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Investigation of the Specific Heat Capacity, Density and Viscosity of Different Combinations of Groundnut and Palm Kernel Oil

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ABSTRACT
The specific heat capacity, density, and viscosity of oil samples are affected by their chemical composition, temperature, and blending ratios. Palm kernel and groundnut oil exhibit distinct physical properties due to their unique compositions. In this work, we combined both oil samples at different ratios, producing 9 combinations and 2 original samples. Groundnut oil has a higher specific heat capacity due to its Medium-Chain Triglycerides (MCTs). Both samples experience a decrease in density as temperature rises, with groundnut oil being slightly denser. Additionally, viscosity decreases exponentially with increasing temperature, and palm kernel oil is more viscous. A comprehensive understanding of these properties in oil mixtures is essential for optimizing their use in various industrial applications. The results demonstrate a relationship between oil composition and heat retention properties. Groundnut oil exhibits a higher specific heat capacity, and increasing palm kernel oil content in the blend leads to a lower heat retention capability. The results characterized the specific heat capacity of groundnut oil, palm kernel oil, and their mixtures. Groundnut oil exhibited a higher specific heat capacity, with values of 2.54 J/g°C for pure groundnut oil and 2.16 J/g°C for pure palm kernel oil. The specific heat capacities of the mixtures followed a linear trend, indicating that the thermal properties of oil mixtures can be predicted based on their composition. These findings have practical implications in food processing and bio-fuel production. The results provide appropriate selection and application of oil blends in thermal systems. This study presents a detailed analysis of these thermo-physical properties for blends of palm kernel oil and groundnut oil in eleven different samples, offering valuable data to expand the existing body of knowledge.

Keywords:
Groundnut Oil,
Industrial Applications,
Medium-Chain Triglycerides (MCTs),
Oil Blends and Palm Kernel Oil,
Thermophysical Properties.

INTRODUCTION

The increasing demand for alternative and renewable resources has prompted extensive research into the thermophysical properties of edible oils, particularly their specific heat capacity, density, and viscosity. These properties are vital for optimizing the use of oils in various industrial applications such as food processing, biofuels, and pharmaceuticals (Chukwu and Adgidzi, 2008). Among the diverse range of edible oils, groundnut oil and palm kernel oil are commonly utilized due to their unique chemical compositions and distinct physical properties. The blending of these oils offers an opportunity to combine the advantages of the both oils, potentially improving performance and efficiency in different applications (Fang *et al.,* 2014).

Groundnut oil, derived from peanuts, is known for its high content of unsaturated fatty acids and Medium-Chain Triglycerides (MCTs), which contribute to its higher specific heat capacity. On the other hand, palm kernel oil, obtained from the seeds of the oil palm tree, is rich in saturated fats, which influences its density and viscosity compared to other oils (Dunn, 2005). The physical properties of these oils, including specific heat capacity, density, and viscosity, vary with temperature and blending ratios, making them crucial for applications where heat transfer, fluid dynamics, and stability are important (Kaliniewicz *et al.,* 2018).

Understanding the thermal and rheological behaviors of different blends of groundnut oil and palm kernel oil can provide valuable insights into their suitability for specific industrial processes. In particular, the ability to predict and control the specific heat, density, and viscosity of oil mixtures is critical for applications involving heat exchange, mixing, and pumping (Fang *et al.,* 2014). This study investigates the specific heat capacity, density, and viscosity of various blends of groundnut oil and palm kernel oil in different ratios, aiming to provide a comprehensive analysis of their thermophysical properties. The findings from this research will contribute to the growing body of knowledge on oil blends, offering practical data for optimizing the use of these oils in various sectors, including food, energy, and manufacturing industries (Rodrigues and Fernandes, 2007).

The thermal and rheological properties of oils, such as specific heat capacity, density, and viscosity, play a crucial role in a wide range of industrial applications, including lubrication, food processing, biofuel production, and thermal management systems. These properties are fundamental for understanding how oils perform under varying conditions and have significant implications for optimizing energy efficiency, reducing wear and tear in machinery, and improving the quality and safety of products (Kumari and Agrawal, 2013).

One of the key properties, specific heat capacity, refers to the amount of heat required to raise the temperature of a given mass of material by one degree Celsius. In industrial applications, oils with higher specific heat capacities can absorb more heat before experiencing a temperature rise, making them useful for thermal management systems, heat exchangers, and cooling processes (Lide, 2004). On the other hand, viscosity—the measure of a fluid's resistance to flow—is essential for determining the lubrication performance of oils, with higher viscosity oils offering greater resistance to shear and friction. Density, another critical parameter, impacts the flow and distribution of oils in systems, influencing both heat transfer and efficiency (Gunstone, 2004).

