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Optical Properties of Poly Vinyl Alcohol (PVA)/Molasses as Biodegradable Films for Agriculture Applications

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ABSTRACT

Biodegradable polymeric films were prepared for agricultural applications. These films based on PVA/ molasses blend mixed with different concentrations (0, 10, 20, 30 and 40 wt. %). These films were characterized by FTIR spectrometer, while UV-Visible technique used to study the molasses effects on the absorption, transmission and reflection properties. Films roughness and their morphologies were studied by AFM technique, while hardness test utilized as a function of the mechanical performance. Thermal IR camera was used to monitor the thermal effects due exposing the prepared film to sun light for 1 minute. Results showed that there is no chemical interaction between film components. The hardness increased generally, and the film contains 20% molasses shows the higher hardness. The absorption of PVA/molasses films increased with increasing molasses content in UV regain by 260%, in visible region by 1788% and in the infrared (IR) region by 647%. The transmittance decreased linearly with the molasses content by the following order: IR > Visible > UV, while reflectance increased from 64.2% to 96.09% in UV region, from 19.76% to 90.8% in visible region and from 15.8% to 72.17% in IR region. As molasses content increased, the film morphology converted from continuous/discontinuous phase to the co-continuous phase domains and the surface roughness increased generally. IR camera results showed significant effects after sun light exposing; there are clear fluctuations in temperature distribution, and the film contains 10% molasses exhibited maximum temperatures.

Keywords: Pigment, PMMA, Reflectance, IR spectrum, carotene shield.

1. INTRODUCTION

Nowadays, greenhouses are considered as important factor in permanence and stability of the vegetable production in all regions of the world [1]. But, the main challenge of using greenhouses is to maintain a constant climate for the vegetables throughout the season. This task needs high cost [2], for example, warming vegetables in the cold weather by burning suitable fossil fuel, may account about 40% of the total investment cost [3]. This high cost can be reduced, for instance, by using renewable energy instead of fuels. Also, there is a challenge in the renewable energy approach because of the difficulty of supplying the required energy to the greenhouses. Currently, thermal curtains represent the practical solution to the energy cost problem. These curtains can reduce the heat transfer between outdoor and indoor regions due to their high thermal resistance [4].

In Arabian Peninsula, with hot climate and saline water resources, the suitable method to cool the greenhouse during summer is by preventing heat from entering the greenhouse [5]. Heat prevention can be done by eliminating radiation by reflection or absorption techniques [6]. This

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can be carried out by using shadings methods, such as using refractive screens, plastic nets, clothes and whitening the exterior surface by an aqueous solution of hydrated calcium oxide [Ca (OH)2] [7]. In addition to their use in reducing buildings heating and cooling loads [8], plastic nets also used widely in the agricultural field, such as for protection from hail, wind, snow, or strong rainfall [9], virus-vector, insects and birds [10]. Usually, greenhouse transmittance about half of the solar radiation and the crop growth rate proportional to transmittance portion of the light. In the summer period, there is a real need to protect crop from the high levels of light intensity to avoid the leaf from sun burning, therefore, screen shading techniques are necessary. For photosynthesis process, not all lights are useful. Crop utilized from the visible light only (400-700 nm), while UV light is harmful and IR light have no significant influence on the photosynthesis process [11].

Poly (vinyl alcohol) or PVA is a polar polymer containing hydroxyl group, which allows for hydrogen bonding (Fig. 1). PVA have desired properties, like film-forming, optical properties, biodegradability and high chemical resistance, which makes it a high candidate and a suitable sustainable polymer as biodegradable films for agriculture applications [12, 13, 14]. On the other hand, PVA have poor mechanical properties, therefore, many methods used to enhance these properties, such as cross-linking, oxidation, grafting and surface modification [15]. Few attempts have been carried out using molasses (a viscous by-product of sugar) as plasticizers [16]. Molasses is a cheap waste from sugar refinement operation, and it is considered as one of the most available waste products, especially in the Arabian Peninsula [17]. It is rich with sugar, protein, amino acids, magnesium, phosphor and potassium, glucose and fructose (Fig. 1) [18].

In the present work, an attempt to prepare IR and UV reflective polymer coating by incorporating molasses pigment from Sugar industry waste in the PVA matrix is performed. PVA mixed with molasses and samples as films were produced with a thickness between (250-300) μm, UV- VIS spectrum and FTIR devices used to examine the optical properties and the structure of the films.

2. MATERIAL AND METHODS

2.1 Materials

Polyvinyl alcohol (PVA) was purchased from the local market. Molasses were purchased from ETIHAD FOOD INDUSTRIES CO. LTD.

