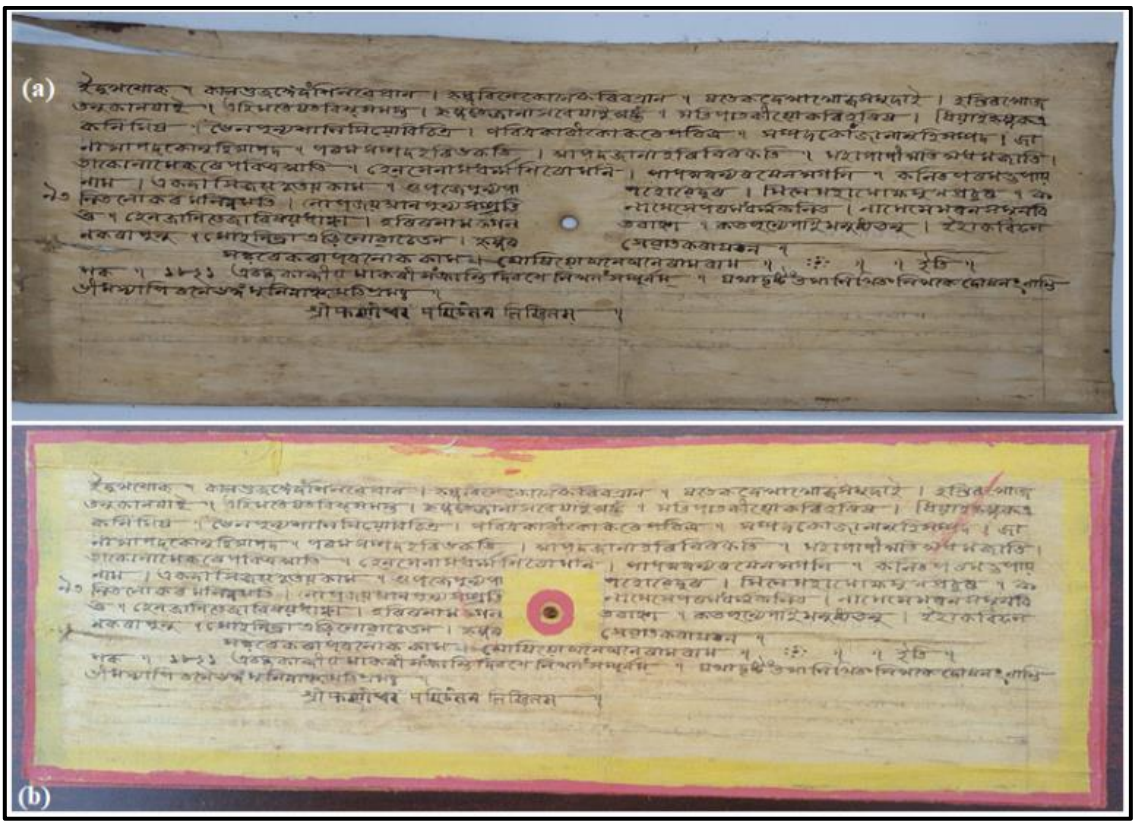


Figure. 1.8: A *Sāncipāt* folio (a) before and (b) after mending with a piece of freshly prepared *Sāncipāt* followed by application of *Hengul-Hāitāl.*

(c) Application of *Hāitāl* and *Hengul*: After physical cleaning and mending, a thin layer of *Hāitāl* is to be applied on the side margins and other free spaces without touching the writings and miniature paintings. After that, a 3-5mm lining of *Hengul* is to be applied on the boarder of the *Sāncipāt* and around the puncture, *Nābhi*, which use to be there at the center of the *Sāncipāt* for tying a bunch of *Sāncipāt* or a *Sāncipāt* manuscript. The *Hāitāl* paint mixture is to be prepared by mixing the powdered pigment to approximately 6.5 μm with Bael gum and water. The ratio has to be

