

Influence of the apex angle of a hollow prism made from an ordinary commercial glass plate as a simple refractometer to the accuracy of the refractive index measurement of the edible oil

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Abstract. The influence of the apex angle of a hollow prism used as a simple refractometer to the accuracy of a refractive index measurement of the edible oil samples was studied. The hollow prism was made from an ordinary commercial glass plate with a thickness of 2 mm. The apex angle of the constructed hollow prism was varied. The edible oil sample used in this study was palm oil, namely the packaged, branded oil sample and the bulk oil sample. For measuring the refractive index, the oil sample was filled in the constructed hollow prism, and then a helium-neon laser beam was passed through the oil sample at a certain angle of incidence. The angle of minimum deviation of the transmitted laser He-Ne beam was measured and then was used for calculating the refractive index of the oil sample. The refractive index measurement was made using the hollow prism with different apex angles, ranging from 30° to 60° . The measurement accuracy was estimated by comparing the refractive index measured using the hollow prisms to that of obtained using a standard Abbe refractometer. It was found that the refractive index of the edible oil can be measured accurately by using the hollow prism. It was also found that the accuracy of the refractive index measurement significantly changes with the apex angle of the hollow prism. The refractive index values measured using this simple refractometer deviate up to 3,49% from the refractive index value measured using the standard Abbe refractometer, especially when the apex angle of the prism is 30° . The measurement results with high accuracies obtained when using the hollow prisms with apex angles of 45° and 60° . The optimum apex angle for the present constructed hollow prism is 45° . The refractive index obtained using the hollow prism with the apex angle of 45° is 1,4623 and 1,4438 for the bulk oil and the packed, branded oil samples, respectively. This result suggests that the apex angle of the prism used affects largely the accuracy of the refractive index measurement.

1. Introduction

Each food materials we use daily have a decent value of consumption by default. Determination of this standard value serves as a prevention of the abuse of use bringing about the bad impact on the health of costumers [1-2]. Thus, inspection of the quality of the food materials must always preserve. One basic important food material is edible oil. There are two kinds of edible oil including animal oil and vegetable oil and it already has a decent value of consumption. Normally along with other properties,



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physical and chemical parameters are used to determine the quality of cooking oil, such as chemical composition, viscosity, conductivity, reflectivity and refractive index [3]. Therefore, several instruments have been developed based on those parameters for determining the quality of vegetable oil such as refractometer, interferometer and Ostwald viscometer [4-8].

In the previous preliminary study, the present author has designed and constructed a simple refractometer for measuring the refractive index of edible oil [9]. The main components of the simple refractometer are a hollow prism as sample cavity and a He-Ne laser as a light source. A hollow prism is a prism made using glass plate with the center part of the prism is vacant. This cavity can be filled with gas or other fluids. Thus, a hollow prism is also commonly called as a fluid prism. This prism is a well-known tool used for determination refractive index of fluid and normally made from a high-quality glass for obtaining highly accurate estimation. The estimation of the refractive index of any fluid sample using the fluid prism based on the refraction of the passed light beam by the fluid sample [10-12]. The measurement of refractive index is carried out by measuring the minimum deviation angle, d_m of the light beam passed through the prism and the apex angle, A of the prism as expressed in the following equation (1).

$$n = \frac{\sin \frac{1}{2}(d_m + A)}{\sin \frac{1}{2} A} \quad (1)$$

n is the refractive index of the fluid sample; d_m is the minimum deviation angle of the light beam after passing through the prism, A is the apex angle of the prism. The minimum deviation occurs when the incident angle and refraction angle are equal. In the previous study, since there is a necessity to make a simple and cheap tool for quickly analyzing the quality of the edible oil sample, a hollow prism was made from an ordinary commercial glass easily available in market at very low cost. The constructed prism was used to make simple, cheap refractometer for determining quickly the quality of the edible oil. In the preliminary study, the thickness of the ordinary commercial glass plate used for constructing the hollow prism was 5 mm and the apex angle of the constructed hollow prism was 60°. As the results, the simple refractometer can be used to measure the refractive index of edible oil with relatively high accuracy, namely the refractive index of the new branded, packed oil sample and the new bulk oil sample is 1,5054 and 1,5152, respectively. These values differ only about 2,00-3,07% from the reference value of the refractive index of edible oil, namely 1,47. The previous results led to a conclusion that a simple refractometer consisting of a hollow prism made from an ordinary commercial glass and a He-Ne laser can be used to measure the refractive index of edible oil with a good measurement accuracy [9]. However, several physical parameters of the prism influence significantly the refractive index. As explicitly formulated in Eq. (1) Above, the apex angle, A determines the value of the refractive index. This present work is intended to study in greater detail the influence of the apex angle of the hollow prism to the measurement accuracy of the refractive index. Changing the apex angle to find the optimal apex angle of a hollow prism that allows for the highest accuracy of the refractive index measurement of the vegetable oil sample.

