

**Ministry of High Education  
and Scientific Research  
University of Babylon  
Materials Engineering  
Polymers Dept.**



**"Polymer Nanocomposites for  
Food Packaging Applications"**

**Submitted by:**

**Zahra Majid**

**Hussein Haider Hasan**

**Supervised by :**

**Prof. Massar Najim Obaid**

**1443 - 2022**

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

﴿وَقُلِ اعْمَلُوا فَسَيَرَى اللَّهُ عَمَلَكُمْ وَرَسُولُهُ  
وَالْمُؤْمِنُونَ وَسَتُرَدُّونَ إِلَىٰ عِلْمِ الْغَيْبِ وَالشَّهَادَةِ  
فَيُنبِّئُكُمْ بِمَا كُنْتُمْ تَعْمَلُونَ﴾

(سورة التوبة): الآية ( 105 )



## **Dedication**

**We dedicate our work to our families and many friends.**

**A special feeling of gratitude to our loving parents, there words of encouragement and push for tenacity ring in our ears.**

**Brothers and sisters have never left our side and were very special**



## Gratitude And Appreciations

First of all we thank God for the most mercy for enabling us to present this project in the best form that we wanted to be, we would like to thank our supervisor of this project ( **Prof. Massar Najim Obaid** ) for her valuable help and advice to come out with this project. We thank our faculty and doctors that provided us with all the knowledge.

We are all thankful for our families for their endless love, assistance, support and encouragement.

For our friends for their understanding and support for us to complete this project.

## **Abstract :**

Food packaging has an important role in food safety, extending the life of food during storage and transportation, protecting against physical, environmental, chemical, microbial hazards, and improving product quality. Petroleum-based plastics are a packaging material that is often used because of their large availability at low cost. However, these materials are not environmentally friendly, which their continuous use will lead to reduced availability, nonbiodegradable waste and environmental pollution.

Three samples are prepared with different percentages of PVA/PEG (70%PVA+30% PEG, 60%PVA/40%PEG and 50%PVA/ 50%PEG) and the best ratio (70 %PVA/30%PEG) was selected and reinforced with different percent of ZnO (1, 2 and 3) w.t % . The tests (contact angle, antibacterial and FTIR) were performed. In examining the contact angle, when mixing PVA with PEG, the wettability and degradability increases and prevents the accumulation of waste of polymers.

When the mixture was reinforced with different percentages of ZnO, the behavior of the polymer was changed from hydrophilic nature to hydrophobic nature (the contact angle was increased), especially when reinforced by 2% and 3 % of ZnO due to the increase in surface roughness and when the results of Antibacterial show the blend (0.7PVA+0.3PEG) and nanocomposite had good activity against bacteria and it was detected in the FTIR spectrum of the blend (70%PVA+30% PEG) and the nanocomposite (70%PVA+30% PEG+2%ZnO) that it does not create chemical bond between polymer blend and nanoparticles but only physical formation of hydrogen bonds between PVA and PEG.

# Contents

No.	Subject	Page No.
	CHAPTER ONE : Introduction	1
1-1	Introduction	2
1-2	Polymer Nanocomposite	5
1-3	Characterization Methods of Polymer Nanocomposite Films	5
1-4	Types of Polymer Nanocomposite Packaging	6
1-4-1	Rigid Packaging	7
1-4-2	Nylon-Based Packaging Materials	8
1-4-3	Biodegradable Packaging	10
1-4-4	Flexible Packaging	10
1-4-5	Active Packaging	11
	The aim of the research	12
	CHAPTER TWO : PREVIOUS STUDIES	13
2-1	Literature Review	14
	CHAPTER THREE : Experimental Part	15
3-1	Introduction	16
3-2	Preparation of Composite Material	17
3-3	Contact angle Test	18
3-4	Fourier Transformation Spectroscopy (FTIR)	18

No.	Subject	Page No.
3-5	Anti-Bacterial Test	18
	CHAPTER Four Results and Discussion	19
4-1	Contact Angle	20
4-2	Anti-Bacterial Activity of Nanocomposites	25
4-3	FTIR Results of Nanocomposites	26
	Chapter FIVE Conclusions and Recommendations	29
5-1	Conclusions	30
5-2	Recommendation	31
	REFERENCES	32

# **CHAPTER 1**

## **Introduction**



## **1-1 Introduction:**

The prime functions of food packaging are extending the shelf life of packaged food materials by preventing unfavorable changes caused by microbial spoilage, chemical contaminants, temperature change, oxygen, moisture, light, external force, and maintaining the quality and safety of food products from the time of production to the time of consumption. The packaging performs the aforementioned functions by creating proper physicochemical conditions for products and acts as a barrier for gases, water vapor, light, and microorganisms not only to maintain the food quality and safety but also to enhance the shelf life of the packaged food products. Besides basic properties like mechanical, optical, and thermal properties, the food packaging material must prevent microbial growth and contamination, hinder gains or loss of moisture, and act as a barrier against water vapor permeability, oxygen, carbon dioxide, and other volatile compounds such as flavor [ 1-2]

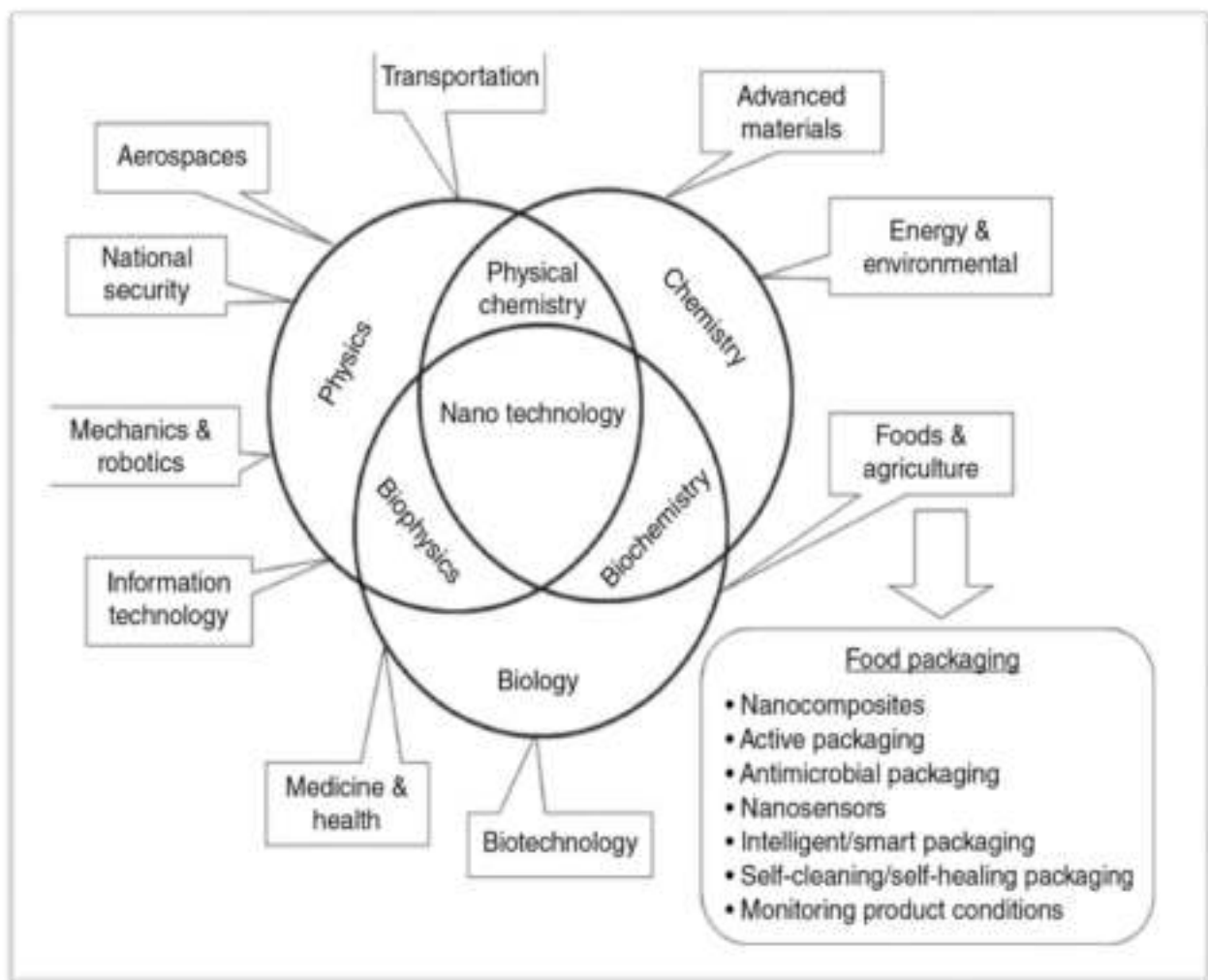
Food packaging is not practiced merely as a container, but it also works as a protective barrier with various advanced functions. In addition, the demands of innovative packaging materials are ever increasing to meet the consumer need for higher quality food with safety, convenience, and sustainability. In this sense, food-packaging industry is a dynamic and futuristic, which gives birth to sweep up or evolve novel technology.

