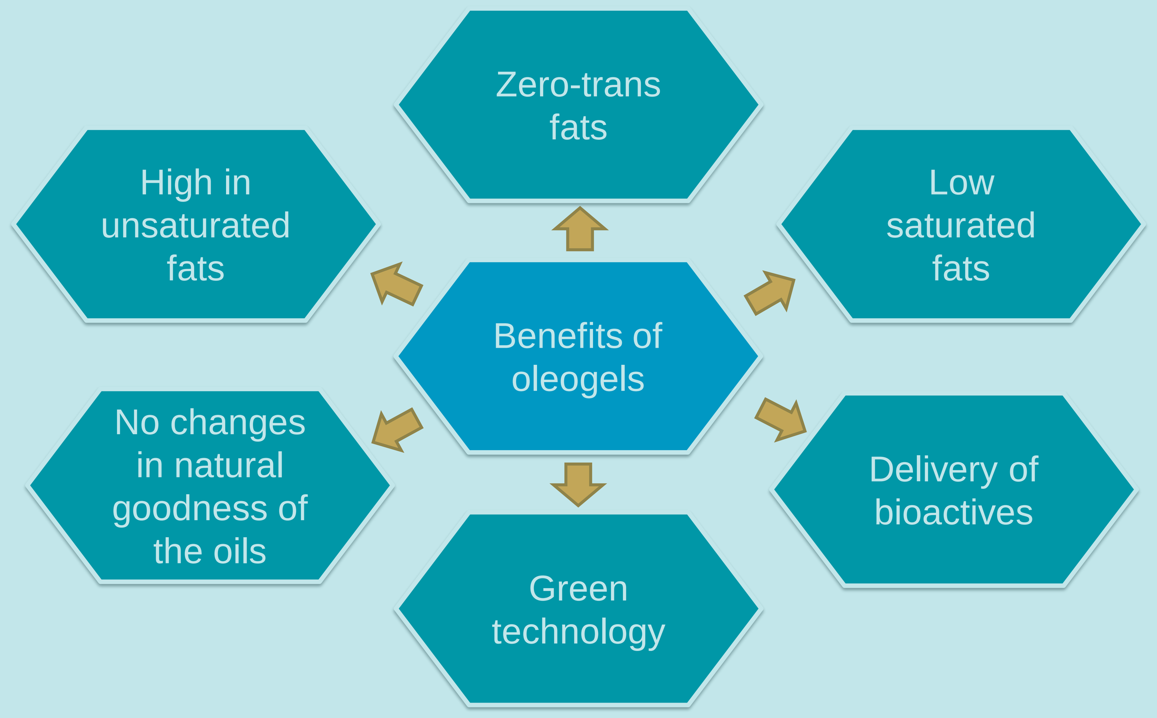
# DEVELOPMENT OF NEW HEALTHY OLEOGEL AS AN ALTERNATIVE TO CURRENT MARGARINES

**SUBAJINY SIVAKANTHAN[a,b,c]*, SABRINA FAWZIA[a], SAGADEVAN MUNDREE[d], TERRENCE MADHUJITH[e], AZHARUL KARIM[a]**

[a]Faculty of Engineering, Queensland University of Technology, Australia, [b]University of Jaffna, Sri Lanka, [c]Postgraduate Institute of Agriculture, University of Peradeniya, Sri Lanka, [d]Faculty of Science, Queensland University of Technology, Australia, [e]Faculty of Agriculture, University of Peradeniya, Sri Lanka

## Introduction

- Traditional solid fats such as margarine contain high amounts of trans and saturated fatty acids which are strongly linked with many human ailments including cardiovascular diseases [1].
- Legislations and recommendations related to the consumption of these unhealthy fats resulted in mounting interest in finding alternatives.
- Oleogelation: A physical method to convert liquid oils into gels (oleogels) by entrapping the oil in 3D network formed by oleogelators.
- Oleogels - promising trans-free and less-saturated fat healthy alternative for traditional solid fats.
- The benefits of oleogels are shown in the figure below.



