ULTRAVIOLET, VISIBLE, AND INFRARED WAVELENGTHS FOR DETERMINATION OF PALM OIL QUALITY

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ABSTRACT

The palm oil gives the highest yield of oil per unit area of any crop and produces two distinct oils, palm oil and palm kernel oil. The palm oil was heated at 180 °C. for six durations (3, 6, 9, 12, 15, and 18 h.) to measure deterioration and exposure by visible and invisible lights, to determine optical characteristics of oils. Three light regions, ultraviolet (200-400nm), visible light (400-700nm), and near infrared (700-900nm) were used in the present work. The obtained results are summarized as follows: 1) The high transmission percentages were found 93.691, 92.411 and 4.942 % for using wavelengths of 900 nm (infrared light), 700 nm (visible light) and 400 nm (ultraviolet light), respectively., 2) The absorption percentages were increased for using from 900 to 700 nm (Near Infrared lights), from 700 to 400 nm (visible lights), and from 400 to 200 nm (Ultraviolet lights). Meanwhile, the transmission percentages were decreased, 3) The highest absorption percentages through heated palm oil were of 0.104, 1.38, and 6.23 % when using 700 nm (Near infrared light), 400 nm (visible light), and 200 nm (ultraviolet) wavelengths., 4) It is possible to use 900 nm (infrared) or 700 nm (visible) wavelengths with 74.18 and 73.84 % as measuring quality of heated palm oil. Meanwhile, 200 nm of wavelength was used as absorption percentage of quality measuring because of the palm oil started deterioration as oxidized is 1.11% (more than 1%)., 5) The heating times were increased from 3 to 18 h., that lead to increased oxidized fatty acid, Polymer, acid value, peroxide value, viscosity, and reflective index, from 0.19 to 1.11%, from 0.15 to 1.78%, from 0.15 to 0.82 mg KOH/g, from 1.1 to 10.1 meq O_2 /kg, from 69 to 122 C.P., and from 1.4646 to 1.4676 no., respectively. Meanwhile, the iodine value was decreased from 58.2 to 54.6 g I_2 /100 g sample.,

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and 8) The changing in heating time of palm oil changes physical and chemical characteristics which, lead to increased absorption percentages of ultraviolet light with 200 nm wavelength from 4.409 to 6.226%. Meanwhile, the decreases in transmission percentage of infrared 900 nm wavelength from 93.691 to 74.189 and of visible light of 700 nm wavelength from 92.411 to 73.878%.

INTRODUCTION

The palm oil *(Elaeis guineensis* Jacq.), native of West and Central Africa, is planted globally on 10 million hectares. Reaching a production of 24 million tonnes oil in 2000. Palm oil has become the most important oil crop next to soybean.

West (1985) observed that the chemical and physical properties of edible oils depend primarily on composition and temperature. Some bulk parameters for different vegetable oils of some Slovene manufacturers focus on electric properties of oils.

Knutson et al. *(*1987) showed that an increase in temperature in a food or any material can be achieved in three possible ways, namely, conduction, convection and radiation. In conventional cooking methods, food is normally heated by conduction and convection, whereas heating through radiation uses radio frequency waves, microwave, and infrared radiation. While the infrared radiation is employed for surface heating, as the IR waves cannot penetrate below the surface. Microwave, on the other hand, penetrates food and produces heat from inside out.

Mudgett (1989) reported that the quantum energy can break the chemical bond when it exceeds the chemical energy. Gamma rays and X-rays, which have short wave lengths, high frequency and high energy, are capable of breaking the chemical bonds. Microwave and radio waves, which come under long wavelength, low frequency, low energy category, do not have enough energy to break chemical bonds.

Hui (1996) mentioned that several semi-empirical equations have been developed that relate the property of interest (e. g. time for fat to drain from a fried potato chip) to independently measurable bulk properties (e.g., density, viscosity, surface tension, etc). With these equations, it is possible to predict how changes in the properties of oil alter the efficacy of a process.

Baumann et al. (1998) referred to the vegetable oils and fats as important constituents of human and animal foodstuffs. Certain grades are industrially used, and together with carbohydrates and proteins, are important renewable resources compared to fossil and mineral raw materials, whose occurrence is finite. The sources of oils and fats are various vegetable and animal raw materials with the vegetable raw materials soybean, palm, rapeseed and sunflower oil being the most important ones.

Martin (1998) observed that there are two types of lipids—fats and oils. Fats come from animals and are solid at room temperature. Oils come from plants and are liquid at room temperature. Oils are necessary in the diet as a source of non-saturated fatty acids, in order to give flavor to foods, as sources of fuel for the body.

Rudan and Klofutar (1999) showed that the vegetable oils were examined and the following indices determined: peroxide value, acid value, iodine value, specification number, specific gravity, refractive index at 298.15 K. Some empirical relations between physical and chemical constants were fitted to the experimental data and the correlation constants for the best fit are presented.

Eisenberg et al. (2000) mentioned that the properties of a discrete diffraction are different. The diffraction can be managed from normal to zero and anomalous depending on the beam incidence angle. The influence of light intensity on the refractive index distribution appearing in non- linear materials makes it possible to control optically discrete diffraction strength, which leads to the propagation of self-trapped beams.

