Egypt. J. of Appl. Sci., 40 (5-6) 2025 *1-15*

SYNTHESIS AND CHARACTERIZATION OF NANOLAMINATES OF HONEY WAX AND ITS USE IN EXTENDING SHELF LIFE OF SOME FRUITS AND VEGETABLES.

Labeeb. A. Al-Zubaidi* ; Suha Mohamed Ibrahim and Taghreed Sabeeh Abdullah

Research & Technology Center of Environment, Water & Renewable Energy/ Scientific Research commission. Baghdad. Iraq.

***E-mail: labeeb.a.alzubaidi@src.edu.iq.**

ABSTRACT

Nanomaterial's play an important role in food preservation due to their ability to improve their physical properties as well as packaging materials. This study included preparation of nanolaminate of honey wax. The different method were characterized nanomaterial. The Fourier transform infrared spectroscopy (FTIR) and water dispensability of particles of the Nano-wax showed the stretching vibration of different group of compounds between wax sample and prepared nano wax, In the other hand, the hydrophobic and hydrophilic groups were transported. From the spectroscopic analysis results, it was revealed that appeared clarity to formation the nanoparticles from beeswax. The Field emission Scanning Electron Microscopy (Fe-SEM) images showed that particles were spherical in shape, this corresponding with Atomic Force Microscope - AFM analysis that showed particles were spherical in shape, single or in aggregates. The energy of the reaction is determined by the atomic number of the element in which it occurs, according to the Energy Dispersive X-ray -EDX test results. It simply refers to the sample's initial composition (Cl, Na, C, O) at varying percentages in the Nano wax sample. When compared to the wax sample and control (untreated bacteria) and fungi (*A. niger*), the inhibitory activities of produced bee wax nanoparticles against two positive and negative gram bacteria (*Pseudomonas aeruginosa* and *Staphylococcus aurous*) showed high activity (*in vitro*). The results showed that honey wax nanolaminate decreased *A. niger* growth when compared to other treatments. As a result, honey wax nanolaminate is an excellent bioresource/ biomaterial for the production of antimicrobial nanoparticles. Since there has been no mention of nanotechnology having any negative consequences to yet and that it can be used efficiently in the food business, which emphasized the concept in a broader sense, as well as the desire for nanotechnology in the packaging industry to increase product shelf life, as well as the safety and quality data of food products.

Key Words: Synthesis, Nanolaminates, Honey wax , Shelf life , Food.

INTRODUCTION

Food safety is the main goal of food laws and quality control. Food products are mainly maintained by the physical and sensory features, the microbial safety of the food, and the nutritional value of the food. Smart packaging is a kind of packaging that expands the communication function of traditional food packaging, and nowadays food packaging has revolutionized in many ways. Nanotechnology or nano packaging is one of the innovative and new technologies that have been introduced in food packaging for safety purposes. Nano food is food that is created using nanotechnologies during farming, manufacturing, and packaging. Nanotechnology can be one of the innovative and useful technologies in the food sector **(Wesley *et al.*, 2014).** Nanotechnology is the technology or tool used to advance the food industry. The main factors of spoilage of fresh fruits and vegetables **(Fuertes *et al.*, 2016; Risch, 2009)** are as follows:

- Microbial load- the growth and activities of microorganisms, especially bacteria, yeasts and moulds.
- Activities of enzymes found in fruits and vegetables (polyphenol oxidase, peroxidase, lipoxygenase).
- Temperatures, whether hot or cold.
- Time.
- Insects and rodents.

The common fungi that can be destroy for rotting vegetables and fruits are fungi such as Alternaria, Rhizopus, Penicillium and Fusarium etc. It is very important to properly pack fresh or semi-finished fruits and vegetables. Environmental factors responsible for fruit and vegetable deterioration are light, oxygen, water activity, and temperature.

Food safety is the main perspective of food manufacturers, which can be achieved through nanotechnology, where nanotechnology is useful in increased security during manufacturing, processing and packaging. It provides sensors that are useful in detecting problems and providing early warnings. Nano packaging is used to influence the shelf life, texture and flavour of products, and various indicators can be used to detect leaks, food pathogens, temperature expansion, etc. Nano encapsulation is the technology used to enhance the nutritional content by incorporating vitamins, minerals, etc. **(Raghav *et al.*, 2016)**. Emulsifying wax application areas are very wide research gap. It has large capacity and wide range, and its main application areas are aspects such as textile, papermaking, leather, fiberboard, glass, gypsum, fruit freshness preservation, construction, horticulture and pottery. Therefore, the aim of the research was to convert beeswax into a nano-emulsion for the purpose of packing some vegetables and fruits in order to increase their preservation and improve texture.

