EXPERIMENTAL ADHESIVE IN PAPER CONSERVATION: COMPARISON BETWEEN STARCH AND SOYA FLOUR AS THE MAIN INGREDIENT

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By

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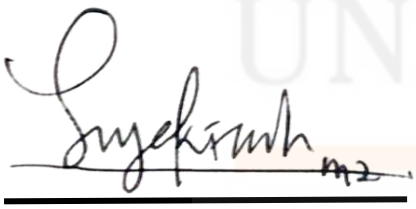

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXPERIMENTAL ADHESIVE IN PAPER CONSERVATION: COMPARISON BETWEEN STARCH AND SOYA FLOUR AS THE MAIN INGREDIENT

ABSTRACT

The efficiency of starch and soya flour as the major constituents in experimental adhesives used for paper conservation is examined in this research. In order to preserve historical records and artwork, paper conservation is essential, necessitating the use of adhesives with both strong bonding and long-term stability capabilities. This study compares the performance of starch- and soya flour-based adhesives while taking into account factors including adhesive strength, ageing characteristics, and paper substrate compatibility.

A number of experimental tests were carried out to achieve the goals. Starch and soya flour were used as the main ingredients in the adhesive samples, with changes in concentration and formulation. Shear and tensile tests were used to measure the force needed to separate adhesive-bonded paper samples in order to assess the adhesive strength. In order to evaluate the adhesives' long-term stability, accelerated ageing tests that mimic the environmental conditions that paper artefacts may experience over time were also carried out.

The results of this study advance the subject of paper conservation by offering concrete proof of the effectiveness of starch- and soya flour-based adhesives. The findings might help conservators choose the best adhesives for certain conservation projects by highlighting factors such as adhesive strength, aging characteristics, and compatibility with paper substrates. The possibility of starch-based adhesives as a workable substitute for traditional adhesive materials used in paper conservation is also highlighted by this study.

CHAPTER 1

INTRODUCTION

1.1 Introduction

The preservation and restoration of cultural heritage materials, particularly paper-based materials are crucial for maintaining historical and cultural significance. Adhesives play a vital role in the restoration process, and their effectiveness, durability, and potential impact on the preserved materials are important factors to consider. This chapter provides an introduction to the study of adhesive by comparing the main ingredient which is starch and soya flour in the restoration of paper materials and discusses the research questions, objectives, scope, and significance of the study.

1.2 Background of Study

Cultural heritage is a crucial aspect of a nation or community's history and identity (Smith, 2006). Cultural heritage objects composed of organic materials such as paper, textiles, wood, and bone often suffer damage due to age, environmental conditions, or human manipulation (Cronyn, 1990). The preservation and conservation of these objects are essential to maintain history and heritage for future generations (Cameron, 2013).

One critical aspect of the preservation and conservation process is the selection of suitable and effective adhesives (Caple, 2000). Adhesives are used in the conservation process to join or repair damaged or separated parts of cultural heritage objects (Horie, 2010). The choice of appropriate adhesive is crucial to ensure successful conservation outcomes, long-term stability, and the preservation of the original material's integrity (Weaver & Ellis, 2007).

Although various adhesive types have been used in conservation, there remains a lack of knowledge regarding their effectiveness, long-term effects, and interactions with organic materials in cultural heritage objects (Koob, 2004). Therefore, this study aims to investigate the difference between adhesive that uses starch as main ingredient and soya flour as their main ingredient in the conservation of paper materials and explore innovative approaches to cultural heritage preservation.

The primary objective of this study is to examine the suitable main material in the making of adhesives in the conservation of paper materials within cultural heritage objects. This research will assess various adhesives and examine their impact on the integrity, stability, and appearance of materials after the conservation process (Young & Hagan, 2011). Additionally, this study will evaluate the long-term effects of adhesives on the preservation of cultural heritage objects and investigate any adverse effects that may arise from using specific adhesives (Michalski, 1994).

The findings of this study are expected to contribute to the knowledge and practice of cultural heritage preservation and conservation by providing better guidance on selecting suitable and effective adhesives for organic materials in cultural heritage objects (Appleton, 2007). The adhesive is one of the basic materials needed because it is "used to adhere reinforcing materials to damaged areas or re-adhere separated components of an object," (BPG Adhesives, 2021). Thus, this research paper is focusing on the effectiveness of the trial-and-error adhesive by comparing starch and soya flour as the key elements in the restoration treatment and the recommendation concluded to preserve it

1.3 Problem Statement

1.3.1 Adhesive effectiveness

A major issue in this study is determining the effectiveness of adhesives used in the preservation of organic materials, specifically paper in cultural heritage objects. Some adhesives may not be suitable for all types of organic materials, and the inappropriate selection of adhesives can lead to restoration failure or further deterioration of the heritage object (Caple, 2000; Weaver & Ellis, 2007).

1.3.2 Long-term effects of adhesives

A problem related to this issue is the long-term effects of adhesives on the integrity, stability, and appearance of organic materials after the preservation process. Unsuitable or less stable adhesives might experience

ageing, colour changes, or degradation, which in turn can impact the heritage object itself (Michalski, 1994; Young & Hagan, 2011).

1.3.3 Interaction between adhesives and organic materials

The third issue to be addressed in this study is how adhesives interact with organic materials, such as paper materials in the context of cultural heritage objects. Undesirable interactions between adhesives and organic materials can lead to a decline in quality, changes in properties, or further damage to the heritage object (Koob, 2004; Horie, 2010). The substrates being connected, the application and usage environment, and the expected lifespan of the adhesive must all be taken into account when choosing one (Swanson, 2015). Also as stated by Swanson (2015) incorrectly curing the adhesive and lack of strength and flexibility are the factors behind failure of adhesive bonding.

1.4 Research Question

The possible questions that should be proposed in completing this research are,

1.4.1. What are the materials and apparatus needed and suitable for making adhesive in the restoration of paper materials?

1.4.2. Between starch and soya flour, which material is suitable and effective to be the main ingredient in producing an adhesive for restoration of paper materials in the context of cultural heritage objects?

1.4.3. What are the long-term effects of using adhesive materials on the stability and appearance of paper-based cultural heritage objects?

1.5 Objective of the Study

This study is concerned with the most suitable adhesives that can be used in the restoration of paper materials and the knowledge of how to maintain their effectiveness for the benefit of future generations' enlightenment. The primary focus of this research is aimed at understanding the factors that make the adhesive effective and protecting

the production process to ensure long-term stability criteria are met. Furthermore, this study has proposed three (3) main objectives:

1.5.1. To identify the materials and apparatus needed and suitable for making adhesive in the restoration of paper-based materials.

1.5.2. To determine the most suitable and effective material between starch or soya flour as the main ingredient in producing an adhesive for restoration of paper materials in the context of cultural heritage objects.

1.5.3. To identify the long-term effects of using adhesive materials on the stability and appearance of paper-based cultural heritage objects.

1.6 Significance of the Study

The significance of this study lies in its potential contributions to the field of cultural heritage preservation, particularly in the context of paper material restoration. By investigating the factors that contribute to the effectiveness of adhesives and their long-term stability, this research aims to provide a better understanding of the best practices for the preservation of valuable paper-based artefacts. This information can lead to the development of improved restoration techniques, which may ultimately result in more effective preservation strategies for cultural heritage objects, benefiting both the field of conservation and society as a whole

1.7 Scope of the Study

The scope of this research is primarily focused on the restoration of paper materials using adhesives. The study will investigate various types of adhesives, their effectiveness in restoring different paper materials, and the factors that contribute to their long-term stability. In addition, the research will explore the methods for preserving the adhesives and maintaining their effectiveness over time. The study will not delve into the restoration of non-organic materials or other aspects of cultural heritage preservation that are unrelated to the use of adhesives. By concentrating on this specific area of conservation, the study aims to provide a clear and focused investigation into the role and importance of adhesives in the restoration of organic materials, in particular of paper-based ones.

The study area chosen in this experimentation plays an important role because the study area should focus on an environment that helps the researcher to be able conduct trial-and-error tasks with the equipment and surroundings that fits the requirements of producing the adhesive. In addition to that, this experimentation will be conducted at Universiti Malaysia Kelantan (UMK) in the Faculty of Technology Creative and Heritage's laboratory.

Universiti Malaysia Kelantan is a public university that is located in Kelantan, Malaysia. The creation of the institution was proposed during the presentation of the Ninth Malaysia Plan and was given the go-ahead on June 14, 2006, by Malaysia's cabinet. Universiti Malaysia Kelantan has three (3) campuses, which are Pengkalan Chepa Campus, Bachok Campus and Jeli Campus.