2. Experimental Procedure

The tool used in this work are a hollow prism and a green He-Ne laser ($\lambda = 594$ nm, 4 mW). The hollow prism constructed from the ordinary commercial glass plate (Asahi ACC) normally uses for house window and other furniture with apex angles of 30°, 45° and 60°. The thickness of the ordinary commercial glass plate is 2 mm. The dimension of each constructed prism is different depending on the intended apex angle. **Figure 1** shows a design of the hollow prism for an apex angle (A) of 60°. The dimension of both sides of the prism is 6,5 x 7,5 cm with the base length of 7,5 cm.

The edible oil sample used in this study is two kinds of palm oil samples, namely the bulk oil and the branded, packed oil samples. For measuring the refractive index, the He Ne laser light beam was passed through the hollow prism before and after the cavity of the hollow prism is filled with the oil sample. The deviation angle of the He-Ne laser beam is then measured as shown in **Figure 2**. The experimental procedure and setup are basically similar to our previous preliminary work published elsewhere [9]. Using the deviation angle and the apex angle, the refractive index of the oil sample is then calculated using equation (1). The refractive index of the edible oil samples was also measured using a standard Abbe Refractometer. To estimate the accuracy, the measurement was also carried out for a distilled water sample. The temperature of each oil samples was measured using a thermometer.

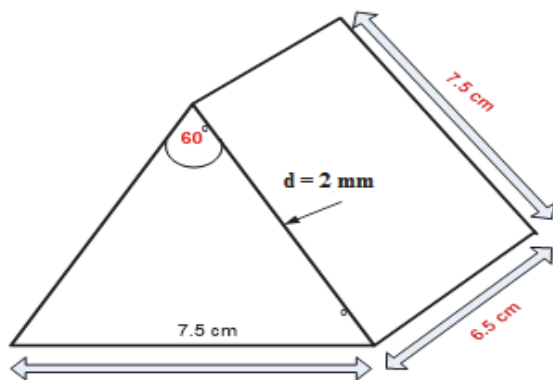


Figure 1. Design of a hollow prism with an apex angle of 60°

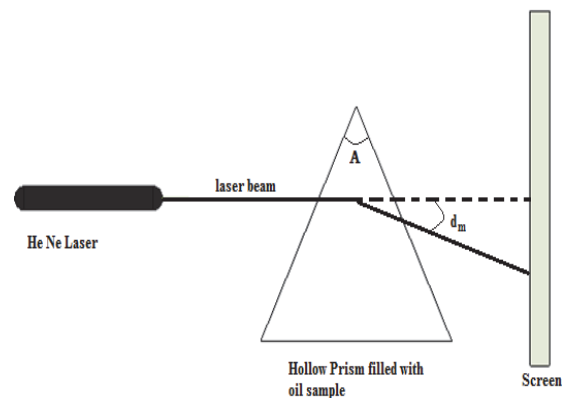


Figure 2. Experimental procedure for measuring the refractive index using the refractive index