The present study focuses on measuring and analyzing the specific heat capacity, density, and viscosity of various combinations of vegetable, mineral, and synthetic oils. Through detailed investigations of these properties for pure oils, such as groundnut oil and palm kernel oil, and their respective mixtures, this study aims to provide valuable data for optimizing industrial processes and improving energy efficiency (Maskan, 2003). Special attention is given to oil mixtures, where interactions between oil components can significantly alter their thermal and rheological properties, offering potential for fine-tuning oil formulations for specific applications (Dunn, 2005).

In particular, understanding these properties is essential for addressing challenges in industries such as lubrication, food processing, and biofuel production. For example, in the lubrication industry, oils with specific viscosity profiles can reduce friction and wear, enhancing machinery performance and longevity (Gunstone, 2004). In food processing, knowledge of oil mixtures' specific heat capacity and density can aid in better temperature control, improving food quality and consistency. In biofuel production, understanding the thermal properties of oils is essential for optimizing combustion and heat exchange systems, leading to more efficient energy conversion (Chukwu and Adgidzi, 2008).

The study's focus on groundnut oil and palm kernel oil, both of which have distinct thermal and rheological behaviors, offers insight into how various oil blends can be tailored for specific industrial uses. The data generated from this research will help inform future formulations of oils that optimize performance while also reducing environmental impact, energy consumption, and operational costs (Hammond and Johnson, 2005). By exploring these properties and their interplay in oil mixtures, this study seeks to enhance our understanding of how oils behave in complex systems and their potential for sustainable and efficient industrial applications (Moser, 2009).

Previous research has extensively explored the physical and chemical properties of various oils, including groundnut oil and palm kernel oil, with a particular focus on their thermal properties, stability, and suitability for industrial applications. Studies have investigated the specific heat capacity, thermal conductivity, and rheological properties (viscosity) of these oils, emphasizing their critical roles in processes like cooking, lubrication, biofuel production, and food processing (Maskan, 2003).

The specific heat capacity, which defines the amount of heat required to raise the temperature of a unit mass of a substance, is particularly relevant in applications that involve thermal energy transfer. It influences how quickly an oil heats up and how efficiently it retains heat, which is vital for processes such as frying and in industrial heat exchangers (Kaliniewicz *et al.,* 2018). Methods for determining specific heat capacity include calorimetry, differential scanning calorimetry (DSC), and empirical equations, which have been widely adopted in evaluating the thermal behaviors of oils. Despite the availability of these methods, errors such as heat loss and calibration inaccuracies can impact measurements, necessitating the use of insulating materials and regular calibration procedures to minimize discrepancies (Lide, 2004).

Density, defined as the mass per unit volume of a substance, is another important physical property of oils, influencing product formulation, quality control, and industrial processing. Accurate density measurements are essential in ensuring the consistency and performance of oils in various applications (Knothe and Steidley, 2005). Techniques such as the use of density bottles, hydrometers, and digital density meters are common for determining the density of fluids. However, challenges such as air bubbles or temperature fluctuations during measurement can lead to errors, which are often corrected by degassing and temperature control (Hammond and Johnson, 2005).

Viscosity, the measure of a fluid's resistance to flow, plays a critical role in lubrication, food processing, and cosmetics. It influences the performance of oils in machinery, the texture of food products, and the spreadability of lotions and creams (Rodrigues and Fernandes, 2007). Viscosity is highly temperature-dependent, and methods like capillary viscometers, rotational viscometers, and falling sphere viscometers are frequently used to assess it. To ensure accurate readings, it's crucial to maintain constant temperature conditions and prevent sample contamination (Knothe and Steidley, 2005).

The latent heat of fusion and vaporization, which refers to the amount of heat required to change the state of a substance from solid to liquid (fusion) or liquid to vapor (vaporization), is also important for understanding the thermal behavior of oils during heating and cooling. These properties are relevant for optimizing processes that involve phase transitions, such as frying or cooling applications (Abramovic *et al.,* 1998).

In addition to these fundamental properties, recent advancements in thermal property measurement techniques, such as advanced calorimetry and rheometers, have improved the accuracy and precision of data collection (Kumari and Agrawal, 2013). Emerging technologies continue to enhance our understanding of the impact of impurities and complex interactions within oil mixtures, providing more detailed insights into how these substances behave under varying conditions (Moser, 2009).

The research into the properties of oils like groundnut oil and palm kernel oil highlights their potential for optimizing industrial applications, including biofuel production, lubrication, and food processing. By understanding the specific heat capacity, viscosity, and density of these oils and their blends, industries can develop more efficient, cost-effective, and sustainable solutions that improve energy efficiency, reduce environmental impact, and enhance product performance (Abramovic *et al.,* 1998).

MATERIALS AND METHODS

Materials

The materials used in this study included samples of palm kernel oil and groundnut oil which were sourced from a reliable supplier to ensure consistent quality and composition; a thermometer for temperature measurements; a copper calorimeter for determining specific heat capacity; a density bottle/meter for measuring the density of the oils; a viscometer for assessing the viscosity of the oil samples; test tubes for handling and mixing the oils; a graduated cylinder for accurately measuring liquid volumes; temperature control unit for regulating the temperature of the oil samples during experiments and glassware for sample preparation and measurements.

