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Quality Assessment of Commercially Available Coconut Oils in Sri Lanka Using Refractometry

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ABSTRACT

Commercially available white, pale yellow and dark yellow coconut oil samples were obtained from eight locations in Sri Lanka and their refractive indices were measured at room temperature 28°C in the wavelength range of 410 – 630 nm using refractometric techniques. Experimental data were fitted to Caushy dispersion formula with a high accuracy (r^2 = 0.98). The refractive index for a given wavelength showed the variation, $n_w < n_p < n_d$ (where n_w, n_p, n_d represents respectively white, pale yellow and dark yellow coconut oils). Independent of its colour, the refractive index decreased monotonically with increasing wavelength. The observed refractive indices of the tested coconut oil samples were higher than the values specified by Sri Lankan Food Act, no. 26 of 1980. The calculated density values of coconut oils samples complied with the accepted norms, independent of the colour of coconut oils.

1. INTRODUCTION

Coconut oil is obtained from coconut fruit is the species *Cocos nucifera* which is an important and essential commodity in Sri Lanka which people use in day to day life. Coconut oil is rich in lauric acid, other medium chain fatty acids (MCFT), and many medium chain triacylglycerols (MCT) with nearly 90% saturated fat [1, 2]. Since saturated fat is associated with the elevation of serum cholesterol levels in the human body, common argument was that the usage of coconut oil is unhealthy. However, many research studies have shown the health benefits of coconut oil due to the presence of MCFT and MCT in coconut oil because they tend to increase HDL cholesterol levels rather than LDL cholesterol levels [3, 4].

The quality of coconut oil depends on the method of extraction from the source. There are two methods of extraction; namely, the dry process and the wet process. The most commonly used method is the dry process where initially the meat to be extracted from the coconut shell is dried using fire or sunlight to produce copra. Then it is pressed manually or in crushes or expellers using solvents to extract coconut oil [5]. The wet process, involves raw coconuts rather than dried copra, coconut milk is obtained first by pressing the coconut fresh meat without drying. The oil is then separated from the water using techniques such as boiling, fermentation, refrigeration, enzymes and mechanical centrifuge etc. [5].

The colour of coconut oils available in the market varies from white to pale yellow to dark yellow. The term “virgin” usually refers to oil that is pure and unadulterated. Virgin coconut oil (VCO) extracted from fresh coconuts with little or no heat and no chemicals are naturally white or clear at room temperature and maintain a

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mild coconut aroma and flavour [6]. Yellow coconut oil could result when VCO is heated to excessive temperatures where oil undergoes hydrogenation resulting in trans-fatty acids [6]. When heated beyond smoke point of 180°C of coconut oil, it turns to dark yellow and will have a strong flavour [6]. In order to make Coconut oil to be more stable and long lasting, manufacturers heat coconut oil excessively and is subjected to partially or fully hydrogenation. However, the hydrogenation process creates *trans*-fatty acids which are unhealthy for human consumption [3, 6].

The refractive index is a physical parameter that could be used to monitor the variation of colour of a substance. Refractive index of a refractometer measurement in general is remarkably re-producible and it is a useful parameter to confirm the identity of mixtures [12]. Refractometric methods could be carried out without the use of sophisticated and high cost instrumentation. There are many methods that could be used to determine the refractive index of a liquid. Some of these methods are namely, the Brewster angle method [7], total reflection ellipsometry [8] and minimum deviation method [9, 10]. For the present study critical angle method [11] has been used to determine the refractive index of coconut oil.

2. THEORY

2.1 Critical angle method [11]

In a prism ABC consisting of an unpolished mat face BC is illuminated with an extended monochromatic light source, where each point acts as a source sending rays into the prism in all directions. If light from point S on the mat surface BC traverses to the face AB of a prism covered with a thin layer of liquid, internally there is a unique ray ST that is incident on the face AB at a critical angle α which corresponds to an angle of incidence β and angle of emergence γ from the surface AC (Fig. 1).

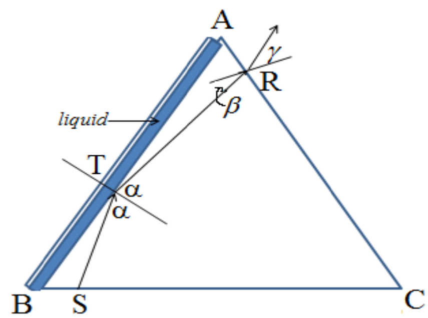

Fig. 1: Ray diagram to determine the refractive index of a liquid

If the refractive index of prism and liquid are μ_g and μ respectively, and $\hat{A}$ is the prism angle, at the glass-liquid interface AB: $\mu = \mu_g \sin\alpha$; (1)

at the glass-air interface AC: $\sin\gamma = \mu_g \sin\beta$; (2)

from geometry: $\hat{A} + \beta = \alpha$ (3)

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Using equations (1), (2) and (3), it can be shown theoretically [11] that the refractive index of the liquid is given by

$$\mu = \sin A\sqrt{\mu_g^2 - \sin^2\gamma} \pm \cos A \sin\gamma \quad (4)$$

The sign on the second term could be either + or – depending on side of the normal to the surface AC the angle γ lie.

