Evaluate the co-crystallisation of saturated triglycerides with wax mono-esters to reduce saturated fat in foods

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Background

- Fats provide shortening properties; giving a tender and more uniform texture to food products [3, 7].
- Saturated fatty acids and *trans*-fatty acids, found in commercial fats are associated with health complications, such as cardiovascular diseases [3].
- Natural saturated fats are used to remove *trans*-fatty acids from food products, such as palm oil (PO).
- PO is split into two fractions; palm olein (liquid fraction) and palm stearin (solid fraction), where palm stearin is used in food products [5].
- Oleogelation is a new method to replace saturated fat, where a gelator (such as wax) is used to structure the liquid oil [4].
- Rice bran wax (RBW) is an efficient gelator due to its highly crystalline structure and high melting temperature. RBW can gel large volumes of liquid, giving strong gel networks [2, 6].

Aim

Understand the effects of partially replacing PO with sunflower oil (SFO) and RBW to reduce the amount of saturated fat in bakery products, whilst maintaining their physicochemical properties.

Objectives

1. Investigate the co-crystallisation of PO and RBW in the different fat blends.
2. Identify the effects of PO and RBW co-crystallisation on blends viscoelastic behaviour.
3. Understand the effects of storage temperature on the crystal morphologies.

Hypothesis

In mixed systems, RBW molecules can co-crystallise with saturated fat, altering the crystallinity and the physicochemical properties.

Materials & Methods

Different RBW blends were made, using SFO, PO and RBW. Fat blends (25% SFO: 75% PO) were made, where RBW was added on top as a percentage of the total mass, at four different concentrations (1%, 2%, 3% and 5%).

The RBW blends were prepared by melting the SFO, PO and fat blend with RBW in a glass vial. The blends were heated in a water bath at 90°C for 20 minutes and cooled at 5°C for 30 minutes. Then the blends were placed into storage ventilators at 5 °C, 20°C and 35°C [1, 6].

The blends were analysed with the following methods:

- Polarised light microscopy – The blends stored at 20°C were analysed after 24 hours and images were taken at a magnification of x40.
- Differential scanning calorimetry (DSC) – The blends were run through on a 14 step applied thermal programme, which looked at the melting and cooling of the blends from 90°C to -60°C.
- Oscillatory rheology – The samples were melted at 90°C in a water bath and poured onto the plate. The water bath was set to 60°C and the plate was set to 75°C. The blends were analysed using a 2 step amplitude sweep.
- X-ray diffraction (XRD) – The blends were analysed at 20°C, with a scanning range of diffraction angle 2θ from 5 to 45°. The samples were analysed after 24 hours and one week in storage ventilators at 5°C, 20°C and 35°C.