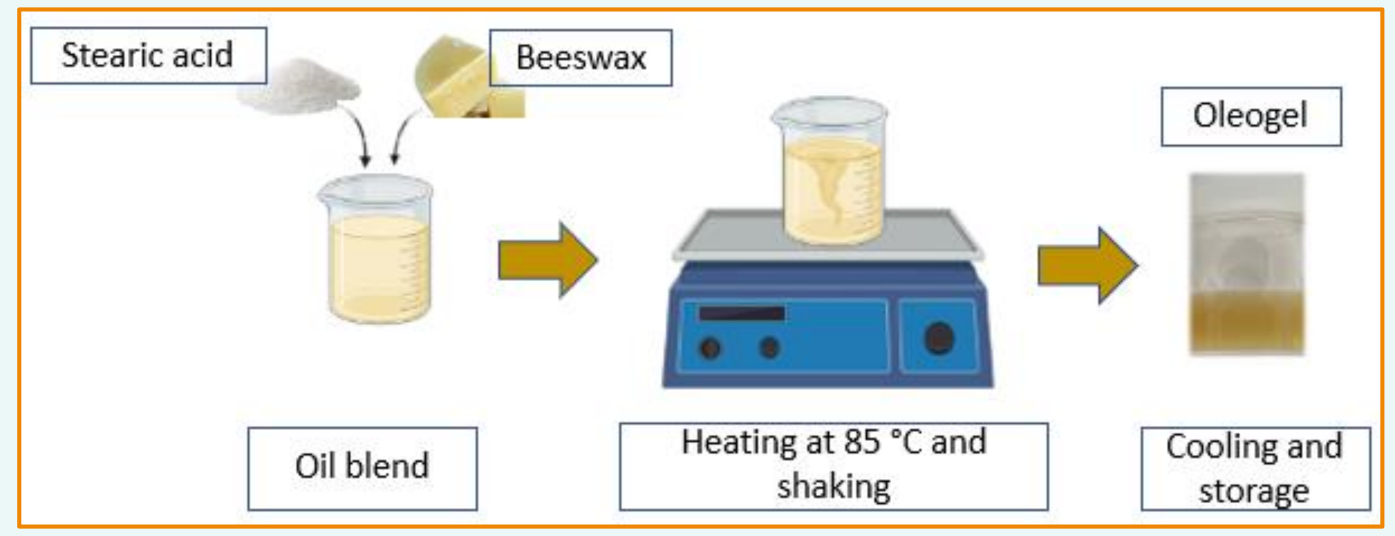

- Sesame oil and rice bran oil: rich in unsaturated fatty acids bioactive compounds such as tocopherols, sterols, etc.
- Beeswax and stearic acid, which are approved food additives by the US Food and Drug Administration (FDA), were used as the oleogelators.
- It is vital to explore the optimum mixture and processing conditions for developing oleogels that can mimic the properties of traditional solid fats.
- The interactions between the oleogelator/s, and the oil/s have a major influence on oleogel properties.

## Aim

- This study aimed to characterize and compare the properties of oleogel optimized in our previous study with those of commercial margarine
- An optimization study was conducted [1] to find out the optimum mixture of oils and oleogelators to develop oleogels with properties close to commercial margarine.
- This study analyzed and compared the properties of the optimized oleogel and commercial margarine.

## Methodology

### Oleogelation protocol




**Oleogel formula - sesame oil: rice bran oil at the ratio of 4:5 (w/w) and beeswax: stearic acid at the ratio of 3:1 (w/w) with a total oleogelator concentration of 11.74% (w/w) of the total mixture.**

### Optimization and analysis

**Preliminary experiments**
- Selection of oils and oleogelators
- Determination of processing parameters – temperature of heating, shaking speed

**Design of experiments**
- Response Surface Methodology
- Extreme Vertices Design with 32 runs using Minitab 21.1
- Factors: Amount of sesame oil, rice bran oil, beeswax, stearic acid

**Optimization**
- Responses : Oil binding capacity, and rheological properties
- Optimization conditions: oil binding capacity - maximum (100%), rheological parameters close to the commercial margarine

