Use of Thermal Imaging Cameras in measureing the Total Emissivity

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ABSTRACT: *Emissivity is an important and necessary parameter for non-contact thermometry. In this research, the emissivity of pistachio was determined by comparing the readings of contact thermometer and that of thermal imaging camera. In addition, the effect of surface temperature of pistachio kernel on its emissivity was investigated. The obtained results show 0.95 as emissivity of pistachio kernel in 4.5% d.b. moisture content. There was observed that the emissivity of pistachio kernel will be increased by increasing of temperature.*

Keywords: Emissivity, Thermal Imaging camera, Pistachio kernel, Temperature

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1. Introduction

The emissivity of a body is a coefficient that shows the ratio of its radiated energy to that of black body at the same temperature [1]. Emissivity specifies the amount of lost or gained thermal radiation by an object [4]. Also, this coefficient is an important parameter for non-contact determination of surface temperature (i.e. using thermal imaging cameras). Equation (1) is the fundamental concept of thermal imaging that shows the important of this parameter [5].

$$W = \varepsilon * \sigma * T^4 \quad (1)$$

Where, W is the energy flux emitted per unit area (W/m^2), ε is the material (surface) emissivity, σ is the Stefan-Boltzmann constant ($5.67\times10^{-8} Wm^{-2} K^{-4}$) and T is the surface temperature (K). After setting surface emissivity, the thermal imaging cameras measure the W and then report surface temperature in a thermogram.

There are two types of emissivity; wavelength-dependent or spectral emissivity and hemispherical or total emissivity. For non-contact determination of material temperature, the spectral emissivity must be known. There was assumed that wavelength has not effect on surface's spectral emissivity, so that the emissivity is a constant. But, to determine heat transfer, the total emissivity should be measured. In this case, surface emission in only a particular direction and a particular wavelength was considered [1, 4].

Also, the emissivity depends on the type of material surfaces. There were emissivity tables in different books and references for different materials [6]. As seen in the tables, the emissivity of each material differs with another. This fact shows the effect of material surfaces on its emissivity. Surface parameters such as moisture content, color and roughness effect on the emissivity.

The emissivity coefficient is depended on surface temperature [2]. As can be seen in Figure 1, the surface at high temperatures, radiate the more thermal energy. This shows that the temperature will increase the emissivity. Also, emission angle and wavelength that received by a camera effects on the emissivity [1]. According to Figure 1, the maximum IR radiation is obtained in a specific wavelength. The emissivity of a material depends on its thickness, so that, thinner materials have lower emisivities. But, in general utilities, the emissivity was measured by considering infinite thickness [1].

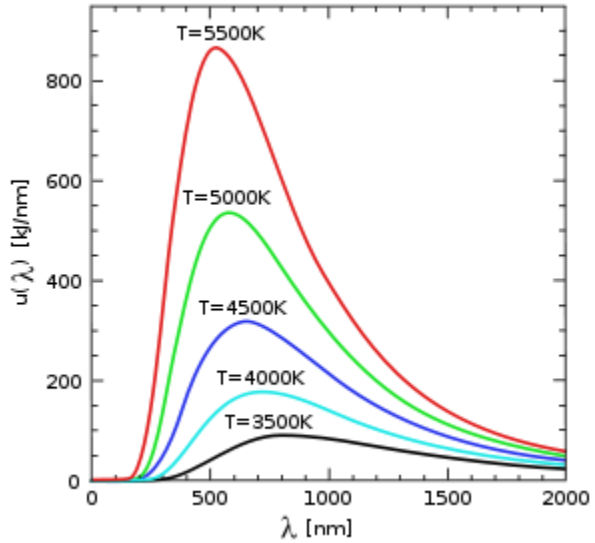

Figure 1. Effect of temperature and wavelength on emissivity [3]

As mentioned above, there are emissivity tables for different materials. But, there aren't such tables for agricultural materials and, also the researches were not conducted to determine the agricultural materials emisivities. So, this research was carried out to measure the emissivity of pistachio that is essential for non-contact thermometry. Also, the effect of temperature and moisture content on pistachio emissivity was investigated.

2. Material and Methods

Akbari variety of pistachio from Rafsanjan region, Kerman, Iran was considered as experimental specimens in this research. The moisture content of specimens was determined by oven method. The moisture content was obtained as 4.5% d.b.

ULIRvision TI160 thermal imaging camera (Zhejiang ULIRvision Technology Co, Zhejiang, China), for non-contact thermometry (Figure 2), and 4 Channels Thermometer, type K/J (LTD Co, Taiwan) for contact thermometry (Figure 3) of pistachios were used.

