

Physico-chemical properties of ice cream mix- II

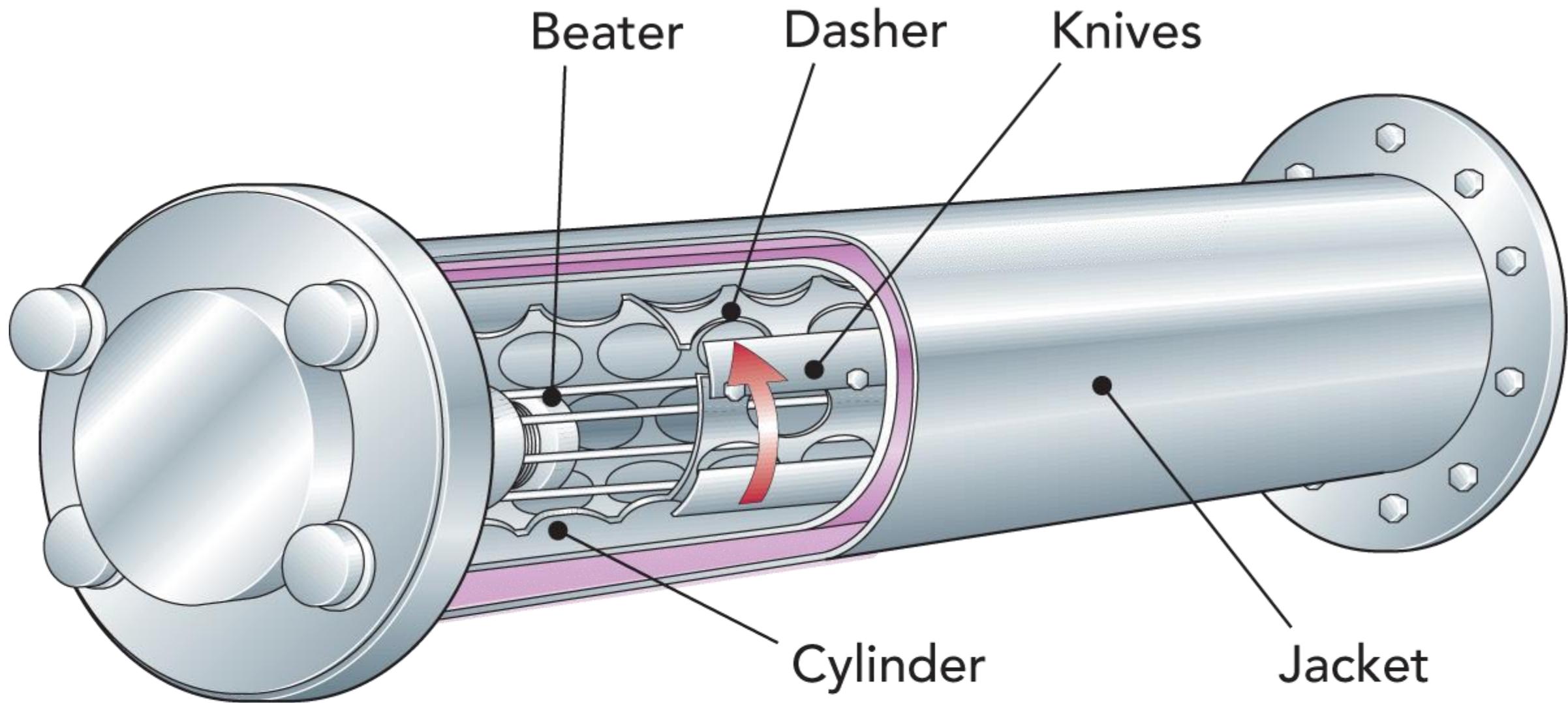
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Introduction

