UNIVERSITI MALAYSIA KELANTAN

PREPARATION AND CHARATERIZATION OF PVA / CELLULOSE NANOCRYSTALS / ZINC OXIDE NANOCOMPOSITE AS POTENTIAL FOR THIN FILM IN CHILI FRESH FRUIT PACKAGING APPLICATION.

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A thesis submitted in fulfilment of the requirements for the degree of Bachelor of Applied Science (Materials Technology) with Honours

FACULTY OF BIOENGINEERING AND TECHNOLOGY
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DECLARATION

I hereby declare that the work embodied in this thesis is the result of the original research and has not been submitted for a higher degree to ant universities or institutions.

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I certify that the report of this final year project entitled "Preparation And Charaterization Of PVA / Cellulose Nanocrystals / ZnO Nanocomposite As Potential For Thin Film In Chili Fresh Fruit Packaging Application" by Khalidah Adilah binti Ibrahim with matric number J20A0458 has been examined and all the correction recommended by the examiners have been done for the Degree of Bachelor of Applied Science (Material Technology, Faculty of Bioengineering and Technology, University Malaysia Kelantan.

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ABSTRACT

The focus of the thesis is on the production and examination of thin films made of polyvinyl alcohol (PVA), cellulose nanocrystals (CNC), and zinc oxide (ZnO), with an eye towards their potential application in food packaging. The research's characterization phase includes a comprehensive investigation of the physical and chemical properties of the resulting thin films. A material endurance can be assessed by examining its tensile strength, flexibility, weight loss, and x-ray diffraction results, among other mechanical properties. Consideration of gas and moisture permeability characteristics is crucial for food packaging materials. By shedding light on these characteristics, the study intends to significantly advance the area of sustainable packaging. Packaging food items requires attention to both mechanical and antimicrobial requirements to ensure continued quality and safety. An eco-friendly and effective replacement for food packaging is what we are aiming for. By incorporating antimicrobial properties into the packaging material, we can prevent the growth of harmful bacteria and extend the shelf life of food products. Additionally, the study will also evaluate the environmental impact of the packaging materials to ensure they are truly sustainable and contribute to reducing waste in the long run. A research study found that PVA, CNC, and ZnO were the most effective in keeping fresh chilies fresh for 20 days. In order to decrease plastic waste from packaged foods with a lengthy shelf life, this study proposes a long-term solution.

Keywords: Poly (Vinyl Alcohol) (PVA), Cellulose Nanocrystals (CNC), Zinc Oxide (ZnO), nanocomposite films, food packaging.

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ABSTRACT

Tumpuan tesis adalah pada penghasilan dan pemeriksaan filem nipis yang diperbuat daripada polivinil alkohol (PVA), nanokristal selulosa (CNC), dan zink oksida (ZnO), dengan tumpuan terhadap potensi penggunaannya dalam pembungkusan makanan. Penggabungan nanokristal selulosa dan zink oksida yang betul ke dalam matriks PVA memerlukan pengendalian yang teliti semasa pembuatan filem nipis ini. Fasa pencirian penyelidikan termasuk penyiasatan menyeluruh tentang sifat fizikal dan kimia bagi filem nipis yang terhasil. Ketahanan bahan boleh dinilai dengan memeriksa kekuatan tegangan, fleksibiliti, penurunan berat badan dan hasil pembelauan sinar-x, antara sifat mekanikal yang lain. Pertimbangan ciri ke boleh telapan gas dan kelembapan, khususnya, adalah penting untuk bahan pembungkus makanan. Dengan menjelaskan ciri-ciri ini, kajian ini berhasrat untuk memajukan dengan ketara bidang pembungkusan mampan. Pembungkusan barangan makanan memerlukan perhatian kepada kedua-dua keperluan mekanikal dan antimikrob untuk memastikan kualiti dan keselamatan yang berterusan. Penggantian mesra alam dan berkesan untuk pembungkusan makanan adalah matlamat kami. Secara keseluruhan, PVA/CNC/ZnO menunjukkan nilai terbaik dalam memanjangkan jangka hayat cili segar selama 20 hari kajian makmal dijalankan. Kajian ini mencadangkan penyelesaian jangka panjang untuk mengurangkan sisa plastik dalam jangka hayat Panjang terhadap barangan makanan yang dibungkus.

Keywords: Poly (Vinyl Alcohol) (PVA), Cellulose Nanocrystals (CNC), Zinc Oxide (ZnO), nanocomposite films, food packaging.

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LIST OF ABBREVIATIONS

PVA Polyvinyl Alcohol

CNC Cellulose Nanocrystal

ZnO Zinc Oxide

TA thermal analysis

g gram

BS breaking stress

EAB elongation at break

cm centimeter

MPa mega pascal

mL milliliter

Min minute

mA milliampere

mm milometer

LIST OF SYMBOLS (optional)

° degree

% Percentage

ϴ Theta

σ Sigma

°C degree Celsius

± plus, minus

CHAPTER 1

1.0 INTRODUCTION

1.1 Background of Study

Water-soluble synthetic polymer polyvinyl alcohol (PVA) has several uses, including in food packaging. PVA-based films and coatings are widely used in the food packaging industry due to their high barrier qualities, high mechanical strength, and biodegradability. PVA-based packaging also offers excellent transparency and flexibility, making it a popular choice for food products that require visual appeal and ease of handling. Additionally, PVA-based packaging can be easily customised to meet specific food packaging requirements. In recent decades, the biodegradable films have been developed and studied by numerous research groups but their applications in food packing industry suffer from several limitations such as frangibility due to low mechanical strength and weak gas exchange inhibition (Vaidya and Bhattacharya 1994).

Nanocrystals made from cellulose, the most common natural polymer, are known as cellulose nanocrystals (CNCs). CNCs have gained attention as a potential reinforcement agent for PVA-based films and coatings due to their excellent mechanical properties, low toxicity, and renewable nature. The addition of CNCs can improve the barrier properties and mechanical strength of PVA-based materials, making them more suitable for food packaging applications. High aspect ratio, high mechanical strength, and large surface area are just a few of the features that make CNCs appealing for usage in a wide variety of applications, including food packaging. CNCs can be added to PVA films to boost their mechanical and barrier qualities, allowing for longer storage of perishable goods. Moreover, CNCs are biodegradable and non-toxic, making them an environmentally friendly alternative to traditional packaging materials.

This makes them an ideal choice for companies looking to reduce their carbon footprint and promote sustainability. Nanoparticles made of zinc oxide (ZnO) have also attracted a lot of interest due to their potential usefulness as an antibacterial agent in recent years. ZnO nanoparticles can further protect PVA/CNC composites from microbial development, making them an ideal material for food packaging. This is because ZnO nanoparticles have a high surface area-to-volume ratio, which enhances

their antibacterial activity. Additionally, PVA/CNC composites have excellent mechanical properties and are biodegradable, making them an eco-friendly alternative to traditional plastic packaging materials.

In this research, PVA, CNCs, and ZnO nanocomposites have shown great promise as a means of creating sustainable, high-performance, antimicrobial food packaging. These materials are promising for the food sector since they could both decrease food waste and improve food safety. Furthermore, the use of these nanocomposites in food packaging can also extend the shelf life of perishable food items, which can lead to significant economic and environmental benefits. This technology has the potential to revolutionise the food packaging industry and promote a more sustainable future.

1.2 Problem Statement

The use of petroleum-based plastics pollition due to contributed the growing concern of plastic pollution and its adverse effects on the environment. As a result, many individuals and organizations have been advocating for the reduction of plastic usage and the implementation of more sustainable alternatives. Some companies have started to invest in biodegradable plastics made from plant-based materials, while others are exploring innovative recycling methods. Governments around the world are also acting by implementing plastic bag bans and imposing taxes on single-use plastics. However, it is not just up to corporations and governments to make a change. Individuals can also play a significant role in reducing plastic pollution by making simple changes such as bringing reusable bags and water bottles, avoiding single-use plastics, and properly disposing of waste. By working together, we can help protect our planet from the harmful effects of plastic pollution and create a more sustainable future for generations to come. (Sèbe et al., 2017)

Using biodegradable polymer alone would be not strong and less flexible for this purpose, thus reinforcement or filler would have to be added. One option for reinforcement is the use of natural fibers, such as hemp or flax, which can improve the strength and flexibility of the biodegradable polymer. Another option is to incorporate

nanoparticles, such as clay or silica, which can enhance mechanical properties and thermal stability. However, it is important to consider the environmental impact of these additives and ensure they are also biodegradable. Additionally, proper processing techniques must be employed to ensure uniform dispersion of the reinforcement or filler throughout the polymer matrix. Overall, incorporating reinforcement or filler into biodegradable polymers can improve their mechanical properties and expand their potential applications in various industries while still maintaining their eco-friendly nature.

1.3 Expected Output

The preparation and characterization of PVA/cellulose nanocrystals/ZnO nanocomposite as a potential food packaging application involves several steps, each of which is critical to achieving the desired properties and performance of the material.

First, the PVA/cellulose nanocrystals/ZnO nanocomposite must be prepared through a series of chemical reactions and processing steps. The preparation process may involve the mixing of PVA and cellulose nanocrystals, followed by the addition of ZnO nanoparticles to the mixture. The resulting nanocomposite can then be processed into a film or sheet using techniques such as casting or extrusion.

Once the PVA/cellulose nanocrystals/ZnO nanocomposite is prepared, it must be characterized to determine its physical, chemical, and mechanical properties. This involves using various analytical techniques, such as X-ray diffraction (XRD), scanning electron microscopy (SEM), transmission electron microscopy (TEM), Fourier transform infrared spectroscopy (FTIR), and thermogravimetric analysis (TGA). These techniques can provide information on the structure, morphology, chemical composition, thermal stability, and mechanical properties of the nanocomposite.

The properties of the PVA/cellulose nanocrystals/ZnO nanocomposite can also be evaluated for their suitability as a food packaging material. This involves testing the material for its barrier properties, such as water vapor and oxygen permeability, as well as its mechanical strength, flexibility, and durability. Other important factors to consider may include the material's biodegradability, toxicity, and potential for migration of harmful substances into food products.

Overall, the preparation and characterization of PVA/cellulose nanocrystals/ZnO nanocomposite as a potential food packaging application is a complex process that requires careful consideration of several factors. Through a thorough understanding of the properties and performance of the material, it may be possible to develop a safe and effective packaging material that can help to improve the shelf life and quality of food products.

1.4 Objectives

1. To prepare and characterize PVA/CNC/ZnO Nanocomposite

2. To itnvestigate the potential of PVA/CNC/ZnO Nanocomposite as food packaging for chili fresh fruit application.

1.5 Scope of Study

The chemical reactions and processing processes required to create a PVA/cellulose nanocrystal/ZnO nanocomposite. Second, the nanocomposite's physical, chemical, and mechanical properties are characterized using a battery of analytical tools including XRD, SEM, TEM, FTIR, and TGA.Third, the nanocomposite's potential as a food packaging material is evaluated by testing its barrier qualities, such as its resistance to the passage of water vapor and oxygen. Putting the nanocomposite through its paces to see if it can resist the stresses of shipping and storage. Evaluation of the nanocomposite's environmental impact and safety for use in food packaging by testing its biodegradability and potential toxicity. The potential of polyvinyl alcohol (PVA)/cellulose nanocrystals/zinc oxide (ZnO) nanocomposite as a food packaging material for a variety of food products and packaging types is being explored. To evaluate the benefits and drawbacks of using the PVA/cellulose nanocrystals/ZnO nanocomposite as a food packaging material, we will compare its performance to that of other materials. The study's overarching objective is to create a sustainable and environmentally friendly food packaging material that will lengthen the freshness and

quality of packaged foods, guarantee their safety, and reduce the environmental impact of packaging waste.

1.6 Significances of Study

The research seeks to produce a biodegradable and renewable material that can lessen the negative effects of packaging waste on the environment and contribute to the establishment of a circular economy in the food packaging industry.In order to improve food safety and preserve public health, it is essential that food packaging be made from safe, non-toxic materials.Developing a packaging material with excellent barrier characteristics to water vapor and oxygen, in addition to good mechanical strength and durability, can aid in the preservation of food quality and the extension of its shelf life.

The research has the potential to advance our understanding of nanocomposite materials for use in food packaging applications and shed light on how to best optimize their preparation and performance. The creation of new products and markets for manufacturers, as well as a competitive advantage in the food packaging business, can be the result of the development of a high-performance and eco-friendly food packaging material. Sustainable development goals, environmental protection, and improved public health are just few of the areas that could benefit greatly from this research.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 Polymer Nanocomposites

2.1. 1 General Introduction - what is polymer nanocomposite

To create a polymer nanocomposite, a polymer matrix is combined with fillers or additives on the nanoscale. In this category of materials, nanoparticles or nanofillers are incorporated into the polymer matrix to strengthen or improve it. Clays, metal oxides, and carbon-based materials like carbon nanotubes and graphene are all examples of the inorganic nanoparticles that may be used as nanofillers.When nanofillers are incorporated into a polymer matrix, the resultant nanocomposite material acquires novel characteristics. Fillers of nanoscale dimensions, generally between 1 and 100 nanometers, have several benefits over more traditional fillers and bulk materials.The mechanical strength, stiffness, thermal stability, barrier qualities, electrical conductivity, and flame retardancy of polymer nanocomposites are only a few of their many appealing features (Ludueńa et al., 2007). The unique physicochemical features of the nanofillers and their high surface-to-volume ratio are what give the composite material its improved qualities.

