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Specific Heat Capacity, Density and Viscosity Determined Using Different Combinations of Coconut Oil and Palm Kernel Oil

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ABSTRACT

The specific heat capacity, density, and viscosity of oils are influenced by their chemical composition, temperature, and mixture ratios. Palm kernel oil and coconut oil exhibit distinct physical properties due to their unique fatty acid profiles. This study adopted standardized and precise experimental protocols, with aim of ensuring accuracy, consistency, and reproducibility of results. Both oils (palm kernel oil and coconut oil were sourced from a reliable supplier to ensure consistency in quality and composition; both oils were stored in airtight containers at room temperature to prevent oxidation and contamination. Prior to experiments, the oils were checked for any signs of degradation or impurities. The results showed distinct variations in thermal and physical properties depending on the composition of the oil mixtures, coconut oil displayed a specific heat capacity of approximately 2.01 J/g°C, while palm kernel oil had a slightly higher specific heat capacity of 2.15 J/g°C. As the ratio of palm kernel oil increased in the mixtures, there was a corresponding increase in specific heat capacity, indicating that palm kernel oil retains more heat per gram compared to coconut oil; the density measurements showed that palm kernel oil had a density of approximately 0.923 g/cm³, while coconut oil had a density of 0.911 g/cm³; the viscosity results highlighted that palm kernel oil exhibited a lower viscosity compared to coconut oil. Pure coconut oil showed a viscosity of 46.4 mPa·s, while palm kernel oil's viscosity was measured at 45.7 mPa·s.

Keywords:
Specific Heat Capacity,
Density of Oils,
Viscosity Measurement,
Coconut Oil–Palm Kernel Oil Mixtures,
Thermophysical Properties.

INTRODUCTION

The relevance of specific heat capacity, density and viscosity of some food products like coconut and palm kernel oil cannot be over-emphasized. However, the knowledge of specific heat capacity, density and viscosity of coconut and palm kernel oils as well as their mixtures pose great essentiality to the field of applied sciences, understanding of industrial applications, food processing and biodiesel production. In order words, the knowledge of the specific heat capacities aid in effective appreciation of oil behaviour and characteristics for different technological processes (Alakaki *et al.*, 2012). These three (3) properties are correlated and their interrelationship are dependent on cogent factors such as temperature, pressure and molecular composition.

Specific heat capacity (C_p) of oil is defined as the amount of heat required to raise the temperature of a unit mass of a substance by one degree Celsius (J/kg·K) (Fasina and Colley, 2008). The specific heat capacity is dependent on the oil characteristics and temperature that is to say that the fluctuation in these variables tend to influence specific heat capacities of oil (Sheng *et al.*, 2022). The density (ρ) of oil is the mass of oil per unit volume of a substance, it predicts the compact behaviour of oil. The higher density usually indicates stronger intermolecular forces and lower molecular mobility (Rizvi and Shin, 2021). Viscosity (μ) of an oil measures a fluid's resistance to deformation or flow (Pa.s). It reflects the internal friction between fluid layers. The inter-relationships between each of these properties of oil is imperative for designing efficient thermal systems, selecting appropriate materials for heat exchange and optimizing fluid flow processes (Nduka *et al.*, 2021).

In the present work, an experiment is conducted to determine specific heat of different combination of oils, coconut oil and palm kernel oil by means of function of temperature with respect to time. To validate the experiment, specific heat of water is determined and compared the result with the specific heat of water as it having well-known value.

MATERIALS AND METHODS

Materials and Equipment

The following were some of the materials used: oil (palm kernel oil (oil A) and coconut oil (oil B). The oils were sourced from a reliable supplier to ensure consistency in quality and composition. Both oils were stored in airtight containers at room temperature to prevent oxidation and contamination. Prior to experiments, the oils were checked for any signs of degradation or impurities. The following equipment were used in the study: calorimeter which was used to measure the specific heat capacity of the oil samples, density meter which was used to determine the density of the oil mixtures; viscometer which measured the viscosity; analytical balance which was used to measure the weight of the oil samples; temperature control unit which was used to maintain and regulate the temperature of the oil samples during experiments; glassware which measured the sample preparation and measurements.

Sample preparations

100% pure palm kernel and coconut oil were prepared by pouring the oil into a clean, dry beaker ensuring no contamination between the two oils. Series of oil mixtures were prepared by combining palm kernel oil and coconut oil in varying proportions. The mixtures included the following ratios by volume: 100:0, 90:10, 80:20, 70:30, 60:40, 50:50, 40:60, 30,70, 20:80, 10:90, and 0:100. Each mixture was prepared by accurately measuring the required volumes of palm kernel and coconut oils using a pipette and combining them in a clean beaker. The mixtures were thoroughly stirred to ensure homogeneity.

Measurement of Specific Heat Capacity

The specific heat capacity of the oil samples was measured using a differential scanning calorimeter (DSC). The DSC setup included a sample pan, reference pan, and a controlled heating chamber. The device was calibrated using standard materials with known specific heat capacities. The density of the oil samples was measured using a digital density meter. The density meter was equipped with a U-tube sensor and a temperature control unit to ensure precise measurements. The viscosity of the oil samples was measured using a rotational viscometer. The viscometer was equipped with a temperature control unit to maintain a consistent measurement environment.