In the absence of a liquid on face AB, μ = 1 and it can be shown theoretically [11] that the refractive index of the liquid is given by

$$\mu_g^2 = 1 + \left(\frac{\sin\gamma + \cos\hat{A}}{\sin\hat{A}}\right)^2 \quad (5)$$

When the prism angle is known, by measuring γ with the prism alone, equation (5) gives its refractive index. μ_g. If γ is then measured with a liquid on face AB, equation (4) the refractive index of the liquid μ could be determined.

3. MATERIALS AND METHODOLOGY

Standard adjustments of the spectrometer were done initially with the eye piece, telescope, collimator and prism table using Sodium light in order to optimize the spectrometer for measurements. The prism angle was determined using standard methods. Illuminate the mat surface BC of the prism without liquid layer (Fig. 1) directly with sodium light and observed the demarcation in the field of view through the surface AC. Since a particular demarcation line was not visible, a setup with a digital illuminance meter (Topcon Corp., Japan) fixed to the telescope was used in order to take accurate readings. Relevant readings were taken corresponding to the maximum intensity of the broad intensity profile observed in the field of view through the surface AC. It was ensured that the intensity profile is maximum at the centre of the field of view. Using equation (5), computed the refractive index of glass of the material of the prism (μ_g). The same procedure was repeated when the surface AB is covered with a thin film of distilled water (Figure 2). Using equation (4) determined the refractive index of distilled water at room temperature in order to test the accuracy of measurements. The sodium lamp was then replaced by a white light source powered by a 6V transformer. White light was filtered using seven optical filters (Paton Hawksley Education Ltd., UK) of wavelength ranges in the visible region corresponding to purple (λ = 410 ± 20 nm), primary blue (λ = 450 ± 20 nm), secondary peacock blue or cyan (λ = 490 ± 5 nm), secondary magenta (λ = 510 ± 10 nm), primary green (λ = 540 ± 20 nm), secondary yellow (λ = 580 ± 10 nm) and primary red (λ = 650 ± 30 nm).

Then the AB surface (Fig. 2) was covered with a thin film of coconut oil and relevant readings were taken for the considered wavelengths of light. The refractive index of coconut oil was computed using equation 4. This procedure has been repeated for white, pale yellow and dark yellow coconut oils obtained from eight locations in Sri Lanka. From each location, a minimum of two samples have been obtained at two different times and used to take measurements.

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The density measurements of coconut oils was carried out using gravimetric technique and the mean density corresponding to different colour ranges of coconut oils has been determined to an accuracy ± 0.001 g cm^{-3}.

4. RESULTS AND DISCUSSION

The calculated refractive index values as a function of wavelength for white, pale yellow and dark yellow coconut oils obtained from different areas in Sri Lanka are summarized in Tables 1, 2 and 3 with their uncertainties. The data in Tables 1, 2 and 3 are used to compute the mean refractive indices for considered wavelength for coconut oil corresponding to its colour (Table 4).

Table 1: Refractive indices of white coconut oils at different wavelengths

Area	Wavelength (nm)						
	410	440	490	510	540	580	630
	Refractive index at temperature 28 °C						
Panchikawatta	1.482 ± 0.001	1.478 ± 0.001	1.473 ± 0.001	1.475 ± 0.001	1.469 ± 0.002	1.467 ± 0.002	1.465 ± 0.002
Bokundara	1.484 ± 0.001	1.481 ± 0.001	1.477 ± 0.001	1.476 ± 0.001	1.474 ± 0.002	1.470 ± 0.002	1.464 ± 0.002
Galle	1.484 ± 0.001	1.482 ± 0.001	1.478 ± 0.001	1.477 ± 0.001	1.475 ± 0.001	1.472 ± 0.002	1.469 ± 0.002
Homagama	1.486 ± 0.001	1.482 ± 0.001	1.475 ± 0.001	1.473 ± 0.002	1.471 ± 0.002	1.468 ± 0.002	1.465 ± 0.002
Kegalle	1.483 ± 0.001	1.480 ± 0.001	1.477 ± 0.001	1.475 ± 0.001	1.470 ± 0.001	1.468 ± 0.002	1.467 ± 0.002