MATERIAL AND METHODS

Three fruit and vegetable samples, as well as leafy vegetables, were collected from local markets in Baghdad, Iraq. To maintain the homogeneity of the experimental materials, only homogeneous fruits (in terms of general appearance, size, and stage of ripeness) were selected, free from pests, diseases, injuries, bruises, and spots. Beeswax was obtained from the beekeeping laboratories at the Scientific Research Commission. Other chemicals used in the analysis were obtained from the laboratories of the Research & Technology Center of Environment, Water & Renewable Energy /Food contamination Research.

Beeswax emulsion was prepared according to the method of **Efendi and Hermawati (2014)** with some modifications. 100 g of beeswax were weighed into a 2-liter conical flask. 300 ml of methanol acidified with HCl were added and melted at 70°C, then heated continuously until the temperature reached 80–90°C. Oleic acid (12.8 ml) was added to the melted wax, followed by 25.6 ml of Triethanolamine (TEA) with continuous stirring. 600 ml of distilled water (preheated to the same temperature of 80–90°C) was added and placed in a reflux flask, where the temperature was kept at 60–80°C for 1 h. After cooling, the flask was stored at room temperature for 48 h before use in a tightly sealed container. They were sieved using a 150-micron laboratory sieve and then filtered using Whatman No. 1 filter paper into a conical flask.

The encapsulated beeswax particles (BWEx/Cs) were prepared according to **Khan *et al*. (2019)** with some modifications using an oil/water emulsion technique. Chitosan- bee wax extract (Cs- BWEx) adduct was prepared according to **Khan *et al*. (2019)** where chitosan and BWEx were mixed in equimolar ratios and condensation reaction takes place using Dean–Stark (reflux) apparatus in presence of xylene until the theoretical amount of water was separated. Chitosan amide product was separated by filtration, washing several times with methanol, hot distilled water, ethanol and then dried in an electric oven at 50 °C and weighed. BWEx/ Cs NPs were obtained through ionic gelation pathway by using TPP with Cs- plant extract adduct as follows:

- Cs- BWEx 25 mg/ ml was dissolved in acetic acid solution (1% w/v) until the solution was clear then, TPP solution was added to Cs- bee wax extract solution at a ratio; 1: 2.5 (w/ w) with continuous stirring at ambient temperature for 6h. The production of Cs- bee wax extract /TPP nanoparticles started via the TPP initiated ionic gelation mechanism. These nanoparticles were separated, washed several times then supernatant layer was removed and the precipitate re-suspended in water and dried.

-Characterization methods.

- **Fourier transform infrared spectroscopy (FTIR)**

The interactions between the wax and the polymers were investigated using a Fourier transform spectrometer (FTIR) (Perkin Elmer spectrophotometer- Model 2000)) in the wavelength region from 4000 to 400 cm−1. FTIR was performed using to analyses the presence of functional groups in synthesized copolymers. Copolymer samples were mixed with KBr and made into pellets for FTIR analysis.

- **Ultra Violet visible spectrometer- UV-Vis.**

UV-Vis spectra were taken on an HP 8453 diode array spectrometer. The measurements were carried out by diluting 50 µL of a 0.01 M solution of the dissolved beeswax in 2 ml of dichloromethane. The absorbance of the UV visible spectrum was measured using a spectrophotometer and a wax coated solution was used. The absorbance was measured at a wavelength of 200-800 nm (**Sionkowska, 2006**). 3 readings were measured for each sample.

Atomic Flame Microscopy

- **Field emission -Scanning Electron Microscopy**

The morphology of the particles was analyzed using a Field emission scanning electron microscopy (Fe-SEM).

- **Energy dispersive spectroscopy-EDX.**

EDX microanalysis was involved in different biomedical fields of study due to its high sensitivity in detecting the different elements in tissues. In fact, EDX technique is made particularly useful in the study of drugs delivery in which the EDX is an important tool in order to detect nanoparticles (generally, used to improve the therapeutic performance of some chemotherapeutic agents (Energy dispersive spectroscopy- EDS), one of the possible methods for detecting elements in tissues and more commonly known as electron probe X-ray microscopy (EDX). Electrons of the beam (8) Next, the effect occurs with atoms, two basic physical events: elastic scattering and inelastic scattering. Elastic scattering is a change in the direction of an electron with no noticeable loss of energy, which generally results from interactions with the nucleus involving materials, while inelastic scattering is a loss of energy with no noticeable change in direction, and is usually generated from interaction with each of bound electrons and nuclei in atoms **(Morgan, 1985)**. Elastic scattering events are the main determinants of the reaction volume shape while inelastic scattering is the main determinant of reaction volume size. However, the atoms ionize and when they return to their ground state, they will emit characteristic X-rays and the energy of the X-ray photon is the potential energy caused by the difference between the orbits involved

in the transition, and the X-ray emission of different wavelengths can then be measured by a photon energy sensitive detector.