Nanotechnology is an interdisciplinary science for the creation of useful/functional materials, devices or systems by controlling at least one dimension of the matter on the nanometer-length scale and the development of new phenomena and physical, chemical, and biological properties as shown in Figure 1-1. The material properties change with the size of particles decreasing to the nanometer scale because of the large surface-to-volume

ratio. For example, a particle of 30 nm diameter has about 5% of its atoms on its surface; however, with 10 nm diameter, the number of surface atoms changes to almost 15%; while for the particle size of 3 nm in diameter have nearly 50% of its atoms on the surface. As a result, the surface area, total surface energy, and reactivity increase [3].

Many industries have known the possible benefits of nanotechnology, and commercial products have among the various existing nanotechnologies, polymer nanocomposite has attracted most attention in the food packaging industry.

Although, extensive researches being undertaken at industry and academic levels, polymer nanotechnology in food packaging is still in the developmental phase. For the growth of polymer nanotechnology in food packaging at advanced level, it is important to glare at the complete life cycle of the packaging (from raw material extraction and production to usage and administration), integrating and balancing cost, performance, health, and environmental considerations. The high point of multidisciplinary research is required in polymer nanocomposite in food packaging to overcome the barriers like safety, technology, regulation, standardization, trained workforce, and technology transfer in order to achieve the benefit for commercial products in the global market. Moreover, owing to the enormous growth application potential of polymer nanocomposite in food packaging, the emerging technology will be a hub of new employment opportunities because of degradable and ecofriendly nature [4 ].



**Fig – 1-1 - Application areas of nanotechnology in various multidisciplinary science and industries with food packaging application [ 5]**

The polymer nanocomposite packaging has a great potential as an innovative food packaging technology to maintain the food quality and safety, and to extend the shelf life of the packaged food products. In view of considering the aforementioned points, this chapter focused on the composition, preparation, characterization, and application of polymer nanocomposite materials in the food packaging areas.

## **1-2 Polymer Nanocomposite :**

Polymer nanocomposite is a multiphase hybrid solid material that contains one of the phases as nanoscale fillers that have at least one dimension in less than 100 nm distributed within a polymer matrix [6]. Owing to the nanometer-sized particles dispersed in the polymer matrix, these nanocomposites exhibit prominently enhanced mechanical, thermal, optical, and physicochemical properties, compared with the pure polymer or conventional composites (microscopic) with very low filler loading, typically 5% wt or below. Plenty of studies have shown a positive impact on barrier properties of polymer nanocomposite after reinforcing with nanofillers. The nanocomposite packaging materials have a high potential as an advanced food packaging technology for maintaining the overall quality of foods and extension of the shelf life of the packaged food products [4 and 7- 9]. Polymer nanocomposites are mainly composed of the polymer matrix, nanofillers, plasticizers, and compatibilizers.

## **1-3 Characterization Methods of Polymer Nanocomposite Films :**

The microstructure and surface morphology of polymer nanocomposites are characterized by scanning electron microscopy (SEM) and transmission electron microscope (TEM). TEM allows a qualitative understanding of the spatial distribution, internal structure, and dispersion of the nanofillers within the polymer matrix. Whereas, chemical compositions of films are determined by energy-dispersive X-ray spectroscopy (EDX) analysis. The crystallinity, crystallite size, and composite structures such as tactoid, intercalated, or exfoliated structures of polymer nanocomposite and polymer/clay composite can be determined using XRD measurements. The functional group and chemical changes due to the interaction of polymer with nanofillers is determined by Fourier transform infrared spectroscopy

(FTIR). It shows the vibration peaks in a particular frequency for a specific chemical group. In addition, a number of analytical techniques have been used to characterize the polymer nanocomposites films including atomic force microscopy (AFM), thermogravimetric analysis (TGA), and nuclear magnetic resonance (NMR).

#### 1-4 Types of Polymer Nanocomposite Packaging :

The reinforcement of nanofillers in the polymer matrix has been explored for the significant enhancement in performance properties of nanocomposites for potential applications in food packaging, such as processed meat products, cheese, bakery products, confectionery, food grains, boil-in-bag foods, fruit juices and dairy products, and for the manufacture of carbonated beverage and beer bottles [10]. There are various reports available on potential applications of nanocomposites in the food-packaging sector Figure-1-2.

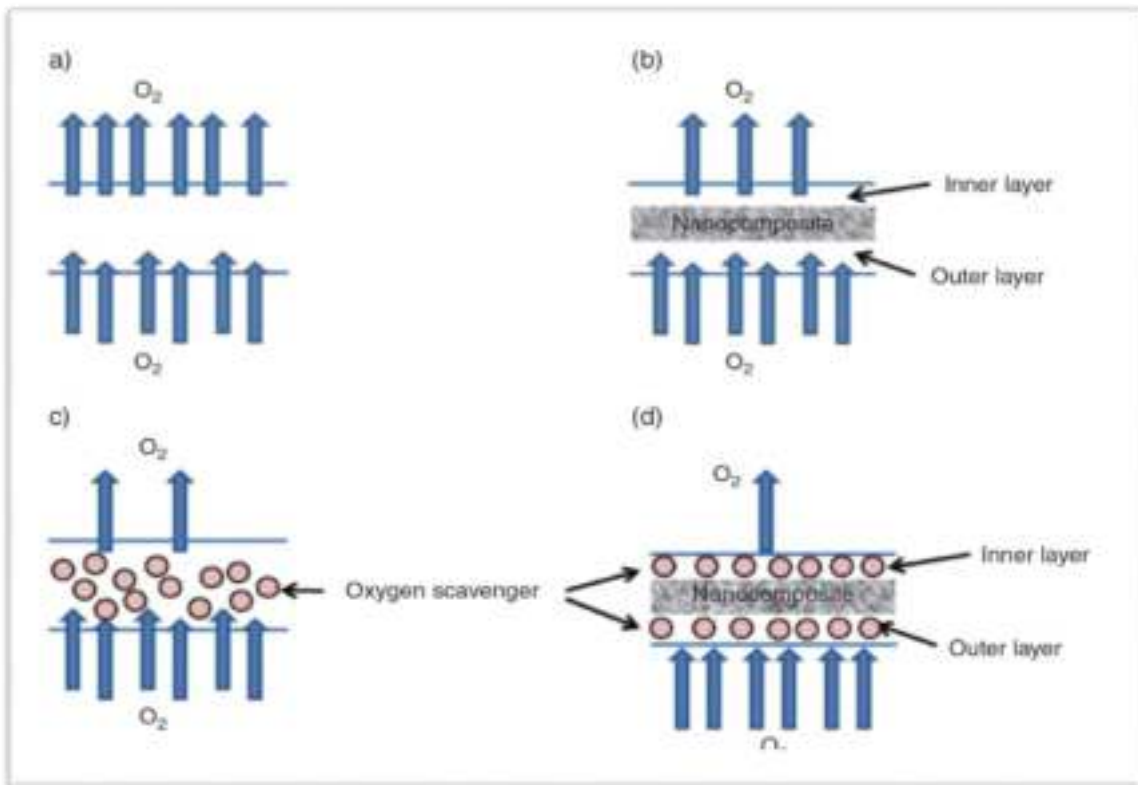


**Figure -1-2- Properties and potential application of polymer nanocomposite in food packaging [ 5]**

However, they are mostly focused on nanocomposites made from thermoset or thermoplastic polymers. Moreover, the use of nanocomposite as food packaging materials is limited because of the relatively high production cost and less feasibility for mass production. In addition, the concern about the food product safety emerging from consumer and government about use of nanomaterials as packaging materials.

