Wax particles for the stabilisation of foams

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Introduction

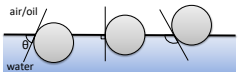
Particles can adsorb almost irreversibly to the air/water interface
- high packing on interface => reduce drainage
- highly viscoelastic interface => reduce bubble shrinkage coarsening
- Increase film strength => stronger interface against rupture

Detachment energy:

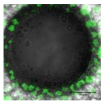
$$E = \pi r^2 \gamma (1 - \cos\theta)^2$$

r: particle radius , γ: surface tension, θ: the contact angle

Competing effect of γ and θ



Particle parameters:
- Size
- Shape
- Concentration
- Hydrophobicity



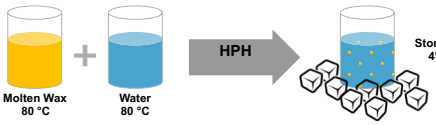
Air bubble stabilised by particulated WPI

Materials to create particles:
- Proteins
- Fibers
- Waxes
- Resistant starches
- Lipids
- Insoluble inorganics

Choice of waxes:
- Paraffin wax (mp 55-57 ºC)
- Bees wax (mp 62-64 ºC)
- Candellila wax (mp 68–70 °C)
- Shellac wax (mp 70-80 ºC)
- Sunflower wax (mp 80 ºC)
- Rice Bran wax (mp 79-82 ºC)
- Carnauba wax (mp 82-85.5 ºC)

Experimental design and methods

Production rout of Wax Particles via molten emulsification (90ºC):



Waxes chosen in this study:
- Paraffin (synthetic)
- Bees wax (natural)
- Concentration: 3.5-20% wt. in water

Emulsifiers used:
- Tween 80, Lecithin
- 3 levels (0.1%, 0.5% and 1% wt.)

Emulsification:
- High Pressure Homogenisation (HPH)
  - 1000 bar (1 pass)

Research aim:
- To verify the fabrication of wax particles made of bees wax or paraffin that can be used to stabilise foams.

Characterisation:
- Effect of the level and type of the emulsifier on the melting behaviour of the waxes.
- Interfacial properties of the waxes and the particles made from them.
- Size of the wax particles
- Viscosity of particle suspensions
- Foaming properties of wax particles.

Characterisation of wax particles

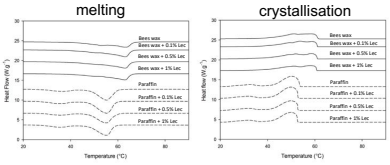


Fig. 1 Thermal behaviour of bees wax (left) and paraffin (right) after the addition of Tween 80 at the same ratio used in the production of the particles during heating from 30 to 100 ºC.

Effect of level of Lecithin on the melting behaviour of waxes:
- Addition of the Lecithin acts as impurity affecting slightly the onset of melting and crystallization (Figure 1).
- The same behaviour is observed in both Bees wax and Paraffin.
- Increasing the amount of Lecithin does not have any further effect.
- Lecithin does not affect the crystal structure of the waxes.

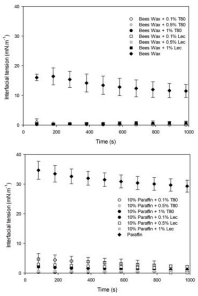


Fig. 2 Interfacial tension (IFT) between water and molten wax with and without surfactant.

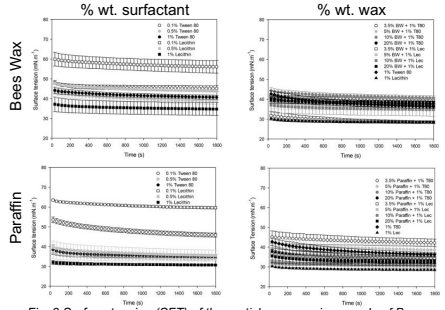


Fig. 3 Surface tension (SFT) of the particle suspensions made of Bees wax and Paraffin by HPH and Sonication

Interfacial properties of pure waxes:
- Bees wax has low IFT with water without the addition of a surfactant (Figure 2) probably due to the presence of natural impurities.
- Paraffin has high IFT with water similar to that of sunflower oil.
- Presence of surfactant dominates the IFT.