- **Water dispensability of particles**

To observe water dispensability of fabricated particles, 2 mg of fabricated particles were dispersed in 2 ml of water in a 5- mL sample vial and monitored visually by keeping the dispersion undisturbed.

- **Fruit and vegetable packaging.**

To wrap the fruits and vegetables samples using the dipping method to prepare the treatments, as the fruits and vegetables were washed with distilled water and left to dry within 20 minutes at a temperature of 25 °C, then immersed again in distilled water for 15 minutes and left to dry within 20 minutes, and washed with distilled water at pH = 7. Then it was immersed again in the same previous conditions to prepare the packaged treatment.

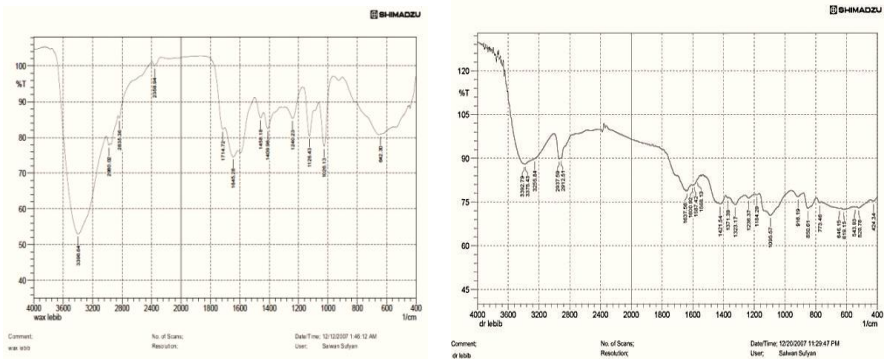
RESULTS AND DISCUSSION

Wax is dispersed by heterogeneous dispersion system with completely settling formed into another type of immiscible liquid with particle form to wax emulsion. Wax is a kind of fatty substance with very strong cohesion, and it is insoluble in water. Then, the wax emulsifier reduces the two-phase surface tensile strength by adding an emulsifying agent, and the wax is evenly dispersed in the water, through the directed adsorption effect of the emulsifying agent, forming an emulsifying sap that is formed under the action of the external force.

Emulsifying wax needs a certain heat to make the wax molten, reduce the cohesion strength, and is suitable for rapid and appropriate dispersion under the influence of stirring. So, the heating temperature is too high to influence the emulsification efficacy. The heating temperature should be 15°C above that of the solution for maximum melting points, to ensure that the wax all melts, even with the emulsion mixture. The oil phase temperature is usually controlled and is 10-15°C higher than the melting point, and the water temperature should be 2-5 °C higher than the oil temperature. Also, during emulsification it need to stir, at a very low speed, the wax and tensile agent are mixed simultaneously. The sheer force of the emulsifier, the emulsifier particles are not homogeneous, stir too quickly, easily to prepare the mixture a large amount of air and form bubbles, the difficulty of breaking the foam affects the quality of the emulsifier.

Fourier transform infrared spectroscopy (FTIR)

Infrared spectroscopy was used to study the interactions between the wax and the polymers. Figure 1 shows IR spectra at a wave number range of 4000 - 400 cm-1. In Figure 2a, the IR spectra of the nano wax shows the stretching vibration of the alkanes and alkyl halides and carboxylic acids groups at 520.78- 850.61 and 916.19 cm-1 After the wavelengths 1026.13, 1126.43 and 1240.23 cm-1 aliphatic amines which moved to the wavelength 1095.57- 1236.37 cm-1 (sugar ring) .The emergence of new compounds, which were alcohols , carboxylic acid and amino acid analyses of sample from various parts of the hives showed larger amounts of amino acids. The peak corresponding to the aromatic groups have been identified at 1409.96 cm-1 and 1458.18 cm-1. Where change in the other position peaks was observed at 1421.54 cm-1, when wax was incorporated in the nanoparticles (Figure.1). The peak corresponding to the diketones group, insoluble fraction of beeswax sample it have been identified presence of chitin (amide I and amide II) at 1568.13–1637.56 cm-1 while it was identified in the wax at 1645.28 cm-1, The C= O stretch carbonyl groups and the H-C = O: C – H stretch groups that appeared in the beeswax sample and their disappearance in the nano wax sample and the appearance of a new peak at 3255.84. It referred to O- H stretch groups (carboxylic acids), The appearance of the a peaks at 2980.02 and 3396.64 that refers to a groups C – H stretch (alkanes) and N–H stretch (1–2 amines, amides) respectively at the wax sample. While changed to the location of the peak in the nano wax sample and its appearance at a new peak at 2912.51- 2937.59 and 3375.43-3392.79 respectively. It can be concluded that bee wax sample observed many changing in the spectra of the nanoparticle (Figure. 1).