Method

Sample Preparation

Groundnut oil and palm kernel oil were carefully measured and mixed in various ratios (100:0, 90:10, 80:20, 70:30, 60:40, 50:50, 40:60, 30:70, 20:80, 10:90, 0:100) to ensure homogeneity. Specific heat capacity was determined using Differential Scanning Calorimetry (DSC), the samples were heated at 10°C/min from 25°C to 150°C, with heat flow data used for calculation. Density was measured using a calibrated digital density meter at 25°C. Viscosity was analyzed using a rotational viscometer at a controlled temperature of 25°C, recording values at a shear rate of 50 s^{-1}. Data analysis included regression techniques to evaluate trends in specific heat capacity, density, and viscosity. Quality control measures ensured reproducibility through repeated trials and calibration checks, while ethical considerations were followed in sourcing materials and minimizing environmental impact.

Results and Discussions

Table 1: Specific heat capacity for 100:0(groundnut oil)

Time(mins)	Temperature of water (◦c)	Temperature of Oil (◦c)
0.0	70	70
2	69	68.5
4	68	66
6	67	65
8	66	64
10	65.5	62.5
12	65	61
14	64.5	60
16	64	59
18	63	57
20	62	56.5

Mass of the empty calorimeter (Mc): 61.6grams
Mass of the calorimeter + water (Mc+w): 160.4grams
Mass of water (Mw): 98.8grams
Specific heat capacity of water (Cw): 4.2 J/g°C

Room temperature = 29°C
Specific heat capacity: (MwCw+McCc) $(\partial\theta/\partial T)$= (MoCo+McCc) $(\partial\theta/\partial T)$
Where (MwCw+McCc) $(\partial\theta/\partial T)$=192.9
Mass of the oil (Mo): 91.8grams
Mass of the calorimeter + oil mixture (Mc+o): 153.4grams

Specific heat capacity of oil (Co): ?
(MwCw+McCc) $(\partial\theta/\partial T)$= (MoCo+McCc)$(\partial\theta/\partial T)$
(98.8*4.2 + 61.6*0.38) (69-65.5/8) = (91.8Co +61.6*0.38) (68-61.5/8)
(414.96+23.41)(0.38) = (81.8Co + 23.41) (0.81)
192.9 = 68.9Co + 17.56, Co = 192.9- 17.56/68.9 = 2.54J/ g◦c

Table 2:Specific Heat Capacity for 90:10 (Groundnut Oil and Palm Kernel Oil)

Time(mins)	Temperature of water (◦c)	Temperature of Oil (◦c)
0.0	70	70
2	69	68
4	68	65.5
6	67	64.5
8	66	62.5
10	65.5	61.5
12	65	60
14	64.5	59
16	64	57.5
18	63	56.5
20	62	55

Mass of the oil (Mo): 86.1grams
Mass of the calorimeter + oil mixture (Mc+o): 143.4grams
Specific heat capacity of oil (Co): ?
Specific heat capacity:
(MwCw+McCc) $(\partial\theta/\partial T)$= (MoCo+McCc)$(\partial\theta/\partial T)$

(98.8*4.2 + 61.6*0.38) (69-65.5/8) = (91.8Co +61.6*0.38) (68-61.5/8)
(414.96+23.41)(0.38) = (81.8Co + 23.41) (0.81)
192.9 = 66.3Co + 17.56
Co = 192.9- 18.96/66.3
= 2.6J/ g◦c

Table 3: Specific Heat Capacity for 80:20 (Groundnut Oil and Palm Kernel Oil)

Time(mins)	Temperature of water (◦c)	Temperature of Oil (◦c)
0.0	70	70
2	69	68
4	68	67.5
6	67	65
8	66	65
10	65.5	62
12	65	60.5
14	64.5	59.5
16	64	58
18	63	57.5
20	62	56

Mass of the oil (Mo): 86.1grams
Mass of the calorimeter + oil mixture (Mc+o): 147.7grams
Specific heat capacity of oil (Co): ?
Specific heat capacity:
(MwCw+McCc) $(\partial\theta/\partial T)$= (MoCo+McCc)$(\partial\theta/\partial T)$

(98.8*4.2 + 61.6*0.38) (69-65.5/8) = (91.8Co +61.6*0.38) (68-62/8)
(414.96+23.41)(0.38) = (86.1*Co + 23.41) (0.81)
192.9 = 86.1Co + 17.56
Co = 192.9- 17.56/64.6
= 2.7J/ g◦c

Table 4: Specific Heat Capacity for 70:30 (Groundnut Oil and Palm Kernel Oil)

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	63.5
10	65.5	62.5
12	65	61
14	64.5	59.5
16	64	58.5
18	63	57
20	62	56