However, in this research it will be done in the Bachok Campus. It is situated close to the Tok Bali beach tourism area in the Bachok district. On September 1st, 2006, UMK formally opened for business. The campus has a total size of 553.8 acres and is being built up in two phases, the first of which will take up 254 acres now and the second of which will eventually occupy the last 300 acres of open space. A former paddy plantation that is ideal for development is part of the campus. A technical skills development institute, communities, and schools surround the location. This campus currently has 3 different faculties, Faculty of Technology Creative and Heritage (FTKW), Faculty of Architecture and Ekistics (FAE) and Faculty of Language Studies and Generic Development (FBI) (Figure 1.1). The coordinates to Universiti Malaysia Kelantan, Bachok Campus are stated in (Figure 1.2)

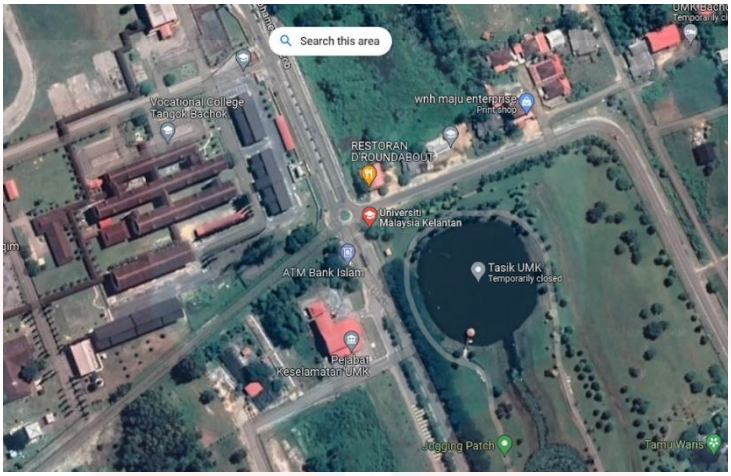


Figure 1.1: Bachok Campus, UMK Location

Source: Google Maps

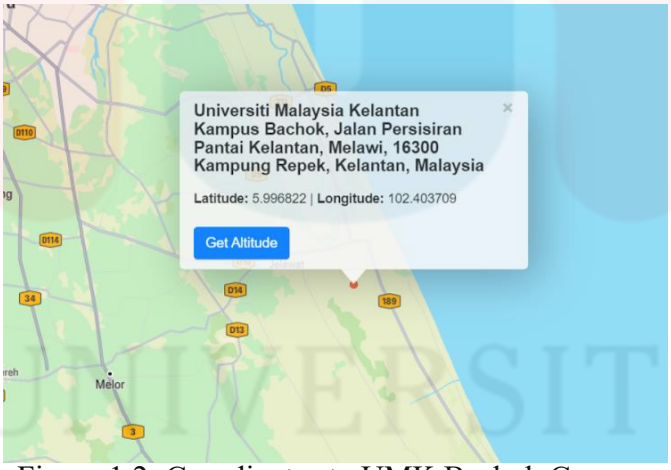


Figure 1.2: Coordinates to UMK Bachok Campus

Source: (https://goo.gl/maps/Et4Yn5zgwnjt1Prt8)

The experimental research will be conducted in a laboratory that is located in the Faculty of Creative Technology and Heritage building. In addition to that, the lab is on the second floor of the four-story building. In the lab itself it has a spacious surrounding and good amount of suitable equipment to work with. The location of the building is stated in (Figure 1.3)

Figure 1.3 Faculty of Creative and Technology and Heritage

Source: Google Maps

1.9 Methodology

1.9.1 Literature Review

Conducting a comprehensive review of existing adhesive materials and their use in preserving paper materials. This involves examining primary and secondary sources, such as journal articles, books, and technical reports, to gather information about adhesives used in previous studies and related preservation techniques.

1.9.2 Adhesive Selection

Based on the literature review, choosing starch and soya flour in comparison for most suitable and potentially useful for preserving paper materials. The selection of adhesives should consider factors such as effectiveness, stability, and long-term effects on paper materials.

1.9.3 Preservation Experiments

Using the selected key elements in producing adhesives to perform preservation experiments on paper materials samples, such as painting, manuscript, paper tickets, receipts and others. This process involves joining or repairing damaged or separated parts of the samples using the adhesive, then monitoring the stability and appearance of the organic materials throughout the preservation process.

1.9.4 Effectiveness Evaluation

Assessing the effectiveness of the adhesives used in the preservation experiments by examining the integrity, stability, and appearance of the paper materials sample after the preservation process. This may involve physical, chemical, and optical testing to determine how the adhesive affects the properties of the paper materials and their long-term impact on cultural heritage objects.

1.9.5 Data Analysis and Conclusions

Collecting and analysing data obtained from the preservation experiments to compare between starch and soya flour-based adhesives and their long-term effects on paper materials. Based on this analysis, making conclusions about the most suitable and effective adhesives for use in preserving paper materials in cultural heritage objects.

1.9.6 Writing and Presenting Findings

Preparing a research report that includes the literature review, methodology, experimental results, data analysis, and conclusions. This report will be presented in a written format that adheres to scientific writing standards and may be submitted for publication or presentation at conferences or other academic forums.

1.10 The Importance of the Study

1.10.1 Enhancing Knowledge

This research will improve the understanding of which main ingredients in producing the adhesive are more effective and suitable in the conservation of paper materials and the long-term effects of their usage on cultural heritage objects. The findings from this study will provide valuable contributions to the field of conservation and preservation.

1.10.2 Developing Better Adhesives

The outcomes of this research may aid in identifying and developing more suitable and effective adhesive materials for use in the conservation of paper materials. This will ensure the integrity, stability, and appearance of cultural heritage objects are maintained over time.

1.10.3 Improving Conservation Techniques

The knowledge gained from this study will assist conservation experts in refining their techniques and adopting more innovative approaches to preserving and protecting cultural heritage.

1.10.4 Promoting Cultural Heritage Sustainability

By enhancing the effectiveness of conservation processes, this study will contribute to efforts to preserve and protect cultural heritage for future generations. This will ensure that these valuable objects continue to serve as sources of inspiration and understanding of history, culture, and community identity.

1.10.5 Impact on Conservation Industry

This research may influence the conservation industry by recommending the use of more suitable and effective adhesive materials in the conservation of paper materials. This will improve the quality and sustainability of conservation outcomes, which in turn will enhance the aesthetic value and historical significance of cultural heritage objects.

1.11 Chapter Description

Chapter 1: Introduction

In this chapter the researcher will explain about the structure of the research to be held which is an experimental study in producing a suitable and most effective adhesive by comparing the main ingredients, either soya flour or starch. Also, in this chapter it is stated the problem statement, research questions, and objectives. In addition to that, there is also an explanation on the significance of the study, the general methodology, scope of the study and also where the experiment will be conducted.

Chapter 2: Literature Review

Chapter 2 will be explained more on the history and background of the study itself based on past studies and other researchers' studies. Furthermore, in this chapter the researcher will also states the definition of adhesives and the chronicle of it. Also, in this chapter there will be a short conclusion on the relationship between effectiveness of the adhesive and the main ingredient in producing one.

Chapter 3: Research Methodology

This chapter will be focused on the suitable approach to be used in obtaining the research's data and information related to completing the study. Thus, because of that, the researcher chooses qualitative methods such as journal reviews, books and technical reports. Moreover, in this chapter will be written in detail on how the data and information gathered by the researcher itself.

Chapter 4: Results and Discussion

In Chapter 4, the researcher will explain in detail about all the collected data by the methodology mentioned above. The results of the study will be presented according to the objective of the study that has been stated earlier in hopes that it will make the reader of this paper understand more and capture the

information collected by the experiment conducted. The self-possessed datas will be used by the researcher in order to make the final conclusion.

Chapter 5: Conclusion, Limitations, and Recommendations

Last but not least, in chapter 5 the researcher will elucidate the conclusion of the whole experiment based on the data collected. Therefore, in this chapter it will determine either the written objective has been achieved or not.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter the researcher explains and deciphers all the past research that has been studied and well written by other and past researchers. The literature that is pertinent to comprehending developmental disorders and interpreting the findings of this convergent investigation will be the focus of this chapter. These completed studies were used as a reference and a map for writing this entire chapter. In this chapter there will be a discussion related to an overview of starch and soya flour-based adhesives. Also, by the listed characteristics there will also be a writing about comparing those two types of adhesives. It aims to acquaint readers with the fundamental principles of problem solving that guided the creation of this programme and the interpretation of the findings.

2.2 Understanding Adhesives in Paper Conservation

Documents, manuscripts, books, artwork, and historical artefacts are just a few examples of the variety of paper-based resources that must be preserved and restored. The preservation of historical and artistic works with a foundation of paper, parchment, or photographic elements is the focus of paper conservation (Westlake Conservator, 2020). Due to their fragility, paper objects need to be handled carefully in order to preserve their aesthetic appeal and financial worth.

Stated in a writing by Masterworks Fine Art Gallery (n.d.), with exposure to hazardous compounds like particular pressure-sensitive tapes, cellulose degradation brought on by light, humidity, and air pollutants is also a contributing factor in this sensitivity. Inappropriate handling of the items and exposures to live mould spores can both cause biological degradation. Methods in conserving could be listed as cleaning, stabilisation, and repair and restoration. In cleaning could also be various according to the necessary of the paper itself, surface cleaning, aqueous cleaning, and also mechanical cleaning. Techniques to chemically and physically stabilise the base structure in conjunction with the visual medium are part of the science of paper conservation. “Inks, paints, pastels, charcoal, pencils, crayons, and any number of

photographic materials are examples of the visual media, which might be a single component or a complex mixture of materials," (Westlake Conservator, 2020). Also, by completing the conservation of paper it is common to mend tears, filling losses, and correction of areas that were damaged.

A paper conservator can lessen the impact these forces have had on the piece, lessen their visual distraction, and avoid further degradations through preventative measures and conservation treatment (Westlake Conservator, 2020). In addition to that, preventive measures that routinely be done are environmental control, handling and storage, and exhibition and display. Preventive treatments are always related to the agents of deterioration such as, temperature, light, fire, vandalism, and etc. In addition to that, it is best to believe the paper materials are preserved to their most suitable surroundings in achieving the mission to protect our cultural heritage.

Although as a conservator, it is the main job to inverter the materials in order to conserve and preserve yet it is also important for them to understand and practise the ethical considerations in the field. There are few basic codes of ethics in the conservation field such as, respect for the object's integrity, keeping one's theoretical and physical capabilities to undertake a given sort of treatment within reasonable bounds, and making sure the possibility of treatment and materials in use are highly reversible.

In summary, paper conservation is a multifaceted field that calls for a careful balancing act between scientific expertise, technological proficiency, and ethical considerations. This approach work of field does not only benefit in protecting our cultural heritage, paper conservation also would help the upcoming generation with valuable knowledge for the purpose of research, education or even in sense of inspiration. Future research, teamwork, and innovation are the chances for paper conservation to step forward and secure the preservation of our collective history.