Polymer nanocomposites rely heavily on the distribution and interaction of nanofillers within the polymer matrix to perform at their best. To get the most out of the nanofillers' reinforcing effects and property improvements, they should be dispersed evenly throughout the polymer matrix and have strong interfacial contacts with the matrix. Depending on the materials used and the required qualities, several methods, such as melt blending, solution mixing, and in-situ polymerization, are employed in the manufacture of polymer nanocomposites. Critical aspects that affect the final characteristics and performance of the nanocomposite include the selection of nanofillers, polymer matrix, and processing procedures.The automotive, aerospace, electrical, energy storage, packaging, and biomedical engineering industries are just some of the many that have achieved success using polymer nanocomposites (Finnigan, 2009). They provide an alternative to typical polymer composites or plain polymers and

allow for the customization of material characteristics to fit the needs of a variety of applications. Research into polymer nanocomposites is ongoing, with a focus on improving processing methods, expanding our knowledge of the science behind structure-property relationships, and discovering novel uses for these cutting-edge materials.In sum, polymer nanocomposites provide a viable path toward creating outstanding characteristics and performance materials, which may then be used to a wide range of industries.

2.1.2 Brodegradable polymer - Poly (Vinyl Alcohol)

Polyvinyl alcohol (PVA) is a synthetic polymer used widely in a variety of industries. It is used for a variety of purposes, including film creation, medicine delivery, recycling polymers, and food packaging. The creation of the polymer complex may be aided by hydrogen bonding, thanks to the abundance of hydroxyl groups on the PVA carbon chain. Due to its exceptional hydrophilicity, it also possesses a high-water vapour permeability. The thin PVA film, however, has weak mechanical properties and is not very effective against germs. Material for food packaging must have good mechanical, antibacterial, and anti-UV qualities. Therefore, improving PVA's mechanical and physical properties is crucial. To construct a PVA-based complex, we have here added a reinforcer, a crosslinker, and an antibacterial agent.

2.1.3 Cellulose

Natural polymers, also known as green polymers, can be used by businesses to minimise their daily output of dangerous non-biodegradables. Cellulose, one of many polymers, is extremely common because it can be extracted from plant cell walls. Anselme Payene made the initial discovery of cellulose. Starch and this plant compound both have molecular formulas that he figured out. It was written about in 1839 (Brogniart, Pelonze, and Dumas) (Vilarinho et al. 2018). Cellulose and its derivatives are the subject of much interest and thought to have major significance due to its biocompatibility and environmental sustainability. Preventing the deterioration of packaged foods is more important than ever today. The current COVID-19 pandemic

situation necessitates the implementation of certain preplanned techniques to prevent food wasting and deterioration in the face of a complete shutdown of industries, labour, and transportation. Food spoiling can be avoided depending on the type of packaging used. Cellulose is an inexpensive material with desirable mechanical qualities and high demand in many markets across the world, especially the food and textile sectors. There is a significant amount of food waste that can be recycled, including fruits, vegetables, cotton stalk, and forest leftovers. The recovery of cellulose from such discards is a particularly novel and beneficial procedure.

2.1.4 Cellulose Nanocrystals

In the biopolymer industry, cellulose nanocrystals (CNCs) work wonderfully as a reinforcing agent. CNCs have several benefits, including a low density, a good ecological impact, and the capacity to be recycled and processed with relative ease. CNCs' surface hydroxyl groups are easily modified, allowing for facile adjustments to characteristics and expanded uses. Because of their enhanced compatibility with the polymer matrix, dispersion of the modified CNCs is aided by the functionalization of covalent and noncovalent frameworks. PVA films reinforced by CNCs, like CNC-modified biodegradable packaging materials, have been the subject of increasing study in recent years.

2.1.5 Zinc Oxide

Zinc oxide (ZnO), on the other hand, is an inorganic molecule made up of zinc and oxygen atoms. It may be used for many different things because it is such a flexible material. ZnO has a number of interesting characteristics that set it apart from other materials, such as its semiconducting nature, piezoelectricity, and great transparency in the visible spectrum. It's used in electronics, optoelectronics, catalysis, sunscreen, and antibacterial coatings, among other things. To improve the mechanical, thermal, and antibacterial characteristics of polymer nanocomposites, ZnO nanoparticles are frequently utilized as fillers. In conclusion, polylysine is a cationic polymer with

biomedical and electrical applications, while zinc oxide (ZnO) is an inorganic chemical with several uses.

2.2 Preparation of Polymer Nanocomposites

2.2.1 Solvent casting

Nanofillers are first dispersed in a solvent, then a polymer matrix is added, and finally the resulting mixture is cast to produce a thin film or bulk material. the standard operating procedure for making solvent-cast polymer nanocomposites. The Selection of Elements Select covalently compatible nanofillers and a polymer matrix for your nanocomposite. Think about how well the polymer and nanofillers work together and how the finished product is supposed to behave. The process of dispersing nanofiller particles in a solvent to form a uniform suspension. Depending on the nanofiller and solvent, this can be accomplished using methods including ultrasonication, magnetic stirring, or ball milling. Keep the nanofillers from clumping together by making sure they are evenly distributed.

The process of making a polymer solution in a suitable solvent. Selecting a solvent that can dissolve the polymer without degrading it or causing it to separate into phases is essential. To adjust the concentration, adjust the ratio of solvent to polymer. The nanofiller suspension gradually receives the addition of the polymer solution, which is being continuously stirred. Combine everything carefully to ensure a smooth and even blend. It is important that the nanofillers are dispersed evenly throughout the polymer. Applying the mixture on a flat surface, such a glass plate or petri dish, or pouring it into a casting mold. The form and thickness of the final nanocomposite film might guide the decision on casting technique. A doctor blade, spin coating, or equivalent method can be used to distribute the mixture. Maintain a constant and manageable film thickness. The evaporation of a solvent can the solvent must evaporate, thus it is best to let the casted film dry somewhere with good ventilation or under regulated conditions. You may speed up the drying process by using either an oven or a desiccator to put the film in. To avoid flaws or cracks in the nanocomposite film, the drying process must be gradual and regulated. After the solvent has evaporated, the resultant nanocomposite film can undergo any additional post-treatment procedures that are called for.

Depending on the polymer matrix, this may involve annealing, crosslinking, or other processing steps.

2.3 Characterization Techniques of Polymer Nanocomposite

2.3.1 Visual inspection

The inspection is a visual analysis of the nanocomposite sample. This first look can reveal important details about the object, such as its color, transparency, homogeneity, and the existence of any obvious faults or anomalies. The texture of the surface and any obvious alterations in form or size can also be evaluated with unaided vision. Any contamination or foreign particles that may have been introduced during production can also be spotted by inspecting the sample closely. In addition, flaws like cracks, bubbles, or discoloration that may point to structural weaknesses or material deterioration can be spotted with the use of a visual inspection. To further analyze the performance and quality of the nanocomposite material, the naked eye observation is used as a preliminary screening technique. This initial visual inspection does not require any specialist equipment or procedures, yet it gives invaluable insights into the general qualities and integrity of the sample.

2.3.2 Optical Microscopy

Polymer nanocomposites are characterized via optical microscopy. The polymer matrix's nanofillers' dispersion and interactions may be viewed at different magnifications. Brightfield microscopy is basic optical microscopy. Transmitted light illuminates the sample, which the user or camera may observe. Brightfield microscopy shows the nanocomposite sample's shape and size. It shows nanofiller dispersion and polymer matrix consistency. Darkfield microscopy, a contrast-enhancing approach, can reveal nanocomposite nanofillers and scattering properties. A particular condenser illuminates the sample at an angle and captures dispersed light. This approach makes nanofillers and agglomerates stand out against the polymer matrix. Polarized light microscopy can analyze polymer nanocomposites and other birefringent materials.

Polarizers and a retardation plate can show how light polarization varies with the sample. Polarized light microscopy can reveal nanofiller alignment, orientation, and anisotropic behavior inside the polymer matrix.

Fluorescence microscopy employs fluorescent probes or dyes that release light at certain wavelengths when triggered. It is often used to view nanocomposite components or functional groups. Fluorescence microscopy can help identify distribution and localization of nanofillers or other functional entities in the polymer matrix. Confocal microscopy produces high-resolution optical sections. Pinholes filter out-of-focus light, resulting in sharp, in-focus photos from various depths in the sample. Confocal microscopy can investigate layered or hierarchical nanocomposite structures in three dimensions. Phase contrast microscopy helps polymer nanocomposites and other low-contrast samples. Phase contrast microscopy employs refractive index variations to create contrast in transparent material. This approach can reveal nanofiller distribution, interface locations, and polymer matrix refractive index variation.

2.3.4 X-ray diffraction (XRD)

The crystallographic structure and phase composition of materials, particularly polymer nanocomposites, X-ray diffraction (XRD) is an extremely useful characterisation method. The X-ray diffraction technique known as "phase identification" may determine which phases make up a polymer nanocomposite. The crystalline phases of the polymer matrix and the nanofillers can be determined by comparing the resultant diffraction pattern with known reference patterns or by consulting crystallographic databases. The proportions of crystalline and amorphous components in the nanocomposite may be calculated using this method. Nanocomposite polymer matrices' degrees of crystallinity may be measured with Crystallinity Analysis to XRD. Crystallinity may be estimated by comparing the XRD pattern's crystalline peaks' intensities to those of the amorphous background. Crystallinity modifications brought on by nanofillers or other processing factors can be measured. Peak Wideninand Peak Shift Analysis In polymer nanocomposites, XRD can reveal details on peakshifts and peak broadening. The presence of nanofillers or processing effects migh cause changes in lattice characteristics, strain, or crystallographic orientation, all which are

reflected in a reorientation of the diffraction peaks. The size of the crystallites or the presence of imperfections in the polymer matrix can both contribute to peak widening.

Analysis of Interfacial Interactions X-ray diffraction (XRD) can shed light on how the polymer matrix and nanofillers in a nanocomposite interact with one another at the interface. Interfacial interactions can be evaluated by analyzing the intensity and position of diffraction peaks corresponding to the polymer matrix and the nanofillers, which can reveal phenomena like the degree of polymer chain ordering near the interface or the formation of polymer-nanofiller complexes. The phase composition of polymer nanocomposites may be quantitatively determined via X-ray diffraction. The amount or concentration of distinct phases present in the nanocomposite may be estimated using methods like Rietveld refinement or the use of typical addition procedures. This investigation can shed light on how nanofillers are dispersed throughout the polymer. X-ray diffraction (XRD) analysis of a polymer nanocomposite's texture can reveal the orientation preferences of the nanocomposite's crystalline domains. Particularly important for polymer nanocomposites with aligned or directed nanofillers is measuring the strength and location of diffraction peaks at different sample orientations to evaluate the degree of texture.

2.3.5 Tensile strength

Tensile strength and other mechanical qualities may be measured with the use of a universal testing machine (UTM). The nanocomposite is tested by applying a uniaxial tensile force to a dog-bone-shaped specimen that has been manufactured in accordance with established protocols. Tensile strength, elongation at break, and other mechanical parameters may be determined by recording the force and displacement. Analysis of stress and strain is the tensile strength of a polymer nanocomposite may be calculated by studying its stress-strain response. The stress and strain experienced by the sample because of being exposed to an increasing tensile load are measured. The tensile strength of a substance is measured by its ultimate stress tolerance. In addition to the modulus of elasticity, yield strength, and elongation at break, the stress-strain curve can reveal information about additional mechanical characteristics.

2.4 Application of Polymer Nanocomposites as Fresh Fruit

Polymer nanocomposites improve packaging material oxygen, moisture, and gas barrier characteristics. Clay nanoparticles or graphene oxide nanofillers in polymer matrix minimise gas and moisture permeability, extending food shelf life and reducing spoiling. Strengthened Mechanically Nanofillers in polymer matrices increase food packaging mechanical qualities. They increase tensile strength, toughness, and impact resistance, making packaging more robust and resistant to physical stress during handling, transportation, and storage. Antibacterial Properties Antimicrobial nanocomposites can limit microbe development and extend food shelf life. Silver nanoparticles or essential oils in the polymer matrix can actively guard against bacteria, fungus, and other diseases. Polymer nanocomposites can be used to create active packaging systems that improve food quality and safety. Nanocomposites can emit antioxidants, antimicrobials, or oxygen scavengers to preserve packaged food. Smart Packaging, Nanocomposites can be used to create smart packaging systems that monitor food quality and freshness. Nanosensors in packaging can detect and report changes in temperature, pH, and gas composition, revealing the food's condition. Lightweight Packaging, Polymer nanocomposites are lighter than standard packaging.

This lightweight feature can reduce shipping and logistics costs and improve sustainability by lowering material and energy use. Environmental Sustainability, Polymer nanocomposites can improve food packaging sustainability. Biodegradable nanofillers like cellulose nanocrystals or starch nanoparticles can be added to the polymer matrix to make packaging products more environmentally friendly. UV defence, Titanium dioxide nanoparticles are UV-blocking nanofillers. These nanofillers in polymer matrices protect UV-sensitive food goods. Polymer nanocomposites in food packaging must be considered for nanoparticle or additive migration. Nanocomposite-based food contact packaging must comply with regulatory criteria.

2.5 Quality Assessment for Wrapped Fruits

2.5.1 Brix

Brix can be used as a quality metric for packaged fruits. Juice from fruit is measured in Brix to show how much sugar is present. It is widely employed as a gauge of the degree of ripeness and sugar content in fruit. Gather an accurate sample of the batch or lot of wrapped fruits. If you want your samples to be representative of the whole, you need to pick them at random. Take the fruit out of its packaging. the fruits to reveal the testable part. When unwrapping fruits, be careful not to injure them in any way. Juice is extracted from the fruit sample by either using a juicer or by hand. Make sure there are no chunks of pulp or other debris in the juice.