Hill (2000) cleared that special attention must be given to coconut oil and palm kernel oil because of their high share of fatty acids with a short or medium chain length (mainly 12 and 14 carbon atoms: C12, C14). Palm, soybean, rapeseed, and sunflower oil, as well as animal fats such as tallow, contain mainly long-chain fatty acids (e.g., C18, saturated and unsaturated) and are used as raw materials for polymer applications and lubricants.

Pantzaris and Ahmed (2000) said that the palm kernel oil is more unsaturated and so can be hydrogenated to a wider range of products for the food industry, while coconut oil has a somewhat greater content of the more valuable shorter-chain fatty acids, which makes it a little more valuable for the oleo chemical industry.

Suzushi et al. (2002) mentioned that the refractive indices versus wave number for the real and imaginary parts of water, freon, and heptane and only the real part of benzene, gas oil, and crude oil. The reason for this is that the real part of the refractive index of the latter three is so close to that of the prism that there no longer exists a situation of attenuated total reflection. As most of the intensity is transmitted into the liquid, the intensity at the detector decreases dramatically.

Atinmo (2003) reported that palm oil is obtained from the fleshy mesocarp, which is 45-55 percent oil by weight. The oil melts over a range of temperatures of 25-35 °C. It is light yellow to orange red in color, the depth of color depending on the amount of carotenoids present, the amount of lipoxidases in bruised fruit stored for various periods before processing, and oxidation, catalysed by iron, during processing and bulking; for edible fat manufacture in Europe.

Abramovi et al. (2005) determined the peroxide value (PV) of fresh camelina oil was (2.38 ±0.01) meq O2/kg, while after 1 month in daylight at room temperature *PV* reached (21.0 ±0.1) meq O2/kg. When stored in darkness *PV* was (8.12 ±0.08) meq O2/kg. In the fresh oil, the p-anisidine value (*A*V) was 6.2 ±0.1, after 11 months at room temperature 10.4 ±0.1, and after the same time at 8 °C in darkness 7.1 ±0.1.

Ruyz et al. (2005) mentioned that the near infrared spectra were obtained using an Ocean optics NIR512 spectrometer with an InGaAs detector and a halogen tungsten lamp in a wavelength range from 850 to 1700 nm. Principal Component Analysis (PCA) of the NIR spectral data can be used for edible oil classification by temperature.

Objective

The aim of: (1) describing general characteristics of the heated palm oil, (2) determined some physico-chemical properties of heated palm oil such as oil fatty acid, iodine value, acid value, peroxide value , polymer, viscosity and reflective index under different heating conditions, and (3) select suitable wavelength from ultraviolet, visible and infrared lights to high oil quality.

MATERIAL AND METHODS

The experiments of chemical analysis were done in Oils Department, Food Technology Institute, Agricultural Research Center and measurement of the optical characteristics of heated palm oil were done at in the Laboratory of

Laser Applications at the National Institute of Laser Enhanced Science, Cairo University, to select suitable wavelength from visible and invisible lights (Ultraviolet, Visible, and Infrared wavelengths) to measure palm oil quality.

Sample preparation: Palm oil was obtained from department of oils, Food Technology Institute, Agricultural Research Center, Giza Governorate. The palm oil was heated at 180 ^{o}C. for six durations (3, 6, 9, 12, 15, and 18 h.) to measure deterioration of oil and exposure to visible and invisible lights to determine optical characteristics of oils at different wavelengths. Also, physical and chemical properties were measured.

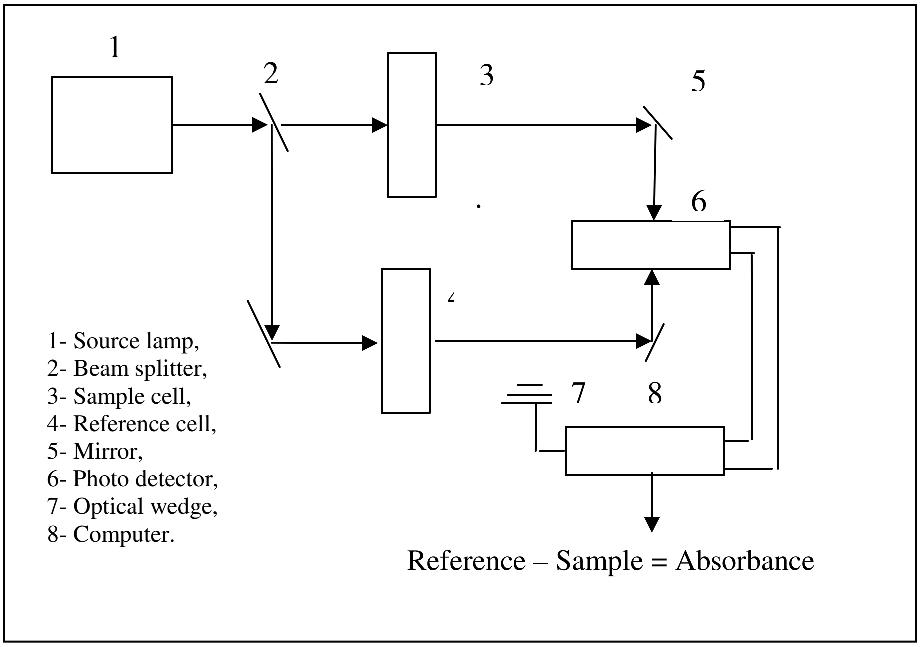
Optical properties: The light beam passes through sample cell of oil. The transmission of incident beam and the absorption percentages of palm oil were measured in the spectrophotometer with a 200 to 900 nm wavelength range. Diagram of beam, which passes through the spectrophotometer and photo it is shown in (Fig .1).

