Selected Properties of Cattail Fibre for Biomedical Applications

By

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Abstract

Researchers at the University of Manitoba have developed a textile fibre from cattail biomass. The current study was primarily focused on investigating the possibility of utilizing an already used solution to extract fibres from cattail plants. Examination of physical and mechanical properties of extracted fibre was carried out, followed by an analysis of its chemical treatment effect through the application of 17^{th}-time reuse of alkali solution. To check the suitability of re-used alkali solution, eight fibre properties, including yield percentage, contact angle, load at break, tensile stress at break, tensile strain at break, Young's modulus, tenacity at break, and moisture regain were determined. One-way ANOVA was used to calculate average and standard deviations of eight properties for all 17^{th} time reuse solutions as well as significant differences among the fibre properties obtained from reused alkali solutions. Data from descriptive statistics were programmed in Python computer language to find out reuse time for single and multiple properties. It was found that for single property, alkali solution can be reused up to R17 for yield (%), contact angle, moisture regain, and strain; R13 for tensile stress; and R14 for Young's modulus. For multiple properties, the reuse time was found in decreasing order with the increasing in the number of properties.

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Dedication

This thesis is dedicated to my Parents and my Supervisor.

Accepted Abstracts from this Thesis

1. **Title: Textiles and Fashion' ways of thinking water: developing waste biomass fibres.**
   Hrishekesh Banik, Dr. Mashiur Rahman, Mostafizur Rahman.
   International Prairie Student Conference 2019, University of Manitoba. August 22, 2019.

2. **Title: Suitability of Cattail Fibre for Wound Dressing Application.**
   Hrishekesh Banik, Dr. Mashiur Rahman.
   University of Manitoba Second Annual Poster Competition in Biomedical Engineering, University of Manitoba, October 29, 2021.

3. **Title: A Critical Review on the Textile Processing Steps Required to Make Garments and Their Impact on CO_2 Emission.**
   Hrishekesh Banik, Dr. Mashiur Rahman, Mostafizur Rahman.
   CSBE/SCGAB Annual General Meeting and Technical Conference, July 15-17, 2019, Vancouver, British Columbia.

4. **Title: Determining the recyclability of alkali on Typha biomass properties using a Python computer programming language.**
   Hrishekesh Banik, Mohammed Shahadat Hossain, Dr. Mashiur Rahman.
   Canadian Society for Bioengineering 2022 Annual General Meeting, July 24-27, 2022, Charlottetown, PEI.

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Chapter 1: Introduction

Medical Textile can be defined as a part of technical textile where it specifically belongs to medical and biological usage and applications focusing on first aid, clinical and hygienic production (Getu & Sahu, 2014). Textile materials and products are required to design through an amalgamation of strength, flexibility, moisture and air-permeability where material created by yarns from “monofilament and multifilament” and fabrics of “woven, knitted, nonwoven and composite” structure (Rigby et al., 1997). Global Harmonisation Task Force (GHTF) controlled the market of the medical textile world, where three geo-graphical groups are dedicated towards monitorization and regulation by four countries’ initiation named as “European Union, the United States, Canada, Australia, Japan” (Czajka, 2005). This organization was founded in 1993 where the main goal of the founding is to meet the standards through the application of rules and regulation in terms of ensuring safety, performance and quality of medical devices (International Medical Device Regulators Forum [IMDRF], n.d.).

Application of medical textile is first introduced by using fibre for wound closure at the time of surgery, which was innovated around 5000-3000 B.C (Dattilo et al., 2002). At the initial time, wound closure was performed by pre-lubricated natural materials like flax, silk, linen strips and cotton through oil and wine (Dattilo et al., 2002). At a later stage, wound surgery performed by the advancement of synthetic polymers and fibers, synthetic sutures where the suture was designed through configuring polymer, types and size of the fiber, and surface modification for individual application (Dattilo et al., 2002).

Nowadays, various types of suture, including natural, synthetic, nonabsorbable, and absorbable, are used by the surgeon according to their particular site preference (Dattilo et al., 2002). The revolution of wound dressing started in 1970 as moist wound care through the application of film and hydrocolloid dressing (Queen et al., 2004). Egyptians first introduced adhesive bandages through applying a composition of honey, grease, and lint on wounds as a plaster (Shah, 2011).

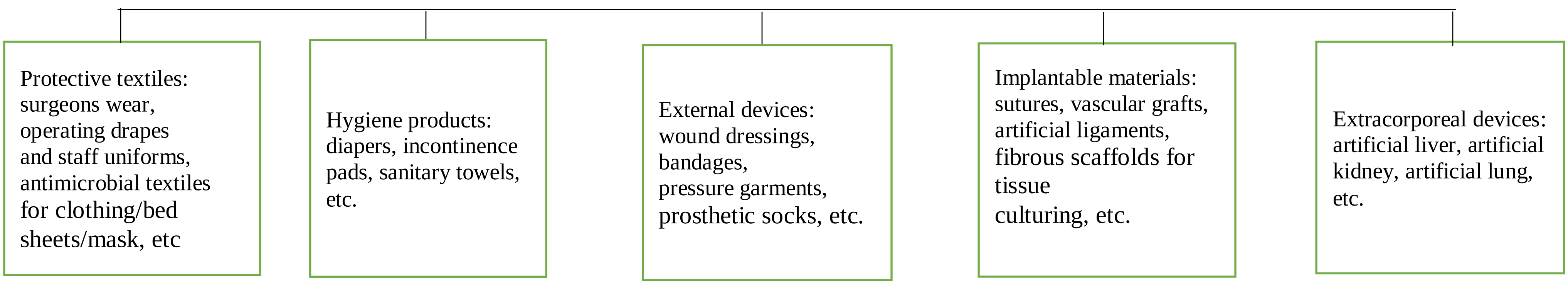
In early 1970, Pressure Garments were widely welcomed as a method of hypertrophic scar management (Shah, 2011). Prosthetic socks were developed as suction socks for lower-limb amputees through the University of California, Berkeley researchers' group in 1946 (Knit-Rite, 2017). The purpose of prosthetic socks is to increase the mobility of patients and their life quality (Knit-Rite, 2017). Hatch (2006) stated that "Polyethylene Terephthalate (PET) is the most important member of the polyester generic groups of fiber which was firstly introduced on the U.S. market in 1951" (p.215). This polyester was introduced to the market in 1941 by Dickson and Whinfield (Hatch, 2006).

An artificial kidney operates exactly like a hemodialyzer, a mechanical instrument, that is utilized outside of the body to act as a kidney through extracting the blood's waste materials (Sakai & Mineshima, 1984). A machine with biomechanical function, which commonly incorporated through a filter system to separate toxins from blood with hepatic cells or tissue, is called an Artificial Liver (Farlex Medical Dictionary, n.d.). A practical way of supplementing respiratory support for patients with acute respiratory failure is through the intravenous route and is called Artificial Lungs (Federspiel et al., 2000).

1.1 Medical Textile Classification

The medical textile is usually divided into five branches: protective textiles, hygienic products, external devices, implantable materials, and extracorporal devices. All of these branches are described below:

Figure 1. 1. Examples of Medical/Healthcare Textiles



Note. adapted from Zhong (2018).

Protective textile can be further classified upon its industrial application and functional usage. According to its application, personal protective textile can be classified in different types where it is utilized on industrial, civilian, medical, space, and military sectors (Zhou et al., 2005). Based on its functional application, it can be classified by its protection from flame, biological, mechanical impact, electrical and wearer visibility.

In the medical textile application field, the design of the textile's fabric offers two functions (Zhou et al., 2005). One of the functions protects the user from being a victim of bacteria, yeast, dermatophytic fungi and other associated microorganisms, called medical, aesthetic, hygienic; another function protects "the textile from biodeterioration caused by mold, mildew, and rot-producing fungi" (Zhou et al., 2005).

In hygiene products, healthcare and hygiene products are furthermore classified into two types named as disposable textile and non-disposable textile, where the application is based on hospital usage such as surgical masks, surgical drapes, surgical footwear, as well as personal care like tampons, sanitary napkins, and incontinence products (Rajendran & Anand, 2006).

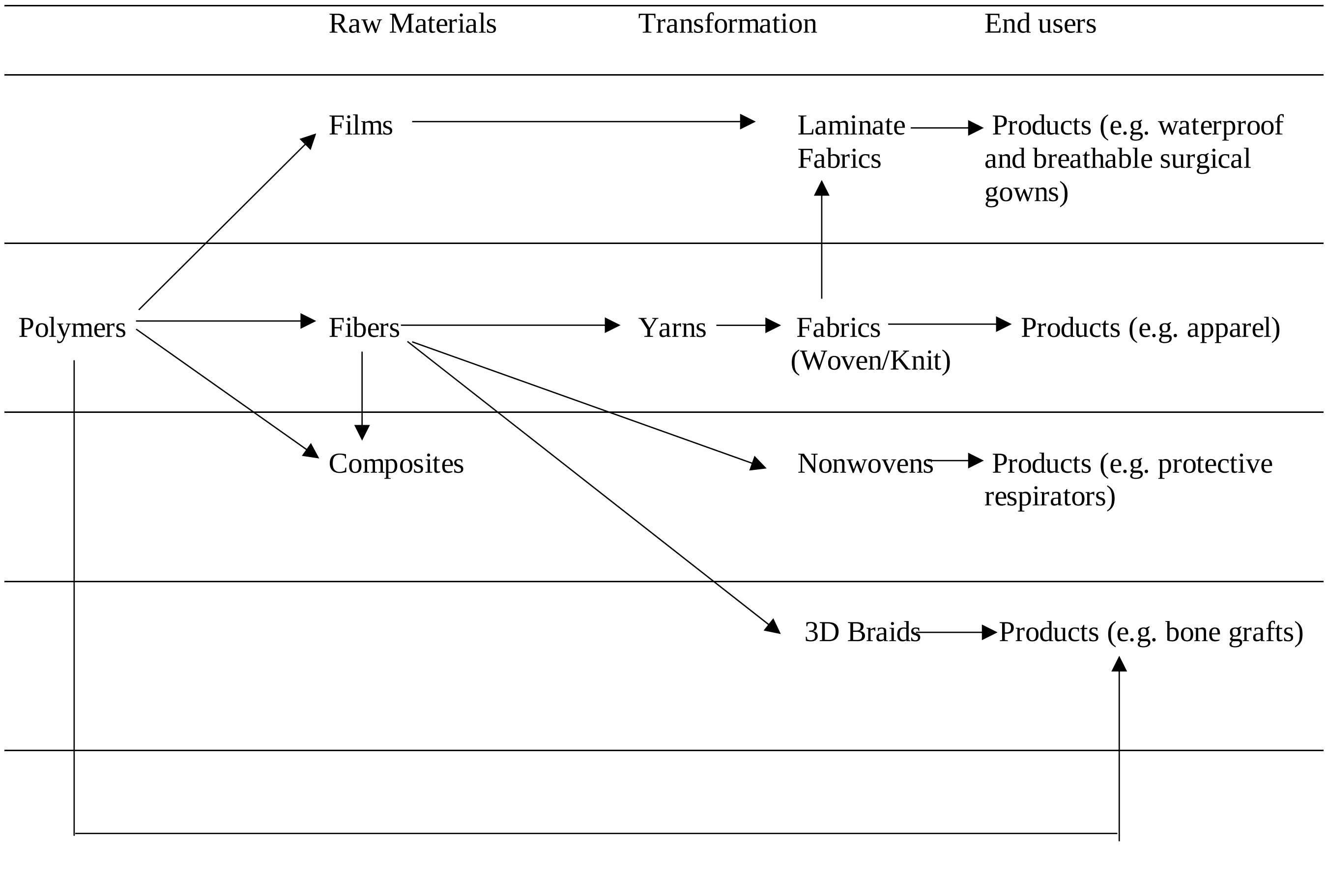
With external devices, wound dressing can be further classified into three types of dressing such as traditional dressings, biological dressings, and artificial dressings, considering the nature of wound (Kamoun et al., 2017). Bandages are made by using woven, non-woven or knitted structure and elastic or non elastic types as they depend on the function of performance considering the wound and other medical requirements (Deopura et al., 2008). Pressure garments are recommended for the patient who has lost thickness of skin either partially or entirely by suffering a major burn injury (Zhong, 2013).

For implantable materials, the suture can be defined as a yarn that supports tissues prior to the start of the natural healing process, which supplies an adequate level of wound strength or restricts blood vessels aiming to end bleeding (Deopura et al., 2008). A vascular graft is a common surgical procedure where blood flow diverts by reuniting the blood vessels from one area to another area of the body (Travers, 2020). Artificial ligaments work as a functional medical device characterized by connecting the end of two bones (Shibli, 2013).

In terms of extracorporeal devices, the artificial liver is configured to support the patient with hepatic failure for a brief period until it can be replaced by a donor's liver (Farlex Medical Dictionary, n.d.). An electrically passive component of the system is the artificial kidney. It functions following pressure of the fluids fleeting by its ports combined with osmatic action through a good art procedure (von der Heide et al., 1979). The artificial lung is an auxiliary respiratory support provided intravenously for the patient in terms of the condition of acute respiratory failure (Federspiel et al., 2000).

1.2. Polymer of Medical Textile

Table 1.1. Materials and Structures Used for Healthcare and Medical Textiles



Note. Based on Zhong (2018).

Textile Polymer can be defined as the multifaction of macromolecules through the bonding of a simple chemical unit by the composition of any type of natural or synthetic substances (Vyas, 2019). Each of the single chemical unit of molecule is called Monomer. The process of merging identical or similar molecules is called polymerization (Vyas, 2019). The history of the polymer name comes from a Greek word where poly stands for many and Meros means part (Vartest, n.d.). Most of the Textile fibres including natural and synthetic have very unique and valuable properties since they produce by polymer (Vartest, n.d.). Due to a characteristic of the large molecular chain by polymer, it is covalently bonded to one another through forming a repeating group of atoms (Vartest, n.d.). Considering the textile fiber structure, three types of polymers are available for the medical product industry. The first type of polymer is called homopolymer, which is characterized by a polymer chain through the same repeating unit. Cotton, nylon, polyester, and olefin fibers are examples of homopolymer (Zhong, 2018). The second polymer is called a copolymer, where the polymer chain consists of two or more monomers (Zhong, 2018). Acrylic, modacrylic, and a few other fibres are made of copolymer (Zhong, 2018). The third polymer is known as block polymers, which is followed by a polymer chain made up of two or more repeated homopolymers (Zhong, 2018). Polyurethane (Spandex) fibres are produced by block polymer (Zhong, 2018). Out of four kinds of medical textile fabric known as woven, knitted, braided, and nonwoven, polymers can be directly applied towards nonwoven fabric production. Medical textile product performances depend on the properties of the polymer, including its structure modification through two to four individual types of organizations (Zhong, 2018). There are different types of specific condition requirements that the polymer needs to meet before it turns to become a fibrous product, including linear, long, flexible, simple, small, or polar, dissolvable or meltable for extrusion, capable of being oriented and crystallized (Gupta, 1998). The characteristic of the polymer can depend on different sources. One of them is called the degree of polymerization, where a repetition of monomer numbers in the polymer chain is found and called the length of the polymer chain (Zhong, 2018). It has three further structures known as orientation, crystalline, and amorphous. A polymer framework with a linear state is followed by chain molecules in the level of same direction called orientation (Zhong, 2018). The crystalline region is built by crystals where a framework of lattice can be found at the polymer chain (Zhong, 2018). The amorphous region is available in the shape of the noncrystalline which is characterized by a lack of order (Zhong, 2018).

Table 1.2. Fibre for Implantable Medical Textile

Fibre type	Collagen, catgut, polyglycolide fibre, polylactide fibre	Polyester fibre, polyamide fibre, PTFE fibre, polypropylene fibre, polyethylene fibre	PTFE fibre, polyester fibre, silk, collagen, polyethylene fibre, polyamide fibre	Polyester fibre, carbon fibre, collagen	Low-density polyethylene fibre	Chitin	Poly (methyl methacrylate) fibre, silicon fibre, collagen,	Silicone, polyacetyl fibre, polyethylene fibre	PTFE fibre, polyester fibre	Polyester fibre
Fabric structure	Monofilament, braided	Monofilament, braided	Woven, braided	Braided	-	Nonwoven	-	-	Woven, knitted	Woven, knitted
Application	Biodegradable sutures	Non-biodegradable sutures	Artificial tendon	Artificial ligament	Artificial cartilage	Artificial skin	Eye-contact lenses and artificial cornea	Artificial joints/bones	Vascular grafts	Heart valves

Note. reprinted from Getu and Sahu (2014).

Four essential components related to biocompability confirm whether the implants have accepted the body reaction; therefore, they determine if the body reaction to the textile materials has been accepted (Horrocks & Anand, 2000). The second factor is the circular fibre, where a small one is a cover superiorly with human tissue rather than the larger fibre having a cross-section (Horrocks & Anand, 2000). The third factor is toxic factors that should not be discharged by the polymer of fibre (Horrocks & Anand, 2000). However, the fibre must be unbounded from an exterior infection like lubricants and sizing agents (Horrocks & Anand, 2000). The fourth and final factor is polymer properties, which impact the implantation progress considering its biodegradability (Horrocks & Anand, 2000). As an example, polyamide is the major reactive material that loses its overall strength every two years, resulting in biodegradation (Horrocks & Anand, 2000).

Table 1.3. Non-Implantable Fibre for Medical Application

Variable	Product application	Fiber types	Fabric types
Wound-care	Absorbent pad	Cotton viscose	Nonwoven
	Wound contact layer	Silk, polyamide fiber, viscose, polyethylene fibers, plastic film	Knitted, woven, nonwoven
	Base material	Viscose, plastic film	Nonwoven, woven
Bandage	Simple inelastic/elastic	Cotton, viscose, polyamide fiber, elastomeric-fiber yarns	Woven, knitted, nonwoven
	Light support	Cotton, viscose, elastomeric-fiber yarn	Woven, knitted, nonwoven
	Compression	Cotton, polyamide fiber, elastomeric-fiber yarns	Woven, knitted
	Orthopaedic	Cotton, viscose, polyesters fiber	Woven, nonwoven
	Plaster	Viscous plastic film, cotton, polyesters fibers, glass fiber	Woven, knitted, nonwoven
	Gauzes	Cotton, viscous	Woven, nonwoven
	Lint	Cotton	Woven
	Wadding	Viscose, cotton linter, wood pulp	Nonwoven

Note. reprinted from Getu & Sahu (2014).

Table 1.4. Fibres Used for Extra Corporeal Device

Fibre type	Hollow polyester fibre, hollow viscose	Hollow viscose	Hollow polypropylene fibre, hollow silicone membrane
Application	Artificial kidney	Artificial liver	Mechanical lung
Function	Remove waste products from patients' blood	Separate and dispose of patients' plasma and supply fresh plasma	Remove carbon dioxide from patients' blood and supply fresh oxygen

Note. reprinted from Getu & Sahu (2014).

Wound care dressing and bandage are mainly two types of non-implantable medical textile products for external usage followed by either contact with skin or not even so (Horrocks & Anand, 2000). For medical and surgical applications, numerous types of wound dressing are available in the market. The main objectives of these materials are to serve as protection in opposition to any type of wound infection, as well as stimulate healing along with putting medication on the surface of the wound (Horrocks & Anand, 2000). Bandages are structured to operate a complete diversity of individual roles based on the last medial specification. To retain the dressing area over wounds is the primary usage of the bandage (Horrocks & Anand, 2000). Cotton or viscose made lightweight bearing knitted, or simple open weave fabrics are chopped into a segment which is followed by scouring, bleaching, and sterilizing (Horrocks & Anand, 2000).

The mechanical organ that purifies blood along with an artificial kidney (dialysis machine), an artificial liver, and a mechanical lung is called an extracorporeal device (Horrocks & Anand, 2000). The operation and progress of this device depends on the quality and materials performance of applied textile fibre during its manufacture (Horrocks & Anand, 2000). The operational activity by using an artificial kidney is accomplished by the blood circulation through a membrane, which could be a flat sheet or a bunch of cellulose fibres with hollows engineered as cellulose membranes to keep and trap the waste materials (Horrocks & Anand, 2000).

Hollow fibre or membranes are harnessed by the artificial liver, the same as what is applied for an artificial kidney for operational performance (Horrocks & Anand, 2000). Although the mechanical lung's microporous membranes retain high permeability of gases, however, liquid permeability and outcomes are identical approaches like a natural lung followed by permitting oxygen to encounter the blood of the patient (Horrocks & Anand, 2000).

Table 1.5. Fibres for Hygiene Products

Fibre type	**Fabric structure**	**Application**
Cotton, polyester fibre, polypropylene fibre,	Woven, nonwoven	Surgical gowns
Viscose	Nonwoven	Surgical caps
Viscose, polyester fibre, glass fibre	Nonwoven	Surgical masks
Polyester fibre, polyethylene fibre,	Woven, nonwoven	Surgical drapes, cloths
Cotton, polyester fibre, polyamide fibre, elastomeric-fibre yarns	Knitted	Surgical hosiery
Cotton, polyester fibre	Woven, knitted	Blankets
Cotton	Woven	Sheets, pillowcases
Cotton, polyester fibre	Woven	Uniforms
Polyester fibre, polypropylene fibre	Nonwoven	Protective clothing, incontinence, diaper/sheet, coverstock
Superabsorbent fibres, wood fluff,	Nonwoven	Absorbent layer
Polyethylene fibre,	Nonwoven	Outer layer
Viscose, lyocell	Nonwoven	Cloths/wipes

Note. reprinted from Getu & Sahu, (2014).

Healthcare and hygiene products are utilized specially in the operating theatre, hygiene care in the hospital ward as well as for the safety of staff and patients (Horrocks & Anand, 2000). Surgical masks include the extra fine glass fibre's fine middle layer or synthetic made microfibres, which are enclosed by both sides through nonwoven either acrylic bonded parallel-laid or wet laid (Horrocks & Anand, 2000). Nowadays, the disposable gown is commonly used to stop sources of infection towards the patients since the surgeon's traditional gown made by woven cotton is responsible for potential contamination (Horrocks & Anand, 2000). In terms of caring for the patient in the hospital ward, bedding, clothing, mattress covers, incontinence products, cloths and wipes are known as healthcare and hygiene products made by textile materials (Horrocks & Anand, 2000). The disposable diaper is a product of a composite which contains three layers including an inner covering layer, an absorbent layer and an outer layer (Horrocks & Anand, 2000).

1.3. Fabric Structure and Performance of Technical Textile

Woven technical textiles are patterned to fulfill the demand of their potential user and consists of an end-use as garments, medicine, clothing, industrial uses, transport, protection, and so many sites (Gandhi & Sondhelm, 2016). Woven fabric provides high strength and stability rather than different fabric structures applying interlaced yarns (Gandhi & Sondhelm, 2016). In terms of fabric production, woven structures are diversified with broadly numerous properties in the direction of warp and weft (Gandhi & Sondhelm, 2016). Three basic types of fabric have numerous structures of weave (Gandhi & Sondhelm, 2016). The first of them is fabric in which the ends as well as picks converge with each other at right angles as well as lie in parallel with the fabric (Gandhi & Sondhelm, 2016). The second one is fabrics in which the specific ends interweave on the right side alternately and the left of the close ends both in gauze and leno fabrics (Gandhi & Sondhelm, 2016). Thirdly, a part of warp or weft yarns from the pile or plush type fabric estimates the cloth's base and a loop of pile is created at the fabric's surface (Gandhi & Sondhelm, 2016). A fabric longitudinal border is created through weft weaving at the time of the edge turning as well as the uninterrupted passing through the fabric's width from the edge (Gandhi & Sondhelm, 2016). The main purpose of the selvedge is to close a piece of the cloth's exterior warp threads and to stop fraying along with providing strength at the fabric's edge to get sufficient performance in weaving and following the required steps (Gandhi & Sondhelm, 2016). In terms of the specification and geometry of the fabric, information about the cloth's diameter, the direction of warp and weft at each centimetre of thread, warp and weft yarns' sorts, linear density (count), weave structure, and finish are significant that requires flawless and accurate interpretations by an adept user (Gandhi & Sondhelm, 2016).

The progress of the ratio from weaving operations are based on the weaver's beam standard given to the weaving machine since every defect of the warp will need modification by ceasing the machine or it will cause a defect in the cloth producing woven fabric structure (Gandhi & Sondhelm, 2016). At the weaving machine, the primary objectives of the warp preparation systems are to mobilize all the edges required in one beam as well as maintain the warp through every end available regularly along with integration structure (Gandhi & Sondhelm, 2016).

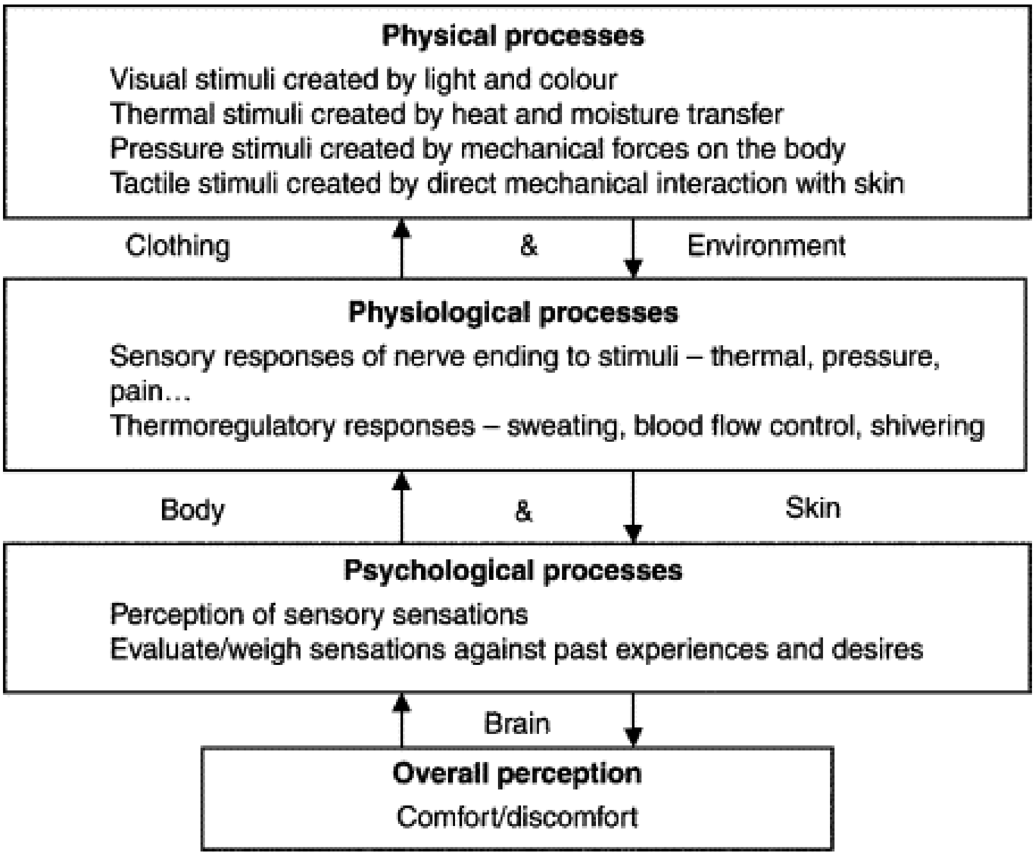
Warp knitting can be defined as a process of producing a fabric through preparing loops from every warp designed significantly throughout the fabric length (Anand, 2016). Every thread of warp is filled up close enough to make a line along with the direction of fabric production (Anand, 2016). With the warp knitted fabric, at the minimum, one separate and individual thread is required at every course filled up through the knitting width of each needle (Anand, 2016). This mechanism of transforming yarn into the fabric is speedy rather than weaving and weft knitting (Anand, 2016). Weft knitting can be defined as a process of producing a fabric through preparing loops from every warp designed significantly throughout the fabric width (Anand, 2016). Every thread of weft is filled up at a right angle to line up along with the direction of fabric production (Anand, 2016). With weft knitted fabric, one set of needles is used to make a single-jersey fabric. In double-jersey fabric, one set of needles is applied depending on the rib or interlock gaiting, which lessens the knitted structure of natural extensibility (Anand, 2016). A row of loops passed on the fabric's width is called the Course. The fabric length is determined by courses and the Course is measured in each centimetre (Anand, 2016). A column of loops with the fabric's length is called the Wale (Anand, 2016). The width of the fabric is determined by wales and is calculated as courses in each centimetre (Anand, 2016). The area of fabric is measured by stitch density as there are stitch numbers through the knitted fabrics per unit area (Anand, 2016). The primary stitches are frequently merged in a single fabric to make both single and double-jersey fabric enormous (Anand, 2016).

Carding systems applied to create nonwovens depend on identical concepts utilized in the production of yarn, although there are differences in the preparation of fibre, including machine configuration (Russell & Smith, 2016). Air laid engages in an uninterrupted accumulation of individual fibres from an airstream towards an operating conveyor to develop a web structure (Russell & Smith, 2016). The procedure for wet laid is obtained from the papermaking mechanism by practising very high line speeds through manufacturing a reliable product in connection with mass per unit area (Russell & Smith, 2016). The production of spunlaid web engages the discharge of constant filaments from the raw material of polymer, attracting the filaments and accumulating them as a web (Russell & Smith, 2016). The action of melt blowing manufactures very fine fibre at a large amount of production (Russell & Smith, 2016). Usually, a thermoplastic polymer composed of molten fibre is released by a metal die tip having from 30 to greater than 100 holes per inch, considering the recommended production rate and fibre diameter (Russell & Smith, 2016). Composite fabrics that are produced from a greater portion of nonwovens consist of melt-blown webs (Russell & Smith, 2016). A polymer is diffused in a solvent as well as exuded through a high temperature and pressure at flash spinning.

1.4. Comfort Properties of Medical Textile Fabric

Comfort can be defined as a state of satisfying the condition of psychological, physiological and physical harmony between a human being and the environment (Kothari, 2006). In terms of clothing comfort, the human conception depends on the interrelationship between physical, physiological and psychological factors through the adjacent environment at the time of wearing a garment (Kilinc-Balci, 2011). A structure of lipids and corneocytes known as the dynamic stratum corneum framework produces a barrier function, which is essential for the skin by providing a shield towards the injury and skin disease inflammation (Hipler et al., 2006). Cloth relates to the action of skin in a dynamic system at textile where unspecified skin reactions such as wool intolerance or keratosis follicularis are developed by one of the mechanical properties roughness surfaces of individual fabric (Hipler et al., 2006). Skin thermoregulation depends on a variable like age, gender and relation with an activity that is acknowledged with the advancement of individually designed fabric (Hipler et al., 2006). Since skin is considered as an essential immune organ with individual and non-individual activities, it interacts with the antimicrobial textile where antimicrobial peptides or the resident microflora properties of skin works as broad defence mechanisms (Hipler et al., 2006). This observation includes a psychological system through a correlative sensory conception that is developed, recorded, integrated and assessed as opposed to the previous involvement and current preference to build a comprehensive evaluation of the comfort condition (Hipler et al., 2006). Comfort depends on the sense of a human mind where the number of stimuli processes a multidimensional thought that arises from the external environment and clothing through the brain (Kilinc-Balci, 2011). Physiologically it happens by different sensory channels where information is accumulated as an answer towards individual perceptions (Kilinc-Balci, 2011). This observation includes a psychological system through a correlative sensory conception that is developed, recorded, integrated and assessed as opposed to previous involvement and current preference to build a comprehensive evaluation of comfort condition (Kilinc-Balci, 2011). Three types of comfort structure are developed where the fluctuation impacts on user comfort condition such as the substantial variable of the environment and garments, psycho-physiological specification of the user and psychological refinement of the brain (Kilinc-Balci, 2011).

Figure 1. 2. Subjective Perception of Human Overall Comfort



Note. adapted from Kilinc-Balci (2011).

Three main components of the comfort properties of textiles, the medical textile fabric, are aesthetic comfort, thermo-physiological comfort, and sensorial comfort, (Zhong, 2018).

1.4.1. Aesthetic Comfort

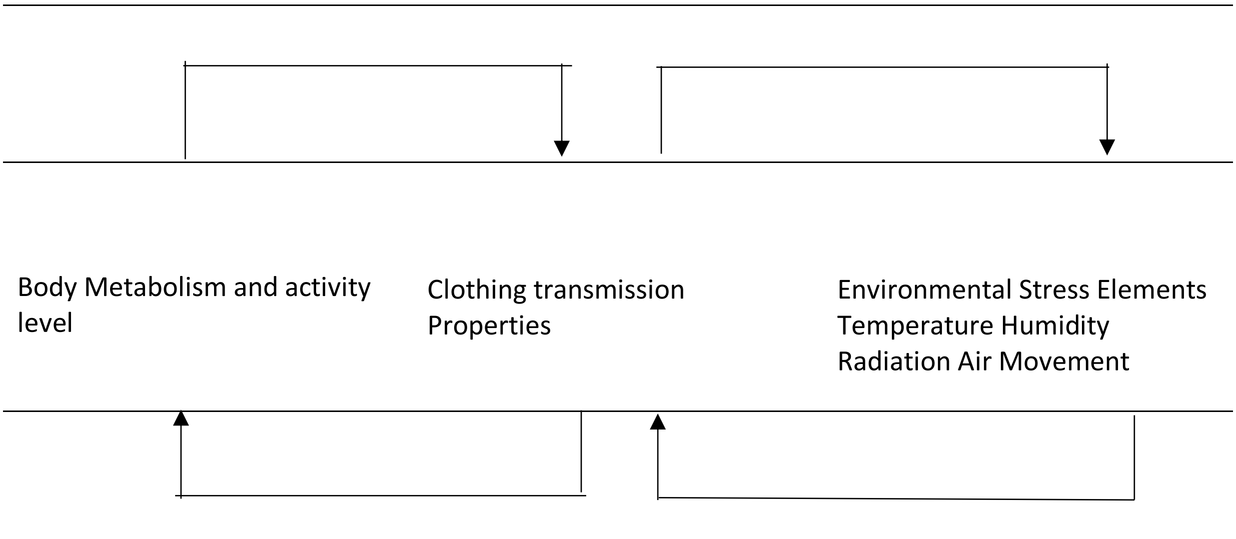
Out of three comfort properties, one of them is known as aesthetic comfort, which is followed by the style of the clothing adopted, the surface texture of the clothing, the drape of fabric used, and the cover, creasing and resilience characteristics of fabrics (Das & Alagirusamy, 2010). In the 21st century, for high-performance apparel, functional finishes are one of the major requirements for finding high performance in the fabric as an aesthetic comfort that is provided by one of the branches of medical textile named Cosmetotextile (Das & Alagirusamy, 2010). Cosmetotextile is counted as a surging innovation field in medical textiles which is followed by skin glowing, anti-aging, pleasant feeling and so forth (Kanjana & Nalankilli, 2018). Cosmetotextile can be defined as a possessor of skin care properties where it carries an active substance which gets in contact with the external parts of the human body for the purpose of cleaning, perfuming, correcting body odor and protection (Alvarez et al., 2017). Moreover, it is notable for its pleasant mechanism experience for the end user where healing and remedial properties are not only everlasting but also keep them fresh and energetic through its dynamic nature (Kanjana & Nalankilli, 2018). The functionality of cosmetotextile is shown through not only a large amount of moisture transformation but also a small amount of fragrance relief (Mathis & Mehling, 2011). The lipophilic cosmetic ingredient is one of the main parts available in the cosmetotextile, which stops the textile material from washing away since the textile material goes through frequent laundering (Mathis & Mehling, 2011). Typical functional characteristics of cosmetotextiles are their qualities of moisturizing, slimming, energizing, refreshing, relaxing, vitalizing, UV protection and perfume (Almeida, 2006).

A technique of substance coating is commonly known as Microencapsulation where either solid or liquid particles are used in association with various ingredients for achieving micrometric size (Tian et al., 2021). Different types of materials are employed to manufacture microencapsulation for specific industries, in particular for cosmetic and pharmaceutics applications (Tian et al., 2021). Microencapsulation works as an auxiliary element to cosmetotextile where it holds fragrance or cosmetic agents through use by grafting, padding, coating, spraying or screen printing (Tian et al., 2021). Encapsulation technique ensures the durability of textile fabric by its application through the discharge process for a particular reason (Rodrigues et al. 2009). Microencapsulated agents provide higher stability to protect the fragrance of fabric environmentally (Specos et al., 2010). Fragrances may have a more lasting effect depending on the construction of the microencapsulation of fabric (Tian et al., 2021).

1.4.2. Thermo-physiological Comfort

In term of defining Thermal Comfort, according to the standard of ISO 7730, it can be stated as a state of mind which reveals satisfaction along with the thermal environment (Kothari 2006).

Table 1.6. Role of Clothing in Protecting the Body and Maintaining the Thermal Balance between Body and Environment



Note. Based on Kothari (2006).

One of the contributory factors of thermal comfort is the sensation, which is followed by an insensible response to the body's effort to manage through the restrictive condition. Warmth is another essential factor that is regulated by the skin surface heat loss rate due to the imbalance and production of heat flow by the skin through physical activity (Kothari 2006).

