FINAL YEAR PROJECT REPORT

DEVELOPMENT OF BIO-ABSORBENT FOAM PAD FOR WOUND DRESSING FROM DOWN CHICKEN FEATHER WASTES.

BY

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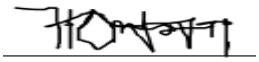
This project report is submitted to the Faculty of Engineering in Partial Fulfilment of the requirements for the Award of the Degree of Bachelor of Science in Polymer Textile and Industrial Engineering of Busitema University

Abstract.

Various environmental studies and research have suggested that non-biodegradable poultry waste, like feathers, poses a serious burden to the environment. The question is how we can utilize the chicken feathers generated from the poultry industry more effectively and sustainably in the environment in an effort to curb pollution. The national environment management authority (NEMA) came up with a national strategy for plastic (2023 to 2040), which involves shaping the market for plastic alternatives. There is a high demand for biodegradable fabric in the world. But the production of these bio-absorbent materials from waste biomass is not a well-developed technology. This study aims to look at the possibilities of using waste down chicken feathers in the production of bio-absorbent foam pad fabric for the biomedical world. Theoretical consideration of using chemical analysis to extract impurities is considered, and after the extraction of the fibre from the whole feather, the foam pad is produced using physical stitching after layering of foam fibres on the plain gauze fabric. Then the fabric will be treated using chemicals for disinfectants. The characteristics of the bio-absorbent are determined, and the optimization with design of experiment using central composite design of RSM in Minitab tool, will be investigated by systematically varying the orientations of fibres in the webs.

DECLARATION

I, KASULE KULAISHI, declare that I have written this project report and that it has never been used for any academic award at an institution of learning or level of education.

Signature 

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Approval

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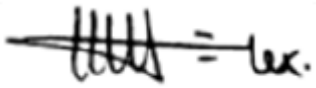
Signature 

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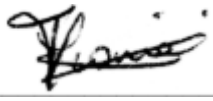
Signature 

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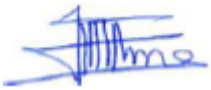
Signature 

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I am so grateful for Allah's providence and guidance through my research and compilation of this proposal.

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1 CHAPTER ONE

1.1 Background

According to **Sen et al. 2009,** the World Health Organization (WHO) reported that globally, wounds cause 1.9 million deaths, mostly from accidental injuries, and 50 million non-fatal injuries each year (2024 WHO report). A proportion of these non-fatal injuries result in open wounds, burns, and abrasion wounds, which require continuous dressing and care. The report indicated increasing chronic wounds (Han and Ceilley 2017) from chronic diseases like diabetes, skin diseases, and cancer, which cause intensive wounds like diabetic foot ulcers, venous leg ulcers, and pressure ulcers. This affects approximately 4% of the world's population. Accidents and chronic wounds consume a vast healthcare resource. The global wound care market was estimated to be over 25 billion dollars in 2024. This continues to grow, reflecting the urgent demand for effective and economical wound dressing materials.

In the African (Adeloye et al. 2016) 246,000 death of wound due to injuries annually and over 20milions non-fatal injuries due to bad road in Africa that make the continent to have the highest wounds and makes people to stay with wound which requiring wound dressing materials WHO report also show the increased diabetes and cancer in Africa over 24million(Kathawala et al. 2019) adult in Africa lives with diabetes causing high risks to chronic foot ulcers but sadly people have limited access to sterile, absorbent wound care materials which leads to prolonged healing, infections and high hospital costs, especially in rural and low income societies.

In Uganda, Wounds are the leading cause of trauma admissions. The Uganda ministry of health report 2024 (Kobusingye, Guwatudde, and Lett 2001) and WHO shows about 12000 wounds (Wangoye et al. 2022) and over 369000 adults from Uganda Diabetes international federation and chronic diseases indicated high number of people that live with chronic diseases wounds that needs daily dressing unfortunately the country relies on imported costly synthetic wound dressing materials, polyurethane, and polyvinyl alcohol, which are too expensive and non- biodegradable making them unsuitable for wide use in rural hospital and health centers this employs production of local product, eco-friendly, and affordable alternatives from down chicken feathers(Pal et al. 2022).

Furthermore, poultry industries generate 47milion metric tons feather wastes globally (Tesfaye, Sithole, and Ramjugernath 2017) and Uganda produces estimated over (Yussif et al. 2023) (Owusu and Banadda 2017) 5,000 tons of feather wastes annually the figures expected to increases daily with the increased consumption of chicken meat from poultry farms from these 3% are converted into animal feeds and the remaining 97% are wasted in land fill and dumped into water bodies. This causes pollution and public health risks, including diseases such as dysentery, typhoid fever, and gastrointestinal illnesses, although the National Environment Management Authority (NEMA) of Uganda has strict measures in place to regulate the effects of the pollution and the diseases mentioned above.

Promisingly, feathers are composed of 90% keratin fibrous protein, a strong, smooth, biodegradable material, of light density, haemostatic, with excellent mechanical properties, porous, but moderately absorbent due to the covalent disulfide bond (Dash and Tripathy 2018). This makes feathers resourceful to develop wound dressing material that covers the wound, absorbs moderate exudates, maintains moisture, protects against contamination, and speeds up the healing mechanism to a patient.

1.2 **Problem statement**.

Wound management is a major public health challenge globally, particularly in Africa. Each year, millions of people sustain wounds from road traffic accidents, burns, and trauma, while others suffer from chronic wounds caused by chronic diseases such as diabetes and cancer. According to the World Health Organization (WHO, 2024), approximately 1.19 million people die of wounds, and 50 million wounds are caused by road traffic accidents, leading to open wounds that require effective and sterile dressing material. In Uganda, the Ministry of Health 2024 reported over 1200 road traffic injuries every year, and over 368,000adult lives with chronic wounds(Wangoye et al. 2022). This creates a significant demand for effective wound dressings that are comfortable and provide a conducive healing environment. However, most modern dressings are made from synthetic materials and are non-biodegradable. Other alternatives include cotton gauze, which requires a lot of pesticides, fertilizers, energy, and water during its processing. Hence, there is a need for other alternatives. (Yussif et al. 2023).

Additionally, 5000 metric tons (Owusu and Banadda 2017) of feather waste are discarded as waste and dumped in water and landfills, causing pollution, yet they can be valorised into useful products. Feather waste represents an untapped renewable resource that has desirable characteristics such as softness, semi-absorbent, breathable, and moisture-porous that could be valorised into a bio-biomedical foam pad used in wound dressing to reduce solid waste accumulation. Therefore, this study aimed to utilise this untapped resource to make a bio absorbent form pad.

1.3 Purpose of the study**.**

purpose of this study was to develop and evaluate a bio-absorbent foam pad from chicken feather fibres for potential wound dressing applications. The study aimed at utilizing poultry feather waste as a sustainable and low-cost source of keratin fibres through cleaning, chemical treatment, fibre extraction, and foam fabrication processes. The developed material was evaluated for its structural, morphological, absorbency, and water retention properties using techniques such as Fourier Transform Infrared (FTIR) spectroscopy, Scanning Electron Microscopy (SEM), absorbency tests, and water retention tests. The study also aimed to promote value addition to poultry waste while contributing to the development of environmentally friendly biomedical absorbent materials.

1.4 Objective of the study

1.4.1 **Main objective**.

To develop a bio-absorbent foam wound dressing using chicken down feathers.

1.4.2 Specific objectives

1. To improve and optimize the absorption properties of chicken down feathers
2. To characterize the improved chicken down feather material
3. To fabricate a foam pad material and evaluate absorbency and retention capacity.

1.4.3 Research question

1. How can chicken down feathers be modified to improve their softness and absorption properties?
2. How does characterization prove the absorbent properties of the treated fibres?
3. How can processing techniques be optimized to produce feather-based foam pads?

1.5 Scope of the study.

1.5.1 Conceptual scope

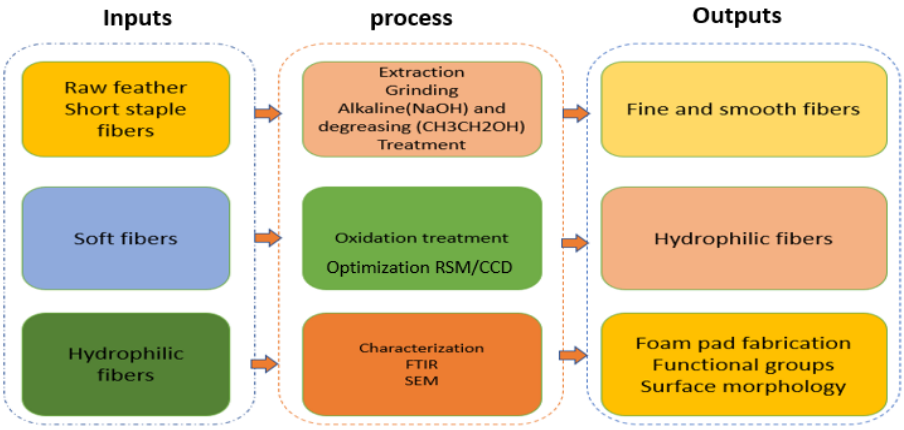


Figure 1.1of conceptual framework

A conceptual framework showing the relationship between the fiber extraction method, fiber properties, fabric treatment methods, and the independent variables is the type of chicken feathers used in this work and the method of fiber extraction. Whereas the dependent variables are the method of fiber treatment and absorbency. Fiber treatment methods affect the fibers' properties, which then affect the method of pad production

1.5.2 Geographical scope

A collection of chicken feathers will be obtained from Kyazanga hotels and other slaughterhouses, and chemical treatment, characterization, and fabrication will be carried out at Busitema University Faculty of Engineering in the PTI material laboratory and textile laboratory.