Setup: The experimental setup consisted of spectrophotometer; visible, invisible lights, filter, lenses, holders, quartz cuvette, and personal computer.

Spectrophotometer: Spectrophotometer is a laboratory grade double-beam UV/VIS spectrometer. The instrument can be operated through the PC. Specifications of spectrophotometer are illustrated in table (1).

Table (1): Specifications of Perkin Elmer Lambda 40 UV/VIS spectrophotometer.

Items	Specifications
Model:	Lambda 40
Made	USA
Wavelength Range: (nm),	190-1100
Wavelength Accuracy: (±nm)	1
Resolution: (nm)	0.5,
Max Scan Speed: (nm/min)	2800,
Monochromator:	1440 ruled line Grating,
Detector	Silicon diode
Slit Width:	2.0 nm,
Grating, mm	Holographic, concave with grating 1053 lenses
Light sources: 6 V/20W	Deuterium and Tungsten- Halogen Lamps
Dimensions: LxWxH"	26 x 9 x 22
Mass:	26 kg.



(a): Diagram of a double beam spectrophotometer.

(b): Photo of spectrophotometer.

Fig. (1): Diagram of double beam and photo of spectrophotometer

Lamps: The light source for the UV wavelength range is a Deuterium lamp, this lamp emits light from 190 nm to 380 nm wavelengths. Meanwhile, light source for the visible and NIR wavelength range is a Tungsten lamp; this lamp emits light from 370 nm to 1100 nm wavelengths.
Light types: Three lights, ultraviolet with wavelengths from 200 to 400 nm, visible light with wavelengths from 400 to 700 nm, and near infrared with wavelengths from 700 to 900 nm were used in the present work as a light source.
Lens: The lens receives the light from both lamps (Deuterium and Tungsten lamps) and collimates it, then the beam passes through the sample.
Shutter: The shutter is electromechanically actuated; it opens and allows light to pass through the sample for measurements. It closes to limit exposure of sample to light.
Stray Light Filter: Sample intensity spectra are measured without stray-light filter in the light beam. Without the filter, the intensity spectrum over the whole wavelength range from 190–1100 nm is measured. The stray-light filter is a blocking with 50 % at 420 nm, and the light place of this filter was measured below 400 nm.
Quartz sample cells (cuvette): Sample cells with quartz face plates are required to use the full 190 to 1100 nm wavelength range, Two optical windows with 1cm/10mm path length; outer dimensions of 12.4x12.4x45mm for standard fit and sample volume of 3.5 ml.
Computer: Utilized the software, which shows the results of optical analysis of oils (Agilent Chem. Station Software).

Physical and chemical characteristics of palm oil:
The following physical and chemical characteristics were measured according to the methods described in the **(A.O.A.C**., **1990)**: reflectivity index, viscosity, oxidized fatty acids, peroxide value, acid value, and iodine number. All tests were performed in triplicate.

RESULTS AND DISCUSSION

Fig. (2) shows the transmission percentages of ultraviolet, visible, and infrared lights with different wavelengths through heated palm oil. It was noticed that the high transmission percentages were found of 93.691, 92.411 and 4.942 % for using wavelengths of 900 nm (infrared light), 700 nm (visible light) and 400 nm (ultraviolet light), respectively. Generally, the transmission percentages decreased when using infrared lights from 900 to 700 nm, visible lights from 700 to 400 nm, and ultraviolet lights from 400 to 200 nm wavelengths for all treatments.

The results showed that the transmission percentages were obtained from using wavelengths infrared and visible lights nearly equally. Therefore, it possible to use 900 nm (infrared) or 700 nm (visible) wavelengths as quality measuring of heated palm oil, but it is preferable to use 700 nm wavelength of visible light because of it is more common in uses than others. So, in the case, using the transmission percentage as measuring, relight select visible light with wavelengths ranging from 700 to 580nm.

Fig. (3) illustrates the absorption percentages of ultraviolet, visible, and infrared lights with different wavelengths through heated palm oil. Generally, the absorption percentages were increased from 900 to 700, from 700 to 400, and from 400 to 200 nm wavelengths for near infrared, visible and ultraviolet lights, respectively. Therefore, the absorption percentages were increased by the decreasing light wavelengths. The results showed that the highest absorption percentages through heated palm oil were of 0.104, 1.38, and 6.23 % when using 700 nm (Near infrared light), 400 nm (visible light), and 200 nm (ultraviolet) wavelengths. The absorption percentage was obtained by using ultraviolet light wavelength used as measuring for palm oil quality. Therefore, it is possible to use 900 and 700 nm of wavelengths as transmission percentage for measuring quality of palm oil. Meanwhile, the wavelength of 200 nm can be used as absorption percentage in measuring.