2.3 Overview of Starch as an Adhesive

Grain or root crops like sweet potatoes, maize, wheat, rice, yams or cassava are used to make starch (Akpa Jackson Gunorubon, 2012). Due to its advantageous

qualities and compatibility with paper-based products, starch is a frequently used glue in paper conservation. To hinge artefacts to mats, to make repairs, or to reattach pages in books, wheat starch paste is a recommended adhesive for use with paper artefacts (Canadian Conservation Institute, 2017). Grain or root crops like sweet potatoes, maize, wheat, rice, yams or cassava are used to make starch (Akpa Jackson Gunorubon, 2012)

Reversibility would be the first property, in which starch-based adhesives are often used rather than other materials because of their reversibility characteristic. In this part, it is possible for a future treatment that involves removing the adhesive without causing any harm towards the paper materials. As widely known, interventive activities that are reversible have priority in conservation treatments. Next, its compatibility with paper substrates due to its natural origin and composition. It connects with the cellulose fibres in paper to form a connection that offers strong adhesion and stability without significantly fading or degrading the paper.

Furthermore, when adhesives that are made with starch it has shown moderate strength and flexibility, which are good in handling any further damage that could occur with the paper materials. They are known to sustain the structure while allowing the paper to stretch and expand naturally. In addition to that, compared to chemical-based adhesive that has complex ingredients, starch is available in most stores, economical, and easy to manage which has been the main reason to be chosen as a base material in making adhesive in the conservation of paper.

Adhesives are essentially sticky substances that are always needed for bonding, securing, or gluing surfaces (Powder Rooms, 2020). Thus, one of the uses of starch as an adhesive is repair and mending especially the ones that are damaged and teared up, consolidating fragile areas and also attaching back or detaching pieces of paper materials. However, with that much of interventive activity, it still manages to be reversible.

Next, it also has the purpose of filling in gaps and lining or mounting paper-based artefacts. In order to proceed with filling the gaps between paper - based materials is to make a paste that is a mixture of starch and cellulose fibre or calcium carbonate. Restoring back the missing pieces would upgrade the artefact’s visual value while also

ensuring its stability. With this it has indirectly leads to how starch-based adhesives helps with enhancing the structural integrity of the paper materials.

When there are advantages there will also be its consequences, in which here starch adhesives could be susceptible to moisture, with the high percentage of humidity or existence of water. In addition to that, it is possible that the adhesive will weaken until it loses the adhesion properties. On the other hand, starch also attracts insects and would make the paper materials end up in pest insect attack. However, these two limitations could be avoided by controlling its display and storage environment to its suitable and best condition. Moreover, unpurified starch paste is concerning because it may cause future out-turn which will appear to become a yellowish colour and will break bonds over the time. Also, every material has its limits in the context of strength, in which starch adhesives are most appropriate for paper - based artefacts and not recommended for heavy duty.

As stated in a journal article written by Akpa Jackson Gunorubon in 2012, "An alternative use of cassava starch has been successfully achieved through its use in the production of an adhesive,". Also, depending on the desired qualities and industrial applications, the result stated by Akpa Jackson Gunorubon, offer a wide range of conditions for manufacturing starch-based adhesives for various purposes. According to the research of (Maurer, 2009, pp. 657–713) in corrugated board, laminated grades, and other goods, starch is used as flocculant and retention aid, as a bonding agent, as a surface sizer, as a binder for coatings, and as an adhesive.

As a summary, adhesives that are made from starch give out a natural, renewable, and environmentally friendly alternative to synthetic adhesives. They are a preferred option across a variety of industries, especially for bonding porous materials because of their adaptability, affordability, and simplicity of preparation.

2.4 Overview of Soya Flour as an Adhesive

Soya flour is defined as a fine powder obtained from grinding roasted soybeans. Soya flour can increase the nutritional value of baked foods by primarily boosting their protein content and enhancing texture through lipid oxidation (Bakerpedia, 2021). In

addition to that, soya flour can also be used as an adhesive in certain applications. It provides an alternative to conventional adhesives and has gained popularity as a sustainable and green choice. There is interest in substituting cheap soy flour (SF) for pricey soy protein isolates (SPI) in wood adhesives in order to create a more affordable soy-based adhesive (Dong-Bin Fan et al., 2012)

The composition of soy flour is originally from grinding and processing soybeans; thus, it contains various elements such as carbohydrates, proteins, fat and fibres. However, the main component in it that shows adhesion properties is part of the proteins which are also known as soy protein isolate. The most refined byproduct with the highest overall protein concentration is soy protein isolate. At least 90% of the protein in soy protein isolates is protein on a dry basis (Schmitz Jr, 2009). Although carbohydrates contribute to viscosity and water binding, proteins are the main functional element in soy coproducts.

The preparation of soya flour-based adhesive is just by mixing water with the powder in order to form a paste or glue-like consistency. The mixture is then heated to help the proteins connect and become activated, creating a glue-like stickiness. The percentage of powder and water needed may vary depending on the thickness and consistency that a person desires. Next, the application of the adhesive is used in various projects such as woodman ship, paperboard lamination, and composite manufacturing. It can bind substances including cardboard, wood, paper, and some polymers. However, elements including the kind of materials used, the desired bond strength, and the surrounding environment may affect its applicability for a certain application.

Stated in the thesis written by John F. (2009) “The major soy proteins are globulins, which are insoluble at their isoelectric point,” which means one of the key physical features of soy proteins is their water solubility. However, they are soluble in salt or water solutions that have a pH above or below their own. Only a small portion of soy proteins are soluble between pH 3.75 and 5.25. In comparison to synthetic adhesives, bio-adhesives have performed worse, particularly in terms of water resistance (Doroteja Vnučec et al., 2017). Also stated that, a protein adhesive's bonding power is influenced by the viscosity of the adhesive. Application of the adhesive is

impacted by viscosity, particularly when it comes to spreading and penetrating the wood.

The advantages of using soya based-flour adhesive are listed as collected from renewable resources which is soybeans and indirectly showing a more environmentally friendly if to be compared to the synthetic adhesives. Next, soya flour is known for its properties of biodegradable and non-toxic characteristics which means it is safe in handling and also in disposal. In applications involving woodworking, in particular, it can offer good initial tack and bond strength. However, every advantage will be paired up with its limitations, soya flour-based adhesive has always been known for its low water resistance compared to synthetic adhesives. In addition to that, this adhesive may not be suitable for projects that are exposed to high moisture. Other than moisture, the bond of soya flour also could be affected by temperature, humidity etc. There were loads of papers written about experimenting with soya flour as an adhesive especially in the woodworking industry. Research by Kan et al. (2023) stated that "because soybean protein is considered a good nutrient for mildew, SF-based adhesives can be easily attacked by mildew,".

Soya flour adhesives can be altered and some additives such as borax, urea or formaldehyde in order to overcome the problems of low water resistance. Also, with those kinds of additives, soya flour adhesives could also have stronger bonds and be more durable. In order to alter the adhesive's rheological characteristics and manage its viscosity, cross-linking agents or fillers may also be added. Unmodified soy proteins are unable to satisfy all of the functional requirements for adhesive applications. Soy proteins can be altered physically, chemically, or enzymatically to have a variety of functional characteristics (Schmitz Jr, 2009).

2.5 Comparison of Soya Starch and Flour as Adhesives in Paper Conservation

It is common to see people using starch or soya flour as the based ingredient in making glue, also specifically in paper conservation. Both of the materials have their own benefits and limitations; however, they are known to have different properties that can offer an advantage in the conservation of paper.

Firstly, comparing based on their composition which starch-based adhesive is produced from plant sources such as corn, wheat or potato. These plants consist of amylose and amylopectin which also gives adhesive properties. Amylose offers a coherent matrix and the ability to form films, whereas amylopectin contributes to the three-dimensional network and stickiness. With these characteristics, starch-based adhesive bonds well to various surfaces which make them also suitable for paper conservation. On the other hand, soya flour adhesives are collected from soybeans which contain proteins and also stated the soy protein isolate as the main element. Because of their intermolecular interactions, wetting properties, cross-linking or curing capabilities, and flexibility, proteins can make materials stickier. Also, making a soya flour-based adhesive will be the alternative to synthetic adhesives which indirectly make up for environmental concerns, biodegradability, and non-toxicity.

Secondly, comparing based on their advantages, which here starch adhesives are popular for its ability to be reversible which also sums up to being easily removed. In the past, Japanese paper hinges, repairs to tears, and fragment consolidation have all been accomplished using starch adhesives, which also provide strong adhesion to paper. However, the advantages that soya flour-based adhesives are also could be listed as a better alternative than starch-based adhesive according to their water resistance. They mostly have really common and similar advantages, in which renewable materials, biodegradable and also non-toxic.

Lastly, in every benefit to be offered, there is always a limitation to it, as starch-based adhesives are very sensitive towards moisture. The more it has been exposed to water or a high humidity environment the less effective it is. In addition to that, because of its organic nature, starch-based adhesive could also attract pests. While for soya flour-based adhesive, its limitation is mostly similar, but it may have more permanent nature to be compared to starch adhesives, which means it does not have that much ability to be reversible and also to be harder to remove after it is applied.