#### **1-4-1 Rigid Packaging :**

The packaging material's resistance to gas intrusion like oxygen and water vapor and retention of gasses like CO<sub>2</sub>, and aroma are the primary limiting actors for the shelf life of many foods and beverages. The migration of CO<sub>2</sub> out of carbonated beverage bottles could reduce the shelf life by making the beverage become flat. However, oxygen migrating into beer bottles reacts with the beer and make it stale. In both cases, the best solution to the problem is providing a barrier to the movement of molecules through the polymer matrix comprising the package. Considerable improvements in gas barrier properties of nanocomposites have been explored in the food packaging industry, and some of them are commercially available already. Polymer nanocomposites with different nanofillers have been developed for improved gas and water vapor barrier properties. The packaging materials for applications in beer bottles, carbonated beverages, and thermoformed containers are multilayer nanocomposites for rigid food packaging as shown in Figure –1- 3. The first type of packaging consists of only polymer that can be a barrier for gas or water vapor molecules. The second type is a passive barrier, in which the middle layer is reinforced with nanocomposite film with enhanced barrier property. The third type is an active barrier packaging materials composed of gas [O<sub>2</sub>] scavenger incorporated into the polymer. The fourth type is the combination of passive and active barrier.



**Figure -1-3- Diagrammatic representation of the structures of multilayer nanocomposite for oxygen (O<sub>2</sub>) barrier packaging [ 5]**

#### **1-4-2 Nylon-Based Packaging Materials :**

##### **1. Polyamide 6 or thermoform nylon:**

It is one of the most widely used plastic material to produce laminated films, sheets, and bottles, because it is cheap, transparent, strong, tough, and thermoformable over a broad range of temperatures and chemicals, but it is more permeable to gasses and water vapor. Thermoformed nylons are used for packing meat and cheese. Nylons are often used as coextrusion with other plastic materials, providing both strength and toughness to the structure. Development of nanocomposite with nylon and clay has been tried in order to improve gas and water vapor barrier properties.

## **2. Nylon-6 nanocomposite ( Bayer Polymers):**

It is known to have better properties than simple polyamide 6 and a barrier for the gasses and water vapor, as well as maintaining excellent transparency. The nanoparticles influence the crystallization of the plastic, acting as nuclei for the crystallization of the polymer, resulting in improving the light transmission through the film. Honeywell produces three types of nylon-6 nanocomposite:

(i) Aegis™: OX.

(ii) HFX

(iii) CDSE with high oxygen barrier properties for plastic beer bottles, hot-fill bottles, and carbonated soft drink bottle, respectively. Nylon-6 nanocomposites showed oxygen barrier properties approximately four times higher than pristine nylon-6 [11]. Nylon-MXD6 is a crystalline polyamide of meta-Xylenediamine and adipic acid, which is widely used in multilayer food packaging applications [12]. Mitsubishi Gas Chemical Company and Nanocor jointly developed MXD6 (trade name: Imperm™), which is semiaromatic nylon in nanocomposite form with high gas barrier properties. In addition, they also produce a nanocomposite of multilayer PET and clay platelets in MXD6 nylon under the trade name "M9" [13]. Imperm is used in food and beverage packaging to increase the shelf life of carbonated beverages. Their CO<sub>2</sub> retention capability determines their shelf life. The multilayered PET bottles blended with nanocomposite have been used for the packaging carbonated beverages to minimize the carbon dioxide loss from the drinks and the oxygen ingress into the bottles, thus maintaining the quality and extending the shelf life of the drinks. Moreover, the resultant bottles are both lighter and stronger than glass bottles and are less likely to shatter.



### **1-4-3 Biodegradable Packaging :**

Various types of biodegradable food packaging films are developed using biopolymers. The nanofillers from renewable resources have been used to increase the water vapor barrier property. Reinforcement of chitin nanofibrils in carrageenan biopolymer increased the mechanical property and decreased the water vapor permeability of nanocomposite films [14]. The water vapor permeability of carrageenan biopolymer also decreased when it was reinforced with paper mulberry pulp nanocellulose [15]. Rhim and Wang [16] reinforced clay into carrageenan biopolymer to increase the water vapor barrier property and mechanical properties of nanocomposite. Kanmani and Rhim [17] mixed nanoclay into gelatin matrix to improve the mechanical and water vapor barrier properties.

### **1-4-4 Flexible Packaging :**

Flexible packaging materials are bags, pouches, envelopes, wraps, and sachets, which are made of materials such as film, foil, or paper sheeting that, when filled and sealed, acquire pliable shape. Some packaging materials contain metal layers and container that can be replaced by nanocomposites to flexible pouches or rigid plastic structures. Packaging films with metal layers increase the amount of solid waste in the environment after their disposal. Many current packaging materials are multilayered, which are unrecyclable, but nanocomposite polymers could help reduce packaging waste and would allow efficient recycling. The prime goal in using polymer nanocomposite is to moderate the amount of solid waste associated with the current packaging as well as to lower the costs by savings material.

Nylon-MXD6 is explored as potential substitutes for foil-based packaging materials in food supply chain nowadays. Nylon-MXD6/clay

nanocomposites can enhance mechanical properties of the polymer in addition to gas barrier properties. Thellen et al [18]. Reported the enhanced oxygen barrier properties of nylon-MXD6/clay nanocomposites decrease in film elongation while improving the tear resistance of the films. Nylon-MXD6/clay nanocomposites showed 4.5, 2.0, and 2.3 times, lower OTR, CO, TR, and WVTR, respectively than those of the neat nylon-MXD6 [19]. Nanocomposite films with improved barrier properties and superior mechanical strength provide an opportunity to reduce the environmental load occurred by currently used packaging materials.

#### **1-4-5 Active Packaging :**

It refers to the techniques concerned with substances that absorb oxygen, carbon dioxide, moisture, ethylene, flavors/odors, and those that release antioxidants, carbon dioxide, flavor, and antimicrobial agents. It can remove undesirable flavor and tastes improve the smell or color of the packed food. Active packaging materials interact with the packed food and the environment surrounding the food and plays an active role in extending the shelf life of packaged food or improving safety or sensory properties, however, maintaining the quality of the food [20-21].

The dynamic packaging technologies modernized to provide dependable quality, food safety also to minimize package-related environmental contamination and disposal problems [22]. The expansion in active packaging has led to advances in many regions, including antioxidant activity, antimicrobial activity, controlled respiration rates, and water vapor permeability. Other active packaging technologies include carbon dioxide absorber/emitters, odor absorbers, ethylene absorber, and aroma emitters. Among these techniques, oxygen scavengers, moisture absorbers, and antimicrobial packaging constitute more than 80% of the market today [23].

**The aim of the research :**

Prepare biodegradable blend polymers reinforced with bio nanoparticle for food packaging applications.

