

Co-op Work Term Report

ACTIVITY A 2.31
JUN-DEC/96 16 WKS
(SINCE WKS COVERED
BY U. OF GUELPH
AS AGENT)
DEC 12 1996

“Whey protein isolates as an emulsifier in ice cream mixes”

A Report

Presented to Dr. Douglas H. Goff

Department of Food Science Ontario Agricultural College
University of Guelph

By

Piyachat

Sintudeacha

School of Food Technology Institute of Agricultural Technology
Suranaree University of Technology
November 29, 1996

Content

Topic	Page
1. Introduction	1
1.1 The definition of ice cream	1
1.2 The composition of and ingredients in ice cream	1
1.3 The manufacturing process of ice cream	2
1.4 Whey protein isolates processing	4
1.5 Functional Properties of Whey Proteins	8
1.6 The Use of Whey Protein Products	10
1.7 Functional Role of Proteins and emulsifiers in ice cream	14
2. Material, Methods and Results	15
2.1 Preparation of the ice cream mix	17
2.2 Freezing of the mixes	18
2.3 Emulsion stability analysis	20
2.4 Viscosity measurement	21
2.5 Particle size distribution analysis	22
2.6 Fat destabilization analysis	23
3. Discussion	29
4. Conclusion	31
5. References	32

List of Tables

Table	page
Table 1 : Composition of Whey Protein Isolated by Different Methods	4
Table 2 : Active Groups Used for Ion Exchangers	5
Table 3 : Applications of, and functional demands made on Whey protein isolates in food products	10
Table 4 : Shown the combination performed during preparation of the ice cream mix	18
Table 5 : The overrun table for Batch Freezer	19
Table 6 : Percent fat of top and bottom of a 100 ml cylinder containing the emulsion which has been prepared with various amount of WPI. The particle size distribution (diameter $D(3,2)$) and surface area (Sp.S.A) is also shown	20
Table 7 : Viscosity of the mix prepared with different concentration of WPI in the emulsion and the thickening solution, and heat treated differently	21
Table 8 : Particle size distribution of the mix prepared and % overrun with different concentration of WPI in the emulsion and the thickening solution, and heat treated differently	22
Table 9 : Tests of Significance for VIS@30 using UNIQUE sums of squares	25
Table10 : Tests of Significance for OVERRUN using UNIQUE sums of squares	26
Table11 : Tests of Significance for D 32 using UNIQUE sums of squares	27
Table12 : Tests of Significance for FD@12.5 using UNIQUE sums of squares	28

List of Figures

Figure	page
Figure 1 : The manufacture of ice cream	3
Figure 2 : Shown the schematic diagram for adsorption, elution, fractionation and regeneration of a cation exchange	5
Figure 3 : Stages involved in protein isolation and fractionation by ion exchange	7
Figure 4 : Functional characteristics of whey protein products	8
Figure 5 : The process of ice cream making	15
Figure 6 : Fat separation of the emulsion stability with various concentration of WPI	20
Figure 7 : Fat destabilization exhibited by mixes prepared with different concentration of WPI in the emulsion and thickening solution. The 1st and 2nd number indicate : the % WPI in the emulsion and thickening solution respectively	23

1.Introduction

1.1 The definition of ice cream

The term “ice cream” is a family of whipped dairy products that are manufactured by freezing and are consumed in the frozen state, including ice cream that consists of either dairy or non-dairy fats, premium, higher fat versions, light, lower, fat versions, ice milk, sherbet, frozen yogurt, etc. The ice cream industry is a large consumer of fat. Fat not only provides flavor to ice cream and related products, but is also produces the smooth-eating texture that is both desired by and expected from the consumers. The manufacturing process for ice cream and related products is similar and involves the preparation of a liquid mix, whipping and freezing this mix with high shear to a semi-frozen slurry, adding flavoring ingredients to this partially frozen mix, packaging and storage of the products (Goff,H.D. 1996).

1.2 The composition of and ingredients in ice cream

Ice cream has the following composition : a) greater than 10% milkfat by legal definition, and usually between 10%-16% fat; b) between 9-12% milk solids-not-fat, the component which contains the proteins (caseins and whey proteins) and carbohydrates (lactose) found in milk; c) 12%-16% sweeteners, usually a combination of sucrose and glucose-based corn syrup sweeteners; and d) 0.2%-0.5% added stabilizers and emulsifiers, depending on each type of products. The balance, usually 55% to 64%, is water which comes from the milk (Goff,H.D. 1996).

The ingredients used to supply this composition include : a) a concentrated source of the milkfat, usually cream or butter ; b) a concentrated source of the milk solids-not-fat component, usually evaporated milk or milk powder; c) sugars including sucrose and glucose solids, a product derived from the partial hydrolysis of the corn starch component in corn syrup; and d) milk

The butter (fat) increases the richness of flavor in ice cream, produces a characteristic smooth texture by lubricating the palate, helps to give body to the ice cream, and aids in good melting properties.

The serum solids or milk solids-not-fat improve the texture of ice cream, help to give body and chew resistance to the finished product, are capable of allowing a higher overrun without the characteristic snowy or flaky textures associated with high overrun, and may be a cheap source of total solids.

The sweeteners improve the texture and palatability of the ice cream, enhance flavors, and are usually the cheapest source of total solids.

The stabilizers are a group of compounds, usually polysaccharides, that are responsible for adding viscosity to the unfrozen portion of the water and thus holding this water so that it can not migrate within the product. This results in an ice cream that is firmer to the chew. Without the stabilizers, the ice cream would become coarse and icy very quickly due to the migration of this free water and growth of existing ice crystals.

Emulsifiers have been used in ice cream mix manufacture for many years. They aid in the production for improvement of the whipping quality of the mix; production of a drier ice cream necessary for molding, fancy extrusion, and sandwich manufacture; smoother body and texture in the finished product; superior drawing qualities at the freezer producing a product with good stand-up properties and melt resistance; and more exact control of the product during the freezing and packaging operations (Goff,H.D.

1988). The emulsifying agents commonly used in the ice cream industry are the mono- and di-glycerides, and Polysorbate 80, polyoxyethylene sorbitan monooleate. Emulsifiers are surface active agents which move instantly to an interface where fat and water meet. Since each molecule of an emulsifier contains a hydrophilic phase, they act to reduce the interfacial tension or the force which exists between the two phases of the emulsion.

1.3 The manufacturing process of ice cream

Ingredients are chosen by the manufacturer on the basis of desired quality, availability and cost. The components are blended together and produce the ice cream mix. The first step of mix manufacture is pasteurization process which is designed to kill all of the possible pathogens that may be present. Organisms such as *Mycobacterium tuberculosis*, *Salmonella*, *Staphylococcus*, *Listeria*, and others that cause human disease can be found associated with farm animals and thus raw milk products must be pasteurized. Pasteurization also reduces the number of spoilage organisms such as psychrotrophs. The mix is also homogenized which forms the fat emulsion by breaking down or reducing the size of the fat globules found in milk or cream to less than 1 μm . Homogenization helps to produce a smooth product when frozen. The mix is then aged for at least four hours and usually overnight (at 2-4°C). This allows time for the fat to cool down and crystallize, and for the proteins and polysaccharides to fully hydrate (Goff, H.D. 1996).

Following mix processing, the mix is drawn into a flavor tank where any liquid flavours, fruit purees, or colours are added. The mix then enters the freezing process which both freezes a portion of the water and whips air into the frozen mix. The barrel freezer is a scraped-surface, tubular heat exchanger, which is jacketed with a boiling refrigerant such as ammonia or freon. Mix is pumped through this freezer and is drawn off the other end in a matter of 30 seconds, (or 10-15 minutes in the case of batch freezers) with about 50% of its water frozen. There are rotating blades inside the barrel that keep the ice scraped off the surface of the freezer and also dashers inside the machine which help to whip the mix and incorporate air. Ice cream contains a considerable quantity of air, up to half of its volume. This gives the product its characteristic lightness. Without air, ice cream would be similar to a frozen ice cube.

As the ice cream is drawn with about half of its water frozen, particulate matter such as fruits, nuts, candy, cookies, or whatever you like, is added to the semi-frozen slurry which has a consistency similar to soft-serve ice cream. In fact, almost the only thing which differentiates hard frozen ice cream from soft-serve, is the fact that soft serve is drawn into cones at this point in the process rather than into packages for subsequent hardening. After the particulates have been added, the ice cream is packaged and is placed into a blast freezer at -30° to -40°C where most of the remainder of the water is frozen. Below about -25°C, ice cream is stable for indefinite periods without danger of ice crystal growth; however, above this temperature, ice crystal growth is possible and the rate of crystal growth is dependant upon the temperature of storage. This limits the shelf life of the ice cream (Goff, H.D. 1996). The manufacture of ice cream that described above are shown in figure 1.