The sugar concentration in the fruit juice can be calculated by Brix measurement with a refractometer. A Brix reading can be obtained by placing a drop of juice on the refractometer's prism and viewing it through the instrument's ocular. Fruit sweetness can be inferred from a Brix reading, which measures the amount of sugar present in the fruit juice. Fruits with higher Brix readings tend to be sweeter and have a higher grade of flavor. Check the obtained Brix reading to industry standards for the given fruit or fruit type. You can then decide if the wrapped fruits are of sufficient quality or if their sweetness falls short of expectations.

2.5.2 Texture Analyzer

A texture analyzer can evaluate wrapped fruits' texture. A texture analyzer measures a sample's reaction under regulated stimuli to determine the fruit's physical qualities. Testing a wrapped fruit batch. Label and randomly choose samples. Carefully unwrap the fruits. Sample conditioning heats unwrapped fruit to testing temperature. depending on the fruit's storage needs. This ensures ripeness. The desirable qualities of packaged fruits will dictate texture analysis parameters. Firmness Find out how much pressure can harm fruit flesh. Pressure resistance indicates ripeness. Fruit exterior stickiness when squeezed or separated. This may benefit sticky or pulpy fruits. Check the fruit's toughness and chewing time. This helps fibrous or difficult fruits.

After compression, the fruit springs back into place. This shows the fruit's suppleness. Cohesiveness is measured by how effectively fruit flesh links back together after being bit or chewed. This trait indicates the fruit's interior strength. Test the processed fruit sample in the texture analyzer after positioning the measuring probe or fixture to apply the correct force or deformation. Follow the manufacturer's instructions for instrument setup and testing. Different fruit portions should be examined for accurate results. The packaging data on fruit textures should be examined and evaluated. Assess the fruit texture quality by comparing results to criteria, referencing values, or examining previous data. Incorrect ripeness, storage or handling circumstances, or textural flaws can affect texture.

CHAPTER 3

3.0 MATERIALS AND METHODS

These methods will explain about the material used to prepare the PVA/CNC/ZnO samples. The amount that used in this method is:

3.1 Material

3.1.1 Chemical and materials

The PVA and ZnO powder will be acquired from R&M chemicals in this experiment. The cellulose nanocrystal (CNC) obtained from Canadian company Cellulose Inc. there are Gram-positive and Gram-negative bacteria cell membranes which have S. aureus and e. coli in both of them. Then, nutrient agar (NA) and nutrient (NB) were purchased from the Himedia in India and Oxoid in England, respectively. A Nano Ultra-pure water system acquired from Thermo Fisher Scientific provided distilled water (USA). These reagents were not purified before being utilized.

3.1.2 Apparatus and materials

Hot plate magnetic stirrer and stirring bar (10 × 4.4 mm) to agitate the samples. The micropipes with the pipette tips for the preparation of the nutrients broths solvents. The analytical balance and Whatman qualitative filter paper from sartorius (USA).

3.2 Method

3.2.1 Preparation of the CNC/ZnO hybrid nanofiller

Begin by mixing 3 weight percent of CNC powder with distilled water to make the CNC suspension. Then, weigh out 3g of CNC and combine it with 100 ml of distilled water. Heat the mixture at 45°C for 30 minutes while stirring continuously. Depending on the % weight to volume ratio, the dilution process will be repeated. One ZnO suspension and two CNC suspensions will be blended to create the CNC/ZnO dispersion.

Subsequently, 1.0 weight percent, 2.0 weight percent, and 3.0 weight percent ZnO powder will be treated with the molten 3 weight percent CNC in the prescribed ratio. The goal is to create a stable aqueous suspension by homogenising the mixture of CNC-ZnO powder. When not in use, common stock solutions are kept at room temperature.

3.2.2 Preparation of polyvinyl alcohol (PVA)

The accomplished preparation of PVA is by weighing 5 g of PVA powder and dissolved in 100ml of distilled water. Then, the solution will be heated at 90℃ for 30 minutes with vigorously stirring to allow the complete dissolution.

3.2.3 Preparation of CNC/ZnO in PVA

The nanocomposite films of CNC/ZnO/PVA dissolving will prepare the CNC/ZnO into 100ml of distilled water and ultrasonicated the mixture for 30 minutes. 50 ml of 5 wt% PVA will have the CNC/ZnO sample solution added in a different ratio, and the mixture will be vigorously mixed for 40 minutes at 90°C until it becomes completely homogeneous. The suspension will be achieved by adding the CNC/ZnO hybrid nanofiller to PVA solutions from the start for even dispersion. After the CNC/ZnO/PVA solution has been thoroughly dispersed, the solution needs to cool for 30 minutes.

3.2.4 Solution casting method

The CNC/ZnO/PVA mixtures will be poured in different petri dishes of 130 mm diameter and will air dry for 48 hours or until the mixture completely dried to ensure slow evaporation of the solvent. The procedures will be repeated with another ration of CNC/ZnO/PVA mixture. Then, the resulting film had been peeled off from the dish and was stored for further characterization.

3.3 Characterization of CNC/ZnO hybrid nanofiller

Minimal the characterization will be performed to observe physically the surface morphology of nanocomposite films of CNC/ZnO/PVA films.

3.3.1 Stability

The CNC/ZnO hybrid filler will be going through the sonication for 15 minutes and after that 10 ml of solution was added to each vial bottle. Before being kept in storage for 24 hours (1 day) and then for 30 days, the solution will be held at room temperature for characterization. For comparison, photographs of the hybrid filler solutions will take on those days.

3.4 Characterization of CNC/ZnO/PVA nanocomposite films

3.4.1 Tensile Analysis

Tensile characteristics of nanocomposite films will be determined utilizing an Instron 4032 universal testing equipment and ASTM D 638 test methods (Instron, Pfungstadt, Germany). Using a steel template and a router cutter, the samples will be cut into rectangular shapes (11cm2cm) (Die BS 6476). Four distinct thin films will be evaluated, with the average of the four results used.

3.4.2Visual Inspection

Visual approaches that can be used on line to inspect products with multiple dimensions and known tolerances. The approaches' output is that the inspected product is accepted or rejected. the developed approach integrates image processing approaches with statistical regression to find out a new index for each quality characteristic of the product; and accordingly, determine whether that characteristic conforms to tolerance specifications.

3.4.3 X-ray diffraction (XRD).

The XRD patterns of e-polylysine and PVA film were generated using a Bruker Kappa APEXII XRD diffractometer, operating at 40 kV and 2 min-1 scan rate.

3.4.5 OPTICAL MICROSCOPY (POM)

To investigate the samples' birefringence characteristics, the POM was conducted using a crossed-polarizer-equipped Olympus BH2 BHM microscope. A 10X objective polarized optical microscope was used to obtain the pictures. The imaging was conducted with a cross-polarization setup to ensure that only the circularly polarized portion of the reflected light was captured.

3.5 Fruit Testing

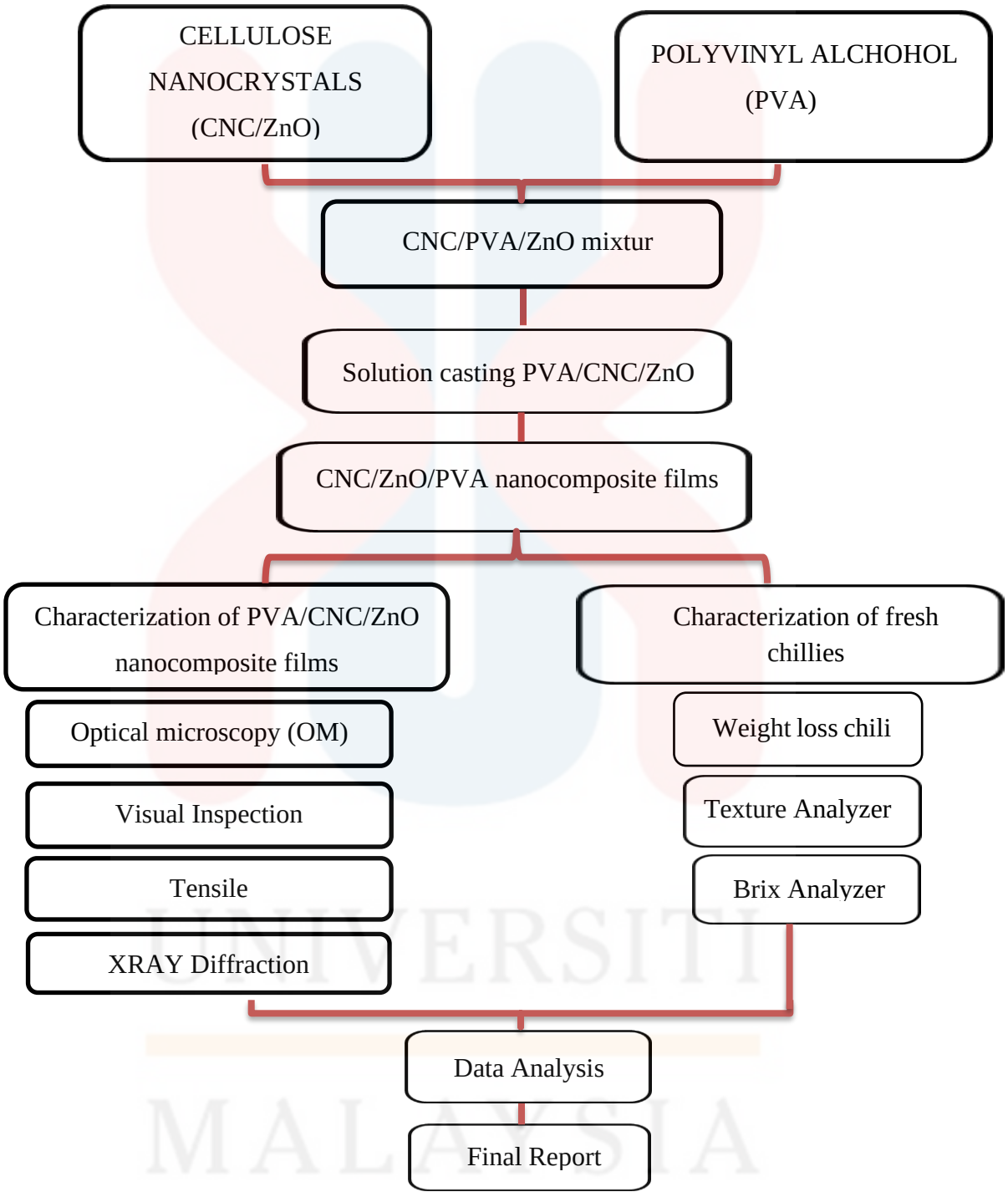
3.5.1 Quality of Fruit

Fruit is examined for its nutritional content, for adulteration, and for pollutants like pesticides. Testing is available for nutrient content, safety, adulteration, and microbiological development in fruits and vegetables. To maintain quality and safeguard the food supply, fruit will be tested. Fruit will be examined for cleanliness and quality. Fruits will be judged on their appearance, including their maturity, color, shape, scent, flavor, and texture. Fruits external and internal properties can be evaluated to determine quality. According to the literature, the ultrasonic method can be used to determine the acidity, viscosity, and sugar content of fruits by correlating ultrasonic parameters with fruit interior components.

3.5.2 Firmness of Fruit

A fruit firmness is related to its level of maturity and ripeness and may vary depending on its variety, as well as its production region and growing environment. The specification for the fruit firmness penetrometer and fruit hardness testing device is to determine the hardness of the pulp of a certain fruit. The retail trade uses the penetrometer to measure consumer-pleasantness and shelf life for their own records, and producers, packers, and distributors use it to help determine the stage of ripeness of a fruit. One of the most popular techniques for assessing maturity and/or ripeness is firmness measurement

3.6 RESEARCH FLOW CHART



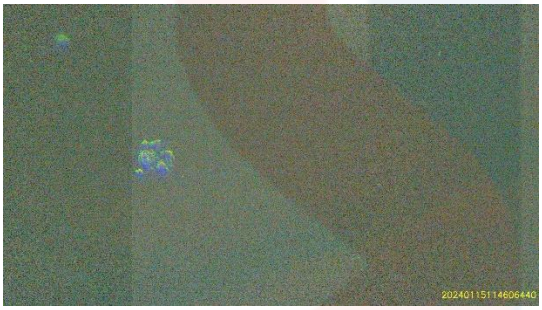
CHAPTER 4

4.1 RESULTS AND DISCUSSTION

4.2 CHARATERIZATION OF RAW MATERIAL

4.2.1 OPTICAL MICROSCOPY (OM)

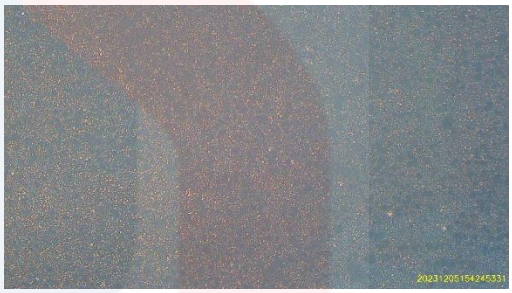
A) Polarized optical microscopy



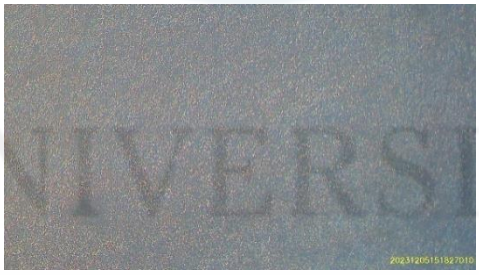
a) PVA

b) PVA + CNC

c) PVA+ CNC+ ZnO (1g)