3. Results and discussion

The hollow prism with different apex angles of 30° , 45° and 60° has been designed and constructed from an ordinary commercial glass plate with a thickness of 2 mm. Figure 3 shows the photographs of the hollow prisms with different apex angles and the laser He-Ne were used as a simple refractometer for measuring the refractive index of edible oil sample. Table 1 shows the refractive index of the bulk palm oil sample measured using the hollow prisms with different apex angles. To estimate the measurement accuracy, the refractive index of the oil sample was also measured using a standard Abbe refractometer and found that the refractive index of the bulk oil sample is 1,4586. The refractive index measured by using the simple refractometer is then compared to the refractive index measured using the standard Abbe refractometer. It can be seen that the apex angle of the hollow prism strongly influences to the measurement of refractive index. The largest value of the refractive index was obtained when using the hollow prism with an apex angle of 30° , while the smallest is when using the hollow prism with an apex angle of 45° . The smallest, 1,4623, is the closest value to the reference value of the refractive index and it deviates only 0.25% from the refractive index value measured using the standard Abbe refractometer. The deviation is expressed in percentage by comparing the measurement results obtained by using the hollow prism to that of using the standard Abbe refractometer.

These results display that the apex angle of the hollow prism determines largely the accuracy of the refractive index measurement. The refractive index measured using the hollow prism with apex angles of 30° and 60° shows higher values, namely 1,5095 and 1,4829, respectively and also larger deviations, namely about 3,49% and 1,16%, respectively from the refractive index measured using the standard Abbe refractometer. The refractive index measured using the hollow prism with the apex angle of 45° exhibits a far lower deviation from the standard Abbe refractometer measurement result, namely 0,25%. The refractive index obtained using the hollow prism with 45° is much closer to the reference value in comparison with the results obtained using the hollow prism with apex angles 30°

and 60°. It can be observed from the results shown in Table 1 there is a general tendency that the smaller apex angle of the hollow prism the higher refractive index obtained. However, these results figure out that the change of the refractive index with a different apex angle of the hollow prism is not purely linear. Thus there is an optimum apex angle of the hollow prism to bring about measurement with high accuracy. The optimum apex angle is featured by the closest value of the measured refractive index to the reference value. As mentioned above, the reference value of the refractive index of the oil sample is the refractive index value measured by using the standard Abbe refractometer. In case of the bulk palm oil sample, the optimum apex angle of the hollow prism is 45°. This implies that the highest measurement accuracy is obtained using the hollow prism with apex angle of 45°. Similar results were also observed for the branded, packed oil palm sample.

Table 1. Refractive index of the bulk palm oil measured employing the simple refractometer

Apex angel (A, degree)	Thickness of the glass plate, (mm)	Refractive index (n)	Deviation from Abbe refractometer (%)
30,0	2	1,5095±0,0001	3,49
45,0	2	1,4623±0,0000	0,25
60,0	2	1,4829±0,0001	1,16

Table 2. Refractive index of the branded, packed palm oil measured employing the simple refractometer

Apex angel (A, degree)	Thickness of the glass plate, (mm)	Refractive index (n)	Deviation from Abbe refractometer (%)
30,0	2	1,4993±0,0004	2,60
45,0	2	1,4438±0,0028	-1,54
60,0	2	1,4829±0,0001	1,16

Table 3. Refractive index of the distillate water measured employing the simple refractometer

Apex angel (A, degree)	Thickness of the glass plate, (mm)	Refractive index (n)	Deviation from Abbe refractometer (%)
30,0	2	1,3570 ± 0,0023	2,03
45,0	2	1,3306± 0,0002	0,04
60,0	2	1,3293±0,00017	-0,02

Table 2 displays the refractive index of the branded, packed oil samples measured by using the hollow prisms with different apex angles of 30°, 45°, and 60°. It can be seen the refractive index of the oil sample changes with apex angle. It is considered although the bulk palm oil sample and the branded, packed oil sample are originally made from the similar raw material, their qualities are different. Thus there is different in their physical and chemical properties at certain extend. The measurement results are shown in Table 1 and Table 2 confirm the difference of the refractive index from the bulk palm oil sample and the branded, packed oil sample. However, the measurement results for the branded, packed oil sample exhibited in Table 2 shares a similar tendency to that for the bulky oil sample shown in Table 1 above regarding the refractive index values and measurement accuracy. The highest value of

the refractive index of the oil sample was obtained in case of using the hollow prism with the apex angle of 30° while the lowest is in case of using the hollow prism with the apex angle of 45° . It also can be seen that in case of using the hollow prism with apex angle of 45° , the value of refractive index measured displays the smallest deviation from the measurement result using the standard Abbe refractometer, while in case of using the hollow prisms with apex angles of 30° and 60° the deviation increases. The minus (-) in Table 2 and Table 3 imply that the present measurement gets lower value than the Abbe refractometer measurement.