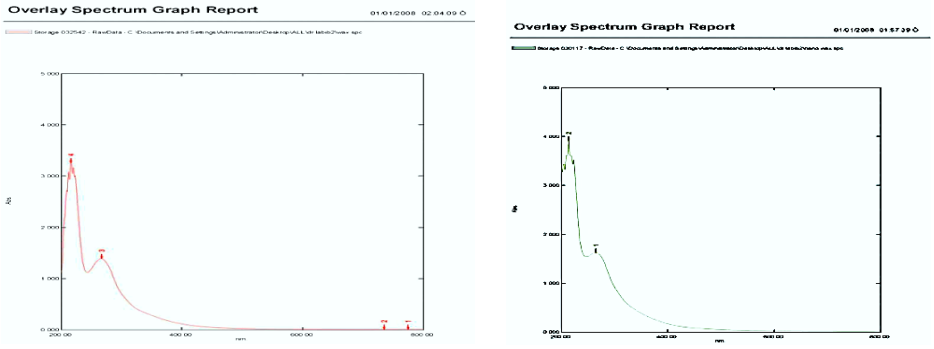


(A) (B)

Figure 1. FTIR diagram of beeswax sample (A). Nano beeswax sample (B).

UV-Vis spectrophotometer

From the spectroscopic examination results, it is clear that the nanoparticles were formed from its main source, which is beeswax, as the wavelength at 214 and 265 nanometers and the absorbance at the nanoparticles were consistent with what was found in the control sample (beeswax). These results are also consistent with the results of an FTIR analysis, which means obtaining nanoparticles from beeswax (Table.1, Figure.2).



(A) (B)

Figure 2: UV-Vis spectrophotometer diagram of (A) Wax control and (B) Nano beeswax

Table 1: UV-Vis spectrophotometer results of beeswax and beeswax nanoparticles samples

Control		Nano wax	
Wavelength	**Abs.**	**Wavelength**	**Abs.**
775.00	**0.007**	**265.00**	**1.625**
753.00	**0.006**	**214.00**	**3.913**
267.00	**1.387**		
216.00	**3.263**		

Field emission- Scanning Electron Microscope (SEM) examination

The results of scanning electron micrographs (Fe- SEM) examination of wax nanoparticles containing sodium alginate and wax show that wax nanoparticles were spherical and not aggregated. The average diameters of the spheres are about 44-71nm nanoparticle dry powder consists of individual nanoparticles that touch each other but retain their original size and shape Figure (3).

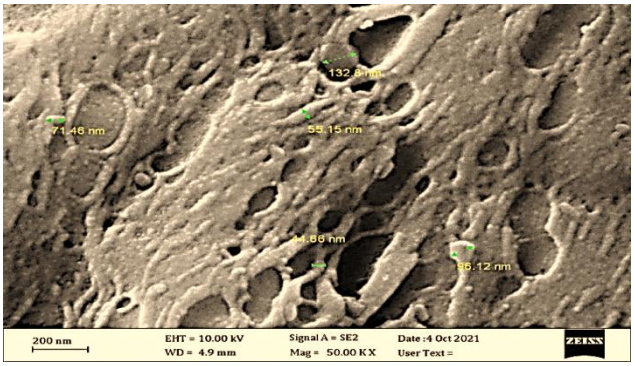


Figure 3: Field emission- scanning electron microscopy (SEM) showing wax nanoparticle cells (1000x). For wax nanoparticles containing sodium alginate, wax nanoparticles were shown to be spherical and not aggregated. The average diameters of the spheres are about 44 - 71 nm. Nanoparticle dry powder consists of individual nanoparticles that touch each other but retain their original size and shape.