(From : Lampert, 1970.)

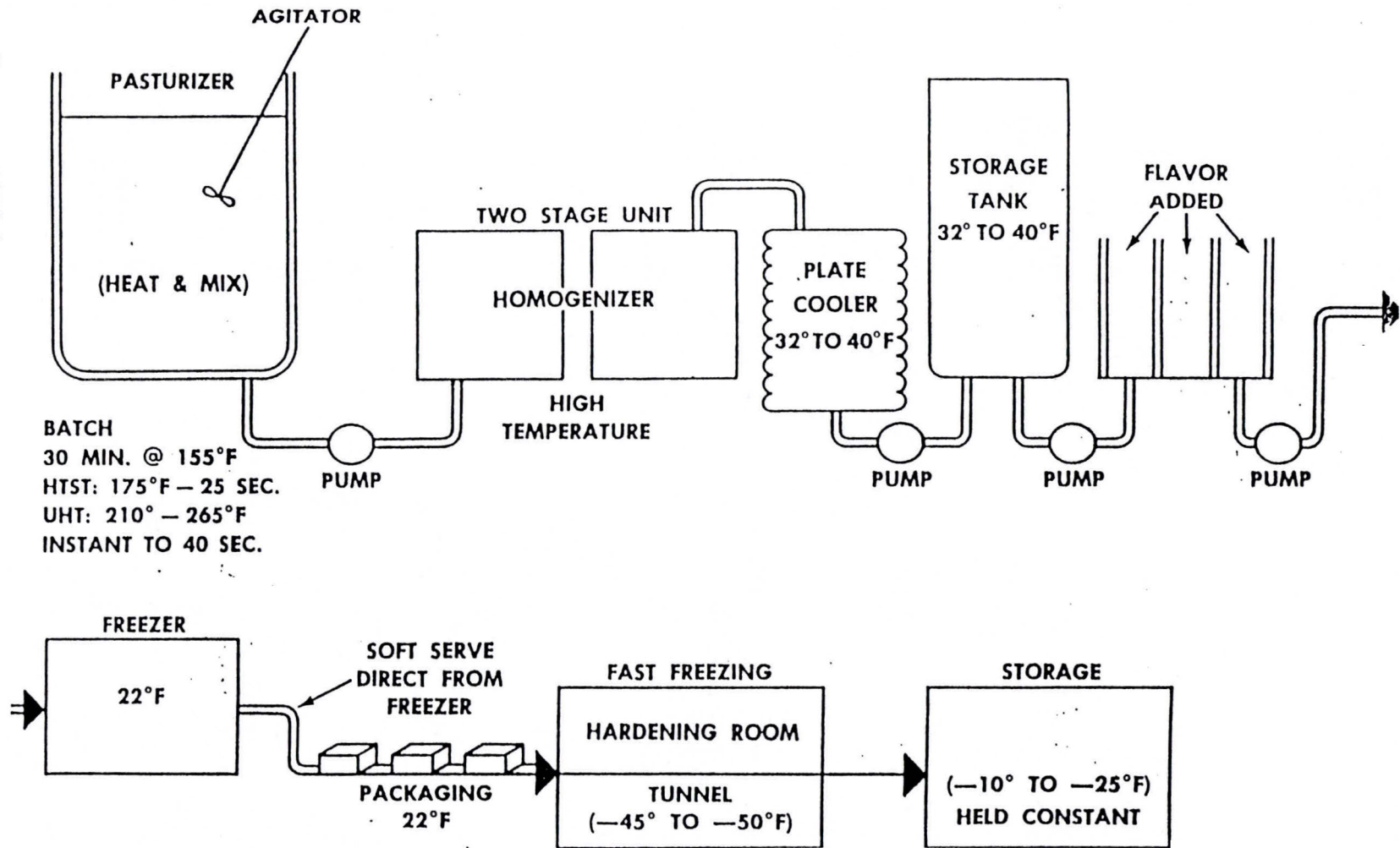


Figure 1: The manufacture of ice cream.

1.4 Whey protein isolates processing

Whey is a dilute liquid containing lactose, proteins, minerals and traces of fat. Most whey is a result of cheese manufacture but some is a byproduct of casein production. Recovery of the proteins from whey can be accomplished using a variety of methods. The protein content of the final product is dependent upon the isolation method chosen. A comparison of ion exchange protein isolates with those produced by other techniques is summarized in Table 1. The table shows that samples isolated by ion exchange are substantially lower in ash, fat and lactose and usually higher in protein (Ross,N. 1989).

Table 1 : Composition of Whey Protein Isolated by Different Methods.

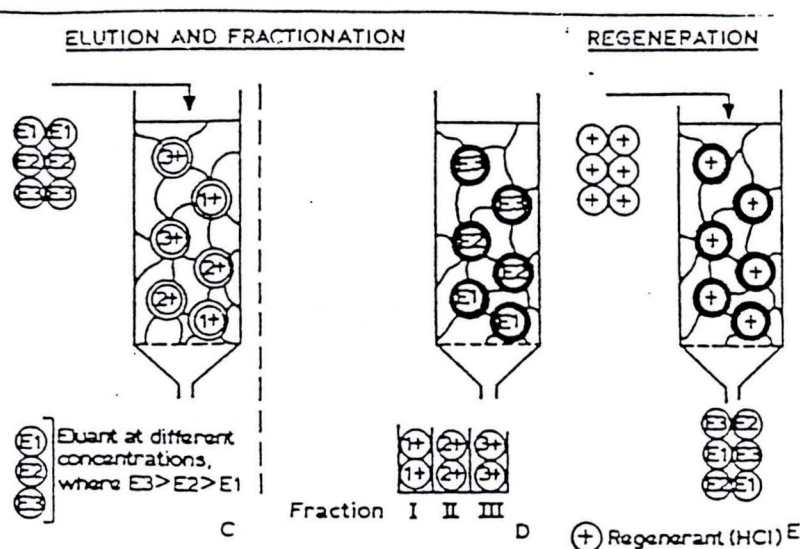
Process	Protein	Lactose	Minerals	fat
Electrodialysis	13-17	82-86	1-2	1
Metaphosphate complex	55-60	18-22	10-18	6-9
Gel Filtration (GF)	54-68	18-25	3-14	2-5
Ultrafiltration (UF)	30-70	20-25	35	45
Demineralisation (IE)	15	78	1	1
GF&UF	81	12	2	3
UF&IE	76	16	2	3
Ion Exchange (CM-C)	88	0.4	1.5	0.3

(From : Kanekanian and Lewis, 1986.)

The ion exchange phenomenon as applied to the manufacturer of whey protein products relies on the amphoteric nature of protein. This ability to act as either an acid or a base permits their adsorption onto a matrix that has a surface layer of charged groups. Recovery of the protein by elution from the matrix can be accomplished by a variety of techniques that act by causing a lowering of the charge-charge attraction between the protein molecules and the ion exchanger (Ross,N. 1989).

Ion exchangers consist of an insoluble matrix to which ionizable groups have been covalently bound. These charged groups (active groups) are associated with exchangeable counter-ions through the formation of electrostatic bonds. These counter-ions are oppositely charged to the active groups on the matrix and can be reversibly exchanged with other ions of the same charge without altering the matrix (Ross,N. 1989).

The term used to name an ion exchanger is dependent on its status of carrying either a positive or negative charge. An anionic exchanger refers to a positively charged material with anionic (negative) counter-ions. Conversely, a negatively charged material with cationic (positive) counter-ions is termed a cationic exchanger (Ross,N. 1989).



(From : Ross, 1989.)

In 2A, the ion exchanger is in the positively charged counter ion form. The molecules in the treated solution also bear a positive charge due to reduction of solution pH to below their isoelectric point. Thus in the adsorption stage (2B) the proteins compete with the counter-ions for the ionizable sites of the ion exchanger. Upon completion of adsorption the ion exchanger is first washed with either water or buffer followed by an elution step to recover the adsorbed protein. This can be done by altering the pH, by increasing the ionic strength or a combination of both. The choice of eluant is dependent upon the type of material adsorbed, the effect of eluant on it and the purity required in the final product (Ross,N. 1989).

Altering the pH away from the optimum for adsorption can effect elution in two ways. In a cation exchanger, a pH lower than the optimum value causes elution through competition of the H^+ with protein molecules for the ionizable sites or if it is a weak cationic exchanger a low pH will suppress ionisation. If the pH is raised above the optimum then elution is effected due to a neutralization of the charge on the adsorbed molecules which weakens the attraction forces between protein and the exchanger.