Fig. (4) indicates the transmission and absorption percentages through heated palm oil when using ultraviolet wavelength, visible, and infrared lights. Generally, the absorption percentages decreased from 900 nm to 700 nm to and 200 nm by increasing the heating time from 3 to 18 h., while the transmission percentage decreased.

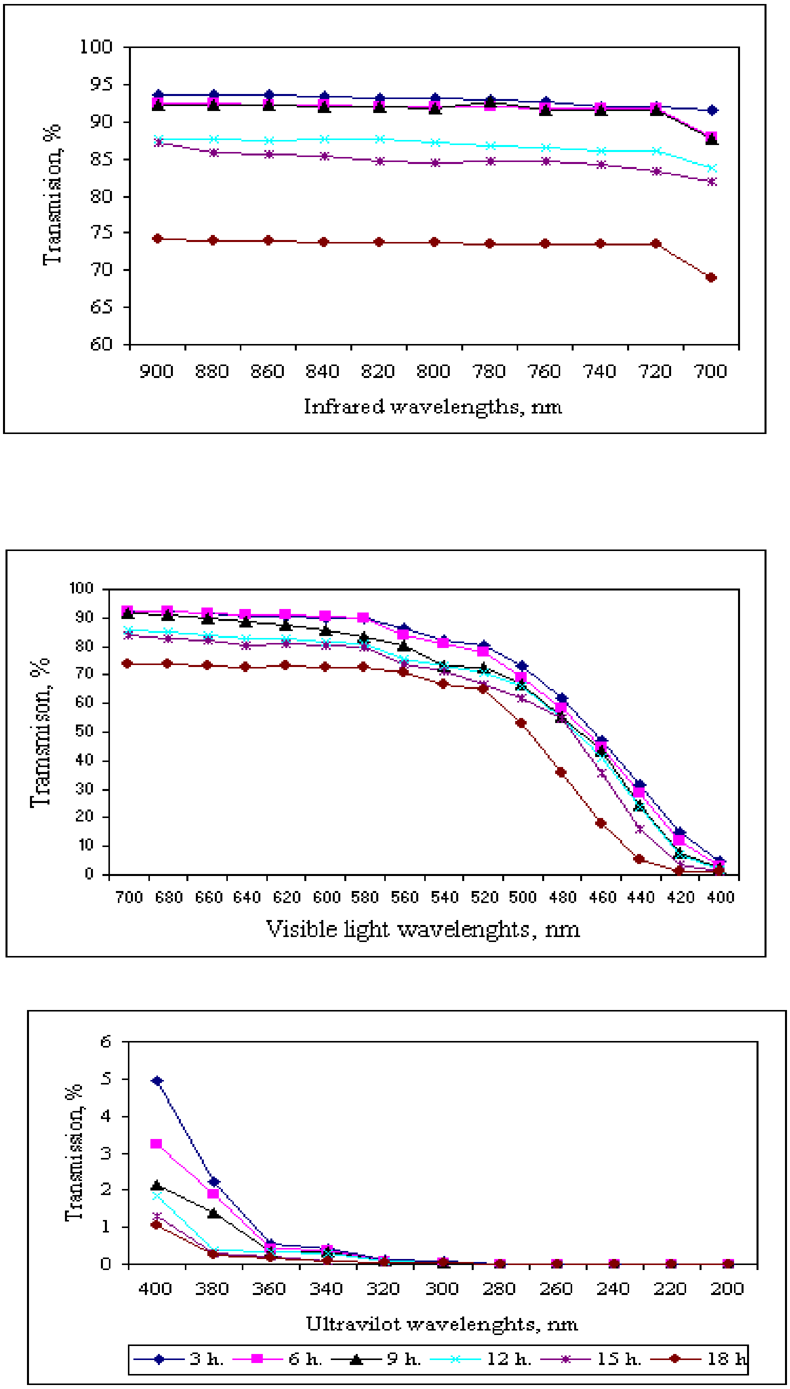


Fig. (2): Transmission percentages of heated palm oil at different wavelengths

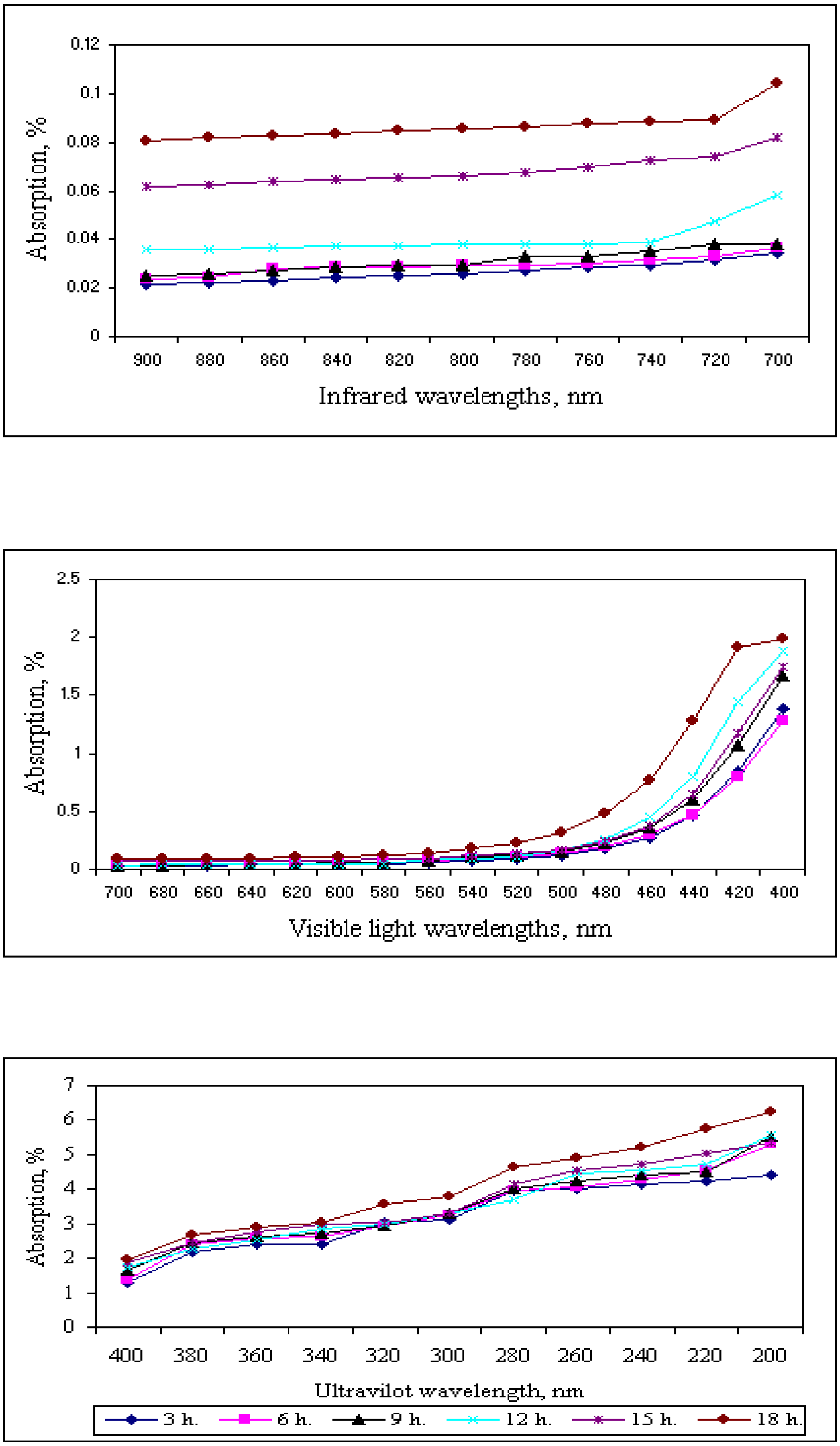
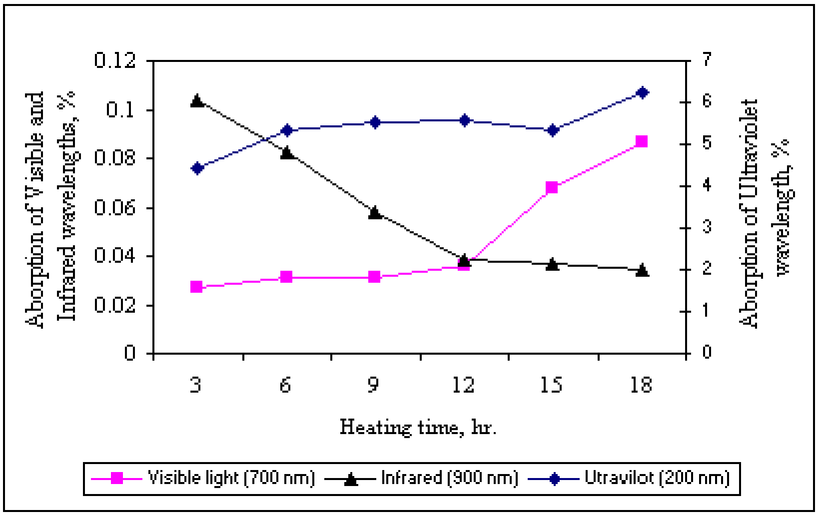