1.5.3 **Time scope**.

The time scope of the project is limited to 4 months according to the Busitema University academic time frame.

1.6 Justification of the study.

The project addresses the urgent need for affordable, biocompatible materials in resource-constrained settings, leveraging local resources to improve healthcare access. This comes out

by transforming an abundant waste product (Reddy and Santosh 2016) into a high-value medical material. This will support a circular economy, aligning with the UN Sustainable Development goals of reducing the environmental poultry waste globally and locally and promoting the sustainable useable material.

To design and develop a bio-absorbent foam pad material from locally sourced chicken feathers as an alternative bio-absorbent used in medical wound dressing, which would replace the excessive synthetic polymer polycarbonic wound dressing material

2 CHAPTER TWO

2.1 Literature review.

Production of down feather absorbent foam from poultry chicken waste,

Absorbent hygiene wound dressings are developed from a variety of raw materials, including both renewable and non-renewable sources, to form the absorbent core (Gobi et al. 2021) responsible for storing exudate. With the integration of chemical treatment, bio-absorbent foam pads evolve from simple materials into thinner, safer, and more efficient absorbents capable of maintaining an optimal healing environment.

However, conventional polymer-based materials such as polyurethane and polycarbonate (Tesfaye, Sithole, and Ramjugernath 2018) continue to contribute to environmental challenges, including excessive resource consumption and pollution. Therefore, this study explores sustainable alternatives by utilizing poultry chicken feather waste as a bio-based material.

Chicken feathers are being investigated as a potential replacement for synthetic superabsorbent due to their intrinsic properties, including smoothness, antibacterial behaviour, biocompatibility, and breathability, which are essential for wound dressing applications.

2.1.1 Wound Dressing Requirements

According to (Ferraz 2025), wound care practices have been documented since ancient times, with early records mentioning treatments like mud, milk, and plant-based poultices. The Egyptians created wound dressings using honey, plant fibres, and animal fats. Major progress in understanding and treating wounds emerged in the 19th century with the rise of microbiology and cellular pathology(Gobi et al. 2021). A significant breakthrough came in the 1960s with the discovery that a moist environment enhances the wound-healing process. This insight became a crucial factor in guiding the creation and advancement of wound dressings. Wound dressings need to fulfil key criteria to promote healing, which include: Modern wound dressings are required to meet several critical criteria to support healing. These will include absorbing excess wound exudate, providing thermal insulation, protecting

the wound from contamination and mechanical damage, and allowing painless removal, being non-toxic and biocompatible

A moist environment should be maintained to enhance healing, as established in modern wound care practices.

2.1.2 Chicken Feather as a Raw Material used in the foam production

2.1.2.1 Composition and Availability

Chicken feathers are made of approximately equal portions of fibres comprised of 91%protein, 1%lipids, and 8% water(Qin 1994). Thus, feathers are a rich source of protein that could be a desirable biomass component that could be used in wound dressing material (Kakonke et al. 2019)

Globally, large quantities of feather waste are generated annually by the poultry industry, yet only a small fraction is utilized. This study will therefore aim to valorise this underutilized biomass into high-value absorbent materials.

2.1.2.2 Estimated Feather Yield per Chicken

An average chicken can yield **60 grams of usable feathers**, depending on breed, size, and age. Feathers represent about **5–7% of the total body weight**(Tesfaye, Sithole, and Ramjugernath 2017) of a chicken. This estimation measurement is important in determining raw material availability and scaling of production, and each pad of 20cmx30cm needs only 10grams, 10cm x 15cm needs 5grams of treated feather materials

2.1.2.3 **Structure and Keratin Composition in Feather Fibres**.

Composition: Feathers are composed of microcrystalline keratin(Fraser et al. 1971) in two forms — the fibres and the quill — which provide good mechanical and thermal stability.

Chicken feathers consist of keratin fibres arranged in a hierarchical(Seawright, Marcicano, and Sanches 2013) structure of barbs and barbules. Variations in keratin composition between local and exotic chicken feathers will influence functional properties such as absorbency and mechanical strength.

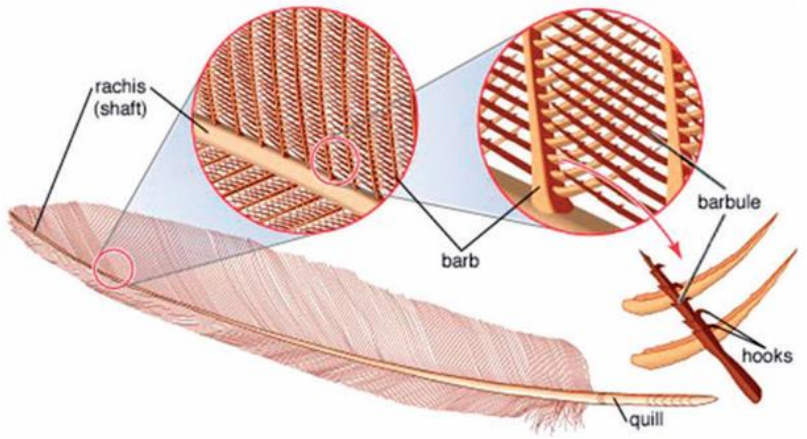


Figure 2.1: Structure of a feather from (Kock 2006)

The keratin structure was stabilized by disulfide (-S-S-) bonds, which contribute to its hydrophobic nature and resistance to degradation before treatment.

2.1.2.4 Properties of Chicken Feather Fibres for Foam Design

Chicken feather fibres will exhibit several properties that will make them suitable for bio-absorbent foam production:

Low Density: Chicken feather fibres have a density ranging between 0.44–0.91 g/cm³, making them among the lightest natural fibres (Seawright, Marcicano, and Sanches 2013). This ensures lightweight and comfortable absorbent materials.

Thermal Insulation: Due to their hollow and porous structure(Dash and Tripathy 2018), chicken feathers act as excellent thermal insulators, helping maintain favourable temperatures in wound and absorbent applications.

Composition: Feathers are composed of microcrystalline keratin(Fraser et al. 1971) in two forms — the fibres and the quill — which provide good mechanical and thermal stability.

Flexibility and Resilience: The fibres exhibit high flexibility, compressibility, and resiliency, contributing to the strength and cohesiveness of foam structures.

Hydrophobic and Hygroscopic Nature: Although feathers are naturally hydrophobic, they also contain hydrophilic amino acids such as serine with hydroxyl (-OH) groups that attract water vapor, giving them balanced moisture-handling properties.

High Surface Area: Chicken feather fibers(Kock 2006) have a finer diameter than wool, resulting in a larger surface area that enhances water absorption and retention.

Porous Structure: The honeycomb-like microstructure between barbs and barbules enhances permeability and moisture transfer, allowing the fiber to absorb and retain liquid efficiently.

Moisture Content: Feathers contain 8–13% moisture, higher than many plant fibers such as cotton or sugarcane bagasse, making them hygroscopic in nature.

Sorption and Absorbency: Their high sorption ability and improved wettability(Khosa, Wu, and Ullah 2013) make them suitable for producing bio-absorbent foams with higher absorbency capacity than synthetic superabsorbent polymers.

Based on these characteristics, feather fibers will make a promising alternative to synthetic absorbent materials.

2.1.3 Bio-Absorbent Foam Pads

Bio-absorbent foam pads (Kakonke et al. 2019) are porous wound dressing materials designed to absorb wound exudates, maintain a moist healing environment, protect the wound from infection, and promote tissue regeneration. These materials are commonly used in the treatment of burns, ulcers, surgical wounds, and chronic wounds due to their high absorbency, softness, and biocompatibility. Foam dressings are usually produced from natural or synthetic polymers with interconnected pores that allow fluid uptake and gaseous exchange.

Bio-absorbent foam pads are commonly manufactured from polyurethane, cellulose, alginate, chitosan, collagen, gelatin, and keratin-based biomaterials. Among these materials, keratin has attracted significant attention because of its excellent biodegradability, biocompatibility, moisture retention ability, and cell-binding properties that support wound healing. Keratin is naturally obtained from feathers, wool, hair, horns, and nails. Chicken feathers are

particularly important because they contain approximately 90% keratin protein and are abundantly available as poultry waste.

The major advantages of bio-absorbent foam pads include high fluid absorption capacity, maintenance of a moist wound environment, thermal insulation, softness, biodegradability, and promotion of faster tissue healing. Foam dressings also reduce wound dehydration and minimize trauma during healing. Keratin-based materials additionally possess natural bioactive amino acid sequences that enhance cell attachment and proliferation. However, these materials also have some disadvantages, including low mechanical strength, poor durability under wet conditions, possible microbial contamination if not properly sterilized, and relatively high production cost for advanced biomedical processing. Some foam dressings may also require secondary support materials because of their weak structural stability.

Bio-absorbent foam pads are generally produced through polymer blending, foaming, freeze-drying, electrospinning, solvent casting, or hydrogel formation methods. In keratin-based foam production, keratin is first extracted from feathers using(Tesfaye, Sithole, and Ramjugernath 2018) chemical, enzymatic, or reduction methods. The extracted keratin is then blended with other polymers or crosslinking agents to improve structural stability and absorbency before being converted into porous foam or hydrogel materials.