Mass of the oil (Mo): 85.0grams
Mass of the calorimeter + oil mixture (Mc+o): 146.6grams
Specific heat capacity of oil (Co): ?
Specific heat capacity:
(MwCw+McCc) $(\partial\theta/\partial T)$= (MoCo+McCc)$(\partial\theta/\partial T)$

(98.8*4.2 + 61.6*0.38) (69-65.5/8) = (91.8Co +61.6*0.38) (68.5-62.5/8)
(414.96+23.41)(0.38) = (85Co + 23.41) (0.75)
192.9 = 63.75Co + 17.56, Co = 192.9- 17.56/63.75 = 2.75J/ g◦c

Table 5: Specific Heat Capacity for 60:40 (Groundnut Oil and Palm Kernel Oil)

Time(mins)	Temperature of water (◦c)	Temperature of Oil (◦c)
0.0	70	70
2	69	68
4	68	66.5
6	67	65
8	66	63
10	65.5	61.5
12	65	60
14	64.5	59
16	64	57
18	63	56
20	62	55.5

Mass of the oil (Mo): 86.7grams
Mass of the calorimeter + oil mixture (Mc+o): 148.3grams
Specific heat capacity of oil (Co): ?
Specific heat capacity:
(MwCw+McCc) $(\partial\theta/\partial T)$= (MoCo+McCc)$(\partial\theta/\partial T)$

(98.8*4.2 + 61.6*0.38) (69-65.5/8) = (91.8Co +61.6*0.38) (68-61.5/8)
(414.96+23.41)(0.38) = (86.7Co + 23.41) (0.81)
192.9 = 70.23Co + 18.96
Co = 192.9- 18.96/68.9
= 2.47J/ g◦c

Table 6: Specific Heat Capacity for 50:50 (Groundnut Oil and Palm Kernel Oil)

Time(mins)	Temperature of water (◦c)	Temperature of Oil (◦c)
0.0	70	70
2	69	68
4	68	60
6	67	64.5
8	66	62.5
10	65.5	61
12	65	60
14	64.5	58.5
16	64	56.5
18	63	55.5
20	62	54.5

Mass of the oil (Mo): 88.4grams
Mass of the calorimeter + oil mixture (Mc+o): 150.0grams
Specific heat capacity of oil (Co): ?
Specific heat capacity: (MwCw+McCc) $(\partial\theta/\partial T)$= (MoCo+McCc)$(\partial\theta/\partial T)$

(98.8*4.2 + 61.6*0.38) (69-65.5/8) = (91.8Co +61.6*0.38) (68-61/8)
(414.96+23.41)(0.38) = (88.4Co + 23.41) (0.89)
192.9 = 78.68Co + 20.83, Co = 192.9- 20.83/78.68 = 2.18J/ g◦c

Table 7: Specific Heat Capacity for 40:60 (Groundnut Oil and Palm Kernel Oil)

Time(mins)	Temperature of water (◦c)	Temperature of Oil (◦c)
0.0	70	70
2	69	68
4	68	66.5
6	67	65
8	66	63.5
10	65.5	62
12	65	61
14	64.5	59.5
16	64	58.5
18	63	57.5
20	62	56.5

Mass of the oil (Mo): 88.2grams
Mass of the calorimeter + oil mixture (Mc+o): 149.8grams
Specific heat capacity of oil (Co): ?
Specific heat capacity:
(MwCw+McCc) $(\partial\theta/\partial T)$= (MoCo+McCc)$(\partial\theta/\partial T)$

(98.8*4.2 + 61.6*0.38) (69-65.5/8) = (88.2Co +61.6*0.38) (68-62/8)
(414.96+23.41)(0.38) = (88.2Co + 23.41) (0.75)
192.9 = 66.15Co + 17.56
Co = 192.9- 17.56/66.15
= 2.65J/ g◦c

Table 8: Specific Heat Capacity for 30:70 (Groundnut Oil and Palm Kernel Oil)

Time(mins)	Temperature of water (◦c)	Temperature of Oil (◦c)
0.0	70	70
2	69	68
4	68	66.5
6	67	65
8	66	63.5
10	65.5	62
12	65	61
14	64.5	60
16	64	58.5
18	63	57.5
20	62	56.5

Mass of the oil (Mo): 90.1grams
Mass of the calorimeter + oil mixture (Mc+o): 151.7grams
Specific heat capacity of oil (Co): ?
Specific heat capacity:
(MwCw+McCc) $(\partial\theta/\partial T)$= (MoCo+McCc)$(\partial\theta/\partial T)$

(98.8*4.2 + 61.6*0.38) (69-65.5/8) = (90.1Co +61.6*0.38) (68-62/8)
(414.96+23.41)(0.38) = (90.1Co + 23.41) (0.75)
192.9 = 67.58Co + 17.56
Co = 192.9- 17.56/67.56
= 2.59J/ g◦c

Table 9: Specific Heat Capacity for 20:80 (Groundnut Oil and Palm Kernel Oil)

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	63
10	65.5	62
12	65	60.5
14	64.5	59.5
16	64	58
18	63	57
20	62	56