Results

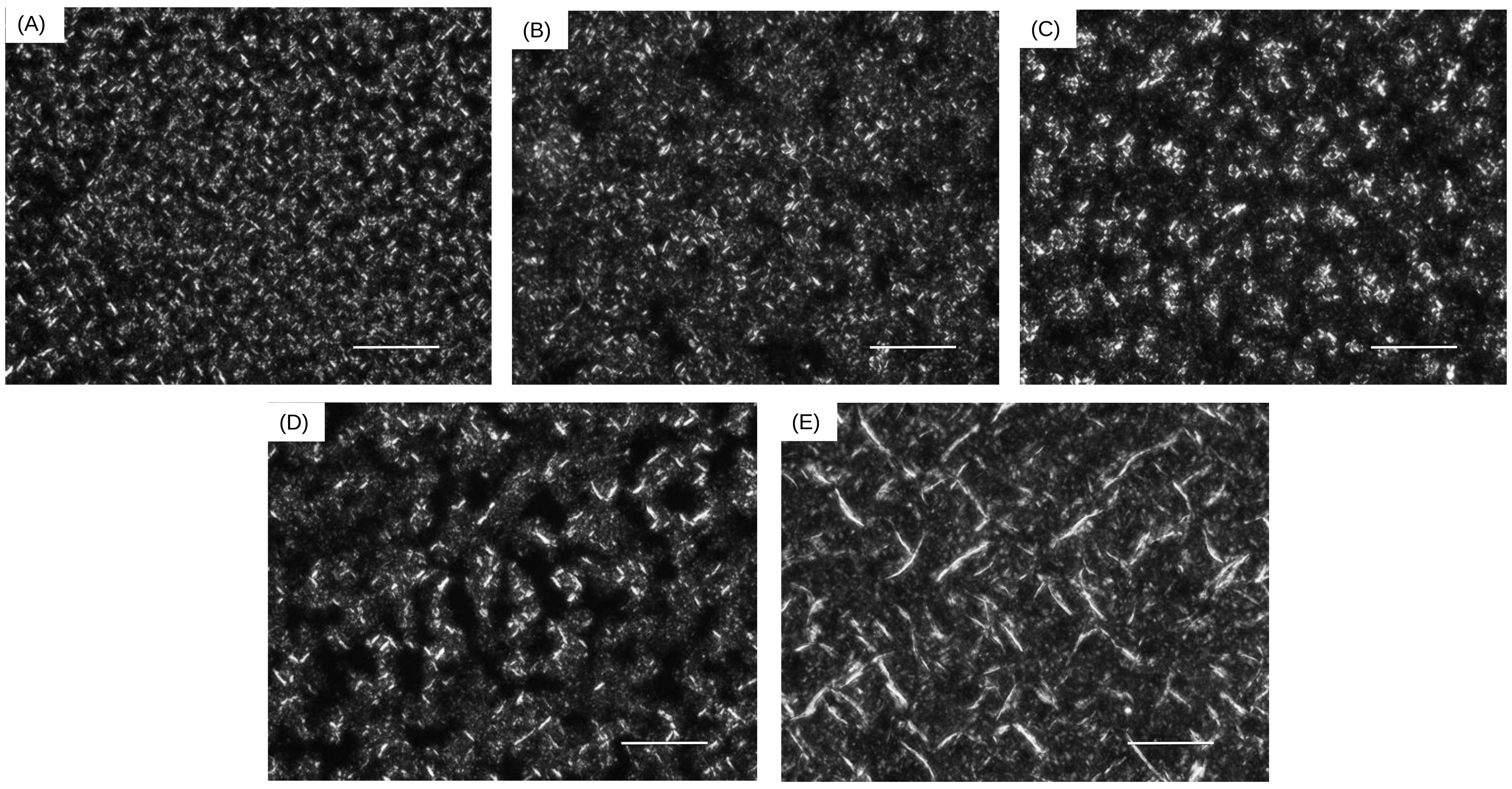

Fig. 1 Polarised light micrographs (Scale bar: 50 μm), of palm oil with rice bran wax additions, (A) 0%, (B) 1%, (C) 2%, (D) 3%, (E) 5% RBW.

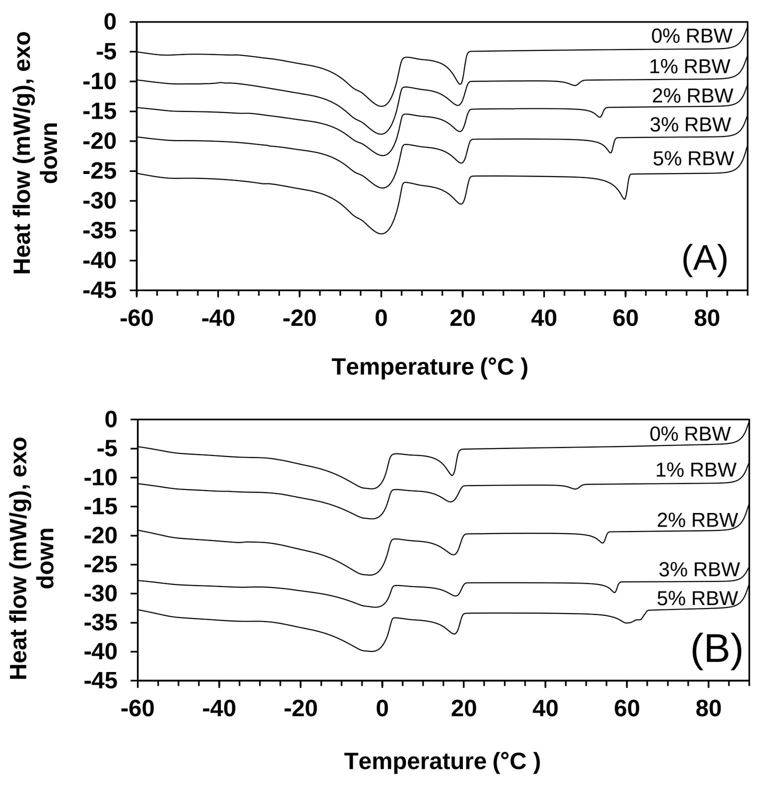

Fig. 2 DSC crystallisation curves of (A) palm oil and (B). fat blends (25% SFO, 75% PO) with RBW additions, cooled at 10°C/min from 90°C to 60°C.