2.6 Summary

In this chapter, I have discussed the use of starch and soya flour in paper conservation, highlighting their adhesive properties and applications. Starch based

adhesive offers reversibility, non-toxicity and good adhesion to paper despite having limitations such as low water resistance and attracts pests while soya flour-based adhesives provide a good bond of adhesion and higher water resistance compared to starch based. However, it still has its limitations of being less reversible than scratch based and harder to be removed once applied. Thus, comparing starch and soya flour gives a conclusion that both play their roles in having good advantages and also to be limited with inevitable disadvantages. Next, the following chapter concentrates on the research technique used in this work, building on the present understanding of starch and soya flour adhesives in paper conservation. With the information gathered in the literature review, such as limitations, advantages and properties of starch and soya flour it could be used in contributing towards the existing body of research and also give useful guidance on how to use adhesives in paper conservation.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter will concentrate on the best method for gathering the researcher's data and information necessary to finish the research. The right approaches, procedures, and instruments must be chosen in order to collect, analyse, and interpret the data in order to respond to research questions or test hypotheses. Research methodology acts as a guide for carrying out thorough and trustworthy research, guaranteeing that the results are accurate, credible, and reliable. The research design, data collection strategies, sample methodologies, data analysis procedures, and ethical considerations are just a few examples of the various elements that make up an effective research methodology. Based on the nature of the research issues, the goals of the study, and the resources available, these components are carefully chosen.

3.2 Research Design

The general structure, plan, and approach that a researcher uses to address the study's objectives are referred to as the research design. It serves as a plan or road map for the study, directing data gathering and analysis to address research questions or test hypotheses. Having a research design is important due to its outcome of determining the reliability of the study's finding; however, different research methodologies are appropriate for various study types and serve various purposes. In this study it aims to experiment with organic based material such as starch and soya flour in making an adhesive for paper conservation.

The research design appropriate for this paper is experimental design, which involves systematic variable manipulation, measurement of the effects on the dependent variable or variables, and correction for any confounding variables. In this research with experimental design, this would allow the researcher to understand the effects of different types of adhesive formulations, application techniques or even on the performance of the man-made adhesive.

In this study, the information and data gathered are by using a quantitative method which the goal of quantitative research is to find patterns, correlations, and statistical trends by gathering and analysing numerical data. The reason behind the chosen method is because mixed methods allow the researcher to obtain an understanding of the research question through both the breadth and depth of it.

In addition to that, the collected data would also be divided into two which are the primary data and secondary data. Primary data are those that the researcher has personally obtained from sources other than the secondary sources for the purposes of the current study, while secondary data are the data that has been gathered by another party for a different reason and can be used by researchers for their own investigations. Primary sources are usually obtained by handling the gathering information activities personally by the researcher. Examples of primary sources that are used in this paper are, experiments, and observational studies.

3.2.2 Experiments

An experimental method is a research strategy that involves changing one or more variables and observing how those changes affect another variable in order to discover cause-and-effect correlations between variables. It is frequently used in quantitative research to verify causality and evaluate hypotheses.

3.2.3 Observational Studies

Observational studies are research techniques that involve keeping a systematic record of actions, occurrences, or phenomena without deliberately modifying any of the variables. These studies seek to characterise and comprehend the behaviours, connections, or patterns that naturally occur in actual environments. Observational studies shed important new light on social interactions, human behaviour, and natural occurrences.

Secondary sources are the data that has already been collected by others and to be used by other researchers to complete their aim in solving the research problem.

Examples of secondary sources that are used in this study are, journal and articles reviews, technical reports and books. In addition to that, mostly secondary sources are known as literature review and collected through offline and online root.

3.3 Experimental Design

According to (Bevans, 2019) a set of techniques is developed through experimental design to systematically examine a hypothesis. A thorough understanding of the system you are researching is necessary for a successful experimental design. In proceeding to experimental design, the researcher has to follow the five key elements that are needed in this design, which are firstly consider the variables in the experiments and how they are related to each other. Secondly, create a specific and testable hypothesis or if it is available by the past researcher, the researcher has to test their hypothesis. Thirdly, design the experimental treatments in order to manipulate the researcher's independent variable. Fourthly, assign your current subjects to different treatment groups, either a completely randomized design or a randomized block design. And lastly, planning on how the researcher will measure their dependent variable.

3.4 Preparation of Adhesive

3.4.1 Preparation of Starch Adhesive

The materials needed in making the starch adhesive are cornstarch, wheat starch and potato starch. However, the choice may vary depending on the availability of the product. And other than that, will be water, preferably distilled water, with the reasoning of its consistency, purity and avoiding interference. Distilled water is also known for its composition of free from impurities, minerals and other chemicals possible to dissolve in liquid. Next, the ratio for start to water used in making the starch adhesives will be set to 1:4. However, it may change and adjust depending on the outcome of its consistency and thickness for the starting ratio. The tools needed could also be listed as beaker, glass rod, weighing scale, containers (for sampling), and hot plate.

The procedure of the experiment will be starting by preparing all the tools and ingredients then to be arranged on a table with enough space to work on. Second step is, with the ratio given pour the amount of starch and water into a beaker, mix it thoroughly and stir continuously. The next step is, by using the hot plate, heat the mixture into medium heat and continue stirring until it becomes the desired consistency and translucent. Lastly, remove the adhesive mixture from the hotplate and let it sit to cool but without stopping the stirring. When the adhesive is finished, and ready to be used, transfer it into a sampling container, label the name and date it has been made.

3.4.2 Preparations of Soya Flour Adhesive

The materials needed for this experiment are only soya flour and water, which is the same as the starch adhesive experiment distilled water. With the same reasoning of consistency, free from impurities and also to prevent any contamination could possibly occur. Just like the starch preparation, the ratio of soya flour and water may vary depending on the desired thickness and strength. Although there is no rule in setting the ratio, the experiment will start with 1:2 soya flour to water. Next is the list of steps needed to be done, in order to prepare the soya flour-based adhesive. The tools that needed are, beaker, glass or metal rod, containers (for sampling), and weighing scale. Arrange all the tools and ingredients needed on a table with a good amount of space to work on it. Firstly, in a beaker partly combine the soya flour and water with the ratio stated and stir continuously, which means the water added by parts and not all together mixed. Secondly, the stirring continues until the desired consistency and evenly dissolved. Thirdly, let the mixture rest for 5 minutes, to allow the powder to be fully hydrated. Lastly, when it is ready, mix well again and transfer it to a sampling container, label the name and date it has been made.

3.5 Experimentation of Adhesives

In preparing for the experimentation of adhesives that have been made, firstly the surface of the object must be examined and ensure to be in a good condition to apply adhesives. Next, with using a brush gently apply the adhesive on an aimed area of the paper. The adhesive should be applied little by little until the surface desired is evenly

covered with it. This step is important because, in order to avoid excessive application which could cause stains, lumps and untidy appearance. Next, gently bring together another exact same cleaned type of paper and stick them together. Lastly, let it set to dry at a space that the researcher can observe and take notes on the changes. The factors that should be considered are, the environmental conditions, such as humidity and temperature.

There will be a few variables that are being measured such as, drying time, bonding strength, reversibility, and ageing and stability. Also, the techniques used in measuring the variables are different for each. Firstly, the amount of time needed for the adhesive to fully cure will be measured using stopwatch and visual observation. Secondly, the technique used in evaluating bonding strength is by either pull-off test or shear test. Thirdly is measuring the reversibility of the adhesive by rating on how easily it is to remove the adhesive once it has fully cured also, this step should be tested using solvents if needed in removing the adhesive. Lastly, in measuring the ageing and stability of the man-made adhesives is by observation of the sample conditions such as colour changing, consistency, and strength of the adhesive.

3.6 Sample Selection

The type of paper chosen in this experiment is set to same ype of paper which is offset paper but with a different weight. The offset paper to be used is in a size of an A4 (origin size) with a weight of 70gsm while the other weight will be 100gsm. The reasoning behind the choice in type of paper is availability and most books are made from offset paper, which could possibly be almost the same composition as old books that may need conservation work. In preparing the sample, the papers are cut into a hand-full size which makes it easier to handle. Next the paper sample will be cleaned in order to make it free from impurities such as dust or dirt then the sample is kept securely ensuring the condition to be stable. In addition to that, the samples are labelled so that it would not get mixed. However, for the sample of an old book the researcher will buy or search for an old book that is qualified enough to be experimented on. The qualifications needed to be considered, such as the condition of it, and the value of the book.

3.7 Data Collection Methods

3.7.1 Observation

Qualitative information about the adhesive application process, such as the adhesive's appearance, its ease of application, or any noteworthy observations made during bonding, may be observed and recorded by researchers.

3.7.2 Measurements

By using certain tools and apparatus, the quantitative data may be collected. Such as stopwatch is used in the process of measuring curing time of the adhesives to be set fully.

3.7.3 Photography

Pictures are taken in order to capture the documentation of the experiment being done. As an example, in order to see a discoloration of the sample, pictures are taken from time to time to see the difference.

To ensure that collected data are reliable and valid are by minimising the sources of errors and variability during collecting data. The steps should be done such as, standardising the procedures, calibrated equipment is used, or try to copy in order to get uniformity. If it is possible the researcher will have a few other individuals to perform the procedure by themselves and compare the results to gain consistency. For validation data, other than re-doing the experiment to get an average result, the researcher chooses to use appropriate tools and measuring techniques in recording the data needed to achieve the objective of the study.

3.8 Data Analysis

Firstly, before analysing the data, all of them are rearranged and get checked on one by one for completeness and accuracy. With this way, any errors or invalid data could be removed earlier without making time to analyse it. Thus, the statistical methods used are listed as, descriptive statistics, hypothesis testing, and regression analysis.

3.8.1 Descriptive Statistics

A summary of the central tendency, variability, and distribution of the data is given by descriptive statistics. Thus, calculating the measurements for an outcome of means, medians, ranges or even percentages depending on the nature of the variables.

3.8.2 Hypothesis Testing

To determine the significance of observable differences or correlations, statistical hypothesis testing is utilised. This process involves making alternative hypotheses by performing tests.