# **CHAPTER 2**

## **PREVIOUS STUDIES**

## 2-1 Literature Review :

In 2021, O. Sabr et. al. Thin films prepared from Poly vinyl alcohol (PVA) and silica nanoparticles (SiO<sub>2</sub>) by using solvent casting method have been studied as potential packaging materials. PVA/ SiO<sub>2</sub> nanocomposites were characterized by Fourier transform infrared (FT-IR), Scanning electron microscopy (SEM), Differential scanning calorimetry, atomic force microscopy (AFM), Water contact angle, Water absorption capacity, Water solubility and mechanical properties.

The results showed that the mechanical properties such as ( tensile strength, elongation at break, modulus) increased with increasing nanoparticle content to 7wt. % compared with pure PVA, while the mechanical properties decreasing with increasing SiO<sub>2</sub> content to 9 wt. % , but it remains higher than the matrix material, also an increase in the crystallinity with addition 7wt. % from SiO<sub>2</sub> which interpreted and supported the improvement of results of mechanical properties for nanocomposites PVA/SiO<sub>2</sub> [24].

In 2021, Raminder Kaur et. al [25] investigated the physicochemical characteristics of ethyl cellulose [EC) based films to be used in food packaging. Ethyl cellulose was plasticized with different percentage of polyethylene glycol (PEG). The samples of standard dimensions were subjected to different testing such as soluble matter content, moisture content, oil permeability, surface morphology, mechanical testing etc. The data obtained was analyzed to decide the moderate percentage of plasticizer that can be used to provide a rational explanation of a perfect quality specimen. It has been revealed that too high or too low percentage of plasticizer was not appropriate for a good film. Tensile stress analysis was used to estimate the mechanical properties of the films [25].

# **CHAPTER 3**

## **Experimental Part**

### 3-1 Introduction

The present chapter covers all the most important details about the methodology that was used in this study starting with materials selection and specification, preparation of sample and the instruments of inspection. Research plane that was carried out is shown in Figure (3-1)

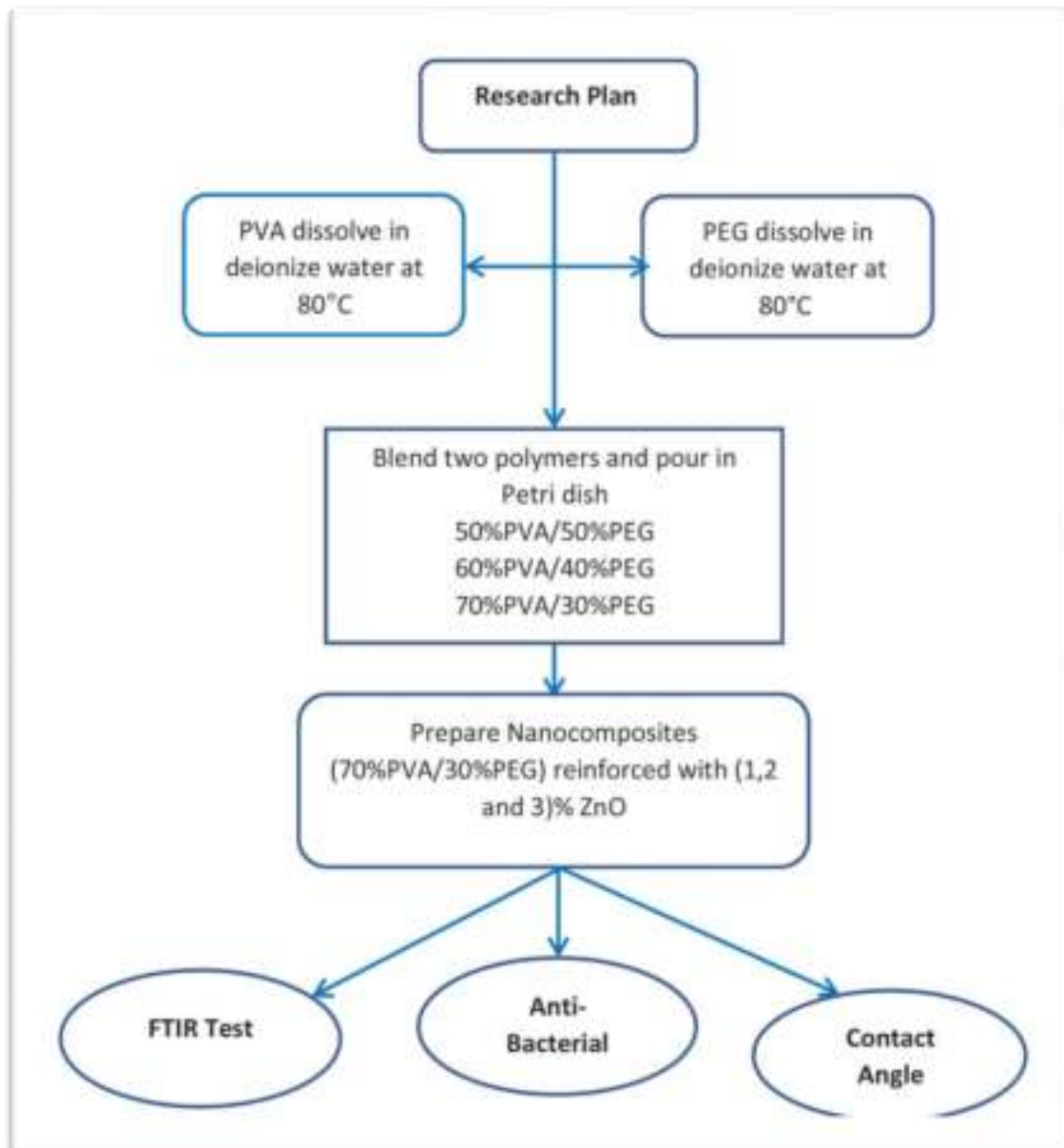


Figure (3-1) The Research of Plane

### 3-2 Preparation of Composite Material:

1. The weight of the polymers PEG and PVA was taken according to the percentages in Table (3-1).
2. Each polymer referred to in the above paragraph was placed in 20ml of water only and placed in a magnetic stirrer at a temperature of 80°C until the polymer was dissolved.
3. The polymers were mixed with continuous mixing on a magnetic stirrer for half an hour.
4. The dissolved blend was placed in Petridish and left to dry at room temperature to form a film.
5. In the case of strengthening the film with the nanomaterial, the nanomaterial was taken in different proportions (1,2,3)ZnO and put in 20ml of distilled water and dispersed with an Ultrasonic device for 15 minutes at a temperature of 40°C. Then the dispersed nanoparticles were poured over the mixture before pouring it in Petri dish With continuous mixing for 30 minutes and then pour it with petridish as shown in point 4.

**Table (3-1) Weight Percentages of Blends and Nanocomposite Material**

	<b>PVA%</b>	<b>PEG%</b>	<b>ZnO%</b>
<b>Polymer Blend</b>	<b>50</b>	<b>50</b>	-----
	<b>60</b>	<b>40</b>	-----
	<b>70</b>	<b>30</b>	-----
<b>Nanocomposite</b>	<b>69</b>	<b>30</b>	<b>1</b>
	<b>68</b>	<b>30</b>	<b>2</b>
	<b>67</b>	<b>30</b>	<b>3</b>



### **3-3 contact angle Test:**

Contact angle test was carried out using the device, SL 200C – Optical Dynamic I Static Interfacial Tensiometer & Contact Angle Meter. The purpose of this test is to study the effect of polyester fibres on the wettability of polymer which impose an effect on the growth of living cells and create blood clots. The left and right contact angles of the water drop are measured.