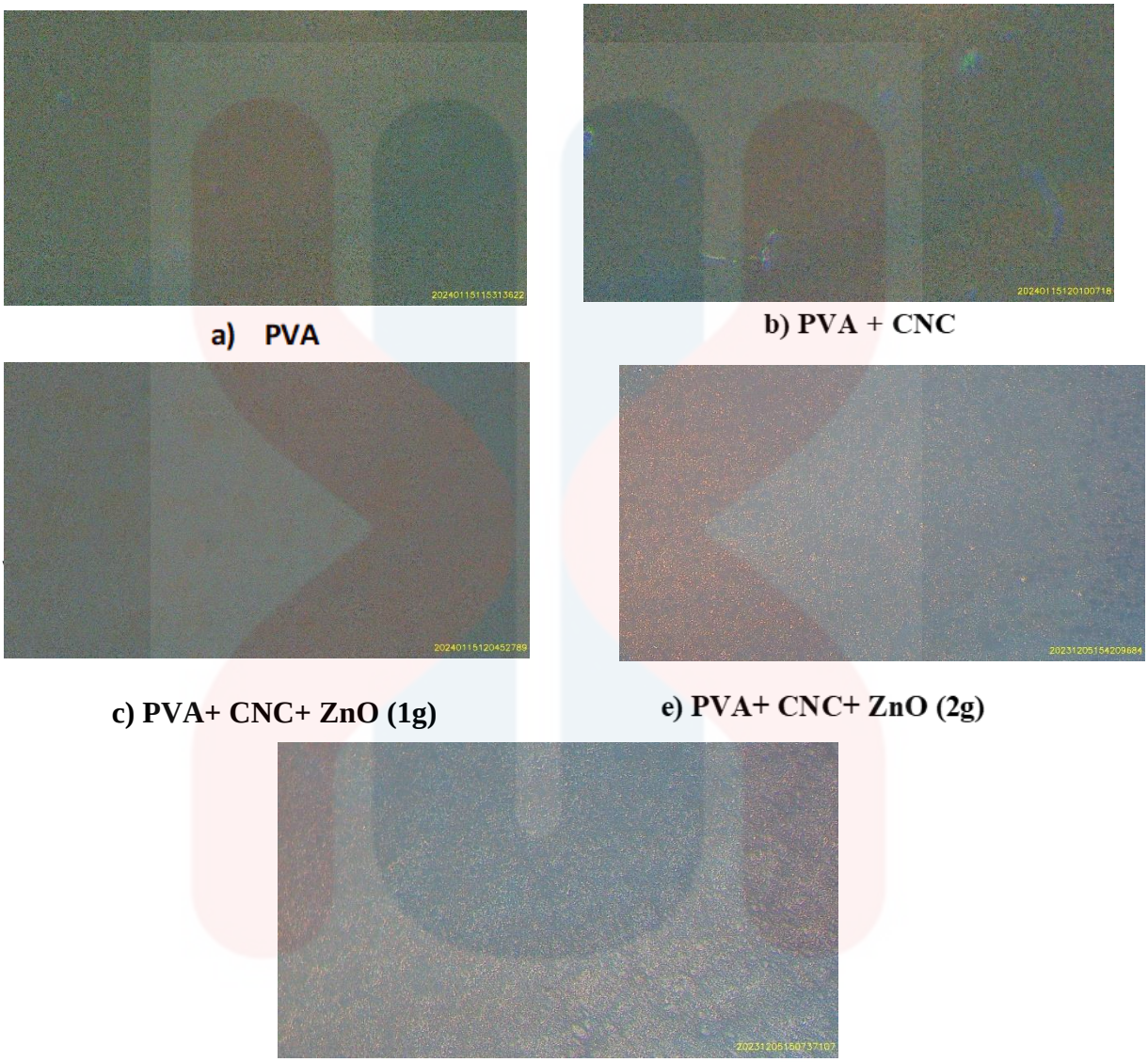
e) PVA+ CNC+ ZnO (2g)



f) PVA+ CNC+ ZnO (3g)

Figure 4.1:OM images of nanocomposite film.

B) Optical Microscopy



a) PVA

b) PVA + CNC

c) PVA+ CNC+ ZnO (1g)

e) PVA+ CNC+ ZnO (2g)

f) PVA+ CNC+ ZnO (3g)

Figure 4.2: OM polarized images of nanocomposite film

Figure 4.1shows the nanocomposite films made of PVA, PVA/CNC, PVA/CNC/ZNO 1g, PVA/CNC/ZNO 2g, and PVA/CNC/ZNO 3g. They were viewed with a 10x optical microscope. At a 10x zoom level, Figure 4.2. shows pictures taken with an optical microscope of PVA, PVA/CNC, PVA/CNC/ZNO 1g, PVA/CNC/ZNO 2g, and PVA/CNC/ZNO 3g nanocomposite films. Bio-nanocomposites are composed of 5% PVA (polyvinyl alcohol), 3% CNC (cellulose nanocrystals), and 1%, 2%, and 3% ZnO (zinc oxide) in varying concentrations. It is probable that images (a), (b), (c), (d), and (e) depict distinct bio-nanocomposites in terms of composition. The application of optical

microscopy demonstrates that visible light is used to capture images that reveal the morphological and structural properties of substances.

Polarised optical microscopy analyses conducted on PVA films reveal uniform and mild birefringence, which suggests that the orientation of the polymer chains is predominantly stochastic. The birefringence of the PVA/CNC film is marginally more pronounced than that of the PVA film, and there are hints of birefringence texture. This implies that the CNCs might be partially aligned, resulting in a certain level of anisotropy in the film. The birefringence of the PVA/CNC/ZnO film (1g) is significantly more pronounced, and its texture is more transparent. The addition of zinc oxide nanoparticles seems to make the polymer chains line up more directionally, which gives the film an anisotropic quality. The birefringence texture of the PVA/CNC/ZnO films (2g) and (3g) is more distinct and pronounced in comparison to the 1g film. This suggests that an increased concentration of ZnO nanoparticles results in a greater degree of polymer chain alignment and a greater degree of anisotropy in the film.

The utilisation of optical microscopy The PVA film exhibits a uniform and transparent appearance, devoid of any discernible structures or features. Although the PVA film appears uniform, the PVA/CNC film has marginally lower transparency than the PVA film. This suggests that the light the CNC emits might be a little bit scattered. OM on PVA/CNC/ZnO (1g, 2g, 3g) As the ZnO content increases, this film appears opaquer. This may be the result of the white ZnO nanoparticles present, which are more intensely reflective of light than PVA or CNC. The utilisation of optical microscopy allows for the examination of the PVA/CNC/ZnO film at different compositions. With the addition of ZnO nanoparticles, the film becomes increasingly opaque due to their highly reflective nature.

In general, comparison images captured by an optical microscope indicate that the inclusion of CNC and ZnO nanoparticles reduces the transparency of the film. We can see that CNC and ZnO nanoparticles can align some of the PVA chains, which makes the film more birefringent and uneven, as shown by POM images. By increasing the concentration of CNC and ZnO nanoparticles, the degree of alignment and anisotropy grew.

4.2.2 VISUAL INSPECTION

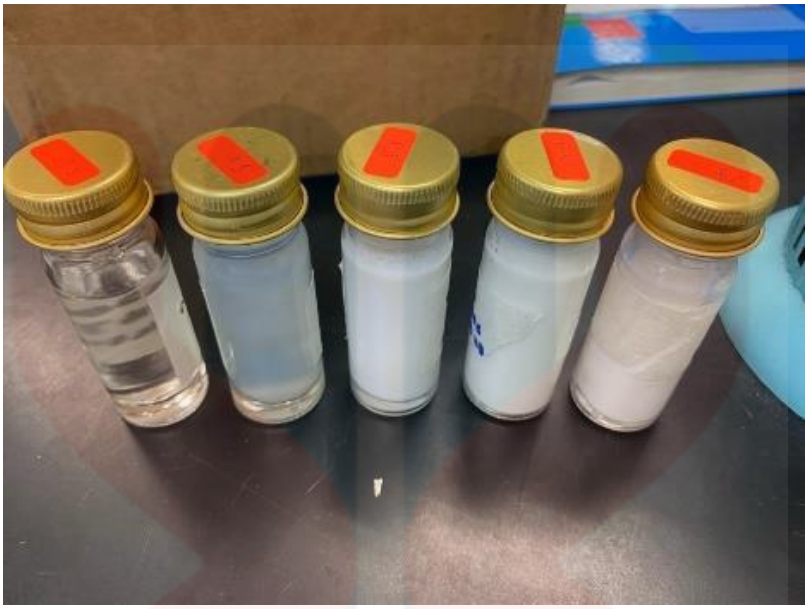


Figura 4.3: Visual Inspection of sample solution

The sample solutions are presented in the following order: PVA 5%, PVA + CNC, PVA + CNC + ZnO (1%), PVA + CNC 1% + ZnO (2%), and PVA + CNC + ZnO (3%), as shown in figure 4.3. While the PVA solution stays clear and transparent, the PVA/CNC mixture turns somewhat murky and translucent. When zinc oxide is added to all three solutions, they get thick and milky white. Zinc oxide, when added to the PVA/CNC mixture, makes the solution totally opaque and stops being transparent. This transformation, which makes it appear milky white, is most likely the result of light scattering by the particles. As a result of the light scattering induced by the various components, the PVA solution changes in colour and transparency. Based on its homogeneous structure and water-matching refractive index, PVA makes a transparent solution, indicating that the PVA itself is a polymer. There is little to no light dispersion as it passes through.

The addition of CNC nanocrystals to the PVA/CNC mixture disturbs the solution's homogeneity. Light is scattered as it passes through these rod-shaped particles because their refractive index is different from that of water and PVA. When contrasted to solutions of pure PVA, the dispersion effect makes them look somewhat hazy and translucent. PVA/CNC/ZnO, which incorporates particles that amplify light scattering even more. Aggregation of these biocompatible, positively charged polymers in solution results in

bigger structures with enhanced light scattering. As a result of the combined effects of multiple scattering centres, the milky white look thickens.

Figure 4.4: Visual Inspection images of nanocomposite

Figure 4.4 illustrates the nanocomposite films as follows: (a) PVA 5%, (b) PVA 5% + CNC 3%, (c) PVA 5% + CNC 3% + ZnO (1%), (d) PVA 5% + CNC 3% + ZnO (2%), and (e) PVA 5% + CNC 3% + ZnO (3%). It is common knowledge that PVA 5% is a relatively diluted solution, denoting its low PVA concentration. Consequently, it finds utility in applications that require a transparent, thin film. PVA 5% has the characteristic

of being a clear and transparent solution, devoid of light absorption and scattering. Aside from that, PVA 5% is water-soluble, facilitating application and cleanup. Additionally, it is biodegradable, meaning it decomposes gradually into harmless byproducts. PVA 5% is non-toxic, rendering it suitable for application in food.

The solution is comprised of a 5% polyvinyl alcohol (PVA) and 3% cellulose nanocrystals (CNC) composition. PVA is an extensively employed synthetic polymer renowned for its attributes including hydrophilic nature, biodegradability, transparency, and absence of toxicity. The composite material produced by combining PVA and CNC may have enhanced properties in comparison to PVA used alone. The final properties of the composite PVA 5% + CNC 3% will be influenced by a variety of factors, including the origin of the materials utilised and the manner in which the material is cut, shaped, and chemically treated on the surface. The manner in which the PVA/CNC mixture is prepared may have an impact on the CNC's dispersion within the PVA matrix, thereby influencing the characteristics of the resulting material during the casting or processing phase.

While PVA 5% is clear, adding CNC and zinc oxide 1% (ZnO) to the film may make it look a little cloudy or foggy. The enhanced light scattering induced by the CNC nanocrystals and the subsequent formation of aggregates with zinc oxide account for this. In contrast to the cloudiness or haziness observed in PVA 5% and CNC 3%, the incorporation of ZnO 1% may result in additional scattering centres and possible alterations to the film's morphology. A minor variation in hue may be introduced into the film because of the colour of VA, CNC, and ZnO in comparison to unadulterated PVA. The precise hue change would be contingent upon the characteristics.

In contrast to PVA 5% and PVA 5% + CNC 3%, the transparency of the film containing 2% ZnO is diminished. Light dispersion is considerably increased, giving it an opaque or milky white appearance. The surface of this film might be marginally textured in comparison to the smoother PVA and PVA/CNC films. This may be the result of ZnO aggregate formation or morphological alterations in the film. Visible alterations in colour may be marginal in comparison to preceding films. Depending on the CNC and ZnO used, the colour may range from translucent hite to As ZnO concentration increases, the number of scattering centres in the film also increases. These may consist of interactions, aggregates, or individual ZnO molecules. The increased scattering diminishes the transmission of light and imparts an opaque appearance to the film. Adding ZnO to the film

changed its shape, which might have affected how the PVA and CNC molecules were arranged in the film. This can result in an additional contribution to the observed light scattering and surface texture by creating a more porous or coarse structure. The subsequent stage involves the PVA/CNC/ZnO interaction, which is contingent upon its surface characteristics and generates a complex within the film. The refractive index of these complexes might differ from that of the PVA matrix that envelops them, which could result in light dispersion and potentially impact the film's colour.

The 3% ZnO film may be opaquer than the 2% film. A higher ZnO particle concentration reduces light transmission and increases light scattering. Increased ZnO aggregates may roughen the surface like the 2% film. The slight colour shift in 2% ZnO may be more evident at 3%. The CNC-ZnO contact determines the difference.