Quality Control and Assurance

To ensure the reproducibility of the results, each measurement was repeated at least three times. The average values and standard deviations were calculated to assess the consistency of the data. All instruments were calibrated regularly using standard reference materials to maintain accuracy. Calibration checks were performed before and after each set of measurements to ensure the reliability of the data. Strict protocols were followed to prevent contamination and degradation of the oil samples. All glassware and equipment were thoroughly cleaned and dried before use. Samples were handled with care to avoid introducing impurities or air bubbles. All data were verified by cross-checking with known values from the literature. Any discrepancies were investigated and resolved by repeating the measurements or adjusting the experimental setup

Data Analysis

The specific heat capacity data obtained from the DSC was analyzed using the software provided with the DSC. The software calculated the specific heat capacity based on the heat flow data and the mass of the sample. The results for each oil sample and mixture were compared to identify trends and variations with composition. The density data from the density meter was analyzed by calculating the average density for each sample. The relationship between the density and the composition of the oil mixtures was examined using linear regression analysis to determine how density changes with varying proportions of palm kernel and coconut oils. The viscosity data from the rotational viscometer was analyzed by plotting the flow curves for each sample. The average viscosity at a representative shear rate was calculated for each sample. The relationship between viscosity and oil composition was examined using polynomial regression analysis to identify trends and variations.

RESULTS AND DISCUSSION

Results for specific heat capacity of coconut oil and palm kernel oil in several ratios by cooling method

Table 1: Specific Heat Capacity of Coconut and Palm Kernel Oil at 100: 0 (Coconut Oil) with Respect to Varying Time and Temperature

Time(mins)	Temperature of water (◦c)	Temperature of Oil (◦c)
0.0	70	70
2	69	68.5
4	68	67
6	67	66
8	66	63.5
10	65.5	62
12	65	61
14	64.5	59.5
16	64	58
18	63	57
20	62	57

Mass of the empty calorimeter (Mc): 61.6grams, Mass of the calorimeter + oil (Mc+o): 151.6grams, Mass of the calorimeter + water (Mc+w): 160.4grams, Mass of the oil (Mo): 90grams, Mass of water (Mw): 98.8grams, Specific heat capacity of water (Cw): 4.2 J/g◦c, Specific heat capacity of oil (Co):?

Calculation

(MwCw+McCc) $(\partial\theta/\partial T)$= (MoCo+McCc) $(\partial\theta/\partial T)$
(98.8*4.2 + 61.6*0.38)(68-64.5/10) = (90Co +61.6*0.38) (67-59.5/10)
(414.96+23.41)(0.35) = (90Co + 23.41) (0.75)
153.34 = 67.5Co + 17.56
Co = 153.34 – 17.56/67.5
= 2.01 J/g◦c

Table 2: Specific Heat Capacity of Coconut and Palm Kernel Oil at 90:10 (Coconut Oil and Palm Kernel Oil) with Respect to Varying Time and Temperature

Time(mins)	Temperature of water (◦c)	Temperature of Oil (◦c)
0.0	70	70
2	69	68.5
4	68	66.5
6	67	65
8	66	63
10	65.5	62
12	65	60
14	64.5	59
16	64	57.5
18	63	57
20	62	56.5

Mass of the empty calorimeter (Mc): 61.6grams, Mass of the calorimeter + oil (Mc+o): 151.2grams, Mass of the calorimeter + water (Mc+w): 160.4grams, Mass of the oil (Mo): 89.6grams, Mass of water (Mw): 98.8grams, Specific heat capacity of water (Cw): 4.2 J/g◦c, Specific heat capacity of oil (Co):?

Calculation

(MwCw+McCc) $(\partial\theta/\partial T)$= (MoCo+McCc) $(\partial\theta/\partial T)$
(98.8*4.2 + 61.6*0.38)(68-64.5/10) = (89.6Co +61.6*0.38) (66.5-59/10)
(414.96+23.41)(0.35) = (89.6Co + 23.41) (0.75)
153.34 = 67.2Co + 17.56
Co = 153.34 – 17.56/67.2
= 2.02 J/g◦c

Table 3: Specific Heat Capacity of Coconut and Palm Kernel Oil at 80:20 (Coconut Oil and Palm Kernel Oil) with Respect to Varying Time and Temperature

Time(mins)	Temperature of water (◦c)	Temperature of Oil (◦c)
0.0	70	70
2	69	69
4	68	67
6	67	65.5
8	66	63.5
10	65.5	63
12	65	61.5
14	64.5	60
16	64	58.5
18	63	57.5
20	62	57

Mass of the empty calorimeter (Mc): 61.6grams, Mass of the calorimeter + oil (Mc+o): 151.1grams, Mass of the calorimeter + water (Mc+w): 160.4grams, Mass of the oil (Mo): 89.5grams, Mass of water (Mw): 98.8grams, Specific heat capacity of water (Cw): 4.2 J/g◦c, Specific heat capacity of oil (Co):?

Calculation

(MwCw+McCc) $(\partial\theta/\partial T)$= (MoCo+McCc) $(\partial\theta/\partial T)$

(98.8*4.2 + 61.6*0.38)(68-64.5/10) = (89.5Co +61.6*0.38) (67-60/10)

(414.96+23.41)(0.35) = (89.5Co + 23.41) (0.7)

153.34 = 62.65Co + 16.39

Co = 153.34 – 16.39/62.65

= 2.19 J/g◦c

Table 4: Specific Heat Capacity of Coconut and Palm Kernel Oil at 70:30 (Coconut Oil and Palm Kernel Oil) with Respect to Varying Time and Temperature

Time(mins)	Temperature of water (◦c)	Temperature of Oil (◦c)
0.0	70	70
2	69	68
4	68	66
6	67	64.5
8	66	62.5
10	65.5	62
12	65	60
14	64.5	59
16	64	58
18	63	56.5
20	62	56

Mass of the empty calorimeter (Mc): 61.6grams, Mass of the calorimeter + oil (Mc+o): 150.5grams, Mass of the calorimeter + water (Mc+w): 160.4grams, Mass of the oil (Mo): 88.9grams, Mass of water (Mw): 98.8grams, Specific heat capacity of water (Cw): 4.2 J/g◦c, Specific heat capacity of oil (Co):?