The heat-transfer mechanism can be defined as the transportation of heat within apparel through conduction, convection, radiation, and latent heat transfer through the moisture transport form (Kothari 2006). Conduction, convection, and radiation are determined by the variation of temperature in-between the skin surface and environment and is called dry heat transfer (Kothari 2006). Moisture transmission associated with water vapour pressure in-between skin surface and the environment is gained through latent heat transfer (Kothari, 2006). The influential factor for fabric thermal resistance is the transportation of heat by textile materials in a combination of air and fibre conduction, convection and infrared radiation (Kothari, 2006). Thermal resistance of textile materials is regulated by thickness. Fabric resistance to air flow is helpful in order to assess protection in opposition to wind protection (Kothari, 2006). It is another essential factor regulating the body heat loss by clothing in the cold state (Kothari, 2006). On the other hand, it is also another reason governing the degree of ventilation supplied by the garment in warm conditions (Kothari, 2006). Thermal conductivity is an in-depth property of a material which demonstrates its capacity of heat conduction (Oğlakcioğlu & Marmarali, 2007). Thermal conductivity can be explained as the portion of air entrapped in the structure of the fabric (Oğlakcioğlu & Marmarali, 2007). At thermal conductivity, a process of heat is transported through the fabric, and it occurs by the fabric's air pore, warp and weft interlaced region, unsupported warp and weft yarn (Mallikarjunan et al., 2011).Thermal resistance is a process of calculating the body's capacity to stop heat from running through it (Oğlakcioğlu and Marmarali 2007). When a cloth's thermal resistance is minor, the heat energy will decease step by step with a feeling of coolness (Oğlakcioğlu and Marmarali 2007). Thermal absorptivity is the impartial evaluation of the fabric's warm-cool feeling and sensation (Oğlakcioğlu and Marmarali 2007). By feeling a garment through human hand touch, an individual temperature is found rather than the skin, where there is heat interchange between the hand and the fabric (Oğlakcioğlu & Marmarali, 2007). A cooler feeling is observed at the first contact when the cloth's thermal absorptivity is high (Oğlakcioğlu & Marmarali, 2007). Many factors are considered to count the quality of air permeability for medical fabric including fibre type, yarn type, ends per inch, picks per inch, thickness of fabric and cover of fabric (Mallikarjunan et al., 2011). Out of different influential factors, one of the main factors is porosity, which can be defined as the proportion of free space to the fibre fabric's allocated volume (Hu et al., 2006). It is characterized by the pore's depth, number as well as sizes, which is controlled by the fibre, yarn and weaves quality (Hu et al., 2006). Another factor is the thickness and yarn linear density of the fabric, which is upsurged, followed by a reduction of air permeability (Hu et al., 2006). When the yarn twist and crimp increase, air permeability also raise as well. Air permeability is directly connected with the extensibility of fabric (Hu et al., 2006). Knitted fabric has a high characteristic of air permeability rather than woven fabric due to its quality of inherent extensibility (Hu et al., 2006). The capability of transfer vapour from the body is known as water vapour permeability (Oğlakcioğlu & Marmarali, 2007). Measurement is done through the water amount vapour passing by a fabric's square meter every day (Mallikarjunan et al., 2011). As a characteristic of low moisture vapour transfer, it is inadequate for the fabric to move enough moisture, directing to the accumulation of sweat. As a result, discomfort has commonly happened (Mallikarjunan et al., 2011). With textile clothing, in terms of absorption and transportation of water, the two most essential parameters are wetting and wicking (Azeem et al., 2017). A contact of the fabric surface with a certain liquid through specific condition is called the wetting of fabric (Priyalatha & Raja, 2018). Wicking is the continuous liquid flow in a porous substrate followed by capillary forces (Priyalatha & Raja, 2018). Since capillary forces are responsible for wetting, wicking is the consequence of involuntary wetting and is a capillary system (Priyalatha & Raja, 2018). The degree of wetting during interacting of solid and liquid is calculated by contact angle (Azeem et al., 2017). The wettability of textile fibre is manipulated by fibre surface chemical type, geometry of fibre and roughness of the surface (Azeem et al., 2017). The contact angle can be defined as an angle produced by a liquid through a solid surface or porous material's capillary wall during which both materials reach together in the connection (Bhuiyan, 2020). The transportation of liquid without any obstruction in a porous substrate, guided by capillary forces through wetting, is called wicking (Azeem et al., 2017). Wetting is responsible for Wicking. Capillary pressure and permeability are the two main reasons for wicking (Azeem et al., 2017). When liquid pores saturation rises, capillary pressure lessens. But media's permeability grows as the time of saturation escalate (Azeem et al., 2017).

1.5. Present Problem with Used Fabric for Medical Textile Industry

One of the disadvantages of regular fabric was the failure to obstruct microbial infiltration at the injured site (Gupta et al., 2010). For the treatment of wound healing, the accumulation of wound exudates is commonly found by the microbial attack which produces a favorable state for frequent infection (Gupta et al., 2010). As a result, physicians prescribe to patients a regular textile fabric for minor wounds only (Gupta et al., 2010). Even though it is applied to wound management, it creates a dry state surrounding the affected area (Gupta et al., 2010). Another feature of the drawback for regular fabric is the absence of stretch and flexibility properties with post-surgical edema which leads a tension blister to cause the problem by creating tension blisters (Downie et al., 2010). "These results illustrate that in vitro, the non-woven type dressing does not provide an effective barrier to the passage of bacteria from the outside of the dressing to the wound contact side" (Downie et al., 2010, p.45).

Due to the wet strength of alginate fibre, it is inapplicable for textile manufacturing as a material (Rajendran & Anand, 2002). Although catgut stays in aqueous alcohol or glycerin to stop the dryness, however, catgut develops stiffness during dryness and reflects a complication for conducting the products (Rajendran & Anand, 2002). Catgut not only induces extreme tissue reactions but also changes the mode of bioabsorption considering the movement of proteolytic enzymes (Rajendran & Anand, 2002). As a result, a rapid strength-loss property can be found through the development of catgut suture (Rajendran & Anand, 2002). One of the elements of suture is called monofilament yams derived from relatively high stiffness and it produces difficulty for surgeons at the time of knotting (Rajendran & Anand, 2002). Having a rough surface by braided multifilaments, it increases a change of getting trauma and breaking tendency for surgeon even though there is high flexibility (Rajendran & Anand, 2002). One of the disadvantages of alginate-fibre dressing is wound adherence by permitting dryness (Gupta et al., 2010). Although silk fibre is utilized in suture for a long time, it has an experience from a deficiency such as insufficient tensile strength and undesirable tissue reaction (Gupta et al., 2010).

Two of the synthetic fibres named polyethylene terephthalate and polypropylene do not provide the expected biological response even though both of their mechanical properties are satisfactory in the result (Martin & Southern, 2000). Chronic inflammation, thrombosis, intimal hyperplasia as well as fatality are seen frequently as negative response of both synthetic fibres (Martin & Southern, 2000). Fibre made from resorbable polymer for body implant lose mechanical properties earlier rather than at the expected timeframe. An example is the fibre made from resorbable polymers like polyglycolic acid, polylactic acid, copolymers of glycolic with lactic acid or e-caprolactone or trimethylene carbonate (Martin & Southern, 2000). Although this fibre is used for implanted organ cells as a scaffold for growth and organization purposes, individual application is not excellent for implant applications such as heart and blood vessel walls, fasciae, ligaments and tendons, bursae and other joint tissues, due to repeated physical/mechanical requirements (Martin & Southern, 2000). The plain-woven cotton, polyester fibres and their blends are used for manufacturing hospital bed sheets (Mallikarjunan et al., 2011). However, inadequate moisture absorbency and heat transportation of plain-woven fabrics make patients unable to sleep for a long time. Slow absorption and transmission of body fluid and heat provide a moist loaded atmosphere which is considered as a paradise for the development of microorganisms like bacteria, fungus and virus (Mallikarjunan et al., 2011). The patient is contaminated easily by frictional festers and pressure ulcers through the plain-woven cotton bed sheets nature of high friction and poor absorbent (Mallikarjunan et al., 2011).

Dermatological problems are common to human skin through the usage of four manmade fibres-nylon, fibreglass, spandex and rubber-and two natural fibres-wool and silk, which are accessed frequently in the market (Hatch, 1984). Nylon alermatitis was first found in 1940 at the time of its severe outbreak through nylon hosiery in the USA (Hatch, 1984). Wool is another fibre where it is the primary factor for cumulative irritant dermatitis, aggravate atopic dermatitis, allergic contact dermatitis and contact urticaria (Hatch, 1984). Atopic dermatitis is aggravated by wool on the skin, through either inhalant or direct contact (Hatch, 1984). The patient's skin atopic dermatitis has an experience of skin outbreak through environmental exposure due to wool fibre (Hatch, 1984). Atopic dermatitis is developed by silk fibre through silk protein consumption (Hatch, 1984). Fiberglass is responsible for itching or pricking of the skin through the process of contact with fiberglass or a contaminated fiberglass surface (Hatch, 1984).

At fiberglass contamination, one of the skin reactions with small, discoloured areas named macular eruption and rarely another skin reaction with macular response named maculopapular rash can be found commonly for an interim period extending several days (Hatch, 1984). In 1966-1968, in the United States and England, spandex dermatitis was reported through two garments products known as brassieres and girdles (Hatch, 1984). Rubber fiber dermatitis includes bras, girdles, and other underwear expect rubber glove dermatitis and shoe dermatitis since rubber is not available as fibrous form in these products (Hatch, 1984).

Cotton dressing fails to stop microbial aggression (Gupta et al., 2010). Patients experience trauma during the removal of cotton dressing since it is attached to the wound surface (Gupta et al., 2010). Wound exudates have a low absorption which is directed to the accumulation of exudates at the wound surface (Gupta et al., 2010). As a result, the affected site gets microbial attacks (Gupta et al., 2010). Cotton dressing has a characteristic of an inability to serve the proper permeability of gases (Gupta et al., 2010). Thus, cotton dressing is only allowed for use for minor wounds, not in major wound application. Cotton dressing offers a healing with dry environment for the wound (Gupta et al., 2010). One of the main characteristic of pressure garments is to maintain the mechanical quality of elastic which provide an adequate stretching sheet for rounding the human body (Xiong & Tao, 2018). With pressure garments, it is hard to maintain the fabric uninterrupted due to nonlinear shapes due to stretching and distortion in fabric and garments (Gokarneshan, 2017). One of the survey studies found that both stiffness and roughness are available on 83% of pressure garments of the user patients (Macintyre & Baird, 2006). A substantial amount of pressure is dropped from the major portion of fabric at primary tension which for the time being, converts to fatigue of fabric leading applied pressure reduction (Gokarneshan, 2017). With pressure garments, fabric fatigue is commonly seen as a fabric and is frequently pressurized in a level of force rather than required to cause a decline in individual application (Gokarneshan, 2017).

1.6. Scope of Cattail Fibre in Medical Textile Application Using Its Biomedical Properties

The most recent source of natural fibre is a prolific marsh plant known as Typha, which originates in Europe, North America, and Africa and is vastly transported to other places, including various subtropical locations (Chakma, 2018). Cattail is a source of vegetable fibre involving 63% cellulose, 8.7% hemicellulose, 40% fibre, 8.9%, moisture content, 9.6% lignin and pectin and other water-soluble matters such as 1.4% wax and 2% ash (Ullah, 2018). Since cattail fibre is not controlled by harvesting weather or either an ideal growing situation, it has numerous environmental benefits (Chakma, 2018). Being eco-friendly, Typha plants work as a soil cleanser to remove the pollution of heavy metals (Chakma, 2018). Fast growth, local distribution and availability, renewable, moldable, hydroscopic, recyclable, adaptable, non-abrasive, porous, viscoelastic, readily available in numerous forms, biodegradable, and reactive are some advantages of employing Typha fibre (Chakma, 2018). Additionally, Typha has multifunctional properties, including thermal insulation, reinforced composite, nutrient seizing, watershed management, and handmade papermaking (Chakma, 2018). With a fast growth rate, producing 15 to 20 tons per hectare yearly and a fibre yield percentage of about 40%, cattail has both economic and environmental advantages (Ullah, 2018). Amalgamation with thermoplastic polymers as well as utilization of the internal panel towards charcoal bars, electronic displays, packaging, and wastewater treatment are common industrial application sectors for utilizing cattail fibre (Ullah, 2018).

1.6.1. Medicinal Characteristic of Cattail Fibre

Treatment of burn, wound and ulcer is done by using the cattail flower in India. Cattail's stamen with their pollen is utilized as per astringent and styptic effect requirement (Morton, 1975). In China, pollen is individually applied as an astringent and as a diuretic (Morton, 1975). Cattail fibre is used as an absorbent for the replacement of cotton at the time of surgery and after childbirth (Morton, 1975). Once the stamen of the cattail is refined, it is dried and applied as an astringent for stopping dysentery and rectal bleeding (Morton, 1975). In Paris, cattail floss is used not only for the purpose of dressing to treat wounds but also for serious burn management, which gives exceptional results (Morton, 1975). By taking every day 3 to 4 cups of boiled cattail leaves with 10% strength, it ceases uterine hemorrhages as well as alleviates bloody diarrhea (Morton, 1975). The rootstock of cattail leaves not only works as a detersive, stimulant, astringent, aphrodisiacal but is also suitable for febrifuge and diuretic in terms of treating retarded or painful urination (Morton, 1975). Boiled cattail leaves are considered as an effective medicine for dropsy and snakebite, dysentery, gonorrhea and measles (Morton, 1975). It not only assists in removing the placenta of humans and domestic animals but also is used by some women at the time of childbirth for uterine contractions (Morton, 1975). Thrush of child's mouth, tumour and ulcers are cleaned by cattail leaves (Morton, 1975). For the treatment of insanity and epilepsy, one of the cattail types named *Typha angustifolia* is commonly used between the santal tribal community (Morton, 1975). The jelly of a cattail with young leaves is utilized to treat for itching as well as a pain reliever (Health Benefits Times, n.d.). The pain-relieving and antiseptic property of cattail fibre slows down and stops bleeding, reduces pain and assists in wiping wounds (Health Benefits Times, n.d.). Cattail contains a major amount of nutrients and organic composition which supplies the capability to heal boils, sores and reduces the scar aspect on skin (Firdous, 2020). The jelly of cattail is utilized on skin to treat insect bites, as well as reduce pain by providing inflammatory characteristic on the affected area (Firdous, 2020). The content of protein and carbohydrates from the cattail works with the adrenal gland to reduce the stress amount by raising the metabolism rate, which lessens stress eventually (Firdous, 2020). Phytochemicals are necessary to establish and continue insulin absorption (Firdous, 2020). Since cattail has a feature of phytochemical, a daily uptake of cattail by human systems battles diabetes mellitus known as non-insulin dependent (Firdous, 2020). Cattail's pollen methanol extract is formed to possess decreasing power along with large metal chelating activity, which forms an acceptable potential for usage as a natural antioxidant (Lim, 2016).

1.6.2. Textile Fibre Characteristic of Cattail Fibre

Being an excellent textile fibre, it is essential to achieve a list of primary properties that affect the product performance and assist in selecting the right fibre for any type of end uses in the textile industry (Chakma, 2018). By finding chemical rating of fibre at first, it is required to examine prime characteristics of the textile properties along with morphological structure and physical, mechanical, and thermal condition (Chakma, 2018). The framework of cattail fibre is very identical to the shape of the flower or comforter (Zhang et al., 2018). Although each single fibre's surface of cattail has some points like bamboo, the pointed parts which are, in fact, flattened give the single fibers a jagged and uneven look (Zhang et al., 2018). Two edges of cattail fibre are small as well as remarkably dispersed (Zhang et al., 2018). But the middle segment's height of the fibre is more centralized (Zhang et al., 2018). The middle part dissemination of cattail fibre stick is extra scattered, and the fineness is concentrated (Zhang et al., 2018). The number of fibres of the cattail flower ranges from 30 to 80 and moderately 56 in amount (Zhang et al., 2018). Fibre length plays an essential role for any textile fibre by the setting of the machine at the time of transformation of yarn to fibre based on the length of fibre (Chakma et al., 2017).

Additionally, the length of fibre is utilized when a couple or more fibres are combined together at the spinning time (Chakma et al., 2017). Median fibre length is lower than the cattail plant cut length because of fibre crimp (Chakma et al., 2017). Although crimp is the vital fault at the time of fibre length calculation, the researcher established a scale of 1:1.2 amid the deliberated fibre length and crimp tailored length (Chakma et al., 2017). The diameter of the fibre depends on its softness, pliability, and hand. Narrow fibre is not only more simply curved but also has a softer and drapery feature (Chakma et al., 2017). In terms of differentiation, the diameter of cotton and wool fibre is calculated as 12.2±1.1 mm and 12.8±2.1 mm commonly (Chakma et al., 2017). Although, by statistical analysis, it is found that the diameter variation between cattail and cotton is notable at 95% amount of reliance, however, variation in between cattail and wool diameter is not outstanding (Chakma et al., 2017). The scale of moisture regain for cattail plant is in-between 9.4 to 12.7. Moisture regain is found approximately 10% at 59% RH and 25°C, which is considered the same as wool (Chakma et al., 2017). The moisture regain of the cattail fibre is higher than the cattail stick (Zhang et al., 2018). The majority proportion of resistor of cattail fibre is extremely narrow compared to the cattail fibre (Zhang et al., 2018). Since the pH value of cattail fibre is 6.7, it is not dangerous for in-person touch by human beings (Zhang et al., 2018). The resistance degree of alkali is lower rather than the cattail fibre acid-resistance level (Zhang et al., 2018). The cattail fibre burning characteristic is relatively identical to cotton (Zhang et al., 2018). Although the cattail does not manufacture fume at the time of flame, neither melt at flame; however, the same as cotton, it burns quickly and is extinguished passively from the removal of the flame (Zhang et al., 2018). Cattail and cotton manufacture debris of ash with a grey and feathery color but polyester generates pellets of hard black (Zhang et al., 2018). Since more extended stability is an indication of fine quality fibre acceptable for application in the textile industry, Typha has features of heat resistance capacity, and goes beyond cotton in terms of direct heating from 0°C to 300°C without any holding time (Chakma, 2018).

1.7. Negative Effect of Alkali

1.7.1. Cattail's Environmental Disadvantages

One of the problems of cattail fibre is the invasion of rice fields, different fertilized agricultural land and farm ponds, which was historically found in other parts of the world (Morton, 1975). Unwanted growth at recreational lacks, clogging of the canal's drainage system is a common phenomenon that interrupts and obstructs both fishing and boat passage in the water canal (Morton, 1975). Trespassing of cattail in a large scale is featured by the expenditure of other plant's life; an increase in growth of water depth has contributed to an adverse effect to sawgrass at the conservative area of Florida (Morton, 1975). Wastage of water by transpiration is commonly found in the state of California (Morton, 1975).

1.7.2. Cattail's Economic Disadvantages

The primary economic disadvantage for cattail fibre is an expensive human resources requirement and consumption of enormous time (Murkin & Ward, 1980). The cost of transplantation is higher, including its materials, labour, production space, and huge cattail production fields (Dubbe et al., 1988). Higher fertilization cost is another problem where the harvesting of cattail fibre requires multiple seasons; it loses a large amount of nutrition, including nitrogen, phosphorus, and potassium at midseason and the end of the season (Dubbe et al., 1988).

Table 1.7. Cost Analysis of Cattail Fibre Extraction

Cost of extracting one metric ton (1000 kg) of cattail plant					
Batch no	Material: Liquor	Total liquor for 100 kg cattail plant	Alkali (5% NaOH)	Fibre extracted	Acetic acid (2%) for 400 L solution
1.	1: 10	1000 L	50 Kg	40 Kg	8 L
2.	1: 10	(800 + 200) = 1000 L	10 Kg	40 Kg	8 L
3.	1: 10	(800 + 200) = 1000 L	10 Kg	40 Kg	8 L
4.	1: 10	(800 + 200) = 1000 L	10 Kg	40 Kg	8 L
5.	1: 10	(800 + 200) = 1000 L	10 Kg	40 Kg	8 L
6.	1: 10	(800 + 200) = 1000 L	10 Kg	40 Kg	8 L
7.	1: 10	(800 + 200) = 1000 L	10 Kg	40 Kg	8 L
8.	1: 10	(800 + 200) = 1000 L	10 Kg	40 Kg	8 L
9.	1: 10	(800 + 200) = 1000 L	10 Kg	40 Kg	8 L
10.	1: 10	(800 + 200) = 1000 L	10 Kg	40 Kg	8 L
Total chemical required			**140 Kg**	**400 Kg**	**80 L**

Note. adopted from Foulk et al., 2000

Goal of the Thesis

The principal goal of this thesis is to determine the effect of reuse of alkali solution of cattail fibre followed by extracting from 1st-time use to 17th-time reuse. It includes establishing the highest reuse sustain span of the same alkali solution without any significant change for cattail fibre's physical and mechanical properties. Some consecutive parameter values without any interruptions will be set for each specific physical and mechanical property.

Chapter 2: Materials and Methods

This chapter discusses the extraction method applied to get cattail fibres from the leaves of *Typha Latifolia* L., the biomedical properties of cattail fibres, and the optimization of processing parameters (time, temperature, concentration of alkali) to find and upgrade the biomedical properties of fibre for medical application.

As shown in Figure 2.1, The primary material, Typha latifolia L., was obtained from the University of Manitoba Research Farm, Carmen, Manitoba (Canada). Plants were collected easily by using a knife. The date of collection for the plants was September 2018 where the colour of the leaves turned from greenish to brownish. A fully developed stem was found on many plants with a flower having a cylindrical shape and dark brown colour. The branches had just about 6-9 leaves on each plant, and leaves were roughly about 2-3 m long and 15-30 mm wide. The stems look light green to brown with a 6-12 diameter around.

Figure 2.1. Typha Latifolia L. Collected from the University of Manitoba Research Farm, Carman, Manitoba.

2.1. Fibre Extraction

In terms of cellulosic fibres extraction, different extraction methods have been evaluated such as water, chemical, microbe, and microbe-chemical retting and in this way the impact on fibre properties are mentioned (Hasan, 2019). However, water retting did not process any fibre from cattail plants and among the chemical rettings, the retting of alkali only affected fibre at 60° C or higher temperatures. Different solutions were investigated to produce fibre such as NaOH, KOH, and LiOH (Hasan, 2019). Out of these alkalis, NaOH treatment is the most efficient along with having minimal environmental influence (Hasan, 2019).

Table 2.1. Chemical Used for Cattail Fibre Extraction

Chemical	Sodium hydroxide
Supplier	Sigma Aldrich-USA
Purity	≥ 97%

Note. Adapted from Hasan (2019, p. 31).

2.1.1. Preparation of Sample

A 5 cm length of leaves of Typha Latifolia L. was cut and put into a rectangular ice pan before being placed into conditioning temperature. Once chopped samples were inducted into the conditioning temperature of room number w 512, and they were kept 24 hours to reach a persistent parched weight status. Then 2 gm of cattail fibre was weighted out through a weighing scale for each time.

Figure 2. 2. Cut off Cattail Leaves into 5 cm Length for Fiber Extraction Purpose

2.1.2. Extraction through Water-bath Machine

At first, the extraction goal was set to collect 200 to 250 gm of cattail fibre. Twelve canister containers were used to use for each extraction to reach the target. Then the pH of the water was measured respectively for every 12 samples before starting every extraction. A concentrated sodium hydroxide solution was prepared by filling up 400 ml of water and 40 gm white solid ionic compounds altogether for each sample. pH measurement was taken for 400 ml of the concentrated sodium hydroxide solution accordingly. The extraction process was run through 12 canister containers with a sealed cap.

Treatment was performed using a water-bath machine with a feature of a temperature control system. Three hours fixed set of time and 80-degree Celsius temperature was set for the extraction process. Before placing all the canister, the temperature of the water must reach 80^{o}C degrees to run the water-bath machine's extraction method. After each treatment, a rigorous wash through distilled water was mandatory to get the extracted fibre and get rid of alkali and liquefied element. The washed extracted fibre was kept outside for 24 hours at room temperature for drying purposes. After 24 hours, every single sample reached a desired drying condition level. Then, the dried fibre was used to measure yield (%), length (mm), diameter (μm), load at break (N), tensile stress at break (MPa), tensile strain at break (%), young’s modulus (GPa), tenacity at break (gf/denier), and moisture regains (%).

Table 2.2. The Machines and Methods Used to Determine the Composite Properties of Typha Fibres

Composite properties	Machine/Method	Standard test method
Yield (%)	Thermo scientific oven and weighting machine	
Length (mm)	Scissor and ruler	
Diameter (µm)	Bioquant life science image analyzer	
Contact angle (°)	The attention sigma 700 force tensiometer	Wilhelmy balance method (WBM)
Load at break (N), Tensile stress at break (MPa), Tensile strain at break (%), Young's modulus (GPa), Tenacity at break (gf/denier)	Instron tensile tester	ASTM D3822
Moisture regain analysis (%)	Humidity chamber and Thermo scientific oven	ASTM D2564

Note. Standard test methods as cited in *Lauren* (2021), *D3822/D3822M Standard test method for tensile properties of single textile fibers* (2014), *and D2564 Standard test method for moisture absorption properties and equilibrium conditioning of polymer matrix composite material (2004).*

2.2. Determining the Properties of Typha Fibre for Composite Reinforcement.

2.2.1. Measurement of Cattail Fibre Yield (%)

The cattail fibre's yield (y%) of each sample is calculated through the percentage of the ratio of the weight of the fibre after chemical extraction and weight of the plant before chemical treatment which is mentioned in equation (2.1). The extraction of fibre yield (%) was calculated through applying the formula stated below:

$$Yield\ (\%) = \frac{weight\ of\ the\ fibre\ after\ extraction}{weight\ of\ the\ plant}\ x\ 100 \ldots\ldots\ldots\ldots\ldots (2.1)$$

2.2.2. Diameter Measurement of Cattail Fibre

A collection of microscope slides was arranged to prepare cattail fibre for microscope analysis. Fibre was calculated by utilizing a computer, a microscope projector and a camera-oriented machine named Bioquant Analyzer located at room # 304 of the Human Ecology

Building, University of Manitoba, Winnipeg, Canada. Every cattail fibre was attached with a microscope slide and placed underneath an objective lens of 10x magnification by fixing through illuminator adjustment. Fibre diameter was determined through the computer software of Bioquant Analyzer, where the unit was counted as micrometer (μm). Diameter calculations of each single cattail fibre are collected through placing three and five different position to reach diameter's accuracy. To determine contact angle, it was planned to get 180 individual fibre from the first-time used to the 17^{th} time reused cattail fibre set. As a part of this process, 10 single individual fibres from each sample are cut off into one-inch lengths for contact angle measurement.

2.2.3. Contact Angle (°) Measurement

In terms of measuring the Contact angle of the cattail fibres, Sigma 700 force tensiometer is utilized to measure fibre's dynamic contact angle by the dipping (advance stage) and withdrawing (receding stage) of a solid sample to the liquid state. This machine's mechanism is to identify the transition of a thin fibre from solid to the liquid state where fibre weight change is detected by its balance. The alteration of balance by identified force is a merger of buoyancy and wetting force. Firstly, individual cattail fibres were lacerated by the length of one inch. It was connected to a hook by placing it in a standard custom rod at the tensiometer's tip. Distilled water was used both to clean thoroughly first as well as when it was filled up. It was then placed on top of the membrane keypad, where its orientation was positioned beyond touching the cattail sample fastened to the knob. The cattail sample was established in an overhead distance of few mm from water. All the parameters come under the setup of two stages, including experimental setup and measurement control. At the experimental setup stage, the Wilhelmy balance method was applied by a custom round rod, diameter, wetted length, solid and liquid state information, vessel information. At the measurement control stage, speed up and down, start and immersion depth, ignore first, and no. of the cycle was set up before beginning the test. The CA of fibre for AM and RM and the visual graph for force per length vs. immersion depth of fibres were recorded. The mean CA at a precise rate of AM and RM can be calculated by averaging the CA, and standard deviation.

2.2.4. Mechanical Properties Measurement

Through utilizing Instron Tensile Tester, the mechanical properties, i.e. tensile strength, modulus of elasticity, and elongation at break (%) were calculated. The process started with placing the single fibre through the holder inside the machine's jaw, where the frames inside length was performed as gauge length. After that, using scissors, the sample frame was cut in both vertical sides, where the fibre's length at the inner frame functioned as a length of a gauge with 25 mm relatively. Although fibre gained some crimp at the time of extraction and washing, it was required to separate the crimp to determine the actual length of the fibre adhered to the frame. Consequently, 'Pretest and Auto-Balance' functions of Instron Tensile Tester were applied by utilizing 'Instron Bluehill 2' software. Although the machine extended fibre through the functional application of 'Pretest,' however, data was unrevealed before the load cell was applied by a small amount of load (0.3 N was selected for the targeted experience). As soon as the load cell met the stated portion of the load, the annex up to this point was treated because of crimp. The mechanism of 'Auto-balance' connected this length with fibre's primary length to run tensile strength test. 'Instron Bluehill 2' software provided all outcomes including tensile strength, modulus of elasticity, and elongation at break and graphs for each individual fibre.

Figure 2.3. Fibres Attached to the Frames by Glue

Figure 2.4. Fibre-frame Placed between the Jaws

2.2.5. Moisture Regain (%) Measurement

The first time to 17th time reused-- NaOH treated cattail fibre was examined in terms of moisture regain measurement, where 216 samples from 18 sets featured it. This process started with weighting of 12 samples of each set through weighing scale machine. Then it was placed on aluminum foil baking cups inside of a desiccator with 75.5% relative humidity for 24 hours. After 24 hours passed, each sample's weight was calculated through the weighing scale machine again. Then it was placed inside of woven with 100-degree Celsius for 8 hours. Finally, the weight of individual samples for each set was calculated by using a weighing scale machine. Thus 18 sets by 216 samples moisture regain were achieved by following this technique for 18 days continuously.

The equation (2.2) of moisture regain calculation is mentioned as

Moisture Regain (%) = $(Mw - Mo)$ x $100/Mo$……………………………. (2.2)

Where, Mw = Weight of the samples after conditioning, and Mo = Oven dry weight of the samples.

2.3. Statistical Analysis

This experimental design was a one-way analysis of variance (One-way ANOVA), which was carried out to measure the statistical significance of fibre including its yield ratio, contact angle, mechanical properties and moisture regain comparing the original use and 17th reuse of NaOH solution. Throughout this analysis, first time usage of NaOH to 17^{th} time reusage of NaOH was considered as input variable and fibre yield (%), contact angle, load at break, young's modulus, tenacity at break, tensile stress at break, tensile strain at break, moisture regain analysis was counted as output variable. The quantity of duplication at individual treatment as well as the entire number of fibres are mentioned in Table 3.4. All statistical analysis has been performed using the One-way ANOVA university edition software and JMP® 14.1. software.

Table 2.3. List of Response Variables along with Number of Replication, Treatment and Samples.

Response variables	**No. of replications per treatment**	**Total no. of treatments**	**Total no. of samples**
Yield (%)	12 (Biological samples)	18	216
Diameter (μm)	30 (Mechanical samples)	18	540
Contact angle (°)	10 (Mechanical samples)	18	180
Load at break (N)	20 (Mechanical samples)	18	360
Tensile stress at break (MPa)	20 (Mechanical samples)	18	360
Tensile strain at break (%)	20 (Mechanical samples)	18	360
Young's modulus (GPa)	20 (Mechanical samples)	18	360
Tenacity at break (gf/denier)	20 (Mechanical samples)	18	360
Moisture regain (%)	12 (Biological samples)	18	360

One-way ANOVA is called a statistical procedure to decide existential variation by utilizing one independent variable measuring two or more groups (MacFarland, 2014, p2). Two types of models are available for the One-way ANOVA application, which the fixed model and random model follow. In this study design, a fixed model is selected to apply where the researcher chose an independent variable (Horn, 2006). Throughout one repetition to another, independent variable levels are chosen voluntarily, which was kept as fixed (Horn, 2006).

2.3.1. Six Assumptions Requirement for One-way ANOVA

In terms of running One-way ANOVA, six assumptions are counted to accomplish (Laerd Statistics, 2013, p.3). The first three assumptions are connected to study design and measurement of choice (Laerd Statistics, 2013, p.3). The second three assumptions depend on choosing a One-way ANOVA model that fits with data accordingly (Laerd Statistics, 2013, p.3). Out of six assumption requirements, at first assumption, one dependent variable calculated by continuous level is the main requirement (Laerd Statistics, 2013, p.3). This study design followed the first assumption, which is started by measuring all dependent variables at a continuous level. As stated by Laerd Statistics (2013), "one independent variable having two or more categorical, independent groups" are needed for the second assumption (p.3). At the time of running One-way ANOVA analysis at this study, assumption number two was applied, followed by one independent variable featuring a couple or extra categorical, separate groups (Laerd Statistics, 2013, p.3). Observational independency is necessary for the independent variable where it should have no connection between groups both individually and collectively (Laerd Statistics, 2013, p.3). This study followed the third assumption rule completely. For the fourth assumption, As stated by Laerd Statistics (2013), "There should be no significant outliers in the groups of your independent variable in terms of the dependent variable" (p.7). For this study design, the fourth assumption of One-way

ANOVA followed at full range by keeping its outlier as it is. Assumption of normality is the fifth necessary rule and regulation where each group of independent variables should be followed by the usual distribution of the dependent variable to find statistical significance (Laerd Statistics, 2013, p.7). Throughout this analysis, it followed the fifth assumption rules. The final assumption is known as a sixth assumption where Individual groups' independent variables are equivalent in terms of variance (Laerd Statistics, 2013, p.7). At this data analysis design, it was fully focused to follow six assumption rules of One-way ANOVA accordingly.

The One-way ANOVA is the most popular test for determining the variability of F ratio based between groups against the variability within groups (Laerd Statistics, 2013, p.3). At this exam method, an expectation of feedback with statistical significance where a post hoc test follows the result is the prominent phenomenon (Laerd Statistics, 2013, p.3). Since it is a significant test with the null hypothesis, one of the significant parts of this test is to verify the true difference of its effect size (Laerd Statistics, 2013, p.3).

2.4. Sample Code of Alkali and Alkali Reuse

2.4.1. Sample Code of Alkali

In the current study, alkali was used 17 times, and the identification of each extraction and sample code using alphanumeric combinations are given in Table 2.4. For example, sample code R0 indicates first-time use of NaOH, R1 means first-time reuse that specifies this sample is generated using the NaOH that has already been used to extract sample R0 and so forth.

Table 2.4. Sample Code with Its Meaning

Sample code	Meaning of sample code	Sample code	Meaning of sample code
R0	1st time use of NaOH solution	R9	9th time reuse of NaOH solution
R1	1st time reuse of NaOH solution	R10	10th time reuse of NaOH solution
R2	2nd time reuse of NaOH solution	R11	11th time reuse of NaOH solution
R3	3rd time reuse of NaOH solution	R12	12th time reuse of NaOH solution
R4	4th time reuse of NaOH solution	R13	13th time reuse of NaOH solution
R5	5th time reuse of NaOH solution	R14	14th time reuse of NaOH solution
R6	6th time reuse of NaOH solution	R15	15th time reuse of NaOH solution
R7	7th time reuse of NaOH solution	R16	16th time reuse of NaOH solution
R8	8th time reuse of NaOH solution	R17	17th time reuse of NaOH solution

2.4.2. Alkali Reuse

As of reference from page 35, since the overall extraction target of cattail fibre was set for 200 to 250 gm, NaOH alkali solution was used from 1st-time use to 17th-time reuse.

2.4.2.1. Number of Extra Added Alkali Solution

Starting from 1st-time use to 17th-time reuse of NaOH solution, there was new extra alkali added in each treatment due to reduction of alkali at the time of washing the extracted individual sample after each test. Although the original alkali solution was 400 ml for each treatment, it was found that 50 ml alkali was required to include as extra new alkali for individual reduced samples. Table 2.5. shows the amount of extra alkali required for each individual treatment which is mentioned below:

Table 2.5. Total NaOH Alkali Solution Samples Used with Required Extra Added Solution

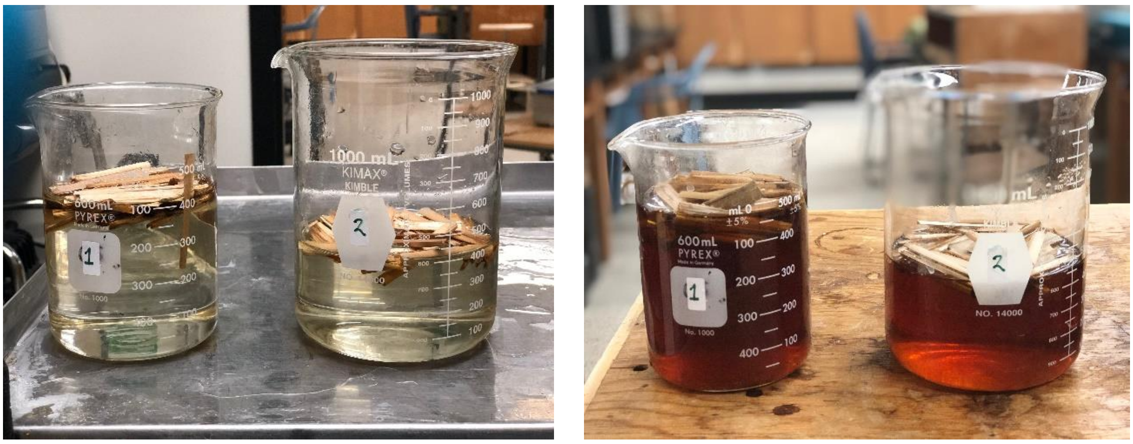
Sl.	**RO**	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**	**R11**	**R12**	**R13**	**R14**	**R15**	**R16**	**R17**	**Unit**
1	400	400	400	400	400	350	400	400	400	350	400	400	350	400	350	400	350	400	ml
	*	*	*	*	*	50	*	*	*	50	*	*	50	*	50	*	50	*	ml
2	400	350	400	400	400	400	400	400	400	350	400	400	400	350	400	350	400	350	ml
	*	50	*	*	*	*	*	*	*	50	*	*	*	50	*	50	*	50	ml
3	400	400	400	400	400	350	400	400	400	350	400	350	400	350	400	400	350	400	ml
	*	*	*	*	*	50	*	*	*	50	*	50	*	50	*	*	50	*	ml
4	400	400	400	400	400	350	400	400	350	400	350	400	400	350	350	400	350	400	ml
	*	*	*	*	*	50	*	*	50	*	50	*	*	50	50	*	50	*	ml
5	400	350	400	400	400	350	400	400	350	400	350	400	400	400	350	400	400	350	ml
	*	50	*	*	*	50	*	*	50	*	50	*	*	*	50	*	*	50	ml
6	400	350	400	400	400	350	400	400	350	400	350	350	350	400	400	350	400	350	ml
	*	50	*	*	*	50	*	*	50	*	50	50	50	*	*	50	*	50	ml
7	400	350	400	400	400	400	400	400	400	350	400	350	400	350	400	350	400	400	ml
	*	50	*	*	*	*	*	*	*	50	*	50	*	50	*	50	*	*	ml
8	400	350	400	400	400	400	400	400	400	350	400	350	400	400	350	400	350	400	ml
	*	50	*	*	*	*	*	*	*	50	*	50	*	*	50	*	50	*	ml
9	400	350	400	400	400	400	400	400	350	400	400	350	400	350	350	400	350	400	ml
	*	50	*	*	*	*	*	*	50	*	*	50	*	50	50	*	50	*	ml
10	400	350	400	400	400	350	400	400	350	400	400	350	400	400	350	400	350	400	ml
	*	50	*	*	*	50	*	*	50	*	*	50	*	*	50	*	50	*	ml
11	400	400	400	400	400	350	400	400	350	400	350	400	400	350	400	350	400	400	ml
	*	*	*	*	*	50	*	*	50	*	50	*	*	50	*	50	*	*	ml
12	400	400	400	400	400	400	400	400	350	400	400	400	350	350	400	350	400	400	ml
	*	*	*	*	*	*	*	*	50	*	*	*	50	50	*	50	*	*	ml

As per Table 2.4., it was found that the extra added solution was applied for most of the NaOH alkali solution of the whole extraction process. The highest number was 7 times of 50 ml solution requirement found at sample codes R1, R5, R8, R13, respectively. At the same time, the requirement of 50 ml solution was seen for sample code R11, R14, R16 (6 times), R9, R15 (5 times), R10 (4 times), R12, R17 (3 times) correspondingly.

2.4.2.2. Visual Observation of Alkali Solution

In terms of visual observation for finding any changes between all kinds of alkali solution, data was analyzed by figure 2.5., 2.6., 2.7., individually.

Figure 2.5. a. First time before Use NaOH Alkali Solution; b. First time after Use NaOH Alkali Solution.



(a) (b)

In figure 2.5. (a), the sample colour was seen as a light green colour before being placed for extraction which was defined as 1^{st} time before use NaOH alkali Solution. However, the alkali colour was found as light deep red after using it for 1st-time extraction.

Figure 2.6. a. First time after Reuse NaOH Alkali Solution; b. Second time after Reuse NaOH Alkali Solution.

(a) (b)

At the above figure 2.6. (a), the alkali colour was found to be a deep dark red soon after being extracted as 1st time after reuse of the NaOH alkali solution. But, as of Figure 2.6. (b), the colour was slightly changed for the extracted solution defined as 2nd time after Reuse NaOH alkali Solution.