3.8.3 Regression analysis

Doing an examination in order to understand the relationship between variables that are available. As an example, the bonding strength and adhesive thickness with the use of various techniques such as linear regression or just logistic regression.

3.9 Ethical Considerations

Any research experiment must take ethical issues into account to guarantee the safety and wellbeing of participants as well as to uphold the values of integrity and respect. Few ethical considerations that are related to the experiment such as, informed consent, confidentiality and privacy, use of heritage objects, and data handling and storage.

3.9.1 Informed Consent

In proceeding the data collecting there may be an involvement of individuals, which they would take part in making a sample for the outcome of uniformity. Gaining informed consent from the participant to ensure the researcher and them are on the same page of understanding procedures, risks and purposes of the involvement.

3.9.2 Confidentiality and Privacy

Any information given relates to the participants that have taken part in the experiment will be safeguarded. To protect participant identities and to adhere to applicable data protection laws, make sure that data is anonymized and kept securely.

3.9.3 Use of Heritage Objects

In completing the analysing data from old books value of the books should be considered and any unnecessary interference should not be done. Any confusion or misunderstanding in the experiment should be referred to professionals such as lecturers. Research and documentation should be done about the books chosen, in order to enhance on decision making for conservation treatment

3.9.4 Data Handling and Storage

All the collected data would be kept within the researcher's eye-sight and to be safeguarded in order to secure the authenticity of the results and any confidential information relates to human participants.

3.10 Limitation of the Research Methodology

In any research there will always be a limitation to it, however it is important to understand and find ways to make them less burdensome. In this paper one of the possible limitations will be the accuracy and reliability of measurements and instruments used in the experiments. However, a way to mitigate the limitation is by conducting pre-tests to observe the reliability and validity of the measurements. Thus, in obtaining consistent results procedures need to be standardised. Next, other limitations such as limited time provided. By not having enough space and time it may have constraints on the scope and depth of the research which indirectly limits the ability for the researcher to explore other segments of the study. However, the mitigation is by setting more realistic expectations and priorities and only focuses on answering the research questions.

3.11 Summary

In this chapter, we went over the research methodology that was employed to find out how well adhesive adhesives preserved paper. The chosen research design was experimental design which allows manipulation of variables and how it affected the performance of the adhesive materials. Also, detailed methods were listed in preparing starch and soya flour-based adhesives and application techniques were also discussed. Methods chosen in collecting data were listed as observation, measurements, and photography which also relates to the statistics method chosen in data analysing. Also, in the chapter the researchers have discussed ethical considerations, limitation of research methodology and mitigation of the limitation. The data gathered for this study will be shown and examined in the following chapter, Chapter 4: Results and Discussion. To address the study questions and test the hypotheses, the data will be interpreted and discussed. To show the main findings, the data will be arranged and presented using the appropriate tables, graphs, or figures. Thus, a thorough comprehension of the information gathered and its implications for adhesive materials in paper conservation are sought after in the Results and Discussion chapter.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter there will be an explanation relates to the findings and results of the experiments comparing soya bean flour and two different starch such as cornstarch and potato starch as the main ingredient in paper materials conservation with the context of cultural heritage objects. Also, in this chapter will be proving the objectives and goals as stated earlier which are;

- To identify the materials and apparatus needed and suitable for making adhesive in the restoration of paper-based materials.
- To determine the most suitable and effective material between starch or soya flour as the main ingredient in producing an adhesive for restoration of paper materials in the context of cultural heritage objects.
- To identify the long-term effects of using adhesive materials on the stability and appearance of paper-based cultural heritage objects.

In identifying materials and apparatus needed for making adhesives specialized in paper-based materials such as manuscript, books and etc, the researcher chose an experimental method. The reasoning behind the chosen method is the meaning behind experimental design itself which is organising a sequence of steps to look into a relationship between variables (Scribbr, 2019). Also stated that an experimental design needs a testable hypothesis, which in this paper, the hypothesis is said by A. Emblem, M Hardwidge in Packaging Technology, 2012 “Based on their properties and characteristics, it is hypothesized that starch paste will be more suitable than soya – flour for paper conservation, considering factors such as adhesive performance, reversibility, long term stability, and compatibility with various paper type,”.

The chosen method would be considered as an alternative towards the modern ready-made adhesive in the market is because it offers more comfortability and less financial stress. The researcher identifies all the apparatus and ingredients by considering the accessibility, cost, availability and chemically safe. Thus, with such advantages it is needed for an experimental design in this research as it helps pinpoint the suitable and needed apparatus and ingredients used in the making of an adhesive for paper-based materials to be preserved. Other than that,

the reproducibility of the researcher experiment is in hopes to be as high as the expected. It is shown as the clarity of the instructions in the designed experiment, the stability of the ingredients that has been chosen, and the consistency of the results recorded as the experiment has been done.

In order to complete this chapter, the researcher herself made three (3) types of self-made adhesive using cornstarch, potato starch, and soyabean flour as the main ingredient. The samples were prepared with the same values of elements and isolated into labelled containers. The researcher also provided photography as proofs records throughout the journey of experiments and by using the method of observation to understand and contribute in answering the research question of the study which are;

- What are the materials and apparatus needed and suitable for making adhesive in the restoration of paper materials?
- Between starch and soya flour, which material is suitable and effective to be the main ingredient in producing an adhesive for restoration of paper materials in the context of cultural heritage objects?
- What are the long-term effects of using adhesive materials on the stability and appearance of paper-based cultural heritage objects?

In conclusion, the project presents a new angle on adhesive manufacture by carefully weighing the drawbacks of current techniques and utilising an unusual combination of materials and production techniques. The researcher's hope in the chosen method by scientific foundation, practical viability, and economical use of resources position it as a significant addition to the adhesive technology field. In addition to addressing important variables, the experimental design guarantees reproducibility, opening the door for additional study and application in this field.

4.2 Identification of Materials and Apparatus

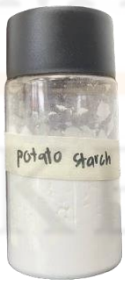
As the experiment took place in the campus laboratory, the researcher has identified a list of apparatus and materials that are suitable for making the adhesive in Table 4.1 and Table 4.2.

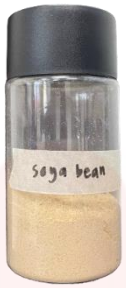
Table 4.1: List of Apparatus

Image of Apparatus	Name of Apparatus
	Scientific Magnetic Stirrer Hot Plate
	Beaker (250ml and 100ml)
	Digital Electronic Balance
	Small Plastic Containers

	Stainless Steel Spatula (Dissecting Set)
	Paintbrush
	pH Meter

Table 4.2: List of Materials

Image of Materials	Name of Materials
	Cornstarch
	Potato Starch

	Soya-bean Flour
	Battery Water
	Multi-purpose A4 Paper (70gsm & 100gsm)

According to Table 4.1 listed 6 types of apparatus that are used in the experiment, which are Scientific Magnetic Stirrer Hot Plate, Beaker (250ml and 100ml), Digital Electronic Balance, Small Plastic Containers, Stainless Steel Spatula (Dissecting Set), pH Meter, and Paintbrush. These tools are chosen in completing the experiment with the reasoning of being the most common apparatus that could be access in any laboratory. Hereby, it is easy for the researcher to produce the experimental adhesive without needing any advanced technology or extra expenses. Thus, apparatus as common as a beaker has very much favoured in most laboratory, they are particularly significant for safely boiling liquids because of their straight sides and flat bottom, which also make them quite sturdy on most surfaces. You can also stir or pour liquids out of them because of their huge opening (Roy, 2021). Other than that, Roy (2021) also stated that, "With a general physical balance, it is tough to get the desired and exact amounts of the reagents and so these weighing machines come into the picture. These machines help in measuring very small units of substances in terms of weight," in which determined the

suitable purpose of digital electronic balance. Lastly, the use of spatula from the dissecting set is chosen because of their characteristics in resistance to heat and acids (Roy, 2021), thereby making it suitable for preparing the adhesive.

Next, on Table 4.2 the researcher has listed 5 materials that were used in the experiment of adhesive. The materials are, Cornstarch, Potato Starch, Soya-bean Flour, Battery Water, and Multi-purpose A4 Paper (70gsm&100gsm). Firstly, it has stated that, grain or root crops like sweet potatoes, maize, wheat, rice, yams or cassava are used to make starch (Akpa Jackson Gunorubon, 2012). Thus, the reasoning behind choosing cornstarch and potato starch as the materials to be experiment is to see the difference in outcome between the two-type starch paste. Other than that, Canadian Conservation Institute (2017) has stated that, due to its advantageous qualities and compatibility with paper-based products, starch is a frequently used glue in paper conservation. To hinge artefacts to mats, to make repairs, or to reattach pages in books, wheat starch paste is a recommended adhesive for use with paper artefacts. In addition to that, according to (Rogers, 2019) The starch molecule's fundamental chemical formula is $(C_6H_{10}O_5)_n$. A polysaccharide, starch is made up of glucose monomers connected by α 1,4 links. Also, it stated that commonly Starch is being used in paper fracturing in order to gain strength of a paper.

In addition to that, in this experiment the researcher has chosen soya-bean flour as the other ingredient to be compared, and the reasoning behind this is mostly because of the properties and common use in the conservation field. Thus, according to Dong-Bin Fan et al., (2012) It provides an alternative to conventional adhesives and has gained popularity as a sustainable and green choice. There is interest in substituting cheap soy flour (SF) for pricey soy protein isolates (SPI) in wood adhesives in order to create a more affordable soy-based adhesive.