To determine the emissivity of pistachio, firstly, the emissivity parameter in the thermal imaging camera was adjusted. The pistachio specimens were singly fixed by a plastic clamp to avoid the human hand effect on pistachio temperature and then moved to the front of the thermal imaging camera's optical lens. The distance between the camera and sample was set about 10 cm. Finally, the thermal imaging camera readings were recorded. The recorded temperatures were plotted versus the emisivities. In the second step, the effect of pistachio temperature on its emissivity was researched. The *temperature* of pistachio in different temperatures was determined. The difference of contact and non-contact thermometers' readings was plotted against pistachio temperature. Figure 4 shows the pistachio thermograms in different temperatures.

3. Results and Discussions

The emissivity parameter in the thermal imaging camera was set in range of 0.01 to 1. In this range, recorded temperatures by

thermal imaging camera versus emissivity were plotted in figure 5. The temperature recorded by the contact thermometer was around 26.5 ºC. When the emissivity was set near zero, the recorded temperature has had highest values. As shown in this figure, the high the emissivity, the low the temperature was recorded by the camera. By increasing of the emissivity the recorded temperature by the camera will close to that recorded by the contact thermometer.

Figure 6 is similar to figure 5 but with lower variation of emissivity (0.9-1). In this diagram, the variation of emissivity is very little, but by closely observation can be seen that the temperature had lowest value (around 29.5 ºC in average) when the emissivity is 0.95. In this time; the deference between the temperature recorded by the camera and that of contact thermometer was lowest (around 3 ºC). For this reason, the emissivity of pistachio was set as 0.95. Chelladurai et al, 2010, considered 0.95 as emissivity of wheat to specify its fungal infection [7].

Figure 2. ULIRVision TI160 thermal imaging camera

Figure 3. 4 Channels Thermometer

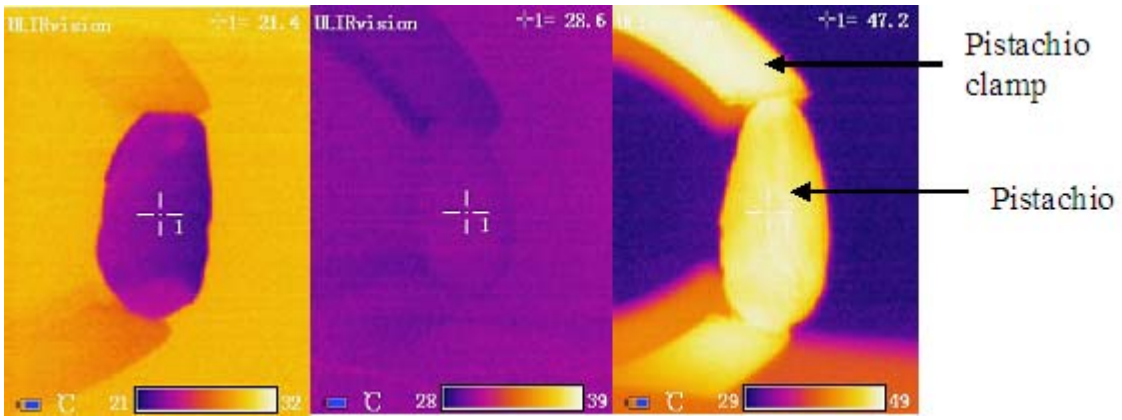

Figure 4. The thermograms of pistachio in different temperatures

Recorded temperature by thermal imaging camera minus corresponding values measured by contact thermometer versus temperature of pistachio surface was plotted in figure 7. Here, can be seen that by increasing of pistachio temperature, the emissivity will be increased. Because, according to figure 1, when the emissivity set lower the temperature was over estimated.

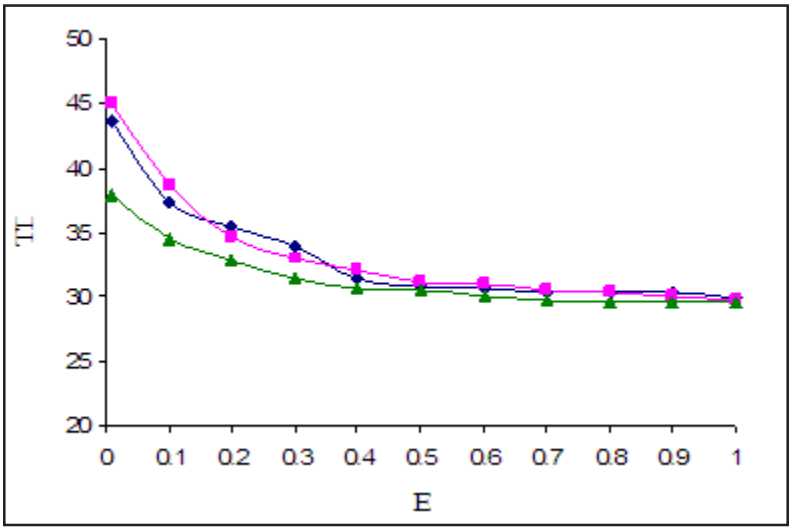

Figure 5. Recorded temperatures versus emisivity of pistachio (0.01-1)