Table 2: Refractive indices of pale yellow coconut oils at different wavelengths

Area	Wavelength (nm)						
	410	440	490	510	540	580	630
	Refractive index at temperature 28 °C						
Panchikawatta	1.496 ± 0.001	1.488 ± 0.001	1.476 ± 0.001	1.472 ± 0.002	1.469 ± 0.002	1.471 ± 0.002	1.467 ± 0.002
Kurunegala	1.493 ± 0.001	1.490 ± 0.001	1.483 ± 0.001	1.479 ± 0.001	1.477 ± 0.001	1.475 ± 0.002	1.469 ± 0.002
Bokundara	1.495 ± 0.001	1.489 ± 0.001	1.483 ± 0.001	1.479 ± 0.001	1.478 ± 0.002	1.471 ± 0.002	1.467 ± 0.002
Negombo	1.496 ± 0.001	1.491 ± 0.001	1.485 ± 0.001	1.480 ± 0.001	1.478 ± 0.001	1.476 ± 0.002	1.466 ± 0.002
Galle	1.492 ± 0.001	1.488 ± 0.001	1.481 ± 0.001	1.478 ± 0.001	1.475 ± 0.002	1.469 ± 0.002	1.468 ± 0.002
Kegalle	1.495 ± 0.001	1.491 ± 0.001	1.482 ± 0.001	1.481 ± 0.001	1.476 ± 0.001	1.473 ± 0.002	1.467 ± 0.002

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Table 3: Refractive indices of dark yellow coconut oils at different wavelengths

Area	Wavelength (nm)						
	410	440	490	510	540	580	630
	Refractive index at temperature 28 °C						
Negombo	1.498 ± 0.001	1.491 ± 0.001	1.484 ± 0.001	1.481 ± 0.002	1.476 ± 0.002	1.474 ± 0.002	1.467 ± 0.002
Seeduwa	1.498 ± 0.001	1.492 ± 0.001	1.485 ± 0.001	1.481 ± 0.001	1.475 ± 0.002	1.474 ± 0.002	1.466 ± 0.002
Homagama	1.497 ± 0.001	1.493 ± 0.001	1.481 ± 0.001	1.479 ± 0.001	1.474 ± 0.002	1.473 ± 0.002	1.467 ± 0.002

Table 4: Refractive indices (mean values) for white, pale yellow and dark yellow coconut oils at different wavelengths

Colour	Wavelength (nm)						
	410	440	490	510	540	580	630
	Refractive index at temperature 28 °C						
White	1.484 ± 0.001	1.481 ± 0.002	1.476 ± 0.002	1.475 ± 0.001	1.472 ± 0.003	1.469 ± 0.002	1.466 ± 0.002
Pale yellow	1.495 ± 0.002	1.490 ± 0.001	1.482 ± 0.003	1.478 ± 0.003	1.476 ± 0.003	1.473± 0.003	1.467 ± 0.002
Dark yellow	1.498 ± 0.001	1.492 ± 0.001	1.483± 0.001	1.481 ± 0.001	1.475 ± 0.002	1.474 ± 0.002	1.467 ± 0.002

The refractive index of a dielectric substance is dependent on the wavelength and it has been demonstrated that Cauchy formula could be used to accurately fit dispersion data [12]

$$n = A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4} + \frac{D}{\lambda^6} \quad (6)$$

where *A*, *B*, *C*, and *D* are constants. Fig. 2 shows the plot of mean refractive index against wavelength for white, pale yellow and dark yellow coconut oils.

Equation (6) was fitted for the dispersion curves with high r^2 values ($r^2 > 0.98$) for the considered spectral range. Data tables (Tables 1, 2 and 3) and the plot in Figure 2 shows that the refractive index for a given wavelength is largest for dark yellow coconut oil and decreases as the colour varied from pale yellow to white. All variations follow the Cauchy dispersion formula where the refractive index of a given colour of coconut oil decreases monotonically with increasing wavelength. Cauchy constants were calculated corresponding to white, pale yellow and dark yellow oils are summarized in Table 5.