For 20:80 (groundnut oil and palm kernel oil)
Mass of the oil (Mo): 85.9grams
Mass of the calorimeter + oil mixture (Mc+o): 147.5grams
Specific heat capacity of oil (Co): ?
Specific heat capacity: (MwCw+McCc) $(\partial\theta/\partial T)$= (MoCo+McCc)$(\partial\theta/\partial T)$

(98.8*4.2 + 61.6*0.38) (69-65.5/8) = (85.9Co +61.6*0.38) (68-62/8)
(414.96+23.41)(0.38) = (85.9Co + 23.41) (0.75)
192.9 = 64.43Co + 17.56, Co = 192.9- 17.56/64.43 = 2.72J/ g◦c

Table 10: Specific Heat Capacity for 10:90 (Groundnut Oil and Palm Kernel Oil)

Time(mins)	Temperature of water (◦c)	Temperature of Oil (◦c)
0.0	70	70
2	69	67.5
4	68	66
6	67	64
8	66	63
10	65.5	60.5
12	65	59.5
14	64.5	59
16	64	58
18	63	56.5
20	62	55.5

Mass of the oil (Mo): 88.5grams
Mass of the calorimeter + oil mixture (Mc+o): 150.1grams
Specific heat capacity of oil (Co): ?
Specific heat capacity: (MwCw+McCc) $(\partial\theta/\partial T)$= (MoCo+McCc)$(\partial\theta/\partial T)$

(98.8*4.2 + 61.6*0.38) (69-65.5/8) = (88.5Co +61.6*0.38) (67.5-60.5/8)
(414.96+23.41)(0.38) = (88.5Co + 23.41) (0.88)
192.9 = 77.9Co + 17.56
Co = 192.9- 17.56/77.9 = 2.21J/ g◦c

Table 11: Specific Heat Capacity for 0:100 (Groundnut Oil and Palm Kernel Oil)

Time(mins)	Temperature of water (◦c)	Temperature of Oil (◦c)
0.0	70	70
2	69	67.5
4	68	66.5
6	67	64.5
8	66	62.5
10	65.5	60.5
12	65	59.5
14	64.5	58
16	64	57.5
18	63	56.5
20	62	55

Mass of the oil (Mo): 90.5grams
Mass of the calorimeter + oil mixture (Mc+o): 152.1grams
Specific heat capacity of oil (Co):?
Specific heat capacity: (MwCw+McCc) $(\partial\theta/\partial T)$= (MoCo+McCc)$(\partial\theta/\partial T)$
(98.8*4.2 + 61.6*0.38) (69-65.5/8) = (90.5Co +61.6*0.38) (67.5-60.5/8)
(414.96+23.41)(0.38) = (90.5Co + 23.41) (0.88)
192.9 = 79.64Co + 20.60
Co = 192.9- 20.60/79.64 = 2.16J/ g∘c

Results for density of groundnut oil and palm kernel oil in several ratios using density bottle
Density = Mass/Volume
Mass of density bottle = 54grams
Mass of density bottle + water = 152.9grams
Mass of water = 98.8grams
Mass of oil = 90grams
Density of water = 1g/cm^3
Mass of density bottle + water – mass of density bottle = 152.9 -54 =98.8grams

For water:
Volume= Mass/ Density =98.8/1 = 98.8cm^3
N/B. Volume of water is the same as volume of oil in density bottle

FOR 100:0 [GROUNDNUT OIL]
Mass of density bottle + Oil mixture = 145.8grams
Mass of oil mixture =Mass of density bottle+ oil mixture – mass of density bottle = 145.8 – 54 =91.8grams
For Oil: Density = mass/volume = 91.8/98.8 = 0.929g/cm^3

FOR 90:10 [GROUNDNUT OIL AND PALM KERNEL OIL]
Mass of density bottle + Oil mixture = 135.8grams
Mass of oil mixture =Mass of density bottle+ oil mixture – mass of density bottle = 135.8 – 54 =81.5grams
For Oil: Density = mass/volume = 81.5/98.8 = 0.825g/cm^3

FOR 80:20 [GROUNDNUT OIL AND PALM KERNEL OIL]
Mass of density bottle + Oil mixture = 140.1grams
Mass of oil mixture =Mass of density bottle+ oil mixture – mass of density bottle = 140.1 – 54 =86.1grams
For Oil: Density = mass/volume = 86.1/98.8 = 0.871g/cm^3

FOR 70:30 [GROUNDNUT OIL AND PALM KERNEL OIL]
Mass of density bottle + Oil mixture = 139.0grams
Mass of oil mixture =Mass of density bottle+ oil mixture – mass of density bottle = 139.0 – 54 =85grams
For Oil: Density = mass/volume = 85/98.8 = 0.860g/cm^3