decided depending upon the original color of the *Sāncipāt.* A pinch of *Hengul* may be mixed with *Hāitāl* for matching the color of the paint with the original color of the *Sāncipāt.* Pure *Hengul* paint for the boarder and *Nābhi* is also prepared same way but without mixing with *Hāitāl.* The application of *Hāitāl* and *Hengul* has to be done as quickly as possible and after application of the paints, the *Sāncipāt* has also to be dried in sun or hot-air oven as quickly as possible to minimize any damage to the *Sāncipāt* by water. A mild hot-pressing by covering the *Sāncipāt* with a white cotton cloth may be done to remove any kinks of waviness from the dried *Sāncipāt.* One must use hand-gloves and masks while working with toxic *Hāitāl* and *Hengul* or handling any on which *Hāitāl* and *Hengul* are applied.

(d) Lā-charowā: The *Sāncipāt* folio is then coated with a very thin layer of *Lā*. Though *Lā*-coating is somewhat similar to varnishing, in *Lā*-coating only pure herbal *Lā* dissolved in hot spirit is applied as a very thin coating using a white cotton cloth (Figure. 1.9). The folio is dried immediately within minutes rendering itself into a physically stronger folio with fungus and insect repellant *Hāitāl* and *Hengul* covered by the transparent coat.

(e) Preserving the conserved manuscript: Finally, the *Sāncipāt* manuscript tied between two 4-5 mm thin and flat sheets of wood coated with *Hāitāl* and *Hengul* to avoid carving or bending of the folios, then wrapped softly with a thin red cotton cloth which is also a traditional practice and kept in a cool dry place. *Hāitāl* is applied on the wooden covers to repel insects and fungus. The tradition of rapping with red cotton cloth might be to partially reflect heat-carrier infra-red radiations.

1.3. Heritage Woodcarvings

Wood carving is a transformative process that turns wood into beautiful and artistic forms. This enables us to appreciate a wide range of cultural, historical, religious, and art traditions [125]. Availability of large quantities of wood is a noteworthy reason for wood carving in ancient times [125]. Acknowledging the diverse styles of wood carving across various regions of the world is crucial when delving into the intricate art form. Our ancestors have left behind a rich heritage of unique techniques and designs that continue to inspire and awe us today [126].

1.3.1. Various types of woodcarvings

Chip carvings: These types of wood carvings are done on the flat surface of a piece of wood and the small ships are carved with the help of knives or chisels. These types of carvings are mainly use for different ornamentation of wood and mainly familiar in the European country and later on American folk art mainly appearing on the wooden gate, house beams, furniture, household containers and implements [127].