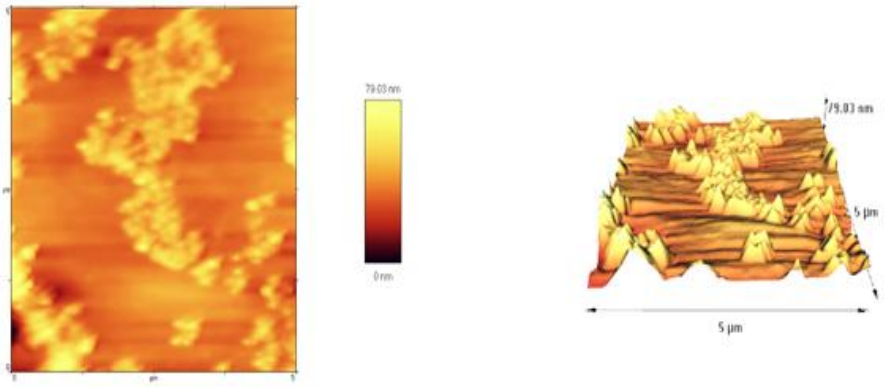
Atomic Force Microscopy - AFM:

AFM utilizes a cantilever with a sharp probe to scan a specimen surface. The cantilever beam is attached at one end to a piezoelectric displacement actuator controlled by the AFM. At the other end of the cantilever is the probe tip that interacts with the surface. At close proximity to the surface, the probe experiences a force (attractive or repulsive) due to surface interactions, which imposes a bending moment on the cantilever. In response to this moment, the cantilever deflects, and this deflection was measured using a laser beam that was reflected from a mirrored surface on the back side of the cantilever onto a split photodiode. A schematic diagram of the system is shown in Figure 4 . The cantilever deflection was measured by the differential output (difference in responses of the upper and lower sections) of the split photodiode. The deflections were very small relative to the cantilever thickness and length. Thus, the probe displacement was linearly related to the deflection. The cantilever was typically silicon or silicon nitride with a tip radius of curvature on the order of nanometers.

Based on the nature of the probe-surface interaction (attractive or repulsive), an AFM can be selected to operate in various modes, namely contact mode, intermittent contact mode, or non-contact mode. In contact mode, the interaction between the tip and surface is repulsive, and the tip literally contacts the surface. At the opposite extreme, the tip interacts with the surface via long-range surface force interactions. This is called

non-contact mode. In intermittent contact mode, the cantilever is oscillated close to its resonance frequency perpendicular to the specimen surface, at separations closer to the sample than in non-contact mode. As the oscillating probe is brought into proximity with the surface, the probe-surface interactions vary from long range attraction to weak repulsion and, as a consequence, the amplitude (and phase) of the cantilever oscillation varies. During a typical imposed 100 nm amplitude oscillation, for a short duration of time, the tip extends into the repulsive region close to the surface, intermittently touching the surface and thereby reducing the amplitude. Intermittent contact mode has the advantage of being able to image soft surfaces or particles weakly adhered to a surface and is hence preferred for nanoparticle size measurements. Figure 4 (a) and (B) refer that the mean size of nano beeswax emulsion was reached 79.03 nm.

In order to confirm particle size and gain insight into their shape, a drop of wax suspension was dried on a freshly cracked mica plate and imaged with AFM. The highest and phase images are shown in the Figure 4 , indicated a spherical geometry of the wax particles. Moreover, the AFM images confirm the multi-dispersion of the suspension characterized by light scattering. The largest elementary particles seen in the image were about 79.03 nm. However, quantitative size analysis of AFM images was challenging due to the formation of agglomerates during drying. These drying agents made it difficult to assess the dispersal state by microscopic techniques **(Michen, *et al.*, 2015)**. Furthermore, the particle size can be controlled by the concentration of the wax during the preparation of the suspension.



(A) (B)

Figure 4: AFM analysis (A) nanowax particles in 2 dimension (B) nanowax particles in 3 dimension. show mean of nano wax particles at 79.03 nm.

The Energy Dispersive X-ray (EDX) microanalysis

It is an efficient technique that allows elements to be analyzed on the surface of samples. This method has some limitations in elemental analysis. First, X-ray spectroscopy detects elements and cannot distinguish between ionic and nonionic types. Moreover, in EDX, all samples need to be analyzed under relatively vacuum and this obviously has serious implications for sample preparation because electron and X-rays are strongly absorbed by air molecules.

In general, X-ray detection is not affected by the chemical state of the elements but is affected by the interference between the elements, known in X-ray spectrometry as peak interference, which causes serious problems in the analysis of the elements. Therefore, it is possible to detect those elements with an atomic number greater than 10. The minimum detectable initial concentration, which requires some average signaling, is about 0.1 mmol per kilogram of dry sample (i.e. 10 ppm), while the accuracy of the spatial range is from about 10 nm to a few μm **(Scimeca *et al.*, 2014; Pivovarova and Andrews, 2013)**. Reducing the detection limit requires more counts, which can be obtained by increasing the counting time and/or beam current. The values given here for the limits of detection refer to biological samples whose mean atomic number (which determines the continuity density) is generally low (eg. C, H, N, K). Biological samples containing heavy elements give higher detection limits due to the higher background. Furthermore, the detection limits for heavy elements (using L or M lines) tend to be somewhat higher because the peak-to-background ratio is lower than the K lines **(Morgan, 1985)**. Edx was characteristic of the element they originated from and contain information about the elements in the sample (Figure 5). In fact, the energy depends on the atomic number of the element in which the reaction takes place. It relates only to the initial composition of the sample.