In 2C, elution is effected by the use of an eluant which increases the ionic strength. The salt ions compete with the protein for the active sites and thus the protein is released. The eluted protein may be collected in bulk or in successive fractions (2D) which comprise proteins having different affinities toward the ion exchanger.

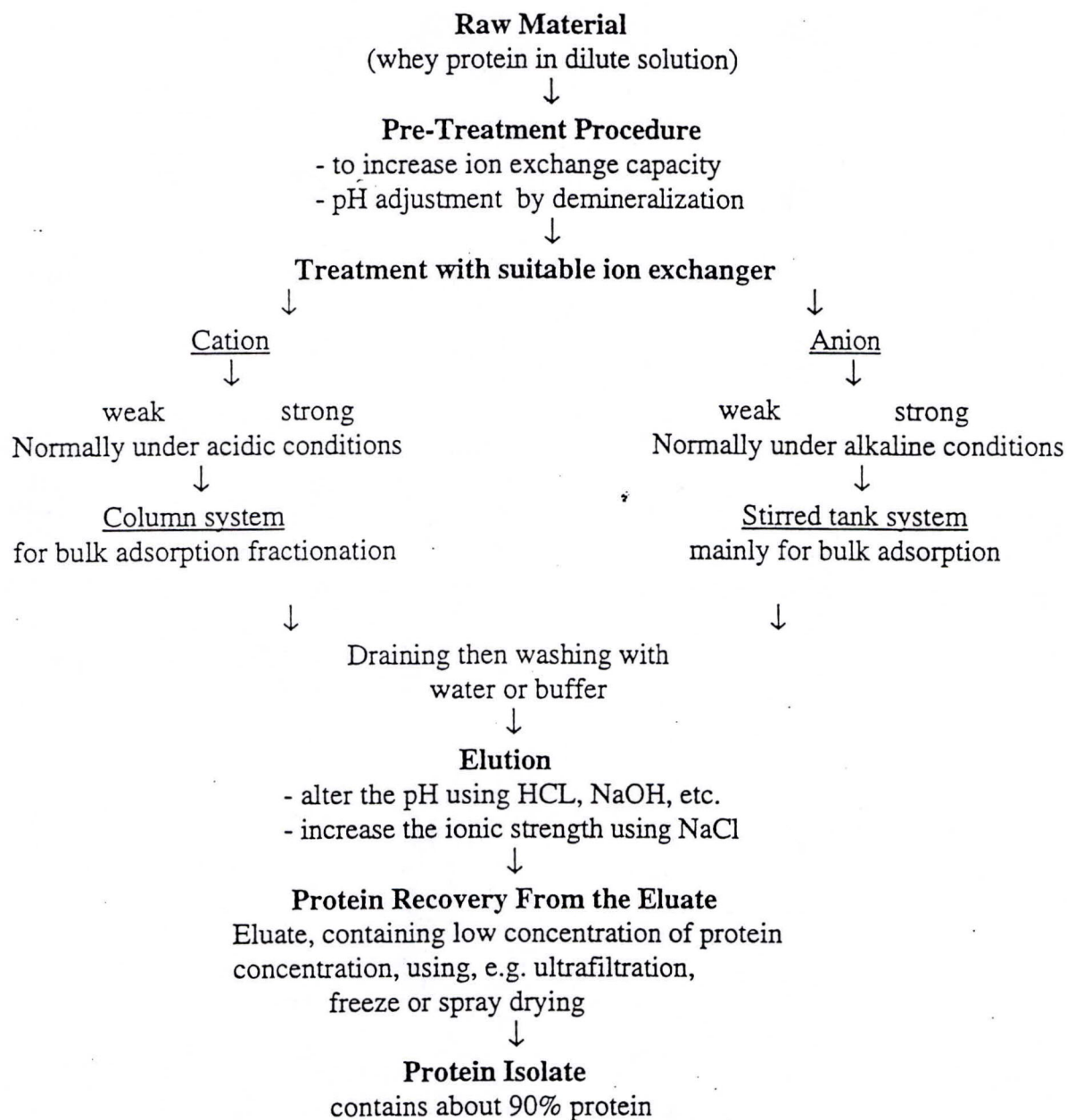
The final stage (2E) involves regeneration of the ion exchanger. In this stage all contaminating ions are removed and the ion exchanger is replenished with positively charged counter-ions.

Optimum performance of an ion exchanger is dependent upon two fundamental properties, selectivity and capacity. The selectivity must be such that there is complete adsorption of the desired ion and efficient use of the desorbing reagent during the elution step. Capacity refers to the number of ions bound per gram (or ml) of ion exchanger. An

ion exchanger that allows the treatment of a large volume of liquid per unit volume of resin is desirable (Ross, N. 1989).

And the stages involved in protein isolation and fractionation by ion exchange is outlined in figure 3.

Figure 3 : Stages involved in protein isolation and fractionation by ion exchange.



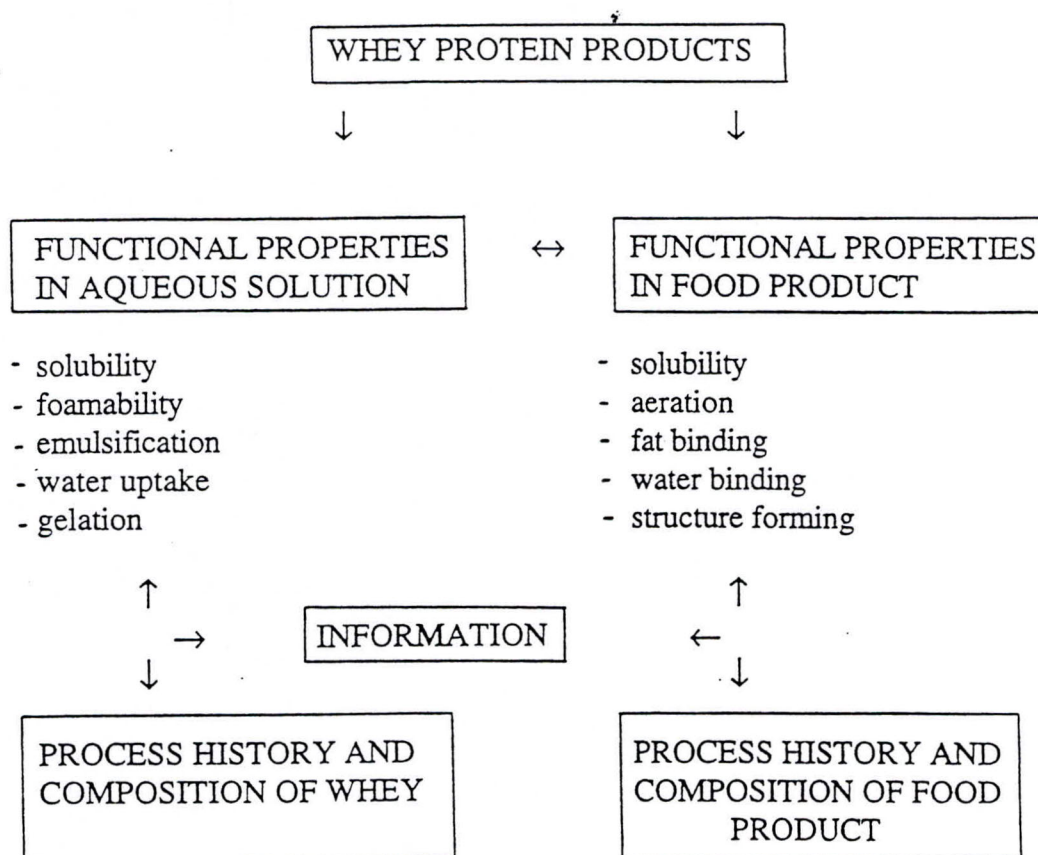
(From : Ross, 1989.)

1.5 Functional Properties of Whey Proteins

Whey protein isolates (WPI) are a group of proteins (88%w/w), consisting mainly of β -lactoglobulins and α -lactalbumins and it has 0.4%(w/w) lactose, 1.5%(w/w) minerals and only 0.3%(w/w) fat (Ross,N. 1989). They are used in the food and beverage industries for production of frozen desserts, ice creams, salad dressings, sport supplements or for replacing higher quantities of caseinates, soy protein, egg whites. They are also emulsifying agent or enhance functional properties and/or nutritional values of foods. The ability of proteins to give emulsifying properties of foods, such as texture, water holding capacity, etc. (Labropoulos,A.E. and Hsu,S.-H. 1996).