### **3-4 Fourier Transformation Spectroscopy (FTIR):**

The test of FTIR was achieved by using Fourier transform infrared spectrometer, FTIR instrument type IR Affinity-1 (made in Japan) available in laboratory of the Materials Engineering Faculty/ Babylon University. It is equipped with a room temperature DTGS detector, mid-IR source (4000 to 400) cm<sup>-1</sup> and a KBr beam splitter. FTIR were performed on a spectrum for blend PVA, PAN/PEG and polymer Nano composites reinforced by ZnO.

### **3-5 Anti-Bacterial Test:**

By using, the Agar Well Diffusion Method was being used to determinate antibacterial activity of the samples. The Muller Hinton agar plates were prepared and were inoculated with Escherichia coli (E. coli), staphylococcus aureus (S. aureus) as test organisms which spreading on the surface of the media with the help of sterile swab. Blend Polymer, and polymer nano composites samples have been inserted to the plates to determine the inhibition zone. Finally, these plates were incubated at 37°C, and after 24 hours of incubation; zones of inhibition were visualized and measured the diameter of the inhibition zone and recorded in mm. The test was being done in laboratory of Science Faculty /Babylon University.

# **CHAPTER 4**

## **Results and Discussion**

## 4-1 Contact Angle

Figure (4-1) and Table (4-1) show the contact angle of pure PEG and PVA and the stability the droplets with the time that indicate the wettability of these materials. The PEG and PVA are hydrophilic (PEG more hydrophilic than PVA which increased the hydrophilicity the PVA) and when blend PVA with PEG the wettability and hydrophilicity is increased that enhance the degradability after used it as food packaging and prevent the accumulated the waste of polymers. Moreover, when the blend is reinforced with different weight fraction of zinc oxide (ZnO) (1,2and 3) w.t%.

The behavior of polymer is changed and transform from hydrophilic to hydrophobic nature (the contact angle is increased and excess the value  $90^\circ$ ) specially at reinforced with 2% and 3% of ZnO due to increase the surface roughness with increased the percentage of Nano particles that prevent the water droplets dispersion within the surface irregularities, increased the contact angle over  $90^\circ$  and increased the stability the water droplets with the time.

Also, due to the use of hydroxyl groups to form a hydrogen bond with the matrix with low number of hydroxyl groups, which leads to making the surface of the nanocomposite hydrophobic [26]. Finally this support the performance the nanocomposite when used as a food packaging by prevent humidity absorption that have negative effect on the food that stored inside the package, hence prevent the growth of bacteria and fungi and also saved the food without spoilage.

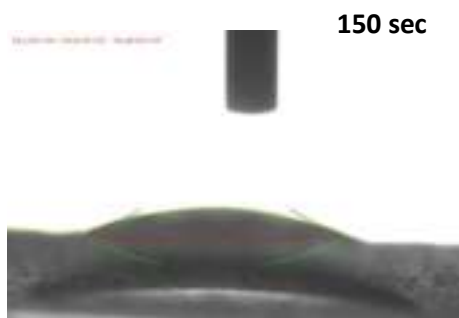
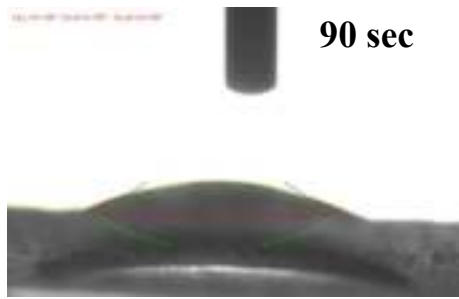
**Table (4-1) Contact angle Pure PEG ,PVA, Bend PVA/PEG and Nanocomposite**

Sample	Contact angle(C A)° at time (0) sec	Contact angle(C A)° at time (30) sec	Contact angle(C A)° at time (60) sec	Contact angle(C A)° at time (90) sec	Contact angle(C A)° at time (120) sec	Contact angle(C A)° at time (150) sec	Contact angle(C A)° at time (180) sec	Contact angle(C A)° at time (210) sec	Contact angle(C A)° at time (240) sec
Pure PEG	27.622	22.850	0						
Pure PVA	47.259	41.097	35.341	29.070	0				
70% PVA +30% PEG+0% ZnO	51.475	37.682	0						
70% PVA +30% PEG+ 1%ZnO	31.739	27.111	22.070	0					
70% PVA +30% PEG+ 2%ZnO	93.706	82.990	89.271	78.016	27.905	59.240	54.713	51.692	44.693
70% PVA +30% PEG+ 3%ZnO	96.757	90.519	89.031	86.782	83.537	81.542	76.467	72.570	

