The Effect of Inorganic Calcium Salts on the Rheological Properties of Ice Cream and Frozen Soy Desserts

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ABSTRACT

Calcium fortification has expanded from staples such as breakfast cereals and crackers to snack foods and indulgence foods such as ice cream. Ice cream typically has 6 - 8% RDI of calcium providing the opportunity for fortification with calcium to achieve an "excellent source" of calcium claim. Inorganic calcium salts such as calcium carbonate provide the greatest cost efficiency because they have the highest level of elemental calcium. Because inorganic calcium salts have negligible aqueous solubility, as suspended solids they will have an impact on the rheology of the complex structure of ice cream.

The objective of this study was to investigate the effect of calcium carbonate particle size and shape on the rheological and organoleptic properties of soft serve ice cream and soy-based frozen dessert.

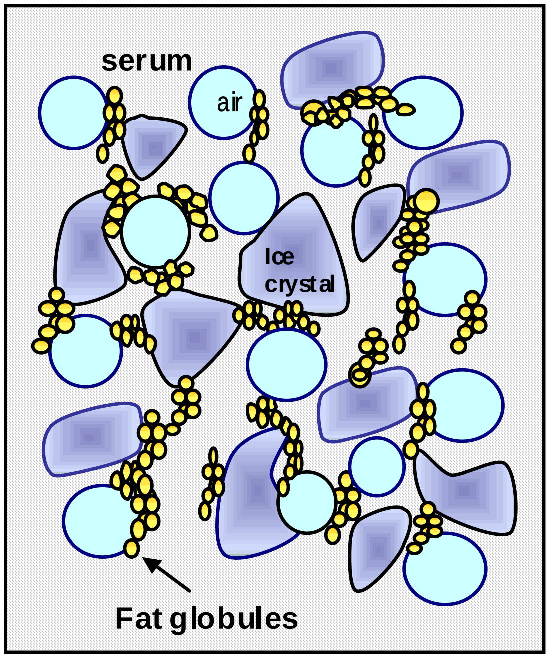
Different grades of calcium carbonate were added to commercial ice cream mixes containing 5% and 10% milk fat at a level to achieve 20% RDI of calcium. In the frozen soy dessert, the calcium carbonate addition level was determined by the amount required to achieve acceptable consistency of the frozen product. Soft serve ice cream was made using a gravity fed freezer. The rheological properties of the ice cream were evaluated at -10 ºC via dynamic sinusoidal oscillatory testing.

Frequency and time sweep curves at low strain show that elastic behavior strongly dominates in the frozen ice cream. The addition of precipitated calcium carbonate generally increased the storage modulus (G'). The use of precipitated calcium carbonate with scalenohedral particle morphology and 2 µm median particle size is most effective in improving the texture of soft serve ice cream. With its addition to 5% milk fat ice cream, the storage modulus was elevated to the same value as the storage modulus of the 10% milk fat ice cream. The texture of the soy-based soft serve dessert formulation was significantly improved by the addition of the scalenohedral calcium carbonate. Our work shows that fine particle size precipitated calcium carbonate, particularly the scalenohedral morphology, functions effectively as a rheological or texturizing agent for soft serve ice cream and soy-based soft serve frozen dessert.

INTRODUCTION

Ice cream has a complex colloidal structure comprised of air, ice crystals, and fat crystals dispersed in an aqueous serum containing proteins and sugars. Milk protein functions as a weak stabilizer to stabilize the air bubbles. The combination of protein stabilized air bubbles and fat crystals provide strength and structure to the ice cream.[1]

The mouthfeel of ice cream is predominately controlled by fat but the dispersed ice crystals also make an important contribution to texture. The desired creamy, smooth mouthfeel is achieved by controlling fat and ice crystal size - keeping both small and evenly dispersed.



Additional stabilizers such as hydrocolloids are required for long term stability. A combination of hydrocolloids serve to control the rate and growth of ice crystal growth during manufacture and freeze-thaw cycling and impart gel structure.

Inorganic calcium salts added for fortification such as calcium carbonate will also become part of the colloidal system because they are insoluble. As a result, they will have an impact on the rheology and hence the texture of final product.

OBJECTIVES

- Determine the effect of calcium carbonate particle size and particle shape on the rheological and organoleptic properties of ice cream.
- Investigate the use of precipitated calcium carbonate as a rheological control agent for soy-based frozen dessert.