The number of scattering centres in the film increases with ZnO concentration. More light contact with these particles scatters light and reduces light penetration, which might influence PVA and CNC molecule packing and organisation. Making denser structures Denser and taller structures improve light scattering and surface texture by changing the film shape and colour.

4.2.3 TENSIL PROPERTIES

The thickness of each sample is 20 mm, and it is ASTM D638 Type V. The temperature (21.7 degrees Celsius), humidity (50.2 percent), and rate (50.0 millimetres per minute) are all adjusted to the same values for all samples.

	Modulus (Young's)	**Stress at Break**	**Elongation at Yield (%)**
PVA	355.57+13.22	46.18+5.00	215.558+29.17
PVA + CNC	4399.97+720.40	44.45+10.51	28.51+7.14
PVA+CNC+ ZNO(1g)	4310.35+378.74	47.17+19.33	6.44+0.21
PVA+CNC+ ZNO(2g)	3741.36+1367.63	40.25+19.79	13
PVA+CNC+ ZNO (3g)	4011.79+1420.36	56.27+20.22	13

Table 4.5: Young Modulus (MPa), Stress at Break (MPa) and Elongation at Break (%) of Samples.

Tensile strength and strain at break indicate the maximum stress and strain that the films may withstand before breaking, while toughness is defined as the area under the stress-strain curve. Data points for each sample are the mean values of measurements taken from five to seven specimens. The five samples of PVA, PVA/CNC, PVA/CNC/ZnO 1g, PVA/CNC/ZnO 2g, and PVA/CNC/ZnO 3g are shown in Table 4.5 along with their respective Young Modulus (MPa), Stress at Break (MPa), and Elongation of Break (%).

a) Modulus (Young's)

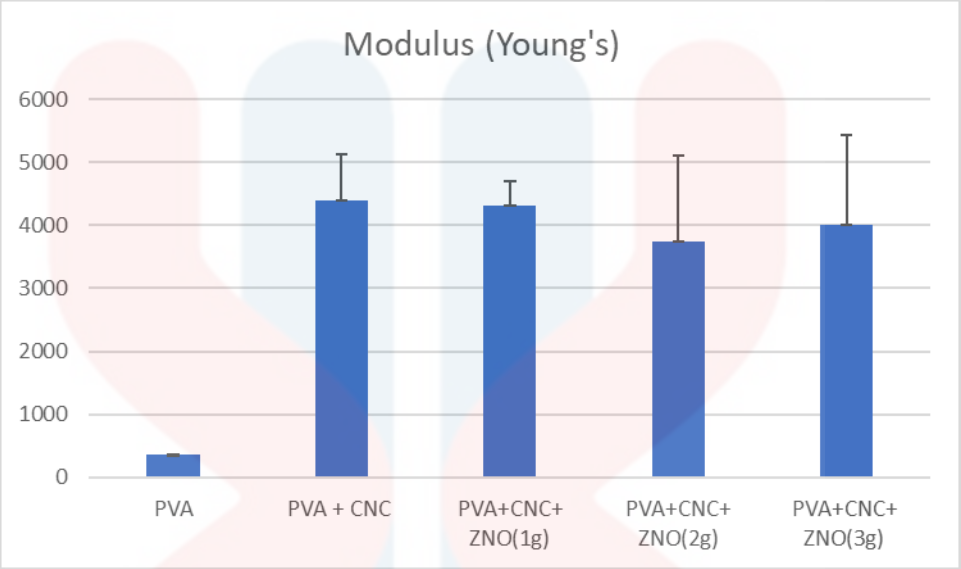


Figure 4.6: Young Modulus (MPa) of the 5 sample

The tensile strength of the PVA nanocomposite film was 303.86 (± 58.75) MPa, which was the lowest among the films tested according to figure 4.6. The tensile strength of the film was raised by nearly 100% from 303.86 (± 58.75) MPa to 4399.97 (± 720.40) MPa when 5 wt% CNC was added to the PVA solution, creating nanocomposite films. MPa Zinc oxide's addition to the film nanocomposite mixture causes its tensile strength to decrease at PVA/CNC/ZnO 1g before rising steadily thereafter. The PVA/CNC/ZnO 1g sample saw a drop to 3741.36 (± 1367.63), while the PVA/CNC/ZnO 2g sample showed an increase to 1599.35 (± 61.26) on the MPa sample. MPa for the 3g sample of PVA/CNC/ZnO last rose.

b) Stress at Break

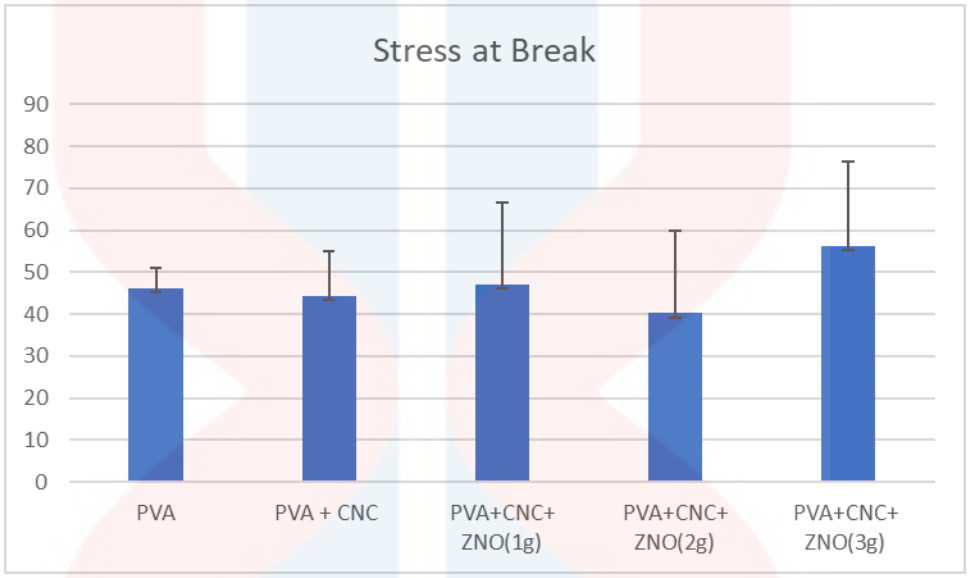


Figure 4.7: Stress at Break (MPa) of the 5 sample

The PVA/CNC/ZnO 3g nanocomposite film exhibited the maximum breaking stress of 56.27 (±20.22) MPa, as shown in Figure 4.7, when it comes to breaking stress (MPa). The PVA nanocomposite film has a stress at break of 46.18 (± +5.00) MPa, which causes the graph to exhibit a little decrease and subsequent increase towards the end of the sample. Zinc oxide's addition to the sample causes a steady decline, as seen on the graph. The least stressed sample was the PVA/CNC/ZnO 2g with a stress of 40.25 (± 19.79) MPa, followed by PVA/CNC with a stress of 27.74 (± 0.49) MPa, and finally PVA/CNC/ZnO 1g with a stress at break of 47.17 (± 19.33) MPa.

c) Elongation at Yield (%)

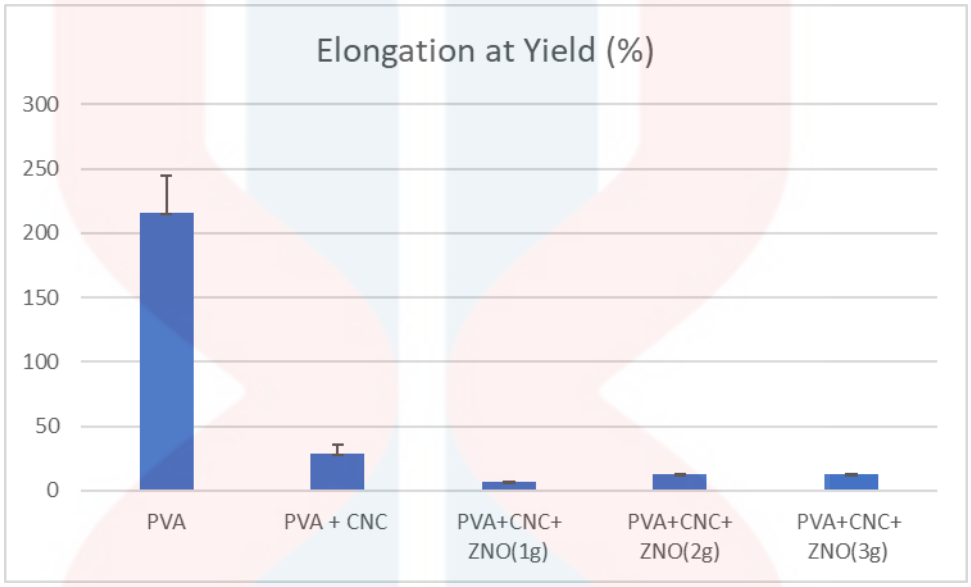
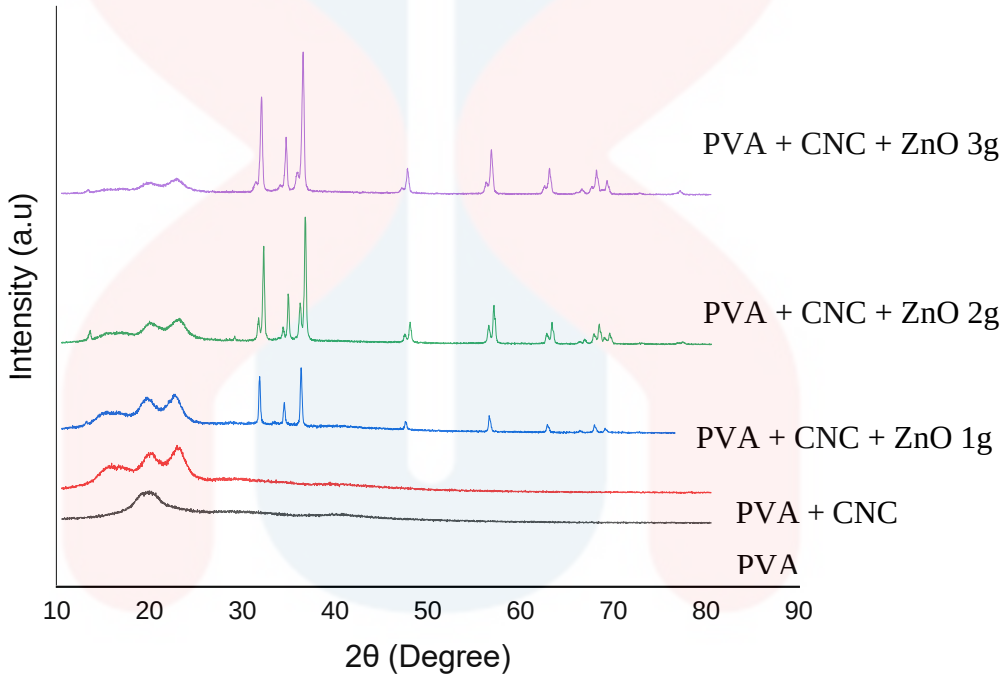


Figure 4.8: Elongation of Break (%) of the 5 sample

The PVA nanocomposite film exhibited the maximum breaking elongation (%) of 215.558 (± 29.17%), as shown in figure 4.8 above. When CNC was added to PVA, a reduction of 28.51 (±7.14) was observed on PVA/CNC. PVA/CNC/ZnO 1g is the sample with the lowest percentage, ending at 6.44 (± 0.21%). The graph demonstrates that the elongation at break for PVA/CNC/ZnO 2g and PVA/CNC/ZnO 3g nanocomposite films is 13% more than that of PVA, PVA/CNC, and PVA/CNC/ZnO 1g.

4.2.4 X-RAY DIFFRACTION (XRD)

The structural features of the milled composite powders were analyzed using X-ray diffraction (XRD). Disperse. The Eva software was used to create corresponding patterns for the composite powders. The information obtained from the peak patterns was used to calculate both the size of the crystallite and the strain therein.



SAMPLE	LATTICE PARAMETER			a/b Ratio	c/b Ratio
	a	b	c		
PVA	17.226	40.0522	19.6088	0.43009	0.48958
PVA/CNC	15.408	19.974	23.264	0.7714	1.16471
PVA/CNC/ZnO (1g)	3.249	3.249	5.207	1	1.60265
PVA/CNC/ZnO (2g)	3.25	3.25	5.21	1	1.60308
PVA/CNC/ZnO (3g)	3.2417	3.2417	5.1876	1	1.60027

Figure 4.9: Graph chart and table result XRD.

Lattice-related parameters Orthorhombic unit cells with comparable a and b parameters but distinct c parameters are present in each sample. PVA has the highest c parameter, followed by samples made of PVA/CNC and PVA/CNC/ZnO. This signifies that the c parameter is diminished because of the ZnO nanoparticles disrupting the crystal structure of PVA/CNC. As ZnO concentration rises, the c/b ratio increases, signifying that the unit cell becomes progressively more elongated in the direction of c.

The pronounced peaks observed in all samples are indicative of high levels of crystallinity. The PVA/CNC/ZnO sample has a slightly wider peak than the PVA and PVA/CNC samples. This suggests that the ZnO nanoparticles cause problems with the crystal structure. In addition, the reference patterns for PVA and cellulose II are matched by the phase identification on PVA and PVA/CNC samples, respectively. In the PVA/CNC/ZnO sample, an additional peak attributable to ZnO is visible. As the concentration of ZnO increases, so does the intensity of this peak. derived from additional observations A minor peak at approximately 28° 2θ on the PVA/CNC/ZnO sample (3g) could potentially indicate the existence of a minor secondary phase.