Figure 2.7. a. Third time after Reuse NaOH Alkali Solution; b. 17th time after Reuse NaOH Alkali Solution.

(a) (b)

By figure 2.7. (a)., it was identified that the alkali colour turned from deep dark red to deep black described as 3rd time after reuse NaOH Alkali Solution. It was continued as identical in colour starting from 3rd time after Reuse NaOH alkali Solution to 17th time after Reuse NaOH alkali Solution. As an example, figure 2.7. (b). which distinguished as 17th time after Reuse NaOH alkali Solution represented dark black colour the same as figure 2.7. (a).

2.5. Statistical Analysis of Data using Python Computer Programming

2.5.1. Methodology

The significance (P-value) value of R1 to R17 is compared with the R0 one at a time one for all eight properties. While comparing, if any value was found to be statistically non-significant ($p>0.05$, for example, if R1 and R0 is insignificant), then the next data is compared with R0 (for example, R2 is compared with R0). The comparison with R0 is continued until R17 – if $p>0.05$.

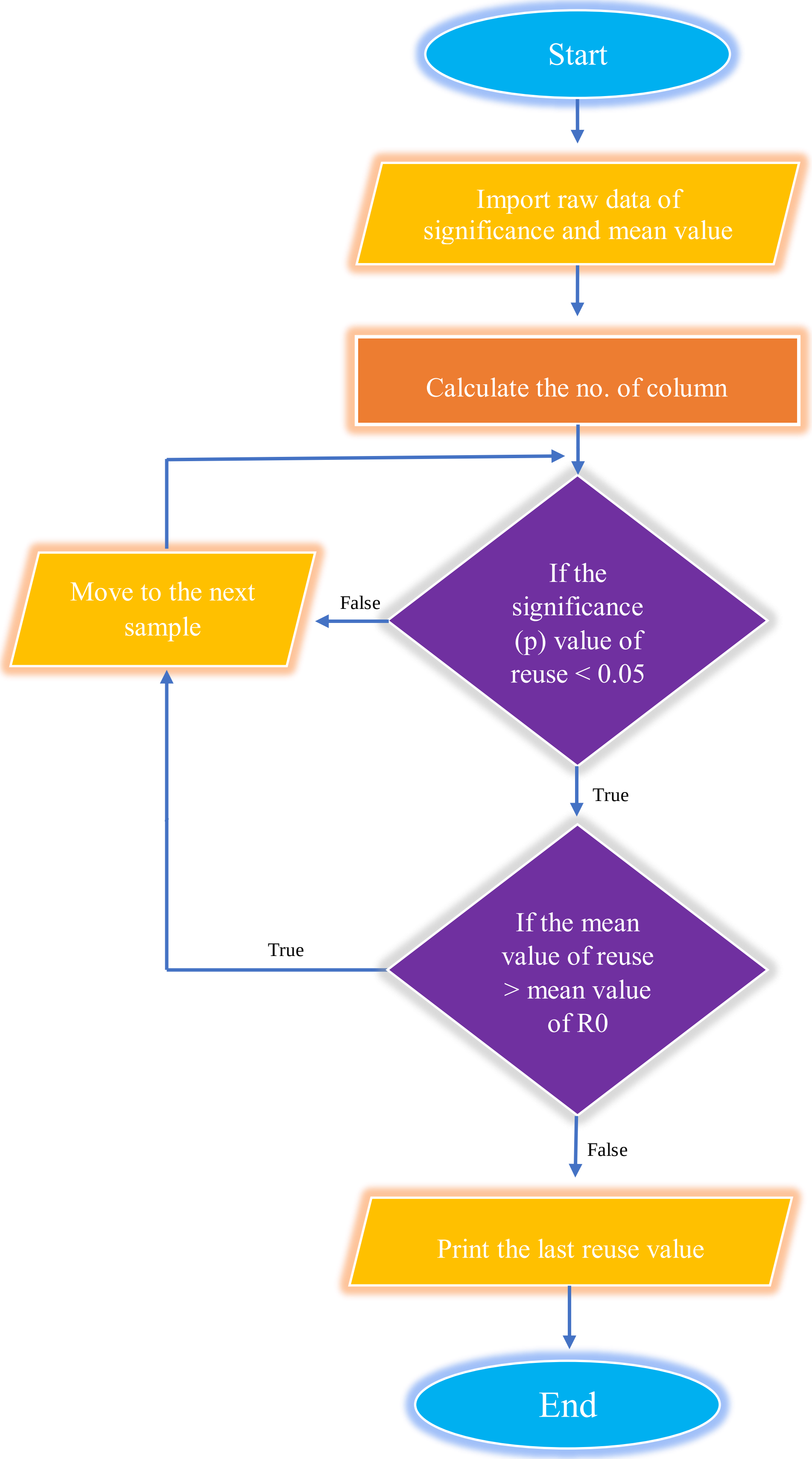
If the data is found to show significant difference ($p<0.05$) with R0, the mean value of that data was compared to the mean value of R0. If the mean value of reuse alkaline data was greater than the mean value of R0, the next reuse value of significance was compared with R0 and repeated the process; else, the mean value of the reused data was less than the mean value of R0, the comparison was terminated, and the previous reuse value was declared to be the maximum reusable times except for the contact angle. Since the contact angle is expected to be less in wound dressing, the mean value of any reused times is expected to be less than the mean value of R0.

2.5.2. Computer Code (Example, for all Eight Properties)

```
import pandas as pd
import numpy as np

df1 = pd.read_excel(r'D:\UoM Study\Rishikesh\CA_Significance.xlsx')
significance_a = df1.to_numpy()

df2 = pd.read_excel(r'D:\UoM Study\Rishikesh\CA_Mean.xlsx')
mean_a = df2.to_numpy()

df3 = pd.read_excel(r'D:\UoM Study\Rishikesh\Yield_Significance.xlsx')
significance_b = df3.to_numpy()

df4 = pd.read_excel(r'D:\UoM Study\Rishikesh\Yield_Mean.xlsx')
mean_b = df4.to_numpy()

df5 = pd.read_excel(r'D:\UoM Study\Rishikesh\Moisture_Significance.xlsx')
significance_c = df5.to_numpy()

df6 = pd.read_excel(r'D:\UoM Study\Rishikesh\Moisture_Mean.xlsx')
mean_c = df6.to_numpy()

df7 = pd.read_excel(r'D:\UoM Study\Rishikesh\Stress_Significance.xlsx')
significance_d = df7.to_numpy()

df8 = pd.read_excel(r'D:\UoM Study\Rishikesh\Stress_Mean.xlsx')
mean_d = df8.to_numpy()

df9 = pd.read_excel(r'D:\UoM Study\Rishikesh\Tenacity_Significance.xlsx')
significance_e = df9.to_numpy()

df10 = pd.read_excel(r'D:\UoM Study\Rishikesh\Tenacity_Mean.xlsx')
mean_e = df10.to_numpy()

df11 = pd.read_excel(r'D:\UoM Study\Rishikesh\Modulus_Significance.xlsx')
significance_f = df11.to_numpy()

df12 = pd.read_excel(r'D:\UoM Study\Rishikesh\Modulus_Mean.xlsx')
mean_f = df12.to_numpy()

df13 = pd.read_excel(r'D:\UoM Study\Rishikesh\Load_Significance.xlsx')
significance_g = df13.to_numpy()

df14 = pd.read_excel(r'D:\UoM Study\Rishikesh\Load_Mean.xlsx')
mean_g = df14.to_numpy()
```

```
df15 = pd.read_excel(r'D:\UoM Study\Rishikesh\Strain_Significance.xlsx')
significance_h = df15.to_numpy()

df16 = pd.read_excel(r'D:\UoM Study\Rishikesh\Strain_Mean.xlsx')
mean_h = df16.to_numpy()

no_of_sample = len(significance_a)

count = 0
for i in range (no_of_sample-1):
    if significance_a[i+1,1] < 0.05 or significance_b[i+1,1] <= 0.05 or
significance_c[i+1,1] <= 0.05 or significance_d[i+1,1] <= 0.05 or
significance_e[i+1,1] <= 0.05 or significance_f[i+1,1] <= 0.05 or
significance_g[i+1,1] <= 0.05 or significance_h[i+1,1] <= 0.05:
        if mean_a[i+1,1] < mean_a[0,1] and mean_b[i+1,1] > mean_b[0,1] and
mean_c[i+1,1] > mean_c[0,1] and mean_d[i+1,1] > mean_d[0,1] and mean_e[i+1,1]
> mean_e[0,1] and mean_f[i+1,1] > mean_f[0,1] and mean_g[i+1,1] > mean_g[0,1]
and mean_h[i+1,1] > mean_h[0,1]:
           count = count + 1
        else:
            break
    else:
        count = count + 1

print(mean_a[count,0])
```

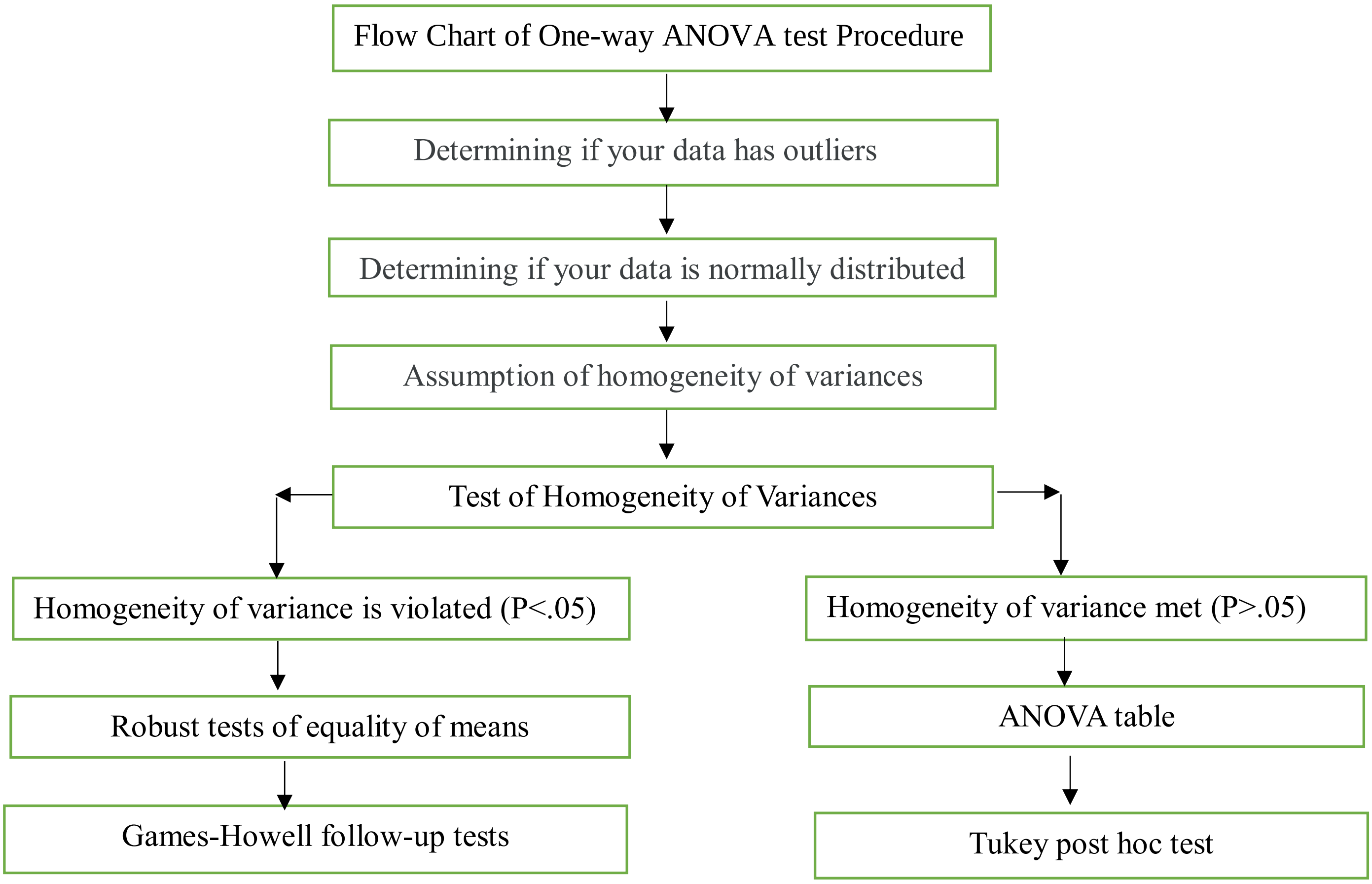
Figure 2.8. Process of Python Computer Programming Flow Chart



Chapter 3. Result and Discussion

One-way ANOVA was conducted in the result and discussion section to determine the statistical significance of Fibre yield (%), Contact angle, Load at break, Young's modulus, Moisture regain analysis, Tenacity at break, Tensile stress at break, Tensile strain at break comparing the original use and 17th reuse of NaOH solution. This process is discussed below:

Figure 3.1. Process of One-way ANOVA Test Flowchart



3.1. Data Outlier

Data Outliers can be defined as data from irregular values. Data points that are more than 1.5 box lengths from the edge of their box are classified by SPSS Statistics as outliers and illustrated as circular dots (Laerd Statistics, 2013, p.9). Any data points that are more than 3 box lengths away from the edge of their box are classified as extreme points (i.e., extreme outliers) and are illustrated with an asterisk (*) (Laerd Statistics, 2013, p.9). Both types of outliers are labelled with their case number – their row number in the Data View window – for easy identification (Laerd Statistics, 2013, p.9). For example, in Fig. 3.2, outliers are available, followed by asterisks and circular dots. In contrast, Fig. 3.2 shows no outlier available in the data, as evidenced by the lack of any circular points or asterisks.

3.1.1. Types of Outliers

Three types of outliers are available to find data errors (Laerd Statistics, 2013, p.9). These are Data entry errors, Measurement errors, and genuinely unusual values (Laerd Statistics, 2013, p.9).

a. Data Entry Errors

Data entry error can be defined as simply entries of wrong value on SPSS statistics systems (Laerd Statistics, 2013, p.9). The first point at any outlier type is to investigate whether the outliers are shown due to data entry errors (Laerd Statistics, 2013, p.9). The easiest type of error is data entry, which can be fixed by entering correct values through modification (Laerd Statistics, 2013, p.9).

b. Measurement Errors

When data entry errors are not responsible for the outlier, the next potential reason is measurement errors featured by equipment malfunction or out-of-range value (Laerd Statistics, 2013, p.9). Since it is not frequently irreversible, removal from the analysis is a conventional method to correct it (Laerd Statistics, 2013, p.9). Although occasionally any value beyond the boundary was established by understanding its navigation, it is possible to restore specific value with the most considerable rational value (Laerd Statistics, 2013, p.9). For instance, in terms of temperature measurement through thermostat might cross above 100°C even having a range from 0 to 100°C, there is an option to change it at 100°C into the system of SPSS although knowing the higher value of real temperature (Laerd Statistics, 2013, p.9). Notably, after correction of data, it is mandatory to repeat all tests of assumptions and mention adjustment towards measurement errors inside of the result finding (Laerd Statistics, 2013, p.9).

c. Genuinely Unusual Values

After getting confirmation that the outlier is not created through either Data entry error or measurement error, the third responsible factor is genuinely unusual data point values (Laerd Statistics, 2013, p.9)**.** Dealing with genuine data points is quite tough regarding statistical perspectives since there are no solid grounds to deny as invalid (Laerd Statistics, 2013, p.9).

3.1.2. Solution of Outlier

There is a two option for outlier solution (Laerd Statistics, 2013, p.9). a. Keeping the outlier(s) (Laerd Statistics, 2013, p.9) b. Remove the outlier(s) (Laerd Statistics, 2013, p.9).

a. Keeping the Outlier(s)

There are four options available in terms of keeping the outliers. First of all is to run the non-parametric Kruskal-Wallis H test (Laerd Statistics, 2013, p.9). Secondly, change the outlier with the value that is the adjacent large value at the outlier (Laerd Statistics, 2013, p.9). Thirdly, modification of dependable variables (Laerd Statistics, 2013, p.9). Finally, Incorporation of the outlier study anyway since the Result is not significant enough to influence (Laerd Statistics, 2013, p.9).

Although in terms of analysis for One-way ANOVA, Kruskal-Wallis H Test is appropriate, the same null hypothesis is not investigated as a One-way ANOVA does (Laerd Statistics, 2013, p.9). The second option is restoring the outlier value by below acute value, which has a few certain benefits and several disadvantages (Laerd Statistics, 2013, p.9). Outlier value is decreased to exact higher than second most significant value to separate the negative effect of an outlier (Laerd Statistics, 2013, p.9). It is characterized by rounding down the most extreme value and rounding up the less extreme value in a way followed by one step up and one step down value of the second highest extreme value and second-lowest extreme value (Laerd Statistics, 2013, p.9). To keep various information within outlier accommodation is the extensive benefit of this solution, but on the other hand, after modification, the genuine value found more partial by examination (Laerd Statistics, 2013, p.9). The third option is a dependent variable transformation where the outlier is decreased in size to consider as nonoutlier compared to other data points (Laerd Statistics, 2013, p.9). Before transforming data, it is mandatory to watch whether the raw data is normally distributed or not since the transformation is only available for normal distribution (Laerd Statistics, 2013, p.9). At this option, the drawback of One-way ANOVA analysis is harder since the original data is no longer going to be used, and it is obvious to rerun all the tests of assumptions when used (Laerd Statistics, 2013, p.9).

For the fourth option, it is challenging to keep the outlier in the analysis (Laerd Statistics, 2013, p.9). However, keeping outliers at analysis is still acceptable by evaluating the situation (Laerd Statistics, 2013, p.9). For the best outcome, run a One-way ANOVA with and without the outlier provides two different results (Laerd Statistics, 2013, p.9). Then having a comparison produces a decision whether both results come to different conclusions or the same conclusion to keep the outlier in the data (Laerd Statistics, 2013, p.9).

b. Remove the Outlier(s)

The second option is to remove the outlier where it needs to remove data from analysis (Laerd Statistics, 2013, p.9). The reason for removal and its effect on results and eliminate allegations are required to explain any data removal (Laerd Statistics, 2013, p.9).

3.2. Determining if the Data is Normally Distributed

The extracted data will be examined to decide whether it is normally distributed by applying the different tests (Laerd Statistics, 2013, p.10). Although different normality test methods such as skewness and kurtosis values or histograms are available, Shapiro-Wilk's test for normality is the most common method which provides trustable analysis of result (Laerd Statistics, 2013, p.10).

3.2.1. Shapiro-Wilk Test of Normality

In terms of running the Shapiro-Wilk test of normality, it is preferable to be a smaller size sample (less than 50) and less assertive graphical methods, including interpretation of Normal Q-Q Plots (Laerd Statistics, 2013, p.10). However, it has the capacity to handle 2000 samples (Laerd Statistics, n.d.). It is mandatory to have a significant level of more than .05 (i.e., $p>0.5$) to count data as normally distributed (Laerd Statistics, 2013, p.10). When the significant level is less than 0.5 (i.e., $p<0.5$), then the distribution of data is considered as not normal and assumption of normality is violated (Laerd Statistics, 2013, p.10). In defining the null hypothesis for the Shapiro-Wilk test, data distribution is identical to the normal distribution (Laerd Statistics, 2013, p.10). In contrast, the alternative hypothesis data distribution is not equivalent to a normal distribution (Laerd Statistics, 2013, p.10). As a result, when the significant level is less than 0.05, it stands for the means of data distribution that is not indistinguishable from a normal distribution (Laerd Statistics, 2013, p.10). On the other hand, data is established as normally distributed when it is unsuccessful in dismissing the null hypothesis (Laerd Statistics, 2013, p.10).

3.2.2. Dealing with Violations of Normality

There are three options to deal in terms of data not normally distributed. a. Transform of the dependent variable, b. Use a non-parametric test, c. Carry on regardless (Laerd Statistics, 2013, p.10).

a. Transform of the Dependent Variable

Normal data distribution can be achieved by transforming the dependent variable and re-run the assumptions on the transformed data (Laerd Statistics, 2013, p.10). The process of transformation is functioned by a similar form of administration of scores in all groups (Laerd Statistics, 2013, p.10). However, various distributions have an insufficient transformation to become normality (Laerd Statistics, 2013, p.10). It especially happens due to the unavailable transformation of numerous shapes of distribution (Laerd Statistics, 2013, p.10).

b. Use a Non-parametric Test

In this option, the Kruskal-Wallis H test is the accepted method for comparing One-way ANOVA even though null and alternative hypotheses are different from One-way ANOVA (Laerd Statistics, 2013, p.10).

c. Carry on Regardless

Although One-way ANOVA is considered robust to non-normality, where non-normality has no significant effect on type I error rate, it is acceptable to run this test where violations of the result are essential to mention (Laerd Statistics, 2013, p.10).

3.3. Run the One-way ANOVA Procedure with a Post Hoc Test

At this point, a One-way ANOVA procedure with a post hoc test was carried out, followed by descriptive, homogeneity of variance test, welch and means plot (Laerd Statistics, 2013, p.12). In terms of checking post hoc multiple comparisons, an examination was done by Tukey test for the assumption of equal variances and Games-Howell for equal variances not assumed (Laerd Statistics, 2013, p.12).

3.3.1. Interpreting Results

There are numerous steps for interpreting results which are discussed below:

3.3.2. Interpreting the Descriptive Statistics

After analyzing data by outlier and normality test, the third vital assumption is to determine whether there is a violation of homogeneity of variance or not (Laerd Statistics, 2013, p.10). Descriptive statistics are considered to be discussed first to determine whether homogeneity of variance is met and the overall impression of visible data (Laerd Statistics, 2013, p.10). It is essential to describe the result of descriptive statistics by utilizing the mean and standard deviation outcomes (Laerd Statistics, 2013, p.10). After getting comprehensive data from the descriptive statistics, the next step is to determine whether the homogeneity of variances is met by running a One-way ANOVA analysis (Laerd Statistics, 2013, p.10).

3.3.3. Assumption of Homogeneity of Variances

A One-way ANOVA considers that the population variances of the dependent variable are identical for the independent variable of all groups (Laerd Statistics, 2013, p.10). Levene's test of equality of variances is one of the methods to test the assumption of homogeneity of variances for deciding if the variances between groups for the dependent variable are identical (Laerd Statistics, 2013, p.10). In Levene statistics, data consisted of 'Based on Mean', 'Based on Median,' 'Based on Median and with adjusted df' and 'Based on the trimmed mean' (Laerd Statistics, 2013, p.17). Out of these four options, each option produced a result with a degree of freedom between groups (df1), degree of freedom within groups (df2), and significant value (Laerd Statistics, 2013, p.17). Out of these four options' results, the only significant value of 'Based on Mean' was considered for One-way ANOVA result interpretation (Daniel, 2017). When the statistical significancy of Levene's test is less than 0.05, it is considered unavailability of equal variances and violation of the assumption of homogeneity of variances known as heterogeneous variances (Laerd Statistics, 2013, p.10). Alternatively, equal variances and non-violation of the assumption of homogeneity of variances are found when Levene's test sig value is more than 0.05, and it is called not statistically significant (Laerd Statistics, 2013, p.10). Through Levene test for equality of variances, it is examined to find that population variances are equivalent with the same variances through null hypothesis (Laerd Statistics, 2013, p.16). It is stated as:

H_0: $\sigma_1^2 = \sigma_2^2 = \sigma_3^2 = \sigma_4^2$ (Laerd Statistics, 2013, p.16).

Here population standard deviation stands for σ, and index notation of 1, 2, 3, and 4 act as independent groups (Laerd Statistics, 2013, p.16).

When the population variances are not identical all, then it is called as alternative hypothesis (Laerd Statistics, 2013, p.16). It can be mentioned as:

HA: $\sigma_1^2 \neq \sigma_2^2 \neq \sigma_3^2 \neq \sigma_4^2$

In this stage, HA stands for all variances that are not equivalent in the population (Laerd Statistics, 2013, p.16).

At Levene's test, statistical computation is administrated through securing p-value, which illustrates the evidence in opposition to the null hypothesis compared to F-distribution (Laerd

Statistics, 2013, p.16). A result with statistical significance recommends receiving the alternative hypothesis, which is followed by inequivalent population variance (Laerd Statistics, 2013, p.16).

3.3.4. Results when Homogeneity of Variances is Met

Once the homogeneity of variance is met, the next step is to check the One-way ANOVA result found in the ANOVA table (Laerd Statistics, 2013, p.16). The statistical significance value of the test at the "Sig." column is the primary key of this section, where it is followed by statistical significance and not statistically significant through considering the p-value (Laerd Statistics, 2013, p.16). When the result of the "Sig." column from the ANOVA table is less than 0.05, it is considered statistically significant and identified as the population of all group means are not similar. Alternatively, if the "Sig." column results are more than 0.05, it is considered non-statistically significant, followed by no difference between group means (Laerd Statistics, 2013, p.17). When the p-value is .000, it should not be considered as zero actually as a significant value. It literally stands as < .0005. A statistical significance in mean scores at different group levels is achieved by considering the value of < .0005 (Laerd Statistics, 2013, p.17). Notably, the ANOVA table result only informs whether the difference between (Quirk, 2018) participating groups or not (Quirk, 2018). However, there is no option for rationale regarding the significance availability on a specific pairwise comparison (Quirk, 2018). More specifically, the ANOVA table does not have information on the particular significance of groups (Quirk, 2018).

3.3.5. Results when Homogeneity of Variances is Violated

When homogeneity of variance is violated, a modified version of anova is used named as Welch ANOVA (Laerd Statistics, 2013, p.19). The result of the Welch's ANOVA is established through Robust Tests of Equality of Means (Laerd Statistics, 2013, p.19). Due to the result of statistical significancy, it is followed by run of Games Howell post hoc test for recognizing any available variance (Laerd Statistics, 2013, p.19).

3.3.6. Post Hoc Procedures for Multiple Comparison

Once the analysis of variance (ANOVA) reflects the overall difference, then it is followed by post hoc comparisons which can be classified as tests of the statistical significance of differences between group means (Horn, 2006). F ratio of ANOVA informs the existence of moderate statistically significant differences between the groups being studied scattered whereas post hoc analysis is more specifically about certain groups types and their location (Horn, 2006). Tukey's Honestly Significant Difference (HSD) test is the most connected post hoc test with ANOVA, which is articulated in a way where it is featured by providing all pairwise comparisons and sustaining experiment-wise error rate at the predetermined α level (Horn, 2006). Multiple Comparisons and Homogeneous Subsets are two parts of the Tukey Post hoc Test, which is followed by single and groupwise comparisons (Horn, 2006). The Tukey post hoc test is applied once the assumption of homogeneity of variance has been met (Quirk, 2018). If the assumption of homogeneity of variance is violated, then the Games-Howell test is used (Quirk, 2018). For both tests, including Tukey post hoc and Games-Howell, the individual comparing group must be placed on the left side starting from R0 to R17 serially. On the other hand, all remaining 17 groups should be situated on the right side to compare with the left side located individual group.

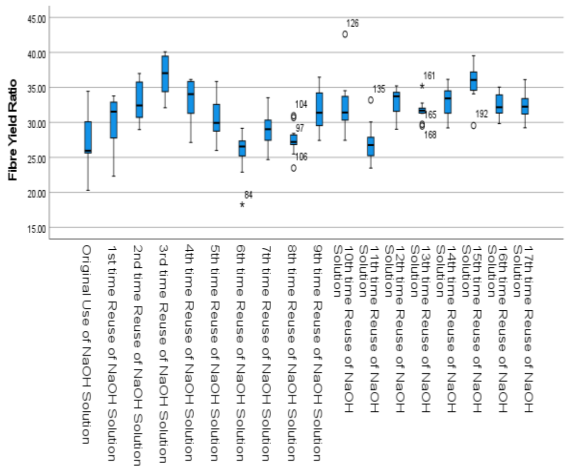
3.4. One-way ANOVA of Fibre Yield (%)

For determining fibre yield (%), firstly data of each group has 12 samples starting from original use to 17th reuse of NaOH solution are counted for collecting the data mentioned in Appendix I (Table 1). Then it is followed by calculating the individual group fibre yield percentage in Appendix I (Table 2). Finally, group fibre yield percentage data was run by SPSS software. Then the result of the SPSS data was extracted for analysis.

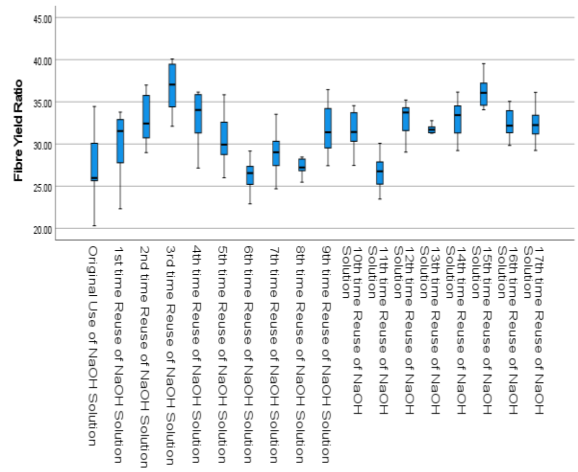
3.4.1. Data Outlier of Fibre Yield (%)

The data outlier of fibre yield (%) is presented by numerous outliers where it is followed by input of the original data.

Figure 3.2. a. Fibre yield (%) with Outlier; b. Fibre Yield (%) after Fixing the Outlier



(a)



(b)

Through the output, it is found that there is no data outlier from the original use to the 5th-time reuse of NaOH solution. At the 6th-time reuse of NaOH solution, there is an outlier identified as 18.28. Data outliers are also found at 30.69, 30.96, 23.49 under 8th time, 42.61 under 10th time, and 33.20 under 11th time, serial number 35.21, 29.49 29.75 under 13th time, and 29.56 under 15th-time reuse of NaOH solution.

According to the section 3.1.1., it is mentioned that three types of data outlier are classified, followed by data entry errors, measurement errors, and genuinely unusual values. At Fibre yield (%), before being placed into SPSS software systems, data of Fibre yield (%) was validated to find any outlier due to data entry error. After confirmation of not finding any data entry error for Fibre yield (%) outlier, the second step of checking any outlier responsible by measurement error, followed by verifying the process of running the SPSS analysis. Once it was established that an outlier was not produced due to measurement error, the final step was to confirm that outlier was created due to genuinely unusual values.

As per section 3.1.2., there are two options available to get a solution for these outliers: keeping this outlier and removing the outlier. The first option known as 'keeping this outlier' was chosen to get the fibre yield (%) outlier solution, followed by restoring the outlier value. It was characterized by rounding up and rounding down the most extreme and less most extreme outlier value. Now, following section 3.1.2., the table is organized to replace the old original value with new original data, which is mentioned below:

Table 3.1. Outlier of Fibre Yield (%) During Extraction Process.

Solution number	**Outlier serial number**	**Fibre yield (%)**	
		Original value	**Modified value**
R6	84	18.28	22.90
R8	97	30.69	28.45
	104	30.96	28.46
	106	23.49	25.48
R10	126	42.61	34.55
R11	135	33.20	30.09
	161	35.21	32.78
R13	165	29.49	31.28
	168	29.75	31.29
R15	195	29.56	34.07

Above the table, the outlier data value is presented by mentioning different reuse of NaOH solution, categorized through reuse of NaOH solution. Serial number 84,106, 165,168,195 is identified as less extreme value, which is followed by rising from 18.28 to 22.90, 23.49 to 25.48, 29.49 to 31.28, 29.75 to 31.29, 29.56 to 34.07 accordingly. Serial number 97, 104, 126, 135, 161 is featured as high extreme value, which is featured by rising down from 30.69 to 28.45, 30.96 to 28.46, 42.61 to 34.55, 33.20 to 30.09, 35.21 to 32.78 subsequently. After this modification, the next step was followed by running the SPSS analysis again. Finally, a result without any outlier was found through this process.

3.4.2. Tests of Normality of Fibre Yield (%)

As referenced in section 3.2., the test of normality is the second mandatory assumption for testing a normal distribution of data run by a test named Shapiro-Wilk's test for normality. The Shapiro-Wilk test produced an individual 'Sig' value from the original solution to the 17th time reuse of NaOH solution for fibre yield (%). Below the table 3.2., 1st time, and 13th-time Reuse of NaOH Solution are only statistically significant with a significant value of .041 and .035. The rest of the NaOH solution, including original and reuse, are not statistically significant where Sig. Columns are more than 0.5 of the p-value. As per rules of Shapiro-Wilk test, 1^{st} time and 13^{th} time reuse of NaOH solution violated the assumption of normality whereas rest of the data met the assumption of the normality.

As per reference from section 3.2.2., in terms of providing the solution, there are three options available: transform the dependent variable, use a non-parametric test, carry on regardless. Referencing from section 3.2.2., for fibre yield (%), the carry-on regardless option is applied since it allowed to mention the violation of result ($p<0.05$). In contrast, referring to section 3.2.2., the other two options (transform the dependent variable, use a non-parametric test) have not been offered to indicate the original result of Shapiro-Wilk's test.

Table 3.2. Test of Normality of Fibre yield (%) Data with Significant Value

Fibre yield (%)	Sig.	Fibre yield (%)	Sig.	Fibre yield (%)	Sig.
R0	.215	R6	.362	R12	.216
R1	.041	R7	.947	R13	.035
R2	.226	R8	.132	R14	.592
R3	.269	R9	.682	R15	.590
R4	.092	R10	.606	R16	.531
R5	.853	R11	.551	R17	.999

3.4.3. Descriptive Statistics of Fibre Yield (%)

Each group has 12 samples starting from original use to 17th reuse of NaOH solution and are counted for collecting the data. Then mean value and standard deviation of each individual group are presented by a table, and the presentation of data is followed by mean ± standard deviation. From original use to 3rd time reuse, mean value increased whereas standard deviation decreased but was not maintained from 4th time reuse to 17th time reuse in terms of value for mean value and standard deviation.

Table 3.3. Descriptive Statistics of Fibre Yield (%)

Sl.	Mean	Std. deviation	Sl.	Mean	Std. deviation
R0	27.3600	4.15358	R9	31.9250	3.00728
R1	30.0717	3.86271	R10	31.6658	2.23924
R2	32.9483	2.96079	R11	26.7867	2.02327
R3	36.7508	2.85169	R12	33.0125	1.85691
R4	33.2583	2.94891	R13	31.8000	.53421
R5	30.4558	2.80728	R14	32.9892	2.07174
R6	26.1833	1.91333	R15	36.1167	1.70067
R7	28.8400	2.51530	R16	32.5233	1.60327
R8	27.2825	1.03414	R17	32.3275	1.88062

3.4.4. Levene Statistic of Fibre Yield (%)

As per reference through section 3.3.3, from Levene statistic box, data is available with four options: Based on Mean, Based on Median, Based on Median and with adjusted df and based on trimmed mean for fibre yield (%). Out of these options, Based on Mean data is considered standard data for One-way ANOVA as mentioned in section 3.3.3. Based on mean data, it was found that the 'Sig' column is .000, which is statistically significant. As per this data, it was also found that the assumption of homogeneity of variances was violated.

Table 3.4. Levene Statistic of Fibre Yield (%) Data with Significant Value

Fibre yield (%)	**Levene statistic**	**df1**	**df2**	**Sig.**
Based on Mean	3.539	17	198	.000
Based on Median	2.137	17	198	.007
Based on Median and with adjusted df	2.137	17	95.194	.011
Based on trimmed mean	3.415	17	198	.000

3.4.5. Robust Tests of Equality of Means for Fibre Yield (%)

After analyzing the Levene statistic result, whether the homogeneity of variances is met or violated is clearly understood. As per section 3.3.5., the next following step was to consider the result of Welch ANOVA where Sig. value was only countable. Table 3.5. indicated that the Sig. value is less than p-value (.05), where homogeneity of variances for fibre yield (%) was violated. According to Table 3.5., it was found that Sig. value is .000, which is not met the homogeneity of variances.

Table 3.5. Robust Tests of Equality of Means Data for Fibre Yield (%)

	Statistic	**df1**	**df2**	**Sig.**
Welch	27.685	17	72.914	.000

3.4.6. Games-Howell Test for Fibre Yield (%)

After confirming the result through robust tests of equality of means where it did not meet the significance, the next step was to investigate the violation of the assumption of homogeneity of variance through pairwise comparison of groups named as Games-Howell test from the reference of section 3.3.6. After getting the outcome from the test, the data was featured by finding the significance value of specific groups in terms of pairwise comparison collected from appendix I (Table 3). Data was represented in table 3.6. below:

Table 3.6. Games-Howell Test Significant Value for Fibre Yield (%)

Sl.	**R0**	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**	**R11**	**R12**	**R13**	**R14**	**R15**	**R16**	**R17**
R0		X	X	√(.00)	√(.04)	X	X	X	X	X	X	X	√(.03)	X	√(.04)	√(.00)	X	X
R1			X	√(.00)	X	X	X	X	X	X	X	X	X	X	X	√ (.01)	X	X
R2				X	X	X	√(.00)	X	√(.00)	X	X	√(.00)	X	X	X	X	X	X
R3					X	√(.00)	√(.00)	√(.00)	√(.00)	√(.04)	√(.00)	√(.00)	X	√(.00)	X	X	√(.02)	√(.01)
R4						X	√(.00)	√(.04)	√(.00)	X	X	√(.00)	X	X	X	X	X	X
R5							√(.02)	X	X	X	X	X	X	X	X	√(.00)	X	X
R6								X	X	√(.00)	√(.00)	X	√(.00)	√(.00)	√(.00)	√(.00)	√(.00)	√(.00)
R7									X	X	X	X	√(.01)	X	√(.01)	√(.00)	√(.02)	X
R8										√(.01)	√(.00)	X	√(.00)	√(.00)	√(.00)	√(.00)	√(.00)	√(.00)
R9											X	√(.00)	X	X	X	√(.03)	X	X
R10												√(.00)	X	X	X	√(.00)	X	X
R11													√(.00)	√(.00)	√(.00)	√(.00)	√(.00)	√(.00)
R12														X	X	√(.02)	X	X
R13															X	√(.00)	X	X
R14																√(.04)	X	X
R15																	√(.00)	√(.00)
R16																		X
R17																		

In the above table 3.6., referencing section 3.3.6., the individual group was placed on the left side in a sequence compared with the 17 groups on the right side successively. Out of altogether 216 samples, 122 samples are statistically significant, whereas the rest of the 94 samples are nonsignificant. It means almost 57% percent of the sample's properties are not similar, but almost 43% are similar for the whole Fibre yield (%). In terms of individual sample comparison, it was found that the number of significances was highest in sample numbers R15 (14 times), R6 (12 times), R3, R8, R11 (11 times), respectively. At the same time the number of significances was lowest at R4, R7, R12, R14, R16 (6 times), R0, R9, R10, R13, R17 (5 times), R2, R5 (3 times), R1 (2 times) correspondingly.