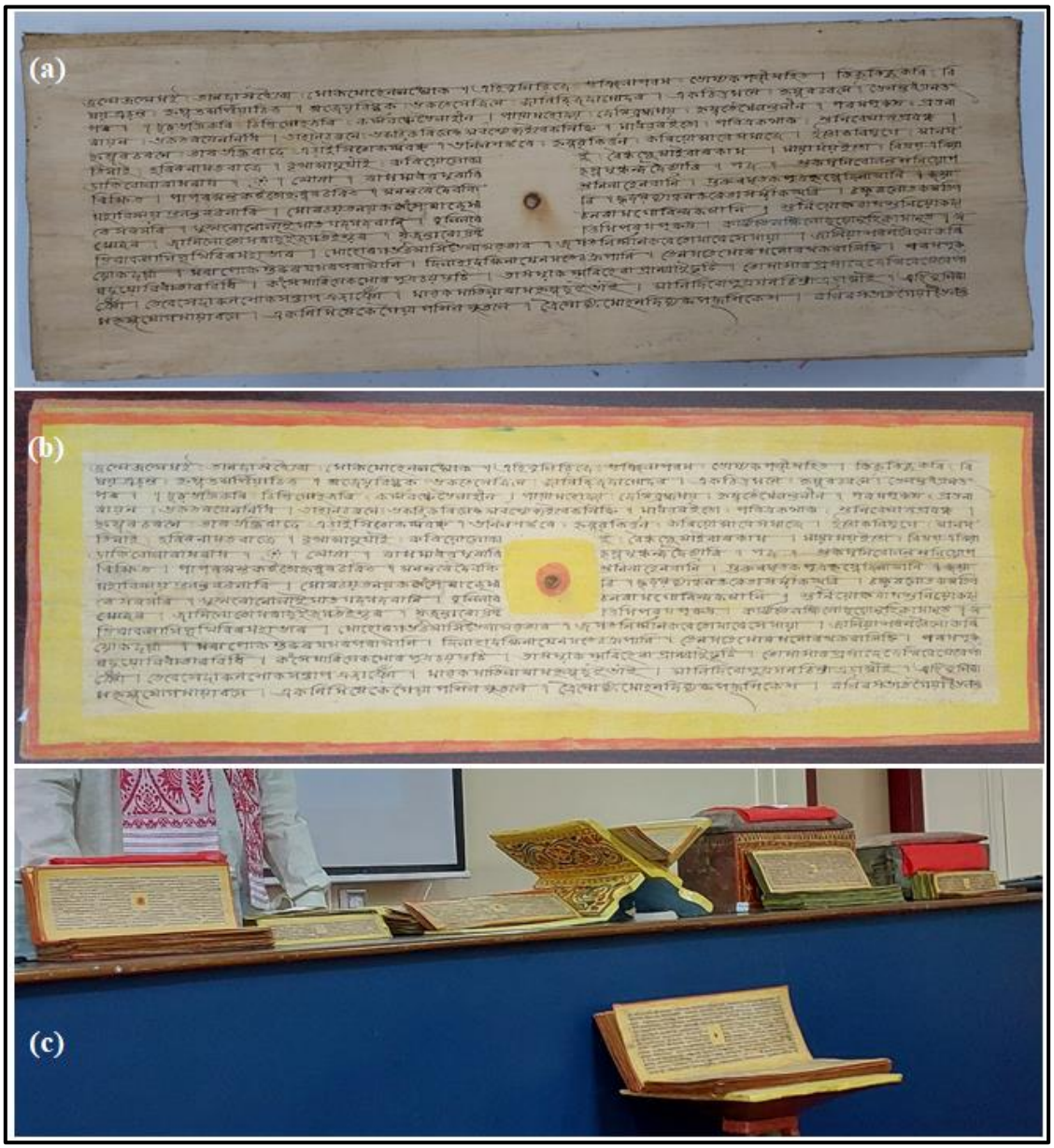


Figure. 1.9: A *Sāncipāt* folio (a) before and (b) after conservation from Kirtan, a manuscript received from Auniati Satra, Majuli, together with that (bottom) and (c) some other manuscripts conserved in the second piloting workshop.

Relief carvings: This particular style of wood carving entails carving figures onto a flat wooden panel. The figures are meant to appear slightly raised from the background, rather than standing independently. In essence, a relief carving should present a distinct visual where the carved wood stands out from the background [128].

Scandinavian carvings: This is a style of figure carvings in which carving knife is use to create a figures in a large flat planes of wood [129].

Love spoon carvings: These unique carvings are traditionally presented as a gift of romantic intent which was carved in a very decoratively and originated from the word "cawal" (soup) spoon. This wooden spoon was normally decorated with symbols of love and due to its intricate designs, these love spoons are not use as daily functioning spoon but also mainly use as a decorative craft [130,131].

Treen carvings: These types of carvings are mainly use for different household essentials furniture like chairs, bed, table and clock etc., [126] [132].

Whittling carvings: These types of carvings are used by many sculptors as a pastime and artistic creation.

Chainsaw carvings: These types of carvings are a fast-growing art form of wood in modern era which combines the ancient and modern art form.