To confirm the accuracy of the hollow prism and the tendency observed for the oil sample, the same measurement was carried out for distillate water sample. Distillate water was used a standard fluid since its chemical and physical properties are well known and unaltered during the experiment. As exhibited in Table 3, it can be seen that the values of the refractive index of the distillate water samples measured using the hollow prisms with different apex angles of 30° , 45° and 60° are very close to the reference value of the refractive index of water, namely 1.33. The deviations of the results measured using the hollow prism from that of obtained using the Abbe refractometer are relatively lower compared to the cases of the bulk oil and the branded, packed oil samples, ranging from -0.02% to 2.03%. This means the measurement of the refractive index using the hollow prism for the distillate water is more accurate than that for the cases of the oil samples. This is probably due to the chemical and physical properties of the distillate water. The result shown in Table 3 displays several important points. Firstly, these results confirm that the hollow prisms made from the ordinary commercial glass plate can be used for measuring the refractive index of fluid including oil and water samples with high accuracy. Secondly, these results display a consistent tendency to the results obtained for the oil samples, namely the apex angle of the hollow prism significantly influences the refractive index values. The higher value of the refractive index observed is in case of using the hollow prism with the apex angle of 30° , the same as observed for the cases of the bulk oil and the branded, packed oil samples. From Table 3, it is observed a general tendency that the smaller apex angle of the hollow prism used yields higher value of refractive index obtained means the higher deviation from the reference value. However the tendency is also not purely linear, similar to the cases of the bulk oil and the branded, packed oil samples. The optimum apex angle of the hollow prism showing the highest measurement accuracy in this case of the distillate water is 45° , the same as the cases of the bulk oil and the branded, packed oil samples. Finally, these results also confirm that the apex angle of the constructed hollow prisms influence significantly measurement accuracy of the refractive index, since the deviation of the refractive index values of the distillate water samples measured using the hollow prisms with different apex angles from the results obtained using the Abbe refractometer changes significantly with the apex angle. The deviation pattern, in this case, shares similarity to the cases of the bulk oil and the branded, packed oil samples, namely the largest deviation observed for the case of the hollow prism with the apex angle of 30° . These confirm the strong influence of the apex angle of the hollow prism to the accuracy of the refractive index measurement. On the other hand, the hollow prisms were constructed using glass plate with a thickness of 2 mm. These results probably will be affected by the difference in the glass plate thickness. Thus other study is being conducted to examine the influence of the glass plate thickness to the accuracy of refractive index measurement and will be published elsewhere in the near future.

4. Conclusion

The hollow prism made from the ordinary commercial glass plate and the He-Ne laser as a light source can be used for measuring the refractive index of the vegetable oil samples including the bulk oil and the branded, packed oil samples. The accuracy of the refractive index measurement using the hollow prism for the oil samples was also confirmed using the distillate water sample. Comparing the measurement results obtained using the hollow prism for the three kinds of samples, namely the bulk edible oil, the branded, packed edible oil, and the distillate water to the results obtained by means of the standard Abbe refractometer confirms that the accuracy of the refractive index measurement using the hollow prisms made from the ordinary glass plate is relatively high since the refractive index of the

samples, obtained from the measurement, is very close to that of measured by the standard Abbe refractometer. It was found that the apex angle of the hollow prism determine the measurement accuracy. From the present study, the measurement with high accuracies obtained using the hollow prisms with apex angles of 45° and 60° since for the three kinds of samples, the deviation of the refractive index measured using the hollow prism from that measured using the standard Abbe refractometer is much smaller in comparison with those of using the hollow prism with apex angles of 30° . The refractive index measured using the hollow prism with the apex angle of 30° shows a largest deviation, in present case up to 3.49% from the reference data of Abbe refractometer result. As the deviation for the hollow prism with apex angle of 45° is in the range of 0,04 to 1,54 % for three samples, thus it is suggested that the apex angle of 45° is the optimal apex angle of the present simple hollow prism design.

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