Several researchers have developed wound dressing materials from chicken feather keratin. Wang and co-workers developed a feather keratin hydrogel for wound repair and reported that the material showed good biodegradability, biocompatibility, and wound healing performance comparable to human hair keratin dressings. (Wang et al. 2017) produced nanofibrous PHBV-keratin mats for wound dressing applications and observed enhanced cell proliferation and accelerated wound healing. Similarly, researchers have fabricated keratin-polysaccharide nonwoven dressings and electro spun keratin nanofibers with promising antibacterial activity, porosity, and absorbency suitable for wound healing applications.

Although several studies have focused on keratin hydrogels, nanofibers, and nonwoven wound dressings, limited research has specifically focused on the development of feather fibre-based bio-absorbent foam pads using simple, low-cost processing methods suitable for sustainable waste management and local biomedical applications. Therefore, this study differs from previous studies by developing a bio-absorbent foam pad directly from treated

chicken feather fibres through washing, chemical treatment, fibre extraction, and foam fabrication processes. The study further evaluates the structural, absorbency, and water retention properties of the developed material using FTIR, SEM, and retention tests. In addition, the present work emphasizes the utilization of locally available poultry feather waste as an environmentally friendly and low-cost alternative material for absorbent wound dressing.

2.1.4 Extraction and Processing of Feather Fibres

2.1.5 Physical and Mechanical Processing

Previous studies have reported that the extraction and preparation of feather fibres begin with collection, sorting, washing, and drying processes to remove contaminants and isolate usable keratin-rich fibres. Chicken feathers collected from poultry farms and slaughterhouses are commonly sorted to separate down feathers from quill feathers because down feathers possess softer and finer fibre structures suitable for absorbent applications. According to Kakonke et al. 2020 washing feathers using warm water and detergent effectively removes dirt, blood stains, oils, and odour, improving cleanliness and fibre quality before further treatment.

After cleaning, the feathers are dried to reduce moisture content and prevent microbial growth. Mechanical processing is then performed to reduce fibre size and improve fibre uniformity. Researchers have reported the use of grinding and milling equipment to break down feather structures into smaller fibres, thereby increasing the available surface area and enhancing liquid absorption performance. In this study, an İKA@A10 basic grinding machine will be used for fibre size reduction. The grinding process is expected to improve absorbency by increasing fibre exposure and facilitating better interaction with liquids and binders.

stability.

2.1.6 Chemical Treatment and Modification

Several researchers have investigated chemical modification methods to improve the hydrophilicity and absorbent performance of keratin fibres obtained from chicken feathers. Naturally, chicken feathers exhibit hydrophobic characteristics due to the compact keratin

structure stabilized by disulfide bonds, as well as the presence of fats, oils, and waxy surface coatings. Because of their hydrophobic nature, untreated feathers exhibit poor wettability and low liquid absorption capacity, necessitating chemical treatment before use in absorbent materials. Previous studies have therefore focused on oxidation, alkaline hydrolysis, and solvent degreasing methods to modify feather fibres and improve their physicochemical properties.

Oxidation treatment using hydrogen peroxide has been widely reported as one of the most effective methods for keratin modification. According to **Sithole and Tesfaye 2019**, hydrogen peroxide oxidizes disulfide bonds in keratin, converting them to sulfonic acid groups and forming cysteic acid derivatives. This reaction changes the keratin structure from a compact hydrophobic arrangement into a more open and hydrophilic structure. As a result, the treated fibres exhibit improved wettability, higher water absorption, and increased compatibility with aqueous systems. Similarly, **(Gao et al. 2020)** explained that oxidation treatment permanently disrupts the original disulfide crosslinks, preventing the reformation of the compact keratin network and thereby enhancing liquid uptake capacity. Researchers have further reported that hydrogen peroxide treatment improves fibre softness and absorbency, making the fibres suitable for use in absorbent pads and other biomedical applications. However, studies also indicate that excessive oxidation may weaken the fibre structure and reduce mechanical stability due to over-degradation of keratin chains. In addition, the oxidation process is irreversible because the original disulfide bonds cannot reform after treatment**(Staroszczyk and Sinkiewicz 2017)**

Alkaline treatment using sodium hydroxide has also been extensively studied as a pre-treatment method for keratin fibres. **(Khosa, Wu, and Ullah 2013)** reported that sodium hydroxide treatment improves fibre swelling, softness, and surface reactivity by disrupting hydrogen bonding and partially cleaving disulfide linkages within the keratin matrix. Typical treatment conditions reported in literature include sodium hydroxide concentrations of approximately 2%, temperatures ranging from 40–60 °C, and treatment durations of about four hours. During the process, the compact feather structure becomes loosened, allowing better fibre separation and exposure of reactive functional groups. **(Yin et al. 2013)** Further observed that alkaline treatment removes surface impurities such as fats, oils, and residual proteins, thereby improving fibre cleanliness and enhancing subsequent chemical modification processes. The benefits associated with alkaline hydrolysis include improved

flexibility, increased fibre dispersion, enhanced hydrophilicity, and better interaction between fibres and surrounding matrices in absorbent or composite materials. Nevertheless, previous studies have also highlighted certain limitations of sodium hydroxide treatment. Excessive alkali concentration or prolonged treatment duration may result in over-hydrolysis and degradation of keratin chains, leading to reduced fibre strength and structural instability. Due to these limitations, many researchers recommend alkaline treatment mainly as a pre-treatment stage before oxidation processes to improve fibre accessibility and increase the effectiveness of further modifications.

In addition to oxidation and alkaline hydrolysis, solvent treatments such as ethanol degreasing have been reported as effective methods for improving feather wettability. (Sadeghi, Dadashian, and Eslahi 2019) noted that ethanol treatment removes fats, oils, and wax coatings present on feather surfaces, which normally hinder water absorption. By eliminating these hydrophobic substances, ethanol treatment exposes the keratin surface and enhances fibre wettability and absorbent behaviour. The method is advantageous because it is relatively simple, effective, and less destructive to the keratin backbone compared to strong chemical hydrolysis. However, ethanol treatment alone does not significantly alter the internal keratin structure or break disulfide bonds; therefore, its effect on improving absorbency is generally lower than that achieved through oxidation treatments. Consequently, ethanol degreasing is commonly used together with alkaline or oxidative treatments to achieve better overall fibre modification.

Previous studies have consistently identified feather treatment as one of the most important stages in keratin modification because it directly influences the physicochemical properties and performance of the fibres in absorbent applications. According to **(Forgács et al. 2013)** treatment processes are essential for altering keratin structure, increasing hydrophilicity, improving fibre separation, and enhancing interfacial bonding within composite systems. Based on the findings of earlier researchers, oxidation treatment using hydrogen peroxide is considered one of the most promising approaches for converting hydrophobic keratin into hydrophilic absorbent material, particularly when combined with suitable pre-treatment methods such as alkaline hydrolysis and solvent degreasing.

2.1.7 Experimental Design and Optimization Approach

Several researchers have applied statistical optimization techniques to improve the treatment conditions and absorbent performance of keratin-based materials. Response Surface Methodology (RSM) has been widely used because it enables simultaneous evaluation of multiple process variables and their interactions while reducing the number of experimental trials required. According to **Tesfaye, Sithole, and Ramjugernath 2018**, factors such as hydrogen peroxide concentration, treatment temperature, and processing time significantly influence the absorbency and structural characteristics of modified keratin fibres. Through RSM, researchers are able to determine the optimum treatment conditions that maximize hydrophilicity and liquid absorption while minimizing fibre degradation. The method also provides mathematical models that describe the relationships between treatment variables and response parameters. Despite its advantages, optimization using RSM may require careful experimental planning and statistical analysis to avoid errors in model prediction. Nevertheless, previous studies have shown that RSM remains an effective and reliable approach for optimizing keratin modification processes and improving the performance of absorbent materials produced from chicken feathers.

2.1.8 Characterization of fibres.

2.1.8.1 Fourier transform infrared spectroscopy.

FTIR characterization is crucial in fibre integration, where it indicates the changes in the chemical structure and functional groups (Yin et al. 2013)in the material. This confirms the main component material present in the structure before and after treatment. Furthermore, the instrument converts the absorption data into a spectrum indicating peaks of different functional groups.

3 Table 3.1FTIR Showing wavenumber and band origin

Position of wavenumber(cm^{-1})	Band origin

3300-3270	N-H stretching (amide A)
3070	=C-H stretching
2950-2850	C-H stretching
1650	C=O stretching (amide 1)
1540	N-H bending +C-N stretching (amide 11)
1230	C-N stretching + N-H deformation
1040-1080	C-O-C or S=O stretching
650-700	C-S or S-S stretching

3.1.1.1 Microscopy using scanning electron microscopy using Hv10 kV, Magnification (250×-500x, SEM)

The surface morphology, microstructure, and topography of chicken down feathers change before and after extraction due to the process modification and the extraction methods used, including both physical, chemical, and mechanical methods. This alters the properties of the feather. More so, chemical treatment like oxidation with hydrogen peroxide alters the disulfide bonding of the feather fibre to be hydrophilic. This is as a result of changing the keratin fibre structure; therefore, SEM assesses the porosity(Kock 2006), smoothness, and fibre alignment, which are useful properties in absorbent wound dressing material

3.1.2 **Pad Formation**.