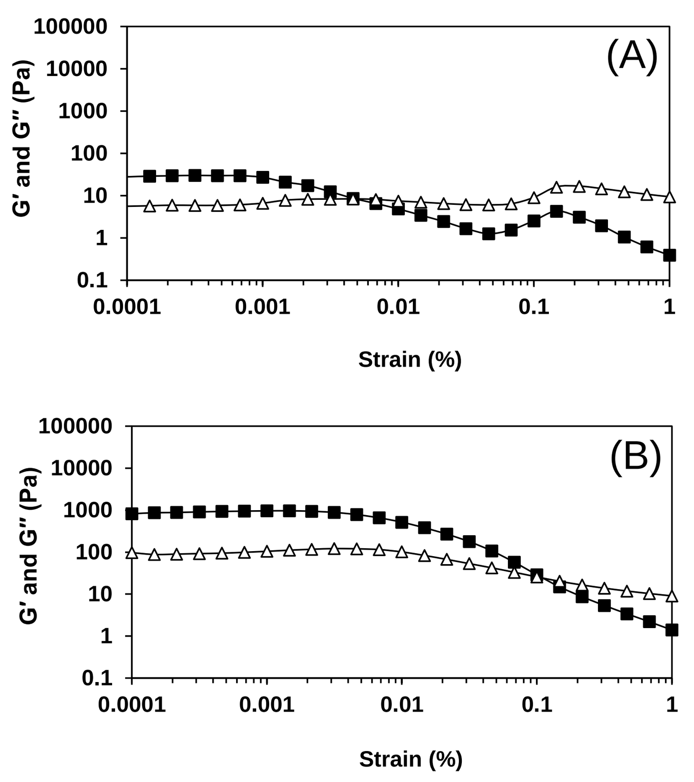

Fig. 3 Amplitude sweep tests showing storage modulus (black squares) and loss modulus (white triangles) of fat blends (25% SFO, 75% PO) with RBW additions (A) 0%, (B) 3% RBW.

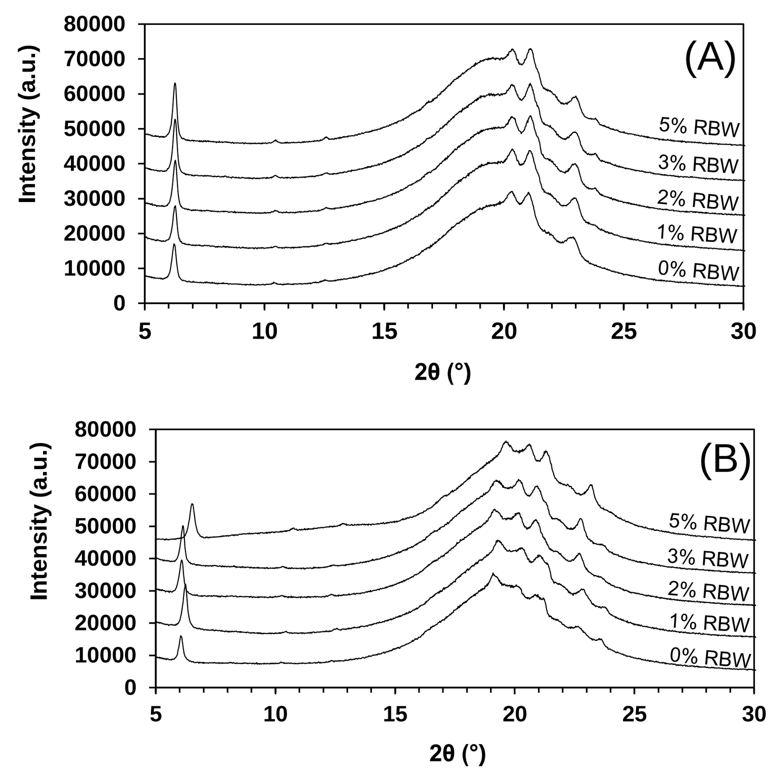

Fig. 4 XRD patterns of fat blends (25% SFO, 75% PO) with RBW additions, stored for 24 hours at (A) 5°C, (B) 20°C.

Polarised microscopy

- There is an interaction between PO and RBW, where the RBW shows the potential to provide nucleation sites for PO crystals (Fig. 2A and Fig. 2B).
- As RBW % increases, RBW starts to structure the palm olein.

DSC

- The peaks of each element of the blend can be seen in Fig. 2B, SFO and palm olein (-40°C to 0°C), palm stearin (20°C) and RBW (50°C - 60°C) [2, 6] (Fig. 2).
- The RBW peak proportionally increases as RBW concentration increases.

Oscillatory rheology

- Once the RBW was added to the blends, there was a significant increase in the crossover, suggesting an elastic component increase.

X-ray diffraction

- The addition of RBW to palm oil caused increases in the β' crystal polymorph.
- The lower the temperature, the more unstable the crystal formed. Fig. 4A shows increased α crystals (most unstable polymorph) at 6 2θ°, whereas Fig. 4B shows increased β crystals (more stable crystal polymorph) at 18 2θ° [6, 8].

Conclusions

- Mixing RBW and PO causes a change in crystal morphology.
- PO crystals appear to cluster around RBW crystals.
- RBW does not appear to significantly change the melting profiles of the PO and PO-SFO blends.
- RBW significantly improves the elastic modulus of the blends.
- The storage temperature has an impact on crystal polymorphs; 20°C storage was the most suitable due to the increased β' crystals.
- XRD showed that the addition of RBW increased the peak at 21 2θ°when stored at 20°C.

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