Fig. (3): Absorption percentages of heated palm oil at different wavelengths



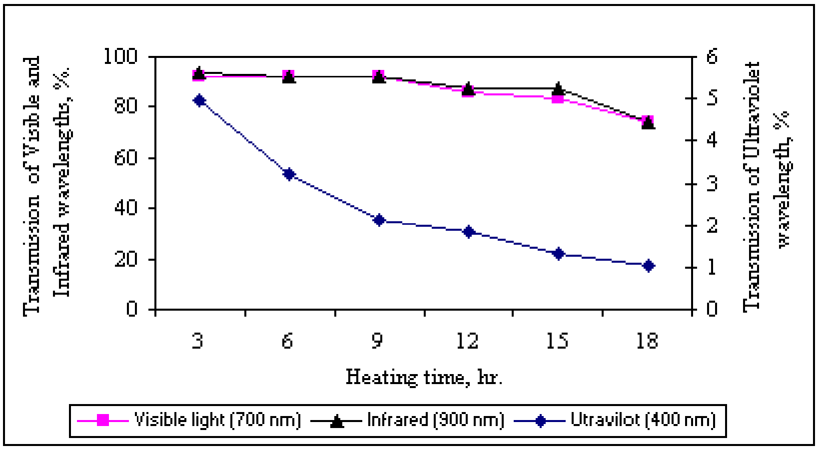


Fig. (4): Transmission and absorption percentages through heated palm oil
at high wavelengths for Ultraviolet, Visible and Infrared lights.

Also, the same figure shows the absorption percentages increased from 4.409 to 6.226%, from 1.386 to 1.982%, and from 0.034 to 0.104% for 200nm (ultraviolet light), 400 nm (visible light), and 700 nm (near infrared light) of wavelengths, respectively during heating time from 3 to 18 h. Meanwhile, the transmission percentages decreased from 93.691 to 74.189%, from 92.411 to 73.878%, and from 4.942 to 1.055%. From previous results, the ultraviolet light with 200 nm wavelength was considered as absorption measuring for palm oil quality. Meanwhile, the infrared light with 900 nm of wavelength or the visible light with 700 nm wavelength are considered as transmission measuring for palm oil quality.

Table (2): Physical and chemical characteristics of the palm oil.

Sample	Heating time, h	Peroxide value, PV (meq O_2/kg)	Iodine value, IV (g I_2 /100 g)	Acid value, AV (mg KOH/ g)	Oxidized fatty acid, OFA (%)	Polymer, P (%)	Reflective index (RI), no.	Viscosity, C.P.
0	0	1.1	58.2	0.15	0.19	0.15	1.4646	69
1	3	6.5	57.11	0.22	0.31	0.26	1.4655	73
2	6	9.26	56.88	0.31	0.38	0.61	1.4663	78
3	9	11.13	56.35	0.36	0.45	0.81	1.4671	99
4	12	12.12	55.25	0.49	0.58	0.96	1.4672	105
5	15	11.03	55.13	0.53	0.79	1.43	1.4674	111
6	18	10.01	54.6	0.82	1.11	1.78	1.4676	122

Figs. (5) and (6) and table (2) shows the effect of heating time on transmission and absorption percentages and some physical and chemical characteristics of palm oil. It was noticed that the heating time increased from 3 to 18 h., that the increases lead to absorption increase and decrease of transmission, which lead to increased oxidized fatty

acid (OFA), polymer (P), acid value (AV), peroxide value (PV), viscosity (V), and reflective index (RI) from 0.19 to 1.11%, from 0.15 to 1.78%, from 0.15 to 0.82 mg KOH/g, from 1.1 to 10.1 meq O_2/kg, from 69 to 122 C.P., and from 1.4646 to 1.4676 n, respectively.

Meanwhile, the iodine value (IV) decreased from 58.2 to 54.6 g I_2 /100 g when heating times of palm oil ranged from 3 to 18 h. That means, the changing in heating time of palm oil changes physical and chemical characteristics which, lead to increased absorption percentages of ultraviolet light with 200 nm wavelength from 4.409 to 6.226%.

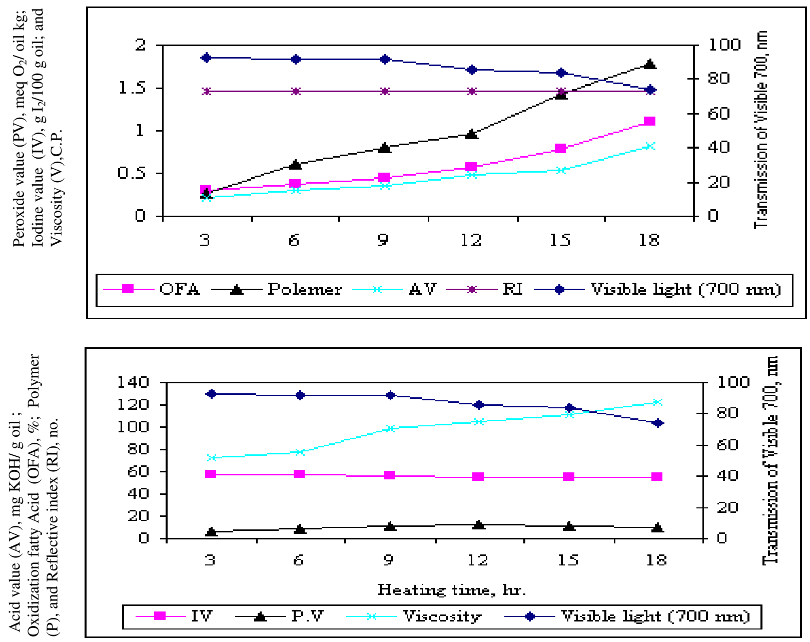


Fig. (5): Transmission percentages of heated palm oil at high wavelengths.