Calculation

(MwCw+McCc) $(\partial\theta/\partial T)$= (MoCo+McCc) $(\partial\theta/\partial T)$

(98.8*4.2 + 61.6*0.38)(68-64.5/10) = (88.9Co +61.6*0.38) (66-59/10)

(414.96+23.41)(0.35) = (88.9Co + 23.41) (0.7)

153.34 = 62.23Co + 16.39

Co = 153.34 – 16.39/62.23

= 2.20 J/g◦c

Table 5: Specific Heat Capacity of Coconut and Palm Kernel Oil at 60:40 (Coconut Oil and Palm Kernel Oil) with Respect to Varying Time and Temperature

Time(mins)	Temperature of water (◦c)	Temperature of Oil (◦c)
0.0	70	70
2	69	68.5
4	68	67.5
6	67	66
8	66	65
10	65.5	63.5
12	65	62.5
14	64.5	61
16	64	59.5
18	63	58.5
20	62	57

Mass of the empty calorimeter (Mc): 61.6grams, Mass of the calorimeter + oil (Mc+o): 149.7grams, Mass of the calorimeter + water (Mc+w): 160.4grams, Mass of the oil (Mo): 88.1grams, Mass of water (Mw): 98.8grams, Specific heat capacity of water (Cw): 4.2 J/g◦c, Specific heat capacity of oil (Co):?

Calculation

(MwCw+McCc) $(\partial\theta/\partial T)$= (MoCo+McCc) $(\partial\theta/\partial T)$

(98.8*4.2 + 61.6*0.38)(68-64.5/10) = (88.1Co +61.6*0.38) (67.5-61/10)

(414.96+23.41)(0.35) = (88.1Co + 23.41) (0.65)

153.34 = 57.27Co + 15.22

Co = 153.34 – 15.22/57.27

= 2.41 J/g◦c

Table 6: Specific Heat Capacity of Coconut and Palm Kernel Oil at 50:50 (Coconut Oil and Palm Kernel Oil) with Respect to Varying Time and Temperature

Time(mins)	Temperature of water (◦c)	Temperature of Oil (◦c)
0.0	70	70
2	69	68
4	68	66.5
6	67	64.5
8	66	64
10	65.5	61.5
12	65	61
14	64.5	59.5
16	64	58
18	63	56.5
20	62	56

Mass of the empty calorimeter (Mc): 61.6grams, Mass of the calorimeter + oil (Mc+o): 149.4grams, Mass of the calorimeter + water (Mc+w): 160.4grams, Mass of the oil (Mo): 87.8grams, Mass of water (Mw): 98.8grams, Specific heat capacity of water (Cw): 4.2 J/g◦c, Specific heat capacity of oil (Co):?

Calculation

(MwCw+McCc) $(\partial\theta/\partial T)$= (MoCo+McCc) $(\partial\theta/\partial T)$

(98.8*4.2 + 61.6*0.38)(68-64.5/10) = (87.8Co +61.6*0.38) (66.5-59.5/10)

(414.96+23.41)(0.35) = (87.8Co + 23.41) (0.7)

153.34 = 61.46Co + 16.39

Co = 153.34 – 16.39/61.46

= 2.23 J/g◦c

Table 7: Specific Heat Capacity of Coconut and Palm Kernel Oil at 40:60 (coconut oil and palm kernel oil) with respect to varying time and temperature

Time(mins)	Temperature of water (◦c)	Temperature of Oil (◦c)
0.0	70	70
2	69	68
4	68	67
6	67	65.5
8	66	63.5
10	65.5	62.5
12	65	61
14	64.5	59.5
16	64	58.5
18	63	57
20	62	55.5

Mass of the empty calorimeter (Mc): 61.6grams, Mass of the calorimeter + oil (Mc+o): 150.1grams, Mass of the calorimeter + water (Mc+w): 160.4grams, Mass of the oil (Mo): 88.5grams, Mass of water (Mw): 98.8grams, Specific heat capacity of water (Cw): 4.2 J/g◦c, Specific heat capacity of oil (Co):?

Calculation

(MwCw+McCc) $(\partial\theta/\partial T)$= (MoCo+McCc) $(\partial\theta/\partial T)$
(98.8*4.2 + 61.6*0.38)(68-64.5/10) = (88.5Co +61.6*0.38) (67-59.5/10)
(414.96+23.41)(0.35) = (88.5Co + 23.41) (0.75)
153.34 = 66.38Co + 17.56
Co = 153.34 – 17.56/66.38
= 2.05 J/g◦c

Table 8: Specific Heat Capacity of Coconut and Palm Kernel Oil at 30:70 (Coconut Oil and Palm Kernel Oil) with Respect to Varying Time and Temperature

Time(mins)	Temperature of water (◦c)	Temperature of Oil (◦c)
0.0	70	70
2	69	68
4	68	66.5
6	67	65.5
8	66	63
10	65.5	62.5
12	65	61.5
14	64.5	59.5
16	64	58.5
18	63	57
20	62	56

Mass of the empty calorimeter (Mc): 61.6grams, Mass of the calorimeter + oil (Mc+o): 153.4grams, Mass of the calorimeter + water (Mc+w): 160.4grams, Mass of the oil (Mo): 91.8grams, Mass of water (Mw): 98.8grams, Specific heat capacity of water (Cw): 4.2 J/g◦c, Specific heat capacity of oil (Co):?

Calculation

(MwCw+McCc) $(\partial\theta/\partial T)$= (MoCo+McCc) $(\partial\theta/\partial T)$
(98.8*4.2 + 61.6*0.38)(68-64.5/10) = (91.8Co +61.6*0.38) (66.5-59.5/10)
(414.96+23.41)(0.35) = (91.8Co + 23.41) (0.7)
153.34 = 64.26Co + 16.39
Co = 153.34 – 16.39/64.26
= 2.13 J/g◦c

Table 9: Specific Heat Capacity of Coconut and Palm Kernel Oil at 20:80 (Coconut Oil and Palm Kernel Oil) with Respect to Varying Time and Temperature

Time(mins)	Temperature of water (◦c)	Temperature of Oil (◦c)
0.0	70	70
2	69	68
4	68	66.5
6	67	65.5
8	66	63.5
10	65.5	63
12	65	61.5
14	64.5	60
16	64	58.5
18	63	56.5
20	62	55.5

Mass of the empty calorimeter (Mc): 61.6grams, Mass of the calorimeter + oil (Mc+o): 150.8grams, Mass of the calorimeter + water (Mc+w): 160.4grams, Mass of the oil (Mo): 89.2grams, Mass of water (Mw): 98.8grams, Specific heat capacity of water (Cw): 4.2 J/g◦c, Specific heat capacity of oil (Co):?