1.3.1.1. History of woodcarvings

The craft of woodcarving, which is still used today, is one of the oldest artistic expressions attributed to humanity. Different woodcarving techniques used in various parts of the world have frequently discussed the illustrious past of our ancestors. The list below includes a few of them,

Europe - Ancient Greece to Victoria era: Wood carving was not the only art in Europe, but it was the backbone of Roman sculpture in the 11^{th} century. From the 15^{th} to the 17^{th} century, various wood carvings can be seen in various buildings and churches of the Baroque period [1,2]. Surprisingly, the ancient Greeks were all doing the practice of woodcarvings of some very inferior type around 700-800 BC. Of course, they were planning to use stone or bronze instead of wood [126,133]. There is also evidence that

wood carvings were used to express spiritual beliefs by local peoples during the Viking Age (793-1066 AD) of North America [117, 118].

Africa - Egypt: Wood carving was a very old and important practice in Africa and Egypt. Sculptures like these give information about the lifestyle of the civilization [134,135]. Makonde means tree of life or Ujamaa is a type of wood carving that is popular in Tanzania, Africa [136]. This type of carving is done using only pieces of wood and can be up to 2 meters in height to capture images of people of all ages and generations [134-136]. Due to the extremely dry climate of Egypt, there is evidence of the presence of many wood carvings. Very smooth wood carvings can be found inside various tombs in Egypt. Almost all of these are believed to be carved for the benefit of the dying person [137].

Asia – South-east Asia, China and India: When we talk about the role of wood carving in the Asian civilization, we must mention the various notable wood carvings found in China, India and Japan [138]. Despite the difficulties of colonization, the islands of the Pacific Ocean accepted great hardships and made various types of wooden weapons, ceremonial buildings, and various wooden chains. In the ancient Hindu temples of India, even today we can see the use of doors, chilling, statues made of wood which are thousands of years old. Chinese woodcarvers still use the extremely ancient Mudiao technique, which dates back centuries [139,140] . These types of carvings are sometimes covered by gold foil and used in the making of different furniture, chests, screens and even in buildings. Relief carvings are usually reflected in Chinese and Japanese tradition. However, the Japanese are often made some flower like lily, lotus shape wood carvings [141].

1.3.1.2. Woodcarvings in medieval Assam

Satra, Namghar and personal possession: The Vaisnavite monasteries, or Satras, of Assam, became one of northeast India's most revolutionary and significant forces in the socio-religious and cultural arenas [142,143]. They are a particular Assamese socio-religious, cultural, and heritage institution founded in the 16th century to spread the Bhakti ideas to the general populace [142,143]. Over more than five centuries, the Satras' preachers of the Assamese Vaisnavite culture have evolved and grown, serving as a fraternity house for the sociocultural, spiritual, moral, and artistic spheres. Following the

neo-Vaishnavism Bhakti movement led by the saint scholar of Assam, Srimanta Sankardeva, there was a tremendous social and cultural revival in the 15th and 16th centuries [142,143]. The Satra's growth and development of their art forms were aided by the readily accessible wood from the surrounding environment [142-144]. There are several rows of cloisters designated for the fraternity, along with a prayer hall. The prayer rooms' name is Namghar, while the cloister rows' names are Hatis [142,143,145]. The Namghar is where congregational prayers, religious theatre performances, readings from the Bhagavata Gita and other holy scriptures, and various religious speeches are held [143,145]. A few distinct parts of the Satras sculpture's base are supported by various delicate wood carvings, door panels, sculptures of mythical characters, holy beings, animals, and floral motifs. Wood carvings: Sculptural representations elicit resemblances or influences from other cultural domains. Satra's sculptural depictions have significantly contributed to the sociocultural and religious spheres. Through its direct interactions with the local populace, the Satras' practice of sculptural representation not only contains an internal resistance to elite art practices but also externally displays the ideals of religious beliefs. Other wooden sculptors are projected around the Kirtanghar, including the Garuda Bird in Bhakti posture, Hanuman holding Rama and Laxmana, and the well-known Kali-damana, Kalki, Hari-Hara, etc. Out of these art forms, various Satras, such as Barduwa Than in the Nagaon district, Auniati Satra, Kamalabari Satra, Gormur Satra in Majuli, Barali Mora Satra in Tezpur, Hati Satra in Sualkuchi, etc., have received significant recognition for their work in conserving the hundreds of year-old customs of Assam's distinctive wood carving. Assamese woodcarving is unique in every aspect of its shape, content, coherence, expressiveness, and consistency. There are nine representations of Lord Vishnu in his seven incarnations. The Khanikers gave them a visual representation by carefully preserving the space and composition within a petite picture frame. The vaisnavite monasteries' khanikers are multifaceted artists equally skilled in woodcarving, painting, building, text creation, and other artistic mediums. Other religions also have woodcarvings in addition to the Satras and Namghars.