2.2 Preparation of coating

The sample was prepared by mixing different concentration molasses (0, 10, 20, 30 and 40 wt. %) in distilled water with PVA. Then, the sample cast in glass petri dish and leave to dry at room temperature for 72 hr.

2.3 Characterizations

Films were examined by using UV-1800 Shimadzu UV-Visible spectrometer range from (190-1100nm), used to get absorbance, transmittance, and reflectance and other optical properties of the films. FTIR -8400s spectrometer is used to analyse the bond of the sample and its content. The morphology and surface roughness were studied by 3000 AFM - Scanning Probe Microscopy, while the hardness property measured by Hardness Shore D TH210. FLIR T64 infrared camera used to study the effects of sun light exposure.

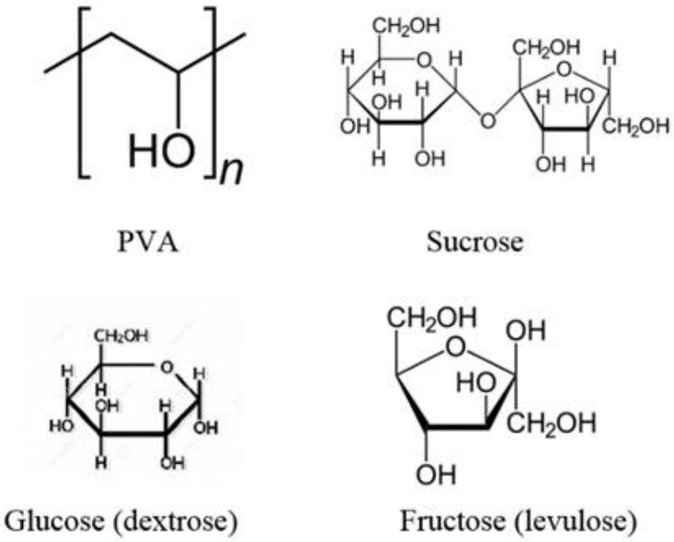

Figure 1. Schematic chemical structure of poly vinyl alcohol (PVA) and the main components of molasses

3. RESULTS AND DISCUSSION

The FTIR spectra of PVA/molasses film (Fig. 2) shows that the hydrogen bonded –OH vibration for sugar at 3335 cm−1. The hydrogen bonded –O–H stretching appeared at lower frequency. FTIR test showed, there is no chemical interaction between molasses and PVA chains. However, the shifting in the OH bands with increasing Molasses content indicates the physical interaction between hydroxyl groups of PVA and molasses [19].