MATERIALS

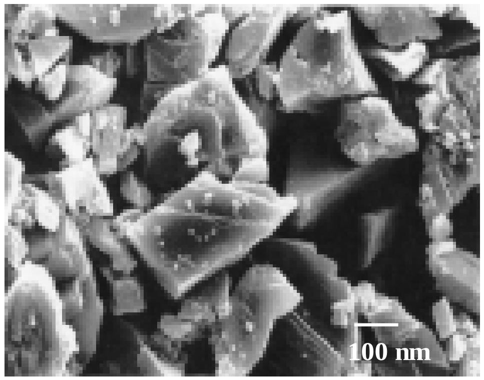
- Calcium Carbonate
  - ViCALity ALBAFIL®
  - ViCALity® Extra Light
  - ViCALity® Heavy
  - ViCALity® GF
  - VICRON® 15-15
- 5% milk fat vanilla ice cream mix - Upstate Farms
- 10% milk fat vanilla ice cream mix - A. Panza & Son, Edison NJ
- Soy soft serve mix
  - Soymilk powder (SMP) - Devansoy Farms
  - Cane sugar
  - Maltodextrin - Maltrin M040, Grain Processing Co.
  - Stabilizer - Dairyblend IC Reg-AF, TIC Gums
  - Salt
  - Pure Vanilla Extract
  - Corn syrup solids (25D) - Maltrin M250, Grain Processing Co.

CALCIUM CARBONATE PROPERTIES

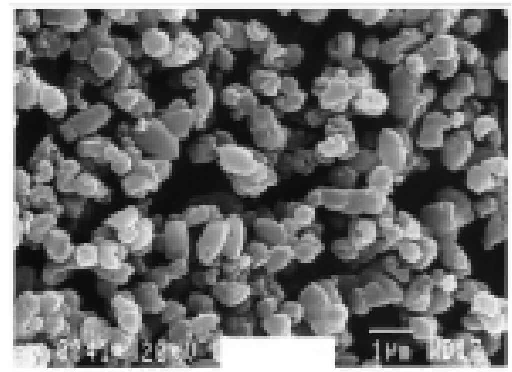
Product Name	TYPE	MORPHOLOGY	Median Particle Size, µm	Oil absorption, gm/100 gm
ViCALity® ALBAFIL	Precipitated	Prismatic	0.7	31
ViCALity® Extra Light	Precipitated	Clustered Scalenohedral	1.9	76
ViCALity® Heavy	Precipitated	Rhombohedral	3.0	30
ViCALity® GF	Ground	Undefined	4.0	19
VICRON® 15-15	Ground	Undefined	3.5	19

CALCIUM CARBONATE MORPHOLOGY

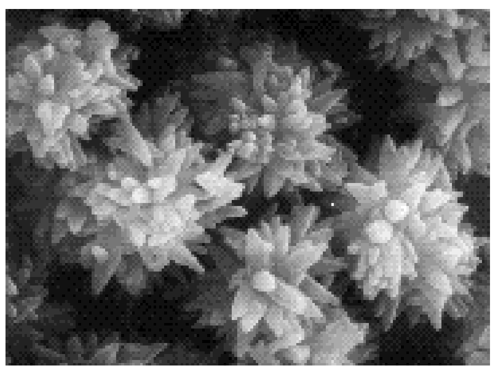
CRYSTAL HABITS OF CALCITE



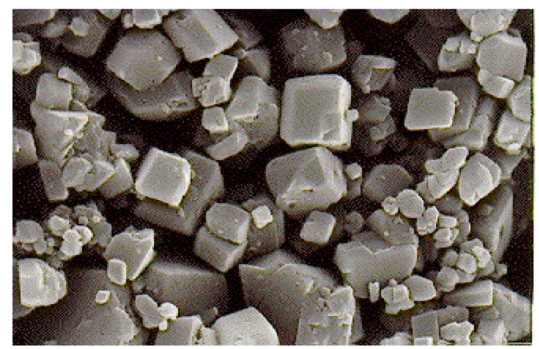
Ground



Prismatic



Scalenohedral



Rhombohedral

PROCEDURES

Ice Cream Mix Preparation

- Calcium carbonate was blended into 3500 gm of commercial ice cream mix with simple hand stirring.
- Mix was homogenized at 1200 PSI, one pass using an APV Gaulin homogenizer.
- The control sample was also homogenized.
- Samples were "aged" in refrigerator for 3-5 hours after homogenization.