Inside Table 3.6., statistical significance is available visible from the original sample (R0) to the farthest sample, (R17). Comparing with original sample (R0), it was found that there was no statistically significant difference between R0 (27.36%) to R1 (30.07%), R2 (32.94%), R5 (30.45%), R6 (26.18%), R7 (28.84%), R8 (27.28%), R9 (31.92%), R10 (31.66%), R11 (26.78%), R13 (31.80%), R16 (32.52%), R17 (32.32%) where p-value of each sample was more than 0.05, followed by .95, .07, .76, 1.00, .99, 1.00, .24, .23, 1.00, .13, .06, .09 respectively. At the same time, in comparison of R0 to R3 (36.75%), R4 (33.25%), R12 (33.01%), R14 (32.98%), R15 (36.11%), it was found that there were statistically significancy available where p-value was less than 0.05, followed by .000, .046, .036, .041, .001 correspondingly.

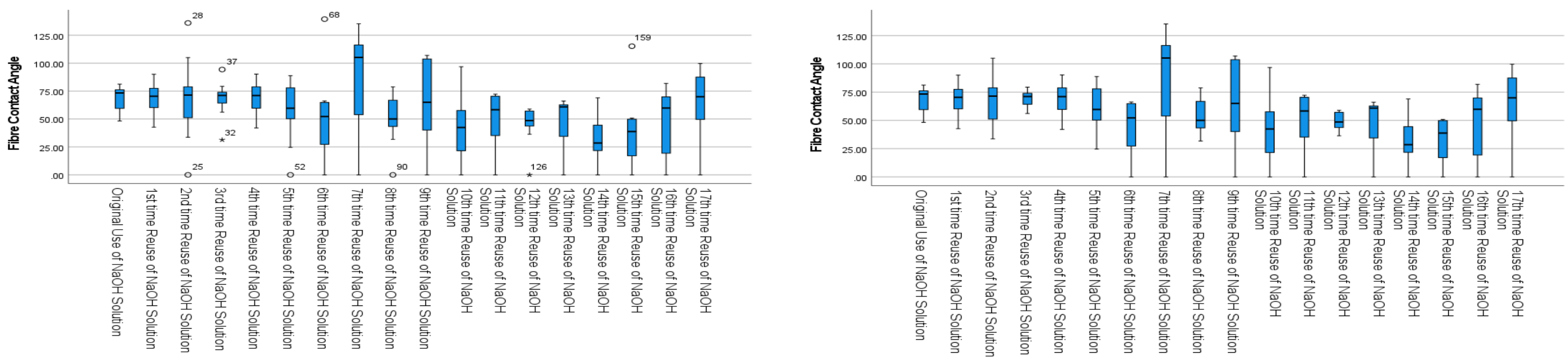
3.5. One-way ANOVA of Fibre Contact Angle (°)

Data from advancing stage measurement was collected from table 1 in appendix II for determining fibre contact angle. Since most of the data was found ‘zero’ and no significant data available at the receding stage of contact angle, advance stage data was considered to be placed and run through SPSS software collected from table 2 of appendix II. After that the outcome of the data was gathered and examined accordingly.

3.5.1. Data Outlier of Fibre Contact Angle (°)

The data outlier was found at fibre contact angle SPSS analysis after inserting primary data**.**

Figure 3.3. a. Fibre Contact Angle with Outlier; b. Fibre Contact Angle after Fixing the Outlier



(a) (b)

The data outlier of fibre contact angle is observed by having various outliers featured by original extracted contact angle data. After output comes, it is observed that there is no outlier available from RO to R1. Except for 4th time reuse of NaOH, from 2nd to 6th time reuse of NaOH solution, there was outlier available where it is followed by 0, 136.04 in 2nd time, 31.37, 94.34 in 3rd time, 0 in 5th time, 139.49 in 6th time reuse of NaOH solution. Starting from 7th-time reuse to 17th-time reuse of NaOH solution, there is only outlier available by 0, 0 and 115.23 in 8th time, 12th time and 15th-time reuse of NaOH solution.

As mentioned in section 3.1.1., there are three reasons for data outlier: data entry errors, measurement errors, and genuinely unusual value. In terms of data entry errors, the whole extracted data is verified before it is placed in the SPSS software system. After verification, it is ensured that there is no reason for contact angle data outlier due to data entry errors. The second possible reason for contact angle data outlier is measurement errors which are validated by going through the process of the SPSS system to find any mistake. After ensuring no mistake in the measurement system, the last contact angle data outlier option is genuinely an unusual value as per reference of section 3.1.1.

The solution reference was mentioned in section 3.1.2., followed by keeping the outlier and removing this outlier. The first solution option, known as keeping the outlier, is categorized by four parts mentioned previously. Out of four parts of keeping the outlier, reinstating the original value is applied, followed by rounding down the highest and lowest value. Now, the table is assembled by maintaining this formula from section 3.1.2., where it is characterized by original value to a modified value which is described below:

Table 3.7. Outlier of Fibre Contact Angle During Extraction Process.

Solution number	Outlier serial number	Contact angle (°)	
		Original value	Modified value
R2	25	0	33.71
	28	136.04	105.03
R3	32	31.37	56.11
	37	94.34	79.4
R5	52	0	24.62
R6	68	139.49	66.26
R8	90	0	31.77
R12	126	0	36.36
R15	159	115.23	50.90

Data is represented in table 3.7, where data were rounded up and rounded down at different stages of use and reused NaOH solution and placed into SPSS software. For an example, serial number 25 (R2), 32 (R3), 52 (R5), 90 (R8), 126 (R12) is round up data value from 0 to 33.71, 31.37 to 56.11, 0 to 24.62, 0 to 31.77, 0 to 36.36 respectively. Simultaneously serial numbers 28 (R2), 37 (R3), 68 (R6), 159 (R15) are round down data values from 136.04 to 105.03, 94.34 to 79.40, 139.49 to 66.26, 115.23 to 50.90 subsequently. Once this modification was done, SPSS analysis was processed again, and it was found that there was no outlier available at the result.

3.5.2. Test of Normality of Fibre Contact Angle (°)

Shapiro-Wilk's test for normality is one of the main tests to check that the data is normally distributed, which is the essential second part of the assumption. Individual Sig. Value of Contact angle data was produced through Shapiro-Wilk's test for normality featuring from the original solution to 17th-time reuse NaOH solution as per section 3.2. Out of all types of use and reuse NaOH solution, 6th and 13th-time reuse of NaOH solution are less than 0.05 of the p-value, followed by .021 and .016, respectively. It represented that all NaOH use and reuse solution samples are not statistically significant except for the 6th and 13th-time reuse of NaOH solution.

For solution, by referencing from section 3.2.2., out of three options including transforming the dependent variable, using a non-parametric test, carry on regardless, last option (carry-on regardless) was selected where it allowed mentioning the violation of result ($p<0.05$). In contrast, referring to section 3.2.2., the other two options (transform the dependent variable, use a non-parametric test) have not been offered to indicate the original result of Shapiro-Wilk's test.

Table 3.8. Tests of Normality of Fibre Contact Angle Data with Significant Value

Contact angle	**Sig.**	**Contact angle**	**Sig.**	**Contact angle**	**Sig.**
R0	.121	R6	.021	R12	.192
R1	.909	R7	.190	R13	.016
R2	.433	R8	.657	R14	.695
R3	.207	R9	.376	R15	.100
R4	.901	R10	.818	R16	.081
R5	.363	R11	.061	R17	.242

3.5.3. Descriptive Statistics of Fibre Contact Angle (°)

From original use to 17th-time reuse of NaOH solution, mean value with standard deviation was collected for each participating group's sample. The data was presented through a table where it represented values both for mean and standard deviation. The table data showed that the mean value was following a trend of increasing from RO to R3 and R14 to R17, whereas the other sample's mean value did not follow any flow of increasing or decreasing consistently.

On the other hand, the standard deviation value was increasing from RO to R2, R4 to R7, except for R3, R8. However, the flow of decreasing the standard deviation value started from R9 to R12. But the trend of increasing or decreasing the value was not maintained from samples R13 to R17.

Table 3.9. Descriptive Statistics of Fibre Contact Angle

Sl.	Mean	Std. deviation	Sl.	Mean	Std. deviation
R0	67.7160	11.71787	R9	66.6280	35.19700
R1	68.4540	14.46615	R10	41.5570	29.94202
R2	68.3430	25.27492	R11	50.8450	22.71376
R3	69.4070	8.35498	R12	48.7070	8.64550
R4	67.8890	14.78989	R13	46.8240	23.02061
R5	59.4560	22.29282	R14	31.0150	21.50840
R6	43.6460	26.10060	R15	33.4030	18.39837
R7	86.4710	44.01302	R16	45.8230	31.89836
R8	53.1010	15.83666	R17	65.4210	31.32962

3.5.4. Levene Statistic of Fibre Contact Angle (°)

Data was gathered from the Levene statistics box, where it produced four options of result followed by Based on Mean, Based on Median, Based on Median and with adjusted df and based on trimmed mean as references from section 3.3.3. In reference to section 3.3.3., the significant value of 'based on mean' is only countable for interpreting the Levene statistics result. As per the

'Sig.' column of Levene statistics of fibre contact angle, it produces a result of '.000', which is considered as a violation of the homogeneity of variances.

Table 3.10. Levene Statistic of Fibre Contact Angle Data with Significant Value

Fibre contact angle	**Levene statistic**	**df1**	**df2**	**Sig.**
Based on Mean	3.951	17	162	.000
Based on Median	2.180	17	162	.006
Based on Median and with adjusted df	2.180	17	91.278	.010
Based on trimmed mean	3.788	17	162	.000

3.5.5. Robust Tests of Equality of Means for Fibre Contact Angle (°)

Once after analyzing the Levene statistic result, the following step was to know that either homogeneity of variances is met or violated by analyzing the result of Welch ANOVA as per section 3.3.5. The result of Welch ANOVA was mentioned in Table 3.10. It was found that the robust tests of equality of means of fibre contact angle Sig. value was less than p-value (.05), which violated homogeneity of variances at Table 3.10.

Table 3.11. Robust Tests of Equality of Means Data for Fibre Contact Angle

	Statistic	**df1**	**df2**	**Sig.**
Welch	4.956	17	60.115	.000

3.5.6. Games-Howell Test for Fibre Contact Angle (°)

Once it was verified that the outcome of the robust test of equality of means violated the homogeneity of variance, the last stage was to validate the reason for statistical significance through pairwise comparison between groups known as the Games-Howell test from the reference of section 3.3.6. The result of the test was presented throughout Table 3.12., gained from appendix II (Table 3), which is stated below:

Table 3.12. Games-Howell Test Significant Value for Fibre Contact Angle

Sl.	R0	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17
R0		X	X	X	X	X	X	X	X	X	X	X	√(.04)	X	√(.02)	√(.01)	X	X
R1			X	X	X	X	X	X	X	X	X	X	X	X	√(.02)	√(.01)	X	X
R2				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
R3					X	X	X	X	X	X	X	X	√(.00)	X	√(.01)	√(.00)	X)	X
R4						X	X	X	X	X	X	X	X	X	√(.02)	√(.01)	X	X
R5							X	X	X	X	X	X	X	X	X	X	X	X
R6								X	X	X	X	X	X	X	X	X	X	X
R7									X	X	X	X	X	X	X	X	X	X
R8										X	X	X	X	X	X	X	X	X
R9											X	X	X	X	X	X	X	X
R10												X	X	X	X	X	X	X
R11													X	X	X	X	X	X
R12														X	X	X	X	X
R13															X	X	X	X
R14																X	X	X
R15																	X	X
R16																		X
R17																		

As mentioned in section 3.3.6., the individual group was placed on the left side of the table, which was compared with all other groups mentioned on the right side of the table. As per the data of the table, it was found that the highest number of significances was available at samples R14, R15 (4 times), midst number of significance was on samples R0, R3 (3 times) and the lowest number of significances was found in R1, R4, R12 (2 times). It has 20 samples of significant value less than 0.05 throughout 180 samples altogether. As per this result, almost 11.5% of the samples are statistically significant, whereas 88.5% of the samples are not statistically significant.

In Table 3.12., for fibre contact angle data, it produced numerous statistically significant value noticeable from R0 until R4. However, it is remarkable that there was no statistically significant available from R5 to R11 as well as R13, R16 and R17. In differentiate with original sample (R0: 67.71%), it observed that the R0 statistically the same for R1 (68.45%), R2 (68.34%), R3 (69.40%), R4 (67.88%), R5 (59.45%), R6 (43.64%), R7 (86.47%), R8 (53.10%), R9 (66.62%), R10 (41.55%), R11 (50.84%), R13 (46.82%), R16 (45.82%), R17 (65.42%) where p value was featured by 1.00, 1.00, 1.00, 1.00, .99, .47, .99, .64, 1.00, .52, .78, .53, .80, 1.00 respectively. However, in comparison of R0 to R12, R13, R14, R15, it was found that R12 (48.70%), R14 (31.01%), R15 (33.40%) was statistically different which is followed by p-value of (.045), (.020), (.011) sequentially.

3.6. One-way ANOVA of Mechanical Properties of Cattail Fibre

In terms of analyzing the mechanical properties including load at break, tensile stress at break, tensile strain at break, Young's modulus, tenacity at break, moisture regain of cattail fibre, out of 12 groups, the first sample of each group was chosen to extract 20 samples. From first-time uses to 17th-time reuse of NaOH solution, 360 samples were taken altogether, where the data is kept under Appendix III (Table 1). Then the data were placed through the SPSS software system, which eventually provided an output of the analysis.

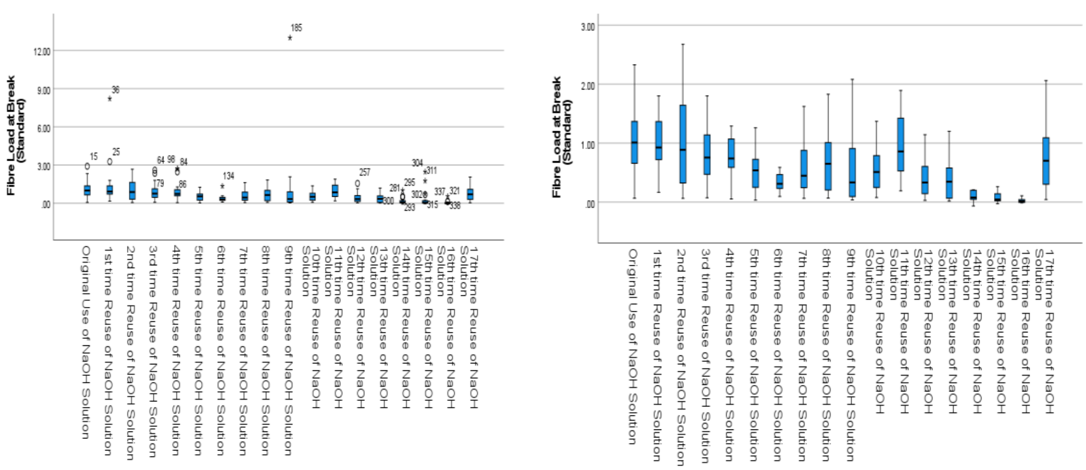
3.6.1. One-way ANOVA of Fibre Load at Break (N)

Firstly, data was gathered from the referencing Table 1 of Appendix III to decide fibre load at break. Data were processed and run through SPSS software. As a part of the process. The last part of data collection was followed by extraction and investigation correspondingly.

3.6.1.1. Data Outlier of Fibre Load at Break (N)

Various outlier was available after analysis of data for fibre load at break

Figure 3.4. a. Fibre Load at Break with Outlier; b. Fibre Load at Break after Fixing the Outlier



(a) (b)

Outlier produced as a result which was found during the first time of SPSS analysis for fibre load at break by utilizing its original value. As per the outcome, there is an outlier available on 2.91 for R0, 3.27, 8.21 for R1, 2.60, 2.35 for R3, 2.46, 2.69, 2.72 for R4, 1.34 for R6, 12.99 for R9, 1.56 for R12, 0.51, 0.48, 0.53, 1.01 for R14, 0.74, 2.47, 1.75, 0.67 for R15, 0.13, 0.14, 0.54 for R16. There is no outlier available on R2, R5, R7, R8, R10, R11, R13, R17.

Throughout table 3.13, data is presented which has an outlier. As per the section 3.1.1., the reason behind this outlier was due to data entry errors, measurement errors, genuinely unusual value. Once it was determined that data entry errors and measurement errors were not responsible for outlier at fibre load at break, the next stage of the responsible factor for outlier was *g*enuinely unusual values as per section 3.1.1.

Keeping this outlier and removing the outlier was the solution for these outliers as per page references from section 3.1.2. To solve this issue, keeping this outlier was chosen, followed by the outlier value rounded up and rounded down, referencing section 3.1.2. before placing it into the SPSS software. Table 3.13 was presented where original value and modified value were provided below:

Table 3.13. Outlier of Fibre Load at Break During Extraction Process.

Solution number	**Outlier serial number**	**Fibre load at break (N)**	
		Original value	**Modified value**
R0	15	2.91236	2.32853
R1	25	3.27359	1.80196
	36	8.21410	1.80197
R3	64	2.60307	1.80105
	79	2.35477	1.80104
R4	84	2.46870	1.29109
	86	2.69627	1.29110
	98	2.72468	1.29111
R6	134	1.34866	0.58935
R9	185	12.99688	1.82871
R12	257	1.56433	1.14451
R14	281	0.51778	0.20685
	293	0.48464	0.20684
	295	0.53714	0.20686
	300	1.01112	0.20687
R15	302	0.74389	0.14069
	304	2.47090	0.14071
	311	1.75956	0.14070
	315	0.67651	0.14068
R16	321	0.13754	0.10840
	337	0.14644	0.10841
	338	0.54694	0.10842

As per the table above, value of serial number 15, 25, 36, 64, 79, 84, 86,98,134,185, 257, 281, 293, 295, 300, 302, 304, 311, 315, 321, 337, 338 was decreased from 2.91236 to 2.32853, 3.27359 to 1.80196, 8.21410 to 1.80197, 2.60307 to 1.80105, 2.35477 to 1.80104, 2.46870 to 1.29109, 2.69627 to 1.29110, 2.72468 to 1.29111, 1.34866 to 0.58935, 12.99688 to 1.82871, 1.56433 to 1.14451, 0.51778 to 0.20685, 0.48464 to 0.20684, 0.53714 to 0.20686, 1.01112 to 0.20687, 0.74389 to 0.14069, 2.47090 to 0.14071, 1.75956 to 0.14070, 0.67651 to 0.14068, 0.13754 to 0.10840, 0.14644 to 0.10841, 0.54694 to 0.10842 respectively.

3.6.1.2. Test of Normality of Fibre Load at Break (N)

A test known as Shapiro-Wilk's test for normality is the essential test featured by testing a normal distribution of data referencing from section 3.2. It is featured by producing individual Sig. value from R0 to R17. By the underneath table 3.14, Sig. value from R0 to R17 was mentioned, respectively. As per this Table 3.14, sig value of R7, R8, R9, R12, R15, R16 are only statistically significant (<0.05) which is followed by .032, .042, .002, .043, .025, .000. The rest of the values are higher than 0.05, which is not statistically significant.

There were three options featured in terms of providing the solution: transforming the dependent variable, using a non-parametric test, and carrying on regardless referred from section 3.2.2. Referencing section 3.2.2., for fibre load at break, the carry-on regardless option is applied since it allows mentioning the violation of result ($p<0.05$). In contrast, referring to section 3.2.2., the other two options (transform the dependent variable, use a non-parametric test) have not been offered to indicate the original result of Shapiro-Wilk's test.

Table 3.14. Test of Normality of Fibre Load at Break Data with Significant Value

Fibre load at break	**Sig.**	**Fibre load at break**	**Sig.**	**Fibre load at break**	**Sig.**
RO	.285	R6	.255	R12	.043
R1	.229	R7	.032	R13	.067
R2	.068	R8	.042	R14	.062
R3	.184	R9	.002	R15	.025
R4	.243	R10	.282	R16	.000
R5	.723	R11	.226	R17	.081

3.6.1.3. Descriptive Statistics of Fibre Load at Break (N)

On descriptive statistics of fibre load at break, the mean and standard deviation values were presented by Table 3.15. As per the Table 3.15, there was a trend for both mean value and standard deviation, which decreased from R0 to R6 except R2. This type of reducing trend was followed by

R12 to R16 again together for mean and standard deviation. For other samples like R2, R7, R8, R9, R10, R11, R17, this direction of ups and down was followed along with mean and standard deviation.

Table 3.15. Descriptive Statistics of Fibre Load at Break

Sl.	Mean	Std. deviation	Sl.	Mean	Std. deviation
RO	1.0938	.59105	R9	.6304	.66354
R1	1.0095	.48958	R10	.5426	.35825
R2	1.0577	.83395	R11	.9825	.52005
R3	.8483	.53926	R12	.4253	.33188
R4	.7745	.38487	R13	.3878	.33078
R5	.5333	.33004	R14	.0995	.08530
R6	.3344	.15944	R15	.0730	.07433
R7	.5844	.43186	R16	.0288	.04413
R8	.7115	.53243	R17	.7759	.58522

3.6.1.4. Levene Statistic of Fibre Load at Break (N)

Levene statistic box data was presented by based on mean, based on median, based on median and with adjusted df and based on trimmed mean, which acted as a resource for determining whether the homogeneity of variance of fibre load at break met or violated referencing from section 3.3.3. From table 3.16., the based on mean data only counted to determine the homogeneity of variance as per section 3.3.3. Based on mean, the ‘Sig’ value was ‘.000’, which was statistically significant. Thus, homogeneity of variance was violated for Fibre Load at Break.

Table 3.16. Levene Statistic of Fibre Load at Break Data with Significant Value

Fibre load at break	Levene statistic	df1	df2	Sig.
Based on Mean	9.017	17	342	.000
Based on Median	7.044	17	342	.000
Based on Median and with adjusted df	7.044	17	192.000	.000
Based on trimmed mean	8.681	17	342	.000

3.6.1.5. Robust Tests of Equality of Means for Fibre Load at Break (N)

Once the result of Levene statistics of fibre load at break was analyzed, the result was found statistically significant. As per reference from section 3.3.5., the next stage of fibre load at break was Robust Tests of Equality of Means if homogeneity of variance was violated. From table 3.17., it showed that the 'Sig' value was '.000', which again proved that the data produced a statistically significant result.

Table 3.17. Robust Tests of Equality of Means Data for Fibre Load at Break

	Statistic	df1	df2	Sig.
Welch	32.345	17	125.064	.000

3.6.1.6. Games-Howell Test for Fibre Load at Break (N)

Soon after robust tests of equality of means produced the result, it was found that the assumption of homogeneity of variance did not meet. As a result, the Games-Howell test followed the next step, which investigated the reason for not meeting the assumption of homogeneity of variance through groupwise comparison as per reference of section 3.3.6. From appendix III (Table 2), statistically significant data from Games-Howell test was mentioned in table 3.18. below:

Table 3.18. Games-Howell Test Significant Value for Fibre Load at Break

Sl.	**R0**	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**	**R11**	**R12**	**R13**	**R14**	**R15**	**R16**	**R17**
R0		x	x	x	x	x	√(.00)	x	x	x	x	x	√(.01)	√(.00)	√(.00)	√(.00)	√(.00)	x
R1			x	x	x	x	√(.00)	x	x	x	x	x	√(.01)	√(.00)	√(.00)	√(.00)	√(.00)	x
R2				x	x	x	x	x	x	x	x	x	x	x	√(.00)	√(.00)	√(.00)	x
R3					x	x	√(.03)	x	x	x	x	x	x	x	√(.00)	√(.00)	√(.00)	x
R4						x	√(.00)	x	x	x	x	x	x	x	√(.00)	√ (.00)	√(.00)	x
R5							x	x	x	x	x	x	x	x	√(.00)	√ (.00)	√(.00)	x
R6								x	x	x	x	√(.00)	x	x	√(.00)	√(.00)	√(.00)	x
R7									x	x	x	x	x	x	√(.00)	√(.00)	√(.00)	x
R8										x	x	x	x	x	√(.00)	√(.00)	√(.00)	x
R9											x	x	x	x	x	X	√(.04)	x
R10												x	x	x	√(.00)	√(.00)	√(.00)	x
R11													√(.02)	√(.01)	√(.00)	√(.00)	√(.00)	x
R12														x	√(0.02)	√(.01)	√(.00)	x
R13															x	√(.03)	√(.00)	x
R14																X	x	√(.00)
R15																	x	√(.00)
R16																		√(.00)
R17																		

As per reference from section 3.3.6., a specific comparing group was set down on the left side chronologically compared with the right side at the above table, placing all other 17 groups. From the above table, it was established that 105 samples showed a significant value lower than 0.05. But 255 samples presented a significant value of more than 0.05. In comparison with individually, it was seen that the significant samples number was highest to lowest from R16 (15 times), R15 (14 times), R14 (13 times), R6 (8 times), R1, R11, R12 (6 times), R0, R13 (5 times), R3, R4, (4 times), R2, R5, R7, R8, R10, R17 (3 times), R9 (1 times). Thus, the characteristic of 71% of data was identical though 31% of data was not indistinguishable for fibre load at break data analysis.

From Table 3.18., it was found that statistical significance is available, distinguished by the original sample (R0) up to the farthest sample, (R17). Considering the comparison with R0 (1.09%), it established that R1 (1.00%), R2 (1.05%), R3 (.84%), R4 (.77%), R5 (.53%), R7 (.58%), R8 (.71%), R9 (.63%), R10 (.54%), R11 (.98%), R17 (.77%) was statistically the same since all of the participating compared samples p-value was more than .05, featured by 1.00, 1.00, .99, .84, .06, .00, .20, .77, .65, .08, 1.00, .95 accordingly. However, R6 (.33%), R12 (.42%), R13 (.38%), R14 (.09%), R15 (.07%), R16 (.02%) was not statistically same in comparison with R0, where the p-value found less than .05, followed by .001, .006, .000, .000, .000 respectively.

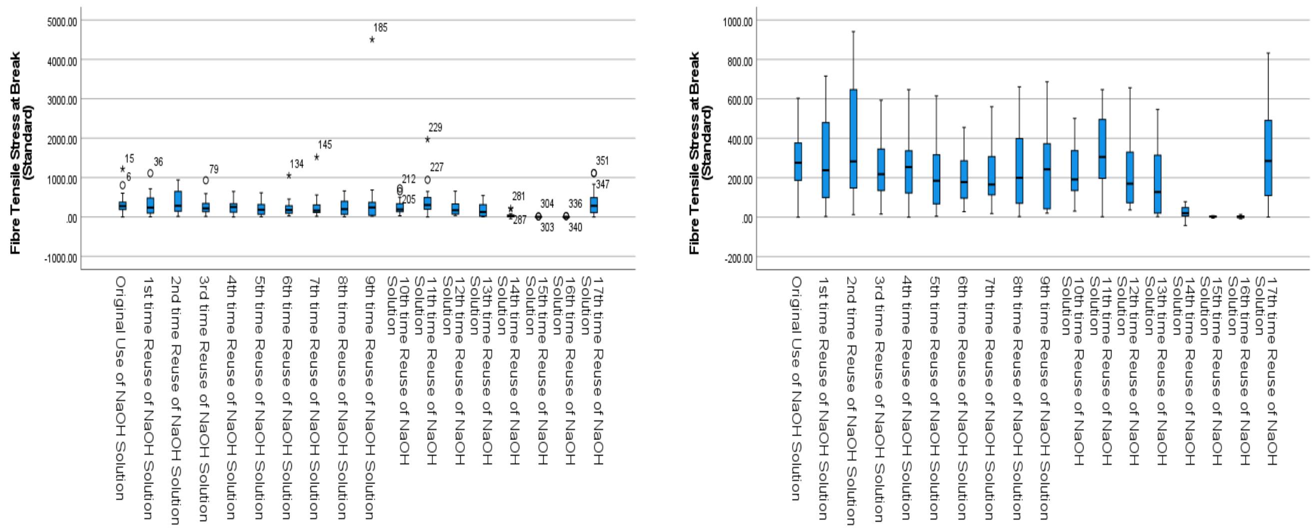
3.6.2. One-way ANOVA of Fibre Tensile Stress at Break (MPa)

For analysis of fibre load at break, data was collected from Appendix III (Table 1). Then it was employed by running SPSS software. After getting an outcome, the result was analyzed accordingly.

3.6.2.1. Data Outlier of Fibre Tensile Stress at Break (MPa)

After analysis of data, it was found that there was various data outlier available at the output.

Figure 3.5. a. Fibre Tensile Stress at Break with Outlier; b. Fibre Tensile Stress at Break after Fixing the Outlier



(a) (b)

The SPSS analysis found that the data created an outlier after inputting the original value. It was followed by 807.05, 1219.61 for R0, 1111.77 for R1, 932.26 for R3, 1052.08 for R6, 1520.46 for R7, 4504.64 for R9, 726.18, 652.51 for R10, 943.75, 1969.59 for R11, 221.54, 198.54 for R14, 16.20, 12.58 for R15, 25.70, 20.13 for R16, 1113.34, 1116.57 for R17.

As per the reference of section 3.1.1., the reason for creating the data outlier was due to data entry errors, measurement errors, genuinely unusual values. Once it was confirmed that data entry errors and measurement errors were not the reason behind this outlier, it concluded that the outlier was found as a result of genuinely unusual value.

Now, the solution for this outlier was featured by Keeping this outlier and removing the outlier as per reference of section 3.1.2. In terms of resolving this problem, the first option known as Keeping this outlier was chosen, followed by escalating and lessening the outlier value by reference of section 3.1.2. Table 3.19. mentioned the value of original and modified data where modified data was finally placed for SPSS analysis.

Table 3.19. Outlier of Fibre Tensile Stress at Break During Extraction Process.

Solution Number	Outlier serial number	Tensile stress at break (MPa)	
		Original value	Modified value
R0	6	807.05194	603.18910
	15	1,219.61316	603.18911
R1	36	1,111.77258	716.17677
R3	79	932.26300	593.16236
R6	134	1,052.08655	455.37367
R7	145	1,520.46545	560.58100
R9	185	4,504.64697	686.79707
R10	205	726.18524	500.87337
	212	652.51471	500.87336
R11	227	943.75604	647.05043
	229	1,969.59338	647.05044
R14	281	221.54739	78.59206
	287	198.54161	78.59205
R15	303	16.20510	6.17501
	304	12.58420	6.17500
R16	336	25.70500	13.88221
	340	20.13605	13.88220
R17	347	1,113.34900	832.20765
	351	1,116.57227	832.20766

As of Table 3.19. serial number 6, 15, 36, 79, 134, 145, 185, 205, 212, 227, 229, 281, 287, 303, 304, 336, 340, 347, 351 value's was dropped down from 807.05194 to 603.18910, 1,219.61316 to 603.18911, 1,111.77258 to 716.17677, 932.26300 to 593.16236, 1,052.08655 to 455.37367, 1,520.46545 to 560.58100, 4,504.64697 to 686.79707, 726.18524 to 500.87337, 652.51471 to 500.87336, 943.75604 to 647.05043, 1,969.59338 to 647.05044, 221.54739 to 78.59206, 198.54161 to 78.59205, 16.20510 to 6.17501, 12.58420 to 6.17500, 25.70500 to 13.88221, 20.13605 to 13.88220, 1,113.34900 to 832.20765, 1,116.57227 to 832.20766.

3.6.2.2. Test of Normality of Fibre Tensile Stress at Break (MPa)

From referencing section 3.2., a second required test was mandatory, which is called the test of normality, where it followed by checking the assumption of homogeneity of variance meet or not. It is known as Shapiro-Wilk's test, which produced individual data starting from R0 to R17. The main goal of this test is to check the normal distribution of data for all samples from R0 to R17 by referencing pages 5 and 6. As per table 3.20., R2, R7, R9, R12, R13, R16 violated the assumption of variance where the ‘Sig’ value was less than 0.05. As per the referencing pages 5 and 6, the ‘Sig’ value less than 0.05 is statistically significant, but the remaining NaOH solution was not statistically significant since their value was less than 0.05.

There were three recommended solutions for this problem: transforming the dependent variable, using a non-parametric test, and carrying on regardless as per reference of section 3.2.2. Regarding fibre tensile stress at break analysis, referencing section 3.2.2, the carry-on regardless option is applied since it allows mentioning the result's violation ($p<0.05$). In contrast, referring to section 3.2.2., the other two options (transform the dependent variable, use a non-parametric test) have not been offered to indicate the original result of Shapiro-Wilk's test.

Table 3.20. Test of Normality of Fibre Tensile Stress at Break Data with Significant Value

Fibre tensile stress at break	**Sig.**	**Fibre tensile stress at break**	**Sig.**
R0	.217	R9	.019
R1	.068	R10	.107
R2	.028	R11	.316
R3	.129	R12	.017
R4	.160	R13	.010
R5	.205	R14	.420
R6	.193	R15	.356
R7	.015	R16	.039
R8	.060	R17	.056

3.6.2.3. Descriptive Statistics of Fibre Tensile Stress at Break (MPa)

From the Table 3.21., descriptive statistics result of 360 samples from fibre tensile stress at break was featured by providing mean and standard deviation values.

Table 3.21. Descriptive Statistics of Fibre Tensile Stress at Break

Sl.	Mean	Std. deviation	Sl.	Mean	Std. deviation
R0	303.0469	173.98940	R9	255.7673	219.28570
R1	303.1681	231.83693	R10	244.0366	151.83809
R2	371.6652	312.98521	R11	337.0067	202.22978
R3	244.8015	174.51537	R12	208.2071	162.63941
R4	235.6599	164.53269	R13	187.9849	185.78348
R5	215.4683	161.42525	R14	25.9136	32.24823
R6	201.2140	132.49940	R15	2.7573	3.00444
R7	232.1156	163.99306	R16	2.6628	6.00986
R8	237.1705	203.82714	R17	336.9606	273.72268

As per the table above, the mean value was increased from R0 to R2 firstly but then decreased again from R3 to R6. At the same time, for standard deviation, it followed the same rule as increased and decreased value from R0 to R2 and R3 to R6, respectively. It pursued the same pathway again in analyzing the samples from R7 to R11 except R10, where the value of mean and standard deviation raised correspondingly. Then once more time, it laid down from R12 to R16 both for mean and standard deviation value. However, for sample R17, mean and standard deviation values were raised again.

3.6.2.4. Levene Statistic of Fibre Tensile Stress at Break (MPa)

By reference of section 3.3.3., it was found that the Levene statistic produced the result which composed of Based on Mean, Based on Median, Based on Median and with adjusted df and based on trimmed mean. However, Based on Mean is only considered in terms of analyzing the result as of section 3.3.3. From table 3.22., the Levene statistic 'Sig' box value was found '.000', which counted as statistically significant.

Table 3.22. Levene Statistic of Fibre Tensile Stress at Break Data with Significant Value

Fibre tensile stress at break	**Levene statistic**	**df1**	**df2**	**Sig.**
Based on Mean	9.499	17	342	.000
Based on Median	6.911	17	342	.000
Based on Median and with adjusted df	6.911	17	224.706	.000
Based on trimmed mean	9.057	17	342	.000

3.6.2.5. Robust Tests of Equality of Means of Fibre Tensile Stress at Break (MPa)

Soon after getting the result from the Levene statistic, which created a statistically significant value, the succeeding step was to run the robust tests of equality of means and check its result as per section 3.3.5. From table 3.23., the outcome of robust tests of equality of means was found '.000', which again established that homogeneity of variance was statistically significant.

Table 3.23. Robust Tests of Equality of Means Data for Fibre Tensile Stress at Break

	Statistic	df1	df2	Sig.
Welch	30.627	17	122.742	.000

3.6.2.6. Games-Howell Test for Fibre Tensile Stress at Break (MPa)

Once it was established that the robust tests of equality of means result violated the 'sig' value, the next step was to run the Games-Howell test to check the reason for violation through groups by pairwise comparison as per the reference from section 3.3.6. After getting the result from the Games-Howell test, from appendix III (Table 3), table 3.24. was created, followed by listing all of the significant data below:

Table 3.24. Games-Howell Test Significant Value for Fibre Tensile Stress at Break

Sl.	**R0**	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**	**R11**	**R12**	**R13**	**R14**	**R15**	**R16**	**R17**
R0		X	X	X	X	X	X	X	X	X	X	X	X	X	√(.00)	√(.00)	√(.00)	X
R1			X	X	X	X	X	X	X	X	X	X	X	X	√(.00)	√(.00)	√(.00)	X
R2				X	X	X	X	X	X	X	X	X	X	X	√(.00)	√(.00)	√(.00)	X
R3					X	X	X	X	X	X	X	X	X	X	√(.00)	√(.00)	√(.00)	X
R4						X	X	X	X	X	X	X	X	X	√(.00)	√(.00)	√(.00)	X
R5							X	X	X	X	X	X	X	X	√(.00)	√(.00)	√(.00)	X
R6								X	X	X	X	X	X	X	√(.00)	√(.00)	√(.00)	X
R7									X	X	X	X	X	X	√(.00)	√(.00)	√(.00)	X
R8										X	X	X	X	X	√(.01)	√(.00)	√(.00)	X
R9											X	X	X	X	√(.01)	√(.00)	√(.00)	X
R10												X	X	X	√(.00)	√(.00)	√(.00)	X
R11													X	X	√(.00)	√(.00)	√(.00)	X
R12														X	√(.00)	√(.00)	√(.00)	X
R13															X	√(.02)	√(.02)	X
R14																X	X	√(.00)
R15																	X	√(.00)
R16																		√(.00)
R17																		

In table 3.24., as per the reference from section 3.3.6., the independent group was located consecutively at the left side, which was differentiated with the right-side based 17th groups repeatedly. It was 360 samples in total. Amid the 360 samples, there were 88 samples that were statistically significant, whereas 272 samples were not. It produced a result where nearly 24.5% of samples properties were not identical, but 75.5% of samples were almost uniform. Statistical significance was extremely high at R16, R15 (15 times), R14 (14 times), and moderately low at R0, R1, R2, R3, R4, R5, R6, R7, R8, R9, R10, R11, R12 (3 times), R13 (2 times) subsequently.

From table 3.24., there was present a statistical significance notably from original sample (R0) to the endmost sample (R17). In differentiation with R0 (303.04%), it was reflected that there was no difference with R1 (303.16%), R2 (371.66%), R3 (244.80%), R4 (235.65%), R5 (215.46%), R6 (201.21%), R7 (232.11%), R8 (237.17%), R9 (255.76%), R10 (244.03%), R11 (337.00%), R12 (208.20%), R13 (187.98%), R17 (336.96%) where p-value followed by 1.00, 1.00, 1.00, .99,.96, .80, .99, 1.00, 1.00, .99, 1.00, .934, .841 respectively. However, in terms of comparison with R0 to R14 (25.91%), R15 (2.75%), R16 (2.66%), there was statistically difference available where p-value featured by .000, .000, .000 accordingly.