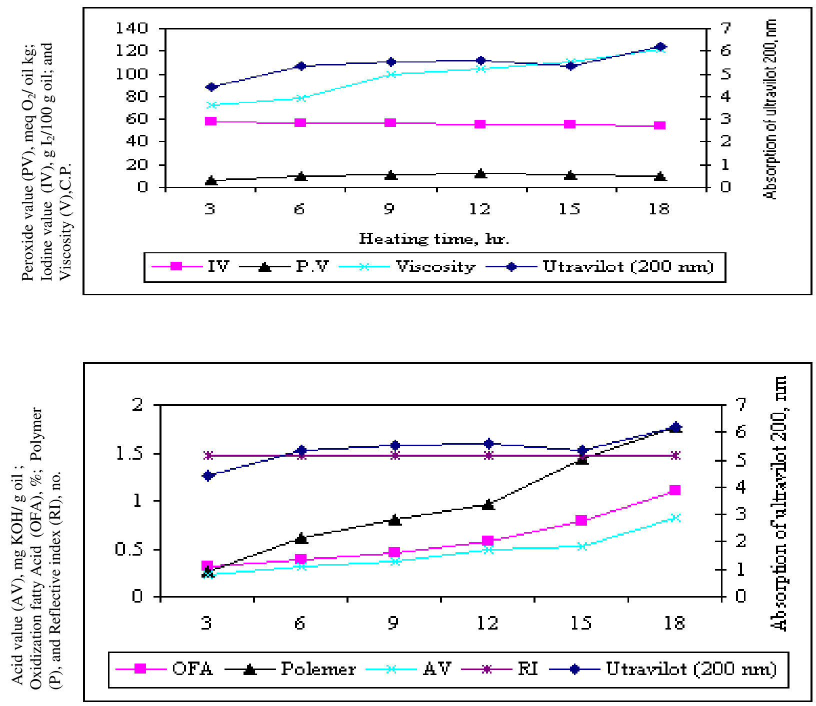


Fig. (6): Absorption percentages of heated palm oil at high wavelengths.

Meanwhile, the decreases in transmission percentage of infrared 900 nm wavelength was ranged from 93.691 to 74.189%, and visible light of 700 nm wavelength was ranged from 92.411 to 73.878%.

Also, table (2) shows the deterioration of palm oil will start after 18 hours of heating time, which oxidization fatty acid more than 1% (1.11%). As well, the transmission percentage measuring can indicate start of deterioration of palm oil with 73.87 and 74.18 % when using 700 nm (visible light) and 900 nm (infrared light) wavelengths, respectively. Meanwhile, the absorption percentage when measuring can be using in 6.226 % at 200 nm (ultraviolet light).

CONCLUSION

The obtained results are summarized as follows:

1- The light transmission percentages were found of 93.691, 92.411 and 4.942 % for using wavelengths of 900 nm (infrared light), 700 nm (visible light) and 400 nm (ultraviolet light), respectively.

2- The absorption percentages increased when using from 900 to 700 nm (Near Infrared lights), from 700 to 400 nm (visible lights), and from 400 to 200 nm (Ultraviolet lights). At the meantime, the transmission percentages decreased.

3- The light absorption percentages, which passed through heated palm oil were of 0.104, 1.38, and 6.23 % when using 700 nm (Near infrared light), 400 nm (visible light), and 200 nm (ultraviolet) wavelengths.

4- The absorption percentage was obtained by using ultraviolet light wavelength, to be used in measuring for quality palm oil.

5- It is possible to use 900 nm (infrared) or 700 nm (visible) wavelengths as measuring quality of heated palm oil but it is preferable to use 700 nm wavelength of visible light because it is more in common uses than others. Meanwhile, 200 nm wavelength was used as absorption percentage in measuring.

6- The heating times were increased from 3 to 18 h., that lead to increased oxidized fatty acid, polymer, acid value, peroxide value, viscosity, and reflective index from 0.19 to 1.11%, from 0.15 to 1.78%, from 0.15 to 0.82 mg KOH/g, from 1.1 to 10.1 meq O_2 /kg, from 69 to 122 C.P., and from 1.4646 to 1.4676 no., resp. While, the iodine value decreased from 58.2 to 54.6 g I_2 /100 g sample.

7- The changing in heating time of palm oil changes physical and chemical characteristics, which lead to increased absorption percentages of ultraviolet light with 200 nm wavelength from 4.409 to 6.226%. Meanwhile, this decreased transmission percentage of infrared 900 nm wavelength from 93.691 to 74.189 and of visible light of 700 nm wavelength from 92.411 to 73.878%.