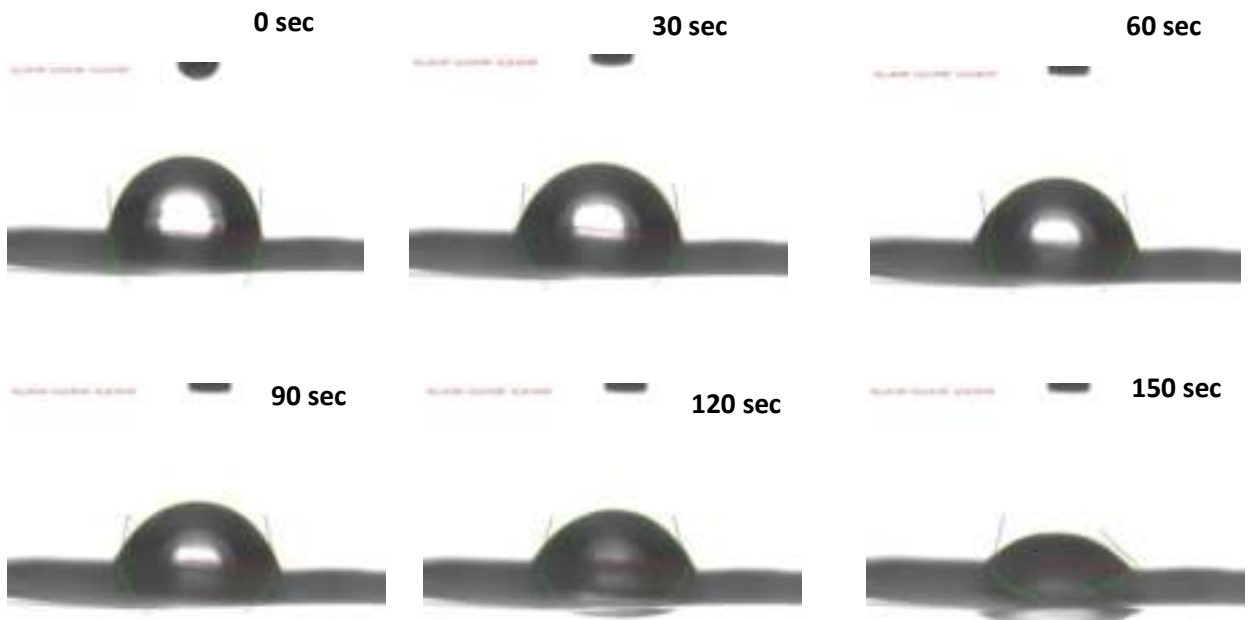


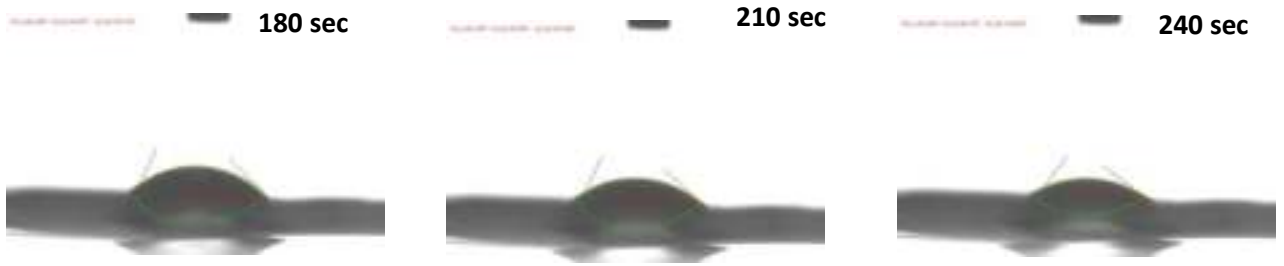
**a- Pure PEG**



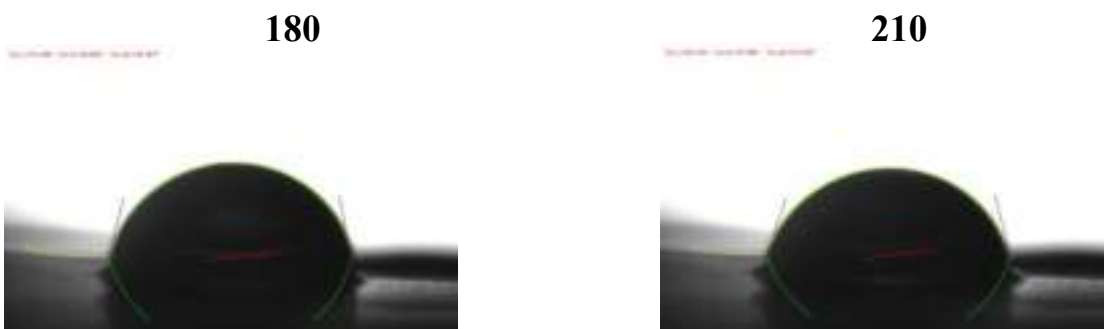


**d- 70% PVA +30% PEG+ 1%ZnO**





**e- 70% PVA +30% PEG+ 2%ZnO**



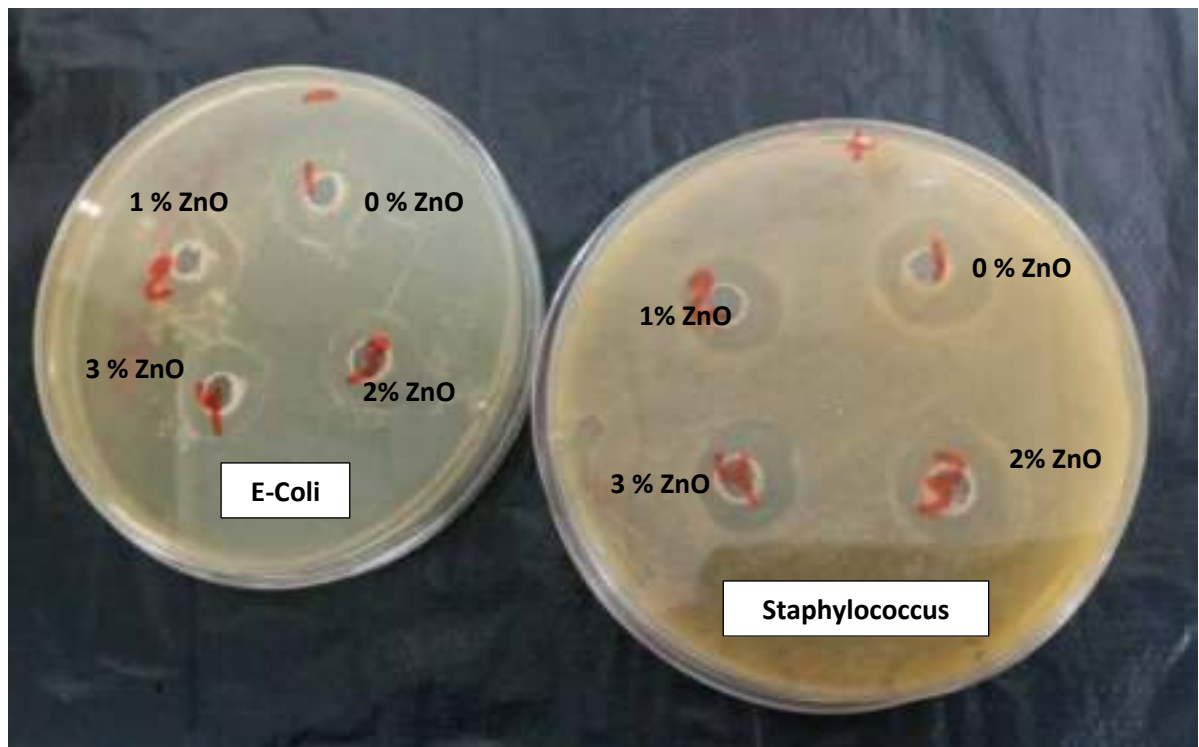
**f- 70% PVA +30% PEG+ 3%ZnO**

**Figure (4-1) Contact Angle of ( a. b. c. d. e. f. ) : With Different Time**

## 4-2 Anti-Bacterial Activity of Nanocomposites

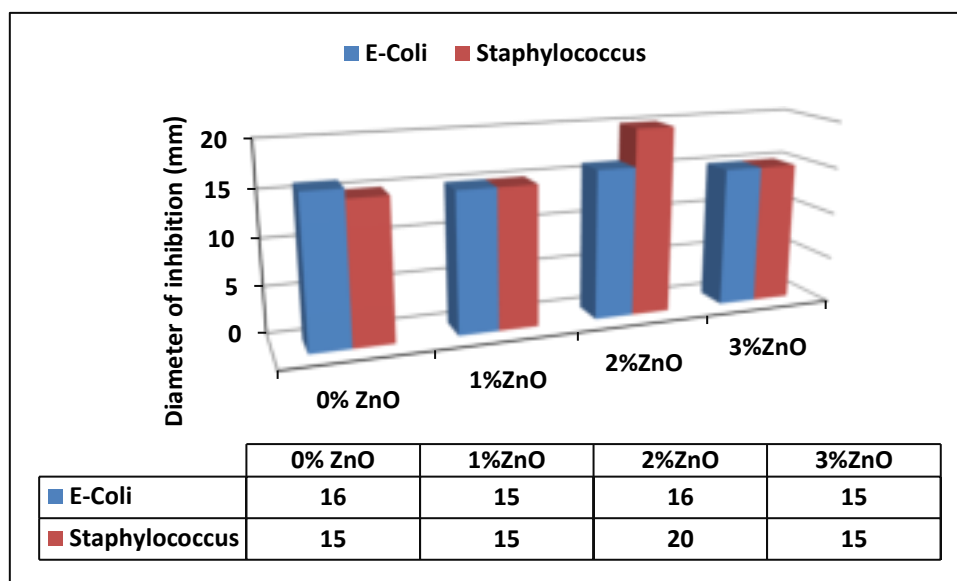
Figure (4-2) and Figure (4-3) show the bacterial inhibition area of blend 70% PVA +30% PEG and nanocomposite material reinforced with different weight fraction of ZnO (1,2 and 3)% which illustrate.