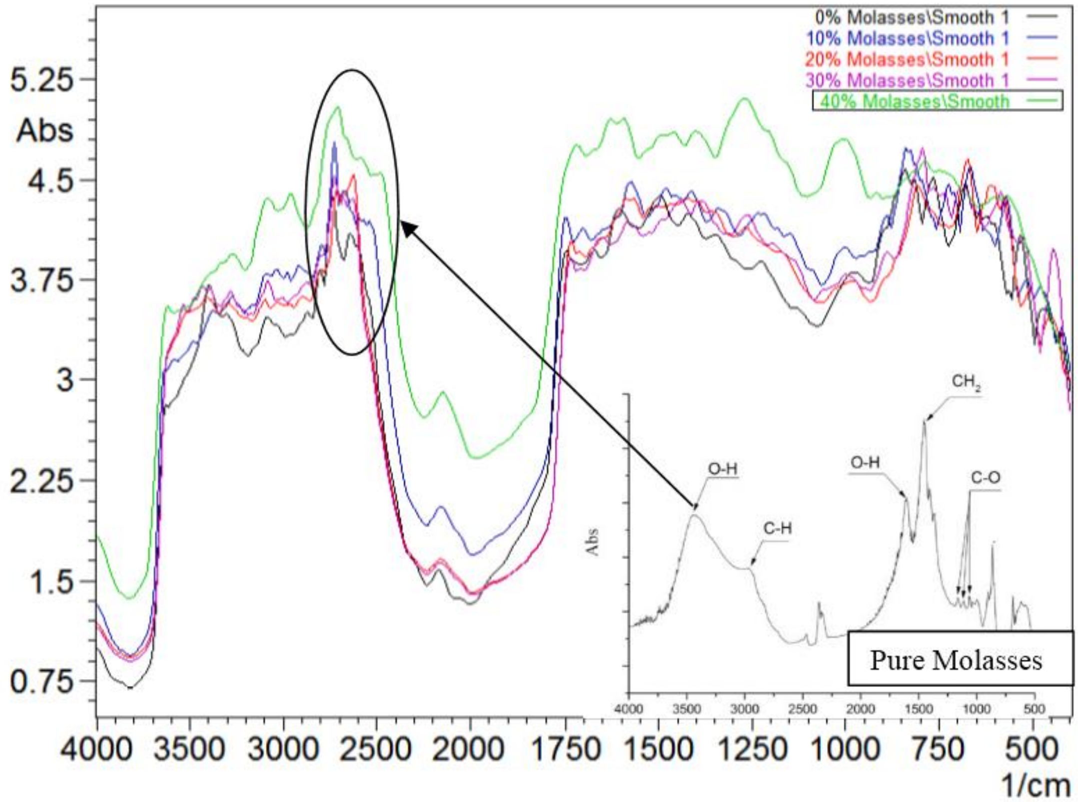

Figure 2. FTIR absorption spectra of PVA/molasses composite at different concentrations of molasses (0, 10, 20, 30 and 40 wt.%)

Fig. 3 shows that the absorption of PVA film increased with increasing molasses content in UV regain (190-380) (Fig. 3-a), where the increment is from 1.08% up to 3.89% in visible region; (375-700) nm, the absorption also increased with molasses content from 0.09% to 1.7% as shown in Fig. 3-b. while, in infrared (IR) region (Fig. 3-c), the absorption increased from 0.075% to 0.56%. These increments proved that, molasses molecules have major role in absorption of UV radiation, which may be due to penetration of molasses molecules within the amorphous structure of PVA. This behavior is clear from all molasses percentages as shown in Fig. 3-d.

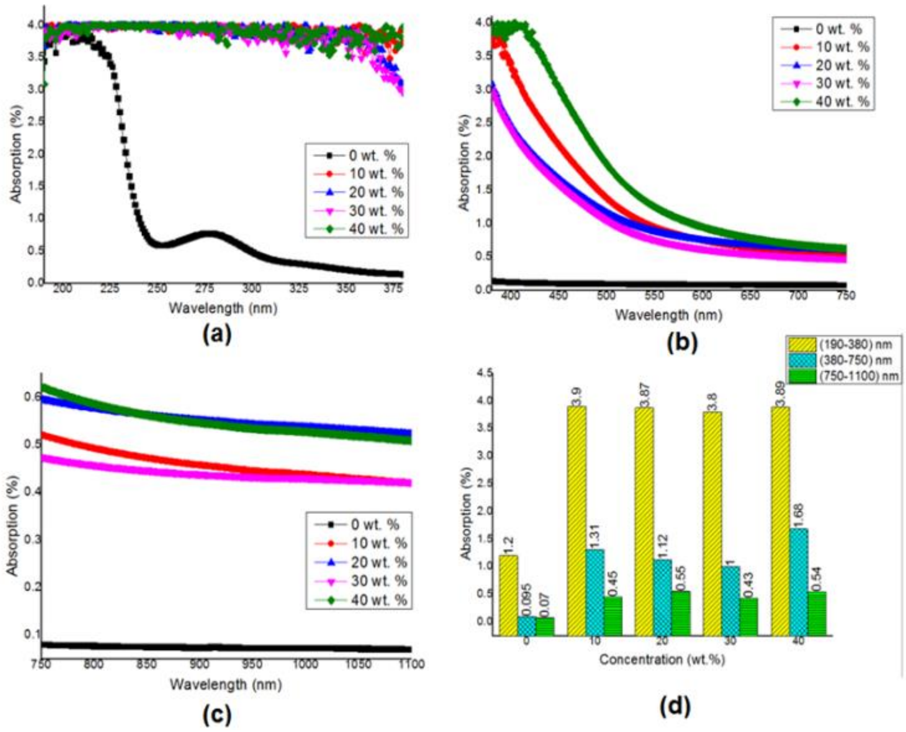

Figure 3. UV-VIS absorption spectra of PVA/molasses composite at different concentrations of molasses (0, 10, 20, 30 and 40 wt. %)