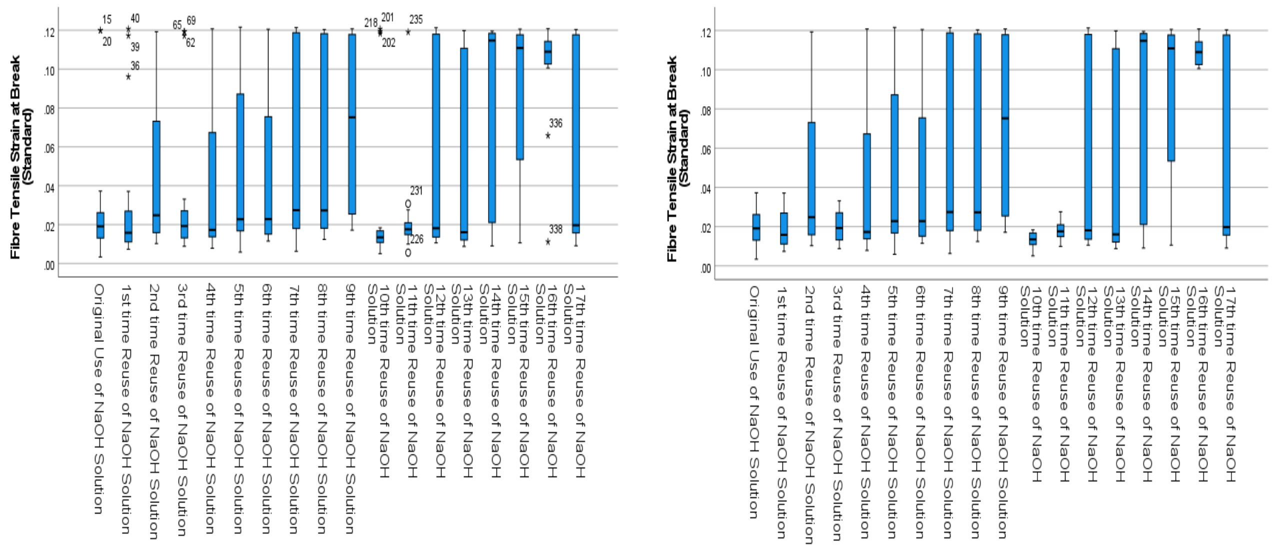
3.6.3. One-way ANOVA of Fibre Tensile Strain at Break (%)

In terms of running the SPSS analysis for fibre tensile strain at break, data was collected through Appendix III (Table 1). Then it was operating through SPSS software. Then the result was noted for further analysis.

3.6.3.1. Data Outlier of Fibre Tensile Strain at Break (%)

There was numerous outlier available after finishing analysis of the data.

Figure 3.6. a. Fibre Tensile Strain at Break with Outlier; b. Fibre Tensile Strain at Break after Fixing the Outlier



(a) (b)

After the first time SPSS analysis, the result created an outlier at fibre Tensile Strain at Break outcome. By evaluating the result, it was found that outlier showed at 0.11, 0.12 for R0, 0.09, 0.11, 0.12 for R1, 0.11, 0.11, 0.11 for R3, 0.12, 0.11, 0.11 for R10, 0.00, 0.03, 0.11 for R11, 0.06, 0.01 for R16. However, the outlier was not present at R2, R4, R5, R6, R7, R8, R9, R12, R13, R14, R15, R17.

According to section 3.1.1., outlier data was produced due to data entry errors, measurement errors, and genuinely unusual values. Once it was confirmed that data entry errors and measurement errors were not the reason behind the outlier found at analysis, then the third option named genuinely unusual value was considered the reason for data outlier by the reference of section 3.1.1.

There were two options for solving these outliers, which were featured as keeping this outlier and removing the outlier from referencing section 3.1.2. For fibre tensile strain at break analysis, keeping the outlier was chosen, followed by a roundup and round down of outlier value as per referencing section 3.1.2. After this adjustment, data was placed under SPSS software for analysis. In Table 3.25., the original value and modified value of fibre tensile strain at break outlier were outlined.

Table 3.25. Outlier of Fibre Tensile Strain at Break During Extraction Process.

Solution number	**Outlier serial number**	**Fibre tensile strain at break (%)**	
		Original value	**Modified value**
R0	15	0.11989	0.03723
	20	0.12000	0.03724
R1	36	0.09617	0.03711
	39	0.11727	0.03712
	40	0.12066	0.03713
R3	62	0.11924	0.03316
	65	0.11720	0.03315
	69	0.11930	0.03317
R10	201	0.12065	0.01837
	202	0.11938	0.01836
	218	0.11836	0.01835
R11	226	0.00560	0.00997
	231	0.03077	0.02759
	235	0.11910	0.02760
R16	336	0.06584	0.10134
	338	0.01118	0.10133

From Table 3.25., serial number 15, 20, 36, 39, 40, 62, 65, 69, 201, 202, 218 values brought down from 0.11989 to 0.03723, 0.12000 to 0.03724, 0.09617 to 0.03711, 0.11727 to 0.03712, 0.12066 to 0.03713, 0.11924 to 0.03316, 0.11720 to 0.03315, 0.11930 to 0.03317, 0.12065 to 0.01837, 0.11938 to 0.01836, 0.11836 to 0.01835, 0.03077 to 0.02759, 0.11910 to 0.02760. At the same time, 226, 336, 338 serial number values were increased from 0.00560 to 0.00997, 0.06584 to 0.10134, 0.01118 to 0.10133.

3.6.3.2. Test of Normality of Fibre Tensile Strain at Break (%)

From referencing section 3.2., Shapiro-Wilk's test for normality is known as the required test for checking whether data are normally distributed or not, which is considered the second part of the assumption. Compared with samples from R0 to R17, Shapiro-Wilk's test for normality produced data for every sample. From table 3.26., it was found that for all samples except R0, R10, R11, R16, Sig values were less than 0.05, which was considered statistically significant as per reference section 3.2.

Out of three options like transforming the dependent variable, using a non-parametric test, carry on regardless, which provided a solution referred by section 3.2.2. For fibre tensile strain at break, referencing from section 3.2.2., the carry-on regardless option is applied since it allowed to mention the violation of result ($p<0.05$). In contrast, referring to section 3.2.2., the other two options (transform the dependent variable, use a non-parametric test) have not been offered to indicate the original result of Shapiro-Wilk's test.

Table 3.26. Test of Normality of Fibre Tensile Strain at Break Data with Significant Value

Fibre tensile strain at break	**Sig.**	**Fibre tensile strain at break**	**Sig.**
R0	.267	R9	.000
R1	.009	R10	.107
R2	.000	R11	.210
R3	.040	R12	.000
R4	.000	R13	.000
R5	.000	R14	.000
R6	.000	R15	.000
R7	.000	R16	.159
R8	.000	R17	.000

3.6.3.3. Descriptive Statistics of Fibre Tensile Strain at Break (%)

In terms of analyzing the Descriptive statistics for fibre tensile strain at break, a data table with results from 360 samples was produced. Data was presented in table 3.27., stating the mean and standard deviation values.

Table 3.27. Descriptive Statistics of Fibre Tensile Strain at Break

Sl.	Mean	Std. deviation	Sl.	Mean	Std. deviation
R0	.0201	.01012	R9	.0716	.04770
R1	.0199	.01052	R10	.0130	.00434
R2	.0450	.04363	R11	.0180	.00545
R3	.0209	.00834	R12	.0578	.05172
R4	.0407	.04308	R13	.0535	.04964
R5	.0452	.04451	R14	.0833	.04796
R6	.0446	.04445	R15	.0869	.04219
R7	.0550	.04859	R16	.1090	.00644
R8	.0517	.04571	R17	.0477	.04801

Table 3.27., showed that there was no direction of data rising up or going down from R0 to R9 and R17. From sample R10 to R16, in terms of mean value, it was increased except at sample R13. On the other hand, for the standard deviation value, it was escalated from R10 to R12 but plunged from R13 to R16.

3.6.3.4. Levene Statistic of Fibre Tensile Strain at Break (%)

Although Levene statistics analysis fulfilled with four types of data featured by Based on Mean, Based on Median, Based on Median and with adjusted df and Based on trimmed mean, Based on Means value was only considered in terms of analysis as per reference of section 3.3.3. The Based on Means value showed that a 'Sig.' of '.000' counted as statistically significant for fibre tensile strain at break.

Table 3.28. Levene Statistic of Fibre Tensile Strain at Break Data with Significant Value

Fibre tensile strain at break	Levene statistic	df1	df2	Sig.
Based on Mean	26.389	17	342	.000
Based on Median	3.949	17	342	.000
Based on Median and with adjusted df	3.949	17	207.481	.000
Based on trimmed mean	22.073	17	342	.000

3.6.3.5. Robust Tests of Equality of Means of Fibre Tensile Strain at Break (%)

In reference to section 3.3.5., the next part of the analysis was Robust Tests of Equality of Means after confirming that Levene Statistic result infringed homogeneity of variances. The analysis result was found at ‘Sig’column, followed by ‘.000’, which was acknowledged as statistically significant.

Table 3.29. Robust Tests of Equality of Means Data for Fibre Tensile Strain at Break

	Statistic	**df1**	**df2**	**Sig.**
Welch	192.893	17	126.122	.000

3.6.3.6. Games-Howell Test for Fibre Tensile Strain at Break (%)

Once the robust tests of equality of means provided the ‘sig’ value, which was less than 0.05, it reflected the result which featured by violation of the assumption of variance referencing from section 3.3.6. As per section 3.3.6., the Games-Howell test was run to verify breaching rationale where testing groups followed it through paired observation. The result of the Games-Howell test was featured in appendix III (Table 4), where the information of finding significant values was noted in table 3.30. below:

Table 3.30. Games-Howell Test Significant Value for Fibre Tensile Strain at Break

Sl.	**R0**	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**	**R11**	**R12**	**R13**	**R14**	**R15**	**R16**	**R17**
R0		X	X	X	X	X	X	X	X	√(.01)	X	X	X	X	√(.00)	√(.00)	√(.00)	X
R1			X	X	X	X	X	X	X	√(.01)	X	X	X	X	√(.00)	√(.00)	√(.00)	X
R2				X	X	X	X	X	X	X	X	X	X	X	X	X	√(.00)	X
R3					X	X	X	X	X	√(.01)	X	X	X	X	√(.00)	√(.00)	√(.00)	X
R4						X	X	X	X	X	X	X	X	X	X	X	√(.00)	X
R5							**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	√(.00)	**X**
R6								X	X	X	X	X	X	X	X	X	√(.00)	X
R7									X	X	X	X	X	X	X	X	√(.00)	X
R8										X	X	X	X	X	X	X	√(.00)	X
R9											√(.00)	√(.00)	X	X	X	X	X	X
R10												X	X	X	√(.00)	√(.00)	√(.00)	X
R11													X	X	√(.00)	√(.00)	√(.00)	X
R12														X	X	X	√(.02)	X
R13															X	X	√(.00)	X
R14																X	X	X
R15																	X	X
R16																		√(.00)
R17																		

From Table 3.30., it was stated that specific groups situating on the left side got a contrast with 17th groups positioning at the right side consecutively as per the reference from section 3.3.6. Through the 360 samples, the 60 individual samples were found less than 0.05 value, which was considered statistically significant. On the other hand, 300 single samples values were more than 0.05 value, counted as non statistically significant. As a percentage ratio, just about 17% of sample properties were not homogenous, but close to 83% of samples were unvaried. R16 (14 times) was the most statistically significant value-wise sample, whereas the other samples like R9, R11, R14, R15 (5 times), R0, R1, R3, R10 (4 times), R2, R4, R5, R6, R7, R8, R12, R13, R17 (1 time) distributivity.

In the above Table 3.30., statistical significance was visible from original sample (R0) to the remotest sample (R17). In comparison with R0 (.02%), there was no statistical difference seen with R1 (.01%), R2 (.04%), R3 (.02%), R4 (.04%), R5 (.04%), R6 (.04%), R7 (.05%), R8 (..05%), R11 (.01%), R12 (.05%), R13 (.05%), R17 (.04%) where p-value featured by .100, .55, 1.00, .79, .57, .61, .22, .27, .33, 1.00, .20, .30 respectively. At the same time, there was a statistical difference seen comparing with R0 to R9 (.07%), R14 (.08%), R15 (.08%), R16 (.10%), where p-value featured by .01, .00, .00, .00 correspondingly.

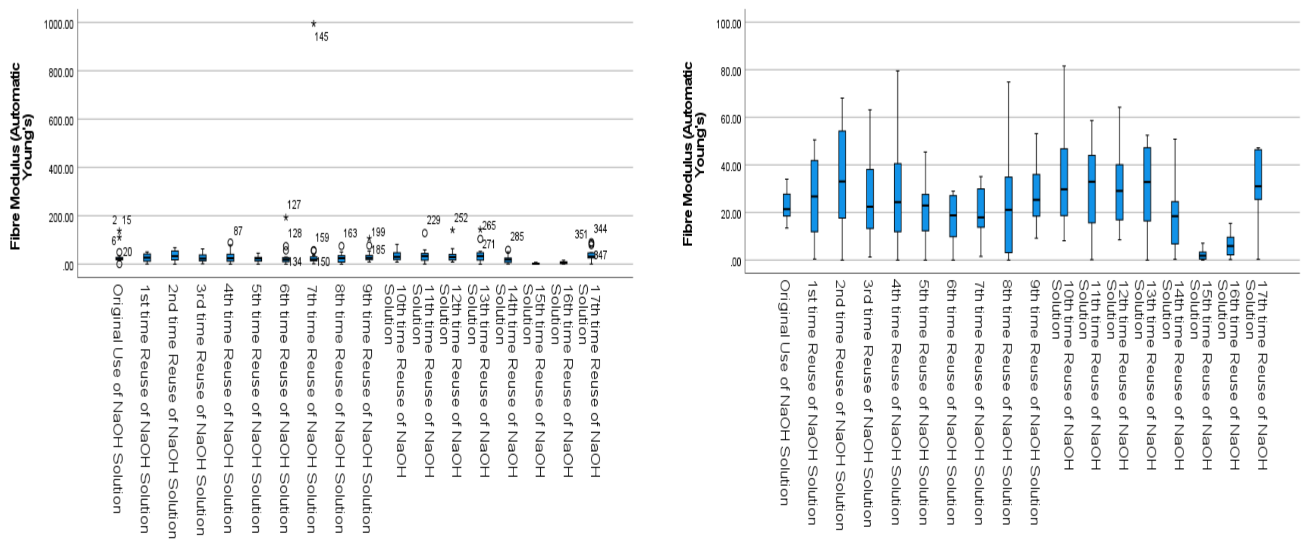
3.6.4. One-way ANOVA of Fibre Young’s Modulus (GPa)

In terms of fibre modulus examination, Appendix III (Table 1) was used as a reference for gathering data. Once data was accumulated, then SPSS software was run, and lastly, the outcome was evaluated correspondingly.

3.6.4.1. Data Outlier of Fibre Young’s Modulus (GPa)

There was numerous outlier available after getting the result from analysis.

Figure 3.7. a. Fibre Young’s Modulus with Outlier; b. Fibre Young’s Modulus after Fixing the Outlier



(a) (b)

Once the data outlier was found after analysis, the next part of the process was to list the specific outlier featuring by 110.37, 49.25, 137.47, 0.17 for R0, 88.98 for R4, 192.95, 74.38, 56.43, for R6, 994.96, 57.51, 54.60 for R7, 74.86 for R8, 106.24, 76.36 for R9, 128.32 for R11, 140.55 for R12, 104.20, 143.25 for R13, 58.91 for R14, 90.28, 84.60, 78.99, for R17.

From referencing section 3.1.1., it was found that data entry errors, measurement errors, and genuinely unusual values are responsible for producing data outliers. Soon after, it was authenticated that data entry errors and measurement errors were not the reason behind the data outlier; the last responsible option was genuinely unusual value as of reference section 3.1.1.

Regarding seeking the solution, keeping this outlier and removing the outlier was available as of reference section 3.1.2. To solve the fibre outlier of fibre tensile stress at break, out of two options, keeping the outlier was selected where it navigated by increase and decrease of outlier value as of reference section 3.1.2. By the table 3.31., there was the list of outliers along with mentioning its original and modified values for fibre Young's Modulus analysis.

Table 3.31. Outlier of Fibre Young's Modulus During Extraction Process.

Solution number	**Outlier serial number**	**Fibre Young's modulus (GPa)**	
		Original value	**Modified value**
R0	2	110.37214	34.00159
	6	49.25776	34.00158
	15	137.47720	34.00160
	20	0.17359	13.43714
R4	87	88.98487	79.48215
R6	127	192.95841	28.92888
	128	74.38393	28.92887
	134	56.43742	28.92886
R7	145	994.96085	35.07545
	150	57.51755	35.07544
	159	54.60050	35.07543
R8	163	74.86153	50.24258
R9	185	106.24436	53.13788
	199	76.36945	53.13787
R11	229	128.32987	58.66321
R12	252	140.55370	64.25158
R13	265	104.20526	52.47413
	271	143.25843	52.47414
R14	285	58.91760	50.81495
R17	344	90.28312	47.16147
	347	84.60815	47.16146
	351	78.99372	47.16145

On table 3.31., serial number 2, 6, 15, 87, 127, 128, 134, 145, 150, 159, 163, 185, 199, 229, 252, 265, 271, 285, 344, 347, 351 values decreased from 110.37214 to 34.00159, 49.25776 to 34.00158, 137.47720 to 34.00160, 88.98487 to 79.48215, 192.95841 to 28.92888, 74.38393 to 28.92887, 56.43742 to 28.92886, 994.96085 to 35.07545, 57.51755 to 35.07544, 54.60050 to 35.07543, 74.86153 to 50.24258, 106.24436 to 53.13788, 76.36945 to 53.13787, 128.32987 to 58.66321, 140.55370 to 64.25158, 104.20526 to 52.47413, 143.25843 to 52.47414, 58.91760 to 50.81495, 90.28312 to 47.16147, 84.60815 to 47.16146, 78.99372 to 47.16145 sequentially. On the other hand, values from serial number 20 were escalated from 0.17359 to 13.43714.

3.6.4.2. Test of Normality of Fibre Young's Modulus (GPa)

Examination of data's normal distribution is the second required assumption known as Shapiro-Wilk's test for normality as per section 3.2. The 'Sig' value was shown at table 3.31., where it showed all individual values. As of section 3.2., 'Sig' values less than 0.05 were statistically significant. Following these references, R4, R10, R13, R14, R15, R17 were statistically significant, whereas R0, R1, R2, R3, R5, R6, R7, R8, R9, R11, R12, R6 were not statistically significant.

There were three options available for the solution, followed by transforming the dependent variable, using a non-parametric test, and carrying on regardless of reference section 3.2.2. Referencing from section 3.2.2., for fibre young's modulus analysis, carry on regardless was selected since it allowed to mention the violation of result ($p<0.05$). In contrast, referring to section 3.2.2., the other two options (transform the dependent variable, use a non-parametric test) have not been offered to indicate the original result of Shapiro-Wilk's test.

Table 3.32. Test of Normality of Fibre Young's Modulus Data with Significant Value

Fibre Young's modulus	Sig.	Fibre Young's modulus	Sig.	Fibre Young's modulus	Sig.
R0	.083	R6	.115	R12	.051
R1	.120	R7	.068	R13	.029
R2	.191	R8	.104	R14	.020
R3	.443	R9	.071	R15	.025
R4	.022	R10	.038	R16	.089
R5	.327	R11	.570	R17	.015

3.6.4.3. Descriptive Statistics of Fibre Young's Modulus (GPa)

The Descriptive statistics of fibre Young's modulus were featured by providing mean and standard deviation values. In table 3.33., it was found that both mean and standard deviation value were raised starting from R0 to R2. However, it was fallen from R3 to R6 except for R4, where both mean value and standard deviation went down. Again, mean value and standard deviation increased from R7 to R10. However, it was decreased both in mean value and standard deviation from R11 to R16 except R12 sequentially. The last sample was R17 which did not follow the trend of increased or decreased eventually.

Table 3.33. Descriptive Statistics of Fibre Young's Modulus

Sl.	Mean	Std. deviation	Sl.	Mean	Std. deviation
R0	23.2667	6.93898	R9	27.5593	14.04033
R1	27.0081	15.91159	R10	33.9123	20.44463
R2	35.1919	21.15494	R11	30.8164	17.34954
R3	25.4032	15.61761	R12	30.8355	17.46686
R4	29.0860	25.30506	R13	30.7983	18.57894
R5	21.7358	13.15076	R14	19.1394	16.10861
R6	17.7509	9.23265	R15	2.1598	2.05280
R7	20.5417	10.00153	R16	6.5257	5.02272
R8	23.3351	20.66579	R17	31.8562	14.58596

3.6.4.4. Levene Statistic of Fibre Young's Modulus (GPa)

In table 3.34., data was shown by four options known as Based on Mean, Based on Median, Based on Median and with adjusted df and based on trimmed mean for collecting the result from Levene statistic box to decide if the assumption of homogeneity of variances was met or violated as of reference section 3.3.3. From the Levene statistic result box, based on Means was only considered as of reference section 3.3.3. In table 3.33., the based on Mean results showed that 'Sig' value found '.000' treated as statistically significant.

Table 3.34. Levene Statistic of Fibre Young's Modulus Data with Significant Value

Fibre Young's modulus	Levene statistic	df1	df2	Sig.
Based on Mean	6.511	17	342	.000
Based on Median	5.940	17	342	.000
Based on Median and with adjusted df	5.940	17	214.312	.000
Based on trimmed mean	6.384	17	342	.000

3.6.4.5. Robust Tests of Equality of Means of Fibre Young's Modulus (GPa)

Once it was confirmed that violation occurred due to homogeneity of variances from the Levene statistics result, the following part of the SPSS process was evaluated Welch ANOVA's 'Sig' values as reference section 3.3.3. As per Table 3.34., it was found that 'Sig.' value '.000' does not meet the homogeneity of variances. From referencing section 3.3.3., the Welch ANOVA outcome was statistically significant once it produced less than 0.05.

Table 3.35. Robust Tests of Equality of Means Data for Fibre Young's Modulus

	Statistic	**df1**	**df2**	**Sig.**
Welch	36.853	17	124.425	.000

3.6.4.6. Games-Howell Test for Fibre Young's Modulus (GPa)

From the referencing section 3.3.6., after getting the result of robust tests of equality of means where it showed a violation of the assumption of homogeneity of variance, the following processing step was to evaluate the reason of differences through pairwise comparison by groups known as the Games-Howell test. Table 3.36. was produced from the extracted result of the Games-Howell test from appendix III (table 5), where it shows the significant value that was less than 0.05 below:

Table 3.36. Games-Howell Test Significant Value for Fibre Young's Modulus

Sl.	R0	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17
R0		X	X	X	X	X	X	X	X	X	X	X	X	X	X	√(.00)	√(.00)	X
R1			X	X	X	X	X	X	X	X	X	X	X	X	X	√(.00)	√(.00)	X
R2				X	X	X	X	X	X	X	X	X	X	X	X	√(.00)	√(.00)	X
R3					X	X	X	X	X	X	X	X	X	X	X	√(.00)	√(.00)	X
R4						X	X	X	X	X	X	X	X	X	X	√(.01)	X	X
R5							X	X	X	X	X	X	X	X	X	√(.00)	√(.00)	X
R6								X	X	X	X	X	X	X	X	√(.00)	√(.00)	X
R7									X	X	X	X	X	X	X	√(.00)	√(.00)	X
R8										X	X	X	X	X	X	√(.01)	X	X
R9											X	X	X	X	X	√(.00)	√(.00)	X
R10												X	X	X	X	√(.00)	√(.00)	X
R11													X	X	X	√(.00)	√(.00)	X
R12														X	X	√(.00)	√(.00)	X
R13															X	√(.00)	√(.00)	X
R14																√(.01)	X	X
R15																	X	√(.00)
R16																		√(.00)
R17																		

Table 3.36. served as a source of information by providing a distinction between the left side located individual group with the right side placed 17 groups serially as per the reference from section 3.3.6. As per table 3.36., 360 samples were analyzed altogether. 58 samples were found statistical significance where it restrained the value less than 0.05. Alternatively, 302 samples were found non-statistical significance, followed by more than 0.05 value. After the data from table 3.36. was calculated proportionally, it was established that almost 16.1% of sample properties were equivalent while, on the contrary, 83.9% of relatively sample properties were different. From R0 to R17, the statistical significance was available in R15 (16) and R16 (13) as extensive. However, for other samples, just couple and single statistical significant numbers were available, which was featured by R0, R1, R2, R3, R5, R6, R7, R9, R10, R11, R12, R13 (2), R4, R8, R14 (1) orderly.

As per table 3.36., there was statistical significance perceptible from the original sample (R0) to hindmost sample (R17). In comparison with R0, it was found that R1 (27.00%), R2 (35.19%), R3 (25.40%), R4 (29.08%), R5 (21.73%), R6 (17.75%), R7 (20.54%), R8 (23.33%), R9 (27.55%), R10 (33.91%), R11 (30.81%), R12 (30.83%), R13 (30.79%), R14 (19.13%), R17 (31.85%) were statistically the same since the p-value was more than .05 followed by 1.00, .62, 1.00, 1.00, 1.00, .78, 1.00, 1.00, .99, .73, .92, .92, .95, 1.00, .63 respectively. On the other hand, R0 was statistically not the same as R15 (2.15%), R16 (6.52%) where p-value was less than .05 featured by .00, .00 correspondingly.

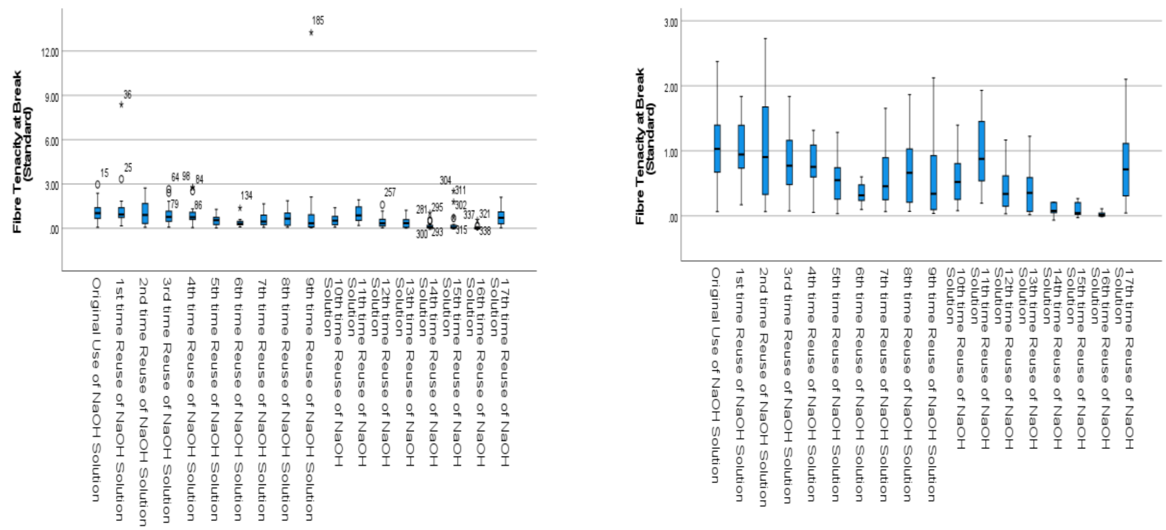
3.6.5. One-way ANOVA of Fibre Tenacity at Break (gf/denier)

The first step of processing the SPSS analysis for fibre tenacity at break was collecting the data from Appendix III (table 1). Then it was followed by conducting analysis and collecting outcomes finally.

3.6.5.1. Data Outlier of Fibre Tenacity at Break (gf/denier)

After analysis of data, it was found that there was various data outlier available at the output.

Figure 3.8. a. Fibre Tenacity at Break with Outlier; b. Fibre Tenacity at Break after Fixing the Outlier



(a) (b)

At the output, it is seen that altogether it produced 22 outliers which are available starting from R0, R1, R3, R4, R6, R9, R12, R14, R15, R16 except for R17. Outlier is available in 2.96 for RO, 3.33, 8.37 for R1, 2.65, 2.40 for R3, 2.51, 2.74, 2.77 for R4, 1.37 for R6, 13.25 for R9, 1.59 for R12, 0.52, 0.49, 0.54, 1.03 for R14, serial number 0.75, 2.51, 1.79, 0.68 for R15, 0.14, 0.14, 0.55 for R16.

As mentioned in section 3.1.1., there are three reasons for data outlier: data entry errors, measurement errors, and genuinely unusual value. Out of these three reasons, the first two reasons were not responsible for the data outlier of Fibre Tenacity at Break since it was verified and ensured accordingly. Thus, it was obvious that produced outlier was considered a genuinely unusual value, which was known as the last reason.

For the solution, it has two options: keeping the outlier and removing this outlier as per section 3.1.2. In this research, Keeping the outlier was chosen as the solution. It was followed by restoration of original value through a round-up and round-down process, as mentioned in section 3.1.2. The process is explained by the table stated below:

Table 3.37. Outlier of Fibre Tenacity at Break During Extraction Process.

Sl. No.	Outlier serial number	Original value	Modified value	Sl. No.	Outlier serial number	Original value	Modified value
R0	15	2.96978	2.37444	R14	281	0.52799	0.21093
R1	25	3.33813	1.83749		293	0.49420	0.21092
	36	8.37605	1.83750		295	0.54773	0.21094
R3	64	2.65439	1.83656		300	1.03105	0.21095
	79	2.40119	1.83655	R15	302	0.75856	0.26750
R4	84	2.51737	1.31655		304	2.51962	0.26752
	86	2.74943	1.31656		311	1.79425	0.26751
	98	2.77840	1.31657		315	0.68985	0.26749
R6	134	1.37526	0.60097	R16	321	0.14026	0.11054
R9	185	13.25313	0.99915		337	0.14933	0.11055
R12	257	1.59517	1.16707		338	0.55772	0.11056

The outlier data is featured by highest and lowest value by data representation above table 3.37. The listed outlier was adjusted according to necessity through the roundup and rounded down concept mentioned on page 3. By following the theory from page 3, serial number 15 (R0), 25 (R1), 36 (R1), 64 (R3), 79 (R3), 84 (R4), 86 (R4),98 (R4), 134 (R6), 185 (R9), 257 (R12), 281 (R14), 293 (R14), 295 (R14), 300 (R14), 302 (R15), 304 (R15), 311 (R15), 315 (R15), 321 (R16), 337 (R16), 338 (R16) is round down from 2.96978 to 2.37444, 3.33813 to 1.83749, 8.37605 to 1.83750, 2.65439 to 1.83656, 2.40119 to 1.83655, 2.51737 to 1.31655, 2.74943 to 1.31656, 2.77840 to 1.31657, 1.37526 to 0.60097, 13.25313 to 0.99915, 1.59517 to 1.16707. As soon as data was modified through this process, it was placed under SPSS software again, and then the end result finally produced data without the outlier.

3.6.5.2. Test of Normality of Fibre Tenacity at Break (gf/denier)

As of reference from section 3.2., Shapiro-Wilk's test for normality is the primary required assumption test to check the normal distribution of data. It produced every individual value, starting from the original solution to the 17th-time reuse NaOH solution. Throughout 18 samples, there was an availability of significant values of R7, R8, R9, R12, R15 and R16 less than 0.05 (P-value), accompanied by .032, .042, .003, .043 .001, .000. The other sample's significant value was more than 0.05 (P-value), known as statistical non-significant samples.

There are three options to solve this issue: transform the dependent variable, use a non-parametric test, and carry on regardless of referencing from section 3.2.2. Out of these three options, for fibre tenacity at break, the carry-on regardless option is applied since it allowed to mention the violation of result ($p<0.05$) as of reference section 3.2.2. In contrast, referring to section 3.2.2., the other two options (transform the dependent variable, use a non-parametric test) have not been offered to indicate the original result of Shapiro-Wilk's test.

Table 3.38. Test of Normality of Fibre Tenacity at Break Data with Significant Value

Fibre tenacity at break	**Sig.**	**Fibre tenacity at break**	**Sig.**	**Fibre tenacity at break**	**Sig.**
R0	.285	R6	.255	R12	.043
R1	.229	R7	.032	R13	.067
R2	.068	R8	.042	R14	.062
R3	.184	R9	.003	R15	.001
R4	.243	R10	.282	R16	.000
R5	.723	R11	.226	R17	.081

3.6.5.3. Descriptive Statistics of Fibre Tenacity at Break (gf/denier)

On Descriptive statistics of fibre tenacity at break, results were produced along with mean value and standard deviation from analyzing through 360 samples. Data from mean value and standard deviation are represented through a table which is mentioned below:

Table 3.39. Descriptive Statistics of Fibre Tenacity at Break

Sl.	Mean	Std. deviation	Sl.	Mean	Std. deviation
R0	1.1153	.60271	R9	.5995	.61963
R1	1.0294	.49923	R10	.5533	.36532
R2	1.0786	.85039	R11	1.0019	.53030
R3	.8650	.54990	R12	.4336	.33842
R4	.7897	.39246	R13	.3955	.33730
R5	.5438	.33655	R14	.1014	.08698
R6	.3410	.16259	R15	.0992	.10929
R7	.5960	.44038	R16	.0293	.04500
R8	.7255	.54293	R17	.7912	.59676

In the table above, it was found that the mean value was lower down from RO to R6 except for R1. Standard deviations were also followed the same pathway starting from R0 to R6, excluding R1 and R2. Sample R11 again followed this trend to R16, where it was raised down both for mean and standard deviation values. However, samples R7, R8, R9, R10, and R17 have maintained ups and down trends for mean value and standard deviation.

3.6.5.4. Levene Statistic of Fibre Tenacity at Break (gf/denier)

As per reference of section 3.3.3., Based on Mean, Based on Median, Based on Median and with adjusted df and based on trimmed mean are four parts of data produced at Levene statistic box. Based on Mean is only computable out of these four data options for Levene statistics of fibre Tenacity at Break as per the reference from section 3.3.3. From the column of Based on Mean, it was found that the ‘Sig’ value is ‘.000’, which is recognized as a violation of the homogeneity of variances.

Table 3.40. Levene Statistic of Fibre Tenacity at Break Data with Significant Value

Fibre tenacity at break	Levene statistic	df1	df2	Sig.
Based on Mean	8.588	17	342	.000
Based on Median	6.881	17	342	.000
Based on Median and with adjusted df	6.881	17	201.358	.000
Based on trimmed mean	8.255	17	342	.000

3.6.5.5. Robust Tests of Equality of Means of Fibre Tenacity at Break (gf/denier)

Once after finding the Levene statistic result of fibre tenacity at break violated the homogeneity of variances, the next stage is to check outcome at ‘Sig.’ column of the Robust Tests of Equality of Means as per reference of section 3.3.5. Table 3.41 mentioned below shows that the ‘Sig.’ value was noted as ‘.000’, which was statistically significant.

Table 3.41. Robust Tests of Equality of Means Data for Fibre Tenacity at Break

	Statistic	df1	df2	Sig.
Welch	32.080	17	124.698	.000

3.6.5.6. Games-Howell Test for Fibre Tenacity at Break (gf/denier)

After getting a result from the robust test of equality of means which was featured by a violation of the assumption of homogeneity of variance, the next level of the exam was to verify its cause as per section 3.3.6. The name of this test is the Games-Howell test, followed by running pairwise differentiation to find the rationale for not meeting the homogeneity of variance. The test result was produced by separating significant values from appendix III (table 6), mentioned in table 3.42.

Table 3.42. Games-Howell Test Significant Value for Fibre Tenacity at Break

Sl.	**R0**	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**	**R11**	**R12**	**R13**	**R14**	**R15**	**R16**	**R17**
R0		X	X	X	X	X	√(.00)	X	X	X	X	X	√(.01)	√(.00)	√(.00)	√(.00)	√(.00)	X
R1			X	X	X	X	√(.00)	X	X	X	X	X	√(.01)	√(.00)	√(.00)	√(.00)	√(.00)	X
R2				X	X	X	X	X	X	X	X	X	X	X	√(.00)	√(.00)	√(.00)	X
R3					X	X	√(.03)	X	X	X	X	X	X	X	√(.00)	√(.00)	√(.00)	X
R4						X	√(.00)	X	X	X	X	X	X	X	√(.00)	√(.00)	√(.00)	X
R5							X	X	X	X	X	X	X	X	√(.00)	√(.00)	√(.00)	X
R6								X	X	X	X	√(.00)	X	X	√(.00)	√(.00)	√(.00)	X
R7									X	X	X	X	X	X	√(.00)	√(.00)	√(.00)	X
R8										X	X	X	X	X	√(.00)	√(.00)	√(.00)	X
R9											X	X	X	X	X	X	√(.04)	X
R10												X	X	X	√(.00)	√(.00)	√(.00)	X
R11													√(.02)	√(.01)	√(.00)	√(.00)	√(.00)	X
R12														X	√(.02)	√(.02)	√(.00)	X
R13															X	X	√(.00)	X
R14																X	X	√(.00)
R15																	X	√(.00)
R16																		√(.00)
R17																		

From the reference of section 3.3.6., at the left side of the table, a sequential order was maintained for the group with the individual comparison, followed by placing 17th every alternative group on the right side. From table 3.42., statistical significance was found from the highest number to the lowest number, which is categorized by R16 (15 times), R14, R15 (13 times), R6 (8 times), R0, R1, R11 (6 times), R12 (5 times), R3, R4, R13 (4 times), R2, R5, R7, R8, R10, R17 (3 times), R9 (1 times). In terms of 360 samples altogether, 256 samples have a value more than 0.05, while 104 samples have a value less than 0.05. It produced data of just about 70% with non-significant whereas 30% of data was significant in Fibre Tenacity at break research analysis.

From table 3.42., the availability of statistical significance showed detectibly from the very first sample (R0) to the rearmost sample (R17). In comparison with R0 (1.11%), there was no statistically significant available from R1 (1.02%), R2 (1.07%), R3 (.86%), R4 (.78%), R5 (.54%), R7 (.59%), R8 (.72%), R9 (.59%), R10 (.55%), R11 (1.00%) as well as R17 (.79%) since the significant value was more than .05, followed by 1.00, 1.00, .99, .83, .06, .21, .77, .43, .08, 1.00, .95 respectively. However, statistical difference was available on R12 (.43%), R13 (.39%), R14 (.10%), R15 (.09%), R16 (.02%) where p-value was less than .05, featured by .43, .39, .10, .09, .02 correspondingly.

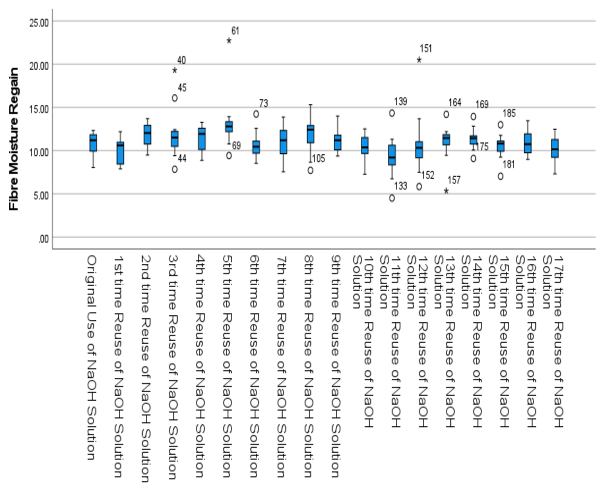
3.7. One-way ANOVA of Fibre Moisture Regain (%)

From the table of Appendix IV (table 1), data was gathered for deciding fibre Moisture Regain. It was followed by running SPSS software. The result of the data was collected and evaluated eventually.

