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Thermal Behaviour of Vegetable Oils: Influence of Viscosity, Composition, and Convection

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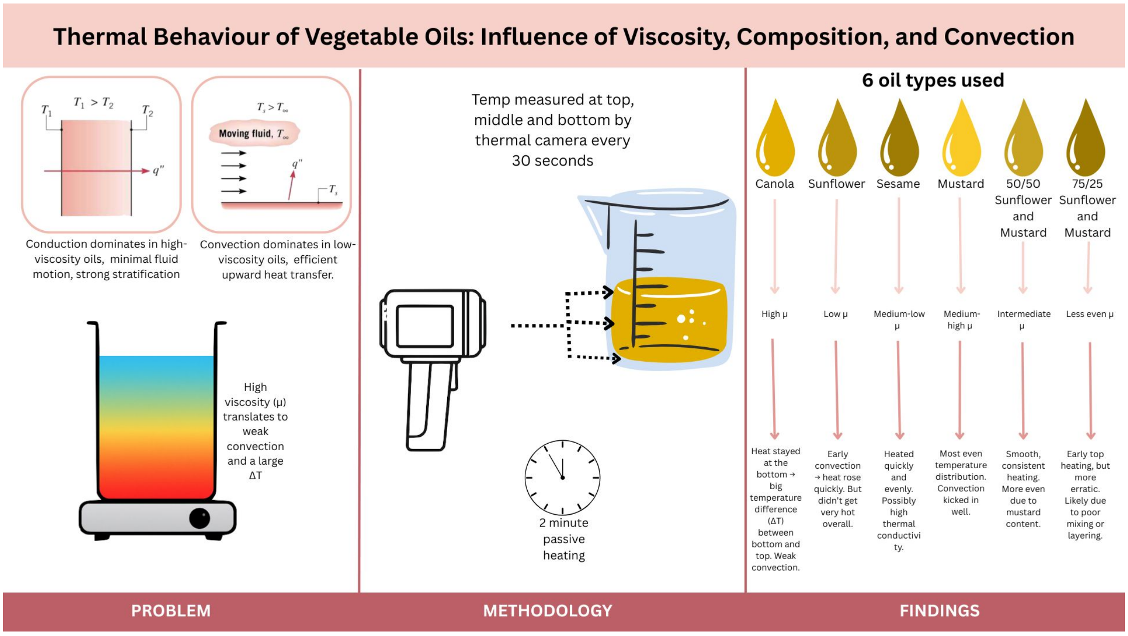
Graphical Abstract



Abstract

Understanding the thermal behaviour of different vegetable oils when exposed to heat is important in contexts ranging from thermal processing to cooking. This experiment investigated temperature variation in Canola, Sunflower, Sesame, and Mustard oils, as well as sunflower - mustard blends, during a two-minute passive heating process. To observe how heat is transferred through the fluid, temperatures were recorded at the bottom, middle, and top of each sample. Results showed that viscosity was the dominant factor influencing heat distribution. Canola, the most viscous oil, developed the strongest temperature gradients, while mustard oil heated more uniformly due to lower viscosity, allowing stronger convection currents. Sunflower and sesame oils produced intermediate results, with sesame showing relatively fast heat transfer. The oil blends displayed heating patterns between those of the pure oils, with higher sunflower content leading to faster and more efficient top heating. Despite variability associated with timing, mixing precision, and equipment inconsistencies, our results aligned with expected physical properties. These results demonstrate how relatively simple heat profiling can offer valuable insights into thermal and fluid behaviour.

Keywords: Heat transfer, convection, viscosity, vegetable oils, thermal stratification, fluid properties.

1. Introduction

Heat is transported through liquids by two interconnected mechanisms. Conduction is the transfer of heat through a material caused by the movement of energy between nearby molecules[1]. Convection transports heat by the bulk motion of the fluid. Warmer, lighter regions rise while cooler, denser regions sink, setting up a circulating flow that redistributes energy[2]. In practice the two mechanisms coexist: conduction controls the microscopic transfer between adjacent fluid layers, but once buoyancy forces overcome viscous resistance, fluid motion begins, forming natural convection currents that speed up heat transfer through the fluid[3].