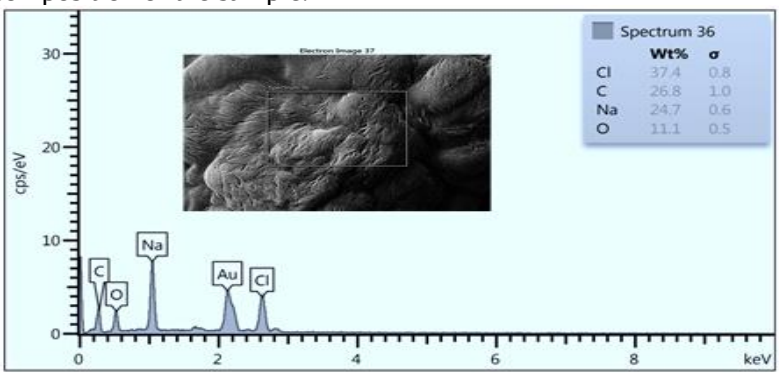


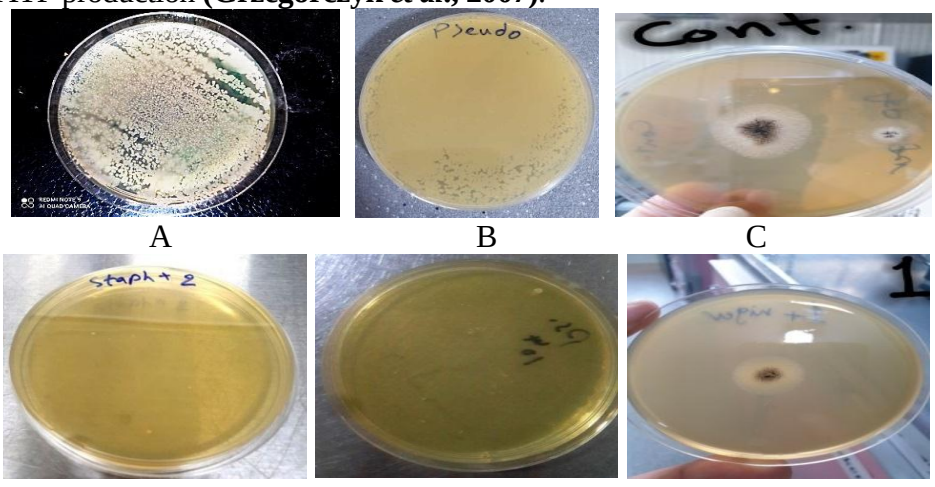
Figure 5: EDX examination diagram showing properties X-rays are generated by the transfers of electrons from the higher to lower shells by sample atoms interacting with the electron beam. The content of wax nanoparticles was detected by microanalysis showing the spectrum of EDX made of wax.

Water dispensability of particles

A dispersion of 1 g/l wax particles was produced from pure wax and water without additional emulsifiers or stabilizers. The initial pH of the dispersion was in the neutral range (pH = 6.8-6.9). This net negative surface charge of the wax particles presented a double-layer electrostatic repulsion and stabilized the dispersion. The origin of these electrostatic charges can be understood by the presence of hydrophilic and functional groups, such as -OH, -COOH, -CHO **(Wagner, *et al.*, 2003)**. In natural wax, when a water-soluble wax is dispersed , these hydrophilic groups can rearrange towards the polar water phase, making the interface of the particles more water-resistant than their core. This hypothesis correlates well with the findings of **Bayer et al.,2011** who found that heat treatment of the carnauba wax film rearranged its hydrophilic clusters towards a hydrophilic glass layer.

- **Activity of nano wax Against different microorganisms.**

The results in Table 2 and Figure 6 confirmed that bees wax nanoparticles displayed anti-bacterial and antifungal activity against *S. aureus* and *Ps. aeruginosa* and *A. niger* were completely inhibited growth and inhibition percentage was 100% compared with the wax sample were reached 97% , 94% and 60 % respectively. The mechanism of bees wax nanoparticles were disturbed transport systems, including ion efflux and interrupt cellular processes such as metabolism and respiration of target organisms. Further, it is speculated that nanoparticles penetrate the cell wall, affect the DNA and its ability to inactivate the expression of ribosomal subunit proteins as well as certain cellular proteins and enzymes essential for ATP production **(Grzegorczyk *et al.*, 2007)**.