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الملخص العربي

الأطوال الموجية فوق البنفسجية، والمرئية ، وتحت الحمراء لا ختبار جودة زيت النخيل

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يعتبر زيت النخيل من أعلى محاصيل الزيوت لوحدة المساحة بالنسبة لأى محصول ، وذو أهمية فى التجارة العالمية. ويهدف البحث الى دراسة جودة زيت النخيل عند تسخين العينات على درجة حرارة ١٨٠ o م والضغط الجوى لأزمنه مختلفة (٣ ،٦، ٩، ١٢ ، ١٥ ، ١٨ ساعة)
ثم تعريض هذه العينات للأشعة المرئية، وغير المرئية ، لتقدير الخصائص الضوئية للزيوت في ثلاث مناطق ضوئية مختلفة، وهى الأشعة الفوق البنفسجية (٢٠٠-٤٠٠ نانو متر)، والضوء مرئى (٤٠٠-٧٠٠ نانو متر)، والأشعة تحت الحمراء (٧٠٠-٩٠٠ نانومتر)...وكانت النتائج المتحصل عليها كالتالي:

١) وجدت أعلى نسبة مئوية للنفاذية ٩٣,٦٩١، ٩٢,٤١١ ، ٤,٩٤٢ % كانت عند إستخدام الأطوال الموجية ٩٠٠ (أشعه تحت الأحمر)، ٧٠٠ (ضوء مرئي) و٤٠٠ نانومتر (أشعة فوق البنفسجية) على التوالي.

١- باحث – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية – الجيزة - مصر.
٢- رئيس بحوث – معهد بحوث تكنولوجيا الأغذية – مركز البحوث الزراعية – الجيزة – مصر.

٢) تزداد النسبة المئوية للإمتصاص الضوئى بأنخفاض الطول الموجى من ٩٠٠ إلى ٧٠٠ نانو متر (أشعة تحت الحمراءِ) ، ومن ٧٠٠ إلى ٤٠٠ نانومتر (ضوء مرئى)، ومن ٤٠٠ إلى ٢٠٠ نانومتر (أشعة فوق البنفسجية). بينما تنخفض النسبة المئوية للنفاذية الضوئية.
٣) أعلى نسبة إمتصاص للضوء خلال زيت النخيل كانت ٠,١٠٤ ، ١,٣٨ ، ٦,٢٣ % عند استخدام الطول ٧٠٠ نانومتر (أشعةِ تحت الأحمرِ)، ٤٠٠ نانومتر (ضوء مرئي)، و٢٠٠ نانومتر (اشعة فوق البنفسجية).
٤) أدت زيادة زمن التسخين من ٣ الى ١٨ ساعه الى زيادة نسبة الأحماض الدهنية المؤكسده ، ونسبة البوليمر ، والرقم الحامضى ، وقيمة البيروكسيد ، واللزوجة ، ومعامل الأنكسار من ٠,١٩ إلى ١,١١ %، من ٠,١٥ إلى ١,٧٨ % ، من ٠,١٥ إلى ٠,٨٢ مج هيدروكسيد بوتاسيوم / ج عينه ، من ١,١ إلى ١٠,١ ملليمكافئ أوكسيجين / كج عينه ، من ٦٩ إلى ١٢٢ مم٢ /ثانية ، ومن ١,٤٦٤٦ إلى ١,٤٦٧٦ على التوالي. بينما إنخفضت قيمة الرقم اليودى من ٥٨,٢ إلى ٥٤,٦ ج يود / ج عينه.. حيث يتضح من ذلك ان زيت النخيل بدأ يفسد بعد زمن تسخين حوالى ١٨ ساعة نتيجة زيادة نسبة الأحماض المؤكسدة الى ١,١١% (أكبر من ١%).
٥) أتضح ان زيادة زمن تسخين زيت النخيل يؤدى الى تغيير فى الخصائص الطبيعية والكيميائية الذي يؤدى بالتالى الى زيادة النسبة المئوية للإمتصاص من الأشعة فوق البنفسجية ذات الطول الموجى ٢٠٠ نانومتر من ٤,٤٠٩ إلى ٦,٢٢٦ %. بينما أنخفضت النسبة المئوية للنفاذية عند اسنخدام الطول الموجى ٩٠٠ نانو متر من الأشعة تحت الحمراءِ من ٩٣,٦٩١ إلى ٧٤,١٨٩ % وعند استخدام الطول الموجى ٧٠٠ نانو متر من الضوء المرئي من ٩٢,٤١١ إلى ٧٣,٨٧٨ %.
٦) أنه يمكن إستخدام الطول الموجى ٩٠٠ نانو متر (أشعة تحت الحمراء) أو ٧٠٠ نانومتر (ضوء مرئى) كقياس لنسبة نفاذية الضوء (٧٤,١٨ و ٧٣,٨٧% على التوالى) لتقدير جودة زيت النخيل ويفضل إستخدام الطول الموجى ذو ٧٠٠ نانومتر لأنه شائع أكثر من الآخرين. بينما يستخدم الطول الموجى ٢٠٠ نانومتر (اشعه فوق بنفسجية) كمقياس لنسبة الإمتصاص الضوئى والتى عندها تصل نسبة الأمتصاص ٦,٢٢ % ويبدأ زيت النخيل فى الفساد.