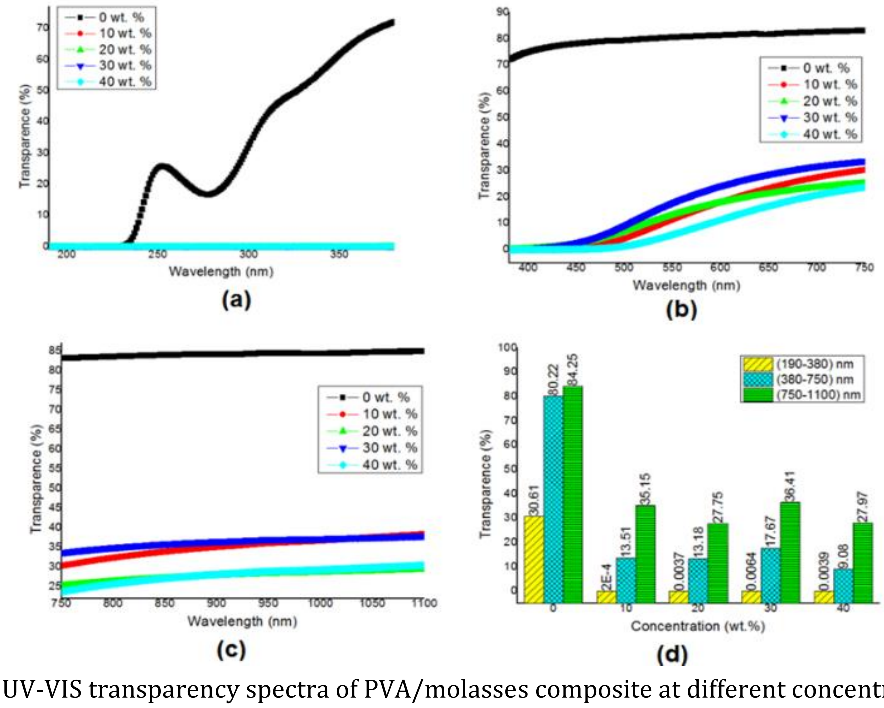

Figure 4. UV-VIS transparency spectra of PVA/molasses composite at different concentrations of molasses (0, 10, 20, 30 and 40 wt.%)

The transmittance decreased linearly with the molasses content as shown in Fig. 4. The transmittance order is IR > Visible > UV, which means the resultants films have an expectance transparency for protective covers.

Fig. 5 shows the reflectance spectrum of UV, visible and near IR regions for the prepared samples. Fig. 5-a clarifies that there is a huge effect of molasses on the reflectance of PVA films, where, the increment was from 64.2% to 96.09%. This is a desirable property which can be employed in protection applications from UV radiation. Similar behaviours occurred at visible and IR regions, where the reflectance increased from 19.76% to 90.8% at visible region (Fig. 5-b) and from 15.8% to 72.17% at IR region (Fig. 5-c). Fig. 5-d shows that the reflectance is always higher in UV regions than other regions because of the phenolic compounds in the molasses that work as reflectors of UV radiation [20].