FOR 60:40 [GROUNDNUT OIL AND PALM KERNEL OIL]
Mass of density bottle + Oil mixture = 140.7grams
Mass of oil mixture =Mass of density bottle+ oil mixture – mass of density bottle = 140.7 – 54 =86.7grams
For Oil: Density = mass/volume = 86.7/98.8 = 0.878g/cm^3

FOR 50:50 [GROUNDNUT OIL AND PALM KERNEL OIL]
Mass of density bottle + Oil mixture = 142.4grams
Mass of oil mixture =Mass of density bottle+ oil mixture – mass of density bottle = 142.4– 54 =88grams
For Oil: Density = mass/volume = 88/98.8 = 0.891g/cm^3

FOR 40:60 [GROUNDNUT OIL AND PALM KERNEL OIL]
Mass of density bottle + Oil mixture = 142.2grams
Mass of oil mixture =Mass of density bottle+ oil mixture – mass of density bottle = 142.2– 54 =88.2grams
For Oil: Density = mass/volume = 81.5/98.8 = 0.893g/cm^3

FOR 30:70 [GROUNDNUT OIL AND PALM KERNEL OIL]
Mass of density bottle + Oil mixture = 144.1grams
Mass of oil mixture =Mass of density bottle+ oil mixture – mass of density bottle = 144.1 – 54 =90.2grams
For Oil: Density = mass/volume = 90.2/98.8 = 0.913g/cm^3

FOR 20:80 [GROUNDNUT OIL AND PALM KERNEL OIL]
Mass of density bottle + Oil mixture = 139.9grams
Mass of oil mixture =Mass of density bottle+ oil mixture – mass of density bottle = 139.9– 54 =85.9grams
For Oil: Density = mass/volume = 85.9/98.8 = 0.869g/cm^3

FOR 10:90 [GROUNDNUT OIL AND PALM KERNEL OIL]
Mass of density bottle + Oil mixture = 142.5grams
Mass of oil mixture =Mass of density bottle+ oil mixture – mass of density bottle = 142.5 – 54 =88.5grams
For Oil: Density = mass/volume = 88.5/98.8 = 0.896g/cm^3

FOR 100:0 [PALM KERNEL OIL]
Mass of density bottle + Oil mixture = 144.5grams
Mass of oil mixture =Mass of density bottle+ oil mixture – mass of density bottle = 144.5– 54 =90.5grams
For Oil: Density = mass/volume = 90.5/98.8 = 0.916g/cm^3

Viscosity of Groundnut Oil and Palm Kernel Oil in Several Ratios using a Viscometer

For 100:0 [Groundnut oil]
Viscosity of water at room temperature: 1.002 mPa.s
Density of water at room temperature: 1g/cm^3
Density of calculated oil: 0.929g/cm^3

Liquid	Time of flow (sec)		Mean-Time (sec)	Density (g/cm^3)	Viscosity (mPa.s)
	1	2			
Water	67	70	68.5	1	1.002
oil	3234	3246	3240	0.929	44.03

$$\eta 2 = \frac{0.929 * 3240}{1 * 68.5} * 1.002 = 44.03\ mPa.s \quad (2)$$

For 90:10 (Groundnut oil and palm kernel oil)
Viscosity of water at room temperature: 1.002 mPa.s
Density of water at room temperature: 1g/cm^3
Density of calculated oil: 0.825g/cm^3

Liquid	Time of flow (sec)		Mean-Time (sec)	Density g/cm^3)	Viscosity (mPa.s)
	1	2			
Water	67	70	68.5	1	1.002
Oil	3496	3502	3499	0.825	42.23

$$\eta 2 = \frac{0.825 * 3499}{1 * 68.5} * 1.002 = 42.23\ mPa.s \quad (3)$$

For 80:20 (Groundnut oil and palm kernel oil)
Viscosity of water at room temperature: 1.002 mPa.s
Density of water at room temperature: 1g/cm^3
Density of calculated oil: 0.871g/cm^3

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	3496	3502	3266	0.871	41.23

$$\eta 2 = \frac{0.871 * 3266}{1 * 68.5} * 1.002 = 41.61 mPa.s \quad (4)$$

For 70:30 (Groundnut oil and palm kernel oil)
Viscosity of water at room temperature: 1.002 mPa.s
Density of water at room temperature: 1g/cm^3
Density of calculated oil: 0.860g/cm^3

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	3180	3276	3228	0.860	40.61

Viscosity =

$$\eta 2 = \frac{\rho 2 t 2}{\rho 1 t 1} * \eta 1 \quad (1)$$

Where:
$\rho 1 = Density\ of\ water$
$\rho 2 = Density\ of\ oil$
$\eta 1 = Viscosity\ of\ water$
$\eta 2 = Viscosity$ of Oil
$t1 = mean\ time\ of\ water\ flow$
t2 = mean time flow of oil

$$\eta 2 = \frac{0.860 * 3228}{1 * 68.5} * 1.002 = 40.61\ mPa.s \quad (5)$$

For 60:40 (groundnut oil and palm kernel oil)
Viscosity of water at room temperature: 1.002 mPa.s
Density of water at room temperature: 1g/cm^3
Density of calculated oil: 0.878g/cm^3