Calculation

(MwCw+McCc) $(\partial\theta/\partial T)$= (MoCo+McCc) $(\partial\theta/\partial T)$

(98.8*4.2 + 61.6*0.38)(68-64.5/10) = (89.2Co +61.6*0.38) (66.5-60/10)

(414.96+23.41)(0.35) = (89.2Co + 23.41) (0.65)

153.34 = 57.98Co + 15.22

Co = 153.34 – 15.22/57.98

= 2.38 J/g◦c

Table 10: Specific Heat Capacity of Coconut and Palm Kernel Oil at 10:90 (Coconut Oil and Palm Kernel Oil) with Respect to Varying Time and Temperature

Time(mins)	Temperature of water (◦c)	Temperature of Oil (◦c)
0.0	70	70
2	69	67.5
4	68	66.5
6	67	65
8	66	64.5
10	65.5	63.5
12	65	60.5
14	64.5	59.5
16	64	58
18	63	56
20	62	55

Mass of the empty calorimeter (Mc): 61.6grams, Mass of the calorimeter + oil (Mc+o): 153.4grams, Mass of the calorimeter + water (Mc+w): 160.4grams, Mass of the oil (Mo): 91.8grams, Mass of water (Mw): 98.8grams, Specific heat capacity of water (Cw): 4.2 J/g◦c, Specific heat capacity of oil (Co):?

Calculation

(MwCw+McCc) $(\partial\theta/\partial T)$= (MoCo+McCc) $(\partial\theta/\partial T)$

(98.8*4.2 + 61.6*0.38)(68-64.5/10) = (91.8Co +61.6*0.38) (66.5-59.5/10)

(414.96+23.41)(0.35) = (91.8Co + 23.41) (0.7)

153.34 = 64.26Co + 16.39

Co = 153.34 – 16.39/64.26

= 2.13 J/g◦c

Table 11: Specific Heat Capacity of Coconut and Palm Kernel Oil at 0:100 (Coconut Oil and Palm Kernel Oil) with Respect to Varying Time and Temperature

Time(mins)	Temperature of water (◦c)	Temperature of Oil (◦c)
0.0	70	70
2	69	67
4	68	66
6	67	65.5
8	66	64
10	65.5	63
12	65	60
14	64.5	59
16	64	58
18	63	55.5
20	62	54.5

Mass of the empty calorimeter (Mc): 61.6grams, Mass of the calorimeter + oil (Mc+o): 152.8grams, Mass of the calorimeter + water (Mc+w): 160.4grams, Mass of the oil (Mo): 91.2grams, Mass of water (Mw): 98.8grams, Specific heat capacity of water (Cw): 4.2 J/g◦c, Specific heat capacity of oil (Co):?

Calculation

(MwCw+McCc) $(\partial\theta/\partial T)$= (MoCo+McCc) $(\partial\theta/\partial T)$

(98.8*4.2 + 61.6*0.38)(68-64.5/10) = (91.2Co +61.6*0.38) (66-59/10)

(414.96+23.41)(0.35) = (91.2Co + 23.41) (0.7)

153.34 = 63.84Co + 16.39

Co = 153.34 – 16.39/63.84

= 2.15 J/g◦c

Table 12: Results for Density of Coconut Oil and Palm Kernel Oil in Several Ratios using Density Bottle

Density =	Mass/Volume
For 100:0 (coconut oil)	
Mass of density bottle =	54grams,
Mass of density bottle + water =	152.9grams
Mass of density bottle + Oil =	144grams
Mass of water =	98.8grams
Mass of oil =	90grams, Density of water = 1g/cm3
Mass of density bottle+water – mass of density bottle =	152.9 -54 =98.8grams
Mass of density bottle+oil – mass of density bottle =	144 – 54 =90grams.
For water: Density = Mass/volume =98.8/1 = 98.8cm3	For Oil: Density = mass/volume = 90/98.8 = 0.911g/cm3
For 90:10 (coconut oil and palm kernel oil)	
Density =	Mass/Volume
Mass of density bottle =	54grams
Mass of density bottle + water =	152.9grams
Mass of density bottle + Oil =	143.6grams
Mass of water =	98.8grams
Mass of oil =	89.6grams
Density of water =	1g/cm3
Mass of density bottle+water – mass of density bottle =	152.9 -54 =98.8grams
Mass of density bottle+oil – mass of density bottle =	143.6 – 54 =89.6grams
For water: Density =	Mass/volume
Volume= Mass/ Density =	98.8/1 = 98.8cm3
For Oil: Density = mass/volume =	89.6/98.8 = 0.907g/cm3
For 80:20 (coconut oil and palm kernel oil)	
Density =	Mass/Volume
Mass of density bottle =	54grams
Mass of density bottle + water =	152.9grams
Mass of density bottle + Oil =	143.5grams
Mass of water =	98.8grams

Mass of oil =	89.5grams
Density of water =	1g/cm3
Mass of density bottle+water – mass of density bottle =	152.9 -54 =98.8grams
Mass of density bottle+oil – mass of density bottle =	143.5 – 54 =89.5grams
For water: Density =	Mass/volume
Volume= Mass/ Density =	98.8/1 = 98.8cm3
For Oil: Density = mass/volume =	89.5/98.8 = 0.906g/cm3