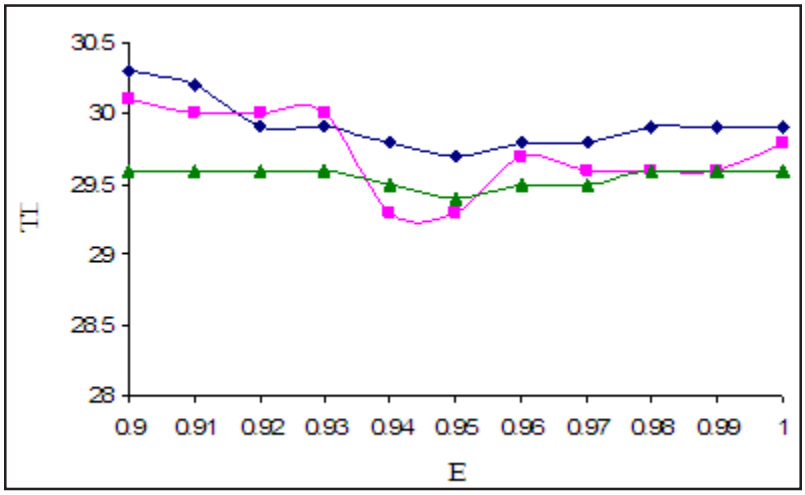

Figure 6. Recorded temperatures versus emisivity of pistachio (0.9-1)

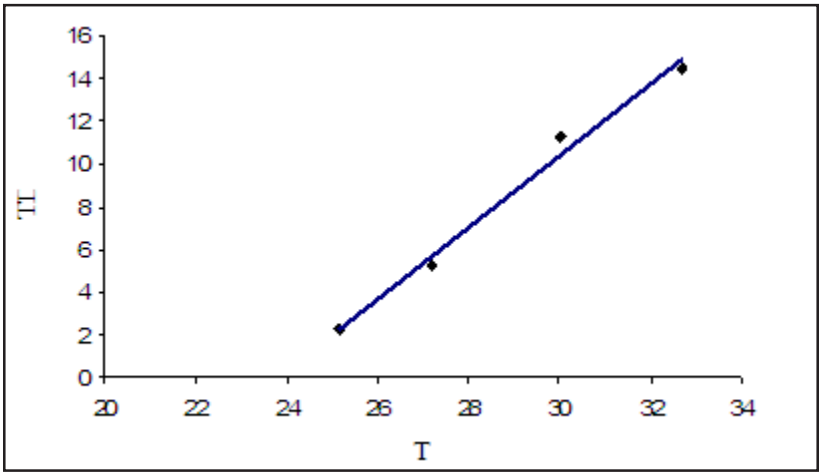

Figure 7. The difference of contact and non-contact thermometry (TD) against temperature of pistachio (T)

To avoid this, the emissivity must be increased. So, to correct reading of the camera in figure 7, (to decrease temperature difference from around 1 ºC to around 3 ºC) the emissivity must be increased. So, can be tolled that increase of temperature, will increase the emissivity of pistachio. This result has agreement with figure 1.

4. Conclusion

There was concluded 0.95 as the emissivity of pistachio when moisture content is 4.5 % d.b. Also, the emissivity of pistachio will be increased by increasing of pistachio surface temperature.

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References

[1] http://en.wikipedia.org/wiki/Emissivity.

[2] An Introduction to Emissivity in Infrared Thermometers. *In*: http://www.openxtra.co.uk/articles/introduction-emissivity-in-infrared-thermometers.

[3] http://en.wikipedia.org/wiki/Thermal_radiation.

[4] http://www.evitherm.org/Default.asp?ID=675&mode=html#aq6.

[5] Gowen, A. A., Tiwari, B. K., Cullen, P. J., McDonnell, K., O'Donnell. C. P. (2010). Applications of thermal imaging in food quality and safety assessment. Trends in Food Science & Technology, 21,190-200.

[6] http://www.omega.com/literature/transactions/volume1/emissivitya.html.

[7] Chelladurai, V., Jayas, D. S., White. N. D. G. (2010). Thermal imaging for detecting fungal infection in stored wheat. *Journal of Stored Products Research* 46, 174-179.