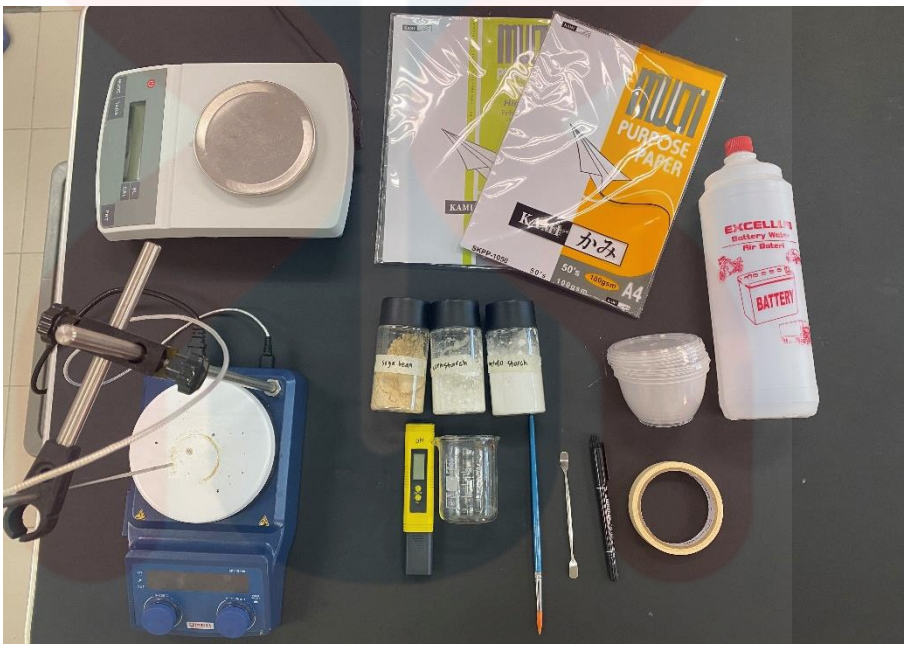
Next, the researcher has chosen battery water as one of the materials needed in mixing up the ingredients to have a glue-like consistency because of it is as close as purified water or also known as distilled water. According to Hanson (2016), using distilled or deionized water is recommended because it is free from additional minerals you would find in water such as regular tap water. The last but not least materials that had been used in the experiment are 70gsm and 100gsm of A4 multi-purpose paper. The reasoning behind choosing this type of paper is, to see the difference in possible results with different thickness of the same multi-purpose A4 papers.

4.2 The Process of The Experimental Adhesives

As the researcher decided on the apparatus and materials needed for the experiment, the next step is undergoing the experiment itself with systematic procedure. In order to have the best and fair result, the researcher decided to use the same steps for each self-made adhesive.

4.2.1 Preparation of the Adhesives in Step – by – Step Procedure

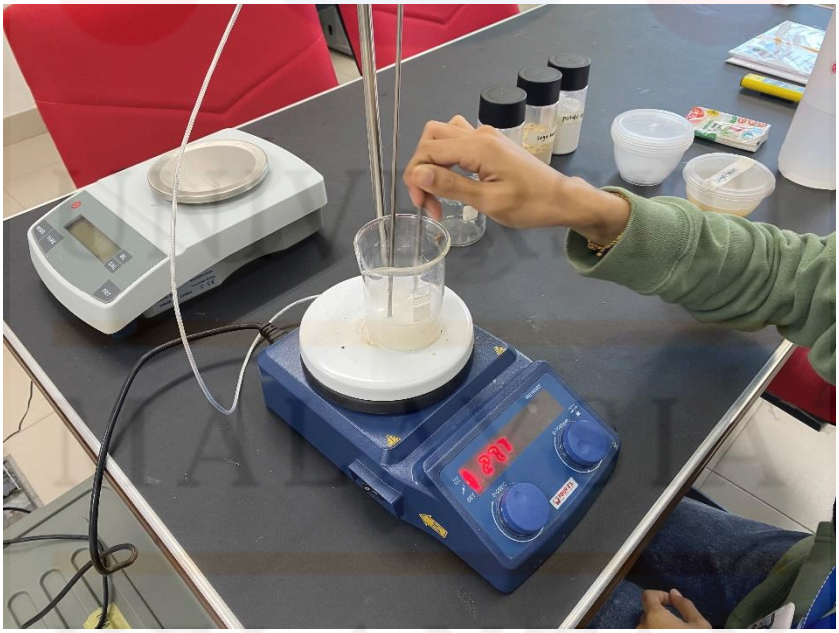
Step 1 - Gather all the apparatus and materials onto a suitable space to work on the experimental adhesive



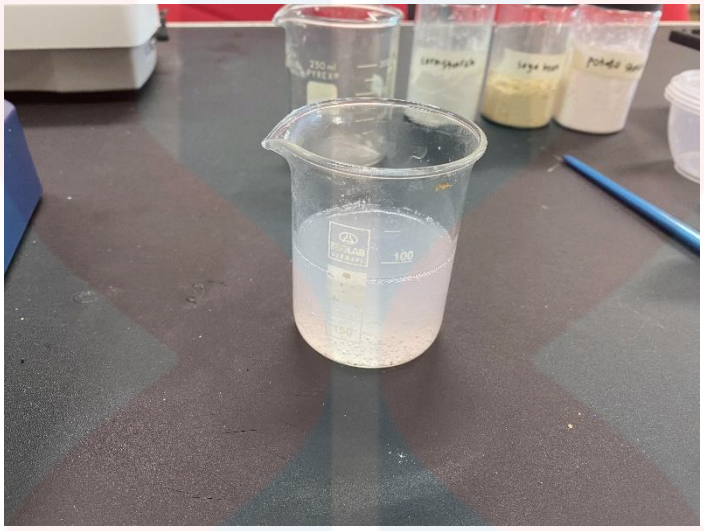
Step 2 - Weigh Potato Starch, Cornstarch, and Soya-bean flour using the Digital Electronic Balance. Making sure all materials have the same amount of weight.

Step 3 - As it takes time for the Scientific Magnetic Stirrer Hot Plate to be ready to use, pour an amount of Battery Water into a beaker.

Step 4 – As the Scientific Magnetic Stirrer Hot Plate is ready, place the beaker at the centre of the plate and stir the solution for an estimate of 5 – 10 minutes using the spatula.



Step 5 – After the materials are fully dissolve, switch off the Scientific Magnetic Stirrer Hot Plate and move the beaker onto the table. Wait for the solution to cool off a bit before pouring it into separates plastic containers.



Step 6 – As the adhesive cool down, when it is time, pour the adhesive into plastic containers.

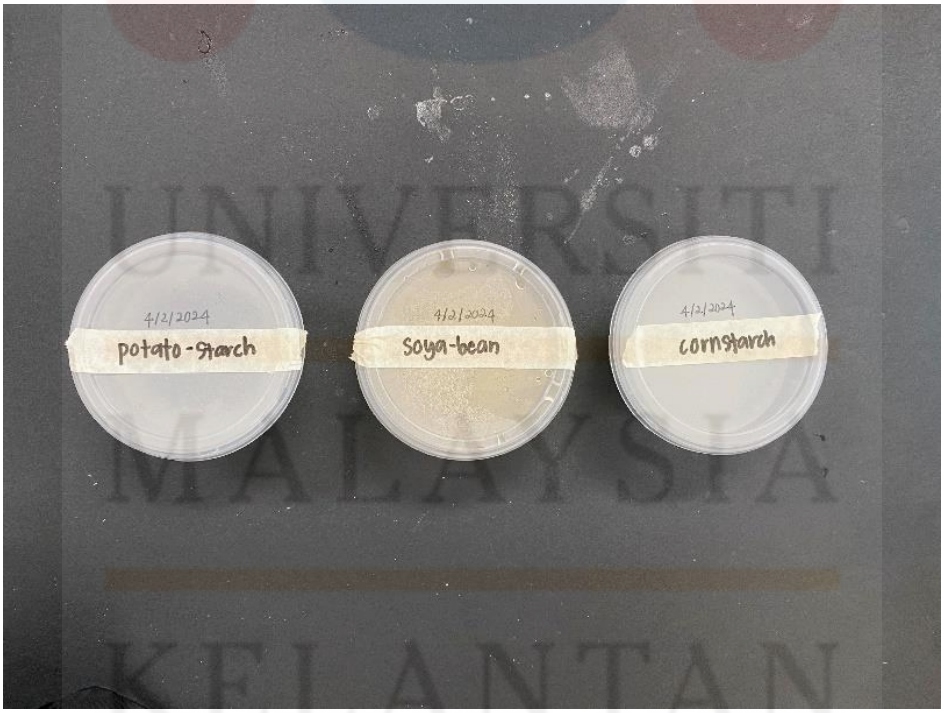
Step 7 – As all the adhesive have been transfer, before storing them, they are labelled using masking tape and marker.

Step 8 – As every adhesive have been labelled, before storing it in the refrigerator, pH value is taken first.

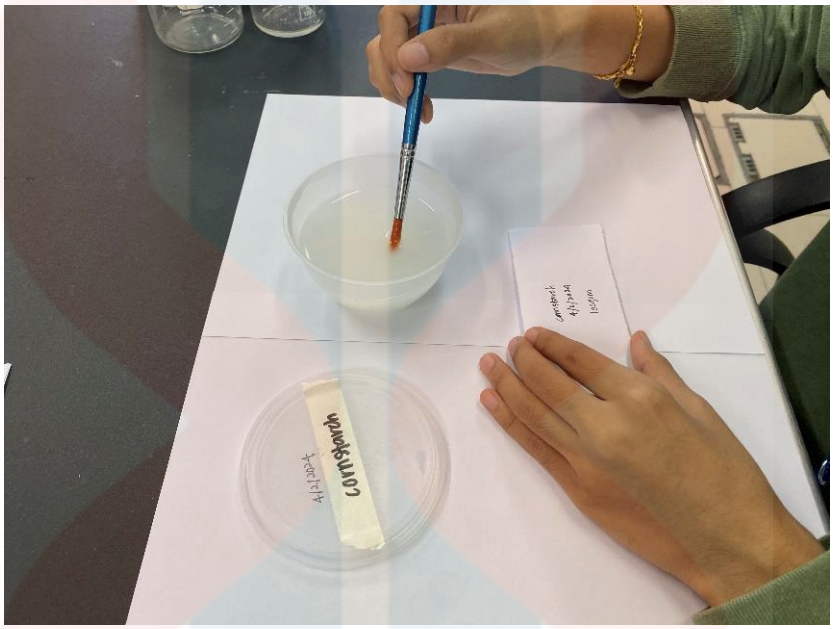
Step 9 – As everything is settled and the adhesive are all set, it is best to store all the adhesive in the refrigerator.