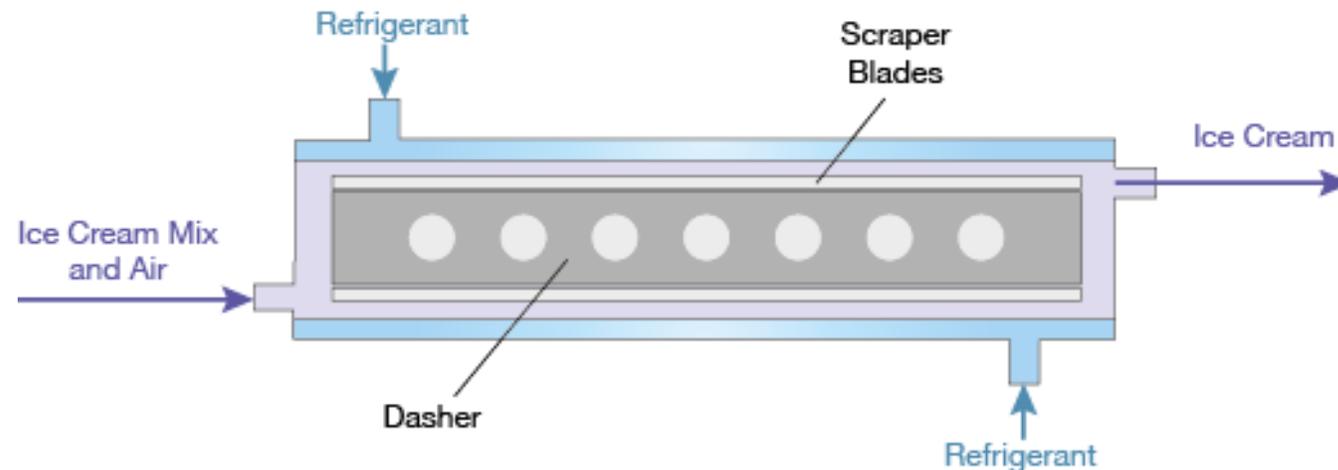
- Ice cream structure is often described as a four phase system.
- These phases include fat, air and ice which are all discrete phases, and the serum phase which surrounds them.
- The fat phase begins as homogenized globules in the mix that are stabilized by a membrane of adsorbed protein and emulsifier.