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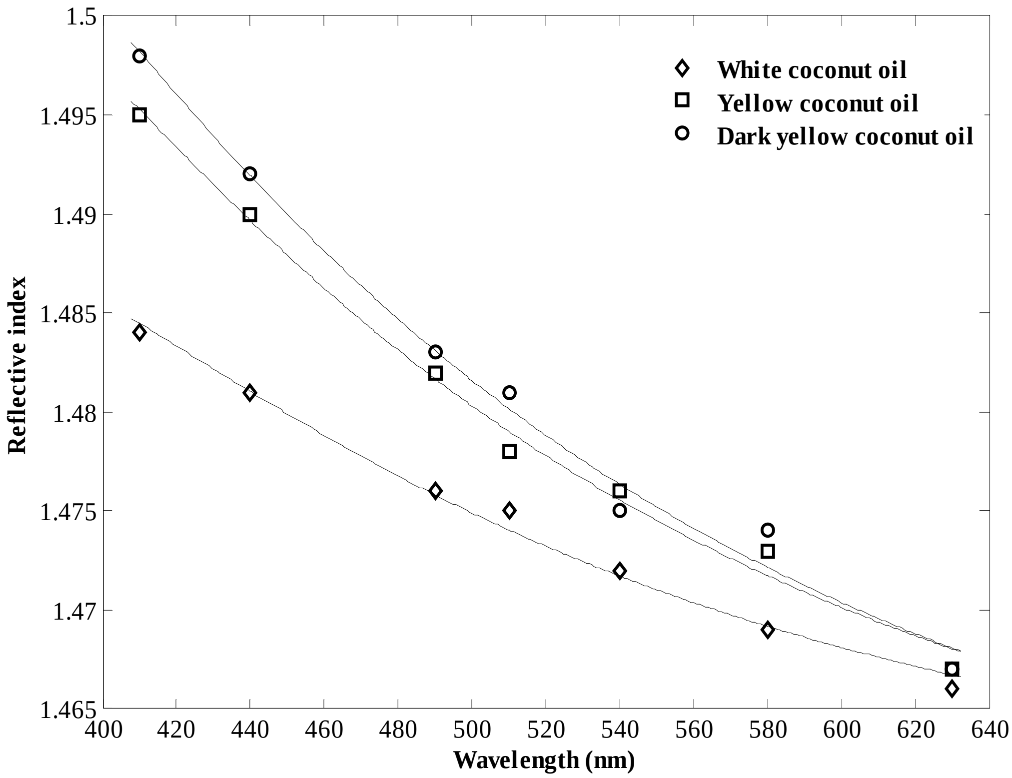

Fig. 2: The plot of mean refractive index against wavelength for white, pale yellow and dark yellow coconut oils measured at 28°C

Table 5: Cauchy constants for different colour ranges of coconut oil

Colour	A	B	C	D
White	1.457	1788	1.07×10^{9}	-1×10^{14}
Pale yellow	1.451	4559	1.07×10^{9}	-1×10^{14}
Dark yellow	1.449	5398	1.07×10^{9}	-1×10^{14}

For the colour variation of coconut oils from white to pale yellow to dark yellow, the Caushy constant *A* decreases. However it is compensated by a greater increase in *B* values of Caushy constants for the same colour variation. As Caushy constants *C* and *D* remains constant for the colour variation, there is a net increase in refractive index for coconut oil colour varied from white to pale yellow to dark yellow.

Yunus *et.al* have reported measurements for VCO in Malaysia at temperature 25° C, in the wavelength range of 491.0 – 667.8 nm, the refractive index is shown to vary in the range of 1.462 –1.448. [13] In the present study, the measurements carried out at 28° C indicates that in the wavelength range of 400.0 – 640.0 nm, the refractive index of white coconut oil vary in the range of 1.484 –1.466. The refractive index of pale

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yellow and dark yellow coconut oil vary in the range of 1.498 –1.466. According to the Sri Lankan Food Act, no. 26 of 1980, coconut oil should have a refractive index at 40° C between 1.4485 and 1.4492. [14] Khodier has reported temperature dependence of refractive index of standard oils and the variation shows that the refractive index decreases linearly by approximately 0.014 in temperature range of 20 °C – 50 °C (i.e. dn/dT = 0.00046 $°C^{-1}$) for oils having refractive indices in the range of accepted refractive index norm of coconut oil [15]. From the present experimental results and using dn/dT value, when estimated the refractive index of white coconut oil at 40° C gives the range of 1.478 –1.460 for the considered wavelength range.

The dispersion curves in Figure 2 corresponding to white, pale yellow and dark yellow coconut oil show that they tend to coincide with each other at larger wavelengths. The graphs were extrapolated to larger wavelengths according to equation (3). It has been found that they coincide with each other at three different wavelengths: 635.90 (pale yellow& dark yellow), 682.57 (white & dark yellow), 698.85 (white & pale yellow) in the visible region.

Independent of the colour of coconut oils, the measured mean relative density value of coconut oils at 28 °C was 0.917 ± 0.001 g cm^{-3}. These results are compatible with already published results for coconut oil at the given temperature. [16]

5. CONCLUSION

In this study the refractive index of commercially available white, pale yellow and dark yellow coconut oil samples was successfully measured as a function of wavelength in the spectral range of 410 – 630 nm and at temperature 28 °C. Experimental data was fitted to Cauchy dispersion formula to obtain Cauchy constants *A*, *B*, *C* and *D*. The refractive index of a given colour of coconut oil decreased monotonically with increasing wavelength. The refractive index for a given wavelength was largest for dark yellow coconut oil. It decreased as the colour is varied from pale yellow to white. The observed refractive indices of the tested coconut oil samples were higher than the values specified by Sri Lankan Food Act, no. 26 of 1980. The calculated density values of coconut oils samples complied with the accepted norms independent of the colour of coconut oils.

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