4.2.2 Procedure of Adhesives Being Tested onto Samples

Step 1 – Take out all the adhesive from the refrigerator and prepare a space for the samples to be tested.



Step 2 – The samples from A4 are been cut off into smaller pieces and labelled. As that done, with a brush the adhesives are applied onto the samples.



Step 3 – As the samples being isolated and let to be cured, time has taken and observation has started. As all the testing finished, the adhesive is stored back in the refrigerator. Thus, all the apparatus and materials are stored at an appropriate space.

4.3 Comparison Between Starch and Soya Flour as Adhesive Materials

This research is to decide between starch or soya-bean flour as the best main ingredient of adhesive in paper conservation in the context of cultural heritage. As stated in chapter 3, preparation of the adhesives has been listed with a step-to-step procedure. 3 types of elements had been introduced in the experiment which are, soya-bean flour, cornstarch, and potato starch. Throughout the experiment, the researcher uses 7 types of apparatus which are, beakers, spatula, plastic containers, pH meter, brushes, digital weighing scale, and a scientific magnetic stirrer hot plate. Thus, other than the three powder ingredients the only other material that had been added in the adhesive mixture is battery water.

4.3.1 Data Collection and Presentation of Results

Table 4.3: Results of The Adhesives Properties

Adhesive Name / Adhesive Properties	Cornstarch	Potato Starch	Soya-bean Flour
Battery Water (ml)	50	50	50
Starch/Flour (g)	5	5	5
pH Value	6.32	7.40	8.03
Colour	Cloudy white and white	Cloudy and colourless	Brown with black dots
Texture	Watery with semisolid substance at bottom	Semisolid (glue-like)	Semi watery and grainy

4.3.2 Comparative Analysis

As the adhesive been made, it had been kept in separated container and labelled with the date of the day the experiment carried out. On 28th November 2023 the first test of the adhesive onto paper material has been done. The 70gsm and 100gsm paper each is used for the three adhesives. The paper has been cut into handful size, which makes it easier for the researcher to handle it. Within the period of time the satisfied adhesives have been kept in the refrigerator (in the laboratory) there were no changes in colour, pH or texture from the day 1 which is 29th October 2023. In addition to that, the first batch of sample on 28th November 2023, the researcher kept it at the laboratory for 14 days until 19th December 2023. The results of after leaving a sample have been stated in Table 4.4 and Table 4.5.

Table 4.4: Adhesive Sample (70gsm A4 Paper)

Adhesive Name / Adhesive Properties	Cornstarch	Potato Starch	Soya-bean Flour
Adhere/ Attachment	No	Yes	No

Curing time (s)	1800	900	600
Remains	White powdery substances	None	Brown grainy substances

Table 4.5: Adhesive Sample (100gsm A4 Paper)

Adhesive Name / Adhesive Properties	Cornstarch	Potato Starch	Soya-bean Flour
Adhere/ Attachment	No	Yes	Yes
Curing time (s)	1800	900	600
Remains	White powdery substances	None	Brown grainy substances

4.3.3 Discussion of Findings

With the results of the experiment, the researcher has concluded that Potato Starch (or Starch) has the best outcome and becomes the most suitable adhesive in conservation of paper materials. According to the research (Cencer et al., 2014) "Adhesives formulated at pH 7.4 demonstrated a good balance of fast curing rate, elevated mechanical properties and interfacial binding ability,". Based on Table 4.3 the pH value stated Potato Starch and Cornstarch are 7.40 and 6.32 respectively, which are considered as weak acids. Hereby, written by John Sherman, that weak acid has large pKa's (2 – 50); they are stable because they have high affinity for their protons and want to stay bound to them. However, Soya Flour with pH value of 8.03 which are considered as basic or alkaline.

Next, the discussion relates to the colour of the adhesive according to Table 4.3, the three adhesives produce different type of colours based on the materials used. In the context of suitable adhesive in paper materials of conservation, it is best to have a colourless adhesive rather than any other colour, the reasoning behind this is because coloured adhesive may or may not leave remaining that are coloured residue. This has been proven by the researcher experiment itself in Figure 4.1 and Figure 4.2.

Remains of Soya Flour Adhesive

Figure 4.1

Remains of Cornstarch Adhesive

Figure 4.2

In addition to that, next on the discussion according to Table 4.3 is the texture of the adhesives, which also has an outcome of different types of texture. The closest to a glue-like texture is Potato Starch which could be considered as one of the many characteristics that is suitable for it to be an adhesive for paper materials conservation. The visual of each adhesive mixture is shown in Figure 4.3, Figure 4.4, and Figure 4.5.

Soya-Bean Flour Adhesive

Figure 4.3

Cornstarch Adhesive

Figure 4.4

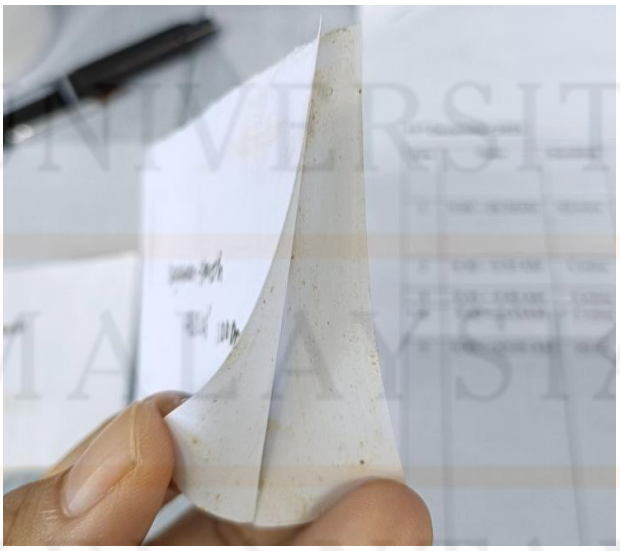
Potato Starch Adhesive

Figure 4.5

Next on the list of the discussion is, the adhesives on different grams per square metre, which are 70gsm and 100gsm A4 paper. Only Potato Starch has the best attachment with both papers. On the other hand, Cornstarch has the same outcome which did not attach both papers thus, leaving a white powdery substance (Figure 4.6). However, Soya-bean Flour has a different result for both papers, it is only attached on the 100gsm paper (Figure 4.7). With this result it can be concluded that, the most suitable adhesive for paper materials in the conservation field according to it is Potato Starch Adhesive.

Powdery residue on cornstarch sample

Figure 4.6



Attachment of Soya-bean Flour on 100gsm paper sample

Figure 4.7

Lastly, the discussion between the curing time needed for the adhesives in Table 4.4 and Table 4.5. It took soya-bean flour adhesive the least time needed in seconds, and cornstarch adhesive has the most time needed in seconds to cure. According to (Cencer et al., 2014), The cure time, mechanical characteristics, and adhesive performance to pericardium tissues were all lowered in adhesive prepared at an acidic pH (pH 5.7–6.7).

4.3 Identify the Long-term Effects of Using Adhesive Materials on The Stability and Appearance of Paper-based Cultural Heritage Objects.

It has been stated in (BPG Adhesives, 2023) the adhesive and the way it is applied should ideally not change how the media or support look. The adhesive, whether it is solvent- or aqueous-based, shouldn't change the colour of the media or the paper, solubilize the media, or leave stains on it. Some media, like pastel or charcoal, cannot withstand the pressure or heat needed to adhere certain adhesives. Examples of these media include acrylics and coloured pencil. In addition to that, adhesives that are made from vegetables starches were commonly used and recognized from the first century A.D. in Pliny the Elder's account of making papyrus with a paste prepared from wheat flour. Also, according to (BPG Adhesives, 2023) that today, starch adhesives are employed globally in a wide range of industrial processes including the production of textiles and papers.

4.3.1 Impact on Physical Integrity

Adhesive can affect the structural integrity of paper over time. As stated in the findings and collection of data, there were few outcomes as the samples have gone through isolation for few weeks.

Table 4.6: Physical Integrity of Sample (70gsm A4 Paper)

Sample/ Structural Changes	Cornstarch	Potato Starch	Soya-bean Flour
Bonding Strength	Low (No Attachment)	High (Full Attachment)	Low (No attachment)
Flexibility	Not Flexible	Partial Flexible	Partial Flexible
Resistance to Mechanical Stress	Low	High	Low

Table 4.7: Physical Integrity of Sample (100gsm A4 Paper)

Sample/ Structural Changes	Cornstarch	Potato Starch	Soya-bean Flour
Bonding Strength	Low (No Attachment)	High (Full Attachment)	Medium (Partial Attachment)
Flexibility	Not Flexible	Partial Flexible	Partial Flexible
Resistance to Mechanical Stress	Low	High	Medium

From the findings stated in Table 4.6 and Table 4.7 it is similar to the data collected in comparative analysis. However, the elaboration for flexibility is considered unsatisfactory because every sample needs and additional physical stress, in order to make it attachable between the adhesive and the sample itself. Other than that, the aging effects of the sample throughout the experiment are also observed. As time passed by, the researcher could conclude that the sample with Potato Starch adhesive gives out the best properties if compared to the other two self-made adhesive which are Cornstarch and Soya-bean Flour. Thus, the researcher observation in Table 4.6 and Table 4.7 made it clear to show that Potato Starch adhesive gave the most positive effects towards paper's structural integrity over the time.