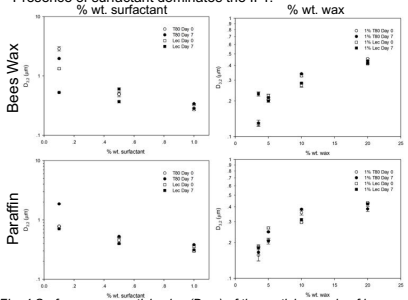


Fig. 4 Surface mean particle size ($D_{[3,2]}$) of the particles made of bees wax and paraffin after production and 1 weeks varying the wt. % of wax or surfactant

Interfacial properties of wax particle suspensions:
- Increasing the concentration of Tween or Lecithin above 0.1% wt. both bees wax and paraffin have similar SFT (Figure 3).

Particle size and stability of wax particle suspensions:
- Increasing the surfactant concentration decreases mean particle size and stability (Figure 4).
- Increasing wax concentration while keeping the surfactant concentration the same, increases the size of the particles but does not affect stability for the time measured.
- Particle suspensions of both bees wax and paraffin with 1% Tween 80 or Lecithin are stable for 6 months at 4 °C (results not shown).
- 1% wt. of surfactant seems adequate quantity to stabilize up to 20% wt. wax with <1μm size particles with reasonable stability.

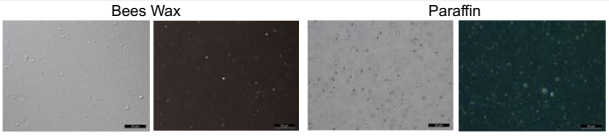


Fig. 5 Micrographs of wax particle suspensions (Bees wax and Paraffin) in brightfield and cross polarised light (dark background) at 3.5% wt. with 1% wt. Tween 80.

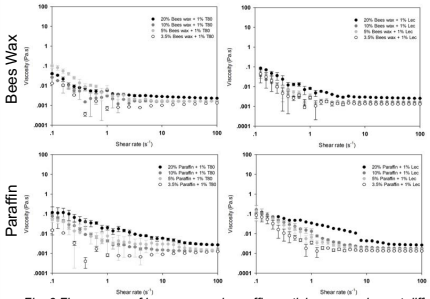


Fig. 6 Flow curves of bees wax and paraffin particle suspensions at different levels wax and surfactant.

Rheological properties of wax particle suspensions:
- Particles made from both wax sources show a shear thinning behaviour typical of particle suspensions.
- The overall viscosity is low even at high wax concentrations.

Foaming properties

Fig. 7 Foams made after whipping bees wax or paraffin particle suspensions after creation and 1 week later.

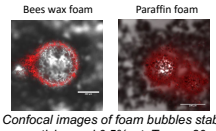


Fig. 8 Confocal images of foam bubbles stabilised by 2.5% wax particles and 0.5% wt. Tween 80.

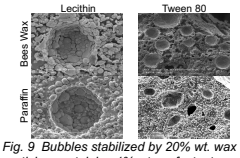


Fig. 9 Bubbles stabilized by 20% wt. wax particles containing 1% wt. surfactant

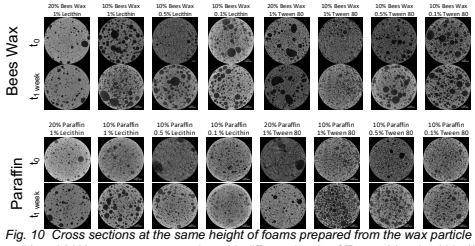


Fig. 10 Cross sections at the same height of foams prepared from the wax particle suspensions at 10 and 20% wt. wax concentration with different levels of Tween 80 or Lecithin (0.1-1% wt.)

Foaming properties:
- Wax particle suspensions have shown remarkable stability against drainage (Figure 7) and coarsening (Figure 10) at concentrations above 10% wt.

Conclusions

- Both Bees wax and Paraffin are capable of producing submicron sized particles via melt emulsification with similar properties in terms of size, rheology of their suspensions and surface activity.
- The use of surfactants mainly facilitates the formation of the particles and aids to the stability of the foams.
- Surfactants alone or with small volume fractions of wax particles do not create stable foams.
- Wax particles have a clear Pickering mechanism by which they stabilise air bubbles by adsorbing on their interface (Figures 8 and 9).
- Increasing the surfactant concentration increases the stability of the foam in terms of drainage.
- Particles adsorb very strongly and as a result bubbles remain stable for at least one week.
- The HLB value of the surfactant used does not seem to affect the stability of these systems.

References

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