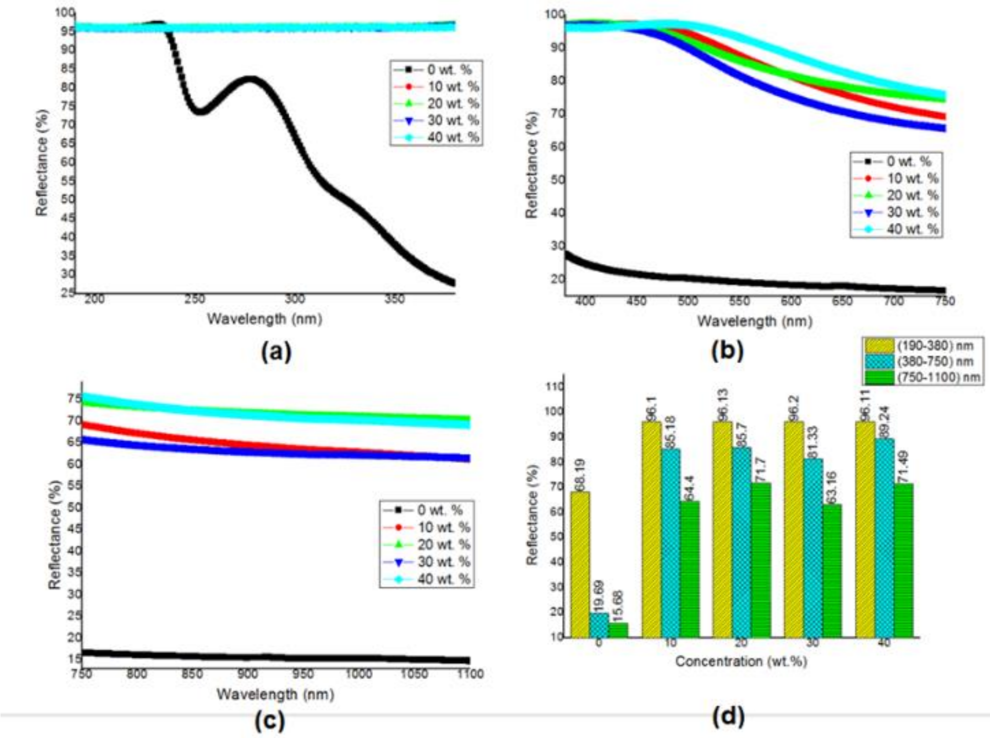

Figure 5. UV-VIS reflectance spectra of PVA/molasses composite at different concentrations of molasses (0, 10, 20, 30 and 40 wt.%)

Fig. 6 monitors that molasses phase was discrete at a low percentage and with increasing the percentage of molasses, a continuous phase within the PVA matrix was observed. As molasses increased, the morphology of PVA/molasses blend changed from continuous/discontinuous phase to the dual-phase domain continuity (or co-continuous phase domains), where there is a continuous path through either PVA or molasses phase, which may be drawn to all phase domains boundaries without crossing any phase domain boundary. At low molasses concentrations, the matrix is the PVA components, which is the host polymer, while at higher concentrations, the matrix phase is the molasses component.

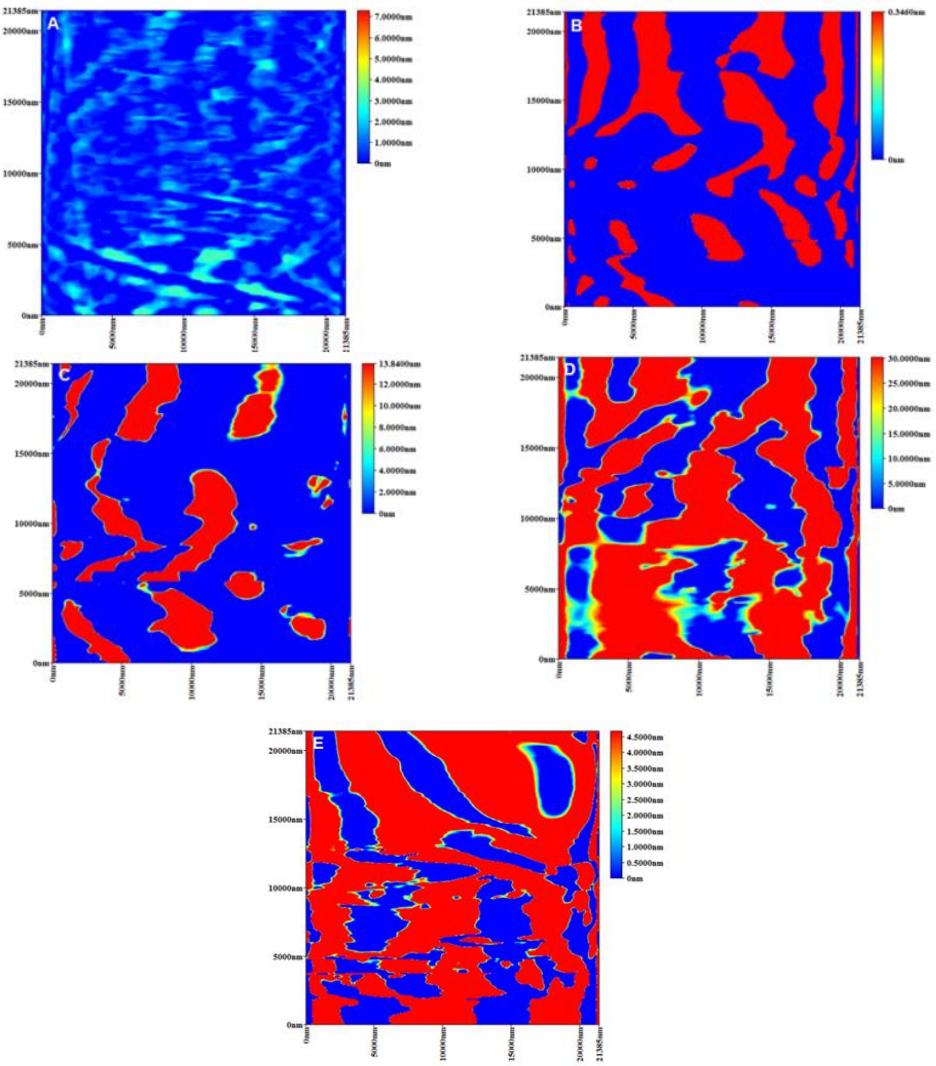

Figure 6. AFM 2D topography images of PVA/molasses composite at different concentrations of molasses (0, 10, 20, 30 and 40 wt.%)