4.3.2 Impact on Visual Integrity

Adhesive that are self-made especially by using natural resources such as starch and flour has possible effects on paper in the context of transparency, clarity, and surface effects. As stated in the beginning, Cornstarch and Soya-bean flour adhesives left stains or considered as residue on the paper and has detracted the visual clarity of the sample itself. On the other hand, for the outcome of Potato Starch adhesive it left no residue and gave a finishing of a transparent and leave no signs of discolouration over time.

Next, as the researcher stated in the beginning, over the time the appearance of the paper has changed thoroughly on the surface of the sample such as residue,

discoloration, and texture. In this research only the Potato Starch adhesive did not give much negative effects on its visual integrity. The Potato Starch adhesive itself has the most similar characteristic such as, glossiness, texture and other visual qualities towards the common glue used commercially. Also, stated by BPG Adhesive (2023) after ageing, high-quality starch adhesives shouldn't alter colour.

In addition to that, the researcher also made an observation upon the adhesives itself, in understanding what condition should the adhesives be kept in order to have a stable and suitable for long-term used self-made adhesives. Thereby, throughout the weeks of experiment, isolation and, observation the adhesives have been kept in air-tight container and stored in the refrigerator. However, the researcher tested out to store all the adhesive only at a room temperature and record the visual outcome. The researcher presents the results in figures.

Cornstarch Adhesive

Figure 4.8

Potato Starch Adhesive

Figure 4.9

Soya-Bean Flour Adhesive

Figure 4.10

In Figure 4.6 it is the result of Cornstarch adhesive, Figure 4.7 is the Potato Starch adhesive and, Figure 4.8 would be the Soya-bean Flour. All the adhesives have gone through changes visually that could be considered as discolouration and growth of mould. According to (BPG Adhesive, 2023) “Starch pastes are subject to fairly rapid biological attack within a few days of preparation,”. This explains the growth on both Potato Starch and Cornstarch adhesives. It is advised, to achieve the best quality of adhesive based on starch are the ones that are made on a daily basis in which to also avoid adhesive failure. As a conclusion the best way is to keep the adhesives refrigerated in an airtight container. The quality quickly deteriorates and it can grow mould or draw mites when kept at room temperature (Kikkoman, n.d.).

CHAPTER 5

SUMMARY, INTERPRATATION, AND RECOMMENDATIONS

5.1 Introduction

Understanding and knowing the process in making an adhesive to complete a work of preserving paper materials in the context of cultural heritage should be considered crucial in the artifact conservation field. The reasoning behind this statement is because neither future nor modern generation could get inspired and take it as a reference, thus making a path for a different approach in the upcoming years aligned with contemporary technologies. As stated in Chapter 1 and restated in Chapter 4 the objectives of the research are mainly focus on deciding whether in the context of paper-based conservation is it suitable to be using starch-based adhesive or soya-flour-based adhesive with the most convenient apparatus. Thus, this whole research is also to prove the hypothesis that has been stated in Chapter 4 previously.

The first objective is identifying the apparatus and ingredients that are needed and suitable in the making of the adhesive itself which in Chapter 4, the researcher has listed the findings with elaboration of reasoning behind the chosen materials. The listed apparatus and ingredients are considered relevant in achieving the first objective as could be seen as reasonable and answering the research question thoroughly. Next, for the second objective which is comparing between starch and soya-bean flour as the main ingredients in making the adhesives. The researcher has listed findings of the comparison between the adhesives and made a conclusion where the Potato Starch is the most suitable if being compared to the other two adhesives. Lastly, the third objective would be identifying the long-term effects of the samples that had been tested out with the self-made adhesives. Thus, with using photography results and tables findings, the researcher has presented and understanding on the stability and effects of the adhesive towards the paper materials. Furthermore, in this last chapter, the researcher will conclude and suggest overall of the study that has been conducted.

5.2 Conclusion of the Study

In conclusion, the researcher has decided according to numbers and observation of the experiment itself, Starch, specifically Potato Starch has the most suitable characteristics in being the adhesive for paper materials in conservation works. Throughout the experiment, the researcher believes that other than helping the conservation field for the future generation,

producing the adhesive would also help students in the same course to have an alternative and lessen the burden of not having advanced equipment for making specified adhesive.

However, throughout the experiment the researcher also learnt that results do not appear as soon as the experiment started, there are procedures and time needed in being able to achieve the actual goal of the study itself. There were also failed results and abnormal value of numbers on certain parts which made the researcher need to re-do the experiments. Hereby, for the upcoming generation of students or researchers within the same scope of study, they could understand the dos and don'ts and make a better outcome.

In order to progress the field and guarantee the successful preservation of priceless artefacts, the implications of results in the context of cultural heritage restoration are essential. As the researcher go through the experiment, it has concluded that the findings play a pivotal role in preserving authenticity of paper based cultural heritage objects. As the chosen adhesive, Potato Starch has been considered the most suitable has been compared to the other two adhesives, it could help other researcher or even conservators to make choices that would minimize alternations to the original appearance and characteristics of the paper-based artifacts.

Other than that, the results provide a route for augmenting the overall resilience of artefacts especially paper-based ones by identifying adhesives that favourably contribute to the structural stability of cultural heritage objects. More resilient restoration methods that take into account both long-term preservation and short-term stabilisation may result from this. Thus, strategies for reducing deterioration factors are influenced by knowledge about the long-term effects of adhesives on materials belonging to cultural heritage. With this knowledge, conservators can choose adhesives that resist environmental stresses like humidity, temperature changes, and light exposure.

5.3 Limitation of the Study

There will always be limitations to any research, but it's critical to recognize them and figure out how to lessen their impact. One potential restriction of this work may be the precision and dependability of the instruments and measurements employed in the studies. To counteract this constraint, pre-tests can be used to assess the validity and reliability of the measures. Therefore, standardizing techniques is necessary to achieve consistent results. Then there are further restrictions, like a time limit. Lack of time and space may limit the breadth and depth

of the investigation, which subsequently restricts the researcher's ability to examine other areas of the topic.

5.4 Recommendation for Future Studies

As it is well known, the conservation field has always needed a high amount of fundings, therefore a self-made adhesive would make little to more difference in the budget. It would be an amazing approach for the new generations to be making organic-based adhesive with minimal cost and help with preserving paper-based materials artifacts.

5.4.1 Evaluation of Material Compatibility

Give careful consideration to integrating thorough material compatibility evaluations into the adhesive selection procedure. Create methodical testing to assess the adhesives' interactions with a variety of organic and paper-based components that are frequently present in items of cultural heritage.

5.4.2 Organize an Experimental Adhesive Making Workshop

Spreading awareness and knowledge would be one of the best approaches to actually show society on how it works and why it needs to work. Rather than passing brochures and posting on social media, physical demonstration is really helpful for people who tend to study and depend on more visual understanding. Once a workshop is being held, any inquiry or misunderstanding could be resolved directly on the spot with one-to-one teaching. Professionals should be handling the workshop and make it possible as an annual activity, so that it could be seen as an important scope of study.

5.4.3 Increasing the studies of work in preserving paper-based materials artifacts

Understanding the importance of preserving materials in the context of cultural heritage are usually taken for granted. Modern generations are not showing interest in the past, which causes conservation fields to not be so admired. That is why, other experimenters using this study as reference, should be making more studies relate to it in order to increase research in preserving paper-based materials artifacts. Thus, when there are more remarks about the study, there will be more people involved which makes the conservation field indirectly famous and not forgotten.

5.4.4 Systems of Hybrid Adhesives and Nanotechnology Integration

Examine the viability of hybrid adhesive systems that integrate the advantages of various adhesive varieties. This method might provide better adherence qualities, adaptability, and compatibility with a wider variety of materials. In addition to that, examine

how adhesive compositions can benefit from the incorporation of nanotechnology to improve adhesive characteristics. Improved bonding strength, longevity, and resistance to environmental deterioration can all be attributed to nanoparticles.

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GLOSSARY

A

Adhesive; a substance used for sticking objects or materials together; glue

C

Cultural; relating to the ideas, customs, and social behaviour of a society

Conservation; prevention of wasteful use of a resource

Cassava; Manihot esculenta, commonly called cassava, manioc, or yuca, is a woody shrub of the spurge family,

Conventional; based on or in accordance with what is generally done or believed

D

Dissecting; methodically cut up (a body or plant) in order to study its internal parts

Dependability; the quality of being trustworthy and reliable

E

Experimental; (of a new invention or product) based on untested ideas or techniques and not yet established or finalized

F

Flour; a powder obtained by grinding grain, typically wheat, and used to make bread, cakes, and pastry

Findings; a conclusion reached as a result of an inquiry, investigation, or trial

H

Heritage; property that is or may be inherited; an inheritance

Hypothesis; a supposition or proposed explanation made on the basis of limited evidence as a starting point for further investigation

L

Laboratory; a room or building equipped for scientific experiments, research, or teaching, or for the manufacture of drugs or chemicals

M

Materials; the matter from which a thing is or can be made

Methods; a particular form of procedure for accomplishing or approaching something, especially a systematic or established one

P

Primary; not derived from, caused by, or based on anything else; original

Preservation; the action of preserving something

R

Reversibility; able to be turned the other way around

Researcher; a person who carries out academic or scientific research

S

Starch; Starch or amylum is a polymeric carbohydrate consisting of numerous glucose units joined by glycosidic bonds

Safeguard; a measure taken to protect someone or something or to prevent something undesirable

INDEX