The XRD results show that PVA, CNC, and ZnO are present in the samples. The findings also show that the ZnO nanoparticles are changing the PVA/CNC composite's lattice properties, crystallinity, and phase composition. This is because the nanoparticles are causing structural problems.

4.3 CHARACTERIZATION OF FRESH CHILLIES

4.3.1 WEIGHT LOSS CHILI

PVA/CNC/ZNO (1%, 2%, AND 3%)		1 	2 	3 	4 	5 
Weight chili before wrap		11.56g	8.22g	7.41g	7.72g	7.19g
After wrap in thin film	**7/12/2023**	16.35g	11.77g	11.63g	11.80g	11.38g
	10/12/2023	16.003	11.292	11.125	11.655	10.946
	13/12/2023	14.827g	10.588g	10.946g	11.557g	10.652g
	17/12/2023	14.367g	9.658	10.058	10.986	9.879
	20/12/2023	13.766g	9.306	9.762	10.372	9.107
	23/12/2023	13.066	8.906	9.214	9.549	8.884
	26/12/2023	12.568	8.572	8.849	8.996	8.692
	28/12/2023	11.645	8.169	8.501	8.284	7.995
	1/1/2023	10.393	7.160	7.974	7.709	7.648
	4/1/2023	9.157g	7.058g	7.665g	7.149g	7.175g
PERCENTAGE (%)		43%	40%	34%	39%	37%

SAMPLE	PERCENTAGE
PVA 5g	**43%**
PVA/ CNC 3g	**40%**
PVA / CNC / ZnO 1g	**34%**
PVA / CNC / ZnO 2g	**39%**
PVA / CNC / ZnO 3g	**37%**

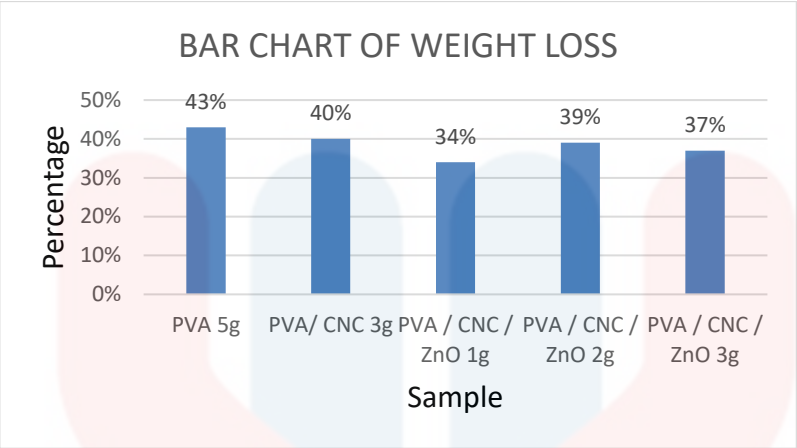


Figure 4.10: Table result and Graph Bar chart of weight loss chili.

The graph depicts the increase and drop in weight after 20 days of covering the chili with thin film, based on the percentage reduction that occurs. The disparity between PVA and PVA/CNC shrank from 43% to 40%, a reduction of 3%. There is a 34% drop in the total percentage on PVA/CNC/ZnO 1g when zinc oxide is added at concentrations of 1%, 2%, and 3%, but a 39% increase on PVA/CNC/ZnO 2g due to a 5% increase. Slightly lower, at 37%, was the PVA/CNC/ZnO 3g sample. In the 1g PVA/CNC/ZnO sample, this manifests as a negligible decrease in mass. The results show that the addition of zinc oxide at concentrations of 1%, 2%, and 3% in PVA/CNC/ZnO 1g leads to significant weight loss. However, the weight gain observed in PVA/CNC/ZnO 2g indicates a potential positive effect on weight. Surprisingly, the PVA/CNC/ZnO 3g sample only showed a slightly lower weight loss.

4.3.2 TEXTURE ANALYSIS

- Hardness of chili before wrap with thin film

HARDNESS TEST (g)	PVA	PVA/CNC	PVA/CNC/ZnO (1g)	PVA/CNC/ZnO (2g)	PVA/CNC/ZnO (3g)
	1144	832	1602	1211	1376
	1023	765	1740	1543	1406
	897	1131	1090	1020	901
	1082	1019	944	1006	1314
	1097	1210	1081	794	359
	1014	1082	838	799	866
	771	991	787	1122	1590
	735	976	1134	999	1131
MEANS	970.375	1000.75	1152	1061.75	1117.875
STD	152.9929387	147.5744364	344.868091	241.1352614	395.970936

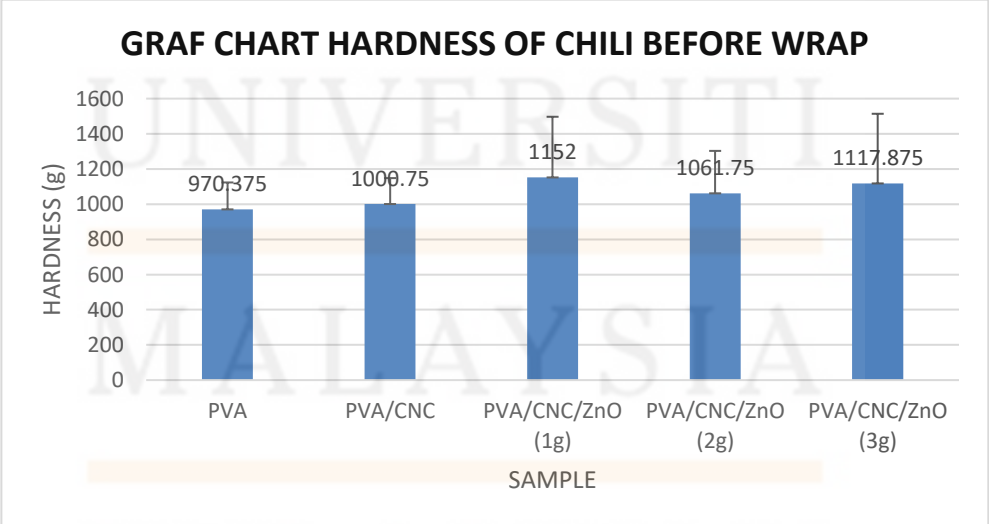


Figure 4.11: Table result and Graph hardness test of chili before wrap with thin film

The hardness of chili before wrap varies considerably across all samples, ranging from 359 grams to 1740 grams.The mean hardness for PVA wraps is 970.375 grams, while the mean hardness for PVA/CNC/ZnO (3g) wraps is 1117.875 grams. This suggests that adding CNC/ZnO to PVA film increases the overall hardness of chili.The standard deviation for all groups is relatively high, indicating a significant variation in hardness within each group. For example, the standard deviation for PVA/CNC/ZnO (3g) wraps is 395.97 grams, which means that the hardness of individual chilies in this group ranged from 721.9 grams to 1513.8 grams.

The image appears to be a graph showing the hardness test results for chili before wrap with thin film. The x-axis labels indicate the different types of chili wraps used (PVA, PVA/CNC, PVA/CNC/ZnO (1g), PVA/CNC/ZnO (2g), PVA/CNC/ZnO (3g). The y-axis label indicates the hardness in grams. Each data point on the graph chart represents the hardness of one individual chili. The blue bars represent the mean hardness for each group of chili wraps, and the error bars represent the standard deviation. the data and image that adding CNC/ZnO to PVA film increases the hardness of chili before wrap. However, there is a significant variation in hardness within each group, which could be due to factors such as the type of chili, the thickness of the wrap, or the conditions under which the hardness test was conducted.

➢ Hardness of chili after wrap with thin film

HARDNESS TEST (g)	PVA	PVA/CNC	PVA/CNC/ZnO (1g)	PVA/CNC/ZnO (2g)	PVA/CNC/ZnO (3g)
	142	695	237	901	363
	676	862	143	308	83
	106	635	259	228	288
	264	837	522	431	72
	75	984	329	497	453
	43	1250	712	131	164
	132	300	1253	228	325
	493	123	635	325	283
MEANS	241.375	710.75	511.25	381.125	253.875
STD	226.7547054	363.4012933	361.265534	240.2792646	135.743916

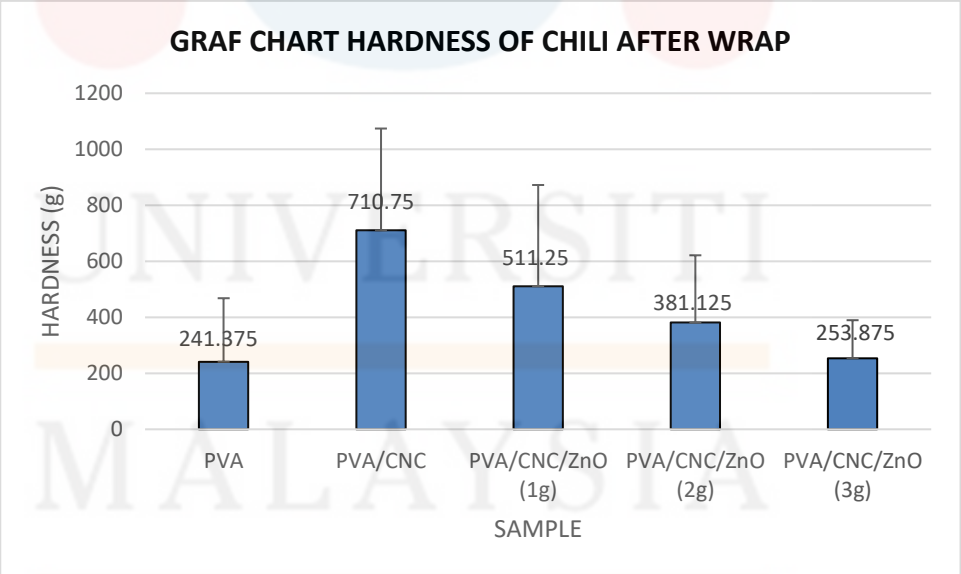


Figure 4.12: Table result and Graph hardness test of chili after wrap with thin film

The graf chart shows the results of a hardness test for five different types of chili wraps: PVA, PVA/CNC, PVA/CNC/ZnO (1g), PVA/CNC/ZnO (2g), and PVA/CNC/ZnO (3g). The x-axis shows the five types of wraps, and the y-axis shows the hardness in grams.

The chili wraps with PVA/CNC/ZnO (2g) have the highest overall hardness, with a mean hardness of 511.25 grams.The chili wraps with PVA have the lowest overall hardness, with a mean hardness of 241.375 grams.There is a large variation in hardness within each type of wrap, as shown by the standard deviation values. For example, the standard deviation for PVA/CNC/ZnO (3g) wraps is 361.27 grams, which means that the hardness of individual tests for this type of wrap ranged from 150.00 grams to 872.49 grams.The addition of CNC/ZnO to the PVA wrap appears to increase the hardness of the chili wraps. In general, the mean hardness increases with increasing concentration of ZnO.

- Springness of chili before wrap with thin film

SPRINGNESS (mm)	**SAMPLE 1**	**SAMPLE 2**	**SAMPLE 3**	**SAMPLE 4**	**SAMPLE 5**
	3.45	4.49	4.19	2.01	3.58
	4.36	4.16	4.74	2.73	3.5
	4.34	4.21	6.51	3.34	2.86
	3.31	4.03	3.71	5.95	3.71
MEANS	3.865	4.2225	4.7875	3.5075	3.4125
STD	0.562997928	0.193799725	1.22301199	1.716670712	0.3783627

➢ Springness of chili after wrap with thin film

SPRINGNESS (mm)	**SAMPLE 1**	**SAMPLE 2**	**SAMPLE 3**	**SAMPLE 4**	**SAMPLE 5**
	5.43	3.35	1.66	1.7	1.31
	3.82	3.23	2.45	3.51	1
	-0.49	1.84	3.47	2.23	4.66
	4.83	0.37	1.84	1.98	2.07
MEANS	3.3975	2.1975	2.355	2.355	2.26
STD	2.675461019	1.397840597	0.81659864	0.799854153	1.66194665

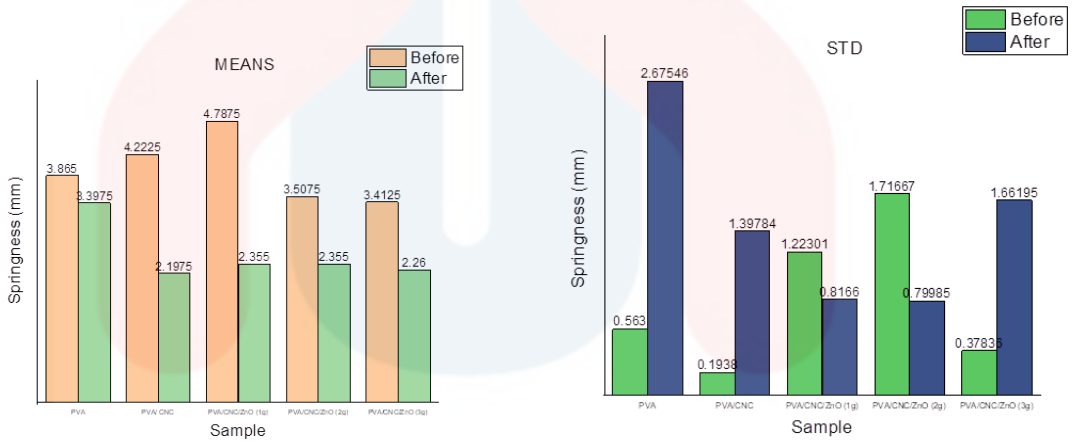


Figure 4.13: Springness of chili before and after wrap.