1.3.1.3. Traditional science in the tradition of woodcarving of Assam

The study presented in this thesis fulfills the critical requirement for restoring century-old traditional woodcarvings and conserving Sāncipāt manuscripts from medieval Assam. This research has brought to light a fascinating painting tradition known as Hengul-Hāitāl from medieval Assam.

Hengul-Hāitāl **painting tradition:** Traditional pigments and other materials used in paintings by our ancestors are of great importance in terms of art history and art conservation [146-148]**.** Many interests of researchers have been drawn on the various pigments used in prehistoric cave paintings [149], ancient fine mural paintings in cave like those in Ajanta Ellora [149], and on the walls of temples and other monuments [148,150]. The history of mural painting shows that there were various painting methods such as encaustic painting, tempera painting, fresco painting, ceramics, oil painting, etc., [151]. Iron containing earth minerals with different hues are said to be the first pigments used by the prehistoric artist in the cave paintings [149]. Evidence of use of different colored rocks, different types of animal blood, charcoal, etc., have also been found in ancient cave paintings [152]. There are evidence of use of different types of red, yellow, black, blue and green pigments as well as of using egg yolk as a binder in the paintings [148]. The art of woodcarvings, often painted with pigments, is also believed to have originated from the beginning of human creation [15,152-154].

In Assam, a north-eastern state of India, where different types of woods are abundant, there was a great medieval tradition of woodcarvings painted with some mineral and herbal pigments [154] These woodcarvings included Vaishnavite mythological characters and different utility items [7,15,154,155] (Figure. 1.10).