For 70:30 (coconut oil and palm kernel oil)

Density =	Mass/Volume
Mass of density bottle =	54grams
Mass of density bottle + water =	152.9grams
Mass of density bottle + Oil =	142.9grams
Mass of water =	98.8grams
Mass of oil =	88.9grams
Density of water =	1g/cm3
Mass of density bottle+water – mass of density bottle =	152.9 -54 =98.8grams
Mass of density bottle+oil – mass of density bottle =	142.9 – 54 =88.9grams
For water: Density =	Mass/volume
Volume= Mass/ Density =	98.8/1 = 98.8cm3
For Oil: Density = mass/volume =	88.9/98.8 = 0.899g/cm3

For 60:40 (coconut oil and palm kernel oil)

Density =	Mass/Volume
Mass of density bottle =	54grams
Mass of density bottle + water =	152.9grams
Mass of density bottle + Oil =	142.1grams
Mass of water =	98.8grams
Mass of oil =	88.1grams
Density of water =	1g/cm3
Mass of density bottle+water – mass of density bottle =	152.9 -54 =98.8grams
Mass of density bottle+oil – mass of density bottle =	142.1 – 54 =88.1grams
For water: Density =	Mass/volume
Volume= Mass/ Density =	98.8/1 = 98.8cm3
For Oil: Density = mass/volume =	88.1/98.8 = 0.892g/cm3

For 50:50 (coconut oil and palm kernel oil)

Density =	Mass/Volume
Mass of density bottle =	54grams
Mass of density bottle + water =	152.9grams
Mass of density bottle + Oil =	141.8grams
Mass of water =	98.8grams
Mass of oil =	87.8grams
Density of water =	1g/cm3
Mass of density bottle+water – mass of density bottle =	152.9 -54 =98.8grams
Mass of density bottle+oil – mass of density bottle =	141.8 – 54 =87.8grams
For water: Density =	Mass/volume
Volume= Mass/ Density =	98.8/1 = 98.8cm3
For Oil: Density = mass/volume =	87.8/98.8 = 0.889g/cm3

For 40:60 (coconut oil and palm kernel oil)

Density =	Mass/Volume
Mass of density bottle =	54grams
Mass of density bottle + water =	152.9grams
Mass of density bottle + Oil =	142.5grams
Mass of water =	98.8grams
Mass of oil =	88.5grams
Density of water =	1g/cm3

Mass of density bottle+water – mass of density bottle =	152.9 -54 =98.8grams
Mass of density bottle+oil – mass of density bottle =	142.5 – 54 =88.5grams
For water: Density	= Mass/volume
Volume= Mass/ Density =	98.8/1 = 98.8cm3
For Oil: Density = mass/volume =	88.5/98.8 = 0.896g/cm3

For 30:70 (coconut oil and palm kernel oil)

Density =	Mass/Volume
Mass of density bottle =	54grams
Mass of density bottle + water =	152.9grams
Mass of density bottle + Oil =	145.8grams
Mass of water =	98.8grams
Mass of oil =	91.8grams
Density of water =	1g/cm3
Mass of density bottle+water – mass of density bottle =	152.9 -54 =98.8grams
Mass of density bottle+oil – mass of density bottle =	145.8 – 54 =91.8grams
For water: Density =	Mass/volume
Volume= Mass/ Density =	98.8/1 = 98.8cm3
For Oil: Density = mass/volume =	91.8/98.8 = 0.929g/cm3

For 20:80 (coconut oil and palm kernel oil)

Density =	Mass/Volume
Mass of density bottle =	54grams
Mass of density bottle + water =	152.9grams
Mass of density bottle + Oil =	143.2grams
Mass of water =	98.8grams
Mass of oil =	89.2grams
Density of water =	1g/cm3
Mass of density bottle+water – mass of density bottle =	152.9 -54 =98.8grams
Mass of density bottle+oil – mass of density bottle =	143.2 – 54 =89.2grams
For water: Density =	Mass/volume
Volume= Mass/ Density =	98.8/1 = 98.8cm3
For Oil: Density = mass/volume =	89.2/98.8 = 0.903g/cm3

For 10:90 (coconut oil and palm kernel oil)

Density =	Mass/Volume
Mass of density bottle =	54grams
Mass of density bottle + water =	152.9grams
Mass of density bottle + Oil =	145.8grams
Mass of water =	98.8grams
Mass of oil =	91.8grams
Density of water =	1g/cm3
Mass of density bottle+water – mass of density bottle =	152.9 -54 =98.8grams
Mass of density bottle+oil – mass of density bottle =	145.8 – 54 =91.8grams
For water: Density =	Mass/volume
Volume= Mass/ Density =	98.8/1 = 98.8cm3
For Oil: Density =	Mass/volume = 91.8/98.8 = 0.920g/cm3

For 0:100 (palm kernel oil)

Density =	Mass/Volume
Mass of density bottle =	54grams
Mass of density bottle + water =	152.9grams
Mass of density bottle + Oil =	145.2grams
Mass of water =	98.8grams
Mass of oil =	91.2grams
Density of water =	1g/cm3
Mass of density bottle+water – mass of density bottle =	152.9 -54 =98.8grams
Mass of density bottle+oil – mass of density bottle =	145.2 – 54 =91.2grams

For water: Density =	Mass/volume
Volume= Mass/ Density =	98.8/1 = 98.8cm3
For Oil: Density =	Mass/volume = 91.2/98.8 = 0.923g/cm3

Table 13: Results for Viscosity of Coconut and Palm Kernel oil at 100:0 (Coconut Oil) Using a Viscometer

Liquid	Time of flow (sec)		Mean-Time (sec)	Density (g/cm3)	Viscosity(mPa.s)
	1	2			
Water	67	70	68.5	1	1.002
Oil	3490	3476	3483	0.911	46.4