Figure 4.12 and 4.13 display the findings before and after the thin film wrap, respectively, and reveal a significant amount of difference. There is a considerable reduction in springiness after wrapping, according to results obtained after 20 days of testing. Incorporating 1%, 2%, or 3% zinc oxide into the wrap mixture reduced its springiness resistance across all five samples. This reduction in springiness suggests that the addition of zinc oxide affects the overall elasticity of the wrap. Furthermore, the decrease in springiness was consistent across all samples, indicating a consistent impact of zinc oxide on the wrap's properties.

➢ Cohesiveness of chili before wrap with thin film

COHESIVENESS	PVA	PVA/CNC	PVA/CNC/ZnO (1g)	PVA/CNC/ZnO (2g)	PVA/CNC/ZnO (3g)
	0.74	0.9	0.72	0.87	0.76
	1.37	0.89	0.61	0.83	1.36
	1.27	0.66	1.18	0.67	1.41
	0.65	1.11	1.06	1	0.68
MEANS	1.0075	0.89	0.8925	0.8425	1.0525
STD	0.365	0.183847763	0.27097048	0.135984068	0.38586483

➢ Cohesiveness of chili after wrap with thin film

COHESIVENESS	PVA	PVA/CNC	PVA/CNC/ZnO (1g)	PVA/CNC/ZnO (2g)	PVA/CNC/ZnO (3g)
	7.61	1.63	0.28	0.2	0.12
	2.72	1.74	1.54	2	0.57
	-0.49	1.15	2.25	0.46	1.01
	4.89	0.11	0.64	1.26	0.51
MEANS	3.6825	1.1575	1.1775	0.98	0.5525
STD	3.426342802	0.743835779	0.88995786	0.816006536	0.36445164

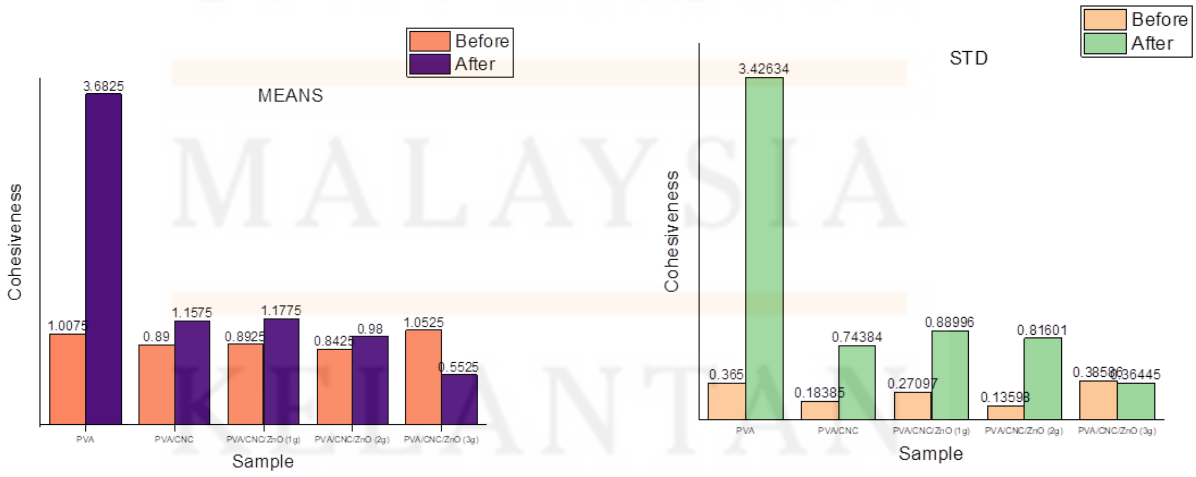


Figure 4.14: Cohesiveness of chili before and after wrap with thin film.

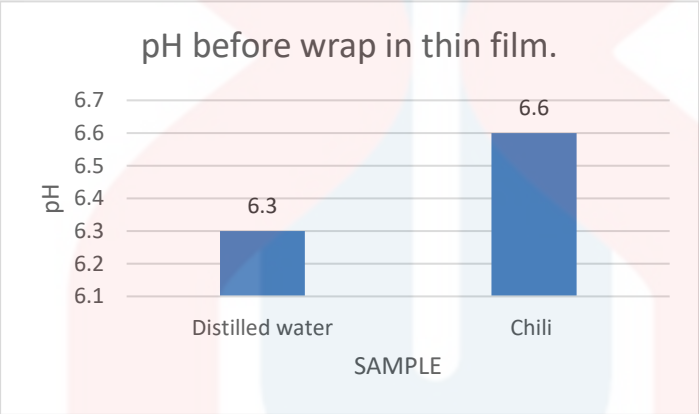
The figure 4.14 Cohesiveness of chili before and after wrap with thin film. The cohesiveness of chili before wrap ranges from 0.65 to 1.37, with a mean of 1.0075 and a standard deviation of 0.365. The cohesiveness of chili after wrap ranges from -0.49 to 7.61, with a mean of 3.6825 and a standard deviation of 3.4263. Overall, the cohesiveness of chili increases after being wrapped with thin film. The average chili cohesiveness before wrap is 1.0075, while the average cohesiveness after wrap is 3.6825. The increase in cohesiveness is most pronounced for PVA/CNC/ZnO (1g) and PVA/CNC/ZnO (2g) wraps, with average increases of 2.49 and 3.47, respectively. There is a large variation in cohesiveness within each group, both before and after wrap. This is indicated by the standard deviation values, which range from 0.1359 to 0.8899.

The possible explanations for the increase in cohesiveness in thin film may help to bind the chili particles together, resulting in a more cohesive product. The wrapping process may apply pressure to the chili, which could also increase cohesiveness.The type of thin film material and the thickness of the film may also play a role in the cohesiveness of the chili. For the limitations of the data sample size is small, so the results may not be generalizable. The type of chili and the conditions under which the experiment was conducted were not specified, so it is difficult to say how these factors may have affected the results. It is not possible to tell from the table how the cohesiveness was measured. The data that wrapping chili in thin film can increase its cohesiveness. However, it is needed to confirm this and to understand the mechanisms.

4.3.3 TEXTURE ANALYZER (PH)

Ph before wrap in thin film.

TESTING	PH
Distilled water	6.3
Chili	6.6



After open wrap in thin film.

TESTING	PH
PVA	6.6
PVA + CNC	7.1
PVA + CNC + Zn0 1g	7.2
PVA + CNC + Zn0 2g	7.8
PVA + CNC + Zn0 3g	6.9

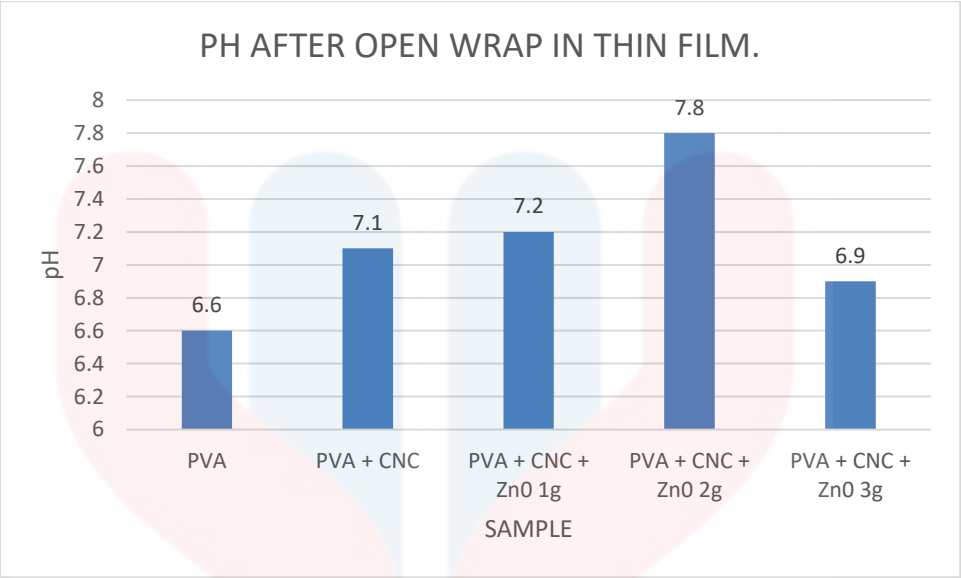


Figure 4.15: Ph before and after wrap in thin film.

The figure of texture analyzer data you sent, which shows the pH before and after wrapping in thin film. The pH of both the chili and the distilled water increased slightly after being wrapped in the thin film. The chili pH increased from 6.6 to 7.1 and the distilled water pH increased from 6.3 to 6.6. The greatest increase in pH was observed in the chili wrapped with PVA + CNC + ZN0 2g, with a change of 1.2. It is important to note that there is no data for the pH before wrap for the PVA + CNC + ZN0 groups. Therefore, it is impossible to say definitively whether the thin film caused the increase in pH in these groups.

The possible explanations for the increase in pH in thin film may have interacted with the chili or the distilled water in a way that caused the pH to increase. The increase in pH could be due to other factors, such as changes in temperature or exposure to air. Limitations of the data the sample size is small, so the results may not be generalizable. The type of chili and the conditions under which the experiment was conducted were not specified, so it is difficult to say how these factors may have affected the results. The pH meter used may not have been calibrated correctly, which could have introduced errors into the data. The data suggests that the thin film may have a slight effect on the pH of chili, but more research is needed to confirm this and to understand the mechanisms involved.

4.3.4 BRIX ANALYZER

Brix before and after wrap in thin film.

TESTING	BRIX
TESTING BEFORE WRAP CHILI	
Distilled water	0.0
Chili	15.1
TESTING AFTER WRAP CHILI	
Chili	4.3

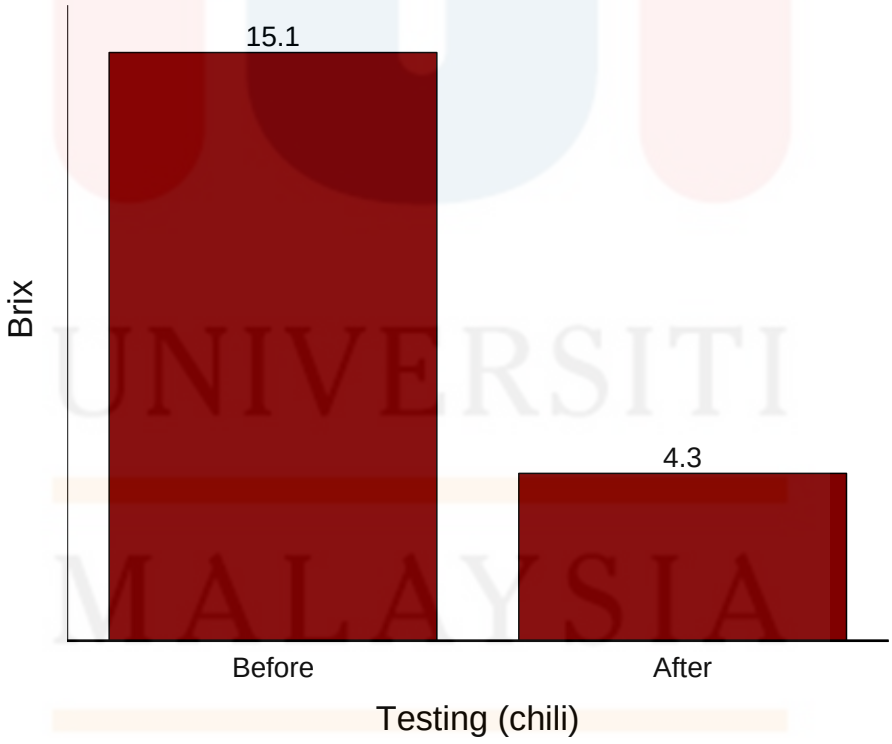


Figure 4.16: Brix before and after wrap in thin film.

The figure show the result before and after chiles were wrapped in a thin film, their Brix values are shown in the image's table. This is the brix result before wrapping 15.1 and after wrapping 4.3, as far as I can tell. If you wrap chili in a thin layer, its Brix value will drop dramatically. In most cases, a lower Brix number implies that the sugar content of the fruit has decreased. A loss of moisture is the likely culprit, according to multiple theories, for the declining Brix value. It is possible that the thin coating prevented the chilies from losing moisture, which would have led to a concentration of sugars and an increase in Brix value. On the other hand, the film might have taken up some of the chilies' moisture, which would explain why the Brix value was lower. When it comes to sugar breakdown, thin coatings might have made things worse. For instance, the fermentation of carbohydrates into alcohol and other byproducts might occur in anaerobic circumstances if the film is not permeable. The Brix value can be influenced by a few other factors, including the type of thin film utilized, the storage circumstances, and the duration of storage.

CHAPTER 5

5.1 CONCLUTION AND RECOMMENDATION

5.2. CONCLUSION

The production and characteristics of PVA, CNC, and ZnO nanocomposite thin films were examined in this thesis. The films have potential applications in food packaging, particularly for fresh cooling. Films with transparent mechanical and structural properties can be produced using the solvent casting technique. Nanocrystals (CNCs), polyvinyl alcohol (PVA), and zinc oxide (ZnO) work together to make films with special qualities that are good for food packaging. Extensive analysis of their mechanical characteristics has shown that they have intriguing features that could be used in real-world applications.

These properties include modulus, tensile strength, and flexibility. Also, using that biodegradable fabric to wrap fresh chiles has shown a lot of promise in the lengthy investigation. In keeping with the needs of effective food packaging, the films display an ideal combination of biodegradability, pliability, and strength. This research aids in the ongoing search for packaging options that are environmentally friendly. Utilizing nanocomposite thin films, which offer biodegradable and bio-based alternatives, could lead to the realization of sustainable applications.