Modern wound dressing systems are commonly designed as multilayer composites **(Kakonke et al. 2019)** in which each component performs a specific role to enhance overall functionality. In this approach, the absorbent core is formed from treated feather fibers, which, after oxidation and softening, become more hydrophilic and capable of efficiently absorbing wound exudate, maintaining moisture balance, and supporting the healing process. These fibers can behave similarly to conventional absorbent materials such as cotton due to their improved water affinity and porous structure. Surrounding this core are outer gauze layers, typically made of cotton, which serve to hold the feather fibers in place while providing mechanical strength, breathability, and protection against external contaminants. This layered configuration resembles advanced wound dressing systems, where a porous,

bioactive core is supported by a textile matrix to optimize both absorption and structural integrity.

In terms of fabrication, literature highlights several practical techniques applicable to this design. The most straightforward method is the layering where feather fibers are evenly distributed between two gauze sheets and then secured using specific stitching methods to ensure stability without compromising absorbency. Commonly, edge stitching (overlock) is applied along the perimeter to enclose the fibers and prevent leakage, while lockstitches are used across the surface at spaced intervals to keep the fiber core evenly distributed. In some designs, quilting or tack stitching (spot stitches at regular distances, 1–2 cm apart) is introduced to minimize fibres shifting during use while maintaining porosity. Care is taken to avoid excessive stitch density, as over-compression can reduce fluid absorption capacity

4 CHAPTER THREE

4.1 METHODOLOGY (Materials and Methods)

Materials and equipment's

Fourier Transform Infrared (FTIR) spectrometer – for analysing molecular structure and functional groups

Scanning Electron Microscope (SEM) – for examining surface morphology and structural characteristics

Equipment

Drying oven – for removing moisture after washing and chemical treatments

Electric blender (ika@a10 crusher machine) – for grinding feathers and facilitating the extraction of fibres

Tweezers, Scissors, a saucepan., Weighing balance, water trough, and sieve

The equipment used was from the material laboratory of Busitema main campus, except the ika@a10 grinding crusher, which was from the Nagongera science Busitema campus branch

Chemical Reagents were

Sodium hydroxide (NaOH) – cleaning and fiber treatment

Hydrogen peroxide (H_2O_2) – bleaching and oxidation

Ethanol – disinfection and cleaning

Acetic acid – pH adjustment and cleaning

Distilled or deionized water – washing and preparation of solutions

Chemicals used in this research were bought from Aboto Chemical Laboratory shop

4.1.1 To modify and improve Structural Properties by Removing Waxes and Fats from Down Feathers

Raw chicken feathers were obtained from Kyazanga hotels and nearby hotel slaughterhouses, which generate significant quantities of poultry feather waste. These feathers served as the primary raw material for the study; all experiments and tests were carried out in the material laboratory at Busitema, main campus, and the chemistry laboratory at Nagongera campus.

A total of 1 kg of chicken feathers was collected and manually sorted to remove visible impurities such as blood, skin particles, and dirt. The feathers were then thoroughly washed using 200 g of Omo detergent(Forgács et al. 2013) mixed with 10litres warm water to remove dirt and blood stains effectively.

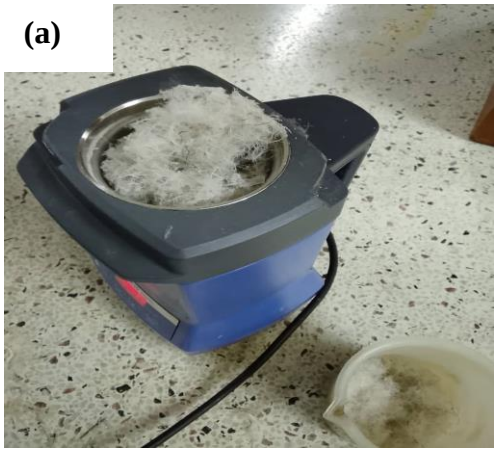
Figure 4.1of sorted down feathers layered on a mat material

After washing, the feathers were disinfected using one 1itres mild 70% ethanol and subsequently rinsed with 10 litres of distilled water to eliminate any residual chemicals. The cleaned feathers were then dried in the sunlight before further processing.

4.1.1.1 Mechanical Extraction of Fibers

Chicken feathers consisted of a central shaft known as the rachis and smaller branching fibers called barbs. The barbs were manually separated from the rachis using scissors to obtain individual fibers for analysis. An IKA A10 grinding machine from the Nagongera campus chemistry laboratory running at 3min/r was used to grind the feathers, and this facilitated fiber separation of short and long fibers.

(a)



b

Long and short feathers were sorted and ground separately. During grinding, the lighter, fluffy fibres accumulated at the top of the container, while the heavier quill fragments settled at the bottom. The processed material was then transferred into small bags that contained two batches, each containing 50 grams, and any remaining quill fragments were manually removed.

4.1.1.2 Chemical Treatment.

4.1.1.2.1 Pre-hydrolysis by alkaline curing of feathers

An alkaline treatment was carried out using a 2% sodium hydroxide (NaOH) solution at 40ºc for 2hours. A total of 80 g of feather fibres was immersed in the prepared 1600ml solution of a 2% sodium hydroxide (NaOH) at 40ºc using metallic heating plates to facilitate keratin modification by hydrolysis and deamination of the amino group. The fibres were allowed to react with the alkaline medium, which promoted the breakdown of disulfide intermolecular bonds and enhanced fibre separation. After treatment, the fibres were removed, dried in an oven at 50 °C for 4 hours to ensure complete dryness, then kept in Aluminium foil and prepared for defatting.

Figure 3.2: Fibres in sodium hydroxide solution

4.1.1.2.2 Degreasing and Fat Removal

Degreasing and fat removal were carried out using 99.9% ethanol. A total of 78 g of treated feather fibres was immersed in 160ml of 99.9% ethanol solution in a saucepan. The mixture was heated on a heating plate at 60 °C, as monitored with a thermometer, for 3 hours to ensure the effective removal of residual fats and oils, thereby softening the fibres and rendering it hydrophilic. The samples are rinsed well with 4litres of distilled water. Then, the sample was dried using an oven at 50 °C for 4hours

Figure 4.2: Sample of fibers after oven drying

4.1.1.2.3 Oxidation Treatment

To evaluate absorbency using the design of experiment of Minitab

Response Surface Methodology (RSM) based on a Central Composite Design (CCD) was employed to evaluate the effects of hydrogen peroxide concentration, drying temperature, and 4grams constant weight for each run, on the absorbency of feather-based absorbent materials. Hydrogen peroxide concentration (10–40%) and drying temperature (20–60°C) were selected as independent variables (Tesfaye, Sithole, and Ramjugernath 2018) , while absorbency was

measured as a response variable. A second-order polynomial model was developed to describe the relationship between variables and responses. Statistical analysis and optimization were performed using Minitab software, and contour and surface plots were generated to identify optimal processing conditions.

Table 3.1: CCD FOR FACTORS OPTIMIZATION

		Levels		
Factors		**-α**	**0**	**α**
hydrogen peroxide	**(%)**	**10**		**40**
temperature	**°c**	**20**		**60**

For the CCD, the total number of experiments is given by this equation**,**

$$\boldsymbol{N = 2^K + 2K + n_c}$$

Where N is the total number of experiments, K is the number of factors, 2^k is factorial points, 2K is axial points, and n_c numbers of center points, and this makes 13 experiments to run

The following equation represents a second-order polynomial for the computation of the response.

This describes how the factors affect the response,

$$\boldsymbol{Y = \beta_0 + \beta_1 A + \beta_2 B + \beta_{11} A^2 + \beta_{22} B^2 + \beta_{12} AB}$$

Where Y is the response, A is %hydrogen peroxide, and B is the temperature.

The fibres material was evaluated for absorbency on dry weight from $WAC(\%) = \frac{W_{wet} - W_{dry}}{W_{dry}} \times 100$ (Sithole and Tesfaye 2019)where W1 is the emersion weight, W2 is the dry weight

4.1.2 Wettability Analysis

The wettability of the treated feather fibres was evaluated using a water droplet spreading method adapted from **Yuan and Lee (2013)**. A small droplet of distilled water was carefully placed on the surface of each fibre sample under ambient laboratory conditions. The spreading behaviour of the water droplet was immediately recorded using a Samsung smartphone camera. Images were captured at fixed time intervals to observe the rate of droplet spreading and absorption. Samples exhibiting faster spreading and absorption of the water droplet were considered to possess higher wettability and hydrophilicity. The test was repeated for all treatment conditions, and the results were compared to assess the effect of surface modification on fibre wettability

4.1.3 Characterization

4.1.3.1 structural and chemical Characterization of Fibre.

In this study, the structural and chemical properties of the treated feather fibres were analysed using characterization techniques.

4.1.3.2 Scanning electron microscopy (SEM).

Scanning electron microscopy was used to examine the surface morphology(Khosa, Wu, and Ullah 2013) and structural features of both untreated and treated feather fibres.

4.1.3.3 Fourier transform infrared spectroscopy (FTIR)

Fourier transform infrared spectroscopy was employed to identify the polar and nonpolar functional groups present in the fibres and to confirm the keratin structure. The FTIR spectra were taken at the wavelength of 4000-500cm-1. The sample of the treated fibres were taken and recorded by FTIR spectrum

4.1.4 Development of Foam Pad Material

The developed wound dressing was constructed as a multilayer composite pad with overall dimensions of 15 cm (width) × 30 cm (length) and 10cm(width) × 150 cm(length), making it suitable for covering medium to large wound areas such as limbs or postoperative sites. At the core of the structure, the feather fiber pad served as the primary absorbent layer. This core

was prepared from treated and softened feather fibers, which exhibited enhanced hydrophilicity after oxidation.