Soy Frozen Dessert Mix Preparation

- Soymilk powder was added to water in a Waring blender set on high. Agitation was applied as powder was added. After addition was completed, sample was mixed for 75 sec.
- Salt and sugar were added. Stabilizer was added slowly. Blend was mixed for 75 sec.
- Remaining ingredients including calcium carbonate were added and mixed at high speed for 75 sec.
- Blend was heated to 95 ºC.
- Mix was cooled in refrigerator for 3 - 5 hours before using.

Calcium calculation

Target is 20% RDI Ca or 200 mg Ca per serving based on RDI of 1000 mg/day Ca. Ice cream contains 60 mg Ca/65 gm serving. 140 mg of elemental Ca must be added.

$$140 \text{ mg Ca} \times \frac{100 \text{ g } CaCO_3}{40 \text{ mg Ca}} = 350 \text{ mg } CaCO_3$$

$$\frac{0.350 \text{ gm Ca}}{65 \text{ gm/svg}} \times 3500 \text{ gm/batch} = 18.83 \text{ gm } CaCO_3 \text{ per batch}$$

Ice cream Preparation

The mixes were frozen using a Frosty Factory Brand soft-server freezer.

TEST PROCEDURES

RHEOLOGY TESTING

A TA Instruments AR 1000 Rheometer equipped with a 6 cm stainless steel parallel plate was used for all rheological testing. All testing was performed in oscillation mode at -10 ºC. The geometries and samples were allowed to equilibrate to temperature before testing. A solvent trap was used to maintain temperature.

Frequency Sweep

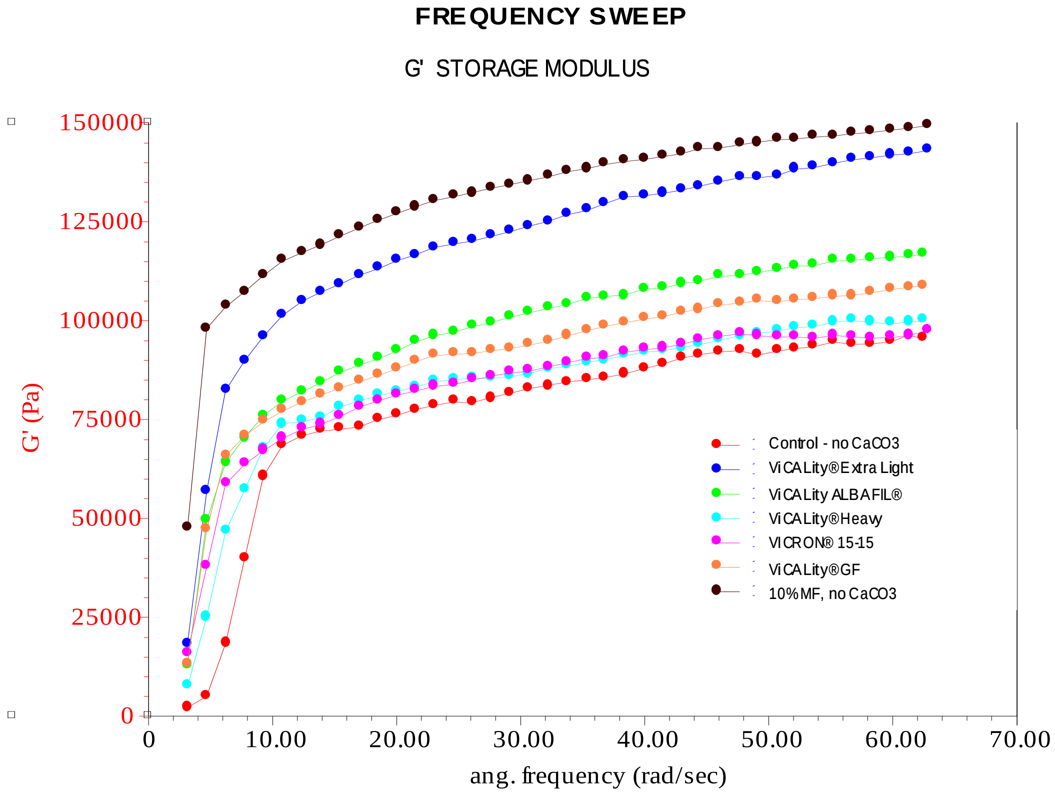
- 0.5 Hz to 10 Hz, 0.25% strain, 450 µm gap