A B C

D E F

Figure 6: Inhibitor activity of nano wax and wax samples against microorganisms. A,B and C (control), wax activity in D, E and F.

Table 2: inhibition activity of nano wax and wax samples against microorganisms.

Sample / Microorganisms	*S. aureus*	*Ps. aeruginosa*	*Asp. niger*
	No of isolated bacteria		Growth dimension mm
Bee wax nanoparticles	Nill	Nill	Nill
wax	4	16	18
control	TNTC	TNTC	30mm

Fruits and vegetables packaging.

It is clearly evident in the form of the difference in colour and texture of fruits and vegetables, leafy vegetable samples treated with emulsion of beeswax nanoparticles grew after a 10 day storage period, and the control samples (untreated) grew after a 2 day storage period at the refrigerator temperature. While the fruit samples treated with beeswax nano emulsion. They kept their strength and freshness for more than 21 days at refrigerator temperature, which gives beyond doubt the efficiency of the beeswax nano-emulsion in preserving vegetables and fruits products despite the sensitivity of leafy vegetables and the high susceptibility to water loss from their tissues and thus lead to wilting and damage fig. (7-A,B).

(A) (B)

Figure 7: Untreated and treat samples of fruits and vegetables (A) and leafy vegetables (B) with Nano beeswax emulsion.

In dealing with fruits and vegetables after harvest, the need arises for the combined use of post-harvest preservation techniques that allow them to be stored for a longer period. Covering fruits with biofilms, such as bees nanowax, has proven to be an effective strategy in terms of preservation (better physical, chemical and sensory quality, less mass loss, reduced physical damage and increased durability) **(Oliveira, *et al.*, 2018; Eshetu *et al.*, 2019 and Baswal *et al.*, 2020).** Considering market potential, consumption and preservation of useful life fruits and vegetables ,the aim of this work was to evaluate the efficiency of coating

with nano-beeswax on physical and chemical quality and control of fruit softening over 21 days of cold storage (13 °C).

CONCLUSION

Possibility of synthesis of nanolaminate from beeswax with a high stability and high storage period. In addition, increasing the efficiency against microorganisms and prolonging the shelf life of fruits and vegetables for preservation (*In vitro*).

REFERENCES.

Baswal, A.K. ; H.S. Dhaliwal and Z. Singh (2020): Coatings on cold storage life and quality of Kinnow mandarin fruit. Scientia Hortic., 260: 1–10.

Efendi, D. and Hermawati, H. (2014). The use of bee wax, chitosan and BAP to prolong shelf life of mangosteen (*Garcinia mangostana* L.) Fruit. J. Hortikultura Indonesia 1(1):32.

Eshetu, A.; A.M. Ibrahim and S.F. Forsido (2019). Effect of treatments with beeswax and chitosan on the quality and shelf life of selected mango cultivars (*Mangifera indica* L.). Heliyon., 5 (1):11–16.

Fuertes, G. ; I. Soto ; R.C. Armijo ; M. Vargas ; J. Sabattin and C. Lagos (2016). Intelligent packaging systems: Sensors and nanosensors to monitor food quality and safety. J. Sensors, 2:1-8**.**

Grzegorczyk, I. ; A. Matkowski and H. Wysokińska (2007). Anti-oxidant activity of extracts from in vitro cultures of *Salvia officinalis* L. Food Chem. 104: 536–41.

Bayer, I.S. ; D. Fragouli ; P.J. Martorana ; L. Martiradonna ; R. Cingolani and A. Athanassiou (2011). Solvent resistant superhydrophobic films from self-emulsifying carnauba wax-alcohol emulsions, Soft Matter., 7: 7939-7943.

Khan, A. ; P. Saikia ; R. Saxena ; D. Rakshit and S. Saha (2019). Microencapsulation of phase change material in water dispersible polymeric particles for the more regulating rubber composites—A holistic approach. Int. J. Energy. Res., Pp:1–13.

Michen, B.; C. Geers ; D. Vanhecke ; C. Endes ; B. Rothen-Rutishauser ; S. Balog and A. Petri- Fink (2015). Avoiding drying-artifacts in transmission electron microscopy: Characterizing the size and colloidal state of nanoparticles, Sci. Rep. 5.

Morgan, AJ. (1985). X-ray microanalysis in electron microscopy for biologists. Interferons: Their impact in biology and medicine, J. Taylor-Papadimitriou. Oxford University Press., New York and Toronto. Doi:10.1038/srep09793.

Oliveira, M.A.J. ; J.M.A. Souza and M.S. Silva (2018). Calcium chloride postharvest application on Roxo de Valinhos fig fruits. Revista de Ciências Agrárias., 41(4): 241–250 .