Thermal conductivity(k) controls how quickly heat spreads through a fluid when the fluid itself is not moving[4]. In refined sunflower, rapeseed and palm oils, *k*, falls from ≈ 0.167 W m⁻¹ K⁻¹ at 20 °C to ≈ 0.137 W m⁻¹ K⁻¹ at 230 °C, so a hotter fryer or transformer tank must rely increasingly on convective motion to move the same amount of heat[5]. Specific heat determines the thermal energy storage capacity: adiabatic scanning calorimetry shows that c_p of vegetable oils rises almost linearly with temperature and is higher in monounsaturated oils, allowing them to absorb more energy per degree than polyunsaturated oils[6]. When convection is free to develop, it often dominates overall transfer. In deep-fat frying using canola, corn, palm, and soybean oils, the surface heat transfer coefficient (*h*) decreased almost linearly as viscosity increased. Oil degradation, which raises viscosity, reduced *h* by up to 30% under the same conditions[7]. These examples underline that *k*, c_p and buoyancy-driven flow jointly dictate how rapidly and uniformly heat can be removed or supplied in industrial and culinary equipment.

Vegetable oils are important in high-temperature cooking. Their flash points around 250 °C, non-toxic nature and flavour neutrality make them the ideal choice for frying and roasting. Interest is also growing in them as bio-derived thermal fluids**.** Solar cookers and domestic sensible-heat storage pots use sunflower, palm or blended oils as sustainable substitutes for synthetic thermal oils, due to lower cost and ready biodegradability[8]. Laboratory 3-ω hot-wire measurements confirm that these fluids retain acceptable conductivity up to 250 °C and can be tailored via fatty-acid composition or nanoparticle additives for specialised cooling, quenching or lubrication services[5].

This study investigates how composition impacts heat transfer by measuring vertical temperature stratification in six oils; canola, sunflower, sesame, mustard and two sunflower–mustard blends, heated from below. By logging temperatures at the base, mid-height and surface for two minutes, we quantify the residual change in temperature (ΔT) across the beaker. A small ΔT indicates strong natural convection, whereas a large ΔT signals conduction-dominated, stratified behaviour. By comparing pure and blended oils under the same heating conditions, we can identify how viscosity, density, and fatty acid composition affect natural convection

1.1 Key Parameters

Viscosity (μ): the main influence on convection. In frying studies, a 70 % rise in μ drove a proportional fall in *h*, a (|r| ≈ 0.96), illustrating how even modest thickening, whether from low-temperature choice or oxidative ageing can suppress circulation and elevate hot-spot temperatures[7].
Density (ρ) & thermal expansion (β): together are the forces behind natural convection. Oils richer in unsaturated chains are slightly less dense and possess larger β, yielding higher Rayleigh numbers and earlier transition to convection.
Thermal conductivity (k) & specific heat (c_p): determine, respectively, controls how fast heat spreads through a fluid and how much energy the fluid can store as its temperature increases. Both vary systematically with degree of saturation, *k* decreasing and c_p increasing as temperature rises[5,6].
Chemical composition: fatty-acid chain length and unsaturation impact all the above. Quench-cooling data show that lower-saturation (thus lower-μ) oils wet hot surfaces faster, while high-saturation oils may partially solidify at room temperature, virtually eliminating convection[9].
By comparing temperature profiles, this experiment identifies which aspects of oil composition, like viscosity or density have the strongest effect on convective heat transfer, a question with direct implications for food engineering, renewable heat storage and bio-based thermal-fluid design.

1.2 *Key Equations*

1. Fourier's Law of Conduction (Describes heat transfer by conduction):
$$q = -k\frac{dT}{dx}$$
Where k = thermal conductivity(W/mK), q = heat flux (W/m²), dTdx = temperature gradient[1]
2. Heat transfer equation:
$$q = m\,c_p\,\Delta T$$
3. Newton's Law of Cooling (Convective Heat Transfer)
$$q = hA(T_s - T_\infty)$$
Where h = heat transfer coefficient (W/m²K), influenced by viscosity, A = surface area, T_s= surface temperature, T_∞ = fluid temperature[2]
4. Rayleigh Number (Predicts the strength of natural convection):
$$Ra = \frac{g\beta\Delta T\,L^3}{v\alpha} = \frac{g\beta\Delta T\,L^3\,\rho^2\,c_p}{\mu k}$$
Viscosity enters here via: v=, kinematic viscosity, lower μ (dynamic viscosity) translates to higher Ra and hence stronger convection.[10]
5. Thermal Diffusivity
$$\alpha = \frac{k}{\rho\,c_p}$$
Which demonstrates how fast a material responds to