FAT CRYSTALLIZATION

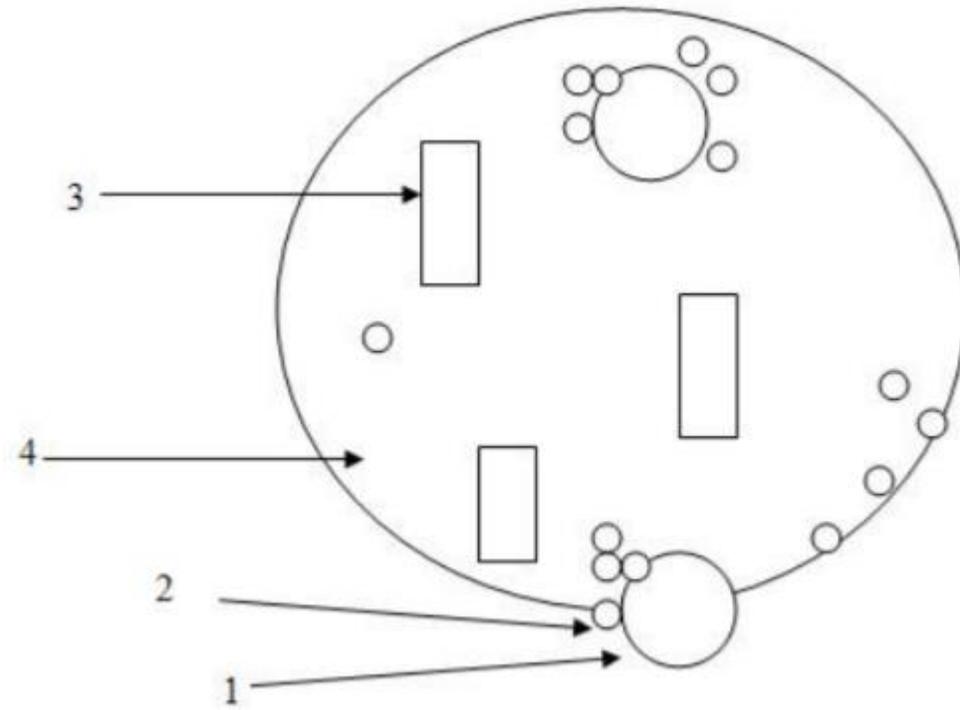
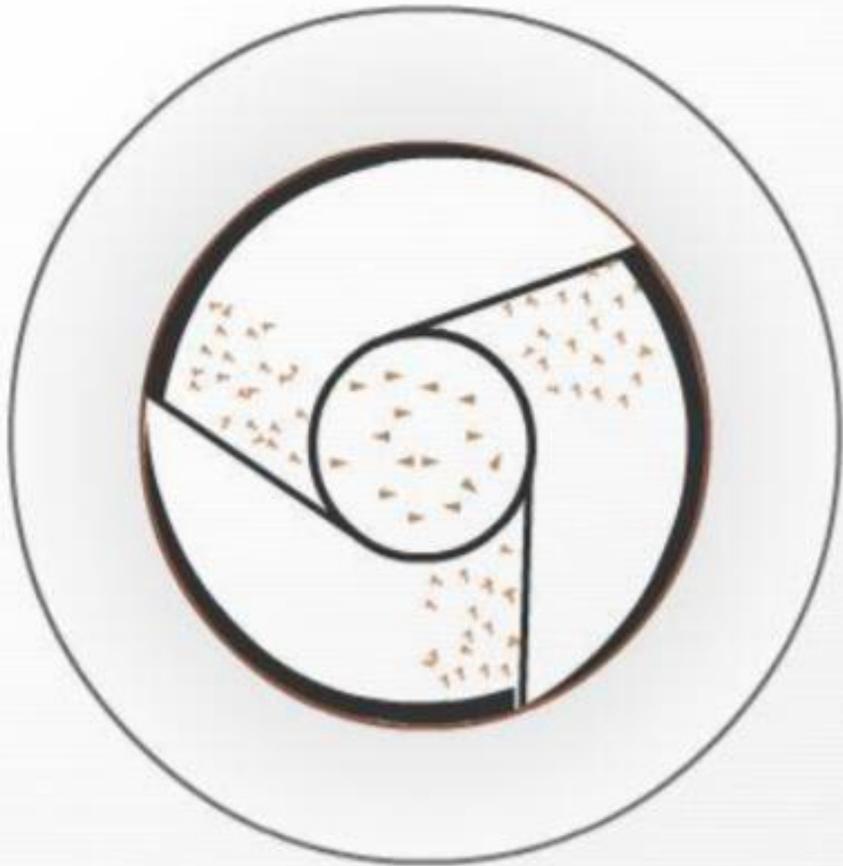
- The fat globules crystallize during cooling and ageing, so after ageing, they contain numerous fat crystals and some non-crystallized liquid oil.
- Some of the protein is displaced from the fat globule membrane by the emulsifiers during ageing, the result of which is that the globules have a very thin membrane (due to the relatively small molecular weight of the emulsifiers, compared to proteins).
- During freezing some of the fat globules partially coalesce due to the whipping and shearing action of the dasher scraper unit.
- The liquid oil cements the globules together while the fat crystals maintain the integrity of the globular shape, so that the aggregates become chains and clusters, rather than large droplets.



- These clusters exist both adsorbed to air bubbles and in bulk phase surrounding the ice and air.
- The air bubbles are stabilized by the globules and clusters, which adsorb to the air surface, and by a membrane of milk protein and emulsifier. The ice crystals are also formed during freezing.
- The ratio of ice to unfrozen water is dictated by the concentration of solutes, hence more sugar in the formulation means less ice at any given temperature



Scraper blades removing ice crystals from the barrel wall



Structure of Ice cream

- 1- Air cells
- 2 - Fat globules and partially coalesced fat surrounding air cells
- 3 - Ice crystals
- 4 - Unfrozen freeze concentrated solution of dissolved and suspended solids