The fibers were evenly distributed and shaped into a rectangular form slightly smaller than the final pad size (10–12 cm × 25–27 cm) to allow proper enclosure within the outer layer.

Figure 4.3stitched foam pad using plain gauze fabric (10cm widthx15cm length)

A plain cotton gauze fabric was used as the outer layer to enclose the absorbent core fully. In the wrapping method, the gauze was folded over the core from both longitudinal sides and then from the ends, ensuring complete coverage of the feather pad. In the stitching method, the edges of the gauze, with an allowance of 2 cm, were stitched along the wedge using white thread to secure the structure and prevent fibre leakage. The resulting multilayer pad was stable, flexible, and capable of maintaining the integrity of the absorbent core during handling. The foam pads were evaluated for their liquid absorption rate and retention ability.

4.1.4.1 Absorbency and Water Retention Test of Foam Pad (500 mL Beaker Test)

The developed pad (5 g of treated foam feather fibres within a 10 cm × 15 cm gauze) was evaluated by immersion in a petri dish of water to assess its absorbency and retention behavior

Table 4.1: Procedure followed during absorption and retention tests.

Parameters	Description
Standard reference	EN 13726 test method
Sample ID	Foam feather pad (treated)
Composition	6grams
Pad dimensions	10cm x 15cm
Dry mass (Wo)	6grams

Test liquid	Distilled water
Volume of liquid	500ml
Temperature	25ºc
Immersion time	5minutes
Drainage method	Gravity drainage
Drainage time	5minutes

Water/fluid absorption is given by

$$WAC(\%) = \frac{W_{wet} - W_{dry}}{W_{dry}} \times 100$$

Where (Sithole and Tesfaye 2019), W1 is the immersion weight, W2 is the dry weight

Water retention capacity is given by,

$$water\ retention\% = \frac{water\ retained}{water\ absorbed}$$

5 CHAPTER FOUR: RESULTS AND DISCUSSION.

5.1.1 To improve the absorption of fibres by oxidation and evaluate the absorbency

The fibre masses were in grams of feather fibres, and the hydrogen peroxide was in % concentration, and the constant 4-gram weight of the fibres was measured using a digital weight balance.

The table below shows the number of runs, experimental factors, and the response, percentage absorption of distilled water on the dry weight of treated fibres

Table 5.1: Absorption response

Run order	%hydrogen peroxide	Temperature(ºc)	Absorption (%)
1	25.0000	11.7157	663
2	46.2132	40.0000	1047
3	40.0000	20.0000	835
4	3.7868	40.0000	495
5	10.0000	20.0000	644
6	25.0000	68.2843	900
7	25.0000	40.0000	903
8	10.0000	60.0000	600
9	25.0000	40.0000	896
10	25.0000	40.0000	910
11	25.0000	40.0000	912
12	40.0000	60.000	984
13	25.0000	40.0000	896

The absorption percentage response Y is given by the equation below,

$$Y=226+20.16A+11.45B-0.3059A^2-0.1589B^2+0.1608AB$$

Table 5.2 presents the effect of hydrogen peroxide concentration (%) and treatment temperature (°C) on the absorption capacity (%) of the developed feather-fibre absorbent material. The experimental design appears to follow a Central Composite Design (CCD) under Response Surface Methodology (RSM), where the two independent variables were hydrogen peroxide concentration and temperature, while absorption was the response variable measured.

The results show that both hydrogen peroxide concentration and temperature significantly influenced the absorption performance of the material. In general, the absorption capacity increased with increasing peroxide concentration and temperature up to an optimum range. At low hydrogen peroxide concentration, the material exhibited poor absorption. For example, run 4, which used only 3.7868% hydrogen peroxide at 40°C, produced the lowest absorption value of 495%. Similarly, run 5, treated with 10% hydrogen peroxide at 20°C,

showed a relatively low absorption of 644%. This suggests that insufficient peroxide concentration resulted in limited removal of fats, waxes, and surface impurities from the feather fibres, reducing pore development and hydrophilicity.

As the hydrogen peroxide concentration increased, absorption improved considerably. The highest absorption value of 1047% was obtained in run 2 at 46.2132% hydrogen peroxide and 40°C. This indicates that higher peroxide concentrations enhanced fibre surface modification, likely by increasing fibre porosity, exposing keratin functional groups, and improving water affinity. Increased oxidation may also have disrupted compact fibre structures, allowing greater fluid uptake.

Temperature also played an important role in absorption behaviour. At moderate to high temperatures, improved absorption values were observed. For instance, Run12, conducted at 40% hydrogen peroxide and 60°C, produced a high absorption of 984%, while Run 6, at 25% hydrogen peroxide and 68.2843°C, achieved 900% absorption. Elevated temperatures likely accelerated the peroxide treatment reaction and improved penetration into the feather fibres, enhancing structural modification and absorbent properties.

However, excessively high temperature alone did not always produce the best performance. Run 8, which used 10% hydrogen peroxide at 60°C, resulted in only 600% absorption. This suggests that temperature alone, without sufficient peroxide concentration, was not sufficient to achieve substantial fibre modification. Therefore, the interaction between peroxide concentration and temperature was important in determining the final absorbency.

The centre-point experimental runs (Runs 7, 9, 10, 11, and 13), all conducted at 25% hydrogen peroxide and 40°C, produced absorption values ranging from 896% to 912%. The close agreement among these repeated runs indicates good experimental reliability, reproducibility, and process stability. The small variation confirms that the experimental procedure was consistent and that measurement errors were minimal.

Overall, the data demonstrate that hydrogen peroxide treatment improved the absorption properties of feather fibres, with the best performance achieved at relatively high peroxide concentration and moderate temperature conditions. The findings suggest that chemical oxidation successfully modified the keratin fibre structure, making the material more suitable for absorbent applications such as bio-absorbent foam pads or wound dressing materials.

5.1.2 Analysis of variance (ANOVA)

From the analysis of variance, the p-value was used to determine whether there was significance in the interaction between variables and the percentage water absorption. P-values were regarded as significant when they were less than 0.05 and non-significant when they were above 0.1. It was found that the volume of %Concentration of hydrogen peroxide and temperature had a significant impact on the absorption percentage.

Table 5.3: Analysis of Variance

source	Df	F-value	P-Value	Significance
Model	5	35.95	0.001	significant
linear	2	71.93	0.002	significant
%H2O2 (A)	1	130.14	0.001	significant
Temperature(B)	1	13.72	0.008	significant
Square	2	15.31	0.003	significant
A^2	1	18.67	0.003	significant
B^2	1	13.93	0.005	significant
2-Way interaction	1	5.28	0.055	Not significant
AB	1	5.28	0.055	Not significant
Lack of fit	3	71.18	0.001	significant

S	R-sq.	R-sq.(adj)	R-sq.(pred
42.013	96.25%	93.57%	73.73%

The overall model is highly significant (F = 35.95, p = 0.000), indicating that the regression equation reliably explains the variation in absorbency. The linear terms are also highly significant (p = 0.000), meaning both % hydrogen peroxide and temperature strongly influence absorbency. Individually, % hydrogen peroxide has the greatest effect (F = 130.14, p = 0.000), showing it is the most dominant factor, while temperature is also significant (F = 13.72, p = 0.008), though with a smaller contribution. The quadratic (square) terms are significant (p = 0.003), which confirms the presence of curvature in the response. This means absorbency does not increase indefinitely with the factors but instead reaches an optimum point. Both % hydrogen peroxide (A^2) (p = 0.003) and temperature (B^2) (p = 0.005) significantly contribute to this curvature behavior. The interaction between % hydrogen peroxide and temperature have a p-value of 0.055, which is slightly above 0.05, indicating that the interaction effect is weak or marginally insignificant, though it may still have some practical influence.

The error term is relatively small, showing good experimental consistency. However, the lack-of-fit is significant (p = 0.001), which suggests that although the model fits well overall, it does not perfectly capture all the variability in the data—possibly due to missing higher-order effects or experimental noise. From the model summary, the R^2 value of 96.25% indicates that the model explains a very high proportion of the variability in absorbency. The adjusted R^2 (93.57%) confirms that the model remains strong even after accounting for the number of terms. However, the predicted R^2 (73.73%) is noticeably lower, suggesting that while the model fits the existing data well, its predictive ability is moderate and could be improved. Therefore, the model is statistically significant and reliable, with % hydrogen peroxide as the most influential factor, followed by temperature. The presence of significant quadratic terms confirms an optimal region for absorbency, though the significant lack of fit and lower predicted R^2 indicate that further refinement of the model may be necessary for better prediction accuracy.