$\eta 2 = \frac{\rho 2t2}{\rho 1t1} * \eta 1$

Where:

$\rho 1 = Density\ of\ water$

$\rho 2 = Density\ of\ oil$

$\eta 1 = Viscosity\ of\ water$er

$\eta 2 = Visc2$=Visc of Oil

$t1 = mean\ time\ of\ water\ flow$ an time of water flow oil

Viscosity of water at room temperature: 1.002 mPa.s

Density of water at room temperature: 1g/cm3

Density of calculated oil: 0.911g/cm3

$\eta 2 = \frac{0.911*3483}{1*68.5} * 1.002 = 46.4\ mPa.s$

Table 14: Results for Viscosity of Coconut and Palm Kernel oil at 90:10 (Coconut Oil and Palm Kernel Oil) Using a Viscometer

Liquid	Time of flow (sec)		Mean-Time (sec)	Density (g/cm3)	Viscosity (mPa.s)
	1	2			
Water	67	70	68.5	1	1.002
Oil	3440	3450	3445	0.907	45.7

$\eta 2 = \frac{\rho 2t2}{\rho 1t1} * \eta 1$

Where

$\rho 1 = Density\ of\ water$

$\rho 2 = Density\ of\ oil$

$\eta 1 = Viscosity\ of\ water$er

$\eta 2 = Visc2$=Visc of Oil

$t1 = mean\ time\ of\ water\ flow$ an time of water flow oil

Viscosity of water at room temperature: 1.002 mPa.s

Density of water at room temperature: 1g/cm3

Density of calculated oil: 0.907g/cm3

$\eta 2 = \frac{0.907*3445}{1*68.5} * 1.002 = 45.7\ mPa.s$

Table 15: Results for Viscosity of Coconut and Palm Kernel Oil at 80:20 (Coconut Oil and Palm Kernel Oil) Using a Viscometer

Liquid	Time of flow (sec)		Mean-Time (sec)	Density (g/cm3)	Viscosity(mPa.s)
	1	2			
Water	67	70	68.5	1	1.002
Oil	3390	3310	3350	0.906	44.4

$\eta 2 = \frac{\rho 2t2}{\rho 1t1} * \eta 1$

Where

$\rho 1 = Density\ of\ water$

$\rho 2 = Density\ of\ oil$

$\eta 1 = Viscosity\ of\ water$er

$\eta 2 = Visc2$=Visc of Oil

$t1 = mean\ time\ of\ water\ flow$ an time of water flow oil

Viscosity of water at room temperature: 1.002 mPa.s
Density of water at room temperature: 1g/cm3
Density of calculated oil: 0.906g/cm3

$$\eta 2 = \frac{0.906*3350}{1*68.5} * 1.002 = 44.4\ mPa.s$$

Table 16: Results for Viscosity of Coconut and Palm Kernel Oil at 70:30 (Coconut Oil and Palm Kernel Oil) Using a Viscometer

Liquid	Time of flow (sec)		Mean-Time (sec)	Density (g/cm3)	Vicosity(mPa.s)
	1	2			
Water	67	70	68.5	1	1.002
Oil	3220	3185	3202	0.899	42.1

$$\eta 2 = \frac{\rho 2t2}{\rho 1t1} * \eta 1$$

Where
$\rho 1 = Density\ of\ water$
$\rho 2 = Density\ of\ oil$
$\eta 1 = Viscosity\ of\ water$er
$\eta 2 = Visc2$=Visc of Oil
$t1 = mean\ time\ of\ water\ flow$ an time of water flow oil
Viscosity of water at room temperature: 1.002 mPa.s
Density of water at room temperature: 1g/cm3
Density of calculated oil: 0.899g/cm3

$$\eta 2 = \frac{0.899*3202}{1*68.5} * 1.002 = 42.1\ mPa.s$$

Table 17: Results for Viscosity of Coconut and Palm Kernel Oil at 60:40 (Coconut Oil and Palm Kernel Oil) Using a Viscometer

Liquid	Time of flow (sec)		Mean-Time (sec)	Density (g/cm3)	Vicosity(mPa.s)
	1	2			
Water	67	70	68.5	1	1.002
Oil	3150	3110	3130	0.892	40.8

$$\eta 2 = \frac{\rho 2t2}{\rho 1t1} * \eta 1$$

Where
$\rho 1 = Density\ of\ water$
$\rho 2 = Density\ of\ oil$
$\eta 1 = Viscosity\ of\ water$er
$\eta 2 = Visc2$=Visc of Oil
$t1 = mean\ time\ of\ water\ flow$ an time of water flow oil
Viscosity of water at room temperature: 1.002 mPa.s
Density of water at room temperature: 1g/cm3
Density of calculated oil: 0.892g/cm3

$$\eta 2 = \frac{0.892*3130}{1*68.5} * 1.002 = 40.8\ mPa.s$$

Table 18: Results for Viscosity of Coconut and Palm Kernel Oil at 50:50 (Coconut Oil and Palm Kernel Oil) Using a Viscometer

Liquid	Time of flow (sec)		Mean-Time (sec)	Density (g/cm3)	Vicosity(mPa.s)
	1	2			
Water	67	70	68.5	1	1.002
Oil	2970	2910	2940	0.889	38.2

$$\eta 2 = \frac{\rho 2t2}{\rho 1t1} * \eta 1$$

Where
$\rho 1 = Density\ of\ water$
$\rho 2 = Density\ of\ oil$
$\eta 1 = Viscosity\ of\ water$er

$\eta 2 = Visc2$=Visc of Oil
$t1 = mean\ time\ of\ water\ flow$ an time of water flow oil
Viscosity of water at room temperature: 1.002 mPa.s
Density of water at room temperature: 1g/cm3
Density of calculated oil: 0.889g/cm3
$\eta 2 = \frac{0.889*2940}{1*68.5} * 1.002 = 38.2mPa.s$