The term “ Functional properties ” generally is used in relation to physicochemical parameters of proteins in aqueous solutions or in simple model systems. Functional properties primarily reveal information on the processing history and composition of the whey protein product. The usefulness of these parameters in predicting corresponding functional characteristics in food products is limited, mainly because of the complex behavior of whey proteins with other ingredients of any food product during food processing. Differences are noted between functional properties in aqueous solution and food products are shown in Figure 4.

Figure 4 : Functional characteristics of whey protein products.



(From : Dewit,1990.)

The solubility of whey protein in aqueous solution may differ widely from their solubility in a pasteurized fruit drink as a consequence of interactions with fruit colloids in this beverage. Similar discrepancies may be observed between foaming properties (of whey proteins in water) and aeration (of food products), between emulsifying properties and fat binding, between gelation properties and structure forming. To predict the functional performance of whey proteins in many food products, these proteins must be in the undenatured state before food processing (Dewit,J.N. 1990).

Commercial milk protein products such as whey protein isolates intended for use in food products must possess reasonably good flavor, texture and color. Because one of the functional properties of whey protein isolates were emulsifying agent, they may be divided into three main groups : 1) those that reduce surface tension at o/w interfaces and promote emulsification and formation of phase equilibria between o/w emulsifier at the interface which stabilizes the emulsion, 2) those that interact with starch and protein components in food that modify texture and rheological properties and 3) those that modify the crystallization of fat and oils. Because food emulsifiers have a wide variety of diverse properties, there are many factors that will be used for selecting the type of emulsifier for a particular food product (Charalambous,G. and Doxastakis,G. 1989).

Cheese whey was once considered a waste protein, but today whey protein isolates have high prices because of their excellent nutritional and functional properties. Whey protein isolates suffer from variations in composition, which influences their functional properties considerably. Most food emulsions are oil-in-water (o/w) systems. Emulsifier must be used in processing to reduce surface tension between fat and water phase that enhance their properties in many ways such as texture and structure of the products. The manufacture of food emulsions is a highly energetic and dynamic process in which successively fresh oil/water interfaces are created, protected by adsorption of surfactants and partially lost again by recoalescence of those emulsion. Stability of o/w emulsions seems to be seriously affected by the pH, temperature, the presence of salts during the emulsification process and the ionic strength of the aqueous phase (Fox,P.E. 1982).

1.6 The Use of Whey Protein Products

Whey proteins are often used to improve food products because of their high nutritional quality and their versatile functional properties. However, the behavior of whey proteins during food processing is very complex and is governed by their heat sensitivity. Many attempts have been made to predict desired functional characteristics in food products on the basis of functional properties of whey proteins (Dewit,J.N. 1990).

A systematic approach for the functional evaluation of whey protein products in a number of food systems has been outlined elsewhere. This procedure, which is shown schematically in Table 3 will be followed in the discussion of the various food product groups. The main product groups mentioned in column 1 of this table are detailed in a number of related model products in column 2, which in turn result in the functional demands on whey proteins summarized in column 3. Most of these demands are related to the functional properties of whey proteins.

Table 3 : Applications of, and functional demands made on, whey protein isolates in food products.

Food products	Related model products	Functional demands
Beverages	Chocolate drink (pH 6.5) Soft drink (pH ~ 3.0)	Colloidal stability Solubility
Confectionery	Frappe Meringue	High whipping powder Foam stability at high temperature
Desserts/dressings	Whipped topping Salad dressing Ice cream	Whipping ability with fat Emulsifying ability at pH 4.0 Emulsifying ability
New dairy products	Cheese-like product Spreadable product	Heat setting Emulsification and water-binding
Meat products	Ham Frankfurter	Water solubility at low viscosity water- and fat-binding
Bakery products	Bread Cake	Dough formation Fat-binding/heat setting

(From : Fox, 1982.)

There are many food products that used the whey protein isolates to improved their textures , structures, and properties, etc. such as (Fox,P.F. 1982) :

1.6.1 Beverages

Whey and whey protein isolates (WPI) are very suitable for the formulation of nutritious soft drinks and high-protein milk-based beverages for school lunches or dietetic products. The application of WPI in drink is, however, governed by high demands on organoleptic and functional qualities, combined with low production costs. This implies that only a bland-tasting WPI may be used, either as a cheap and nutritious extender for milk, or as a protein supplement for soft drinks with additional functional properties, e.g. cloud stability and viscosity. Good solubility or colloidal stability of the whey protein product in the drink is a primary requirement. The main protein functions required in milk-like drinks are to impart viscosity body (mouth-feel) and colloidal stability. Moreover, the flavor of these drinks should not be adversely affected by the added protein ; in this respect, whey of good quality does not cause problems. The organoleptic and functional demands on a WPI for use as a protein supplement in soft drinks are very stringent. Therefore, it is concluded that moderate concentrations of WPI of different origin and composition may be used in both milk-like and soft drinks, provided they have a bland flavor and contain whey proteins with a low ash content. Best results are obtained with defatted crystal-clear WPI which ensure best physical and organoleptic stability during storage of the drink.

1.6.2 Confectionery

Milk, in its various forms, is a well-known basic ingredient in many confectionery products because of its contribution to the characteristic texture, flavor and color but it was very expensive so was replaced with cheaper materials as whey protein isolates. Candy-type products are cooked syrups, originally texturized and flavored by the use of sweetened interactions with sugars, resulting in a visco-elastic texture and the generation of a number of compounds that give the product its characteristic flavor and color. During the cooking process, whey proteins will form a soft, flocculent coagulum that is less capable of contributing firmness to the confectionery structure than are caseins, and this may hamper the use of WPI in these products. In addition, the functional whey proteins include acid stability, texture and moisture control (softening) in these products, and they support the foaming, emulsifying and heat-setting properties.

1.6.3 Convenience Foods

During the past few decades there has been a proliferation of products known as convenience foods, i.e. products which require a minimum of preparation by the consumer. Commercial interest in these products has been stimulated by both economic considerations and opportunities for preparing products with improved physical characteristics, such as increased uniformity and improved storage stability. In a variety of convenience foods, whey protein products provide a number of useful functions, e.g. flavor enhancers, whiteners, emulsifiers, thickeners, whipping agents, etc. One convenience food is a salad dressing, an o/w emulsion with a low pH value (4.0), containing egg yolk as an emulsifying agent, and vinegar as an acidulant, together with flavoring and coloring materials. The principal emulsifying agent in salad dressings is egg yolk, which also affects the stiffness and stability of the emulsion. For mainly economic

reasons, there is much interest in replacing egg yolk by cheaper whey protein products with suitable emulsifying and stabilizing properties at low pH values.

1.6.4 Desserts

Within a wide range of textures and consistencies of desserts one may distinguish : (1) aerated products such as whipped toppings and ice cream, (2) jellied products such as puddings, fillings and cheese-like products. Important characteristics of the topping are a high whipping rate and adequate firmness and stability of the whipped product. The ice cream industry has been very active in looking for products that can replace part of the skim milk solids normally used, and this interest has grown in recent years because of more severe competition and increasing costs. Skim milk solids may be replaced by whey powder up to 10% without adverse effects on flavor, appearance and texture. A lactose content higher than 9% causes excessive growth of lactose crystals, causing sandiness in the ice cream. However, a higher level of replacement appears to be possible by using delactosed or lactose-hydrolysed whey products that they containing 35% protein in total solids resembles the composition of skim milk powder. Replacement of 25% skim milk solids by these products has no adverse effects on the flavor, texture, appearance and melt-down of standard ice cream.

1.6.5 Dairy Products

The dairy industry itself has always shown a great interest in the use of whey proteins in various dairy products. Different whey protein products have been produced which, as such or after modification, are used as functional ingredients in a number of dairy products. Important functional properties of whey protein in cream cheeses include the binding of water and fat without affecting the taste of the product. To achieve this, heat-denatured whey proteins are pulverized and subsequently homogenized with fat to give non-syneresing emulsions. These emulsions are used as a protein base for the preparation of all-dairy formulated cream cheeses and cream cheese spreads. The viscosity and stability of yoghurt is almost wholly dependent on the protein content of the milk. A combination of whey protein addition and heat (pre-) treatment of the milk improves the viscosity and water-binding properties of yoghurt.

1.6.6 Meat Products

The high price of meat products and the large variations in the quality of meat proteins are important stimuli for using non-meat proteins in both whole and comminuted meat products. Two properties of meat proteins are of particular importance, i.e. water-holding capacity and their fat-binding and/or emulsifying abilities. The emulsifying properties of proteins are important for the preparation of comminuted meat products such as frankfurters and luncheon meats. These are meat emulsions consisting of a dispersion of extracellular fat particles in an aqueous network of minced and finely chopped meat. Sometimes, extra fat is added and emulsified in these products. Thus, the main functional requirements of whey protein added to comminuted meat products are good emulsifying and/or fat binding properties and the ability to support network formation. In particular, during subsequent cooking or sterilization, fat and water must be entrapped in order to prevent the formation of fat caps or jelly separation.