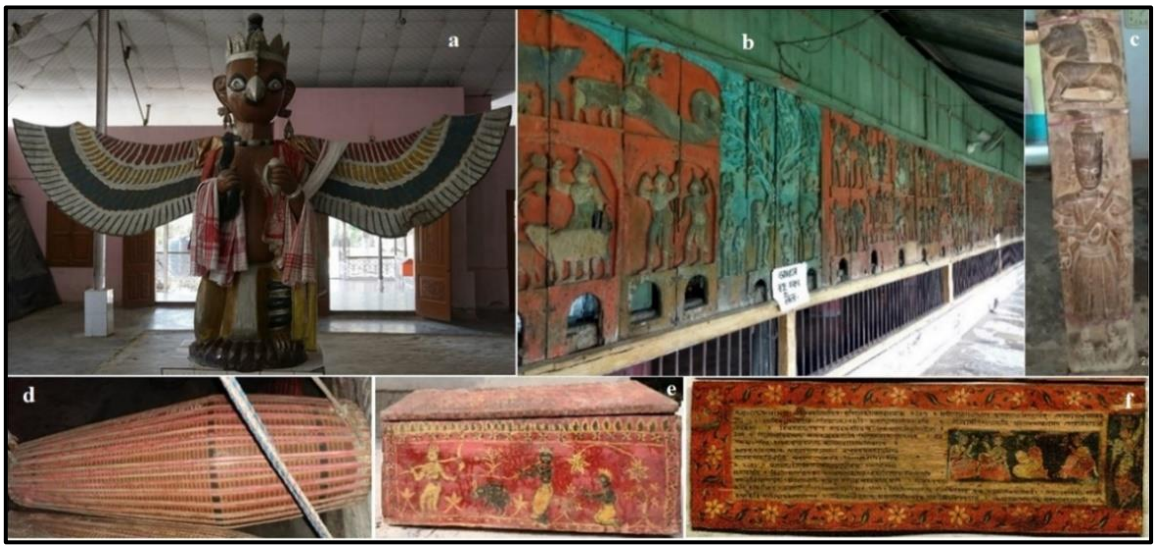


Figure. 1.10: Traditional woodcarvings and other things painted with *Hengul* and *Hāitāl.* (a) Garud Pakhi deity at Āuniāti Satra, (b) Vaishnavite story in woodcarving on wall of Namghar, (c) pole of Namghar, (d) a Khol (a lather musical instrument with lather at two

ends of a hollow wood), (e) a folio of a *Sāncipāt* manuscript and (f) a box for preserving *Sāncipāt* manuscript.

Mural painting for a drama, Cihna-yatra of 1497 AD, by Srimanta Sankardeva, a Vaishnavite saint, is considered to be the oldest recorded paintings in Assam using the *Hengul* and *Hāitāl* [156,157]. Records also say, *Sankardeva* and his disciple, *Madhavadeva* used *Hengul-Hāitāl* in paintings on pillars and walls of *Namghar*, a kind of Vaishnavite community prayer house [156]. Blue, white, green, brown and black colors were also used along with *Hengul* and *Hāitāl* in Assam [158]. The most widely used and developed style of painting in Assam is known as Satria painting style [159]. There are records about the use of the different mineral colors and herbal dyes in Tai-Ahom style or royal style of Assamese paintings of contemporary or even older sub genres in the period of 15th to the 19th century [7,160,161]. *Nīl*, the blue herbal pigment, was cultivated in Assam towards the end of the 16th century AD [162] A white clay, *Kharimati*, was used for the white color. The green color was derived by mixing *Hāitāl* and *Nīl*. *Hengul* and *Hāitāl* are still applied on the handle of a traditional hand-fan of Auniati Satra, Majuli [162]. Various brown shades were obtained by mixing *Hengul* and *Hāitāl* at different ratios. The black color was either carbon black or was derived by mixing *Hengul*, *Hāitāl* and *Nīl*. *Bael* glue, obtained from *Bael* fruit (stone apple, *Limonia acidissima*), Outenga glue, obtained from Outenga fruit (elephant apple, *Dillenia indica*) and *Dhekiya* glue obtained from gum of fiddlehead fern were used as natural glue in medieval Assam [154]. The tradition of painting using these mineral and herbal pigments gained much popularity in medieval Assam. These mineral and herbal pigments became popular for using in mural paintings as well as miniature illustration in *Sāncipāt* manuscripts, a special kind of manuscripts with folios made of bark of Sānci or Agaru tree (Aquilaria malaccensis Lamk. syn. A. agallocha Roxb.), another medieval tradition in Assam. The tradition became known as *Hengul-Hāitāl* probably due to their attractive colors or their high cost, though there were some other ingredients too. Even today, people in Assam refer to the old tradition of painting as '*Hengul-Hāitāl lagōwā*', where '*lagōwā'* means to apply or to fix in Assamese.

There are several interesting things to note about the *Hengul-Hāitāl* painting tradition. Firstly, the traditional knowledge of preparation of different shades of composite colors by mixing three primary colors, *viz.*, red, yellow and blue was known to them. Secondly,

and more importantly, selection of antifungal and insect-repellant *Hengul* and *Hāitāl* for the red and the yellow colors, respectively, and inclusion of at least one of them for any shade of color which protected the woodcarvings from fungus and termite which are abundant on hot and humid climate like that of Assam. Thirdly, the selection of a very robust and transparent adhesive of Bael (*Aegle marmelos*) gum which neither leaves any stain nor affects the color [162]. Fourthly, the practice of application of primer-coat of low-cost *Kharimati* before application of the paints. Finally, '*Lā carōwā'*, application of a final coating of *Lā*, a natural glue, which protects the paints from natural erosion and also protects contamination of the hands, of the devotees of the idol woodcarvings or users of the utility materials, with antifungal and insect-repellant *Hengul* and *Hāitāl*. We have observed head of woodcarvings with hair painted with colors other than *Hengul* and *Hāitāl*, e.g., black using carbon black or white using *Kharimati* have been damaged by termites while those painted using composites colors containing *Hengul* and/or *Hāitāl* remain intact for centuries.