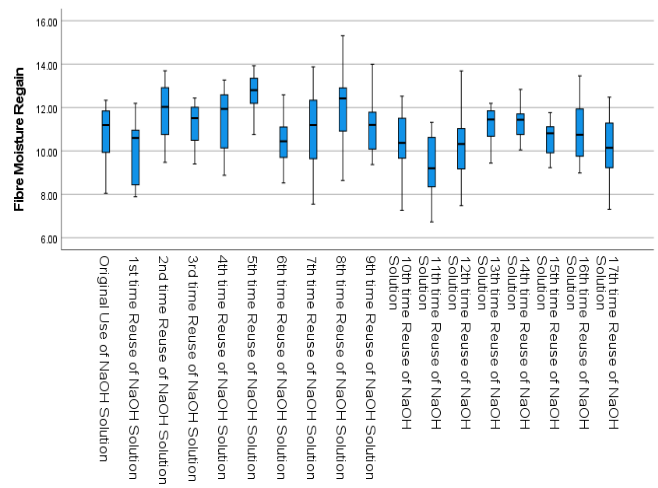
3.7.1. Data Outlier of Fibre Moisture Regain (%)

On fibre moisture regain analysis, data outlier was found after input of original data.

Figure 3.9. a. Fibre Moisture Regain with Outlier, b. Fibre Moisture Regain after Fixing the Outlier



(a)



(b)

From the result of SPSS analysis for fibre moisture regain, it was found that the outlier was not available from R0 to R2 and R4, R7, R9, R16, R17. However, the outlier was produced at R3 for 19.30, 7.84, 16.08, R5 for 22.72, 9.42, R6 for 14.23, R8 for 7.71, R11 for 4.50, 14.34, R12 for 20.50, 5.84, R13 for 5.34, 14.19, R14 for 13.94, 9.09, R15 for 7.03, 12.99.

According to section 3.1.1., the outlier was produced due to data entry errors, measurement errors, and genuinely unusual values for fibre Moisture Regain. Data was evaluated comprehensively to see any outlier responsible through data entry errors, and measurement errors. Soon after establishing that data entry errors and measurement errors were not the reason for data outlier, the last option was genuinely unusual values.

In terms of seeking a solution for outlier at fibre moisture regain, keeping this outlier and removing the outlier were two options as per section 3.1.2. The 'Keeping this outlier' option was selected for fibre moisture regain, where it worked through re-establishing outlier value for solution purposes. At this option, rounding up and rounding down the most extreme and less extreme values was applied. As per this method, table 3.43. was categorized by replacing the old original value with a new modified value.

Table 3.43. Outlier of Fibre Moisture Regain During Extraction Process.

Solution number	Outlier serial number	Fibre moisture regain (%)	
		Original value	Modified value
R3	40	19.30926217	12.03
	44	7.843137255	9.40
	45	16.08222491	12.02
R5	61	22.72727273	13.93
	69	9.427609428	10.76
R6	73	14.23220974	12.59
R8	105	7.719928187	8.64
R11	133	4.508196721	6.73
	139	14.34108527	11.32
R12	151	20.50359712	13.69
	152	5.845181675	7.48
R13	157	5.348460292	9.44
	164	14.19753086	11.92
R14	169	13.94557823	12.84
	175	9.090909091	10.05
R15	181	7.038123167	9.23
	185	12.99435028	11.77

From the table 3.43., it was found that outlier values were decreased for serial number 40, 45, 61, 73, 139, 151, 164, 169, 185 which followed by 19.30926217 to 12.03, 16.08222491 to 12.02, 22.72727273 to 13.93, 14.23220974 to 12.59, 14.34108527 to 11.32, 20.50359712 to 13.69, 14.19753086 to 11.92, 13.94557823 to 12.84, 12.99435028 to 11.77 sequentially.

On the other hand, outlier values by serial numbers 44, 69, 105, 133, 152, 157, 175, 181 raising from 7.843137255 to 9.40, 9.427609428 to 10.76, 7.719928187 to 8.64, 4.508196721 to 6.73, 5.845181675 to 7.48, 5.348460292 to 9.44, 9.090909091 to 10.05, 7.038123167 to 9.23 correspondingly.

3.7.2. Tests of Normality of Moisture Regain (%)

The referencing section 3.2. mentioned that Shapiro-Wilk's test for normality is the essential test to know about the normal distribution of data considered as the secondary part of the assumption. Starting from R0 to R17, each sample produced an individual 'Sig' value at Shapiro-Wilk's test for normality. In table 3.43., it was found that all samples' values were more than 0.05. As per reference of section 3.2.1., more than 0.05 value is considered non statistically significant. Thus, as per table 3.44., all samples' data were normally distributed.

Table 3.44. Test of Normality of Fibre Moisture Regain (%) Data with Significant Value

Fibre moisture regain (%)	Sig.	Fibre moisture regain (%)	Sig.
R0	.106	R9	.642
R1	.111	R10	.899
R2	.654	R11	.368
R3	.101	R12	.355
R4	.203	R13	.060
R5	.181	R14	.416
R6	.545	R15	.133
R7	.932	R16	.403
R8	.247	R17	.942

3.7.3. Descriptive Statistics of Fibre Moisture Regain (%)

The descriptive statistics of fibre moisture regain analysis were organized through a table followed by mean and standard deviation values. In table 3.45, the trend of data was followed by ups and downs, starting from R0 to R2 as well as R6 to R7 and R15 to R17. However, there was a trend of increasing the mean value starting from samples R3 to R5 and R12 to R14. Additionally, a flow of decreasing mean was followed by samples R8 to R10. Notably, an ups and down trend was followed by a standard deviation value.

Table 3.45. Descriptive Statistics of Fibre Moisture Regain

Sl.	Mean	Std. deviation	Sl.	Mean	Std. deviation
R0	10.7447	1.42322	R9	11.1387	1.31115
R1	10.0453	1.46391	R10	10.3420	1.50275
R2	11.8110	1.40770	R11	9.2974	1.59761
R3	11.1702	1.04374	R12	10.3314	1.98237
R4	11.4339	1.46193	R13	11.1451	.92334
R5	12.6416	1.05647	R14	11.3609	.90095
R6	10.5094	1.22798	R15	10.6162	.88163
R7	10.9634	1.98295	R16	10.9980	1.46203
R8	12.0889	2.09035	R17	10.1854	1.48566

3.7.4. Levene Statistic of Fibre Moisture Regain (%)

Data was gathered from the Levene statistics box, where it produced four options of result followed by Based on Mean, Based on Median, Based on Median and with adjusted df and based on trimmed mean as of section 3.3.3. From reference to section 3.3.3., out of four result options, 'Based on Mean' is only countable, followed by producing 'Sig' value. As of table 3.46., the 'Sig' value was '.189'. As per references page 8, the 'Sig' value is more than 0.05, counted as meeting the homogeneity of variances.

Table 3.46. Levene Statistic of Fibre Moisture Regain Data with Significant Value

Fibre moisture regain	Levene statistic	df1	df2	Sig.
Based on Mean	1.310	17	198	.189
Based on Median	1.042	17	198	.415
Based on Median and with adjusted df	1.042	17	153.347	.417
Based on trimmed mean	1.296	17	198	.198

3.7.5. ANOVA Table of Fibre Moisture Regain (%)

Since the Levene statistics result showed the homogeneity of variance met where the 'Sig' value was more than 0.05, the next part evaluated the ANOVA table 'Sig' value as a reference from section 3.3.4. As per table 3.47., it was found that the ‘Sig’ value ‘.000’, which was considered statistically significant.

Table 3.47. ANOVA Table Data for Fibre Moisture Regain

Fibre moisture regain	**Sum of squares**	**df**	**Mean square**	**F**	**Sig.**
Between groups	127.889	17	7.523	3.606	.000
Within groups	413.031	198	2.086		
Total	540.920	215			

3.7.6. Tukey HSD Test for Fibre Moisture Regain (%)

When the ANOVA table produced a result where the ‘sig’ value was found less than 0.05, it confirmed a violation of the variance assumption through the reference of section 3.3.6. In reference to section 3.3.6., the subsequent stage was examined through the Tukey HSD test, where it featured by finding a statistically significant value from utilizing groupwise comparison. The result of the Tukey HSD test was found in appendix IV (table 2), where significant value was provided through table 3.48., below:

Table 3.48. Tukey HSD Test Significant Value for Fibre Moisture Regain

Sl.	**R0**	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**	**R11**	**R12**	**R13**	**R14**	**R15**	**R16**	**R17**
R0		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
R1			X	X	X	√(.00)	X	X	X	X	X	X	X	X	X	X	X	X
R2				X	X	X	X	X	X	X	X	√(.00)	X	X	X	X	X	X
R3					X	X	X	X	X	X	X	X	X	X	X	X	X	X
R4						X	X	X	X	X	X	√(.03)	X	X	X	X	X	X
R5							√(.03)	X	X	X	√(.01)	√(.00)	√(.01)	X	X	X	X	√(.00)
R6								X	X	X	X	X	X	X	X	X	X	X
R7									X	X	X	X	X	X	X	X	X	X
R8										X	X	√(.00)	X	X	X	X	X	X
R9											X	X	X	X	X	X	X	X
R10												X	X	X	X	X	X	X
R11													X	X	X	X	X	X
R12														X	X	X	X	X
R13															X	X	X	X
R14																X	X	X
R15																	X	X
R16																		X
R17																		

Referencing from section 3.3.6., in table 3.48., the data was organized in a way where the left side data known as individual groups was compared with right side data designated as 17 groups sequentially. From table 3.48., out of 216 samples, only 18 are statistically significant, whereas the rest of 198 samples are nonsignificant. Almost 92% of the fibre properties were analogous, although next to 8% of properties were unrelated. By analysis of table 3.48., it showed that the most statistical significance was available at R5 (6 times), R11 (4 times). However, the least statistical significance was found sequentially at R1, R2, R4, R6, R8, R10, R12, and R17 (1 time).

By referencing table 3.48, although there was no statistical significance available at original sample (R0), it was observable from the first-time reuse sample (R1) to the final sample (R17). In differentiation with R0 (10.74%), it was seen that R1 (10.04%), R2 (11.81%), R3 911.17%), R4 (11.43%), R5 (12.64%), R6 (10.50%), R7 (10.96%), R8 (12.08%), R9 (11.13%), R10 (10.34%), R11 (9.29%), R12 (10.33%), R13 (11.14%), R14 (11.36%), R15 (10.61%), R16 (10.99%), R17 (10.18%) were statistically the same where p-value was more than .05 featured by .99, .93, 1.00, .99, .12, 1.00, 1.00, .69, 1.00, 1.00, .56, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00 respectively.

Chapter 4: Conclusion

4.1. Overall Summary of Finding

The overall result are summarized in Table 4.1. and 4.2., where the outcome of different properties was organized as sequentially.

4.1.1. Summary of Finding for Uninterrupted Acceptable Reuse of Alkali Solution

Table 4.1. Uninterrupted Acceptable Reuse of Alkali Solution Range for Different Fibre Properties with Original Sample (R0) Comparison

Sl.	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**	**R11**	**R12**	**R13**	**R14**	**R15**	**R16**	**R17**
Fibre yield (%)	√	√															
Fibre tenacity at break	√	√	√	√	√												
Fibre load at break	√	√	√	√	√												
Fibre tensile strain at break	√	√	√	√	√	√	√	√									
Fibre contact angle	√	√	√	√	√	√	√	√	√	√	√						
Fibre tensile stress at break	√	√	√	√	√	√	√	√	√	√	√	√	√				
Fibre Young's modulus	√	√	√	√	√	√	√	√	√	√	√	√	√	√			
Fibre moisture regain	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√

In Table 4.1., the data was presented for finding uninterrupted acceptable reuse of alkali solution range for individual fibre properties. It is featured by comparing the original sample (R0) with the reuse sample by scaling unique properties until disrupted by a significant value less than .05. In terms of usages of fibre yield (%), the acceptable range started from R1 to R2. Moreover, Fibre tenacity at break and load at break range started from R1 till R5 for the required application. In addition, the fibre contact angle showed the span starting from R1 to R11. Furthermore, tensile stress at break produced a result where it plunged from R1 to R13 comparing contact angle. However, modulus thrusted one more reusage of 14th times (R14) from R1. Finally, moisture regain showed complete unchanged properties while using alkali solution from 1st-time reuse to 17th-time reuse. Considering all the properties, the maximum of 2nd-time reusages is recommended without changing any properties.

4.1.2. Summary of Finding for Interrupted Acceptable Reuse of Alkali Solution

Table 4.2. Interrupted Acceptable Reuse of Alkali Solution Range for Different Fibre Properties with Original Sample (R0) Comparison

Properties	**Uninterrupted sample compared to R0**	**Sig. sample (higher mean value) compared to R0**	**Sig. sample (lower mean value) compared to R0**	**R0/R17**	**Decision**
Fibre yield (%)	Up to R2	R3, R4, R12, R14, R15	N/A	NS (R0=R17)	R1-R17
Fibre tenacity at break	Up to R5	N/A	R6, R12-R16	NS (R0=R17)	R1-R5, R7-R11, R17
Fibre load at break	Up to R5	N/A	R6, R12-R16	NS (R0=R17)	R1-R5, R7-R11, R17
Fibre tensile strain at break	Up to R8	R9, R14-R16,	N/A	NS (R0=R17)	R1-R17
Fibre contact angle	Up to R11	R12, R14, R15	N/A	NS (R0=R17)	R1-R11, R13, R16-R17
Fibre tensile stress at break	Up to R13	N/A	R14-R16	NS (R0=R17)	R1-R13, R17
Fibre Young's modulus	Up to R14	N/A	R15-R16	NS (R0=R17)	R1-R14, R17
Fibre moisture regain (%)	Up to R17	N/A	N/A	NS (R0=R17)	R1-R17

In Table 4.2., the data was organized to provide the information of maximum usage of individual fibre alkali solutions for common industrial applications. It is followed by identifying the highest range of interrupted acceptable reuse of alkali solution by comparing higher and lower mean values of specific solutions with the original solution (R0). Out of eight fibre properties, only contact angle require a lower mean value, whereas the other seven fibre properties, including fibre yield (%), fibre tenacity at break, fibre tensile strain at break, fibre load at break, fibre tensile stress at break, fibre young's modulus, fibre moisture regain essential to have higher mean value for any standard industrial applications. Starting with fibre yield (%), it was found that interrupted alkali solution of R3, R4, R12, R14, R15 has a higher mean value compared to R0. At the same time, it was also seen that the alkali solution from R1 to R2, R5 to R11, R16 to R17 are non-statistically significant with R0. As a result, using up to maximum alkali solution R17 for fibre yield (%) for industrial application is recommended. For fibre tenacity at break, the interrupted alkali solution starting from R12 to R16 showed a lower mean value as per table 4.2. Therefore, reuse alkali solutions from R1 to R11 and R17 are non-statistically significant with R0 and suggested for fibre tenacity at break since a lower mean value is not recommended for any potential application of industrial usage. In fibre load at break, there was a lower significant mean value found for R6, R12 to R16. Thus, the industrial usage of fibre load at break, R1 to R5, R7 to R11 and R17, is recommended as non-statistical values except R6, R12 to R16. At Fibre Tensile Strain at Break, compared to R0, it was seen that interrupted alkali solution of R9, R14 to R16 has a higher mean value, which is recommended in terms of industrial usage for fibre tensile strain at break. Thus, for fibre tensile strain at break, 17th time reuse of alkali solution is treated as the maximal range where non-statistically significant data is found from R1 to R8, R10 to R13 and R17. Although samples R12, R14, and R15 have been identified as interrupted alkali solutions for fibre contact angle analysis, they are not acceptable for industrial application due to their higher mean value than R0. For this reason, it is suggested to use from R1 to R11, R13, R16 to R17, where all of them were found non-statistically significant for fibre contact angle. In terms of fibre tensile stress at break, the significant mean value was lower from R14 to R16. Therefore, excluding R15 to R16, R1 to R13 and R17 is preferred for any industrial application due to being non-statistically significant. For fibre young's modulus, statistically significant was found from R15 to R16 with a lower mean value. Consequently, R1 to R14 are only allowed for any industrial application due to its non-statistically significant apart from R15 to R16. For fibre moisture regain analysis, statistically significant were not available for any samples. As a result, all of the samples are suggested for any industrial application.

4.1.3. Decision Making by Python Computer Programming

The decision making from python computer programming was presented in table 4.3., which featured producing results for fibre single and multiple property combinations consecutively.

Table 4.3. Reuse Time for Single and Multiple Combination of Fibre Properties

Property & ID	Single Property		Combination of 2 properties (max. combination: 28)		Combination of 3 properties (max. combination: 56)		Combination of 4 properties (max. combination: 70)		Combination of 5 properties (max. combination: 56)		Combination of 6 properties (max. combination: 28)		Combination of 7properties (max. combination: 8)	
	Prop-erty	Max. reuse	Comb.	Max. reuse	Comb.	Max. reuse	Comb.	Max. reuse	Comb.	Max. reuse	Comb.	Max. reuse	Comb.	Max. reuse
1 - Yield (%)	1	R17	1/2	R2	1/2/5	R2	1/2/5/7	R2	1/2/4/5/7	R2	2/1/3/4/5/6	R2	2/1/3/4/5/6/7	R2
2 - CA	2	R17	1/5	R2	1/5/7	R2	2/8/5/7	R5	1/3/5/7/8	R2	2/1/3/4/5/7	R2	2/1/3/4/5/6/8	R2
3 - LAB	3	R5	5/6	R8	1/5/6	R2	1/4/8/7	R2	1/2/5/6/7	R2	2/1/3/4/5/8	R2	2/1/3/4/5/8/7	R2
4 - MR	4	R17	5/7	R13	2/5/7	R11	1/4/6/7	R11	1/3/5/6/7	R2	2/1/3/4/6/7	R2	2/1/3/4/8/6/7	R2
5 - Stress	5	R13	6/7	R13	2/6/7	R13	1/5/4/7	R2	2/3/5/7/8	R5	2/1/3/4/6/8	R2	2/1/3/8/5/6/7	R2
6 - Strain	6	R17	4/8	R5	4/5/8	R5	4/5/6/8	R5	1/4/5/6/7	R2	2/1/3/5/6/7	R2	2/1/8/4/5/6/7	R2
7 - Modulus	7	R14	4/5	R13	4/5/7	R13	4/5/7/8	R5	4/5/6/7/8	R5	2/7/3/5/6/8	R5	2/8/3/4/5/6/7	R5
8 - Tenacity	8	R5	8/6	R5	5/6/8	R5	1/5/6/7	R2	1/5/6/7/8	R2	2/1/4/5/6/7	R2	8/1/3/4/5/6/7	R2
Eight properties						1/2/3/4/5/6/7/8								R2

In Table 4.3., data was represented through single and multiple combinations of fibre properties to identify the maximum potential usage of alkali reused solution for any industrial application. Individual fibre property was identified through numerical digit stated as 1 for Fibre yield (%), 2 for fibre contact angle, 3 for fibre load at break, 4 for fibre moisture regain (%), 5 for fibre stress at break, 6 for fibre strain at break, 7 for fibre Young's modulus, 8 for fibre tenacity at break. Combination of the property was featured as starting from single property to eight properties combination, followed by single property (1P), combination of 2 properties (2P), combination of 3 properties (3P), combination of 4 properties (4P), combination of 5 properties (5P), combination of 6 properties (6P), combination of 7 properties (7P), combination of 8 properties (8P).

It was found that for single property (1P), the reuse time can be up to R17 for 1, 2, 4, and 6, R5 for property 3 and 8, R13 for property 5, and finally, R14 for property 7. For two properties combination (2P), there are 28 combinations, however, only 8 combinations are shown in Table 4.3, which are R2 for 1/2 and 1/5, R8 for 5/6, R13 for 5/7 and 4/5, and R13 for 6/7. Similarly, there are 56 combinations for three properties, 70 for four properties, 56 for five properties, 28 for six properties, and eight for seven properties for which 8 combinations are shown in Table 4.3. There is only one combination for eight properties (1/2/3/4/5/6/7/8) and the reuse time is R2.

4.2. Problems with Research

The problems of the research are observed at different stages. Although extraction of samples was finished without any interruption for this research, however, accessing the limited inner space of the water bath machine was quite challenging. Alkali preparation and refill is one of the most tedious and time-wasting phenomena during the extraction process. A lack of measurement of the extracted sample purification was seen soon after finishing the sample washing process since there was no specific parameter to check. As a result, it was uncertain whether akali and liquefied elements were present after cleansing individual samples. At the drying stage for each individual extracted sample, it was placed open inside of the room. However, the whole drying process was very time-consuming. For fibre contact angle analysis, before getting the measurement of the diameter of 180 individual fibre manually balanced and placed into a 'Bioquant Analyzer.'

4.3. Future Work

It is recommended to use an updated water bath machine with more inner space for further research work. It is suggested to prepare a minimum amount of additional alkali before starting the research work to save time and use it constructively. In terms of checking whether the sample is purified or not after extraction, there is a manual technique to check thorough colour change during washing time. At the time of rigorous washing of the sample, there is a stage when the chemical colour changes towards water colour, then it is considered as samples are out of chemical. For expediting the sample drying process, woven might be considered an alternative machine by placing its function at a certain temperature. For balancing the fibre to run contact angle analysis, it is recommended to use the Digital Crimp Tester, which is available at the textile lab (W260), located at the Duff Roblin Building, University of Manitoba.

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Appendix I

Table 1. Fibre Yield (%) Individual Samples from Re-use NaOH

Time with sample ID (left to right)	Number of uses	Yield (%) of individual sample												Average of yield (%)
		1	2	3	4	5	6	7	8	9	10	11	12	
3 Hrs (sample ID 106-117)	1st time Use (original Solution)	25.83%	26.51%	25.98%	29.13%	34.45%	25.85%	31.05%	23.61%	34.16%	25.97%	20.31%	25.47%	27.36%

3 Hrs (sample ID 118-129)	1st time reuse	33.79%	24.18%	30.24%	32.09%	31.58%	33.79%	22.33%	29.49%	32.21%	26.06%	33.59%	31.51%	30.07%
3 Hrs (sample ID 130-141)	2nd time reuse	33.04%	28.99%	31.83%	34.39%	31.29%	34.88%	36.64%	36.99%	30.80%	36.88%	28.99%	30.66%	32.95%
3 Hrs (sample ID 142-153)	3rd time reuse	38.03%	40.09%	35.11%	32.11%	36.15%	40.03%	37.95%	32.93%	38.91%	40.03%	33.71%	35.96%	36.75%
3 Hrs (sample ID 154-165)	4th time reuse	27.15%	30.81%	31.81%	32.99%	36.15%	35.97%	35.74%	35.31%	36.15%	30.00%	35.09%	31.93%	33.26%

3 Hrs (sample ID 166-177)	5th time reuse	32.64%	29.21%	33.96%	35.85%	32.53%	29.96%	30.25%	29.91%	28.31%	29.26%	26%	27.59%	30.46%
3 Hrs (sample ID 178-189)	6th time reuse	27.40%	25.96%	27.16%	27.25%	27.31%	27.88%	29.17%	25.01%	25.83%	22.91%	25.42%	18.28%	25.79%
3 Hrs (sample ID 190-201)	7th time reuse	25.15%	24.69%	27.96%	28.12%	30.17%	28.42%	30.49%	29.76%	33.53%	26.93%	31.22%	29.64%	28.84%
3 Hrs (sample ID 202-213)	8th time reuse	30.69%	28.44%	25.49%	27.77%	28.01%	26.72%	27.21%	30.96%	27.18%	23.49%	27.23%	26.95%	27.51%

3 Hrs (sample ID 214-225)	9th time reuse	36.46%	36.29%	33.21%	28.78%	31.45%	34.66%	30.31%	33.76%	28.25%	31.34%	27.43%	31.16%	31.93%
3 Hrs (sample ID 226-237)	10th time reuse	30.36%	34.54%	32.44%	27.46%	31.30%	42.61%	31.55%	29.06%	34.39%	33.05%	30.98%	30.31%	32.34%
3 Hrs (sample ID 238-249)	11th time reuse	25.29%	28.18%	33.20%	25.14%	27.39%	30.08%	25.46%	25.21%	27.09%	23.48%	27.58%	26.45%	27.05%
3 Hrs (sample ID 250-261)	12th time reuse	29.04%	32.05%	33.53%	31.46%	34.05%	35.22%	31.74%	31.45%	35.06%	34.04%	34.57%	33.94%	33.01%

3 Hrs (sample ID 262-273)	13th time reuse	32.23%	31.30%	31.37%	32.77%	35.21%	31.78%	31.86%	31.56%	29.49%	31.72%	31.66%	29.75%	31.73%
3 Hrs (sample ID 274-285)	14th time reuse	32.86%	29.22%	31.24%	33.42%	33.43%	34.47%	34.65%	34.25%	36.16%	30.19%	34.59%	31.39%	32.99%
3 Hrs (sample ID 286-297)	15th time reuse	36.49%	37.61%	35.41%	36.11%	36.82%	38.04%	36.03%	34.39%	34.08%	34.81%	39.54%	29.56%	35.74%
3 Hrs (sample ID 298-309)	16th time reuse	31.78%	32.06%	29.83%	32.29%	31.87%	30.83%	33.78%	30.89%	33.99%	33.98%	33.92%	35.06%	32.52%

3 Hrs (sample ID 310-321)	17th time reuse	31.38%	29.24%	33.62%	32.50%	30.04%	36.13%	32.01%	34.33%	31.02%	33.22%	32.69%	31.75%	32.33%

Table 2. Fibre yield (%) with Mean and Standard Deviation from Re-use NaOH

NaOH	**Yield (%)**	**NaOH**	**Yield (%)**	**NaOH**	**Yield (%)**	**NaOH**	**Yield (%)**
R0	27.36±3.98	R5	30.46±2.69	R10	32.34±3.66	R14	32.99±1.98
R1	30.07±3.69	R6	25.79±2.74	R11	27.05±2.49	R15	35.74±2.39
R2	32.94±2.83	R7	28.84±2.41	R12	33.01±1.78	R16	32.52±1.54
R3	36.75±2.73	R8	27.51±1.92	R13	31.73±1.38	R17	32.33±1.80
R4	33.25±2.82	R9	31.923±2.88				

Table 3. Games-Howell Test Data for Fibre Yield (%)

Sl.	RO	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17	V
R0	*	.95	.07	.00	.04	.76	1.00	.99	1.00	.24	.23	1.00	.03	.13	.04	.00	.06	.09	Sig.
R1	.95	*	.81	.00	.69	1.00	.25	1.00	.61	.99	.99	.49	.63	.96	.67	.01	.81	.90	Sig.
R2	.07	.81	*	.19	1.00	.78	.00	.08	.00	1.00	.99	.00	1.00	.99	1.00	.21	1.00	1.00	Sig.
R3	.00	.00	.19	*	.30	.00	.00	.00	.00	.04	.00	.00	.07	.00	.08	1.00	.02	.01	Sig.
R4	.04	.69	1.00	.30	*	.62	.00	.04	.00	.99	.98	.00	1.00	.93	1.00	.33	1.00	1.00	Sig.
R5	.76	1.00	.78	.00	.62	*	.02	.98	.11	.99	.99	.08	.47	.95	.54	.00	.72	.87	Sig.
R6	1.00	.25	.00	.00	.00	.02	*	.32	.92	.00	.00	1.00	.00	.00	.00	.00	.00	.00	Sig.
R7	.99	1.00	.08	.00	.04	.98	.32	*	.83	.41	.32	.73	.01	.08	.01	.00	.02	.06	Sig.
R8	1.00	.61	.00	.00	.00	.11	.92	.83	*	.01	.00	1.00	.00	.00	.00	.00	.00	.00	Sig.
R9	.24	.99	1.00	.04	.99	.99	.00	.41	.01	*	1.00	.00	.99	1.00	1.00	.03	1.00	1.00	Sig.
R10	.23	.99	.99	.00	.98	.99	.00	.32	.00	1.00	*	.00	.96	1.00	.98	.00	.99	1.00	Sig.
R11	1.00	.49	.00	.00	.00	.08	1.00	.73	1.00	.00	.00	*	.00	.00	.00	.00	.00	.00	Sig.
R12	.03	.63	1.00	.07	1.00	.47	.00	.01	.00	.99	.96	.00	*	.74	1.00	.02	1.00	1.00	Sig.
R13	.13	.96	.99	.00	.93	.95	.00	.08	.00	1.00	1.00	.00	.74	*	.85	.00	.97	1.00	Sig.
R14	.04	.67	1.00	.08	1.00	.54	.00	.01	.00	1.00	.98	.00	1.00	.85	*	.04	1.00	1.00	Sig.
R15	.00	.01	.21	1.00	.33	.00	.00	.00	.00	.03	.00	.00	.02	.00	.04	*	.00	.00	Sig.
R16	.06	.81	1.00	.02	1.00	.72	.00	.02	.00	1.00	.99	.00	1.00	.97	1.00	.00	*	1.00	Sig.
R17	.09	.90	1.00	.01	1.00	.87	.00	.06	.00	1.00	1.00	.00	1.00	1.00	1.00	.00	1.00	*	Sig.

Appendix II

Table 1. Fibre Diameter with the Result of Contact Angle (°) Measurement at Advancing Stage from Re-use NaOH

NaOH solution	Fibre dia (µm) and contact angle									
	Fibre 1	Fibre 2	Fibre 3	Fibre 4	Fibre 5	Fibre 6	Fibre 7	Fibre 8	Fibre 9	Fibre 10
R0	204 (DIA)	382 (DIA)	196 (DIA)	247 (DIA)	254 (DIA)	283 (DIA)	121 (DIA)	161 (DIA)	223 (DIA)	225 (DIA)
	59.53 (CA)	75.69 (CA)	81.25 (CA)	59. 83 (CA)	48.21 (CA)	71. 47 (CA)	75.35 (CA)	52.20 (CA)	76.25 (CA)	77.38 (CA)
R1	654 (DIA)	145 (DIA)	205 (DIA)	169 (DIA)	113 (DIA)	148 (DIA)	148 (DIA)	184 (DIA)	113 (DIA)	320 (DIA)
	81.58 (CA)	77.49 (CA)	68.45 (CA)	42.68(CA)	49.81(CA)	76.17(CA)	65.63 (CA)	60.27(CA)	90.08(CA)	72.38(CA)
R2	213 (DIA)	506 (DIA)	384 (DIA)	185 (DIA)	86 (DIA)	235 (DIA)	357 (DIA)	261 (DIA)	413 (DIA)	242 (DIA)
	56.08 (CA)	78.87 (CA)	51.21 (CA)	76.90 (CA)	0 (CA)	33.72 (CA)	105.02 (CA)	136.04 (CA)	73.98 (CA)	68.91 (CA)
R3	452 (DIA)	207 (DIA)	296 (DIA)	766 (DIA)	263 (DIA)	315 (DIA)	383 (DIA)	387 (DIA)	349 (DIA)	270 (DIA)

	79.30 (CA)	31.37 (CA)	74. 00(CA)	56.12(CA)	69.10 (CA)	64.31(CA)	94.34 (CA)	69.18(CA)	73.38(CA)	73.17(CA)
R4	280 (DIA)	463 (DIA)	145 (DIA)	358 (DIA)	235 (DIA)	126 (DIA)	250 (DIA)	218 (DIA)	174 (DIA)	230 (DIA)
	60.14 (CA)	59.71 (CA)	42.06 (CA)	70.96 (CA)	81.21 (CA)	50.16 (CA)	71.16 (CA)	74.36 (CA)	78.88 (CA)	90.25 (CA)
R5	159 (DIA)	154 (DIA)	688 (DIA)	278 (DIA)	156 (DIA)	293 (DIA)	191 (DIA)	142 (DIA)	256 (DIA)	194 (DIA)
	86.07 (CA)	0 (CA)	58.02(CA)	88.82 (CA)	77.90 (CA)	61.40 (CA)	57.02 (CA)	65.78 (CA)	50.30(CA)	24.63(CA)
R6	181 (DIA)	483 (DIA)	189 (DIA)	188 (DIA)	340 (DIA)	107 (DIA)	181 (DIA)	51 (DIA)	295 (DIA)	117 (DIA)
	0 (CA)	50.78 (CA)	42. 94 (CA)	0 (CA)	64.88 (CA)	66.25 (CA)	64.36 (CA)	139. 49 (CA)	27. 31 (CA)	53.68 (CA)
R7	202 (DIA)	255 (DIA)	297 (DIA)	321 (DIA)	150 (DIA)	274 (DIA)	258 (DIA)	118 (DIA)	276 (DIA)	177 (DIA)
	53.87 (CA)	135. 30 (CA)	129. 44 (CA)	116.34 (CA)	99.38 (CA)	111.03 (CA)	113.41 (CA)	49.01 (CA)	56.93 (CA)	0 (CA)
R8	200 (DIA)	87 (DIA)	222 (DIA)	199 (DIA)	156 (DIA)	200 (DIA)	449 (DIA)	186 (DIA)	213 (DIA)	158 (DIA)

	78.79 (CA)	47.99 (CA)	68.73 (CA)	43.43 (CA)	31.78 (CA)	66.85 (CA)	52.12 (CA)	62.78 (CA)	46.77 (CA)	0 (CA)
R9	157 (DIA)	347 (DIA)	192 (DIA)	198 (DIA)	152 (DIA)	160 (DIA)	272 (DIA)	324 (DIA)	419 (DIA)	174 (DIA)
	103.78 (CA)	50.59 (CA)	40.17 (CA)	0 (CA)	65.96 (CA)	39.82 (CA)	107.03 (CA)	105.15 (CA)	89. 67 (CA)	64.11 (CA)
R10	129 (DIA)	309 (DIA)	328 (DIA)	175 (DIA)	231 (DIA)	103 (DIA)	269 (DIA)	243 (DIA)	244 (DIA)	332 (DIA)
	68.27 (CA)	34. 91 (CA)	47.35 (CA)	0 (CA)	0 (CA)	37. 61 (CA)	57.66 (CA)	21. 64 (CA)	51. 28 (CA)	96. 85 (CA)
R11	526 (DIA)	309 (DIA)	285 (DIA)	235 (DIA)	288 (DIA)	237 (DIA)	138 (DIA)	251 (DIA)	248 (DIA)	224 (DIA)
	59.01 (CA)	35.23 (CA)	70.46 (CA)	31.17 (CA)	52.71 (CA)	0 (CA)	72.26 (CA)	59.14 (CA)	70.80 (CA)	57.67 (CA)
R12	305 (DIA)	274 (DIA)	266 (DIA)	160 (DIA)	237 (DIA)	340 (DIA)	245 (DIA)	282 (DIA)	288 (DIA)	321 (DIA)
	46.10 (CA)	55.53 (CA)	57.14 (CA)	58.87 (CA)	36.37 (CA)	0 (CA)	57.96 (CA)	43.87 (CA)	51.18 (CA)	43.69 (CA)
R13	581 (DIA)	220 (DIA)	329 (DIA)	289 (DIA)	220 (DIA)	208 (DIA)	269 (DIA)	114 (DIA)	187 (DIA)	98 (DIA)

	62.18 (CA)	60.58 (CA)	38.75 (CA)	18.35 (CA)	0 (CA)	61.20 (CA)	63.92 (CA)	34.45 (CA)	66.11 (CA)	62.70 (CA)
R14	108 (DIA)	189 (DIA)	408 (DIA)	262 (DIA)	143 (DIA)	373 (DIA)	158 (DIA)	175 (DIA)	80 (DIA)	128 (DIA)
	28.48 (CA)	28.61 (CA)	37.61 (CA)	0 (CA)	27.67 (CA)	52.55 (CA)	21.74 (CA)	0 (CA)	68.97 (CA)	44.52 (CA)
R15	244 (DIA)	481 (DIA)	553 (DIA)	101 (DIA)	108 (DIA)	295 (DIA)	224 (DIA)	154 (DIA)	136 (DIA)	616 (DIA)
	24. 43 (CA)	45.12 (CA)	0 (CA)	49.81 (CA)	48.40 (CA)	50.89 (CA)	14.96 (CA)	32.42 (CA)	115.23 (CA)	17.10 (CA)
R16	240 (DIA)	262 (DIA)	616 (DIA)	93 (DIA)	334 (DIA)	454 (DIA)	138 (DIA)	232 (DIA)	447 (DIA)	155 (DIA)
	66.97 (CA)	81.90 (CA)	0 (CA)	61.24 (CA)	0 (CA)	69.86 (CA)	22.86 (CA)	19.38 (CA)	58.45 (CA)	77.57 (CA)
R17	329 (DIA)	701 (DIA)	428 (DIA)	109 (DIA)	235 (DIA)	335 (DIA)	184 (DIA)	359 (DIA)	103 (DIA)	135 (DIA)
	87.52 (CA)	86.45 (CA)	96.81 (CA)	38.42 (CA)	0 (CA)	49.64 (CA)	56.66 (CA)	55.82 (CA)	83.18 (CA)	99.71 (CA)

Table 2. Fibre Diameter with the Result of Contact angle (°) Measurement at Receding Stage from Re-use NaOH

NaOH Solution	Fibre dia (µm) and contact angle									
	Fibre 1	Fibre 2	Fibre 3	Fibre 4	Fibre 5	Fibre 6	Fibre 7	Fibre 8	Fibre 9	Fibre 10
R0	204 (DIA)	382 (DIA)	196 (DIA)	247 (DIA)	254 (DIA)	283 (DIA)	121 (DIA)	161 (DIA)	223 (DIA)	225 (DIA)
	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)
R1	654 (DIA)	145 (DIA)	205 (DIA)	169 (DIA)	113 (DIA)	148 (DIA)	148 (DIA)	184 (DIA)	113 (DIA)	320 (DIA)
	45.09 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	54.92 (CA)	0 (CA)	0 (CA)	48.13 (CA)
R2	213 (DIA)	506 (DIA)	384 (DIA)	185 (DIA)	86 (DIA)	235 (DIA)	357 (DIA)	261 (DIA)	413 (DIA)	242 (DIA)
	0 (CA)	52.56 (CA)	0 (CA)	43.54 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)
R3	452 (DIA)	207 (DIA)	296 (DIA)	766 (DIA)	263 (DIA)	315 (DIA)	383 (DIA)	387 (DIA)	349 (DIA)	270 (DIA)

	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	19.18 (CA)	0 (CA)	0 (CA)
R4	280 (DIA)	463 (DIA)	145 (DIA)	358 (DIA)	235 (DIA)	126 (DIA)	250 (DIA)	218 (DIA)	174 (DIA)	230 (DIA)
	0 (CA)	0 (CA)	0 (CA)	44.14 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)
R5	159 (DIA)	154 (DIA)	688 (DIA)	278 (DIA)	156 (DIA)	293 (DIA)	191 (DIA)	142 (DIA)	256 (DIA)	194 (DIA)
	0 (CA)	0 (CA)	0 (CA)	16.93 (CA)	32.92 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)
R6	181 (DIA)	483 (DIA)	189 (DIA)	188 (DIA)	340 (DIA)	107 (DIA)	181 (DIA)	51 (DIA)	295 (DIA)	117 (DIA)
	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	54.73 (CA)	0 (CA)	99.82 (CA)	0 (CA)	0 (CA)
R7	202 (DIA)	255 (DIA)	297 (DIA)	321 (DIA)	150 (DIA)	274 (DIA)	258 (DIA)	118 (DIA)	276 (DIA)	177 (DIA)
	0 (CA)	132.23 (CA)	134.88 (CA)	129.60 (CA)	180 (CA)	122.21 (CA)	113.32 (CA)	0 (CA)	0 (CA)	0 (CA)

R8	200 (DIA)	87 (DIA)	222 (DIA)	199 (DIA)	156 (DIA)	200 (DIA)	449 (DIA)	186 (DIA)	213 (DIA)	158 (DIA)
	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	23.71 (CA)	0 (CA)	0 (CA)	0 (CA)
R9	157 (DIA)	347 (DIA)	192 (DIA)	198 (DIA)	152 (DIA)	160 (DIA)	272 (DIA)	324 (DIA)	419 (DIA)	174 (DIA)
	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	134.31 (CA)	109.23 (CA)	0 (CA)	0 (CA)
R10	129 (DIA)	309 (DIA)	328 (DIA)	175 (DIA)	231 (DIA)	103 (DIA)	269 (DIA)	243 (DIA)	244 (DIA)	332 (DIA)
	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)
R11	526 (DIA)	309 (DIA)	285 (DIA)	235 (DIA)	288 (DIA)	237 (DIA)	138 (DIA)	251 (DIA)	248 (DIA)	224 (DIA)
	26.73 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)

R12	305 (DIA)	274 (DIA)	266 (DIA)	160 (DIA)	237 (DIA)	340 (DIA)	245 (DIA)	282 (DIA)	288 (DIA)	321 (DIA)
	0 (CA)	0 (CA)	9.02 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)
R13	581 (DIA)	220 (DIA)	329 (DIA)	289 (DIA)	220 (DIA)	208 (DIA)	269 (DIA)	114 (DIA)	187 (DIA)	98 (DIA)
	18.00 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)
R14	108 (DIA)	189 (DIA)	408 (DIA)	262 (DIA)	143 (DIA)	373 (DIA)	158 (DIA)	175 (DIA)	80 (DIA)	128 (DIA)
	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)
R15	244 (DIA)	481 (DIA)	553 (DIA)	101 (DIA)	108 (DIA)	295 (DIA)	224 (DIA)	154 (DIA)	136 (DIA)	616 (DIA)
	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)
R16	240 (DIA)	262 (DIA)	616 (DIA)	93 (DIA)	334 (DIA)	454 (DIA)	138 (DIA)	232 (DIA)	447 (DIA)	155 (DIA)
	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)

R17	329 (DIA)	701 (DIA)	428 (DIA)	109 (DIA)	235 (DIA)	335 (DIA)	184 (DIA)	359 (DIA)	103 (DIA)	135 (DIA)
	0 (CA)	50.88 (CA)	58.84 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)	0 (CA)

Table 3. Games-Howell Test Data for Fibre Contact Angle (°)

Sl.	R0	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17	V
R0		1.00	1.00	1.00	1.00	.99	.47	.99	.64	1.00	.52	.78	.04	.53	.02	.01	.80	1.00	Sig.
R1	1.00		1.00	1.00	1.00	.99	.48	.99	.69	1.00	.53	.80	.10	.55	.02	.01	.80	1.00	Sig.
R2	1.00	1.00		1.00	1.00	1.00	.76	.99	.95	1.00	.75	.95	.66	.84	.11	.12	.92	1.00	Sig.
R3	1.00	1.00	1.00		1.00	.99	.34	.99	.36	1.00	.40	.60	.00	.36	.01	.00	.69	1.00	Sig.
R4	1.00	1.00	1.00	1.00		1.00	.52	.99	.75	1.00	.56	.83	.13	.59	.02	.01	.83	1.00	Sig.
R5	.99	.99	1.00	.99	1.00		.98	.92	1.00	1.00	.97	1.00	.98	.99	.33	.36	.99	1.00	Sig.
R6	.47	.48	.76	.34	.52	.98		.47	1.00	.95	1.00	1.00	1.00	1.00	.99	1.00	1.00	.94	Sig.
R7	.99	.99	.99	.99	.99	.92	.47		.69	.99	.46	.68	.48	.54	.13	.16	.63	.99	Sig.
R8	.64	.69	.95	.36	.75	1.00	1.00	.69		.99	.99	1.00	1.00	1.00	.49	.51	1.00	.99	Sig.
R9	1.00	1.00	1.00	1.00	1.00	1.00	.95	.99	.99		.93	.99	.95	.97	.43	.48	.99	1.00	Sig.
R10	.52	.53	.75	.40	.56	.97	1.00	.46	.99	.93		1.00	1.00	1.00	1.00	1.00	1.00	.93	Sig.
R11	.78	.80	.95	.60	.83	1.00	1.00	.68	1.00	.99	1.00		1.00	1.00	.83	.88	1.00	.99	Sig.
R12	.04	.10	.66	.00	.13	.98	1.00	.48	1.00	.95	1.00	1.00		1.00	.61	.62	1.00	.94	Sig.
R13	.53	.55	.84	.36	.59	.99	1.00	.54	1.00	.97	1.00	1.00	1.00		.96	.98	1.00	.97	Sig.
R14	.02	.02	.11	.01	.02	.33	.99	.13	.49	.43	1.00	.83	.61	.96		1.00	.99	.36	Sig.
R15	.01	.01	.12	.00	.01	.36	1.00	.16	.51	.48	1.00	.88	.62	.98	1.00		.99	.40	Sig.
R16	.80	.80	.92	.69	.83	.99	1.00	.63	1.00	.99	1.00	1.00	1.00	1.00	.99	.99		.99	Sig.
R17	1.00	1.00	1.00	1.00	1.00	1.00	.94	.99	.99	1.00	.93	.99	.94	.97	.36	.40	.99		Sig.