1.6.7 Bakery Products

For both nutritional and organoleptic reasons, there is continuous interest in fortifying or substituting wheat flour by milk solids in bakery products. It is well established that gluten, the major wheat protein complex, is the important determinant of the visco-elastic properties of dough in the breadmaking process. Moreover, the whey protein fraction appears to contain a loaf volume depressant, which is tentatively identified as proteose peptone component. Characteristic parameters in the breadmaking process are the water absorption of the mix, the rheological behaviour of the dough and the volume and crumb of the bread. The lipid fraction in whey is very important for the baking properties of WPI in bread. The use of WPI as a nutritious supplement in bread is an area with considerable potential. The removal of loaf volume depressants and the accumulation of whey lipids, will hopefully improve the functional quality of whey proteins for breadmaking. A quite different situation exists in cake where, mainly for economic reasons, eggs are replaced by cheaper protein products. The main functions for egg proteins in a cake are encapsulation of the fat droplets during the mixing process, stabilization of the aqueous foam in the intermediate bakery stage and coagulation of the egg proteins during the heat-setting stage of the cake batter that replaced by WPI.

1.7 Functional Role of Proteins and Emulsifiers in ice cream

Ice cream is a complex system, composed of fat globules, air bubbles, ice crystals and an unfrozen serum phase. The fat globules (coated with a protein / emulsifier layer) are linked together in a partially coalesced structure around the air bubbles to form a matrix which holds the foam structure together with the ice crystals. The unfrozen serum phase is composed of the sugars and high molecular weight polysaccharides in a freeze concentrated form (Goff, H.D. and Jordan, W.K. 1989).

Emulsifiers and stabilizers are used quite extensively in the manufacture of ice cream, they both play an important role in the formation of the structure of ice cream. Stabilizers are added to increase smoothness in body, texture and reduce or protect crystal growth during storage and temperature fluctuation, and to improve melt down properties (Goff, H.D. and Caldwell, K.B. 1991).

Emulsifiers (surface active agents) are used to improve the whipping quality, create a drier ice cream with smoother body and texture and increase the standing properties and melt resistance. Emulsifiers act during homogenization. Homogenization increases the number of fat globules by greatly reducing them in size. This reduction in size causes an increase in total surface area exposed which results in an increase in total free energy in the emulsion. The newly formed globules are devoid of protective membrane, and readily absorb material from the environment to lower this total free energy. The material that can lower the interfacial tension the most more readily adsorbs at the interface. Emulsifier can lower the interfacial tension much more than the natural material present in the milk serum (casein, undenatured whey protein, phospholipid, lipoprotein molecules, and components of the original milk fat globule membrane), thus are preferably adsorbed at the interface. Emulsifiers reduce the stability of the fat globules to partial coalescence during whipping / freezing stage (which also produces a lot of air bubbles in the system) which leads to the desirable structure of the ice cream. (Goff, H.D. and Jordan, W.K. 1989). Fat destabilization results from a lower interfacial tension between fat globules and air bubbles than interfacial tension between air bubbles and water, or fat globules and water. So when the ice cream mix was frozen the fat globules partly or completely cover the air bubbles. Thus, these fat globules surround air bubbles by partial coalescence. This is how the air bubbles are stabilized in the ice cream structure.

2. Material , Methods and Results

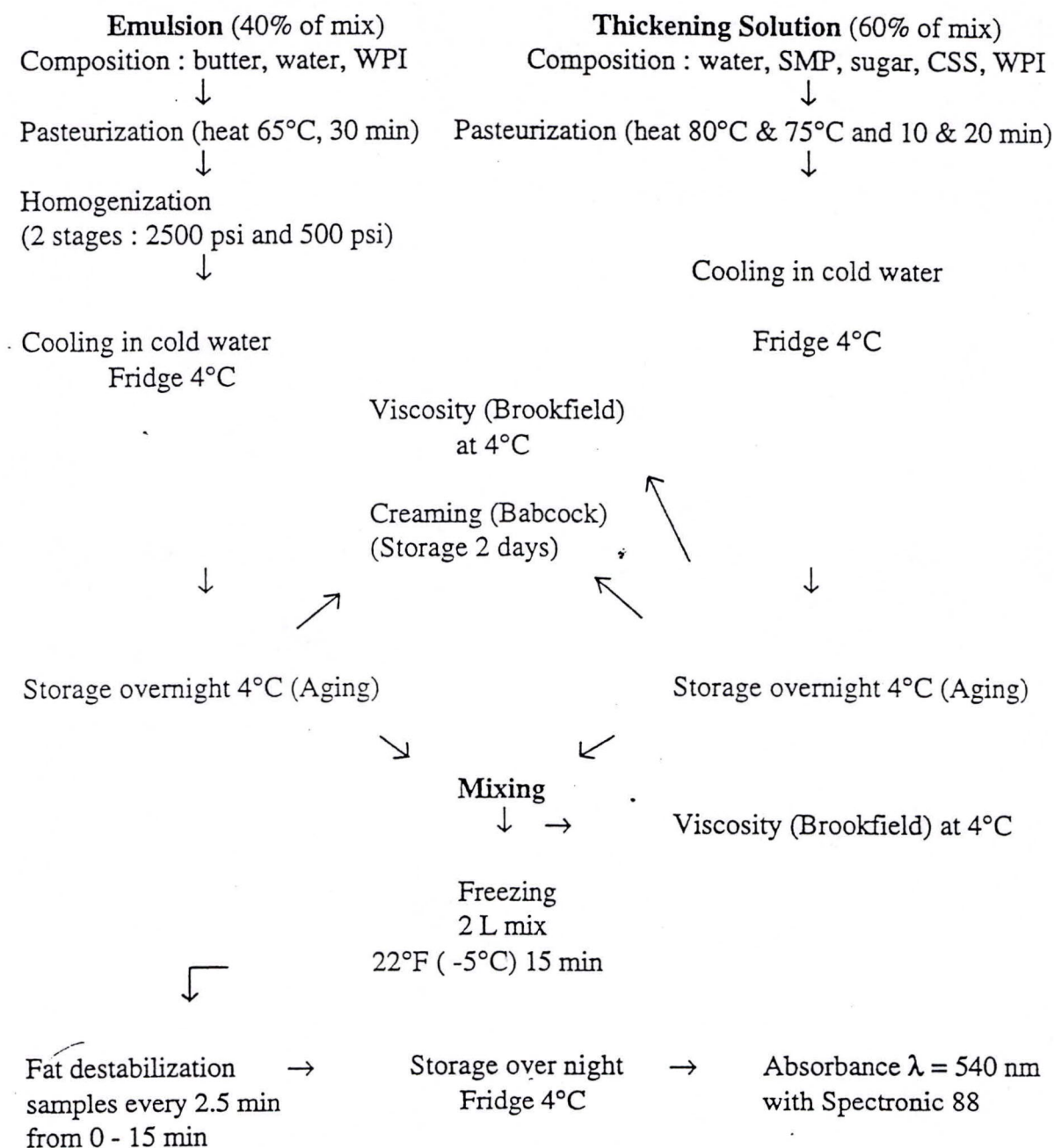


Figure 5 : The process of ice cream making ; WPI = whey protein isolates, SMP = skim milk powder, CSS = corn syrup solids.

Objective

- To study the effect of heating conditions and levels of whey protein isolates added in ice cream mixes. These proteins are intended to replace other emulsifying agents, as well as being a protein source for the mix.

Variables

1. % WPI in Emulsion
2. % WPI in Thickening Solution
3. Heating temperature of Thickening Solution
4. Heating time of Thickening Solution

Measurements

1. Stability of Emulsion (Top/Bottom)
2. Size distribution of Emulsion
3. Viscosity of Mixes
4. Viscosity of Thickening Solution
5. Overrun of Ice Cream
6. Fat destabilization in Ice Cream
7. Size distribution of Ice Cream

2.1 Preparation of the ice cream mix

The standard formulation was used for all preparation consisting of 10% fat, 10% sugar, 5% glucose solids, 11% milk solid non-fat (MSNF), and 64% water added. The mix prepared with butter, skim milk powder, sucrose, corn syrup solids and whey protein isolates.