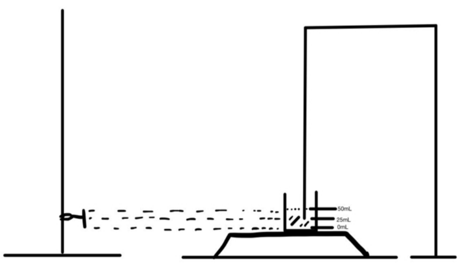
heating[11]

2. Methods

2.1 Experimental Setup

Given our experiment aimed to analyse convection of heat through different types of oil, our experimental setup aimed to measure the heat of oil at three points against time. To achieve this, 100mL beakers were filled to the 50mL graduation with the respective oils, whereby the three points could be measured to maintain simplicity at 0mL (the base of convection), 25mL and 50mL. Furthermore, a hot plate was installed beneath the beaker to heat the oil. The hot plate used was temperature probe based thus its heating was in accordance with the heat of the liquid used mostly for maintaining an elevated heat of liquid. Additionally, a thermal camera was installed horizontally to the hotplate's base using a retort stand. The thermal camera intended to observe and measure the heat at the desired measurement zones (bottom - 0mL, middle - 25mL, top - 50mL). Finally, the oils to be measured were, canola oil, sunflower oil, sesame oil, mustard oil and a 50/50 by volume blend of sunflower-mustard oil and a 75/25 by volume blend of sunflower-mustard oil (75% being sunflower oil). A diagram of this experimental setup is shown below.

Figure 1 *- Experimental setup:*



2.2 Data Collection Procedure

1. A 100 mL beaker was filled with 50 ml of canola oil.
2. Beaker was placed on the heating plate with the temperature probe submerged in the oil, not touching the base.
3. The thermal camera's capture points were set on the computer software at the base of the beaker, the 25 mL and 50 mL graduation line.
4. The temperature of the oil was recorded at all thermal camera capture points every 30 seconds for 2 minutes including the initial temperatures.
5. Steps 1-4 were repeated five times with the canola oil
6. Steps 1-5 were repeated with the other oils.
7. Once individual oils testing was completed, steps 2-5 were carried out with 50 mL of 1:1 sunflower-mustard oil blend and again for 50 mL of a 3:1 ratio of sunflower-mustard oil blend.
8. When blended mixtures were tested, observation of homogeneity was visually assessed and recorded.

2.3 Sources of Experimental Error

To assess the reliability of the results, errors were grouped into human error, equipment-related error and experimental design limitations. While these factors caused some inconsistencies, the overall trends remained fairly consistent with expected thermal behaviour.

Human Error

Accurately starting and recording time points was difficult across trials, especially when we often had to reposition the beaker or thermal camera. A Delay of a few seconds was common at the beginning of each trial. The 50 mL oil volumes were estimated by eye in 100 mL beakers, leading to small variations in fluid height. Parallax error may have also affected meniscus readings, resulting in slight volume errors. Additionally, creating 50/50 or 75/25 oil blends without pipettes also created decent variability, which could influence heating behaviour due to differences in viscosity and density between oils.

Equipment Error

The hotplate operated based on internal oil temperature targets instead of hot plate surface temperature, which caused significant variation between trials , with some beakers starting to heat on a surface over 200°C and others around 60°C. Slight changes in thermal camera positioning may have skewed results, particularly at the bottom of the beaker where reflected heat affected readings. In some cases, early measurements were delayed due to the time required to select bottom, middle, and top zones on the thermal camera interface.

Experimental Design Limitations

Mixtures were not stirred during heating to allow for natural convection and temperature gradient formation. As a result, the heavier oils like mustard may have settled unevenly, causing localised differences in heating. Even when they were pre-mixed, density and viscosity differences between oils could have led to stratification during heating.