5.3 RECOMMENDATION

Some potential directions for future work that have emerged from this investigation are as follows:

1. Improving film drafting.

    - Modifying the mechanical characteristics: To get the right combination of mechanical strength, flexibility, and durability resistance for packaging fresh chilies, try varying the ratios of PVA, CNC, and ZnO.
    - Look into other ways of processing: Explore different technologies, such as extrusion, that could enhance film characteristics and provide benefits compared to solvent casting.

2. Evaluation of Barmer's Efficiency

    - Evaluate in comparison to currently used form factors: Evaluate the potential of their competitors by benchmarking their barrier qualities against commonly used chili packaging.
    - Value for preventing damage from outside sources: Investigate the film's ability to shield the chili from airborne gases that impart freshness, wetness, and quality by conducting a comprehensive test.

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APPENDIX

A) PH

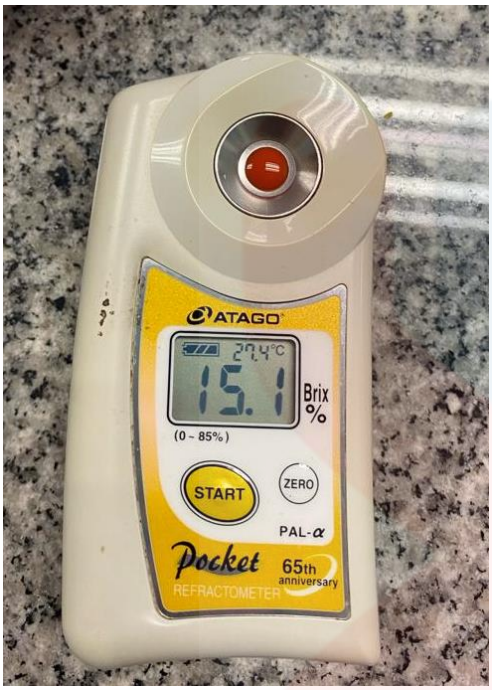
BEFORE AFTER

PH before rap thing film.

PVA PVA+CNC PVA+CNC+ ZN0 1g PVA+CNC+ ZN0 2g PVA+CNC+ ZN0 3g

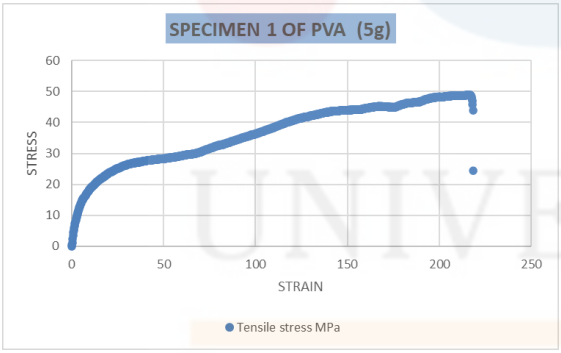
After open thing film.

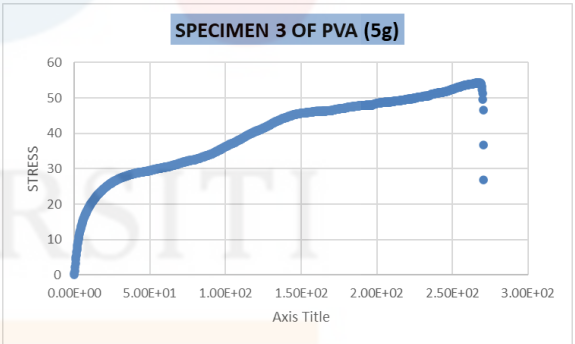
B) BRIX ANALYZER

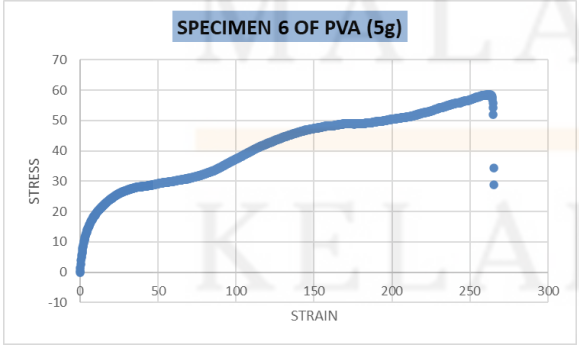


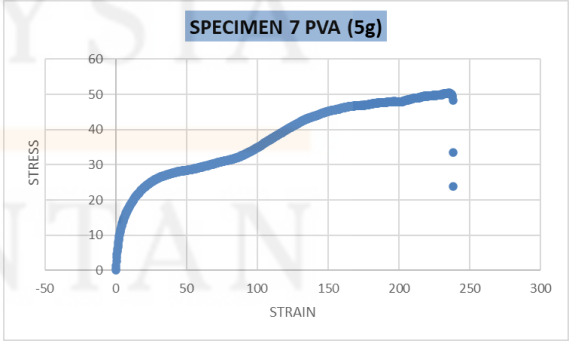
TENSIL

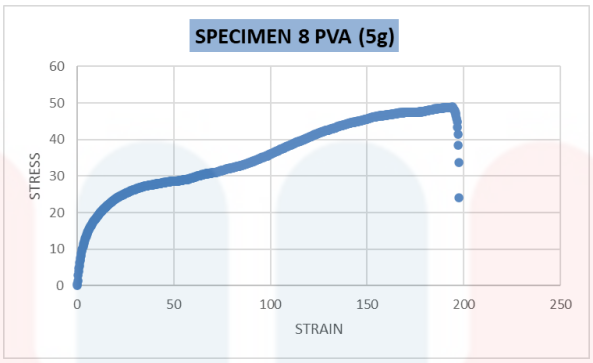
PVA



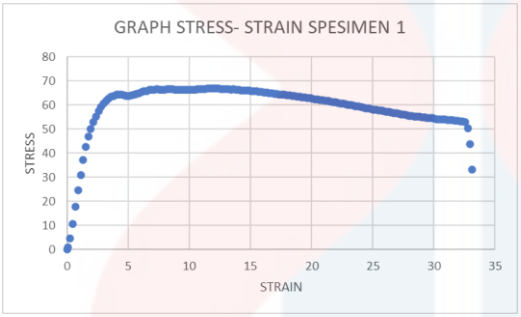


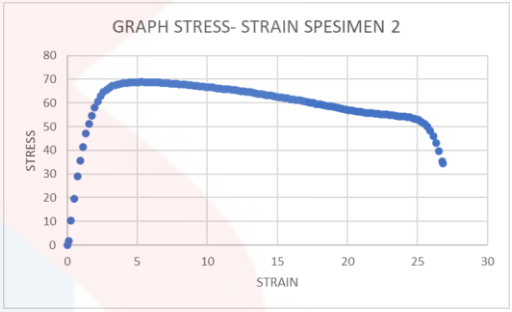


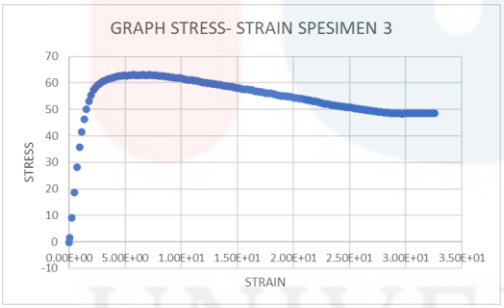


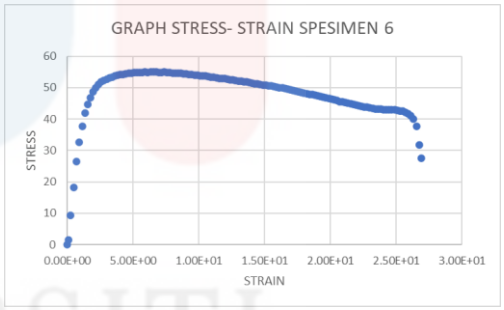


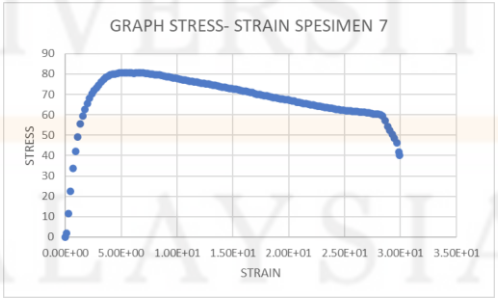
PVA + CNC



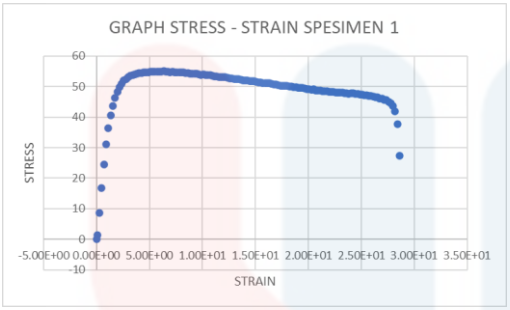


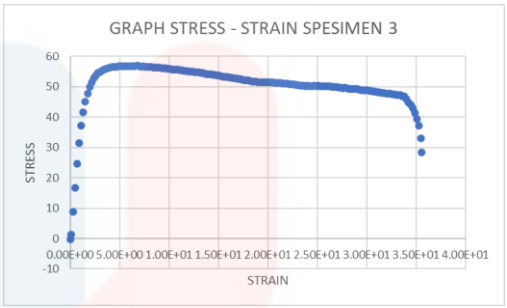


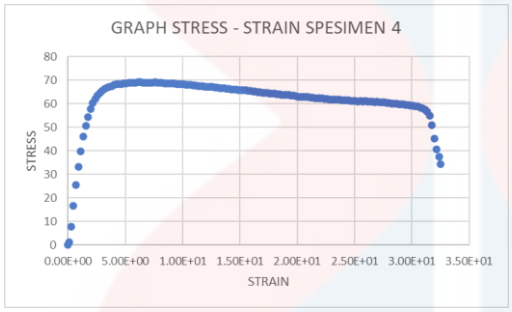


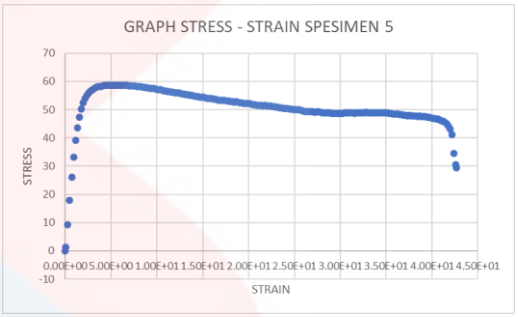


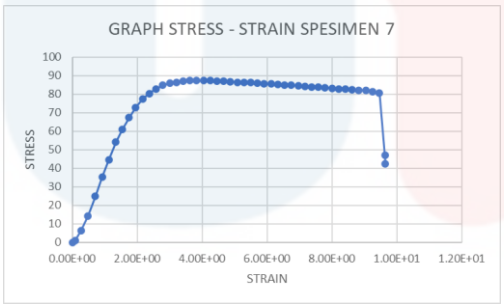
PVA + CNC + ZNO (1g)



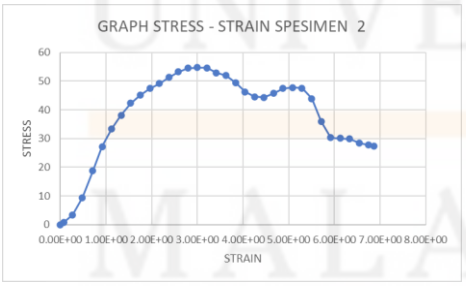


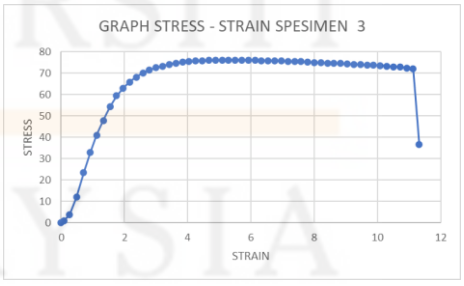


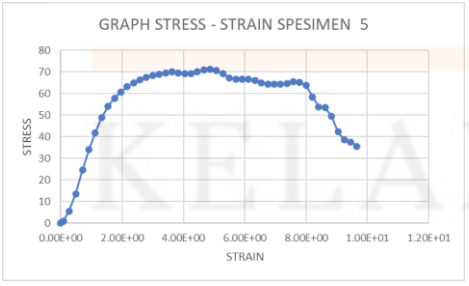


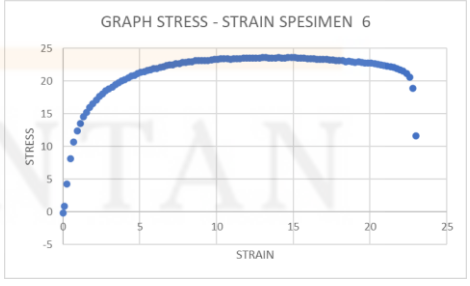


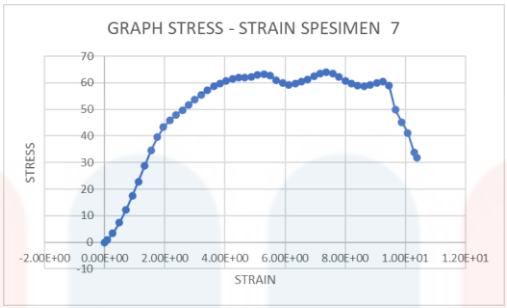
PVA + CNC + ZNO (2g)











PVA + CNC + ZNO (3g)