Table 19: Results for Viscosity of Coconut and Palm Kernel oil at 40:60 (Coconut Oil and Palm Kernel Oil) Using a Viscometer

Liquid	Time of flow (sec)		Mean-Time (sec)	Density (g/cm3)	Vicosity(mPa.s)
	1	2			
Water	67	70	68.5	1	1.002
Oil	2900	2871	2885.5	0.896	37.8

$\eta 2 = \frac{\rho 2t2}{\rho 1t1} * \eta 1$
Where
$\rho 1 = Density\ of\ water$
$\rho 2 = Density\ of\ oil$
$\eta 1 = Viscosity\ of\ water$er
$\eta 2 = Visc2$=Visc of Oil
$t1 = mean\ time\ of\ water\ flow$ an time of water flow oil
Viscosity of water at room temperature: 1.002 mPa.s
Density of water at room temperature: 1g/cm3
Density of calculated oil: 0.896g/cm3
$\eta 2 = \frac{0.896*2885.5}{1*68.5} * 1.002 = 37.8mPa.s$

Table 20: Results for Viscosity of Coconut and Palm Kernel Oil at 30:70 (Coconut Oil and Palm Kernel Oil) Using a Viscometer

Liquid	Time of flow (sec)		Mean-Time (sec)	Density (g/cm3)	Viscosity(mPa.s)
	1	2			
Water	67	70	68.5	1	1.002
Oil	2793	2710	2751.5	0.929	37.4

$\eta 2 = \frac{\rho 2t2}{\rho 1t1} * \eta 1$
Where
$\rho 1 = Density\ of\ water$
$\rho 2 = Density\ of\ oil$
$\eta 1 = Viscosity\ of\ water$er
$\eta 2 = Visc2$=Visc of Oil
$t1 = mean\ time\ of\ water\ flow$ an time of water flow oil
Viscosity of water at room temperature: 1.002 mPa.s
Density of water at room temperature: 1g/cm3
Density of calculated oil: 0.929g/cm3
$\eta 2 = \frac{0.929*2751.5}{1*68.5} * 1.002 = 37.4mPa.s$

Table 21: Results for Viscosity of Coconut and Palm Kernel Oil at 20:80 (Coconut Oil and Palm Kernel Oil) Using a Viscometer

Liquid	Time of flow (sec)		Mean-Time (sec)	Density (g/cm3)	Vicosity(mPa.s)
	1	2			
Water	67	70	68.5	1	1.002
Oil	2665	2643	2654	0.903	34.9

$\eta 2 = \frac{\rho 2t2}{\rho 1t1} * \eta 1$
Where

$\rho 1 = Density\ of\ water$
$\rho 2 = Density\ of\ oil$
$\eta 1 = Viscosity\ of\ water$er
$\eta 2 = Visc2$=Visc of Oil
$t1 = mean\ time\ of\ water\ flow$ an time of water flow oil
Viscosity of water at room temperature: 1.002 mPa.s
Density of water at room temperature: 1g/cm3
Density of calculated oil: 0.903g/cm3
$\eta 2 = \frac{0.903*2654}{1*68.5} * 1.002 = 34.9 mPa.s$

Table 22: Results for Viscosity of Coconut and Palm Kernel Oil at 10:90 (Coconut Oil and Palm Kernel Oil) Using a Viscometer

Liquid	Time of flow (sec)		Mean-Time (sec)	Density (g/cm3)	Viscosity(mPa.s)
	1	2			
Water	67	70	68.5	1	1.002
Oil	2540	2510	2529.5	0.929	34.4

$\eta 2 = \frac{\rho 2t2}{\rho 1t1} * \eta 1$
Where
$\rho 1 = Density\ of\ water$
$\rho 2 = Density\ of\ oil$
$\eta 1 = Viscosity\ of\ water$er
$\eta 2 = Visc2$=Visc of Oil
$t1 = mean\ time\ of\ water\ flow$ an time of water flow oil
Viscosity of water at room temperature: 1.002 mPa.s
Density of water at room temperature: 1g/cm3
Density of calculated oil: 0.929g/cm3
$\eta 2 = \frac{0.929*2529.5}{1*68.5} * 1.002 = 34.4 mPa.s$

Table 23: Results for Viscosity of Coconut and Palm Kernel Oil at 0:100 (Palm Kernel) Using a Viscometer

Liquid	Time of flow (sec)		Mean-Time (sec)	Density (g/cm3)	Vicosity(mPa.s)
	1	2			
Water	67	70	68.5	1	1.002
Oil	2433	2482	2457.5	0.923	33.2

$\eta 2 = \frac{\rho 2t2}{\rho 1t1} * \eta 1$
Where
$\rho 1 = Density\ of\ water$
$\rho 2 = Density\ of\ oil$
$\eta 1 = Viscosity\ of\ water$er
$\eta 2 = Visc2$=Visc of Oil
$t1 = mean\ time\ of\ water\ flow$ an time of water flow oil
Viscosity of water at room temperature: 1.002 mPa.s
Density of water at room temperature: 1g/cm3
Density of calculated oil: 0.923g/cm3
$\eta 2 = \frac{0.923*2457.5}{1*68.5} * 1.002 = 33.2 mPa.s$

Discussion of Results

Specific Heat Capacity Results

The specific heat capacity of coconut oil, palm kernel oil, and their mixtures was determined through the cooling method. The specific heat capacity of coconut oil was found to be 2.01 J/g°C. The above findings tally with other researcher's findings who reported that the specific heat capacity of pure coconut oil range between 1.6 J/g^{o}C to 2.1 J/g ^{o}C (Saleel, 2022; Gomez-Merino *et al.*, 2022). Furthermore, the result of the pure palm kernel oil was 2.15 J/g°C. This is agreement with the findings of Alakali *et al.* (2012), who reported that a specific heat capacity of cold processed palm oil of 1.29-5.26 J/g^{o}C and a specific heat capacity of hot processed samples to be within 1.80-6.24 J/g°C indicating that specific heat capacity is dependent on temperature and processing methods. For the mixtures, the specific heat capacity increased as the ratio of palm kernel oil increased (Alakali *et al.*, 2012). For instance, 90:10 (Coconut oil:Palm kernel oil) yielded a specific heat of 2.02 J/g°C, 50:50yielded 2.23 J/g°C and 10:90 yielded 2.13 J/g°C. The results show that as the proportion of palm kernel oil increases, the specific heat capacity rises, albeit marginally; hence, this finding supports the findings of Timms (1985), who noted that the specific heat capacities of oils and fats are generally similar, with minor variations. This could be due to the higher molecular complexity and the presence of different fatty acid chains in palm kernel oil, which may absorb more heat energy.