PROCESS OF ICE CRYSTALLIZATION AND RE-CRYSTALLIZATION

- Ice crystals are relatively unstable, and during frozen storage, they undergo changes in number, size, and shape, known collectively as re-crystallization.
- This occurs due to temperature fluctuations.
- If the temperature during the frozen storage of ice cream increases, some of the ice crystals, particularly the smaller ones, melt and consequently the amount of unfrozen water in the serum phase increases.
- Conversely, as temperatures decrease, water will refreeze but does not re-nucleate.
- Rather, it is deposited on the surface of larger crystals, so the net result is that the total number of crystals diminishes and the mean crystal size increases.
- Each time the temperature changes, the smaller ice crystals disappear while the larger ones grow even larger.
- Re-crystallization can be minimized by maintaining low and constant storage temperatures



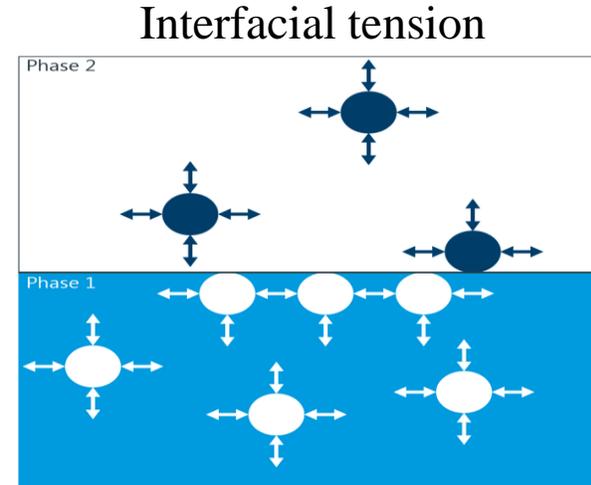
MELTING PROPERTIES

- The meltdown of ice cream is important property. Customers expect it to eventually collapse and flow into a smooth liquid with no curdiness or watery separation.
- When an ice cream melts two events occur. i) The ice crystals melt, and the rate of which they do is a function of the temperature of ice cream and ii) the temperature of the environment.
- As the ice is melting, the structure of ice cream must also collapse and flow, but usually at a slower rate thereby providing shape retention.
- This process is governed primarily by the fat structure of ice cream.
- As the ice crystals melt, the water dilutes the unfrozen phase. The melted ice cream will collapse and flow at a rate that is dictated solely by the melting of the ice cream.

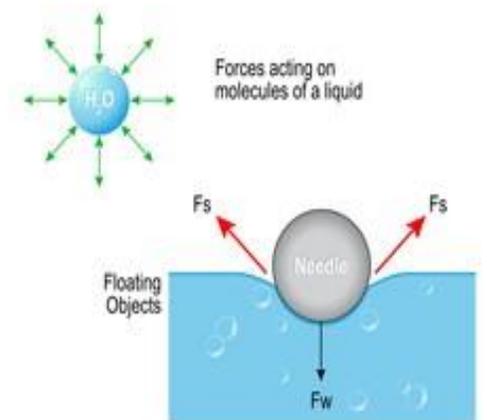
- The air bubbles would soon collapse as the protein surrounding them would be insufficiently strong to support the weight.
- The melt would resemble the mix from which it was made and would include all the discrete fat globules.
- However, if fat destabilization occurred, the presence of fat globules adsorbed to the air bubbles and the presence of chains and clusters of aggregated fat would support the weight of the structure as the ice crystals melted, hence resulting in a slower meltdown, dictated not only by the rate of melting of the ice but also by the collapse and flow of the fat network structure.
- With more extensive destabilization of fat, there may be very high shape retention and little collapse after several hours.