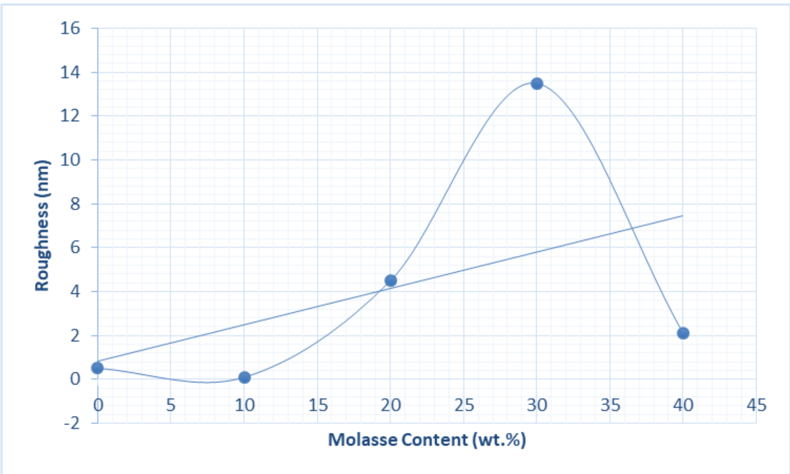

Figure 7. Roughness average curve of PVA/molasses composite surface by AFM at different concentrations of molasses (0, 10, 20, 30 and 40 wt.%)