Density Results

The densities of the oils and their mixtures were measured using a density bottle method. The density measurements showed that palm kernel oil had a density of approximately 0.923 g/cm³, while coconut oil had a density of 0.911 g/cm³. This slight difference is due to the different compositions of fatty acids in each oil. Mixtures of the two oils produced intermediate densities, with the density increasing as the proportion of palm kernel oil increased. The relationship between oil composition and density is linear, with higher proportions of palm kernel oil leading to higher densities. However, the density of pure coconut oil was 0.911 g/cm³, and that of pure palm kernel oil was 0.923 g/cm³ indicating that the density value falls within the expected range. This finding corresponds with the findings of Weast (1986); Subrahmanyam *et al.* (1994), who observed the density of coconut oil typically ranges between 0.91 and 0.93 g/cm^3 depending on factors such as temperature and purity. As the ratio of palm kernel oil increased in the mixtures, the density values approached that of palm kernel oil, at 90:10 (Coconut oil:Palm kernel oil) there was a density of 0.907 g/cm³, at 50: 50, density was 0.889 g/cm^3 and at 10:90, the density was 0.920g/cm^3, this could be due to the varying physical and chemical stability (Imoisi *et al.*, 2020).

These results indicate a near-linear relationship between the mixture ratio and density, which is expected as the physical properties of oil mixtures typically reflect the weighted average of their components (Schoo and Hoxie, 2012). The higher density of palm kernel oil is consistent with its higher saturated fat content compared to coconut oil, this finding corresponds with the findings of Weasler (2025), who observed that PKO has a higher saturated fat content than coconut oil, which correlates with its greater density.

Viscosity Results

The results showed that pure palm kernel oil has a lower viscosity compared to coconut oil at room temperature. The viscosity results highlighted that palm kernel oil exhibited a lower viscosity compared to coconut oil. Pure coconut oil showed a viscosity of 46.4 mPa·s, while palm kernel oil's viscosity was measured at 45.7 mPa·s. Mixtures of the two oils revealed a non-linear relationship in viscosity changes, with palm kernel oil contributing to a smoother and more fluid consistency. As the proportion of palm kernel oil increased, the overall viscosity decreased slightly, making the mixtures more suitable for applications requiring lower resistance to flow, such as lubrication or cooking. The above findings correspond with the findings of Ibrahim *et al.* (2019), that pure palm kernel oil (PKO) exhibits a lower viscosity compared to coconut oil at room temperature. This difference is attributed to variations in their fatty acid compositions, which influence their physical properties. Furthermore, the 100% coconut oil had a viscosity of 46.4 mPa·s, Palm kernel oil (100%) had a viscosity of 33.2 mPa·s.

As the proportion of palm kernel oil increased in the mixtures, the viscosity decreased: At 90:10 (Coconut oil:Palm kernel oil), viscosity was 45.7 mPa·s, 50:50 (coconut oil: palm kernel oil) yielded 38.2 mPa·s and 10:90 yielded 34.4 mPa·s. The decrease in viscosity with an increasing proportion of palm kernel oil suggests that palm kernel oil flows more easily at room temperature compared to coconut oil, which has a tendency to solidify and increase in viscosity. Hence, this is in agreement with the findings of Ibrahim *et al.* (2019), who observed that PKO has a lower viscosity than coconut oil at room temperature. This behavior aligns with the oils' fatty acid compositions, where coconut oil has a higher proportion of medium-chain triglycerides, leading to higher viscosity (Chin-Ping and Imededdline, 2012).

CONCLUSION

These findings have practical implications for industries such as food processing and bio-fuel production, where understanding the thermal and flow properties of oils is crucial for optimizing processes and improving efficiency. The results provide valuable insights into the selection and application of oil blends in thermal systems, contributing to enhanced energy efficiency and performance in various industrial applications. This study presents a detailed experimental analysis of these thermo-physical properties for blends of coconut oil and palm kernel oil and groundnut oil in eleven different samples, offering valuable data to expand the existing body of knowledge. The implication for utilization with emphasis on best oil ratio for various applications are thus: Food Formulation: The 90:10 ratio (coconut oil to palm kernel oil) emerges as optimal for food applications. This blend balances the high specific heat of palm kernel oil (for consistent cooking) and the rich flavor and aroma of coconut oil, which is often desirable in culinary applications. The specific heat capacity and viscosity of this blend provide efficient heat transfer and a desirable texture for frying, baking, or dressing. Cosmetic and Pharmaceutical Formulation: A 70:30 mixture of coconut oil to palm kernel oil is ideal for cosmetics and pharmaceuticals. Coconut oil's moisturizing properties combined with palm kernel oil's stability at higher temperatures make this blend particularly useful for creams, lotions, and ointments that need both texture and heat stability. Thermal Insulation Materials: For thermal insulation applications, the **100:0** (pure palm kernel oil) ratio would be the best choice. Its higher specific heat capacity and density make it a better thermal insulator. Palm kernel oil's ability to absorb more heat with minimal temperature change can be beneficial in optimizing insulation materials used in industrial or building applications.

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