The traditional arts of Hengul and Hāitāl painting in Assam have been gradually fading away due to the growing usage of synthetic paints. Now a days, newly made Vaishnavite woodcarvings are often colored with synthetic paints. It is disappointing to note that hundreds of such heritage woodcarvings, some of them centuries-old, which were originally painted with the traditional pigments, are losing their original glare due to natural weathering and dirt as they are always kept in open condition at *Namghars*. Some of them are being destroyed slowly by fungus and termites as a passive air-conditioned environment is impractical in the rural set up of *Namghars* in villages and *Satras*, Vaishnavite monasteries in Assam. Unfortunately, many of such centuries-old heritage woodcarvings are often repainted by the Namghar authorities with synthetic paints destroying their antique look due to ignorance of the importance of heritage conservation or due to easy availability of synthetic paints, with the tradition of *Hengul-Hāitāl* painting at the verge of extinction.

1.3.1.4. Proposed method of restoration of woodcarvings

We have proposed a method of restoration of partially damaged woodcarvings based on the findings of the above study of the ingredients, properties, and the traditional recipe of the *Hengul-Hāitāl* painting. Rainy season, July to September, must be avoided for the restoration for two reasons: firstly, for unavailability of Bael gum and secondly to avoid high humidity which makes drying difficult. The steps are described below:

(a) Cleaning of woodcarvings: The woodcarving must be thoroughly cleaned through physical means removing dirt by brushing and rubbing with coarse cotton cloth using water and isopropyl alcohol. No further step is required if the woodcarving is not cracked, damaged by termite, or painted with synthetic paints destroying the original heritage look.

(b) Removal of synthetic paints: Any synthetic paints, if applied on it, have also to be removed using knife and sandpaper. If an original *Hengul-Hāitāl* painting is found beneath the synthetic paints, then photographs of the original painting pattern have to be captured so that the final painting can be done in the same pattern.

(c) Mending: Any crack or portions damaged by termite have to be cleaned and then filled with sawdust paste made with a polyvinyl adhesive (Fevicol) and Tutia. The filling has to be dried completely before the nest step of restoration.

(d) Extraction of Bael gum: Matured Bael fruits are cut across into two pieces and the gum is squeezed out along with the seeds using a small spatula. This is mixed with equal quantity of water and strained through a porous cloth.

(e) Application of primer coat of *Kharimāti*: A thin primer coat of a paste of finely powdered *Kharimāti,* made with water, Bael gum and Tutia as per Table 1, is to be applied on the woodcarving and allowed to dry naturally.

(f) Application of *Hengul-Hāitāl*: Paints of different required shades are to be made of finely ground pigments (5-25μm) in different proportions with water and Bael gum taking the examples in Table 1 as a guidance. The paints after preparation, should be applied using a brush as early as possible, to avoid agglomeration of the paint, in the same original pattern. A second coat or any decoration may be done after the first coat completely dries up. Mask and gloved must be used during grinding, handling, and application of Hengul-Hāitāl [7].

(g) Application of *Lā*: Finally, a coat of *Lā,* dissolved in spirit (alcohol) is applied on completely died painted woodcarvings softly with a small piece of cotton cloth. The *Lā* solution is prepared by dissolving 100g of solid *Lā* flakes in 250 ml spirit.

It is possible to preserve numerous culturally significant woodcarvings, including those found in Assam, through this method. This approach can effectively restore these worn-out artifacts, which have played a vital role in sustaining our rich heritage.