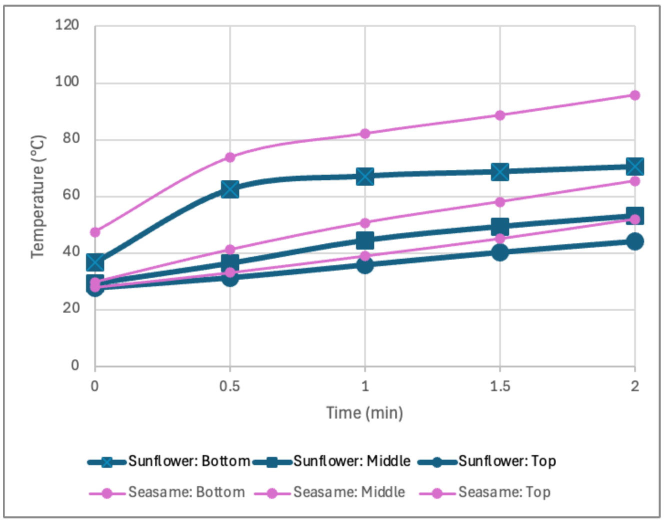
3. Results and Discussion

3.1 Temperature Profiles of Pure Oils

The temperature profile of pure oils was examined at various height intervals (bottom, middle, top) in order to analyse key factors of heat transfer such as viscosity, thermal conductivity and specific heat capacity. All these factors influence heating behaviour, in particular the ratio between conduction and convection, and which factor is dominating heat transfer. This notion was evident in the results where intriguing discoveries were made.

Figure 2 highlights the temperature increase, and thus heat transfer through the height of sesame oil over the course of 2 minutes. Among all the pure oils tested, sesame oil consistently reached the greatest final temperature across all levels (bottom: 95.74°C, middle: 65.42°C, top: 51.9°C). This finding suggests that sesame oil has a higher thermal conductivity, enabling a faster rate of energy transfer. Alternatively, it may also indicate a lower specific heat capacity, allowing the oil to heat up quicker per unit of energy. Additionally, the consistent rise of each level's temperature as opposed to a more asymptotic nature is indicative that convection-based heat transfer was likely developed in the later stages of the experiment. Thus, initially, when the oil was still, before convection currents influenced oil movement, conduction from the base layer of the oil was relatively efficient in heating vertically upwards.

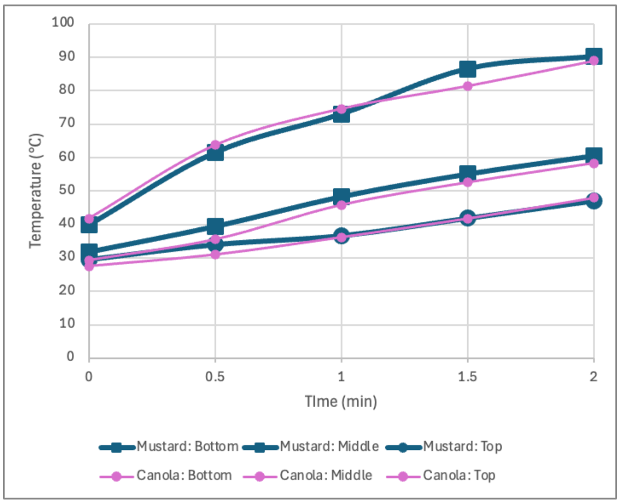
Figure 2 *- Temperature over time for sesame oil & sunflower oil:*



Conversely, sunflower oil displayed a high level of early convection compared to other oils due to its relatively lower viscosity. Figure 2 showcases the highest rate of temperature increase in the top layer in the earlier stages of heating, indicating the early onset of convection compared to other pure oils. This is likely due to sunflower's lower viscosity compared to sesame oil for example, and thereby, fluid motion is initiated sooner allowing for greater heat distribution upwards. However, despite the early onset of convection, this oil did not reach particularly high temperatures after the 2 minutes of elapsed time, suggesting sunflower oil may have a lower thermal conductivity. This intriguing finding conveys the essential distinction between high rates of convection, and total heat absorbed. Although natural convection is driven primarily by temperature-induced density gradients, the ability for heat to transfer through the oil (i.e., thermal conductivity) ultimately granting the formation of these convection currents. In sunflower oil, fluid motion is initiated earlier due to its lower viscosity, facilitating vertical heat transfer despite the total thermal energy absorbed being relatively low.