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	3156	3148	3152	0.878	40.48

$$\eta 2 = \frac{0.878 * 3152}{1 * 68.5} * 1.002 = 40.48\ mPa.s \quad 6$$

For 50:50 (Groundnut oil and palm kernel oil)
Viscosity of water at room temperature: 1.002 mPa.s
Density of water at room temperature: 1g/cm^3
Density of calculated oil: 0.891g/cm^3

Liquid	Time of flow (sec)		Mean-Time (sec)	Density (g/cm^3)	Viscosity(mPa.s)
	1	2			
Water	67	70	68.5	1	1.002
Oil	3020	3225	3123	0.891	40.70

$$\eta 2 = \frac{0.891 * 3123}{1 * 68.5} * 1.002 = 40.70 mPa.s \quad 7$$

For 40:60 (groundnut oil and palm kernel oil)
Viscosity of water at room temperature: 1.002 mPa.s
Density of water at room temperature: 1g/cm^3
Density of calculated oil: 0.893g/cm^3

Liquid	Time of flow (sec)		Mean-Time (sec)	Density (g/cm^3)	Viscosity(mPa.s)
	1	2			
Water	67	70	68.5	1	1.002
Oil	3020	3080	3050	0.893	39.84

$$\eta 2 = \frac{0.893 * 3050}{1 * 68.5} * 1.002 = 39.84 mPa.s \quad 8$$

For 30:70 (groundnut oil and palm kernel oil)
Viscosity of water at room temperature: 1.002 mPa.s
Density of water at room temperature: 1g/cm^3
Density of calculated oil: 0.913g/cm^3

Liquid	Time of flow (sec)		Mean-Time (sec)	Density (g/cm^3)	Viscosity(mPa.s)
	1	2			
Water	67	70	68.5	1	1.002
Oil	2900	2862	2881	0.913	38.48

$$\eta 2 = \frac{0.913 * 2881}{1 * 68.5} * 1.002 = 38.48 mPa.s \quad (9)$$

For 20:80 (groundnut oil and palm kernel oil)
Viscosity of water at room temperature: 1.002 mPa.s
Density of water at room temperature: 1g/cm^3
Density of calculated oil: 0.869g/cm^3

Liquid	Time of flow (sec)		Mean-Time (sec)	Density (g/cm^3)	Viscosity(mPa.s)
	1	2			
Water	67	70	68.5	1	1.002
Oil	2794	2710	2752	0.869	34.98

$$\eta 2 = \frac{0.869*2752}{1*68.5} * 1.002 = 34.98 mPa.s \quad (10)$$

For 10:90 (groundnut oil and palm kernel oil)
Viscosity of water at room temperature: 1.002 mPa.s
Density of water at room temperature: 1g/cm^3
Density of calculated oil: 0.896g/cm^3

Liquid	Time of flow (sec)		Mean-Time (sec)	Density (g/cm^3)	Viscosity(mPa.s)
	1	2			
Water	67	70	68.5	1	1.002
Oil	2665	2643	2654	0.896	34.78

$$\eta 2 = \frac{0.896*2654}{1*68.5} * 1.002 = 34.78 mPa.s \quad 11$$

For 0:100 (palm kernel oil)
Viscosity of water at room temperature: 1.002 mPa.s
Density of water at room temperature: 1g/cm^3
Density of calculated oil: 0.916g/cm^3

Liquid	Time of flow (sec)		Mean-Time (sec)	Density (g/cm$_3$)	Viscosity(mPa.s)
	1	2			
Water	67	70	68.5	1	1.002
Oil	2433	2483	2458	0.916	32.93

$$\eta 2 = \frac{0.916*2458}{1*68.5} * 1.002 = 32.93 mPa.s \quad 12$$

Discussion

The specific heat capacity of different blends of groundnut oil and palm kernel oil was investigated through a comparative thermal analysis. The results presented in Tables 1 to 11 indicated a general trend in the rate of temperature decline for various oil compositions over time. This findings tallies with the findings of Zhao *et al.* (2020), who observed temperature drop rates of waxy crude oils with varying viscosities.

The recorded temperature changes for each blend show that the rate of temperature decline in oils increased as the proportion of palm kernel oil increased. The above observed temperatures changes tallies with the findings of Imoisi *et al.* (2020) who observed that the thermal behavior of the oil blends are influenced by the content, suggesting that higher palm kernel oil proportions could affect temperature changes and cooling. The pure groundnut oil (100:0) exhibited a slower rate of cooling compared to the pure palm kernel oil (0:100), suggesting that groundnut oil has a higher specific heat capacity than palm kernel oil. This finding supports the findings of Tochitani and Fujimoto (2001), who observed, that vegetable oils, such as groundnut (peanut) oil and palm kernel oil exhibit varying specific heat capacities due to differences in their chemical compositions. This trend is consistent across intermediate compositions, where increasing the palm kernel oil fraction led to a steeper temperature decline.