Wagner, P. ; R. Fürstner ; W.C. Barthlott and Q. Neinhuis (2003). Quantitative assessment to the structural basis of water repellency in natural and technical surfaces, J. Experimental Botany., 54: 1295-1303.

Pivovarova, N.B. and S.B. Andrews (2013). Measurement of total calcium in neurons by electron probe X-ray microanalysis. J. Vis Exp; e50807.

Raghav, P.K. ; N. Agarwal ; M. Saini ; J. Vidhyapeeth and J. Vidhyapeeth, (2016). Edible Coating of Fruits and Vegetables : I Nternational J. Sci. and Modern Edu., I(I): 188–204.

Risch, S.J. (2009). Food packaging history and innovations. J.Agric. and Food Chem., 57 (18): 8089– 8092.

Scimeca, M. ; A. Orlandi ; I. Terrenato ; S. Bischetti and E. Bonanno (2014): Assessment of metal contaminants in non-small cell lung cancer by EDX microanalysis. Eur. J. Histochem., 58:2403.

Sionkowska, A. (2006) Effects of solar radiation on collagen and chitosan films. J. Photochem. and Photobiol. B, Biol., 82 (1): 9-15.

Wesley, S.J. ; P. Raja ; A.A. Raj and D. Tiroutchelvamae (2014): Review on - nanotechnology applications in food packaging and safety. Int. J. Eng. Res., 3(11): 645–651.

بناء وتوصيف الصفائح النانوية لشمع العسل واستخدامها في إطالة مدة صلاحية بعض الفواكه والخضروات.

لبيب احمد الزبيدي ، سهى محمد ابراهيم ، تغريد صبيح عبد الله

هيئة البحث العلمي، مركز بحوث وتكنولوجيا البيئة والمياه والطاقات المتجددة، بغداد، العراق.

تلعب المواد النانوية دورًا مهمًا في حفظ الأغذية نظرًا لقدرتها على تحسين خصائصها الفيزيائية بالإضافة إلى مواد التعبئة والتغليف. تضمنت هذه الدراسة تحضير صفائح نانوية من شمع العسل، وشخصت المواد النانوية المحضرة بطرائق تشخيصية مختلفة. يُظهر مطياف الأشعة تحت الحمراء لتحويل فورييه (FTIR) الى قابلية جزيئات الشمع النانوي على منع تبخر الماء من خلال اهتزاز الامتدادات بوجود اختلافات في مجاميع عدد من المركبات بين عينة الشمع والشمع النانوي المُحضر، ومن ناحية أخرى، حصول انحرافات في المجاميع الكارهة للماء ومجاميع المحبة للماء. ومن نتائج التحليل الطيفي، تبين أن الوضوح الظاهر في تكوين الدقائق النانوية من شمع العسل. أظهرت صور المجهر الإلكتروني الماسح – الانبعاث الحقلي (Fe–SEM) أن الدقائق كروية الشكل، وهذا يتوافق مع تحليل مجهر القوة الذرية (AFM) الذي أظهر أن الدقائق كروية الشكل، مفردة أو في مجموعات. يتم تحديد طاقة التفاعل من خلال العدد الذري للعنصر الذي يحدث فيه، وفقًا لنتائج اختبار الأشعة السينية المشتتة للطاقة – EDX. يشير ببساطة إلى التركيب الأولي للعينة (Cl، Na، C، O) بنسب متفاوتة في عينة الشمع النانوي. وبالمقارنة مع عينة الشمع وعينة السيطرة (البكتيريا غير المعالجة) والفطريات (*A.*

niger)، أظهرت الأنشطة المثبطة لدقائق شمع النحل النانوية المنتجة ضد نوعين من بكتيريا الموجبة والسالبة لصبغه جرام (*Pseudomonas aeruginosa* و *Staphylococcus aurous*) نشاطًا عاليًا (مختبريا)، وأظهرت النتائج أن الصفائح النانوية لشمع العسل ثبطت نمو *A. niger* عند مقارنتها بالمعاملات الأخرى. ونتيجة لذلك، فإن الصفائح النانوية لشمع العسل هي مورد حيوي/ مادة حيوية ممتازة لإنتاج دقائق نانوية مضادة للميكروبات. ونظرًا لأنه لم يتم ذكر أي عواقب سلبية لتكنولوجيا النانو حتى الآن وأنه يمكن استخدامها بكفاءة في صناعة الأغذية، مما أكد على المفهوم بمعنى أوسع، بالإضافة إلى الرغبة في استخدام تكنولوجيا النانو في صناعة التعبئة والتغليف لزيادة العمر الافتراضي للمنتج، بالإضافة إلى بيانات السلامة والجودة للمنتجات الغذائية.