The initial study was performed to determine the appropriate range of WPI concentration required in the mix to act as an emulsifier and stabilizer. To facilitate the experiment the mix was prepared as two separate solution : an emulsion composed of water, fat and WPI and a solution of high viscosity composed of skim milk powder, sugar, glucose solids, water and WPI. The sugar and corn syrup solids were added to the thickening solution to restore the standard formulation of ice cream mixes when added to the emulsion.

The emulsion was prepared by melting the butter in tap water (at ~ 45°C) using a double jacketed steam pot. Once the butter was melted, the selected concentration of WPI (see Table 4) was added and mixed in to solution using a mechanical stirrer. The emulsion was homogenized immediately after pasteurization using a two stage super homogenizer. The first stage was set at 2500 psi and the second at 500 psi. The homogenized emulsion was then placed in a cool water bath for 20 minutes followed by storage at 4°C for 24 hours. Samples for creaming (emulsion stability) analysis(100 ml in a 100 ml graduated cylinders) and a sample for particle size distribution analyses (40 ml) were taken before the homogenized emulsion was placed in the cooling bath and then stored at refrigeration temperatures until used (24 hrs).

The thickening solution was prepared in a double bottom steam pot by dispersing the dry ingredients in tap water (~ 45 °C) and heat treated according to the conditions outlined in Table 4. The WPI was blended with the sugar prior and then the dry ingredients where mixed into solution using a mechanical stirrer and followed to aging at 4°C for 24 hrs.

Table 4 : Shown the combination performed during preparation of the ice cream mix.

Type	% WPI	Heating temperature	Heating time
Emulsion	0.15%	65°C	30 min
	0.275%	65°C	30 min
	0.40%	65°C	30 min
Thickening Solution	15% replacement of SMP with WPI	75°C	10 min
			20 min
		80°C	10 min
	20% replacement of SMP with WPI		20 min
		75°C	10 min
		80°C	20 min

2.2 Freezing of the mixes

The emulsion and thickening solution were blended together after aging overnight at 4°C in the ratio 1:1.5, obtained from figure 5. In the situation where a gel formed, a Black & Decker household 3 speed mixer was used to disperse the structure. Once blended together, the solution was mixed using a mechanical mixer for about 1 min. A flavoring vanilla-vanillin extract was added at a concentration of 1.5 ml/kg to all mixes after aging. Mixes were frozen in a Taylor batch freezer until the mix temperature reached -5°C (22°F). Once the correct temperature was reached, the refrigeration was turned off and the mix whipping continued. Aliquots (40ml) of frozen mix were removed from the barrel of the batch freezer every 2.5 min starting at time zero and analysed for fat destabilization by Spectronic 88. The overrun was measured at time 15 min for each ice cream by compared weight of ice cream (at 15 min) in the cup measured with overrun table for Batch Freezer that is shown in Table 5.

Table 5 : The overrun table for Batch Freezer.

Weight Empty Cup : - 40.5 g
 Weight Ice Cream Mix : - 1.1 Kg/L
 (Cup held 254.5 g ice cream mix)

Weight Ice Cream + Cup (g)		% Overrun (OR)	
295	159	0	115
272	156	10	120
262	154	15	125
253	151 *	20	130 *
244	149	25	135
236	147	30	140
229	144	35	145
222	142	40	150
216	140	45	155
210	138	50	160
205	137	55	165
200	135	60	170
195	133	65	175
190	130	70	180
186	128	75	190
182	127	80	195
178	125	85	200
174		90	
171		95	
168		100	
165		105	
162		110	

(From : Goff, : based on calculation. ; * = Example)

When weight is used, the formula becomes :

$$\% \text{ Overrun} = \frac{\text{Weight of mix (kg) in the cup} - \text{Weight of ice cream (kg) in the cup} \times 100}{\text{Weight of ice cream (kg) in the cup}}$$

Example $\% \text{ Overrun} = \frac{254.5 - (151 - 40.5)}{(151 - 40.5)}$

$$\% \text{ Overrun} = 130$$

2.3 Emulsion stability analysis

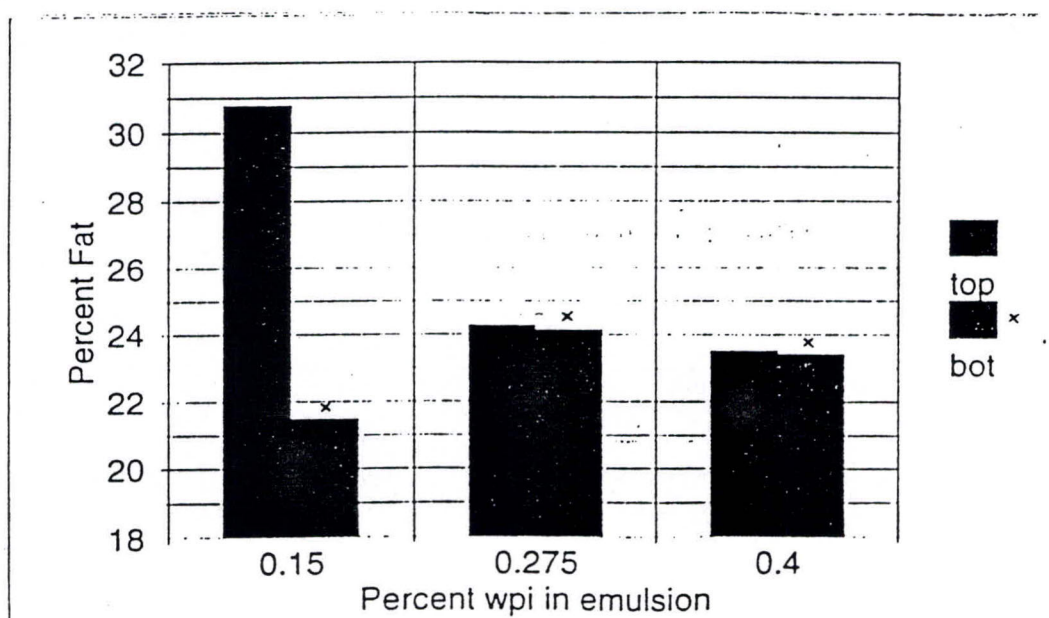
Emulsion stability was measured by measuring the percent fat from the top and bottom of a 100 ml graduated cylinder of emulsion which had been aged for two days at 4°C. The percent fat emulsion was determined using the "Pennsylvania Method (Babcock)". The samples were removed from the fridge and placed in warm water to bring the emulsion to room temperature. Nine grams of the top and bottom the sample were placed in a Paley test bottle was mixed (agitated) for approximately 1 min. Next, three ml of butyl alcohol was added and mixed for approximately 1 min, followed by ml of diluted sulfuric acid and mixing until digestion was completed. The bottles were centrifuged for 5 min using the Improved Jalco model 48. Water between 54 - 60°C was added to bring the content within one-fourth of an inch of the base of the bottle, and the bottles were centrifuge for another 2 min. More hot water was added to float the fat up to the neck of the bottle, followed by another centrifuge for 1 min. The bottles were placed in a water bath at 54°C for 5 min after which they were removed and the percent fat was directly read on the neck of the bottle.

Results

Table 6 : Percent fat of top and bottom of a 100 ml cylinder containing the emulsion which has been prepared with various amount of WPI. The particle size distribution (diameter D(3,2)) and surface area (Sp.S.A) is also shown.

% wpi in emulsion	top	bot	D(3,2)	Sp.S.A
0.15	30.78	21.48	1.01	7.15495
0.275	24.26	24.13	0.82	7.382263
0.4	23.51	23.41	0.74	8.14585

Figure 6 : Fat separation of the emulsion stability with various concentration of WPI.



2.4 Viscosity measurement

Samples of the thickening solution and mixes were measured for apparent viscosity the same day the mixes were made (i.e. after aging for 24 hrs). In this experiment, the rheology of the mixes were tested using the Brookfield; synchro-electric viscometer model LVT. The spindles were used depending on sample. Full 400 ml beaker of sample and spindles were allowed for equilibrium at 4°C (~ 1 hr) before measurement.

Results

Table 7 : Viscosity of the mix prepared with different concentration of WPI in the emulsion and the thickening solution, and heat treated differently.