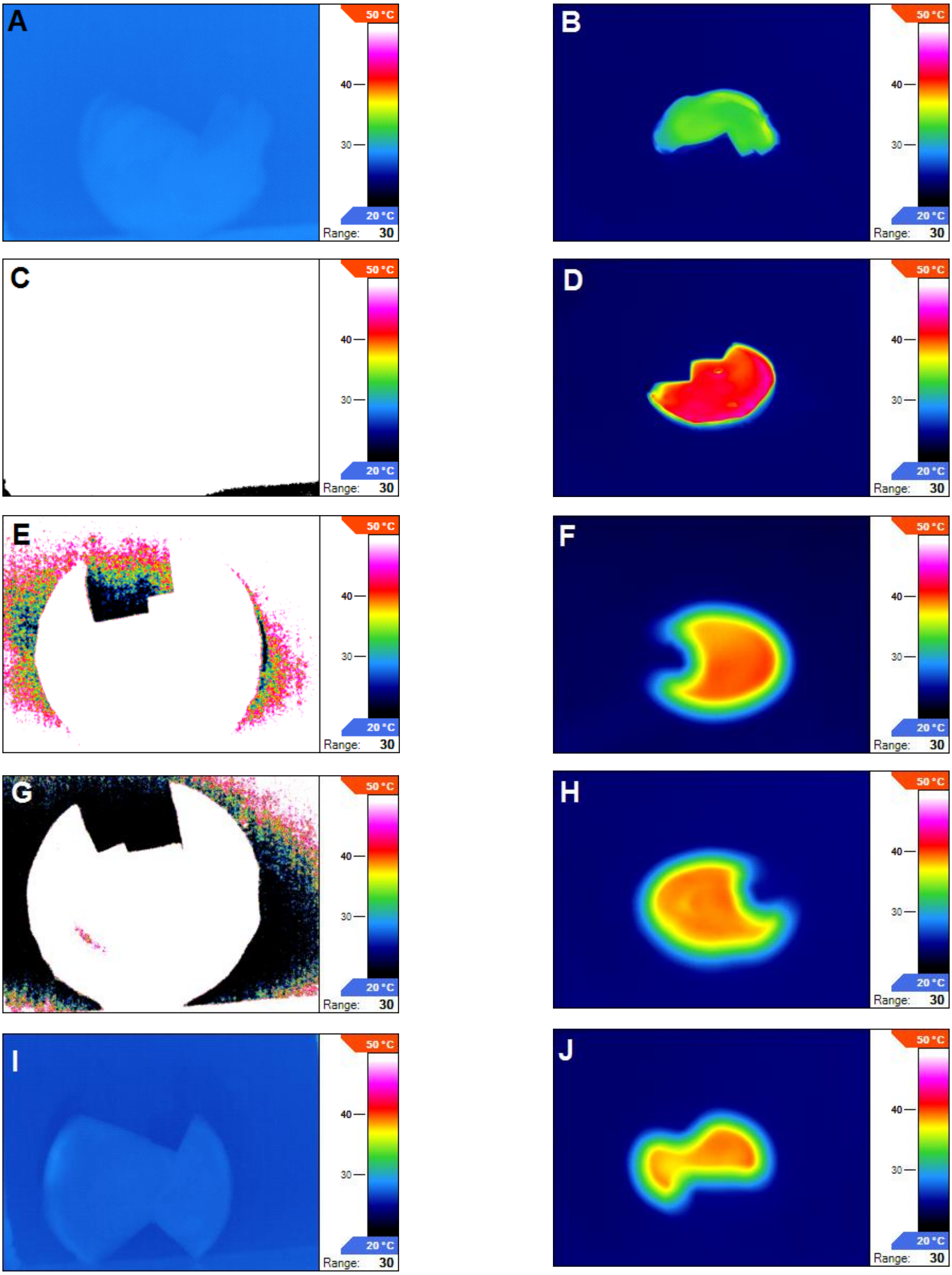

Figure 8. IR images of PVA/molasses composite by IR camera at different concentrations of molasses (A and B=0, C and D=10, E and F=20, G and H=30, as well as I and J=40 wt.%), before and after demonstration of sun light for 1 minute, respectively

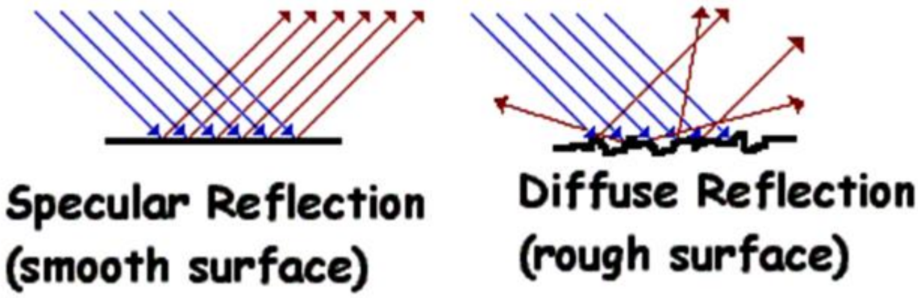

Figure 9. Schematic shape of smooth and rough surface and it is affecting on magnetic waves reflection

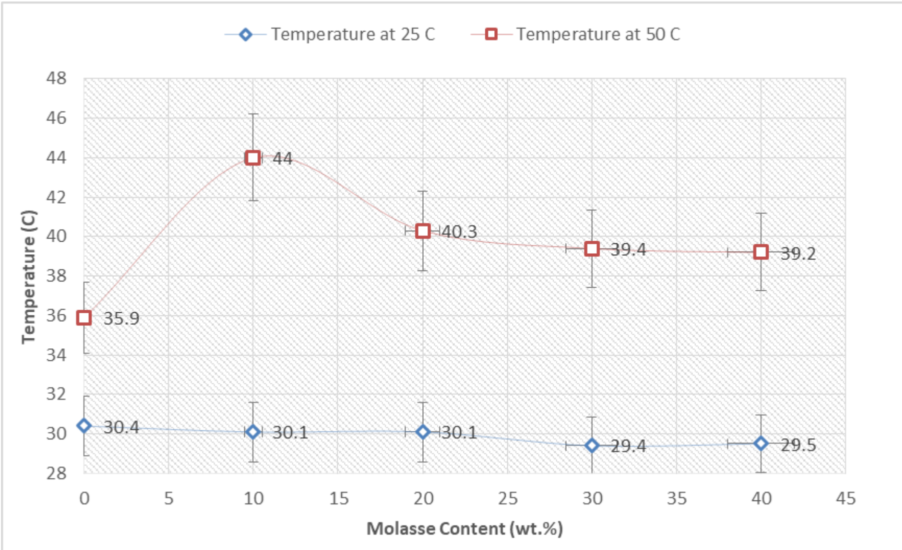

Figure 10. Maximum temperatures curve of PVA/molasses composite by IR camera at different concentrations of molasses before and after demonstration of sun light for 1 minute (0, 10, 20, 30 and 40 wt. %)