Time Ramp

- 0 to 300 seconds, 1.65 Hz, 0.4% strain, 450 µm gap

RESULTS

5% MILKFAT SOFT SERVE ICE CREAM



RESULTS

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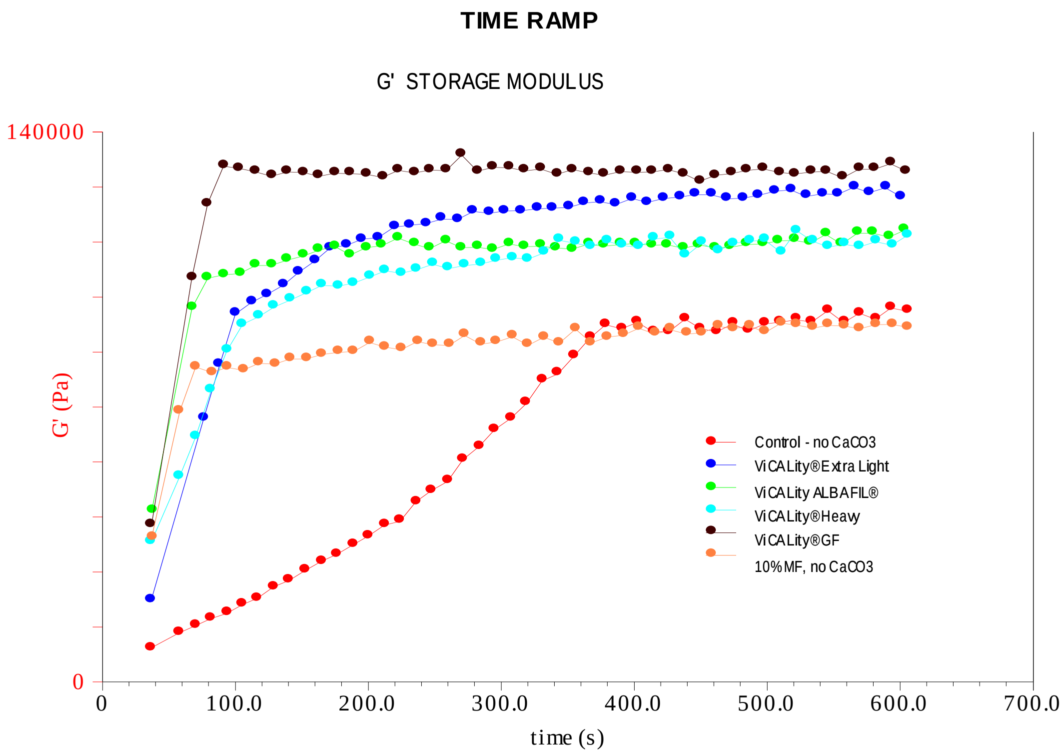