**Analysis**
- Oleogel was prepared according to optimized formula
- Properties analyzed: oil binding capacity, rheological parameters, thermal properties, and fatty acid profile

### Characterization

Oleogel and commercial margarine

- Oil binding capacity
- Rheological properties
- Thermal properties
- Fatty acid profile

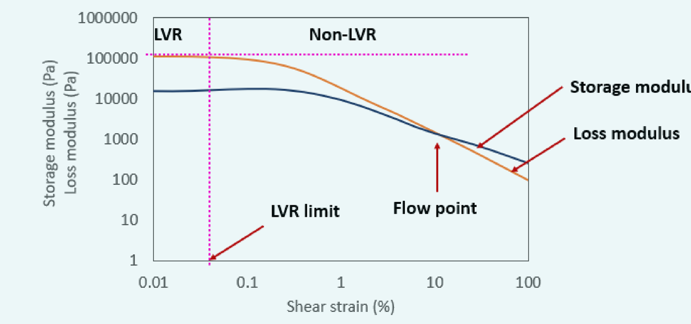
### Oil binding capacity

$$\text{Oil binding capacity (\%)} = 1 - \frac{\text{Weight of gel after draining the oil}}{\text{Total weight of gel}} \times 100$$

### Rheological properties

**Amplitude sweep**

- to determine Linear Viscoelastic Range (LVR), storage modulus (G′) at LVR, flow tau (τ), flow gamma (γ), G′ at flow point
- Parameters used are Strain: 0.01–100% , Frequency: 1 Hz

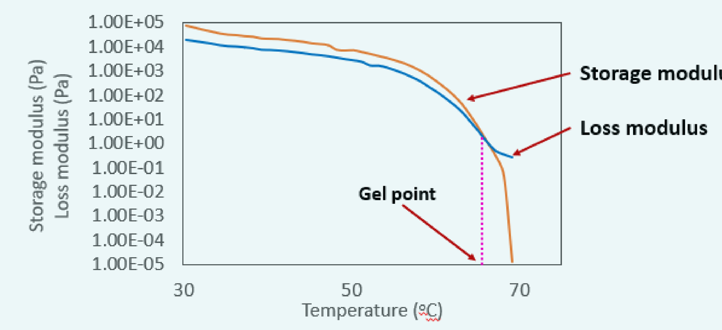



**Frequency sweep**

- To determine the frequency dependent nature of the samples
- Parameters used are frequency: 0.01–100 Hz, strain value within LVR

**Temperature sweep**

- To determine the gel point
- Dynamic temperature ramp test
- Programme: 20 to 70 °C, 2 °C min$^{-1}$, frequency of 1 Hz, strain value within LVR

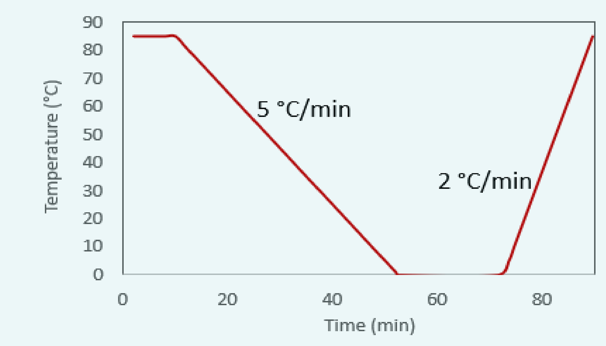



**Thixotropy**

- To determine the structure recovery ability
- Three Interval Thixotropy Test (3 ITT): alternating constant shear rates (0.1, 10, and 0.1 s-1) in three intervals (10, 5, and 10 min)
- The structure recovery was calculated by considering the change in viscosity

### Thermal properties

- To determine onset and peak melting and onset and peak crystallization using Differential Scanning Calorimetry
- Samples were subjected to the temperature programme as shown in the figure




### Fatty acid profile

- Fatty acid methyl esters were prepared from samples and analyzed by GCMS
- Cis and trans fatty acids were identified and quantified using reference standards - Supelco 37 component FAME mix, linoleic acid methyl ester mix, methyl trans-vaccinate

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## Statistical analysis

Statistical analyses were performed using the Minitab 21.1 software package (Minitab, LLC, USA). Values are expressed as mean ± standard deviation. One-way ANOVA and Duncan's test were employed to measure the statistical significance. The significance level used was 95% ($p < 0.05$).