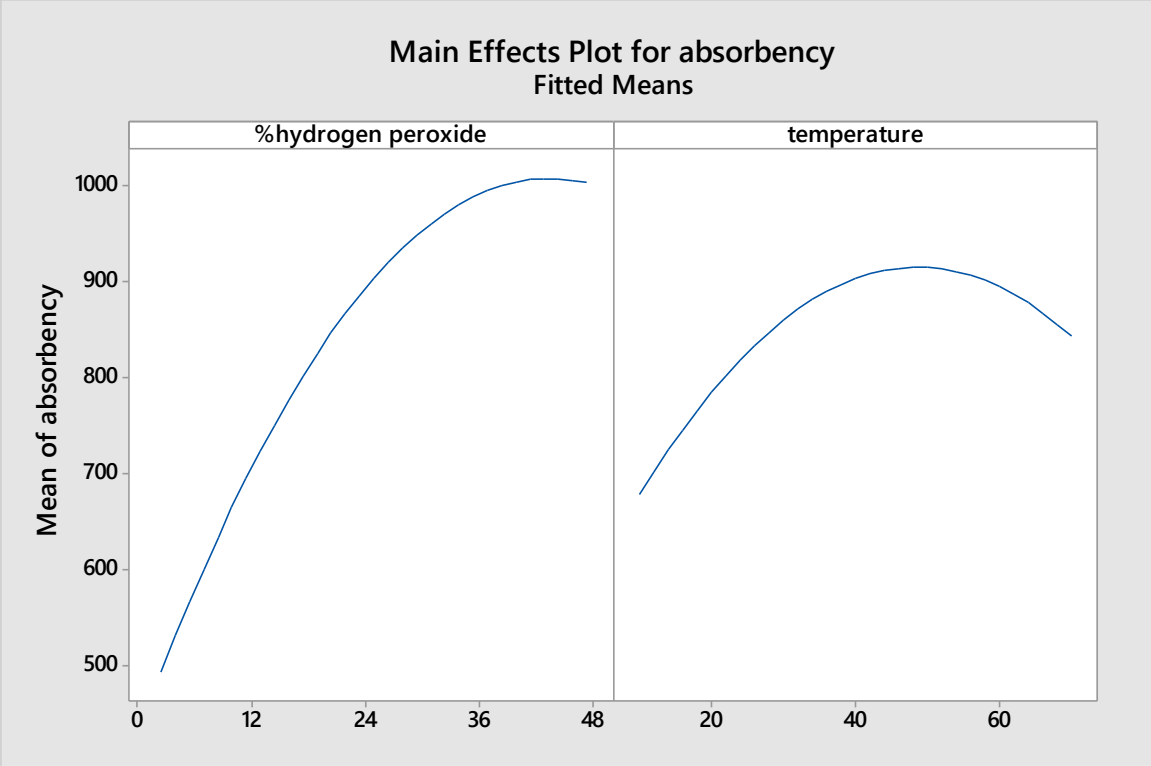


Figure 5.1:Mean graph for absorption percentage

This main effect plot shows how each factor individually affects absorbency, using fitted (model-predicted) values. And the effect of % Hydrogen Peroxide

The curve rises steeply at first, meaning that increasing H_2O_2 concentration strongly increases absorbency.

Around 35–45%, the curve begins to flatten, indicating the improvement slows down.

At the highest levels, it slightly levels off or declines, showing that too much peroxide can start reducing performance. Therefore, it is a clear optimal region for hydrogen peroxide. Increasing it helps, but only up to a point—after that, the fibres may begin to degrade or lose structure, reducing absorbency.

Effect of Temperature, Absorbency increases steadily from low temperatures (~20°C) up to about 45–50°C. After this peak, the curve drops, meaning higher temperatures reduce absorbency. Temperature improves fibre modification and absorbency up to an optimum, but excessive heat likely damages the fibre structure or reduces moisture retention ability. Both factors show curved (nonlinear) relationships, confirming your ANOVA result that quadratic

terms are significant. The graph clearly indicates the presence of an optimum operating region, not just “higher is better.”

Best performance occurs at moderate–high peroxide concentration and moderate temperature, not at the extremes**.**

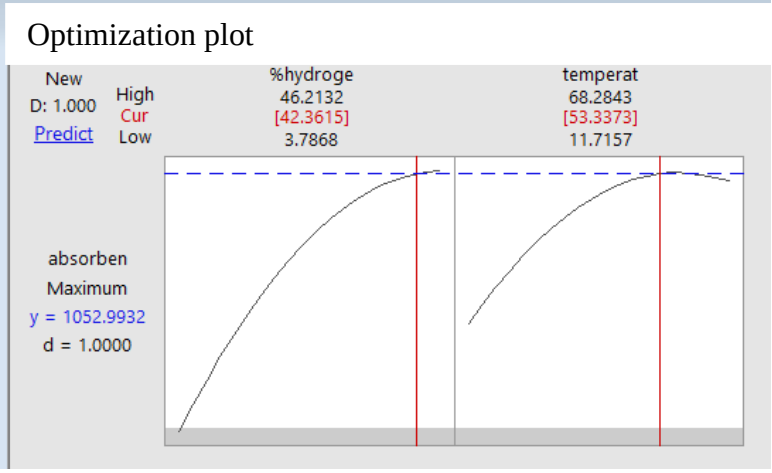


Figure 5.2:optimal plots

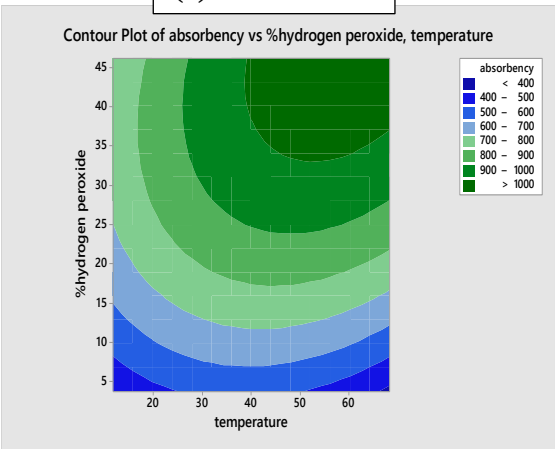
The figure of the optimization plot indicates the optimal conditions required to maximize absorbency based on the developed response surface model. The results show that the maximum predicted absorbency of approximately 1052.99 is achieved at a hydrogen peroxide concentration of about 42.36% and a temperature of around 53.34°C, with a desirability value of 1.000, indicating perfect optimization. The shape of the curves for both factors confirms a quadratic relationship, where absorbency increases with increasing hydrogen peroxide concentration and temperature up to an optimum point, after which it begins to decline. This behaviour suggests that excessive oxidation or high temperature may damage the feather fibre structure, thereby reducing its absorbent capacity. Therefore, the identified optimal conditions represent a balanced combination of factors that enhance fibre modification without causing degradation, making them suitable for achieving maximum absorbency in the developed material.

5.1.3 Response surface

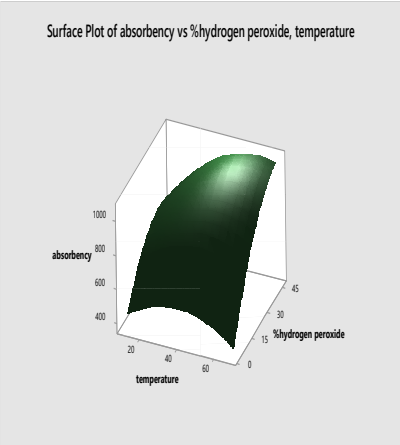
The following figures represent the 3D surface plots and 2D contour plots, which show the effect of the interaction of different parameters on the absorbance of the material. Some

factors are kept constant, and then the effect of the interaction of the left 2 factors on absorbance is described by the graphs

(a)



(b)



5.1.4 Wettability behaviour of treated feather and untreated feather fibre underwater.

The wetting behaviour(Gao et al. 2020) of the fibres was evaluated using water droplet contact angle captured by a Samsung camera at constant angle measurements to compare untreated (ground feather fibre) and chemically treated feather fibre.

The untreated fibres exhibited relatively lower wettability, with a higher water contact angle which was above as indicated by the red arrow

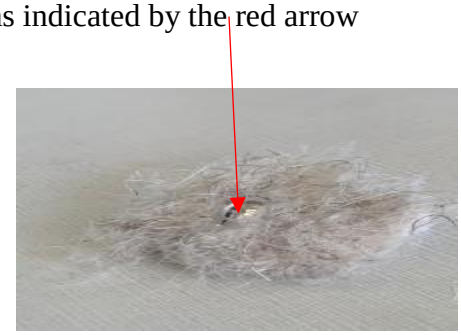


Figure 5.3: water drop above, indicating a more hydrophobic nature due to the presence of natural lipids and intact keratin structure, which limits water penetration.

Treated fibres showed significantly improved wettability, with a much lower contact angle, fully absorbed wettability

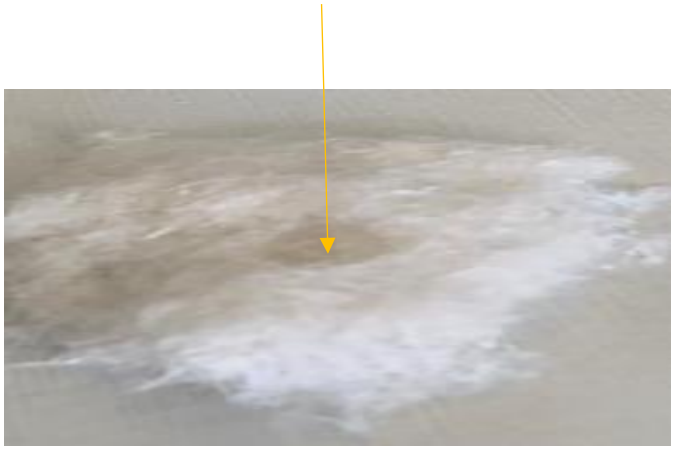


Figure 5.4: A water drop fully absorbed below the surface as indicated by the yellow arrow

As evidenced by the rapid spreading or absorption of water droplets on the surface. This enhancement can be attributed to chemical modification during treatment, which removed surface impurities and disrupted disulfide bonds, thereby exposing more polar functional groups such as hydroxyl(-OH) and amino groups(-NH_2) (Gao et al. 2020).