RESULTS

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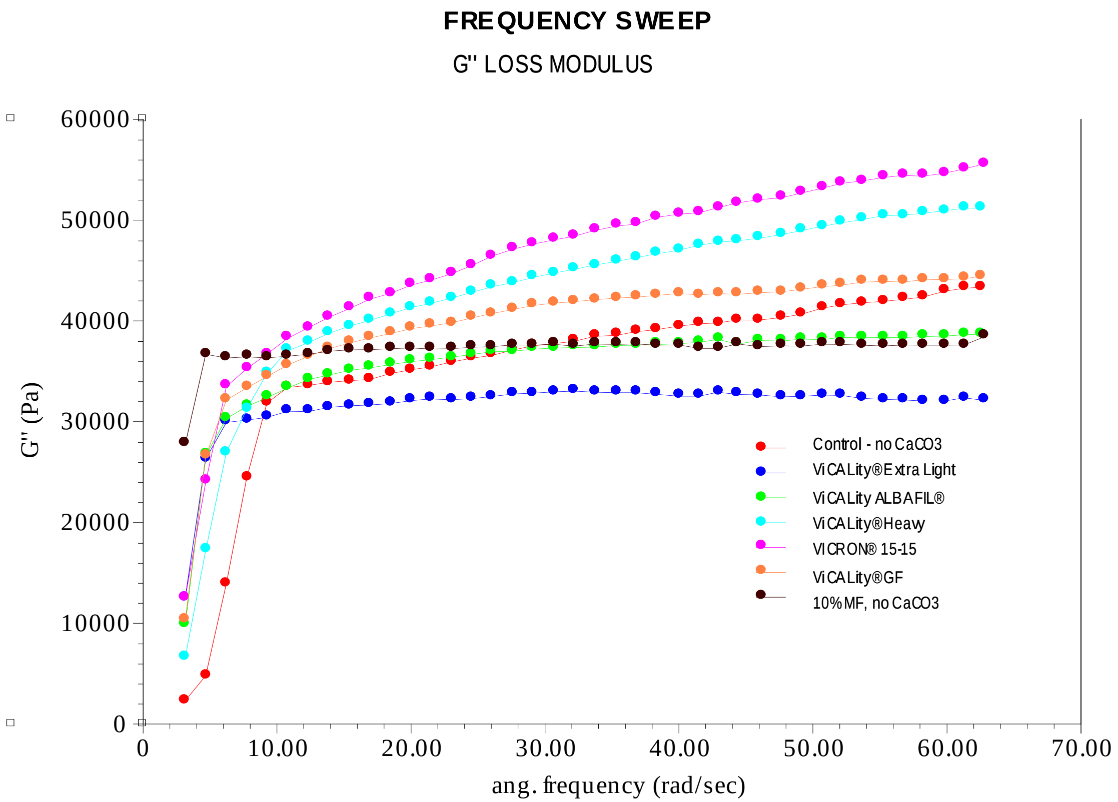
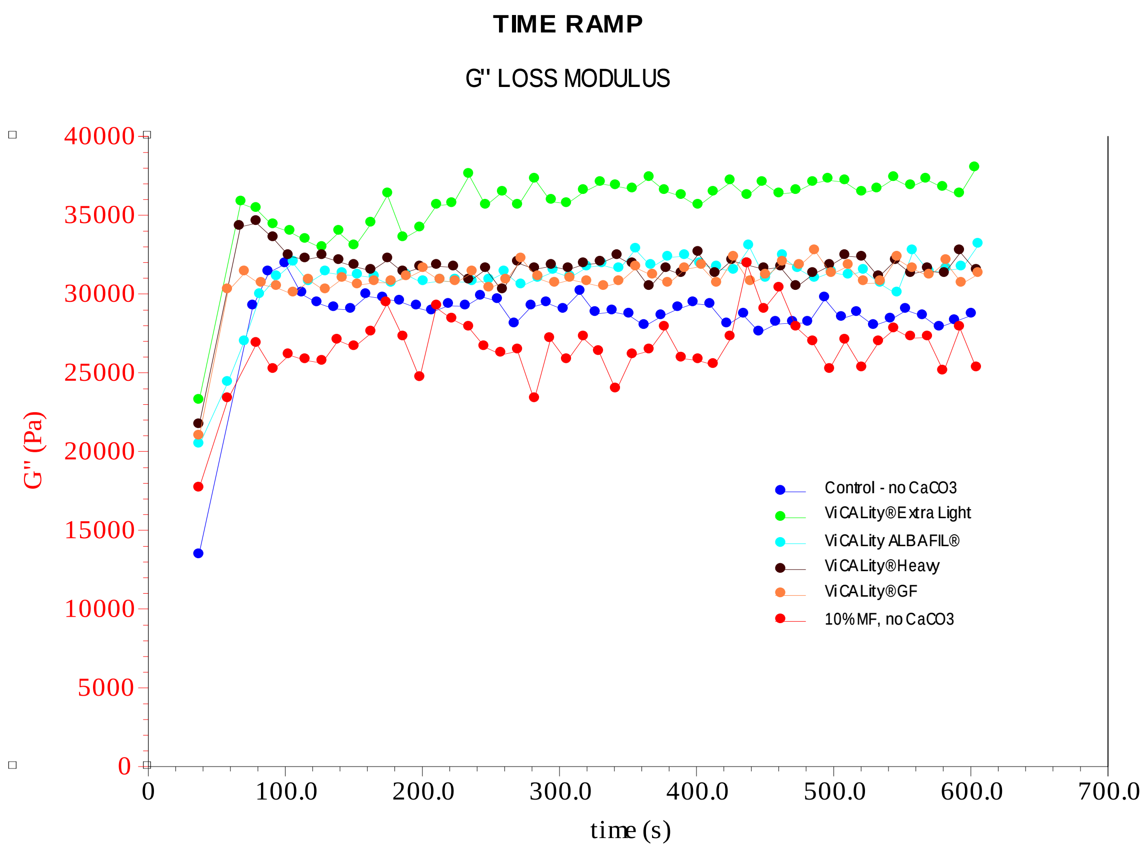