Mustard oil had the most uniform and efficient heat transfer and distribution, exhibiting the second highest overall temperature. Additionally mustard oil's final temperature difference between the bottom level and top level is relatively small, and thus this more uniform heating profile is indicative of consistent and effective convection currents throughout the oil after the onset of convection. Although Mustard oil is considered to be the most viscous of the 4 pure oils studied, its performance suggests that once convection was initiated in the fluid, convection dominated in heat transfer, significantly contributing.

Figure 3 *- Temperature over time for mustard oil & canola oil:*



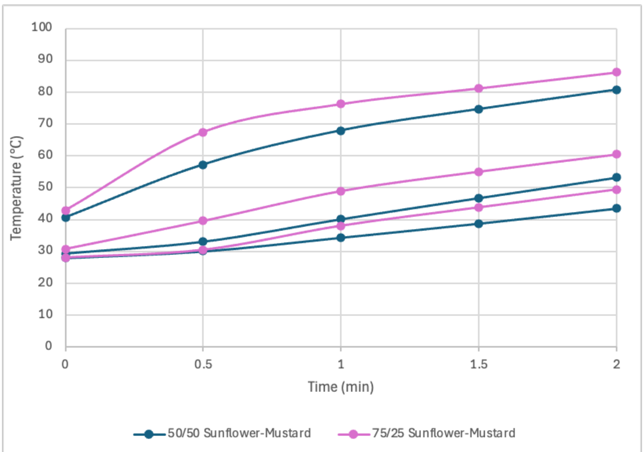
It is evident in our findings that viscosity is a key driver for convection performance. However there are other thermal properties which play a crucial role. It is important to state that based on the experimental data, it can be concluded that viscosity of the oils significantly impacts the onset and efficiency of convection, but not necessarily their overall performance in heat transfer. For example, figure 3 represents the temperature profile for canola oil. It can be deduced that despite canola oils' relatively lower viscosity compared to other oils, temperatures across all levels were particularly low over the 2 minutes. This observation is indicative that other thermal properties such as thermal conductivity and specific heat capacity heavily impact overall heat transfer, and the fluids ability to develop strong convection currents and transfer heat, despite the perceived advantage of a less viscous liquid.

As fluids heat, density gradients are created, governing density driven convection as the fluid begins to circulate. A fluid with a low thermal conductivity may struggle to create these steep temperature gradients necessary for density based convection. In a similar context, a high specific heat value would suggest poor convection too given the innate requirement in this context for a greater energy input to reach the same increase in temperature. Given this insight, it can be taken that an oil such as mustard oil, which is comparably more viscous than canola oil, may outperform canola oil (or a less viscous oil) in the possibility that either its thermal conductivity is higher, and/or its specific heat capacity is lower.

3.2 Temperature Profiles of Oil Blends

Figure 4 presents the temperature profiles of the two sunflower-mustard oil blends (50/50, 75/25). Both blends experienced a similar final temperature at the top level of the beaker, highlighting a likely comparable overall capacity for heat transfer performance. However, a few nuances can be explored in how these blends heated and reached their final temperatures. The 50/50 blend experienced a steadier, more gradual and linear temperature increase, while conversely the 75/25 blend suggested a slightly fast heating at the top layer compared to the 50/50 blend. Additionally the 75/25 mix showcases greater variations through lower levels too. These findings suggest that the 50/50 blend facilitated greater heat retention and uniform conduction, likely due to a greater quantity of mustard oil, and therefore more favourable thermal conductivity properties. Furthermore, the 75/25 mix experienced greater convection early on due to sunflower oil's lower viscosity. It can additionally be noted that the heat transfer process in the 75/25 mix (more sunflower oil) can be described as less consistent and efficient.

Figure 4 *- Temperature over time for 50/50 sunflower-mustard oil and 75/25 sunflower-mustard oil:*



As the oil blends were mixed by hand in the experiment, there is a level of human error, and more so natural propensity for the oil to be ineffectively mixed (due to differences in viscosity, density etc). Thus, despite our best efforts to physically mix the oils, differing densities and viscosities cause the mixture to behave not as a single, homogeneous fluid. Therefore, temporary layering in the oil or incomplete mixing may have been involved, and thus causing thermal stratification and distinct (or not distinct) density layers/regions, with the denser mustard oil settling to the bottom, and vice versa with sunflower oil. This can cause local regions in the beaker where thermal properties are altered (conduction dominating in some regions and convection in others). Overall, it can be concluded that errors with layering and inconsistent miscibility, leading to thermal stratification may have contributed to inconsistencies observed in the 75/25 blend's temperature profile.