Additionally, the increased surface roughness and porosity after treatment promoted water retention within the fibre structure. As a result, the treated feather fibres demonstrated superior hydrophilicity and water absorption capacity (Gao et al. 2020) compared to untreated fibres, making them more suitable for an absorbent core.

5.2 To characterize fibres from down feathers

5.2.1 Scanning electron microscopy results.

Untreated fibres(a)

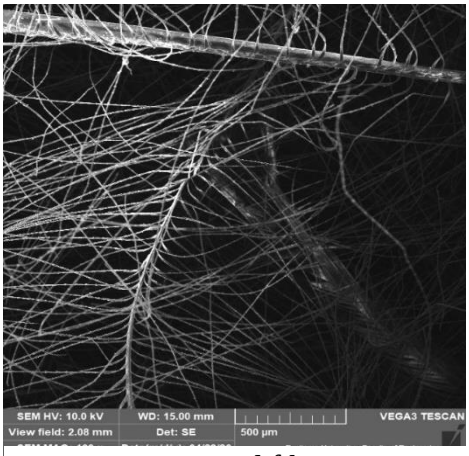


Figure 5.7 untreated fibres

Treated fibres(b)

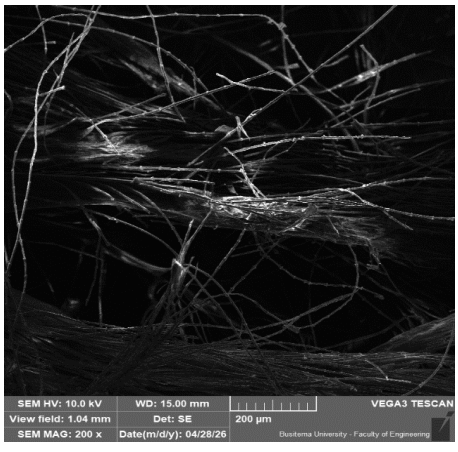


Figure 5.5 treated fibres

Presented above are the down feather fibres SEM micrographs before and after alkaline, ethanol, and oxidation treatment. The micrographs in **Figure 5.6** represent the surface appearance of untreated feather fibres. This shows a randomly arranged network of keratin fibres with barbs and fine barbules. The fibres appear elongated and cylindrical (Kakonke et al. 2020) with relatively smooth surfaces. Some particles and irregular deposits are visible on the fibre surface, indicating the presence of natural impurities, residual fats, protein, and dirt, hence hydrophobic. Absence of surface roughness confirms no chemical applied and shows the natural keratin structure remains intact in **Figure 4.7,** after treatment of hydrolysis by 2% sodium hydroxide(NaOH), oxidation by hydrogen peroxide, micrograph **Figure 4.6** shows more separate fibres, roughness and porous of fibres this indicated removal of outer layer by mild sodium hydroxide initially used which removed the residual fats and dirt, the increased porosity with visible voids and gaps between fibres made more individualization in **figure 4.6** showed breakdown of covalent disulphide bond(Gao et al. 2020) in fibres by hydrogen peroxide that increase **-OH** polar group made the better absorbency and fluid interaction hydrophilicity of fibres.

5.2.2 FTIR CHARACTERIZATION OF FIBERS

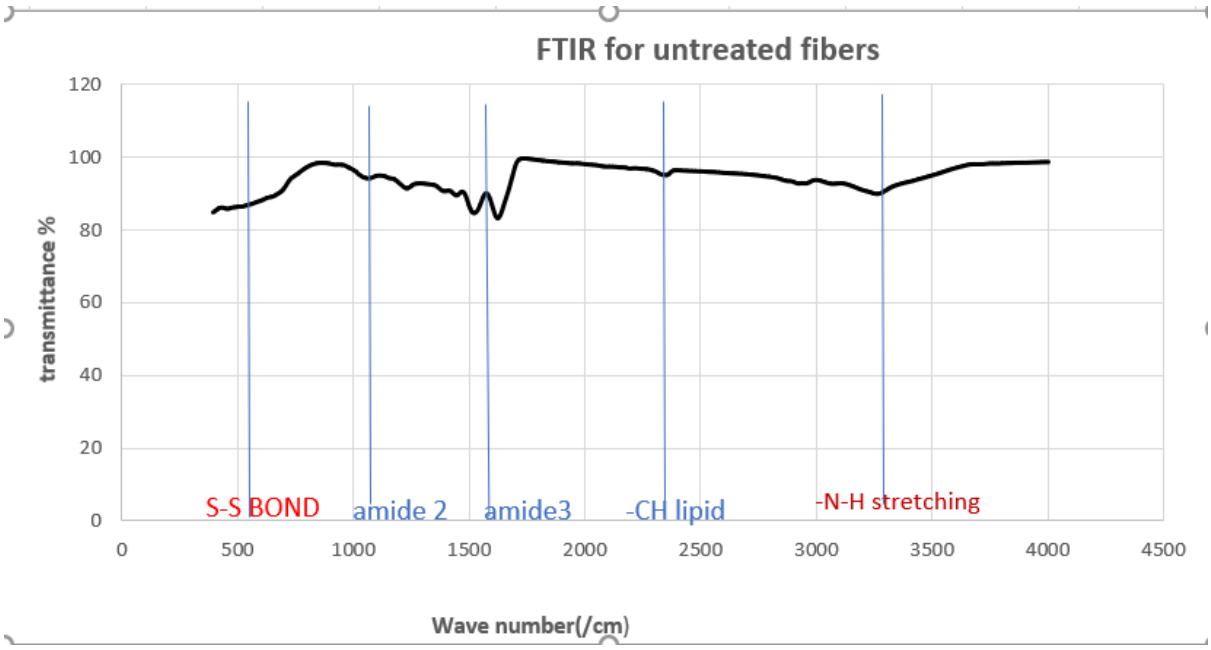


Figure 5.7 of FTIR results of untreated fibres

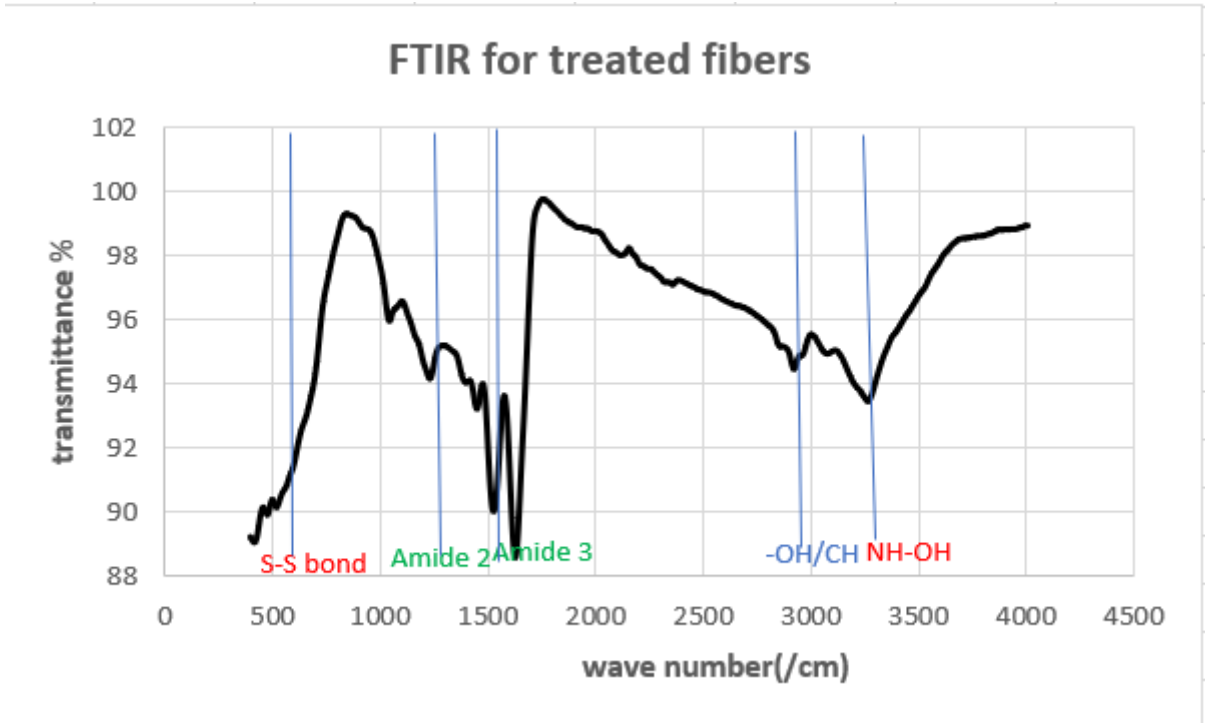


Figure 5.8of FTIR results of treated fibres

Table 5.4: Explanation of wave number in the FTIR results of fibres

Wave number(cm-1)	Functional group	Vibration table	Indication in fibre
3200-3400	O-H/N-H	Stretching (amide A)	(O-H) Stronger in treated fibres
2920	C-H	Stretching (aliphatic)	Aliphatic chains in keratin and lipids
1650	C=O	Amide 1 band (stretching)	Backbone of keratin
1530	N-H, C-N	Amide 11 band (bending +stretching)	Keratin secondary structure
1230	C-N, N-H	Amide 111 band (stretching +bending)	Keratin structure
1030-1100	C-O	Stretching	Oxidation increased polar groups
600-700	S-S	Disulphide bond	Crosslink in keratin is stronger in the untreated fibres

Explanation

The graphs above show the results of the FTIR spectrum of treated feather fibres and untreated fibres. **Figure 5.9** represents treated and **Figure 5.8** represents the untreated feather fibres. The FTIR spectrum of treated fibres confirms the presence of characteristic keratin functional groups with significant modifications due to chemical treatment. An absorption band observed around 3200-3400cm^{-}1(Gao et al. 2020) corresponds to O-H and N-H stretching vibrations, indicating enhanced hydrophilicity of the fibres. The prominent peaks at 1650cm-1 (amide 1), 1530cm-1 (amide 11), and 1230 cm-1 (amide 111) confirm the preservation of the keratin backbone structure after treatment. However the increased intensity in the 1000-1100cm-1 region suggests the formation of C-O functional groups due to oxidative treatment, weakening of bands associated with 600-700cm-1 disulphide(S-S)

bond indicated structural modification, which contributes to improved softness and liquid absorption properties without destroying keratin structure while the FTIR spectrum of untreated feather fibres shows keratin peaks (amide11) 650cm-1, (amide 11) 1530cm-1 and (amide 111) 1230cm-1 (Gao et al. 2020)confirm keratin structure there is minor weaker broad band at 3200-3400cm-1 which indicates hydrophobicity function group this pronounces the intact disulphide bond at 600-700cm-1 which makes a rigidity of the fibres and therefore the untreated fibres exhibits lower intensity in the O-H region and weaker C-O peaks indicating few polar groups and reduced interaction with water.