% wpi in emulsion	% wpi replacement	T(C)/time	Viscosity (mPa.s)
0.15	15%	75/10	20
		75/20	19.3
		80/10	356.4
		80/20	536.7
	20%	75/10	19.2
		75/20	19.3
		80/10	462.8
		80/20	2438.4
0.275	15%	75/10	18.68
		75/20	18.78
		80/10	151.25
		80/20	257.25
	20%	75/10	15.8
		75/20	17.4
		80/10	183.5
		80/20	379.1
0.4	15%	75/10	15.2
		75/20	18.6
		80/10	31.8
		80/20	312
	20%	75/10	14.5
		75/20	18.6
		80/10	178.7
		80/20	299.1

2.5 Particle size distribution analysis

Particle size measurement of the emulsion and mixes were performed using a Mastersizer X (Malvern Instruments) by optical parameters of a presentation code 0303. In the case of the emulsion, the sample was tested after 24 hours of storage so they could be tested at the same time as the samples of the ice cream. Samples of ice cream were tested the same day they were prepared. The particle size is expressed as the $D_{(3,2)}$ value and the area of fat surface of particle size is presented in Sp.A.S.(m²/g) of the solution.

Results

Table 8 : Particle size distribution of the mix prepared and % overrun with different concentration of WPI in the emulsion and the thickening solution, and heat treated differently.

Mix no.	rep	% wpi E	% wpi TS	H-temp	H-time	visc @ 30 rpm	over run	Size distribution of particles		
									1 peak	2 peak
1	1	0.15	15	75	10	19	45	normal	0.68	
2	2	0.15	15	75	10	22.4	60	normal	0.7	
3	1	0.275	15	75	10	22	70	binomial	0.69	75
4	2	0.275	15	75	10	15.2	73.8	normal	0.75	
5	1	0.4	15	75	10	14.5	75	binomial	0.88	75
6	2	0.4	15	75	10	15	67.5	binomial	0.78	70
7	1	0.15	20	75	10	21.8	57.5	normal	0.83	
8	2	0.15	20	75	10	16	55	binomial	0.93	100
9	1	0.275	20	75	10	14.8	72.5	normal	0.58	
10	2	0.275	20	75	10	16.5	71.3	normal	0.63	
11	1	0.4	20	75	10	15	70	binomial	0.55	77.5
12	2	0.4	20	75	10	13	75	binomial	0.56	80
13	1	0.15	15	75	20	17	60	normal	0.61	
14	2	0.15	15	75	20	19.2	80	normal	0.65	
15	1	0.275	15	75	20	20	62.5	normal	0.65	
16	2	0.275	15	75	20	12	67.5	binomial	0.71	
17	1	0.4	15	75	20	16	67.5	binomial	0.84	68
18	2	0.4	15	75	20	21	65	binomial	0.88	80
19	1	0.15	20	75	20	20	57.5	binomial	1.2	100
20	2	0.15	20	75	20	17	60	normal	0.95	33
21	1	0.275	20	75	20	14.5	72.8	normal	0.7	
22	2	0.275	20	75	20	20	71.3	normal	0.64	
23	1	0.4	20	75	20	17.6	62.5	binomial	0.64	80
24	2	0.4	20	75	20	18.5	73.8	normal	0.69	
25	1	0.15	15	80	10	445	80	binomial	0.85	75
26	2	0.15	15	80	10	37.4	58.8	binomial	0.82	80
27	1	0.275	15	80	10	180	62.5	binomial	1.11	73
28	2	0.275	15	80	10	111	66.3	binomial	0.8	68
29	1	0.4	15	80	10	35	67.5	binomial	0.83	73
30	2	0.4	15	80	10	30	62.5	normal	0.79	
31	1	0.15	20	80	10	522.5	57.5	binomial	1	74
32	2	0.15	20	80	10	297.5	58.75	binomial	0.98	75
33	1	0.275	20	80	10	186.2	58.8	binomial	0.98	65
34	2	0.275	20	80	10	157	65	binomial	0.9	77
35	1	0.4	20	80	10	155	57.5	binomial	0.85	74
36	2	0.4	20	80	10	158	73.8	binomial	0.78	70
37	1	0.15	15	80	20	785	57.5	binomial	0.78	70
38	2	0.15	15	80	20	84	56.3	binomial	0.9	70
39	1	0.275	15	80	20	150.5	57.5	binomial	0.95	60
40	2	0.275	15	80	20	307.5	67.5	normal	0.85	
41	1	0.4	15	80	20	417.5	58.8	binomial	0.84	57
42	2	0.4	15	80	20	151.4	70	binomial	0.81	63
43	1	0.15	20	80	20	204.8	56.3	binomial	0.88	73
44	2	0.15	20	80	20	2000	55	binomial	0.8	70
45	1	0.275	20	80	20	365	73.8	normal	0.94	
46	2	0.275	20	80	20	336.25	70	normal	0.81	
47	1	0.4	20	80	20	252	57.5	binomial	0.7	70

2.6 Fat destabilization analysis

Samples for fat destabilization were thawed overnight in the fridge and 40 ml gently mixed before analyses. Three grams of thawed mix was weighed into a 50 ml erlenmeyer flask and diluted with 27 ml of dionized water at room temperature. One ml of this solution was removed into a 50 ml volumetric flask and added with dionized water at room temperature (1: 50 dilution) and measured for absorbance at 540 nm using the Spectronic 88 Spectrophotometer. Percent fat destabilized was calculated as :

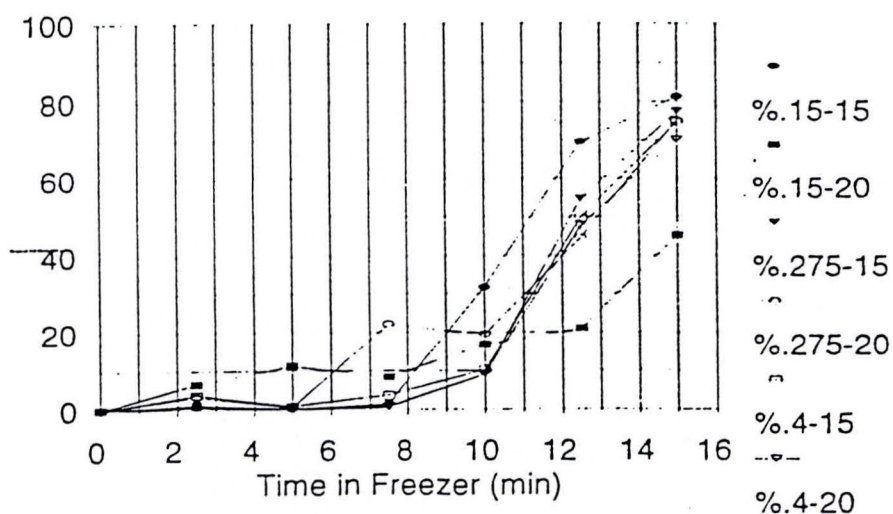
$$\frac{A_{\text{unfrozen mix}} - A_{\text{sample}}}{A_{\text{unfrozen mix}}} \times 100 \%$$

A = Absorbance

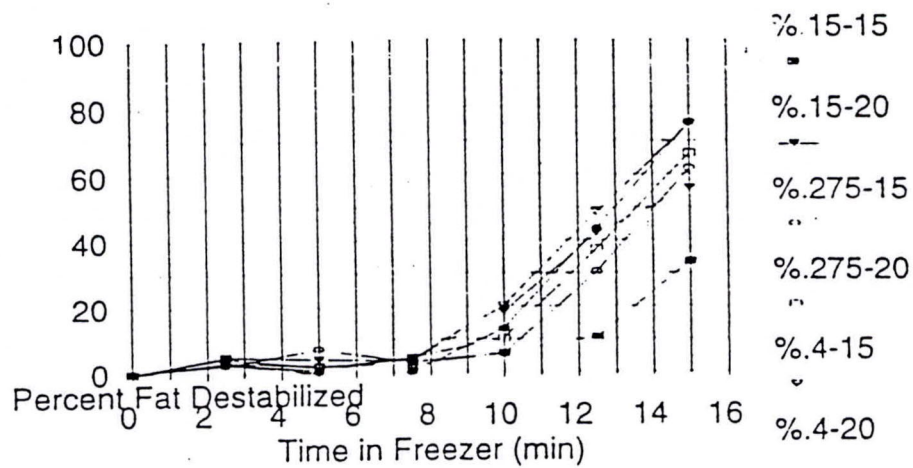
Dionized water was used as blank. The percent of fat destabilized was then plotted against time in the barrel freezer (Goff, H.D. and Jordan, W.K. 1989).