The blend 70% PVA +30% PEG had good antibacterial activity and the nanocomposite material cause to increase the diameter of inhabitation of E-coli Bactria and Staphylococcus Bacteria due to ZnO nanoparticles had antibacterial properties [27] , spatially at 2% ZnO



**Figure (4-2) Illustrated the Inhibition Area of blend 70% PVA +30% PEG and nanocomposite material reinforced with different weight fraction of ZnO (1,2 and 3)%for E. coli and Staphylococcus Colony**





**Figure (4-3) Diameter of Inhabitation of Nanocomposite Material as Function of ZnO wt.% Content in Composite**

#### 4-3 FTIR Results of Nanocomposites

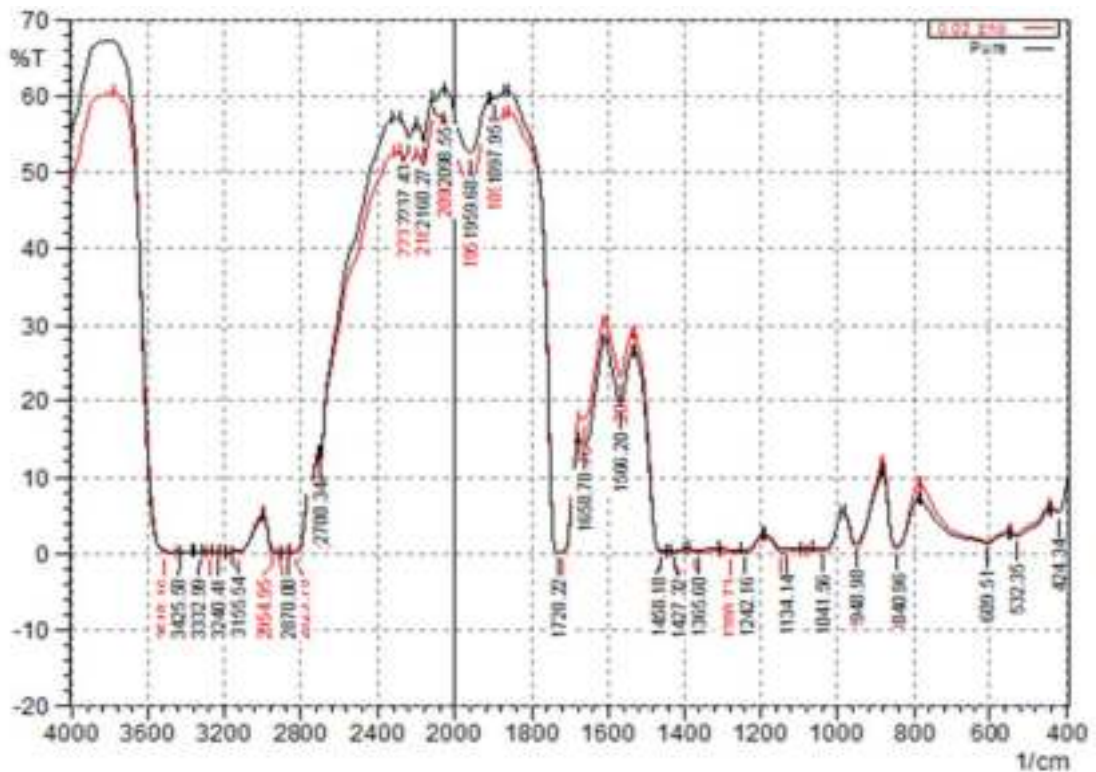
FTIR Analysis. FTIR spectroscopy is one of the most common techniques, which provides useful information regarding the interactions between their functional groups. It is also considered a powerful method for studying the conformational changes in biopolymer systems [28-29]. It is clear from the spectra of all PVA/PEG blends that extensive H-bonding exists in the range 3000–3500 cm<sup>-1</sup> due to stretching vibration of –OH groups which results from strong H-bonds that form during blending.

Figure (4-3) and Table (4-2) revealed to FTIR spectrum for blend 70% PVA/30% PEG and nanocomposite (70% PVA/30% PEG +2% ZnO) and Table (4-3) show the transmitted bands which referred to CH stretching band at 2870 ,CH<sub>2</sub> bending at 1458, C=O at 1658 and OH stretching at 3425 and

3240 which are shifted from band of standard (3450 and 3280) which referred to create hydrogen bonding between PVA and PEG [30-31],

Moreover, The characteristic absorption peaks of PVA/PEG blends that were observed at wavenumbers 1365, 1427, 1134, and 840  $\text{cm}^{-1}$  correspond respectively to C–O–C, C–O–H, C–C, –OH, and C–H. However, there was a slight shift observed for peak position and relative intensity of the stretching vibration of the hydroxyl group (–OH) for all blends, which is attributed to the H-bonding formation between PVA and PEG at different PEG contents [29 and 32].

From Figure (4-3), the absorption band of –OH groups observed got wider and with higher intensity in the spectra of the nanocomposites indicating occurrence of H-bond interactions between the –OH groups present in the blend and the oxygen groups of zinc oxide [33 –35] .



**Figure (4-3) FTIR Spectrum of blend (70%PVA+30%PEG) & Nanocomposite Materials (70%PVA+30%PEG+ +2% ZnO).**

**Table (4-2) The Transmission Bands of IR Spectrum Characteristic of blend (70%PVA+30%PEG) & Nanocomposite Materials (70%PVA+30%PEG+ +2% ZnO).**

Types of bond	Standard PVA[36]	Standard PEG [31]	Standard PVA/ PEG [29]	Exp. 70%PVA +30%PEG	70%PVA+30% PEG+ +2% ZnO
CH <sub>2</sub> stretching	2917	3863		2870	2823
OH stretching	3280	3450	3300	3425 3240	3464
CH <sub>2</sub> bending	1425	1456		1458	1458
C=O	1690	1658		1658	1658
C–O–C			1330	1365	1373
C <sub>6</sub> H <sub>6</sub>			1421	1427	1427
C–C			1100	1134	1149
C–H			851	840	840

# **Chapter 5**

## **Conclusions and Recommendations**

## 5-1 Conclusions

From the current study results are mentioned in previous chapters that interested for used hybrid composites for food packaging applications. It concluded the following:

1. There is a good compatibility between PVA and PEG which get a good blend between them. The best ratio is (70%PVA + 30% PEG).
2. From the antibacterial test, it was found that the polymeric blend has good antibacterial activity and nanoparticles can enhance antibacterial properties of the polymeric blend.
3. From the test of the wettability, it was found that the addition of PEG to PVA decreased the contact angle, but the contact angle increased with addition ZnO nanoparticles which transform the composite materials from a hydrophilic to a hydrophobic nature that prevent the interaction between the food and the packaging.
4. From the FTIR results, it can have concluded the are no create chemical bond between polymers but also it create hydrogen bonding between PVA and PEG and the result of FTIR of reinforcement blend with nanoparticles (ZnO) there is not chemical bond create between polymer blend and ZnO but only physical interaction. The shifting in bands indicated to good distribution of ZnO within matrix (PVA/PEG).

## **5-2 Recommendation**

From the present study, the following recommendation can be helpful for further studies:

1. Addition another nanomaterials and study their effect on wettability behavior and antibacterial properties. Such as Nano (Mgo) and  $\text{TiO}_2$ .
2. Test the nanocomposite by mechanical test such as tensile test and thermal analyses (DSC Test) and other test (SEM, AFM)

## REFERENCES

---

[1 ] O. Sabra, A. Husseina, M. Obaid," Preparation and evaluation water resistance, mechanical and morphological characteristics of PVA/SiO<sub>2</sub> nanocomposites for food industry applications ", Vol. 16, No. 2, April – June 2021, p. 733 – 745.

[2 ] Helmiyati Helmiyati , Zahra Shabira Zakiyah Hidayat, Ida Frisca Royani Sitanggang, and Dyah Liftyawati "Antimicrobial packaging of ZnO–Nps infused into CMC–PVA nanocomposite films effectively enhances the physicochemical properties ", Polymer Testing 104 [2021] 107412.

[3 ] B. J. Goodfellow and R. H. Wilson, “A Fourier transform IR study of the gelation of amylose and amylopectin,” Biopolymers, vol. 30, no. 13-14, pp. 1183–1189, 1990.

[4 ] Fahad H. Falqi, Osamah A. Bin-Dahman, M. Hussain , and Mamdouh A. Al-Harhi , " Preparation of Miscible PVA/PEG Blends and Effect of Graphene Concentration on Thermal, Crystallization, Morphological, and Mechanical Properties of PVA/PEG (10wt%] Blend ", Volume 2018, Article ID 8527693, 10 pages.

( 5) Shiv Shankar and Jong - Whan Rhim " Polymer Nanocomposites for Food Packaging Applications " , 2016 John Wiley & Sons, Ltd.