Localised convection currents likely impacted uniform heating and convection onset timing. As discussed, sunflower oil experienced convection currents early on. Hence, the 75/25 oil mix would have experienced more early convection currents. However, these currents were likely formed locally in convection cells, especially near the bottom where viscosity was lowest (highest temperature), and lacked the ability to circulate upwards promoting heat transfer. Conversely, in the 50/50 blend, while the more viscous mustard oil created a higher resistance to motion initially, this blend likely developed stronger convection currents, properly transporting and transferring heat upwards through the oil blend, due to greater heat accumulation in the mustard-oil base (denser), and thus creating more drastic density gradients for convection to be thereby facilitated. This notion is represented in figure 4 where the 50/50 mix, while exhibiting lower temperatures at each level, displays a smoother, more consistent heating trend.

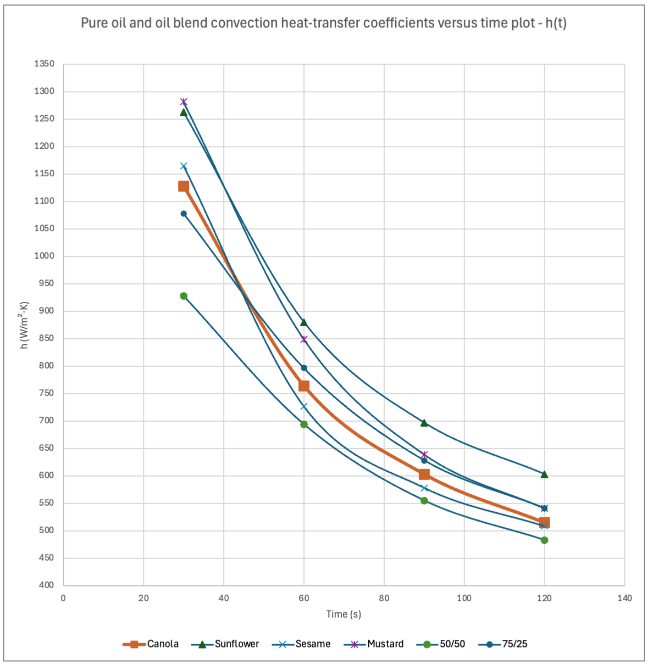
3.3 h-values for Oils/Oil Blends

Figure 5 identifies the heat transfer coefficient (h), for pure oils as well as oil blends, insightfully quantifying the efficiency of heat transfer between the heated plate and the oil via convection. Consistent with transient natural convection, h decreases asymptotically as the thermal boundary layer thickens and the temperature difference between the hot surface and the bulk oil shrinks, weakening buoyancy-driven flow (lower density gradient) and reducing heat flux per unit temperature, hence balancing convection and conduction towards a steady-state condition.

Derivation of h-values are sourced from equating equation 2 (heat transfer equation), and equation 3 (Newton's law of cooling):

$$q = m\, c_p\, \Delta T, \quad q = hA(T_s - T_\infty)$$
$$m\, c_p\, \Delta T = hA(T_s - T_\infty)$$

Figure 5 *- Convection heat-transfer coefficients plot:*



Findings of the convective heat transfer coefficient (h) and trends seen in figure 5 reinforce experimental findings in sections 3.1 and 3.2. Calculation of the convection coefficient values for the mustard oil blend found that initially heat transfer by convection occurred in a large magnitude due to the large temperature disparity between the solution and the heating mantle. As the temperature became more uniform throughout the solution and the density differences driving natural convection weakened, less convection occurred and the convection coefficient value decayed. The nonlinearity of the graph can be explained by the solution beginning to approach steady state conditions, with the h value decreasing until the heating effects and the cooling from the external surroundings balance and h reaches a stable level. Figure 5 shows a fast initial drop in h meaning that initial heat exchange in the system is efficient, providing evidence that the mustard and sunflower oil mixture is a viable option for thermal energy storage systems as it quickly absorbs heat and effectively retains and slowly releases it.

3.4 Key Influencing Factors

Several fluid properties influenced the heating behaviour observed in the experiment. These include viscosity, thermal conductivity, convection strength, and the formation of density gradients. Table 1 outlines the key factors in order of importance based on the experimental results.