## Results

- The optimized formula (per g) was sesame oil = 0.40 g, rice bran oil = 0.48 g, beeswax = 0.09 g, and stearic acid = 0.03 g (sesame oil and rice bran oil at the ratio of 4:5 and beeswax and stearic acid at the ratio of 3:1 with a total oleogelator concentration of 11.74% [2]

Table 1: Oil binding capacity and rheological parameters of oleogel and commercial margarines

| Parameter | Oleogel | Margarine |
|---|---|---|
| Oil binding capacity (%) | $99.99 \pm 0.00^{a}$ | 70.13 – 79.65* |
| LVR limit | 0.056±0.002 | 0.022 – 0.034* |
| Flow G′ (Pa) | 1,180.67±70.23 | 1,210 – 2,260* |
| G′ at LVR (Pa) | 108,000±1,550 | 4,9300 – 7,8600* |
| Loss factor | $0.14 \pm 0.003^{a}$ | $0.14 \pm 0.006^{b}$ |
| Flow τ (Pa) | 217.15±26.81 | 255.10 – 372.5* |
| Flow γ (%) | 12.17±1.93 | 11.73 – 14.90* |
| Gel point (°C) | 62.63±0.50 | 56.29 – 61.02* |

Different superscript letters (a-b) in the same row show a significant difference ($p < 0.05$). *Values for the references are provided as a range of values of four commercial samples

- Oil binding capacity explains the ability of the gel structure to hold the oil.
- The oil binding capacity of the commercial samples was much less compared to the oleogels (Table 1).
- The very high oil binding capacity of the oleogel indicates that the structure of oleogels is stronger than that of commercial margarines
- Rheology plays a crucial role in understanding and manipulating the properties of oleogels.
- Amplitude sweep experiments were conducted to determine the LVR limit and flow point-related properties (Figures 1).
- Frequency sweep is used to investigate the long-term and short-term behaviour of the sample at low and high frequencies (Figures 2).

- **The LVR limit of oleogel and G′ at LVR were significantly higher than commercial margarine (Table 1).**
- **A higher LVR limit and G′ at LVR indicates that oleogel has a stronger gel structure than commercial margarine (Table 1 and Figure 1).**
- **Flow properties except flow τ of oleogel were similar to those of commercial margarine (Table 1)**
- Oleogel showed a frequency-independent nature at lower frequencies from 0.1 Hz to 10 Hz, however, slight frequency-dependent nature at frequencies higher than 10 Hz compared to commercial margarine was observed (Figure 2).