Appendix III

Table 1. Fibre Diameter with the Result of Instron Universal Testing Machine from Re-use NaOH

Sample ID	Number	Length (mm)	Diameter (um)	Load at break (N)	Tensile stress at break (MPa)	Tensile strain at break	Young's modulus (GPa)	Tenacity at break (gf/denier)
	1	25.40000	74.75000	1.18759	270.61606	0.01594	22.74210	1.21100
	2	25.40000	56.60000	0.73438	291.87524	0.00342	110.37214	0.74886
	3	25.40000	68.81000	0.87465	235.20259	0.00879	34.00157	0.89190
	4	25.40000	66.79000	0.59106	168.70096	0.01162	19.98737	0.60271
	5	25.40000	62.76000	0.63572	205.50006	0.01317	22.10005	0.64826
	6	25.40000	60.61000	2.32852	807.05194	0.02203	49.25776	2.37443
	7	25.40000	76.79000	0.65819	142.11874	0.02956	18.83435	0.67117
	8	25.40000	76.87000	1.46674	316.04581	0.02165	20.17903	1.49566
	9	25.40000	86.87000	1.34538	226.99522	0.01876	18.15660	1.37191
	10	25.40000	62.76000	1.86599	603.18909	0.03722	20.67264	1.90278

RO	11	25.40000	54.69000	0.65978	280.86172	0.01365	27.22786	0.67279
	12	25.40000	82.83000	0.39600	73.49051	0.00647	15.05067	0.40381
	13	25.40000	89.10000	0.84035	134.77614	0.01301	13.43715	0.85691
	14	25.40000	76.87000	1.26122	271.76111	0.02141	16.19807	1.28609
	15	25.40000	55.14000	2.91236	1,219.61316	0.11989	137.47720	2.96978
	16	25.40000	50.55000	1.06353	529.92993	0.02280	28.17076	1.08450
	17	25.40000	66.70000	1.39224	398.44797	0.03131	20.29032	1.41969
	18	25.40000	66.70000	1.22369	350.21237	0.01947	26.05930	1.24782
	19	25.40000	58.59000	0.95637	354.72433	0.01668	26.78369	0.97523
	20	25.40000	857.00000	0.06513	0.11291	0.12000	0.17359	0.06642
R1	1	25.40000	74.77000	0.79635	181.36760	0.01121	28.16897	0.81205
	2	25.40000	109.26000	0.90403	96.42108	0.00864	15.48973	0.92186
	3	25.40000	103.35000	1.08877	129.78581	0.01540	11.58052	1.11024
	4	25.40000	62.76000	1.55360	502.20923	0.01308	47.86276	1.58424
	5	25.40000	105.05000	3.27359	377.69556	0.02930	17.45145	3.33813
	6	25.40000	56.60000	1.20833	480.24405	0.02191	38.39809	1.23215

	7	25.40000	56.60000	1.80195	716.17676	0.03710	34.40706	1.83748
	8	25.40000	66.70000	1.08630	310.89059	0.01627	25.29304	1.10772
	9	25.40000	123.30000	0.77999	65.32389	0.00984	8.25505	0.79537
	10	25.40000	39.23000	0.56149	464.53012	0.01888	33.81435	0.57256
	11	25.40000	571.40000	0.87401	3.40835	0.01051	0.43867	0.89124
	12	25.40000	95.14000	1.52509	214.52557	0.02457	11.05675	1.55516
	13	25.40000	42.47000	0.93626	660.90796	0.02398	43.90471	0.95472
	14	25.40000	50.67000	0.96741	479.75406	0.01454	40.51238	0.98648
	15	25.40000	84.94000	0.58394	103.05158	0.01111	10.97945	0.59545
	16	25.40000	96.99000	8.21410	1,111.77258	0.09617	49.59721	8.37605
	17	25.40000	80.83000	0.91861	179.01849	0.01292	16.96869	0.93673
	18	25.40000	56.71000	0.66056	261.51822	0.00736	50.52148	0.67358
	19	25.40000	50.67000	0.16808	83.35474	0.11727	43.16746	0.17140
	20	25.40000	76.87000	0.17172	37.00193	0.12066	12.29494	0.17511
	1	25.40000	40.45000	1.21037	941.86847	0.01560	68.08753	1.23423
	2	25.40000	76.87000	0.78879	169.96516	0.02669	17.46411	0.80435

	3	25.40000	68.72000	0.51563	139.02113	0.02621	0	0.52579
	4	25.40000	56.71000	2.26589	897.07617	0.03001	61.71437	2.31056
	5	25.40000	93.13000	2.27806	334.42279	0.02120	22.51771	2.32297
	6	25.40000	56.60000	1.86972	743.11255	0.02477	52.63584	1.90659
	7	25.40000	135.41000	2.26195	157.06940	0.02991	10.04057	2.30655
	8	25.40000	44.63000	0.06398	40.89965	0.11906	40.19436	0.06524
	9	25.40000	34.58000	0.15219	162.05316	0.11632	44.99443	0.15519
R2	10	25.40000	60.64000	1.05110	363.94598	0.01615	26.85317	1.07183
	11	25.40000	80.91000	0.16133	31.37754	0.11930	12.30405	0.16451
	12	25.40000	38.38000	0.98579	852.08990	0.01539	67.68603	1.00523
	13	25.40000	54.58000	0.72249	308.79999	0.01030	39.17601	0.73674
	14	25.40000	85.06000	0.11186	19.68515	0.11914	17.79457	0.11407
	15	25.40000	88.91000	0.08158	13.13979	0.11667	19.27620	0.08319
	16	25.40000	115.17000	2.67540	256.81531	0.02482	15.66826	2.72815
	17	25.40000	54.55000	1.41668	606.16809	0.01612	59.56667	1.44461
	18	25.40000	72.76000	0.78389	188.53008	0.01365	23.33092	0.79935

	19	25.40000	48.48000	1.26927	687.60370	0.02453	55.87008	1.29429
	20	25.40000	34.58000	0.48804	519.66052	0.01483	48.66347	0.49767
R3	1	25.40000	60.61000	0.48711	168.82884	0.01487	15.24026	0.49671
	2	25.40000	68.69000	0.14299	38.58708	0.11924	10.82983	0.14581
	3	25.40000	82.85000	1.34146	248.82959	0.01960	15.82591	1.36791
	4	25.40000	74.75000	2.60307	593.16235	0.03314	41.55916	2.65439
	5	25.40000	60.64000	0.07470	25.86515	0.11720	23.81237	0.07617
	6	25.40000	60.61000	0.95541	331.13986	0.01842	20.97565	0.97425
	7	25.40000	285.70000	1.00822	15.72700	0.02609	1.31485	1.02810
	8	25.40000	72.76000	0.94675	227.69843	0.01137	26.35235	0.96542
	9	25.40000	50.55000	0.07804	38.88443	0.11930	41.72424	0.07958
	10	25.40000	50.67000	0.42133	208.94501	0.01339	19.97741	0.42964
	11	25.40000	54.58000	1.18162	505.03638	0.01250	63.15717	1.20492
	12	25.40000	60.64000	0.45724	158.31854	0.01323	15.23856	0.46625
	13	25.40000	92.95000	1.09808	161.82455	0.02806	10.11477	1.11973
	14	25.40000	56.60000	0.59328	235.79572	0.00884	35.73312	0.60498

	15	25.40000	46.51000	0.61337	361.02557	0.01316	32.66942	0.62546
	16	25.40000	64.68000	0.64993	197.80473	0.02441	30.15753	0.66274
	17	25.40000	54.58000	0.69590	297.43472	0.01903	7.18261	0.70962
	18	25.40000	143.45000	1.80103	111.43736	0.02375	11.26334	1.83654
	19	25.40000	56.71000	2.35477	932.26300	0.02616	44.45860	2.40119
	20	25.40000	52.56000	0.81694	376.52191	0.01281	40.47684	0.83305
R4	1	25.40000	62.66000	0.81645	264.76294	0.07926	47.27600	0.83254
	2	25.40000	62.66000	0.67120	217.66238	0.01599	17.08156	0.68444
	3	25.40000	68.72000	1.10346	297.50891	0.01479	31.26331	1.12521
	4	25.40000	113.20000	2.46870	245.29301	0.05540	19.34354	2.51737
	5	25.40000	95.14000	0.61574	86.61239	0.12077	10.63040	0.62788
	6	25.40000	72.84000	2.69627	647.04419	0.01275	73.11202	2.74943
	7	25.40000	38.38000	0.20509	177.27167	0.11880	88.98487	0.20913
	8	25.40000	38.44000	0.40070	345.27200	0.00870	49.11317	0.40860
	9	25.40000	70.71000	1.03587	263.78815	0.01321	30.46058	1.05630
	10	25.40000	571.40000	1.03428	4.03335	0.01729	0.43301	1.05467

	11	25.40000	857.00000	0.68829	1.19322	0.01274	0	0.70186
	12	25.40000	58.73000	0.61631	227.50456	0.01847	17.40275	0.62846
	13	25.40000	53.14000	0.89115	401.80899	0.01728	29.08462	0.90872
	14	25.40000	70.74000	1.29108	328.49890	0.01435	33.80252	1.31654
	15	25.40000	50.55000	0.74837	372.89148	0.00788	79.48214	0.76312
	16	25.40000	714.20000	0.05364	0.13389	0.11568	0.20513	0.05469
	17	25.40000	44.49000	0.56039	360.47653	0.01483	30.40449	0.57144
	18	25.40000	147.49000	2.72468	159.47778	0.01729	13.21649	2.77840
	19	25.40000	571.40000	0.15226	0.59375	0.11705	0.32688	0.15526
	20	25.40000	54.69000	0.73145	311.37057	0.02100	19.59830	0.74587
	1	25.40000	60.64000	0.70949	245.66199	0.02555	11.15721	0.72348
	2	25.40000	62.63000	0.19315	62.69565	0.11760	5.97073	0.19696
	3	25.40000	50.51000	0.83991	419.16824	0.01194	43.08501	0.85647
	4	25.40000	54.69000	0.42611	181.39305	0.00590	44.99745	0.43452
	5	25.40000	571.40000	1.26008	4.91393	0.01331	0.48016	1.28493
	6	25.40000	46.46000	0.53264	314.18677	0.01695	24.12198	0.54314

R5	7	25.40000	34.58000	0.03400	36.19736	0.05865	23.92505	0.03467
	8	25.40000	80.81000	0.54603	106.46203	0.01670	11.65194	0.55679
	9	25.40000	52.56000	0.68436	315.41711	0.01778	22.84292	0.69785
	10	25.40000	58.62000	0.09723	36.02453	0.12158	0	0.09914
	11	25.40000	62.63000	0.58023	188.34059	0.02543	18.03928	0.59167
	12	25.40000	46.46000	0.30631	180.68179	0.01809	14.79033	0.31235
	13	25.40000	58.62000	0.19589	72.58083	0.11952	31.76773	0.19975
	14	25.40000	56.57000	0.41198	163.91350	0.11707	12.91970	0.42010
	15	25.40000	46.51000	1.04501	615.09003	0.01685	45.44058	1.06562
	16	25.40000	52.56000	0.50615	233.28172	0.01244	21.97741	0.51613
	17	25.40000	54.58000	0.74398	317.98392	0.02411	24.78593	0.75865
	18	25.40000	40.45000	0.04773	37.13998	0.11575	23.02402	0.04867
	19	25.40000	48.65000	0.70230	377.80704	0.02150	30.40564	0.71615
	20	25.40000	50.55000	0.80363	400.42654	0.02794	23.33389	0.81947
	1	25.40000	50.51000	0.09557	47.69429	0.12054	10.19620	0.09745
	2	25.40000	46.64000	0.45499	266.31738	0.01510	20.60121	0.46397

R6	3	25.40000	64.65000	0.32630	99.39973	0.01427	12.02621	0.33273
	4	25.40000	50.51000	0.21637	107.98016	0.01614	9.03057	0.22063
	5	25.40000	52.53000	0.13850	63.90554	0.01492	5.96983	0.14123
	6	25.40000	42.42000	0.24988	176.80431	0.01780	23.48252	0.25480
	7	25.40000	30.30000	0.32835	455.37366	0.11914	192.95841	0.33483
	8	25.40000	34.40000	0.28527	306.93274	0.11807	74.38393	0.29089
	9	25.40000	48.53000	0.58934	318.60812	0.02184	20.48399	0.60096
	10	25.40000	48.48000	0.29336	158.92522	0.01597	12.64076	0.29915
	11	25.40000	48.53000	0.46330	250.46898	0.02854	16.74676	0.47244
	12	25.40000	70.74000	0.10971	27.91493	0.11819	9.44135	0.11188
	13	25.40000	66.67000	0.12215	34.98948	0.11901	22.23000	0.12456
	14	25.40000	40.40000	1.34866	1,052.08655	0.02833	56.43742	1.37526
	15	25.40000	30.37000	0.28117	388.14359	0.02534	28.58216	0.28672
	16	25.40000	36.42000	0.25480	244.58722	0.01514	17.12702	0.25983
	17	25.40000	62.66000	0.47338	153.51033	0.01443	25.52919	0.48271
	18	25.40000	48.48000	0.35898	194.47072	0.01154	28.92885	0.36606

	19	25.40000	62.66000	0.55310	179.36378	0.03293	0	0.56401
	20	25.40000	82.83000	0.50391	93.51670	0.02385	5.21522	0.51385
R7	1	25.40000	50.67000	0.93287	462.62326	0.03003	18.15730	0.95126
	2	25.40000	64.68000	0.38360	116.74798	0.01805	8.98262	0.39116
	3	25.40000	285.70000	1.18230	18.44242	0.01799	1.48862	1.20561
	4	25.40000	50.55000	0.29935	149.15836	0.01796	12.53261	0.30525
	5	25.40000	36.87000	1.62335	1,520.46545	0.11898	994.96085	1.65536
	6	25.40000	64.77000	0.20544	62.35170	0.00829	14.76202	0.20949
	7	25.40000	66.67000	0.82193	235.44189	0.02933	12.32180	0.83813
	8	25.40000	50.51000	0.21908	109.33270	0.12027	30.69178	0.22340
	9	25.40000	42.62000	0.66798	468.21970	0.02180	27.01526	0.68115
	10	25.40000	34.40000	0.52101	560.58099	0.01849	57.51755	0.53128
	11	25.40000	52.56000	0.21186	97.64509	0.11951	22.10288	0.21604
	12	25.40000	58.73000	0.52109	192.35399	0.11862	14.00469	0.53136
	13	25.40000	52.56000	0.36084	166.30664	0.11375	17.77003	0.36795
	14	25.40000	70.82000	1.26333	320.71231	0.03462	13.53641	1.28824

	15	25.40000	42.85000	0.15348	106.42655	0.12142	29.10172	0.15650
	16	25.40000	62.76000	0.51108	165.21001	0.01377	14.68540	0.52116
	17	25.40000	70.82000	1.09711	278.51401	0.02559	15.25383	1.11874
	18	25.40000	46.51000	0.27023	159.05894	0.00631	35.07542	0.27556
	19	25.40000	26.34000	0.06425	117.90531	0.11991	54.60050	0.06551
	20	25.40000	40.45000	0.37871	294.69998	0.02553	18.12466	0.38618
R8	1	25.40000	500.00000	0.58180	2.96306	0.02457	0.18426	0.59327
	2	25.40000	64.68000	1.10712	336.94977	0.02887	15.06102	1.12895
	3	25.40000	46.86000	0.19859	115.14898	0.12039	74.86153	0.20250
	4	25.40000	60.61000	1.75203	607.24384	0.03028	43.28276	1.78657
	5	25.40000	46.64000	0.15180	88.85368	0.11774	33.59521	0.15480
	6	25.40000	542.80000	0.64207	2.77467	0.02841	0.12037	0.65473
	7	25.40000	54.69000	1.55410	661.56763	0.01679	49.22047	1.58474
	8	25.40000	64.68000	0.17278	52.58603	0.11918	10.79625	0.17619
	9	25.40000	58.62000	1.12133	415.48279	0.03227	0	1.14344
	10	25.40000	58.59000	0.77572	287.72009	0.01896	18.01673	0.79102

	11	25.40000	34.87000	0.43176	452.11884	0.01243	50.24257	0.44028
	12	25.40000	40.40000	0.17628	137.51350	0.12024	36.14242	0.17975
	13	25.40000	56.57000	0.69886	278.05389	0.02621	18.04388	0.71264
	14	25.40000	828.50000	1.82909	3.39282	0.02600	0.21677	1.86516
	15	25.40000	48.48000	0.70697	382.98950	0.01731	28.39822	0.72091
	16	25.40000	44.44000	0.65847	424.51941	0.01731	-----	0.67145
	17	25.40000	66.67000	0.91543	262.22397	0.01320	25.84399	0.93347
	18	25.40000	54.69000	0.21350	90.88504	0.11887	32.47763	0.21771
	19	25.40000	82.85000	0.47488	88.08651	0.02586	5.97120	0.48424
	20	25.40000	40.61000	0.06779	52.33499	0.11924	24.22770	0.06912
	1	25.40000	48.53000	0.04832	26.12149	0.11748	19.50258	0.04927
	2	25.40000	42.47000	0.12068	85.18772	0.12078	39.80082	0.12306
	3	25.40000	56.57000	0.68686	273.27798	0.02623	9.15990	0.70040
	4	25.40000	66.70000	1.82870	523.36005	0.03171	27.40626	1.86475
	5	25.40000	60.61000	12.99688	4,504.64697	0.11865	106.24436	13.25313
	6	25.40000	42.62000	0.97982	686.79706	0.02257	39.33477	0.99914

R9	7	25.40000	62.63000	1.26538	410.74069	0.02530	21.05151	1.29033
	8	25.40000	32.39000	0.27622	335.23041	0.02018	29.62978	0.28167
	9	25.40000	38.44000	0.26810	231.01324	0.01714	17.36151	0.27338
	10	25.40000	40.40000	0.03722	29.03392	0.11726	21.53167	0.03795
	11	25.40000	64.65000	0.83662	254.86038	0.03810	23.26417	0.85312
	12	25.40000	44.63000	0.05576	35.64587	0.11837	27.68029	0.05686
	13	25.40000	50.51000	0.09963	49.72263	0.12065	53.13786	0.10160
	14	25.40000	60.64000	0.76101	263.50177	0.01998	19.66142	0.77602
	15	25.40000	62.63000	0.06377	20.70004	0.11740	10.49686	0.06503
	16	25.40000	60.61000	0.10038	34.79173	0.11812	14.21243	0.10236
	17	25.40000	68.72000	2.08187	561.30389	0.02561	32.68257	2.12292
	18	25.40000	62.66000	0.39116	126.84809	0.11243	29.43381	0.39887
	19	25.40000	22.22000	0.08731	225.14912	0.11763	76.36945	0.08903
	20	25.40000	62.76000	0.78967	255.26277	0.02615	9.56282	0.80523
	1	25.40000	44.44000	0.08316	53.61237	0.12065	18.33965	0.08480
	2	25.40000	56.71000	0.07768	30.75232	0.11938	15.65366	0.07921

R10	3	25.40000	64.65000	0.25403	77.38420	0.01128	8.11645	0.25904
	4	25.40000	50.67000	0.30526	151.38135	0.01370	13.01623	0.31127
	5	25.40000	40.45000	0.93320	726.18524	0.01327	65.29659	0.95160
	6	25.40000	80.91000	0.97726	190.07173	0.01188	19.62531	0.99653
	7	25.40000	80.91000	1.36963	266.38361	0.01622	20.42819	1.39663
	8	25.40000	40.45000	0.24793	192.92903	0.00512	68.76726	0.25282
	9	25.40000	62.63000	0.85671	278.08652	0.01834	18.62159	0.87360
	10	25.40000	62.92000	0.45133	145.15483	0.01043	18.69906	0.46023
	11	25.40000	58.59000	0.48893	181.34587	0.00582	46.36774	0.49857
	12	25.40000	44.49000	1.01439	652.51471	0.01486	53.30109	1.03439
	13	25.40000	44.49000	0.53495	344.10965	0.01530	30.02088	0.54550
	14	25.40000	54.69000	0.69913	297.61157	0.01198	29.48242	0.71291
	15	25.40000	50.51000	0.24955	124.54105	0.00565	35.13301	0.25447
	16	25.40000	48.53000	0.61194	330.82578	0.01393	31.83662	0.62401
	17	25.40000	42.85000	0.72230	500.87335	0.00832	81.57293	0.73654
	18	25.40000	44.49000	0.13252	85.24381	0.11836	47.23146	0.13513

	19	25.40000	42.47000	0.62266	439.53745	0.01733	36.45084	0.63494
	20	25.40000	38.38000	0.21882	189.14151	0.01168	20.28583	0.22313
R11	1	25.40000	60.64000	1.33332	461.66464	0.01480	39.10892	1.35961
	2	25.40000	62.63000	0.75116	243.82355	0.01076	28.91483	0.76597
	3	25.40000	62.66000	1.64775	534.34485	0.01561	45.06184	1.68024
	4	25.40000	50.55000	0.64701	322.38809	0.00998	39.63146	0.65977
	5	25.40000	52.56000	0.40850	188.27469	0.01544	15.16155	0.41655
	6	25.40000	62.66000	0.40607	131.68457	0.00560	36.97011	0.41408
	7	25.40000	50.55000	1.89405	943.75604	0.02096	58.66320	1.93140
	8	25.40000	58.62000	0.55728	206.48738	0.01772	14.24848	0.56827
	9	25.40000	30.57000	1.44563	1,969.59338	0.01927	128.32987	1.47413
	10	25.40000	68.72000	1.74763	471.18616	0.02100	35.99466	1.78208
	11	25.40000	119.21000	1.18043	105.76102	0.03077	4.92800	1.20371
	12	25.40000	78.79000	1.06514	218.46109	0.02180	12.52281	1.08614
	13	25.40000	64.65000	0.78941	240.47775	0.01726	17.43237	0.80497
	14	25.40000	571.40000	0.50058	1.95211	0.02019	0.12758	0.51045

	15	25.40000	70.74000	0.19162	48.75415	0.11910	29.87611	0.19539
	16	25.40000	34.58000	0.44130	469.89139	0.01193	51.43540	0.45000
	17	25.40000	58.59000	1.40341	520.53302	0.01504	46.36851	1.43108
	18	25.40000	56.71000	1.63436	647.05042	0.01882	42.95156	1.66658
	19	25.40000	54.58000	0.67474	288.38934	0.01751	22.05233	0.68804
	20	25.40000	58.62000	0.93086	344.90930	0.02758	16.21518	0.94922
	1	25.40000	32.57000	0.54680	656.29883	0.01637	64.25157	0.55758
	2	25.40000	24.33000	0.16274	350.04056	0.01061	34.94841	0.16595
	3	25.40000	32.39000	0.03075	37.32431	0.11823	50.66129	0.03136
	4	25.40000	60.64000	1.14450	396.28378	0.04402	14.38519	1.16706
	5	25.40000	80.83000	0.23558	45.90939	0.11664	10.99881	0.24022
	6	25.40000	52.53000	0.60466	279.00119	0.01930	19.16726	0.61658
	7	25.40000	44.49000	0.50174	322.74643	0.01394	30.08553	0.51163
	8	25.40000	44.49000	0.12592	80.99933	0.11777	17.59783	0.12840
	9	25.40000	60.64000	0.60407	209.15881	0.01609	16.16784	0.61598
	10	25.40000	58.62000	0.10886	40.33560	0.01475	14.94128	0.11101

R12	11	25.40000	78.89000	0.31113	63.65174	0.01233	8.53037	0.31727
	12	25.40000	22.31000	0.06095	155.92204	0.11900	140.55370	0.06215
	13	25.40000	68.72000	0.24614	66.36305	0.12087	35.58943	0.25099
	14	25.40000	34.34000	0.07452	80.45517	0.12019	56.52498	0.07598
	15	25.40000	42.85000	0.53057	367.91476	0.01299	34.45446	0.54103
	16	25.40000	66.67000	0.64319	184.24167	0.01327	17.94597	0.65587
	17	25.40000	76.79000	1.56433	337.77618	0.01287	34.65836	1.59517
	18	25.40000	68.81000	0.35417	95.23958	0.11770	44.53861	0.36115
	19	25.40000	60.61000	0.79559	275.74600	0.01701	19.00464	0.81127
	20	25.40000	54.69000	0.27892	118.73286	0.12129	28.00641	0.28442
	1	25.40000	50.55000	0.33069	164.77328	0.01510	0	0.33721
	2	25.40000	32.39000	0.39758	482.51120	0.01181	45.28524	0.40541
	3	25.40000	52.68000	0.77455	355.36099	0.00962	46.95221	0.78982
	4	25.40000	64.65000	0.07662	23.33989	0.11777	18.39636	0.07813
	5	25.40000	26.34000	0.02133	39.13599	0.09821	104.20526	0.02175
	6	25.40000	22.22000	0.03187	82.19882	0.11805	49.32776	0.03250

R13	7	25.40000	36.42000	0.56948	546.64874	0.01377	52.47412	0.58071
	8	25.40000	50.55000	0.13703	68.27942	0.11981	41.70247	0.13973
	9	25.40000	40.45000	0.35118	273.28000	0.01110	28.25804	0.35811
	10	25.40000	62.76000	0.05510	17.81126	0.10689	44.96847	0.05619
	11	25.40000	30.30000	0.29655	411.26581	0.11727	143.25843	0.30240
	12	25.40000	642.80000	1.20054	3.69944	0.00978	0.51016	1.22421
	13	25.40000	58.73000	0.49930	184.31039	0.01665	14.47728	0.50914
	14	25.40000	38.38000	0.58712	507.48846	0.01355	47.56002	0.59869
	15	25.40000	571.40000	0.77925	3.03884	0.01247	0.30870	0.79462
	16	25.40000	42.47000	0.34225	241.59882	0.00878	37.35541	0.34900
	17	25.40000	66.67000	0.86641	248.18452	0.01556	21.57754	0.88350
	18	25.40000	72.84000	0.37752	90.59535	0.11461	21.03687	0.38496
	19	25.40000	72.73000	0.04380	10.54195	0.03463	14.37730	0.04466
	20	25.40000	64.77000	0.01857	5.63537	0.10468	26.44911	0.01893
	1	25.40000	54.55000	0.51778	221.54739	0.01394	20.66061	0.52799
	2	25.40000	50.55000	0.04433	22.08616	0.11311	49.49179	0.04520

R14	3	25.40000	52.53000	0.10509	48.49200	0.11728	18.06449	0.10717
	4	25.40000	52.56000	0.04854	22.36981	0.11537	50.81494	0.04949
	5	25.40000	54.58000	0.08105	34.64114	0.11880	58.91760	0.08265
	6	25.40000	38.44000	0.05680	48.94029	0.11905	30.15937	0.05792
	7	25.40000	36.42000	0.20683	198.54161	0.01204	19.83579	0.21091
	8	25.40000	50.51000	-0.03991	-19.91945	0.11945	14.63203	-0.04070
	9	25.40000	58.62000	0.14865	55.07841	0.11681	3.31410	0.15158
	10	25.40000	88.89000	0.12112	19.51678	0.11672	6.69739	0.12350
	11	25.40000	96.99000	0.05723	7.74601	0.11887	18.77152	0.05836
	12	25.40000	48.53000	0.07326	39.60693	0.11953	23.91281	0.07471
	13	25.40000	542.80000	0.48464	2.09436	0.00911	0.33818	0.49420
	14	25.40000	56.57000	0.19753	78.59204	0.11409	25.22011	0.20143
	15	25.40000	571.40000	0.53714	2.09469	0.00907	0.31588	0.54773
	16	25.40000	68.69000	0.03145	8.48575	0.06285	9.25553	0.03207
	17	25.40000	44.44000	-0.06475	-41.74187	0.11039	22.61440	-0.06602
	18	25.40000	70.74000	0.07372	18.75679	0.02491	6.93159	0.07517

	19	25.40000	54.58000	0.02129	9.09755	0.11807	10.53219	0.02171
	20	25.40000	500.00000	1.01112	5.14957	0.01733	0.41051	1.03105
R15	1	25.40000	84.16000	-0.02666	-4.79314	0.11838	4.63155	-0.02719
	2	25.40000	542.80000	0.74389	3.21469	0.01282	0.32759	0.75856
	3	25.40000	143.56000	0.26231	16.20510	0.11902	3.17833	0.26748
	4	25.40000	500.00000	2.47090	12.58420	0.02857	0.74153	2.51962
	5	25.40000	138.70000	-0.02783	-1.84215	0.11579	2.46880	-0.02838
	6	25.40000	163.37000	0.03525	1.68150	0.11708	1.43891	0.03594
	7	25.40000	207.92000	0.14067	4.14309	0.11848	2.12409	0.14345
	8	25.40000	707.94000	0.00997	0.02534	0.11046	0.06768	0.01017
	9	25.40000	332.02000	0.12796	1.47798	0.01060	0.22149	0.13049
	10	25.40000	99.13000	0.02431	3.14937	0.11684	6.00546	0.02479
	11	25.40000	542.80000	1.75956	7.60385	0.02388	0.61098	1.79425
	12	25.40000	143.56000	0.03190	1.97068	0.11472	1.34625	0.03253
	13	25.40000	109.02000	0.05722	6.13004	0.09060	3.45240	0.05835
	14	25.40000	158.42000	0.12172	6.17499	0.12058	2.21922	0.12412

	15	25.40000	542.80000	0.67651	2.92351	0.01675	0.24338	0.68985
	16	25.40000	138.70000	0.01090	0.72161	0.11917	0	0.01112
	17	25.40000	282.22000	0.02825	0.45163	0.07842	0.56572	0.02881
	18	25.40000	138.70000	0.05153	3.41068	0.10568	2.25401	0.05255
	19	25.40000	99.01000	0.02392	3.10717	0.11131	4.22985	0.02439
	20	25.40000	99.01000	0.02499	3.24580	0.08970	7.06931	0.02548
	1	25.40000	500.00000	0.13754	0.70050	0.12083	0.22949	0.14026
	2	25.40000	36.42000	-0.00827	-7.94127	0.10066	15.35228	-0.00844
	3	25.40000	62.66000	0.02551	8.27221	0.10132	7.63894	0.02601
	4	25.40000	48.53000	0.02568	13.88219	0.11034	14.85018	0.02618
	5	25.40000	48.65000	-0.00448	-2.40834	0.10344	15.44981	-0.00457
	6	25.40000	54.58000	0.01781	7.61042	0.10183	5.72622	0.01816
	7	25.40000	542.80000	0.10839	0.46841	0.11820	0.72204	0.11053
	8	25.40000	56.60000	0.00034	0.13659	0.11530	9.07747	0.00035
	9	25.40000	56.57000	-0.00483	-1.92200	0.10602	12.58492	-0.00493
	10	25.40000	80.83000	-0.01363	-2.65546	0.10645	1.82322	-0.01389

R16	11	25.40000	78.89000	-0.01091	-2.23112	0.11382	3.85684	-0.01112
	12	25.40000	113.13000	-0.00355	-0.35282	0.11472	2.61405	-0.00362
	13	25.40000	90.93000	0.00841	1.29576	0.10408	5.23273	0.00858
	14	25.40000	82.85000	0.01408	2.61133	0.11182	6.16350	0.01436
	15	25.40000	84.87000	-0.00441	-0.77967	0.11273	4.62452	-0.00450
	16	25.40000	40.40000	0.03295	25.70500	0.06584	7.15070	0.03360
	17	25.40000	285.70000	0.14644	2.28428	0.11751	0.91905	0.14933
	18	25.40000	571.40000	0.54694	2.13290	0.01118	0.26788	0.55772
	19	25.40000	60.61000	0.01266	4.38802	0.11028	10.12257	0.01291
	20	25.40000	58.62000	0.05434	20.13605	0.10765	6.10822	0.05542
	1	25.40000	62.92000	0.93760	301.54211	0.02058	30.45085	0.95608
	2	25.40000	48.48000	0.17108	92.68124	0.11996	46.89643	0.17446
	3	25.40000	54.58000	0.29706	126.96764	0.12039	23.94801	0.30292
	4	25.40000	30.30000	0.42334	587.10175	0.00962	90.28312	0.43169
	5	25.40000	48.65000	0.30698	165.13971	0.11894	45.59763	0.31303
	6	25.40000	50.51000	0.04414	22.02726	0.11730	29.81062	0.04501

R17	7	25.40000	38.60000	1.30285	1,113.34900	0.01891	84.60815	1.32854
	8	25.40000	52.56000	0.78543	361.99643	0.01853	26.98892	0.80091
	9	25.40000	46.51000	1.41389	832.20764	0.02398	15.16431	1.44176
	10	25.40000	56.60000	0.62464	248.26051	0.00913	36.85399	0.63696
	11	25.40000	48.48000	2.06111	1,116.57227	0.02284	78.99372	2.10175
	12	25.40000	54.69000	1.12629	479.45105	0.02844	29.19652	1.14850
	13	25.40000	74.86000	0.15824	35.95211	0.11849	21.35171	0.16136
	14	25.40000	542.80000	0.19808	0.85602	0.11812	0.31494	0.20199
	15	25.40000	357.10000	1.05789	10.56262	0.01717	0.76577	1.07875
	16	25.40000	46.51000	0.45407	267.26608	0.01561	28.94520	0.46303
	17	25.40000	68.81000	1.00076	269.11520	0.01143	31.49791	1.02049
	18	25.40000	40.45000	0.40027	311.47372	0.01198	34.75710	0.40816
	19	25.40000	46.51000	0.78168	460.09634	0.01732	45.93908	0.79710
	20	25.40000	70.74000	1.97337	502.09927	0.01581	47.16144	2.01228

Table 2. Games-Howell Test Data for Fibre Load at Break (N)

Sl.	RO	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17	V
R0		1.00	1.00	.99	.83	.06	.00	.20	.77	.65	.08	1.00	.01	.00	.00	.00	.00	.95	Sig.
R1	1.00		1.00	1.00	.95	.07	.00	.29	.91	.82	.10	1.00	.01	.00	.00	.00	.00	.99	Sig.
R2	1.00	1.00		1.00	.99	.47	.06	.70	.97	.93	.52	1.00	.20	.14	.00	.00	.00	.99	Sig.
R3	.99	1.00	1.00		1.00	.72	.03	.95	1.00	.99	.79	1.00	.26	.16	.00	.00	.00	1.00	Sig.
R4	.83	.95	.99	1.00		.78	.00	.98	1.00	1.00	.86	.99	.21	.10	.00	.00	.00	1.00	Sig.
R5	.06	.07	.47	.72	.78		.59	1.00	.99	1.00	1.00	.15	1.00	.99	.00	.00	.00	.96	Sig.
R6	.00	.00	.06	.03	.00	.59		.59	.26	.86	.63	.00	.99	1.00	.00	.00	.00	.18	Sig.
R7	.20	.29	.70	.95	.98	1.00	.59		1.00	1.00	1.00	.45	.99	.97	.00	.00	.00	.99	Sig.
R8	.77	.91	.97	1.00	1.00	.99	.26	1.00		1.00	.99	.96	.82	.67	.00	.00	.00	1.00	Sig.
R9	.65	.82	.93	.99	1.00	1.00	.86	1.00	1.00		1.00	.90	.99	.98	.11	.08	.04	1.00	Sig.
R10	.08	.10	.52	.79	.86	1.00	.63	1.00	.99	1.00		.20	1.00	.99	.00	.00	.00	.98	Sig.
R11	1.00	1.00	1.00	1.00	.99	.15	.00	.45	.96	.90	.20		.02	.01	.00	.00	.00	.99	Sig.
R12	.01	.01	.20	.26	.21	1.00	.99	.99	.82	.99	1.00	.02		1.00	.02	.01	.00	.65	Sig.
R13	.00	.00	.14	.16	.10	.99	1.00	.97	.67	.98	.99	.01	1.00		.06	.03	.00	.49	Sig.
R14	.00	.00	.00	.00	.00	.00	.00	.00	.00	.11	.00	.00	.02	.06		1.00	.15	.00	Sig.
R15	.00	.00	.00	.00	.00	.00	.00	.00	.00	.08	.00	.00	.01	.03	1.00		.68	.00	Sig.
R16	.00	.00	.00	.00	.00	.00	.00	.00	.00	.04	.00	.00	.00	.00	.15	.68		.00	Sig.
R17	.95	.99	.99	1.00	1.00	.96	.18	.99	1.00	1.00	.98	.99	.65	.49	.00	.00	.00		Sig.