INTERFACIAL TENSION, SURFACE TENSION, ADSORPTION AND WHIPPING

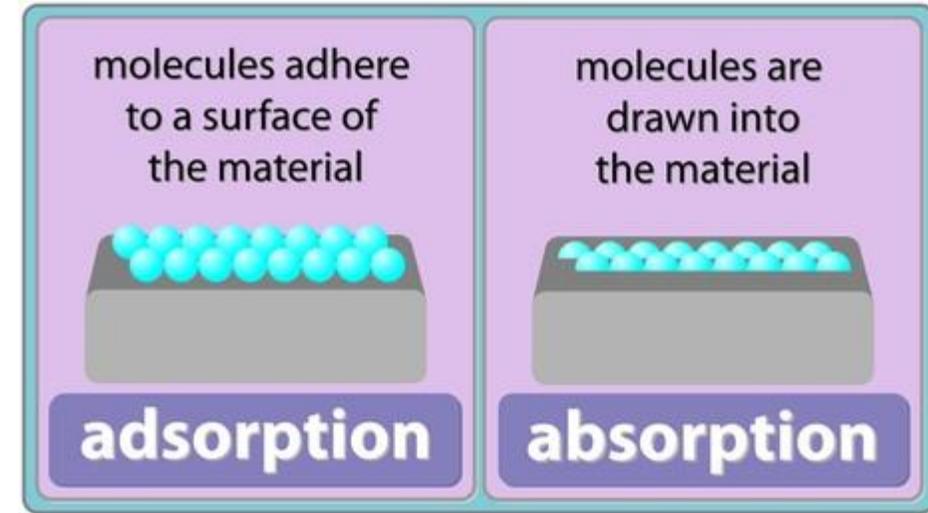
- Interfacial tension in ice cream mix refers to the force acting at the interface between the fat and water, which is largely determined by the type and quantity of material adsorbed at the fat interface.
- Surface tension refers to the force acting at the interface between water and air which is also determined by the type and quantity of material
- Good ‘surfactants’ (surface active agents) are those with both hydrophilic and hydrophobic portions and sufficient molecular flexibility to rearrange at interfaces. Examples are proteins and emulsifiers.



SURFACE TENSION



- Adsorption involves substances migrating to the interface, forming a layer or film, and hence reducing the interfacial or surface tension.
- Substances accumulate at a surface in order of their abilities to lower down the interfacial tension.
- Thus, emulsifiers displace proteins adsorbed to the fat globules.
- Therefore, interfacial tension with regard to emulsifier action is a predictor of protein desorbed at the air interface adsorption/displacement, which in turn is primarily responsible for controlling the extent of fat destabilization.
- Surface tension provides an indication of ease of air incorporation in the mix and the stability of the resulting air bubbles.



Whipping

- The major factors at work during the freezing process that affect whipping rate are
 - (1) effective agitation,
 - (2) the presence of a controlled volume of air, and
 - (3) concomitant freezing of the mix.
- It is vital that the mix contains surface-active components that will quickly migrate to the surfaces of the formed air cells to stabilize them.
- Proteins, phospholipids and added emulsifiers, perform this function. It is also important that the fat globules and ice crystals do not mechanically interrupt and weaken the lamellae of the air cells.
- Therefore, as the freezing progresses, it is required that the fat globules be small and well dispersed.
- However, to prevent collapse of the foam, especially during storage, and to produce dryness and stiffness, it is vital that fat globules be partially destabilized.

- The size, number and physical condition of the fat globules in an ice cream mix determine the rate of whipping and stability of the whipped product.
- Small fat globules and limited clumping enhance whipping.
- Non-fat mixes whip more rapidly than those containing fat, but when frozen, they possess a foam structure that is susceptible to shrinkage.
- Partial coalescence of the fat of ice cream during freezing produces a bridging structure that provides resistance to shrinkage.
- Protein from MSNF is important for whipping.

- Addition of sodium caseinate improves whipping properties and affect air cell and ice crystal distribution.
- High levels of caseinate may lead to insufficient fat destabilization, due to its excessive adsorption at the fat interface.
- Egg yolk solids and buttermilk solids from sweet cream improve whipping ability presumably due to lecithin existing as a lecithin-protein complex.
- Emulsifiers also improve whipping ability.
- Finally, the design and operation of the freezer determine whether maximum whipping ability of a given mix is obtained.