RESULTS

5% MILKFAT SOFT SERVE ICE CREAM



RESULTS

5% MILKFAT SOFT SERVE ICE CREAM

OBSERVATIONS - FREQUENCY SWEEP

- G’ shows frequency dependence across the range.
- G’ increases with $CaCO_3$ addition.
- ViCALity® Extra Light provides the greatest structure increase. G’ approaches that of the 10% milk fat ice cream.
- G” is independent of frequency.
- Only ViCALity® Extra Light gives a lower G” than the 10% milk fat ice cream.
- The larger size calcium carbonates actually produce an increase in viscous component, G”.

RESULTS

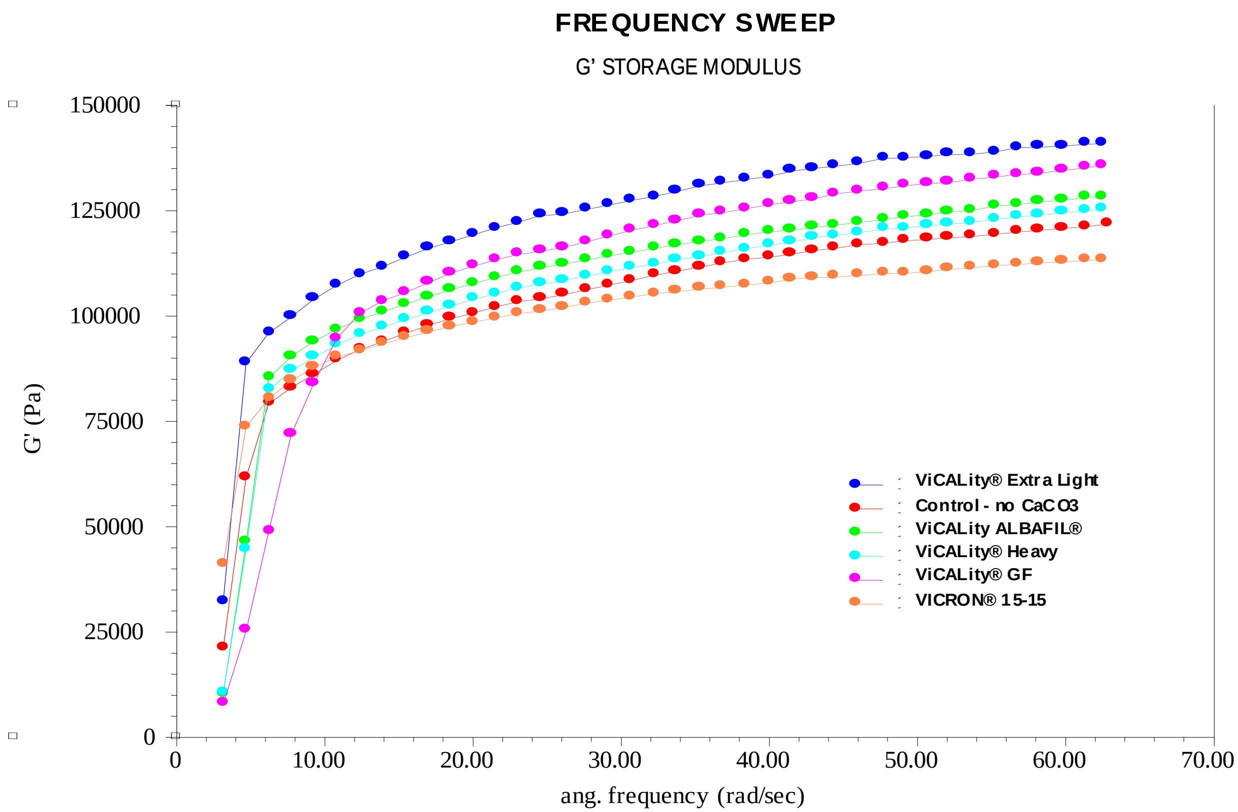
5% MILKFAT SOFT SERVE ICE CREAM

OBSERVATIONS - TIME RAMP

- G', storage modulus indicates that the unfortified 5% milk fat ice cream is less stable than ice creams containing calcium carbonate.
- 10% milk fat ice cream has higher G',i.e. greater amount of structure.
- Ice cream with ViCALity® Extra Light provides significantly higher G' than other calcium carbonates. G' value is very close to that of 10% milk fat ice cream.
- Ground $CaCO_3$ does not give more structure but is more stable than unfortified 5% milk fat ice cream.
- G", loss modulus, is independent of time, i.e. stable for all the samples.