[6 ] N.B. Halima, Poly(vinyl alcohol): review of its promising applications and insights into biodegradation, RSC Adv. 6 (2016)39823–39832.

[7] Ashok M. Sajjan , Manu L. Naik , Akshay S. Kulkarni , Umme Fazal-E-HabibaRudgi , Ashwini M , Geeta G. Shirnalli , Sharanappa A , and Prakash B. Kalahal," Preparation and characterization of PVA-Ge/PEG-400 biodegradable plastic blend films for Packaging applications ", 2020.

---

[8] M. Abu Ghalia and Y. Dahman, “Radiation crosslinking polymerization of poly (vinyl alcohol] and poly (ethylene glycol] with controlled drug release,” *Journal of Polymer Research*, vol. 22, no. 11, p. 218, 2015.

[9] J. Jose, M. A. Al-Harhi, M. A.-A. AlMa'adeed, J. B. Dakua, and S. K. De, “Effect of graphene loading on thermomechanical properties of poly(vinyl alcohol]/starch blend,” *Journal of Applied Polymer Science*, vol. 132, no. 16, 2015.

[10 ] J. Jose and M. A. Al-Harhi, “Citric acid crosslinking of poly(- vinyl alcohol]/starch/graphene nanocomposites for superior properties,” *Iranian Polymer Journal*, vol. 26, no. 8, pp. 579– 587, 2017.

[11 ] A. Brody, Nano, nano: Food packaging technology, *Food Technol.*, 57, 52–54 (2003).

[12 ] A. Ammala, Nylon-MXD6 resins for food packaging, in *Multifunctional and Nanoreinforced Polymers for Food Packaging*, J. M. Lagarón (Ed), pp. 243–260, Woodhead Publishing Ltd. Cambridge, UK (2011).

[13 ] C. Sanchez, B. Julian, P. Belleville, and M. Popall, Applications of hybrid organic–inorganic nanocomposites, *J. Mater. Chem.*, 15, 3559–35912 (2005).

[14 ] S. Shankar, J. P. Reddy, J. W. Rhim, and H. Y. Kim, Preparation, characterization, and antimicrobial activity of chitin nanofibrils reinforced carrageenan nanocomposite films, *Carbohydr. Polym.*, 117, 468–475 (2015).

[15 ] J. P. Reddy and J. W. Rhim, Characterization of bionanocomposite films prepared with agar and paper-mulberry pulp nanocellulose, *Carbohydr. Polym.*, 110, 480–488 (2014).



- 
- [16 ] J. W. Rhim and L. W. Wang, Preparation and characterization of carrageenan-based nanocomposite films reinforced with clay mineral and silver nanoparticles, *Appl. Clay Sci.*, 97–98, 174–181 (2014).
- [17 ] P. Kanmani and J. W. Rhim, Physical, mechanical and antimicrobial properties of gelatin based active nanocomposite films containing AgNPs and nanoclay, *Food Hydrocoll.*, 35, 644–652 (2014).
- [18 ] C. Thellen, S. Schirmer, J. A. Ratto, B. Finnigan, and D. Schmidt, Co-extrusion of multilayer poly(m-xylene adipimide) nanocomposite films for high oxygen barrier packaging applications, *J. Membr. Sci.*, 340, 45–51 (2009).
- [19 ] T. Lan and Y. Liang, Commercial development of nanocomposite packaging, in *Packaging Nanotechnology*, A. K. Mohanty, M. Misra, and H. S. Nalwa (Eds), pp. 299–304, American Scientific Publishers, Stevenson Ranch, CA (2009).
- [20 ] A. Scully, Active packaging, in *The Wiley Encyclopedia of Packaging Technology*, 3rd ed, K. L. Yam (Ed), pp. 2–9, John Wiley & Sons, Inc., Hoboken, NJ (2009).
- [21 ] L. Vermeiren, F. Devlieghere, M. van Beest, N. de Kruijf, and J. Debevere, Developments in active packaging of foods, *Trends Food Sci. Technol.*, 10, 77–86 (1999).
- [22 ] M. Ozdemir and J. D. Floros, Active food packaging technology, *Crit. Rev. Food Sci. Nutr.*, 44, 185–193 (2004).
- [23 ] D. K. R. Robinson and M. J. Morrison, Nanotechnologies for food packaging: Reporting the science and technology research trends; Report for the ObservatoryNANO, August 2010. Available at: [www.observatorynano.eu](http://www.observatorynano.eu) (accessed on December 22, 2015).
- [ 24 ] O. Sabra, A. Husseina, M. Obaid," Preparation and evaluation water resistance, mechanical and morphological characteristics of PVA/SiO<sub>2</sub>

---

nanocomposites for food industry applications ", Vol. 16, No. 2, April – June 2021, p. 733 – 745.

[25 ] Raminder Kaur and Neelam Yadav," Biodegradable Polymeric Film for Food Packaging ",2021.

[26 [ O. Sabra, A. Husseina, M. Obaid," Preparation and evaluation water resistance, mechanical and morphological characteristics of PVA/SiO<sub>2</sub> nanocomposites for food industry applications ", Vol. 16, No. 2, April – June 2021, p. 733 – 745

[27 ] Helmiyati Helmiyati , Zahra Shabira Zakiyah Hidayat, Ida Frisca Royani Sitanggang, and Dyah Liftyawati "Antimicrobial packaging of ZnO–Nps infused into CMC–PVA nanocomposite films effectively enhances the physicochemical properties ", Polymer Testing 104 (2021] 107412

[28 ] B. J. Goodfellow and R. H. Wilson, “A fourier transform IR study of the gelation of amylose and amylopectin,” Biopolymers, vol. 30, no. 13-14, pp. 1183–1189, 1990.

[29 ] Fahad H. Falqi,Osamah A. Bin-Dahman, M. Hussain , and Mamdouh A. Al-Harhi , " Preparation of Miscible PVA/PEG Blends and Effect of Graphene Concentration on Thermal, Crystallization, Morphological, and Mechanical Properties of PVA/PEG (10wt%] Blend ", Volume 2018, Article ID 8527693, 10 pages

[30 ] N.B. Halima, Poly(vinyl alcohol]: review of its promising applications and insights into biodegradation, RSC Adv. 6 (2016]39823–39832.

[31 ] Ashok M. Sajjan , Manu L. Naik , Akshay S. Kulkarni , Umme Fazal-E-HabibaRudgi , Ashwini M , Geeta G. Shirnalli , Sharanappa A , and Prakash B. Kalahal," Preparation and characterization of PVA-Ge/PEG-400 biodegradable plastic blend films for Packaging applications ", 2020.

---

[32 ] M. Abu Ghalia and Y. Dahman, “Radiation crosslinking polymerization of poly (vinyl alcohol] and poly (ethylene glycol] with controlled drug release,” *Journal of Polymer Research*, vol. 22, no. 11, p. 218, 2015.

[33 ] J. Jose, M. A. Al-Harhi, M. A.-A. AlMa'adeed, J. B. Dakua, and S. K. De, “Effect of graphene loading on thermomechanical properties of poly(vinyl alcohol]/starch blend,” *Journal of Applied Polymer Science*, vol. 132, no. 16, 2015

[34 ] J. Jose and M. A. Al-Harhi, “Citric acid crosslinking of poly(- vinyl alcohol]/starch/graphene nanocomposites for superior properties,” *Iranian Polymer Journal*, vol. 26, no. 8, pp. 579– 587, 2017

[35 ] X. Yuan, “Enhanced interfacial interaction for effective reinforcement of poly(vinyl alcohol] nanocomposites at low loading of graphene,” *Polymer Bulletin*, vol. 67, no. 9, pp. 1785– 1797, 2011.

[36 ] Alireza Kharami, Nastaran Faraji, Roslina Mat Hussin, *Beilstein Journal of Nanotechnology* 6, 2015.