Figure 6, Table 1 - Ranked Factors affecting heat transfer in oils

Factor	**Effect on heat transfer**	**Observed impact**
Viscosity	Affects how easily convection currents form. Higher viscosity slows down fluid motion.	Canola oil showed strong stratification, while mustard oil heated more evenly.
Convection strength	Circulates heat from the bottom to the top once a temperature gradient forms	Mustard and sunflower oils showed earlier or stronger convection compared to canola.
Thermal conductivity	Determines how well heat moves through the fluid.	Sesame oil heated up faster and more evenly than others, suggesting better conductivity.
Specific heat capacity	Oils with higher specific heat require more energy to heat up.	Sunflower oil heated slowly overall despite early convection.
Mixing and stratification	Uneven mixing can cause localised layering and inconsistent heating.	75/25 blend had more variation, likely due to incomplete mixing or separation.
Initial surface temperature	Hotplate control affected how much energy was delivered early in the experiment.	Some trials (e.g. sesame oil) had high starting temperatures at the base due to heat retention.

While not all results were perfectly consistent, most trends generally matched what would be expected from each oil's physical properties. Canola, the most viscous, showed delayed and weak convection, with heat staying mostly at the bottom. Mustard, although viscous, heated more evenly once convection had started, possibly due to a lower specific heat or stronger fluid circulation. The sesame oil consistently reached high temperatures at all levels which suggests better internal heat transfer, likely due to higher thermal conductivity. Furthermore, the sunflower oil, which had low viscosity, showed signs of early convection but lower overall heating, suggesting that lower conductivity limited how much energy the fluid retained.

A lot of the differences between how the oils heated up can be explained using heat transfer principles. The first concept is the **Rayleigh number**, which tells us when natural convection is likely to kick in. It depends on factors such as viscosity and the temperature difference across the fluid. Oils like mustard and sunflower are less viscous, so they're more likely to start circulating earlier which was reflected in our results, with both showing early signs of convection and more even heating compared to thicker oils like canola, where the heat mostly stayed near the bottom.

Similarly, the **Biot number** helps explain how heat moves inside the fluid compared to how it interacts with outside air. Oils like canola, which developed strong internal temperature gradients and slow top heating, likely had higher Biot numbers, meaning that their internal resistance to heat flow was dominant. However, sesame likely had a lower Biot number which allowed for more even internal heating.

The blended oils also showed these patterns to some extent, with the 50/50 mix showing steady and consistent heating, while the 75/25 mix heated faster at the top but was less uniform overall. This could be due to uneven mixing, or slight stratification caused by differences in density or viscosities between the two oils.

3.5 Real-World Relevance

The thermal behaviour of vegetable oils plays a crucial role in both culinary applications and industrial process design. In the kitchen, oils with higher specific heat capacities can absorb and retain heat more efficiently, offering better temperature stability during cooking processes such as frying or sautéing. The main implications of heat retention and absorption in vegetable oils apply to the quality and safety of food preparation, highlighting the essentiality of understanding of chemical properties in vegetable oils specifically. In industrial settings, particularly within process engineering, the thermal conductivity and heat capacity of oils influence their suitability as heat transfer fluids in systems such as biofuel production, lubrication, and thermal storage. Understanding these properties is therefore essential for optimizing heat management, ensuring process consistency, and maintaining system efficiency.

The thermal stability of cooking oils is crucial for food safety and product quality control especially during processes that require high temperatures or an even heat distribution. Since the specific heat capacity of a stationary fluid directly impacts how its temperature changes over time, its value provides a myriad of implications for how the fluid behaves chemically under different thermal conditions. For culinary applications, these behaviours can influence the quality of the product and the safety of its consumption, in the case of vegetable oils, using an oil that is not able to suitably adjust to high temperatures results in the production of harmful chemicals and smoke. Selecting an oil that is suitable for its respective use is crucial to avoid this, and thus knowledge of the oils ability to absorb and retain heat is required. As seen in the data collected throughout this report a range of vegetable oils interact differently with temperature due to their ability to conduct heat, with oils with higher specific heats taking longer to heat up but retaining the heat for longer, and oils with low specific heats increasing in temperature at a faster rate. The heat transfer coefficient also influences the oils thermal properties, with oils like sesame and canola having lower h values and therefore lower heat exchange initially. This information allows culinary experts to determine the suitability of vegetable and other types of oils when using them for their practice, for instance, oils with higher specific heats retain heat for longer and therefore affect how evenly food can be cooked or seared. Other applications involve the oil's stability at a certain heat which is critical in deep frying, or preventing substantial temperature swings when food is added to the hot oil. Overall, knowledge of an oil's thermal properties can hold significant influence in their application in a culinary context.