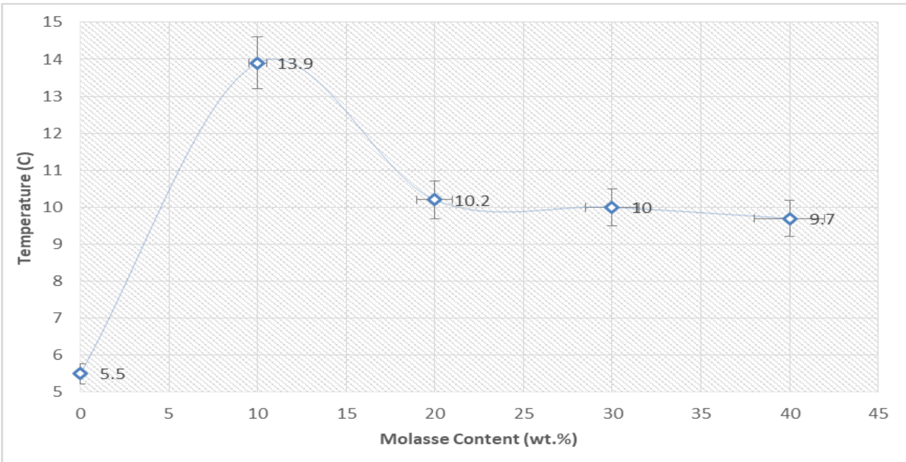

Figure 11. Difference maximum temperatures curve between before and after demonstration of sun light for 1 minute of PVA/molasses composite by IR camera at different concentrations of molasses (0, 10, 20, 30 and 40 wt.%)

Before sun exposure, the temperature distribution is evenly along molasses content, while after exposure, there is clear fluctuations in this distribution due to the differences in the thermal conductivities between PVA and molasses. Thermal conductivity (K) of PVA is 0.31 W m-1 K-1 and for molasses is 0.08 to 0.39 W m-1 K-1.

The hardness property, generally increased with the molasses content, which proved the penetration of molasses molecules within PVA structure, filling its voids, which could be as a result for the physical interaction between their hydroxyl groups. The sample with 20% molasses shows the higher hardness, which suggest this sample to be the optimum one. This behaviour means that higher molasses content can causes agglomerations, which were illustrated by AFM topography in Fig. 6. Consequently, these active sites are not enough to create secondary interactions between PVA and molasses components.

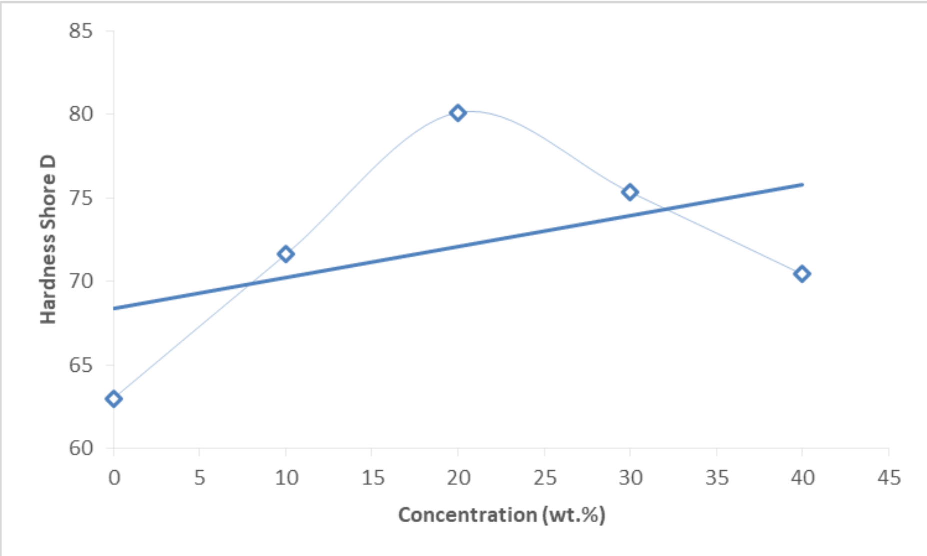

Figure 12. Hardness shore D average of PVA/molasses composite at different concentrations of molasses (0, 10, 20, 30 and 40 wt. %)

4. CONCLUSION

1-Although there is no chemical interaction between film components, hardness generally increased, and the film contains 20% molasses shows the higher hardness, which might be as a result to fill the voids between PVA chains by Molasses chains.
2-As molasses increased, absorption and reflections properties increased in UV, Visible and IR regions, while transmittance property decreased.
3-With increasing molasses, the surface roughness increased and the film morphology converted towards the co-continuous phase domains.
4-Exposing to sun light for 1 minute causes significant fluctuations in temperature distribution, and the film contains 10% molasses exhibited maximum differences temperatures.

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