Table 3. Games-Howell Test Data for Tensile Stress at Break (MPa)

Sl.	**RO**	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**	**R11**	**R12**	**R13**	**R14**	**R15**	**R16**	**R17**	**V**
R0		1.00	1.00	1.00	.99	.96	.80	.99	1.00	1.00	.99	1.00	.934	.841	0.00	0.00	0.00	1.00	Sig.
R1	1.00		1.00	1.00	1.00	.993	.950	.99	1.00	1.00	1.00	1.00	.98	.94	.00	.00	.00	1.00	Sig.
R2	1.00	1.00		.97	.94	.85	.71	.93	.97	.99	.96	1.00	.810	.70	.00	.00	.00	1.00	Sig.
R3	1.00	1.00	.97		1.00	1.00	1.00	1.00	1.00	1.00	1.00	.98	1.00	1.00	.00	.00	.00	.99	Sig.
R4	.99	1.00	.94	1.00		1.00	1.00	1.00	1.00	1.00	1.00	.94	1.00	1.00	.00	.00	.00	.991	Sig.
R5	.96	.99	.85	1.00	1.00		1.00	1.00	1.00	1.00	1.00	.79	1.00	1.00	.00	.00	.00	.95	Sig.
R6	.80	.95	.712	1.00	1.00	1.00		1.00	1.00	1.00	1.00	.53	1.00	1.00	.00	.00	.00	.84	Sig.
R7	.99	.99	.93	1.00	1.00	1.00	1.00		1.00	1.00	1.00	.92	1.00	1.00	.00	.00	.00	.98	Sig.
R8	1.00	1.00	.97	1.00	1.00	1.00	1.00	1.00		1.00	1.00	.97	1.00	1.00	.01	.00	.00	.99	Sig.
R9	1.00	1.00	.99	1.00	1.00	1.00	1.00	1.00	1.00		1.00	.99	1.00	1.00	.01	.00	.00	1.00	Sig.
R10	.99	1.00	.96	1.00	1.00	1.00	1.00	1.00	1.00	1.00		.96	1.00	1.00	.00	.00	.00	.99	Sig.
R11	1.00	1.00	1.00	.98	.94	.79	.53	.92	.97	.99	.96		.72	.59	.00	.00	.00	1.00	Sig.
R12	.93	.98	.81	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	.72		1.00	.00	.00	.00	.92	Sig.
R13	.84	.94	.70	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	.59	1.00		.06	.02	.02	.84	Sig.
R14	.00	.00	.00	.00	.00	.00	.00	.00	.01	.01	.00	.00	.00	.06		.21	.21	.00	Sig.
R15	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.21		1.00	.00	Sig.
R16	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.21	1.00		.00	Sig.
R17	1.00	1.00	1.00	.99	.99	.95	.84	.98	.99	1.00	.99	1.00	.92	.84	.00	.00	.00		Sig.

Table 4. Games-Howell Test Data for Tensile Strain at Break (%)

Sl.	RO	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17	V
R0		.100	.55	1.00	.79	.57	.61	.22	.27	.01	.33	1.00	.20	.30	.00	.00	.00	.54	Sig.
R1	1.00		.55	1.00	.79	.56	.60	.21	.26	.01	.42	1.00	.20	.29	.00	.00	.00	.53	Sig.
R2	.55	.55		.59	1.00	1.00	1.00	1.00	1.00	.91	.18	.41	1.00	1.00	.45	.21	.00	1.00	Sig.
R3	1.00	1.00	.59		.83	.61	.65	.24	.30	.01	.05	.99	.22	.33	.00	.00	.00	.57	Sig.
R4	.79	.79	1.00	.83		1.00	1.00	1.00	1.00	.77	.35	.65	.99	1.00	.26	.10	.00	1.00	Sig.
R5	.57	.56	1.00	.61	1.00		1.00	1.00	1.00	.92	.20	.43	1.00	1.00	.47	.23	.00	1.00	Sig.
R6	.61	.60	1.00	.65	1.00	1.00		1.00	1.00	.91	.22	.46	1.00	1.00	.44	.20	.00	1.00	Sig.
R7	.22	.21	1.00	.24	1.00	1.00	1.00		1.00	1.00	.06	.15	1.00	1.00	.91	.73	.00	1.00	Sig.
R8	.27	.26	1.00	.30	1.00	1.00	1.00	1.00		.99	.07	.18	1.00	1.00	.78	.52	.00	1.00	Sig.
R9	.01	.01	.91	.01	.77	.92	.91	1.00	.99		.00	.00	1.00	.99	1.00	1.00	.12	.97	Sig.
R10	.33	.42	.18	.05	.35	.20	.22	.06	.07	.00		.16	.06	.09	.00	.00	.00	.20	Sig.
R11	1.00	1.00	.41	.99	.65	.43	.46	.15	.18	.00	.16		.14	.21	.00	.00	.00	.41	Sig.
R12	.20	.20	1.00	.22	.99	1.00	1.00	1.00	1.00	1.00	.06	.14		1.00	.97	.87	.02	1.00	Sig.
R13	.30	.29	1.00	.33	1.00	1.00	1.00	1.00	1.00	.99	.09	.21	1.00		.88	.68	.00	1.00	Sig.
R14	.00	.00	.45	.00	.26	.47	.44	.91	.78	1.00	.00	.00	.97	.88		1.00	.63	.64	Sig.
R15	.00	.00	.21	.00	.10	.23	.20	.73	.52	1.00	.00	.00	.87	.68	1.00		.67	.38	Sig.
R16	.00	.00	.00	.00	.00	.00	.00	.00	.00	.12	.00	.00	.02	.00	.63	.67		.00	Sig.
R17	.54	.53	1.00	.57	1.00	1.00	1.00	1.00	1.00	.97	.20	.41	1.00	1.00	.64	.38	.00		Sig.

Table 5. Games-Howell Test Data for Young's Modulus (GPa)

Sl.	**RO**	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**	**R11**	**R12**	**R13**	**R14**	**R15**	**R16**	**R17**	**V**
R0		1.00	.61	1.00	1.00	1.00	.77	1.00	1.00	.99	.73	.92	.92	.94	1.00	.00	.00	.62	Sig.
R1	1.00		.99	1.00	1.00	.99	.70	.98	1.00	1.00	.99	1.00	1.00	1.00	.98	.00	.00	1.00	Sig.
R2	.61	.99		.96	1.00	.60	.13	.36	.93	.99	1.00	1.00	1.00	1.00	.41	.00	.00	1.00	Sig.
R3	1.00	1.00	.96		1.00	1.00	.89	.99	1.00	1.00	.98	1.00	1.00	1.00	.99	.00	.00	.99	Sig.
R4	1.00	1.00	1.00	1.00		.99	.89	.99	1.00	1.00	1.00	1.00	1.00	1.00	.98	.01	.055	1.00	Sig.
R5	1.00	.99	.60	1.00	.99		.99	1.00	1.00	.99	.71	.90	.90	.93	1.00	1.00	.00	.67	Sig.
R6	.77	.70	.13	.89	.89	.99		1.00	.99	.47	.18	.27	.28	.35	1.00	.00	.00	.06	Sig.
R7	1.00	.98	.36	.99	.99	1.00	1.00		1.00	.92	.46	.68	.68	.75	1.00	.00	.00	.32	Sig.
R8	1.00	1.00	.93	1.00	1.00	1.00	.99	1.00		1.00	.96	.99	.99	.99	1.00	.01	.11	.98	Sig.
R9	.99	1.00	.99	1.00	1.00	.99	.47	.92	1.00		.99	1.00	1.00	1.00	.93	.00	.00	1.00	Sig.
R10	.73	.99	1.00	.98	1.00	.71	.18	.46	.96	.99		1.00	1.00	1.00	.51	.00	.00	1.00	Sig.
R11	.92	1.00	1.00	1.00	1.00	.90	.27	.68	.99	1.00	1.00		1.00	1.00	.73	.00	.00	1.00	Sig.
R12	.92	1.00	1.00	1.00	1.00	.90	.28	.68	.99	1.00	1.00	1.00		1.00	.74	.00	.00	1.00	Sig.
R13	.94	1.00	1.00	1.00	1.00	.93	.35	.75	.99	1.00	1.00	1.00	1.00		.78	.00	.00	1.00	Sig.
R14	1.00	.98	.41	.99	.98	1.00	1.00	1.00	1.00	.93	.51	.73	.74	.78		.01	.15	.46	Sig.
R15	.00	.00	.00	.00	.01	.00	.00	.00	.01	.00	.00	.00	.00	.00	.01		.08	.00	Sig.
R16	.00	.00	.00	.00	.055	.00	.00	.00	.11	.00	.00	.00	.00	.00	.15	.08		.00	Sig.
R17	.62	1.00	1.00	.99	1.00	.67	.06	.32	.98	1.00	1.00	1.00	1.00	1.00	.46	.00	.00		Sig.

Table 6. Games-Howell Test Data for Tenacity at Break (gf/tex)

Sl.	**RO**	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**	**R11**	**R12**	**R13**	**R14**	**R15**	**R16**	**R17**	**V**
R0		1.00	1.00	.99	.83	.06	.00	.20	.77	.43	.08	1.00	.01	.00	.00	.00	.00	.95	Sig.
R1	1.00		1.00	1.00	.95	.07	.00	.29	.91	.60	.10	1.00	.01	.00	.00	.00	.00	.99	Sig.
R2	1.00	1.00		1.00	.99	.47	.06	.70	.97	.83	.52	1.00	.20	.14	.00	.00	.00	.99	Sig.
R3	.99	1.00	1.00		1.00	.72	.03	.95	1.00	.99	.79	1.00	.26	.16	.00	.00	.00	1.00	Sig.
R4	.83	.95	.99	1.00		.78	.00	.98	1.00	.99	.86	.99	.21	.10	.00	.00	.00	1.00	Sig.
R5	.06	.07	.47	.72	.78		.59	1.00	.99	1.00	1.00	.15	1.00	.99	.00	.00	.00	.96	Sig.
R6	.00	.00	.06	.03	.00	.59		.59	.26	.91	.63	.00	.99	1.00	.00	.00	.00	.18	Sig.
R7	.20	.29	.70	.95	.98	1.00	.59		1.00	1.00	1.00	.45	.99	.97	.00	.00	.00	.99	Sig.
R8	.77	.91	.97	1.00	1.00	.99	.26	1.00		1.00	.99	.96	.82	.67	.00	.00	.00	1.00	Sig.
R9	.43	.60	.83	.99	.99	1.00	.91	1.00	1.00		1.00	.73	1.00	.99	.11	.11	.04	1.00	Sig.
R10	.08	.10	.52	.79	.86	1.00	.63	1.00	.99	1.00		.20	1.00	.99	.00	.00	.00	.98	Sig.
R11	1.00	1.00	1.00	1.00	.99	.15	.00	.45	.96	.73	.20		.02	.01	.00	.00	.00	.99	Sig.
R12	.01	.01	.20	.26	.21	1.00	.99	.99	.82	1.00	1.00	.02		1.00	.02	.02	.00	.65	Sig.
R13	.00	.00	.14	.16	.10	.99	1.00	.97	.67	.99	.99	.01	1.00		.06	.07	.00	.49	Sig.
R14	.00	.00	.00	.00	.00	.00	.00	.00	.00	.11	.00	.00	.02	.06		1.00	.15	.00	Sig.
R15	.00	.00	.00	.00	.00	.00	.00	.00	.00	.11	.00	.00	.02	.07	1.00		.46	.00	Sig.
R16	.00	.00	.00	.00	.00	.00	.00	.00	.00	.04	.00	.00	.00	.00	.15	.46		.00	Sig.
R17	.95	.99	.99	1.00	1.00	.96	.18	1.00	1.00	1.00	.98	.99	.65	.49	.00	.00	.00		Sig.

Appendix IV

Table 1. Sample with Result from the Moisture Regain (%) Analysis

NaOH treated solution		Before place in Desiccator			After the removing from the Desiccator and before placing inside the Woven			After removing from the Woven		
	Sl.	Sample weight	Container weight	Sample and container weight	Sample weight	Container weight	Sample and container weight	Sample weight	Container weight	Sample and container weight
RO (1st time used solution of NaOH) sample 106 to 117	1	0.50	3.92	1.41	0.51	3.93	4.44	0.472	3.918	4.395
	2	0.55	3.97	4.53	0.59	4.02	4.61	0.535	3.971	4.508
	3	0.54	3.92	4.47	0.56	3.93	4.49	0.507	3.917	4.424
	4	0.61	4.00	4.61	0.64	4.06	4.71	0.574	4.004	4.579
	5	0.70	4.02	4.72	0.72	4.01	4.74	0.664	4.011	4.675
	6	0.54	4.01	4.55	0.56	4.02	4.58	0.511	3.996	4.510
	7	0.67	4.00	4.69	0.71	4.01	4.72	0.634	3.994	4.630
	8	0.48	1.69	2.18	0.51	1.70	2.21	0.454	1.693	2.151
	9	0.54	1.70	2.25	0.57	1.70	2.27	0.514	1.704	2.220
	10	0.75	1.70	2.46	0.80	1.70	2.50	0.716	1.704	2.422
	11	0.45	1.72	2.17	0.47	1.72	2.19	0.420	1.721	2.142
	12	0.52	2.37	2.89	0.56	2.37	2.92	0.501	2.353	2.856
R1 (1st time reused solution of NaOH) sample 118 to 129	1	0.66	3.93	4.59	0.69	3.94	4.62	0.615	3.921	4.536
	2	0.56	3.97	4.56	0.58	3.99	4.58	0.537	3.974	4.514
	3	0.66	3.93	4.59	0.68	3.94	4.62	0.617	3.918	4.536
	4	0.69	4.02	4.71	0.71	4.01	4.73	0.642	4.005	4.651
	5	0.72	4.02	4.73	0.74	4.02	4.76	0.664	4.011	4.676
	6	0.77	4.01	4.78	0.79	4.02	4.81	0.713	4.001	4.715
	7	0.48	4.01	4.49	0.50	4.01	4.51	0.450	3.995	4.449
	8	0.65	1.68	2.34	0.67	1.69	2.37	0.621	1.692	2.311
	9	0.78	1.71	2.47	0.80	1.70	2.49	0.722	1.703	2.427

	10	0.59	1.71	2.30	0.60	1.71	2.32	0.552	1.706	2.260
	11	0.73	1.73	2.44	0.74	1.72	2.48	0.684	1.721	2.406
	12	0.70	2.36	3.06	0.73	2.36	3.08	0.660	2.354	3.016
R2 (2nd time reused solution of NaOH) sample 130 to 141	1	0.68	0.79	1.47	0.69	0.77	1.49	0.625	0.774	1.400
	2	0.65	0.76	1.44	0.67	0.75	1.44	0.612	0.745	1.360
	3	0.74	0.76	1.51	0.75	0.75	1.54	0.683	0.743	1.429
	4	0.76	0.80	1.58	0.81	0.82	1.62	0.713	0.783	1.500
	5	0.70	0.78	1.49	0.75	0.81	1.54	0.663	0.773	1.438
	6	0.77	0.76	1.53	0.81	0.76	1.57	0.721	0.743	1.466
	7	0.84	0.80	1.63	0.88	0.81	1.68	0.774	0.779	1.554
	8	0.85	0.78	1.63	0.89	0.79	1.69	0.799	0.760	1.557
	9	0.74	0.77	1.51	0.78	0.78	1.56	0.692	0.750	1.446
	10	0.78	0.79	1.57	0.82	0.79	1.61	0.732	0.758	1.492
	11	0.63	0.79	1.43	0.67	0.82	1.48	0.598	0.774	1.375
	12	0.68	0.75	1.42	0.70	0.77	1.47	0.630	0.736	1.366
R3 (3rd time reused solution of NaOH) sample 142 to 153	1	0.79	3.93	4.72	0.83	3.94	4.77	0.749	3.922	4.671
	2	0.89	3.98	4.87	0.94	4.05	4.99	0.843	3.987	4.830
	3	0.75	3.93	4.68	0.78	3.93	4.71	0.704	3.919	4.623
	4	0.66	4.02	4.68	0.76	4.07	4.83	0.637	4.020	4.657
	5	0.78	4.03	4.81	0.83	4.03	4.86	0.741	4.016	4.757
	6	0.88	4.02	4.90	0.94	4.02	4.96	0.836	4.003	4.839
	7	0.82	4.00	4.82	0.86	4.05	4.91	0.786	4.006	4.792
	8	0.75	1.69	2.44	0.77	1.70	2.47	0.714	1.694	2.408
	9	0.89	1.70	2.59	0.96	1.67	2.63	0.827	1.702	2.529
	10	0.83	1.71	2.54	0.91	1.71	2.62	0.816	1.704	2.520
	11	0.77	1.72	2.49	0.80	1.72	2.52	0.726	1.720	2.446
	12	0.75	2.36	3.11	0.79	2.37	3.16	0.706	2.356	3.062
R4 (4th time reused solution of NaOH)	1	0.58	3.93	4.51	0.58	3.94	4.52	0.527	3.925	4.452
	2	0.69	4.03	4.72	0.72	4.08	4.80	0.639	4.030	4.669
	3	0.72	3.92	4.64	0.73	3.93	4.66	0.665	3.905	4.570
	4	0.71	4.05	4.76	0.73	4.05	4.78	0.652	4.030	4.682

sample 154 to 165	5	0.80	4.03	4.83	0.82	4.08	4.90	0.726	4.032	4.758
	6	0.79	4.03	4.82	0.81	4.09	4.90	0.72	4.025	4.745
	7	0.78	4.02	4.80	0.80	4.02	4.82	0.724	4.004	4.728
	8	0.80	1.69	2.49	0.81	1.70	2.51	0.72	1.693	2.413
	9	0.81	1.72	2.53	0.83	1.71	2.54	0.753	1.703	2.456
	10	0.67	1.71	2.38	0.65	1.71	2.36	0.597	1.705	2.302
	11	0.75	1.72	2.47	0.77	1.73	2.50	0.688	1.731	2.419
	12	0.68	2.36	3.04	0.70	2.36	3.06	0.618	2.357	2.975
R5 (5^{th} time reused solution of NaOH) sample 166 to 177	1	0.70	0.79	1.49	0.81	0.74	1.55	0.66	0.779	1.439
	2	0.68	0.77	1.45	0.72	0.76	1.48	0.632	0.750	1.382
	3	0.71	0.76	1.47	0.73	0.77	1.50	0.659	0.750	1.409
	4	0.77	0.81	1.58	0.82	0.81	1.63	0.725	0.789	1.514
	5	0.76	0.80	1.56	0.81	0.80	1.61	0.717	0.779	1.496
	6	0.71	0.75	1.46	0.72	0.76	1.48	0.64	0.740	1.380
	7	0.70	0.81	1.51	0.74	0.82	1.56	0.657	0.777	1.434
	8	0.65	0.79	1.44	0.70	0.77	1.47	0.617	0.761	1.378
	9	0.64	0.77	1.41	0.65	0.78	1.43	0.594	0.753	1.347
	10	0.67	0.78	1.45	0.71	0.79	1.50	0.631	0.757	1.388
	11	0.56	0.79	1.35	0.59	0.79	1.38	0.521	0.782	1.303
	12	0.63	0.75	1.38	0.64	0.76	1.40	0.572	0.739	1.311
R6 (6^{th} time reused solution of NaOH) sample 178 to 189	1	0.57	3.94	4.51	0.61	3.93	4.54	0.534	3.924	4.458
	2	0.58	4.00	4.58	0.61	4.10	4.71	0.551	4.016	4.567
	3	0.58	3.94	4.52	0.61	3.93	4.54	0.551	3.919	4.470
	4	0.59	4.03	4.62	0.60	4.08	4.68	0.547	4.031	4.578
	5	0.60	4.01	4.61	0.61	4.06	4.67	0.556	4.016	4.572
	6	0.61	4.01	4.62	0.64	4.06	4.70	0.575	4.009	4.584
	7	0.65	4.00	4.65	0.68	4.02	4.70	0.604	4.004	4.608
	8	0.58	1.67	2.25	0.59	1.70	2.29	0.532	1.692	2.224
	9	0.56	1.68	2.24	0.57	1.71	2.28	0.519	1.702	2.221
	10	0.52	1.68	2.20	0.53	1.69	2.22	0.481	1.701	2.182
	11	0.56	1.70	2.26	0.56	1.73	2.29	0.512	1.718	2.230

	12	0.41	2.34	2.75	0.42	2.37	2.79	0.387	2.352	2.739
R7 (7th time reused solution of NaOH) sample 190 to 201	1	0.52	0.79	1.31	0.54	0.83	1.37	0.491	0.770	1.261
	2	0.53	0.80	1.33	0.56	0.82	1.38	0.497	0.775	1.272
	3	0.62	0.79	1.41	0.63	0.83	1.46	0.571	0.775	1.346
	4	0.60	0.77	1.37	0.64	0.80	1.44	0.563	0.749	1.312
	5	0.62	0.79	1.41	0.66	0.81	1.47	0.592	0.761	1.353
	6	0.61	0.76	1.37	0.64	0.79	1.43	0.562	0.739	1.301
	7	0.69	0.79	1.48	0.71	0.84	1.55	0.639	0.777	1.416
	8	0.68	0.77	1.45	0.70	0.80	1.50	0.625	0.753	1.378
	9	0.71	0.80	1.51	0.74	0.83	1.57	0.677	0.772	1.449
	10	0.57	0.81	1.38	0.57	0.84	1.41	0.53	0.792	1.322
	11	0.69	0.77	1.46	0.71	0.79	1.50	0.638	0.757	1.395
	12	0.66	0.76	1.42	0.68	0.78	1.46	0.628	0.747	1.375
R8 (8th time reused solution of NaOH) sample 202 to 213	1	0.59	3.94	4.53	0.62	3.94	4.56	0.552	3.922	4.474
	2	0.59	4.04	4.63	0.62	4.06	4.68	0.549	4.030	4.579
	3	0.53	3.92	4.45	0.57	3.92	4.49	0.495	3.921	4.416
	4	0.61	4.04	4.65	0.64	4.04	4.68	0.567	4.027	4.594
	5	0.60	4.05	4.65	0.64	4.09	4.73	0.57	4.049	4.619
	6	0.58	4.04	4.62	0.61	4.07	4.68	0.542	4.038	4.580
	7	0.61	4.02	4.63	0.64	4.03	4.67	0.555	4.008	4.563
	8	0.65	1.70	2.35	0.68	1.70	2.38	0.613	1.694	2.307
	9	0.59	1.71	2.30	0.60	1.72	2.32	0.557	1.705	2.262
	10	0.59	1.63	2.22	0.54	1.71	2.25	0.497	1.703	2.200
	11	0.57	1.74	2.31	0.62	1.72	2.34	0.551	1.723	2.274
	12	0.56	2.37	2.93	0.59	2.37	2.96	0.532	2.352	2.884
R9 (9th time reused solution of NaOH)	1	0.67	0.80	1.47	0.70	0.80	1.50	0.628	0.771	1.399
	2	0.76	0.77	1.53	0.78	0.79	1.57	0.710	0.748	1.458
	3	0.72	0.77	1.49	0.75	0.77	1.52	0.672	0.749	1.421
	4	0.60	0.82	1.42	0.64	0.81	1.45	0.570	0.792	1.362
	5	0.64	0.80	1.44	0.68	0.80	1.48	0.609	0.781	1.390
	6	0.74	0.76	1.50	0.79	0.78	1.57	0.693	0.750	1.443

sample 214 to 225	7	0.64	0.80	1.44	0.65	0.81	1.46	0.587	0.792	1.379
	8	0.67	0.86	1.53	0.77	0.79	1.56	0.698	0.763	1.461
	9	0.58	0.77	1.35	0.62	0.78	1.40	0.554	0.753	1.307
	10	0.67	0.78	1.45	0.69	0.79	1.48	0.630	0.760	1.390
	11	0.61	0.80	1.41	0.63	0.81	1.44	0.576	0.780	1.356
	12	0.69	0.76	1.45	0.71	0.76	1.47	0.640	0.741	1.381
R10 (10^{th} time reused solution of NaOH) sample 226 to 237	1	0.59	3.91	4.50	0.61	3.96	4.57	0.552	3.922	4.474
	2	0.72	4.02	4.74	0.76	4.04	4.80	0.678	4.029	4.707
	3	0.67	3.91	4.58	0.69	3.93	4.62	0.629	3.920	4.549
	4	0.59	4.01	4.60	0.62	4.06	4.68	0.551	4.036	4.587
	5	0.68	4.02	4.70	0.70	4.10	4.80	0.635	4.057	4.692
	6	0.92	4.00	4.92	0.96	4.07	5.03	0.862	4.035	4.897
	7	0.67	4.02	4.69	0.70	4.03	4.73	0.627	4.006	4.633
	8	0.61	1.69	2.30	0.62	1.70	2.32	0.578	1.692	2.270
	9	0.76	1.70	2.46	0.78	1.70	2.48	0.710	1.706	2.416
	10	0.71	1.71	2.42	0.75	1.70	2.45	0.677	1.705	2.382
	11	0.68	1.73	2.41	0.69	1.73	2.42	0.636	1.723	2.359
	12	0.64	2.36	3.00	0.66	2.36	3.02	0.602	2.352	2.954
R11 (11^{th} time reused solution of NaOH) sample 238 to 249	1	0.49	3.93	4.42	0.51	3.91	4.42	0.488	3.892	4.380
	2	0.61	3.98	4.59	0.63	3.96	4.59	0.571	3.971	4.542
	3	0.70	3.87	4.57	0.71	3.86	4.57	0.652	3.870	4.522
	4	0.53	3.94	4.47	0.54	3.93	4.47	0.494	3.942	4.436
	5	0.56	3.90	4.46	0.57	3.87	4.46	0.534	3.881	4.415
	6	0.64	3.90	4.54	0.65	3.89	4.54	0.598	3.896	4.494
	7	0.55	3.85	4.40	0.59	3.82	4.41	0.516	3.849	4.365
	8	0.53	2.54	3.07	0.54	2.52	3.06	0.500	2.531	3.031
	9	0.59	2.53	3.12	0.62	2.50	3.12	0.559	2.521	3.080
	10	0.52	2.55	3.07	0.55	2.52	3.07	0.499	2.541	3.040
	11	0.57	2.54	3.11	0.60	2.52	3.12	0.550	2.538	3.088
	12	0.56	2.50	3.06	0.60	2.47	3.07	0.539	2.500	3.039
	1	0.56	3.91	4.47	0.59	3.94	4.53	0.519	3.925	4.444

R12 (12th time reused solution of NaOH) sample 250 to 261	2	0.69	4.01	4.70	0.71	4.06	4.77	0.641	4.027	4.668
	3	0.72	3.90	4.62	0.74	3.93	4.67	0.676	3.909	4.585
	4	0.66	4.01	4.67	0.68	4.06	4.74	0.618	4.036	4.654
	5	0.72	4.04	4.76	0.75	4.08	4.83	0.683	4.057	4.740
	6	0.76	4.00	4.76	0.78	4.06	4.84	0.701	4.033	4.734
	7	0.66	4.03	4.69	0.67	4.03	4.70	0.556	4.006	4.622
	8	0.66	1.72	2.38	0.67	1.71	2.38	0.633	1.685	2.318
	9	0.76	1.72	2.48	0.76	1.72	2.48	0.698	1.705	2.403
	10	0.74	1.73	2.47	0.77	1.71	2.48	0.695	1.707	2.402
	11	0.75	1.74	2.49	0.76	1.73	2.49	0.707	1.720	2.427
	12	0.72	2.56	3.28	0.74	2.55	3.29	0.669	2.541	3.210
R13 (13th time reused solution of NaOH) sample 262 to 273	1	0.64	3.92	4.56	0.65	3.94	4.59	0.617	3.892	4.509
	2	0.66	3.98	4.64	0.70	3.98	4.68	0.628	3.968	4.596
	3	0.71	3.88	4.59	0.73	3.87	4.60	0.657	3.870	4.527
	4	0.72	3.96	4.68	0.74	3.95	4.69	0.669	3.944	4.613
	5	0.74	3.89	4.63	0.77	3.90	4.67	0.688	3.885	4.573
	6	0.70	3.91	4.61	0.74	3.89	4.63	0.662	3.893	4.555
	7	0.65	3.86	4.51	0.69	3.85	4.54	0.615	3.850	4.465
	8	0.69	2.54	3.23	0.74	2.53	3.27	0.648	2.531	3.179
	9	0.65	2.53	3.18	0.66	2.52	3.18	0.603	2.520	3.123
	10	0.65	2.55	3.20	0.68	2.55	3.23	0.609	2.542	3.151
	11	0.72	2.55	3.27	0.75	2.54	3.29	0.673	2.539	3.212
	12	0.63	2.51	3.14	0.67	2.51	3.18	0.605	2.497	3.102
R14 (14th time reused solution of NaOH) sample 274 to 285	1	0.62	3.94	4.56	0.67	3.94	4.61	0.588	3.924	4.512
	2	0.64	3.98	4.62	0.65	3.98	4.63	0.587	3.971	4.558
	3	0.69	3.88	4.57	0.71	3.88	4.59	0.636	3.870	4.506
	4	0.75	3.96	4.71	0.80	3.94	4.74	0.709	3.944	4.653
	5	0.74	3.89	4.63	0.77	3.89	4.66	0.693	3.883	4.576
	6	0.71	3.88	4.59	0.74	3.90	4.64	0.662	3.895	4.557
	7	0.77	3.86	4.63	0.78	3.86	4.64	0.715	3.848	4.563
	8	0.70	2.54	3.24	0.73	2.54	3.27	0.654	2.528	3.182

	9	0.75	2.52	3.27	0.79	2.53	3.32	0.708	2.520	3.228
	10	0.65	2.54	3.19	0.67	2.54	3.21	0.602	2.541	3.143
	11	0.72	2.54	3.26	0.75	2.54	3.29	0.677	2.540	3.217
	12	0.69	2.50	3.19	0.70	2.50	3.20	0.636	2.500	3.136
R15 (15th time reused solution of NaOH) sample 286 to 297	1	0.73	3.91	4.64	0.73	3.93	4.66	0.682	3.897	4.579
	2	0.84	4.04	4.88	0.87	4.05	4.92	0.785	4.026	4.811
	3	0.77	3.93	4.70	0.81	3.92	4.73	0.731	3.918	4.649
	4	0.78	4.04	4.82	0.79	4.05	4.84	0.712	4.037	4.749
	5	0.75	4.07	4.82	0.80	4.08	4.88	0.708	4.058	4.766
	6	0.84	4.03	4.87	0.86	4.06	4.92	0.775	4.036	4.811
	7	0.77	4.02	4.79	0.80	4.03	4.83	0.725	4.009	4.734
	8	0.72	1.69	2.41	0.76	1.70	2.46	0.680	1.692	2.372
	9	0.72	1.70	2.42	0.75	1.71	2.46	0.685	1.705	2.390
	10	0.79	1.70	2.49	0.82	1.71	2.53	0.737	1.703	2.440
	11	0.90	1.71	2.61	0.91	1.73	2.64	0.833	1.722	2.555
	12	0.64	2.54	3.18	0.65	2.56	3.21	0.587	2.541	3.128
R16 (16th time reused solution of NaOH) sample 298 to 309	1	0.62	3.94	4.56	0.66	3.91	4.57	0.582	3.920	4.502
	2	0.70	3.97	4.67	0.72	3.96	4.68	0.648	3.972	4.620
	3	0.68	3.87	4.55	0.70	3.89	4.59	0.632	3.870	4.502
	4	0.71	3.96	4.67	0.74	3.95	4.69	0.679	3.944	4.623
	5	0.72	3.89	4.61	0.75	3.89	4.64	0.661	3.885	4.546
	6	0.65	3.89	4.54	0.66	3.89	4.55	0.596	3.894	4.490
	7	0.73	3.86	4.59	0.75	3.85	4.60	0.683	3.848	4.531
	8	0.71	2.54	3.25	0.75	2.54	3.29	0.678	2.530	3.208
	9	0.71	2.53	3.24	0.74	2.51	3.25	0.659	2.521	3.180
	10	0.74	2.55	3.29	0.79	2.54	3.33	0.708	2.542	3.250
	11	0.72	2.55	3.27	0.76	2.55	3.31	0.694	2.538	3.232
	12	0.75	2.51	3.26	0.78	2.51	3.29	0.711	2.499	3.210
R17 (17th time reused solution of NaOH)	1	0.62	3.93	4.55	0.65	3.93	4.58	0.590	3.922	4.512
	2	0.60	4.03	4.63	0.64	4.06	4.70	0.569	4.028	4.597
	3	0.72	3.93	4.65	0.74	3.93	4.67	0.672	3.920	4.592

sample 310 to 321	4	0.69	4.04	4.73	0.71	4.04	4.75	0.636	4.036	4.672
	5	0.67	4.06	4.73	0.70	4.08	4.78	0.631	4.058	4.689
	6	0.77	4.04	4.81	0.78	4.06	4.84	0.713	4.031	4.744
	7	0.67	4.02	4.69	0.68	4.02	4.70	0.626	4.008	4.634
	8	0.71	1.69	2.40	0.74	1.68	2.42	0.660	1.693	2.353
	9	0.68	1.71	2.39	0.71	1.71	2.42	0.651	1.704	2.355
	10	0.68	1.70	2.38	0.71	1.70	2.41	0.645	1.703	2.348
	11	0.68	1.73	2.41	0.69	1.72	2.41	0.643	1.725	2.368
	12	0.71	2.56	3.27	0.75	2.54	3.29	0.680	2.541	3.221

Table 2. Tukey HSD Test Data for Moisture Regain (%) Analysis

Sl.	**RO**	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**	**R11**	**R12**	**R13**	**R14**	**R15**	**R16**	**R17**	**V**
R0		.99	.93	1.00	.99	.12	1.00	1.00	.69	1.00	1.00	.56	1.00	1.00	1.00	1.00	1.00	1.00	Sig.
R1	.99		.21	.90	.64	.00	1.00	.98	.06	.92	1.00	.99	1.00	.92	.73	1.00	.97	1.00	Sig.
R2	.93	.21		1.00	1.00	.99	.74	.99	1.00	1.00	.54	.00	.52	1.00	1.00	.85	.99	.34	Sig.
R3	1.00	.90	1.00		1.00	.53	1.00	1.00	.98	1.00	.99	.13	.99	1.00	1.00	1.00	1.00	.97	Sig.
R4	.99	.64	1.00	1.00		.84	.98	1.00	1.00	1.00	.92	.03	.91	1.00	1.00	.99	1.00	.80	Sig.
R5	.12	.00	.99	.53	.84		.03	.29	1.00	.49	.01	.00	.01	.50	.76	.06	.33	.00	Sig.
R6	1.00	1.00	.74	1.00	.98	.03		1.00	.40	1.00	1.00	.83	1.00	1.00	.99	1.00	1.00	1.00	Sig.
R7	1.00	.98	.99	1.00	1.00	.29	1.00		.90	1.00	1.00	.30	1.00	1.00	1.00	1.00	1.00	.99	Sig.
R8	.69	.06	1.00	.98	1.00	1.00	.40	.90		.97	.22	.00	.22	.98	.99	.53	.92	.12	Sig.
R9	1.00	.92	1.00	1.00	1.00	.49	1.00	1.00	.97		.99	.15	.99	1.00	1.00	1.00	1.00	.97	Sig.
R10	**1**.00	1.00	.54	.99	.92	.01	1.00	1.00	.22	.99		.94	1.00	.99	.95	1.00	1.00	1.00	Sig.
R11	.56	.99	.00	.13	.03	.00	.83	.30	.00	.15	.94		.95	.15	.05	.72	.27	.98	Sig.
R12	1.00	1.00	.52	.99	.91	.01	1.00	1.00	.22	.99	1.00	.95		.99	.95	1.00	1.00	1.00	Sig.
R13	1.00	.92	1.00	1.00	1.00	.50	1.00	1.00	.98	1.00	.99	.15	.99		1.00	1.00	1.00	.97	Sig.
R14	1.00	.73	1.00	1.00	1.00	.76	.99	1.00	.99	1.00	.95	.05	.95	1.00		.99	1.00	.86	Sig.
R15	1.00	1.00	.85	1.00	.99	.06	1.00	1.00	.53	1.00	1.00	.72	1.00	1.00	.99		1.00	1.00	Sig.
R16	1.00	.97	.99	1.00	1.00	.33	1.00	1.00	.92	1.00	1.00	.27	1.00	1.00	1.00	1.00		.99	Sig.
R17	1.00	1.00	.34	.97	.80	.00	1.00	.99	.12	.97	1.00	.98	1.00	.97	.86	1.00	.99		Sig.