Vegetable oils have gained increasing attention as alternative heat storage and heat transfer fluids in industrial applications such as their use in chemical reactors or thermal energy storage systems. The specific heats and heat transfer coefficients of the oils plays a critical role in their suitability for these applications, as it is often required that the oil be a viable means of transferring or retaining heat effectively. Oils with higher h values initially with steady decreases in h as they heat up are suitable for thermal energy systems due to their ability to quickly absorb heat and retain it for extended periods of time, this study found that sunflower and mustard oils match this criteria the most effectively. Sunflower oils have recently been integrated into the energy space with their use in solar thermal systems. In a comparative study that tested the viability for sunflower oil and water for a solar collector, sunflower oil was found to dissipate heat at a faster rate (0.462°C/min)[11] while also being heated more efficiently (12.4%)[11] when flowing through the system compared to waters 0.292°C/min[11] and 9.9%[11] respectively, making it a great option for efficient energy collection. This is partly due to the oil's lower heat capacity which enables it to absorb and dissipate heat at a faster rate than that of other fluids. Vegetable oils also offer sustainability advantages, as they are biodegradable and have a significantly lower environmental impact surrounding their production process. Thus vegetable oils provide a promising look into future solutions for energy storage that are cost efficient and stable for the long term.

An additional consideration is the phenomenon of stratified heating, where uneven temperature distribution occurs within a fluid body. This is especially relevant in large-scale operations, where inadequate mixing or poor thermal conductivity can lead to localized overheating or under processing. Thermal stratification is highly relevant in the utilisation of vegetable oils in thermal energy storage (TES) systems, as the formation of distinct temperature layers can enhance their efficiency as maintaining thermal stratification enables better temperature control and energy efficiency. Sunflower is another apt candidate for TES systems as upon testing it showed many valuable thermal properties, such as minimal thermal degradation until about 400°C [12], additionally, sunflower offered many similar characteristics to that of other thermal oils making it a viable option due to its wide availability and relatively cheap production costs. The use of vegetable oils in TES systems becomes particularly advantageous at higher storage temperatures, as oils maintain stable thermal properties while water is limited by its boiling point, making it necessary to undergo additional costs to ensure the storage vessel is pressurised and fitted with stratification devices to ensure optimal heat distribution. Overall, sunflower oil particularly and other vegetable oils provide a viable solution to maintaining optimal stratification in TES systems due to their thermal characteristics.

4. Conclusion

Within our experiment five different oils were used as well as oil blends to determine their convection profiles and their convective heat transfer coefficient. Sesame oil reached the highest temperatures and heated the fastest, reflecting its high conductivity and/or low specific heat capacity, whilst sunflower oil had high convective heat transfer potentially due to low viscosity whilst having a low temperature increase. This finding suggested lower conductivity whereby convective forces dominated. Mustard oil had the most uniform temperature distribution once density/convection currents developed. Finally, canola oil's strong stratification can be attributed to its high viscosity. Furthermore, the 50/50 blend had a relatively smooth heating whilst maintaining moderate responsiveness hence effective convection. In comparison, the 75/25 blend warmed quickly but unevenly amongst the thermal camera capture points. This was likely due to partial layering (nonhomogeneity) and thermal stratification. The convective transfer coefficient (h) decreased asymptotically as the thermal boundary layer thickened, reflecting transient heating natural convection.

Through our experiment, it is suggested that heat-transfer of oils in any industry as well as culinary applications engineering strategies should control mixing to maintain homogeneity within the oils and disrupt boundary layering. Moreover, engineers can consider finned surfaces to accelerate convection of oils to increase area limited by the beaker base. Additionally, our results made evident the changes oil blends can have convective heat transfer by manipulating physical attributes such a viscosity or density. Hence, implementing more complex blends based on these attributes can accelerate heating and thereby increase energy efficiency.

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