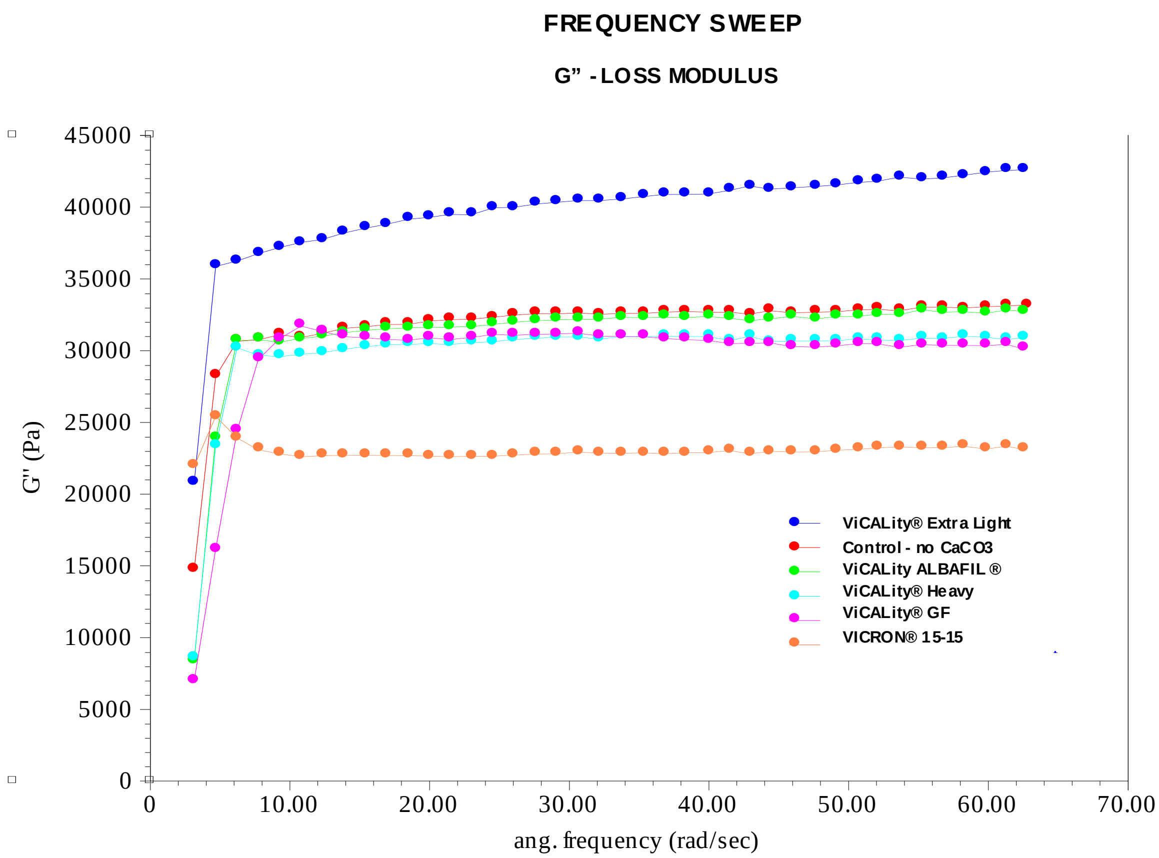
RESULTS

10% MILKFAT SOFT SERVE ICE CREAM



RESULTS

10% MILKFAT SOFT SERVE ICE CREAM



RESULTS

10% MILKFAT SOFT SERVE ICE CREAM

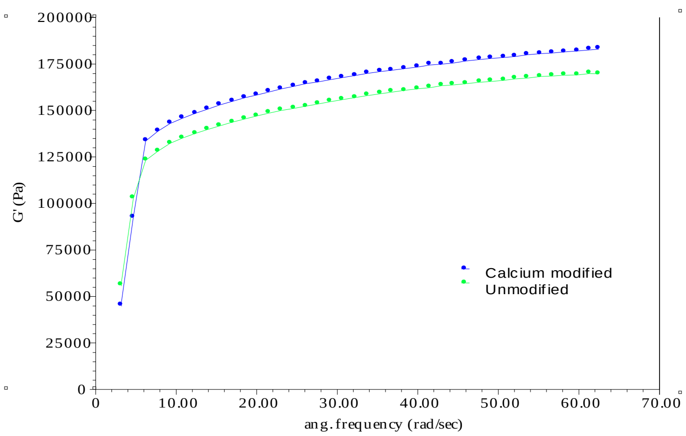
OBSERVATIONS - 10% MILK FAT ICE CREAM

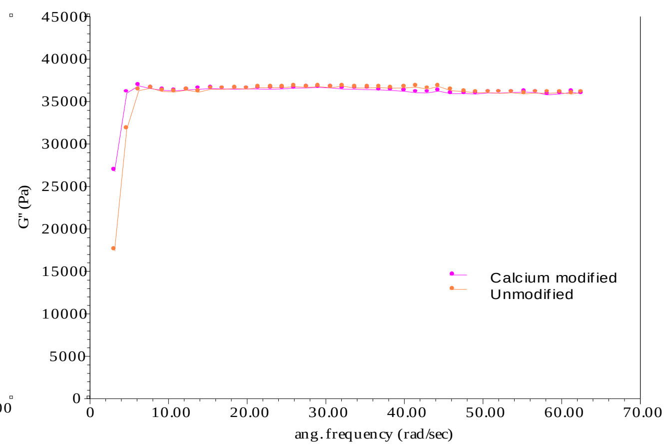
- G', storage modulus, shows slight frequency dependence.
- Increase in G' with addition of calcium carbonate but not as dramatic as in 5% MF system.
- ViCALity® Extra Light gives greatest increase in G'.
- G'' independent of frequency.
- ViCALity® Extra Light increases loss modulus.

RESULTS

SOY-BASED FROZEN DESSERT

Calcium carbonate was added at a level of 28 grams per 1000 gram batch to give a total calcium RDI of 80%. ViCALity® Extra Light was the only calcium carbonate that affected the rheological properties of the soy frozen dessert. It enhanced the structure of the frozen dessert as evidenced by the higher G' value. The result was a product with creamier and smoother texture as assessed by an informal taste test panel.





CONCLUSIONS

- The storage modulus, G', is associated with structure and creaminess in ice cream. Calcium carbonate positively contributes to the development of structure as defined by an increase in G' in low fat soft serve ice cream.
- Calcium carbonate with scalenohedral particle morphology is particularly effective in increasing G' and thereby increasing structure and enhancing texture.
- An informal taste test panel cited an improvement in creaminess and smoother texture in those ice cream samples containing calcium carbonate.
- High oil absorption, fine particle size calcium carbonates are effective texturizing agents for low fat frozen desserts. Addition levels required are higher than typically used for fortification in systems that do not have saturated fats such as soy-based frozen desserts.
- Calcium carbonate can serve the dual function of calcium source and cost effective texturizing agent for soft serve ice cream and frozen soy desserts.

CONTINUING WORK

- Define the mechanism by which calcium carbonate enhances the structure of ice cream and frozen desserts.
  - Particle stabilization of lamella?
  - Interaction with milk protein or hydrocolloid stabilizer?
  - influence on ice crystal and fat globule particle size?
- Cryogenic microscopy to analyze structure.
- Investigate the effect of calcium carbonate on unfrozen mix rheology.
- Determine the effect of calcium carbonate on hard ice cream texture and structure.

REFERENCES

1. Adapa, S., Dingeldein, H., Schmidt, K. A., and Herald, T.J. "Rheological Properties of Ice Cream Mixes and Frozen Ice Creams Containing Fat and Fat Replacers. 2000. J. Dairy Science 83:2224-2229.
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3. Hoefler, A.C. 2004. Hydrocolloids. AACC Inc.