1.4. Aim of the present work

The aim of my work is to carry out a comprehensive and thorough scientific study of traditional method of preparation of *Sāncipāt* through investigation of it's physical, physicochemical and biochemical properties; and of traditional method of painting of wood carving using natural pigments and adhesives with special reference to the factors which impart beautiful glaze to them and help them in surviving for centuries in an unfavourable hot and humid condition.

1.5. Objectives

The following objectives have been set to meet the aim:

Study of Sāncipāt:

(a) Scientific study of traditional method of preparation of *Sāncipāt* folio.
(b) Physicochemical characterization of *Sāncipāt* at various stages of its preparation.
(c) Study of microbial properties of old and new *Sāncipāt*.
(d) Study of cellulose and the lignin extracted from *Sānci* bark.
(e) Modification and scaling up of the preparation method of *Sāncipāt*.
(f) Development of a scientific method of restoration *Sāncipāt* manuscript.

Study of traditional Hengul-Hāitāl paintings:

(a) Scientific study of application of traditional pigments of *Hengul-Hāitāl* on wooden artefacts.
(b) Study of restoration of woodcarvings in traditional way with *Hengul-Hāitāl*.

1.6. Plan of research

In order to meet these aims and objectives the author prepared a plan of methodology of experimental work and analysis which will be based on the following approaches:

(a) The inherent physicochemical properties of *Sānci* bark at different stages of its preparation and of freshly prepared *Sāncipāt* will be investigated using standard methods for them.
(b) Upscaling of *Sāncipāt* preparation will be done by modifying the traditional method using modern scientific tools without affecting the properties of *Sāncipāt*.
(c) The factors contributing to the longevity of *Sāncipāt*, such as, additives used during degumming and coatings of mineral pigments applied on *Sāncipāt* will

be examined through antifungal testing. The different factors causing deterioration of old *Sāncipāt* manuscript also will be examined. Based on this information, a method will be suggested for restoration of *Sāncipāt* manuscripts.

(d) Based on our findings on the protective properties of the different traditional pigments used for traditional painting of wood carvings will be studied using antifungal and insect repelling tests.

There are several documents on preparation of *Sāncipāt* found in the literature. The widely accepted procedure reported by a noted historian, E. Gait in his book, 'A History of Assam' has been adopted for preparation of *Sāncipāt* [60]. The *Sāncipāt* strips has been analyzed after each step of preparation by using various spectroscopic techniques and mechanical devices. For all the spectroscopic analysis, the *Sānci* strips were dried in desiccator for few days to analysis. After drying, the fibber portion was collected very carefully for different scientific analysis. The *Sāncipāt* folios were prepared following the traditional procedure under the supervisor of the practicing expert of the tradition. The universal tensile measurement techniques were carried out to find out the improvement in physical strength of the *Sānci* bark during preparation of *Sāncipāt* and the glossiness of different stages of *Sāncipāt* were observed by using gloss index meter. The morphological structure, availability of minerals, thermal property of the *Sānci* bark and *Sāncipāt* were studied. Some common fungus and bacteria were selected for the anti-fungal test which easily deteriorated the paper, woodcraft, sculptors etc., under different environment like open control, closed negative control, closed positive control. Hence, the antifungal and antibacterial properties of *Sānci* bark, *Sāncipāt* and most importantly the traditional pigments of *Hengul-Hāitāl* were observed. Since we noticed that there are lots of examples of uses of different artificial colours on the woodcraft, old historic monuments, old manuscripts, but their glossiness property as well as durability, validity existed for very short period of time. Therefore, traditional pigments like *Hengul-Hāitāl* were used as an alternative colour to maintain the glossiness, durability as well as the validity of the *Sāncipāt* manuscripts and century old heritage woodcarvings. Different Instrumental techniques as well as Physicochemical measurements like UV-visible spectroscopy, FTIR, p-XRD, FTIR, DLS, RAMAN, TGA, TEM, EDXA, UTM, Gloss-index, CHN, Antifungal and antibacterial test, DSC etc. were used to complete the whole investigation.