5.3 Evaluate water retention and absorption of foam pad material

Absorbency and Water Retention Test of Foam Pad (500 mL Beaker Test)

The developed pad (5 g of treated foam feather fibres within a 1 g of 10 cm × 15 cm gauze) was evaluated by immersion in a petri dish of water to assess its absorbency and retention behaviour.

Upon immersion, the pad demonstrated rapid fluid uptake, which was attributed to the porous structure of the treated feather fibres and the capillary action provided by the gauze layer. The material absorbed a significant amount of water within a short time, indicating a strong affinity for liquid.

Based on the typical behaviour of porous keratin-based fibres, the pad absorbed 15 times its own weight.

Initial dry weight of pad (Fibres + gauze) = 6 g

water absorption capacity = 56 mL of water, which was equivalent to 56 grams

5.3.1 Water Retention Test Evaluation

After saturation, the pad was removed from the petri dish and allowed to drain under gravity, without squeezing, for 5 minutes. The retained water was determined.

The dry weight of the pad was 6grams

Water absorbed at saturation was 56 g

The final weight of the wet pad after drainage was 51grams

Therefore, water retained=51-6=45grams

Table 5.5 Water Retention Test Data

Sample ID	Saturated weight(g)	Weight after drainage W2	Water retained (W2-W1) g	Retention capacity(g/g)	Retention %
Treated pad	62	51	45	7.5	80.04

$water\ retention\% = {}^{45}/_{56}$=0.803, this make 80.03%, which was good water retention of the pad.

EN 13726 states that Conventional foam wound dressings should exhibit retention values between 45% and 80%. Therefore, the developed feather-fibre pad with 80.04% (Ferraz 2025) demonstrates competitive retention efficiency suitable for moderate wound exudate management, this retention ratio(g/g) $= {}^{45}/_{6}$=7.5g/g this indicated porous and hollow structure of keratin-based fibres, which allows water within internal cavities, good capillary forces within the gauze layer for liquid holding capacity, and the interconnected fibre network, reducing rapid fluid.

5.3.2 Water absorption of the pad test evaluation

Dry weight of the pad was 6grams and the weight of the pad after absorption was 56grams, therefore water absorption% was,

Water absorption

Table 5.6 Water Absorption Test Data

Sample ID	Dry weight Wo(g)	Wet weight W1(g)	Weight absorbed (W1-Wo) g	Absorption capacity(g/g)	Absorption%
Treated pad	6	62	56	10.33	933.333

Percentage of water absorption = $\frac{(56)}{6}$ =933 .333%

EN 13726 states that Conventional foam wound dressings should exhibit absorbency values between 5 -15 g/g (Ferraz 2025). Therefore, the developed feather-fibre pad with 10.33 g/g demonstrates competitive absorbent performance suitable for moderate wound exudate management. This is because of the porous and hollow microstructure, surface wettability after chemical treatment, and capillary action due to the gauze matrix of the foam pad. This proves that the pad was suitable for biomaterial.

6 CHAPTER FIVE: **CONCLUSIONS, CHALLENGES, AND RECOMMENDATIONS**

6.1 Conclusion

According to the experimental data, fibres were softened by a mild NaOH solution which improved the surface modification. Fats and wax were highly removed by the 99.9%ethanol solution, which made the fibres' structure polar and open, reducing the hydrophobic bond of keratin. This was observed by an SEM micrograph and FTIR

Response Surface Methodology (RSM) using Central Composite Design (CCD) successfully optimized the treatment conditions affecting absorbency. The statistical model showed that hydrogen peroxide concentration and temperature significantly influenced fibre absorbency, with hydrogen peroxide being the most dominant factor. The optimum conditions predicted by the model produced a maximum absorbency of approximately 1053%, indicating excellent liquid uptake performance.

The developed multilayer foam feather pad demonstrated high absorbency and good water retention characteristics. The pad absorbed about 10.33 times its dry weight (933.33%) and retained approximately 80% of the absorbed water after drainage. These properties were attributed to the porous hollow structure of keratin fibres, improved surface wettability, and capillary action provided by the gauze structure.

6.2 Challenges.

Maintaining the required parameter for a long time of experiment, most especially temperature at 40 with varying conditions during boiling of hydrolysis of alkaline and oxidation, wasn't possible because the system was open, which brought steady loss in temperature, which brought inefficient removal of wax and disulfides in keratin structure, which limited the absorbency and bleaching action of the fibres

because the tools available, like scissor couldn’t work flexibly and the grinding machine couldn’t grind the quill shaft and even that grinding machine was from only Nagongera, which was a long distance because of their hardness which limited the ability to obtain of the required weight to run the experiments.

Tests like antibacterial and cytotoxicity(biocompatibility) were not done on the final product because of a lack of animal tissue to test on and skilled medical personnel who can biologically analyse the data from the tests

6.3 Recommendations

More research is recommended to investigate the blending of treated feather fibres with cotton fibres to enhance the overall performance of the material. Cotton fibres can improve the mechanical strength, flexibility, and comfort of the composite, while feather fibres contribute high absorbency due to their porous structure. The combination is expected to produce a balanced material with improved structural integrity and fluid absorption capacity, making it more suitable for wound dressing applications.

Further research should investigate the use of needle punching as a fabrication method for forming nonwoven pads. This technique can improve fibre entanglement, structural stability, and uniformity without the need for adhesives, resulting in a more practical and scalable wound dressing material.

To evaluate the biomedical applicability of the developed material, it is essential to conduct in vitro cytotoxicity tests to assess biocompatibility with human cells for clinical validations. Additionally, antibacterial studies should be performed to determine the material's ability to inhibit microbial growth, which is critical for wound healing applications.

6.4 Reference

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DEVELOPMENT OF BIO-ABSORBENT FOAM PAD FOR WOUND DRESSING FROM DOWN CHICKEN FEATHER WASTES

KASULE KULAISHI

Compliance sheet

Comments	**Response**	**Page number**
Objective 3 should be reformulated to improve clarity and specificity	Redesigned to fabricate a foam pad and evaluate the absorbency and retention capacity of the foam pad	Page 14
Remove all untitled or improperly cropped SEM images, as these compromise the clarity and interpretability of the microstructural analysis	It was a mistake made in PowerPoint, but in the report, the images are not cropped and are in the original design	Page 45
The methodology for wettability analysis appears to lack adherence to a clearly defined or recognized standard; specify the governing protocol and ensure methodological transparency	Wettability of the treated feather fibers was assessed using a water droplet spreading method. A droplet of distilled water was placed on the fiber surface, and its spreading behaviour was captured using a Samsung smartphone camera under controlled conditions. Faster droplet spreading indicated improved wettability and hydrophilicity of the modified fibers. This method is commonly used for evaluating surface wettability changes in modified materials (Yuan & Lee, 2013)	Page 34
The fiber extraction procedure does not appear to follow a standardized or method; advised to justify the approach or align it	The fibre extraction procedure used in this study was adapted from established methods reported in the literature for processing chicken feathers into keratin fibres. The approach involved cleaning, drying, fibre separation, and chemical treatment to	Page 24 Page 27 and 30

with established protocols in the literature.	obtain fibres suitable for absorbent applications. Similar procedures have been successfully applied by Tesfaye et al. (2017) and Forgács et al. (2013), demonstrating their effectiveness in producing modified keratin fibres with improved functional properties.	
The experimental design requires verification, particularly with respect to factor levels and coding. Some coded levels (e.g., −1 and +1) appear to be missing or inconsistently represented, which may affect the validity of the analysis	The experimental design was reviewed and verified to ensure that all factor levels and coded values were correctly represented. Any missing or inconsistent coded levels were corrected, and the coding scheme was aligned with the requirements of the Response Surface Methodology (RSM) design to ensure accurate analysis and valid interpretation of results.	Page 33 and 35
The stated objective 1 has not been comprehensively addressed in the results and discussion. Incorporate comparative analysis (e.g., baseline vs. optimized conditions) to clearly demonstrate performance improvements and substantiate the claim.	Comparative baseline and optimized-condition analyses were corrected using CCD of RSM and were well structured.	Page 14 and page 33