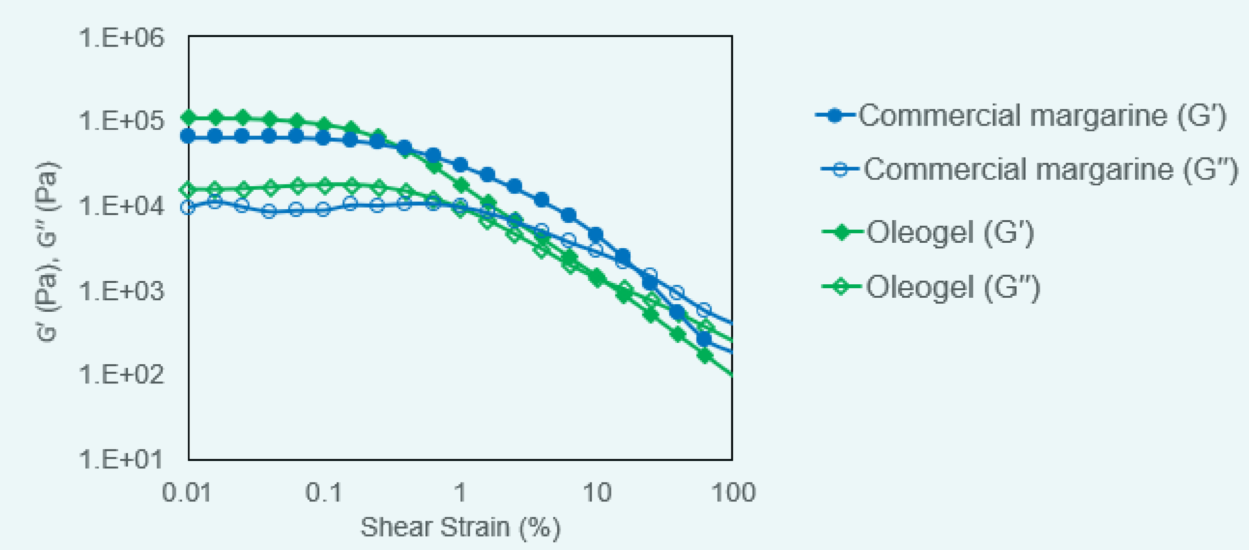


Figure 1: Amplitude sweep rheogram

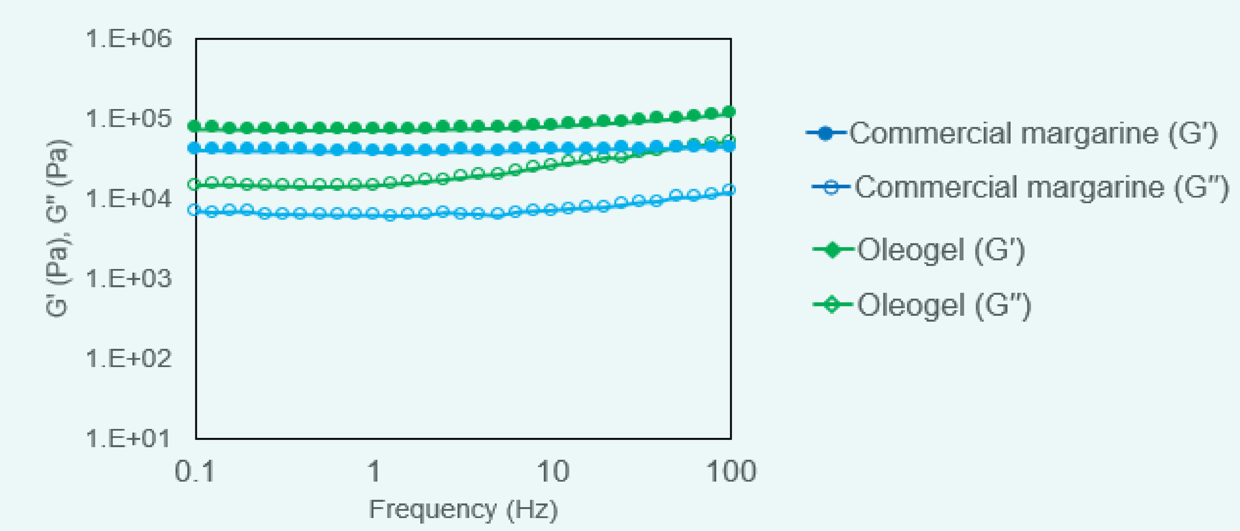


Figure 2: Frequency sweep rheogram

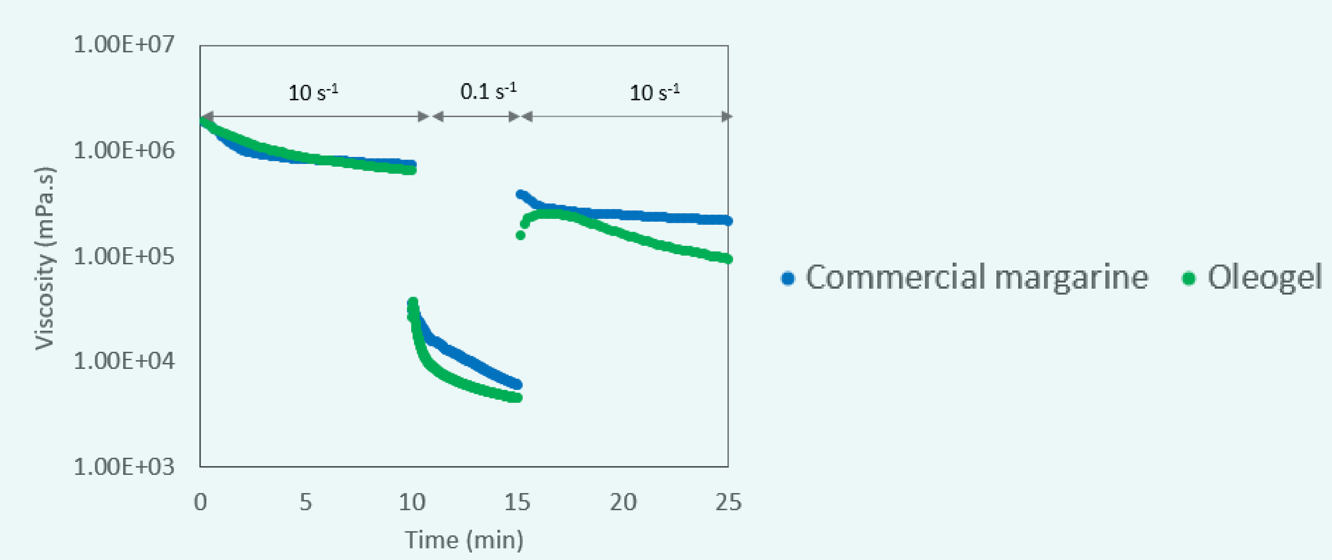


Figure 3: Thixotropy

Table 2: Thermal properties of oleogel and commercial margarines

| Sample | Onset melting (°C) | Peak melting (°C) | Onset crystallization (°C) | Peak crystallization (°C) |
|---|---|---|---|---|
| Oleogel | 34.70±0.71 | 50.33±0.55 | 48.00±0.53 | 47.40±0.52 |
| Margarine | 51.70-57.10* | 51.90-61.80* | 16.10-16.70* | 15.40-16.20* |

*Values for the references are provided as a range of values of four commercial samples

- **Thixotropic recovery of oleogel was significantly less than that of commercial margarine (Figure 3).**
- Thixotropic recovery is related to spreadability.
- Therefore, further modifications are required to enhance the spreadability of oleogel.
- **Gel point temperature of oleogel and commercial samples were not significantly different**.
- **Thermal properties of oleogel except peak melting were significantly different from those of commercial margarine (Table 2).**
- Oleogel had significantly higher unsaturated fatty acid (85%) content and less saturated fatty acid (15%) content than commercial margarine (76% and 23%, respectively).
- There were **no trans fatty acids detected in the oleogel, while commercial margarine had trans fatty acid content ranging from 0.5-1.%.**

## Conclusion

- The oleogel possesses better properties than commercial margarines in terms of oil binding capacity, LVR limit, G′ and at LVR
- However, the structural recovery ability of the oleogel was poor compared to commercial margarine
- There is a promising potential for the development of oleogels as a healthy alternative to commercial margarines from sesame oil and rice bran oil using beeswax and stearic acid

## Further studies

- Further studies will be oriented to enhance the structural recovery ability and frequency-independent nature of oleogel and to enhance the functional properties of oleogel by incorporating bioactives.

## Industrial implications

- The outcomes of this study will contribute to the knowledge of developing oleogel with added functional benefits and as a replacement for current margarines in food industries.

## References

1. Sivakanthan, S., Fawzia, S., Mundree, S., Madhujith, T., & Karim, A. (2023). Optimization and characterization of new oleogels developed based on sesame oil and rice bran oil. Food Hydrocolloids. 142, 108839. https://doi.org/10.1016/j.foodhyd.2023.108839

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