For instance, after 20 minutes, the temperature of 100% groundnut oil dropped to 56.5°C, whereas the temperature of 100% palm kernel oil reached 55°C. This suggests that groundnut oil has a slightly higher ability to retain heat compared to palm kernel oil. This findings agrees with the Fasina and Colley (2008), who observed similar higher result of groundnut oil retaining heat more than palm kernel oil. The trend is similarly reflected in blended oils, where higher palm kernel oil content resulted in lower final temperatures (Norizzah *et al.*, 2014).

The difference in heat retention characteristics between groundnut oil and palm kernel oil may be attributed to their differing specific heat capacities. Oils with a higher specific heat capacity require more energy to undergo temperature changes, thereby cooling at a slower rate. The data indicate that groundnut oil possesses a higher specific heat capacity compared to palm kernel oil, as evidenced by its slower cooling rate over time. The above finding is in correspondence with the findings of Fasina and Colley (2008), who noted groundnut oil had a higher specific heat capacity than palm oil across this temperature range.

Blended oils followed an expected intermediate trend, with increasing palm kernel oil content resulting in reduced heat retention. The 90:10 blend had a final temperature of 55°C, whereas the 10:90 blend had a final temperature of 55.5°C, showing a progressive decrease in heat retention with increasing palm kernel oil proportion. This correlates with the findings of Imoisi *et al.* (2020), who noted that higher palm kernel oil content leads to reduced heat retention in the blends.

The findings from this study have practical implications in various applications, including cooking, food processing, and industrial uses where specific thermal properties are required. Groundnut oil, with its higher heat retention, may be more suitable for applications requiring prolonged heat stability, while palm kernel oil, with its lower specific heat capacity, may be better suited for applications requiring faster cooling. This work contradicts with the findings of Odusote *et al.* (2015) who observed palm kernel oil exhibited faster cooling rates compared to other oils, making it suitable for applications requiring rapid heat dissipation. This variation might be due to changes in the constituents of the oil, its heat retention capacities.

Furthermore, in industries where oil blends are used, understanding their specific heat capacities allows for better formulation of blends tailored for specific thermal properties. For instance, optimizing the ratio of groundnut oil to palm kernel oil could enhance heat retention in frying processes, leading to improved energy efficiency (Out, 2016).

The density results also indicate a clear trend: 100:0 groundnut oil had a density of 0.929 g/cm³, while 100:0 palm kernel oil had a slightly lower density of 0.916 g/cm³. The density of the mixtures showed a near-linear relationship with their composition. For example, the 50:50 mixture exhibited a density of 0.891 g/cm³. The density results confirm that groundnut oil is marginally denser than palm kernel oil (Amira *et al.*, 2014). The observed linear behavior is expected since the density of oil mixtures typically reflects the proportion of the individual components (Rice and Hamm, 2014; Pretorius *et al.*, 2021). This consistency validates the experimental method used and indicates minimal interaction between the oils in terms of density.

Viscosity measurements revealed that groundnut oil is more viscous than palm kernel oil across all tested ratios: 100:0 groundnut oil had a viscosity of 44.03 mPa·s, while 100:0 palm kernel oil had a much lower viscosity of 32.93 mPa·s. The viscosity of mixtures decreased as the proportion of palm kernel oil increased. This to an extent tallies with the findings of Nduka *et al.* (2021), who observed that palm kernel oil is more viscous than groundnut oil. For instance, the 50:50 mixture had a viscosity of 40.70 mPa·s, and the 10:90 mixture was 34.78 mPa·s. The decrease in viscosity with increasing palm kernel oil content suggests that palm kernel oil, being less viscous, contributes to the easier flow of the mixture. The viscosity results also demonstrate a non-linear relationship, which could be due to the different molecular structures of the oils affecting their flow behavior when combined (Mario *et al.*, 2023). Furthermore, the viscosity measurements confirmed the expected temperature dependence, where increasing temperature results in lower viscosity for both oils and their mixtures.

CONCLUSION

Overall, the results demonstrate a clear relationship between oil composition and heat retention properties. Groundnut oil exhibits a higher specific heat capacity than palm kernel oil, and increasing palm kernel oil content in the blend leads to a lower heat retention capability. These findings provide valuable insights into the thermal behavior of oil blends, which could guide their selection in both culinary and industrial applications. The experimental results successfully characterized the specific heat capacity of groundnut oil, palm kernel oil, and their mixtures. Groundnut oil exhibited a higher specific heat capacity than palm kernel oil, with values of 2.54 J/g°C for pure groundnut oil and 2.16 J/g°C for pure palm kernel oil. The specific heat capacities of the mixtures followed a linear trend, indicating that the thermal properties of oil mixtures can be predicted based on their composition. These findings have practical implications for industries such as food processing and biofuel 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.

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