Results

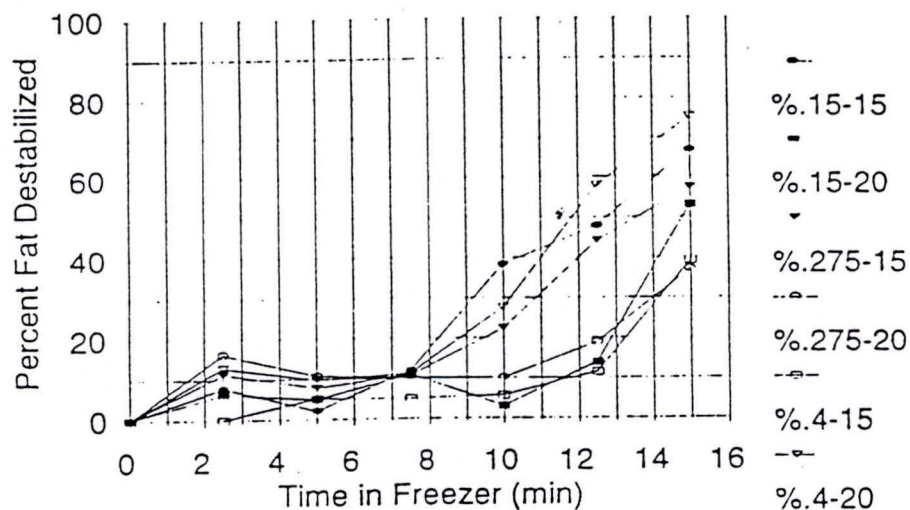
Figure 7 : Fat destabilization exhibited by mixes prepared with different concentration of WPI in the emulsion and thickening solution. The 1st and 2nd number indicate: the % WPI in the emulsion and thickening solution respectively.



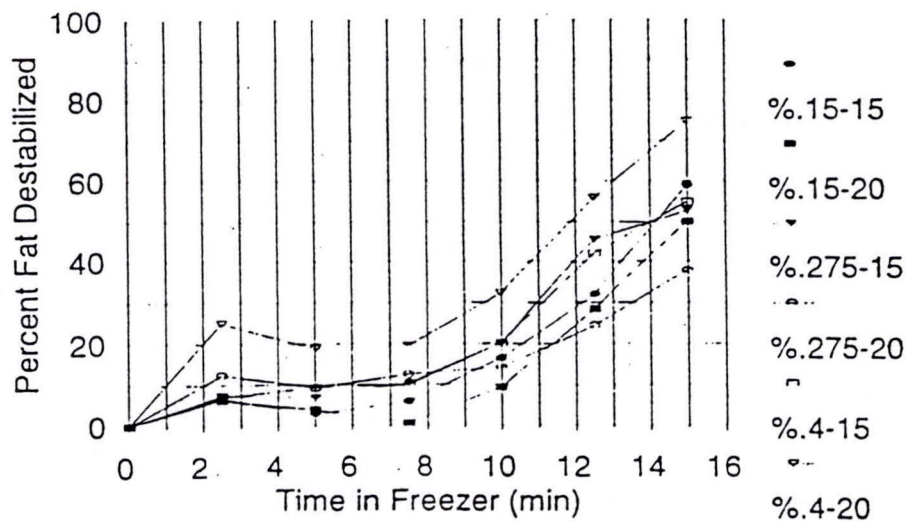
a) Heat treated at 75C for 10 min



b) Heat treated at 75C for 20 min



c) Heat treated at 80C for 10 min



d) Heat treated at 80C for 20 min

Table 9 : Tests of Significance for VIS@30 using UNIQUE sums of squares.

* * * * * A n a l y s i s o f V a r i a n c e -- design 1 * * * *

Tests of Significance for <u>VISC@30</u> using UNIQUE sums of squares					
Source of Variation	SS	DF	MS	F	Sig of F
WITHIN+RESIDUAL	2017525.97	24	84063.58		
HTEMP2	1094161.12	1	1094161.1	13.02	.001
HTIME2	192970.58	1	192970.58	2.30	.143
WPITS2	99722.66	1	99722.66	1.19	.287
WPIE2	318277.97	2	159138.99	1.89	.172
HTEMP2 BY HTIME2	191047.88	1	191047.88	2.27	.145
HTEMP2 BY WPITS2	101296.78	1	101296.78	1.21	.283
HTEMP2 BY WPIE2	309190.25	2	154595.12	1.84	.181
HTIME2 BY WPITS2	18183.81	1	18183.81	.22	.646
HTIME2 BY WPIE2	54544.64	2	27272.32	.32	.726
WPITS2 BY WPIE2	83209.38	2	41604.69	.49	.616
HTEMP2 BY HTIME2 BY WPITS2	17155.53	1	17155.53	.20	.656
HTEMP2 BY HTIME2 BY WPIE2	56503.31	2	28251.65	.34	.718
HTEMP2 BY WPITS2 BY WPIE2	83194.33	2	41597.16	.49	.616
HTIME2 BY WPITS2 BY WPIE2	51610.18	2	25805.09	.31	.739
HTEMP2 BY HTIME2 BY WPITS2 BY WPIE2	51179.50	2	25589.75	.30	.740
(Model)	2722247.91	23	118358.60	1.41	.205
(Total)	4739773.88	47	100846.25		
R-Squared =	.574				
Adjusted R-Squared =	.166				

Table 10 : Tests of Significance for OVERRUN using UNIQUE sums of squares.

* * * * * A n a l y s i s o f V a r i a n c e -- design 1 * * * *

Tests of Significance for OVERRUN using UNIQUE sums of squares
Source of Variation SS DF MS F Sig of F

WITHIN+RESIDUAL	3134.50	72	43.53		
HTEMP2	128.34	1	128.34	2.95	.090
HTIME2	52.51	1	52.51	1.21	.276
WPIE2	1658.64	2	829.32	19.05	.000
WPITS2	3.76	1	3.76	.09	.770
HTEMP2 BY HTIME2	2.67	1	2.67	.06	.805
HTEMP2 BY WPIE2	355.05	2	177.52	4.08	.021
HTEMP2 BY WPITS2	60.17	1	60.17	1.38	.244
HTIME2 BY WPIE2	33.69	2	16.85	.39	.681
HTIME2 BY WPITS2	73.50	1	73.50	1.69	.198
WPIE2 BY WPITS2	120.88	2	60.44	1.39	.256
HTEMP2 BY HTIME2 BY WPIE2	435.10	2	217.55	5.00	.009
HTEMP2 BY HTIME2 BY WPITS2	49.59	1	49.59	1.14	.289
HTEMP2 BY WPIE2 BY WPITS2	58.22	2	29.11	.67	.516
HTIME2 BY WPIE2 BY WPITS2	81.77	2	40.88	.94	.396
HTEMP2 BY HTIME2 BY WPIE2 BY WPITS2	74.73	2	37.37	.86	.428
(Model)	3188.63	23	138.64	3.18	.000
(Total)	6323.13	95	66.56		

R-Squared = .504

Adjusted R-Squared = .346

Table 11 : Tests of Significance for D32 using UNIQUE sums of squares.

* * * * * A n a l y s i s o f V a r i a n c e -- design 1 * * * *

Tests of Significance for <u>D32</u> using UNIQUE sums of squares					
Source of Variation	SS	DF	MS	F	Sig of F
WITHIN+RESIDUAL	2.62	72	.04		
HTEMP2	1.60	1	1.60	43.87	.000
HTIME2	.08	1	.08	2.26	.137
WPIE2	.06	2	.03	.83	.438
WPITS2	.05	1	.05	1.32	.254
HTEMP2 BY HTIME2	.01	1	.01	.27	.602
HTEMP2 BY WPIE2	.13	2	.07	1.82	.170
HTEMP2 BY WPITS2	.04	1	.04	1.03	.313
HTIME2 BY WPIE2	.05	2	.02	.63	.537
HTIME2 BY WPITS2	.08	1	.08	2.15	.147
WPIE2 BY WPITS2	.46	2	.23	6.25	.003
HTEMP2 BY HTIME2 BY WPIE2	.11	2	.05	1.44	.243
HTEMP2 BY HTIME2 BY WPITS2	.20	1	.20	5.46	.022
HTEMP2 BY WPIE2 BY WPITS2	.18	2	.09	2.49	.090
HTIME2 BY WPIE2 BY WPITS2	.05	2 *	.02	.62	.541
HTEMP2 BY HTIME2 BY WPIE2 BY WPITS2	.02	2	.01	.22	.804
(Model)	3.10	23	.13	3.69	.000
(Total)	5.72	95	.06		

R-Squared = .541

Adjusted R-Squared = .395

Table 12 : Tests of Significance for FD@12.5 using UNIQUE sums of squares.

* * * * * A n a l y s i s o f V a r i a n c e -- d e s i g n 1 * * *

Tests of Significance for <u>FD@12.5</u> using UNIQUE sums of squares					
Source of Variation	SS	DF	MS	F	Sig of F
WITHIN+RESIDUAL	34278.24	72	476.09		
HTEMP2	440.50	1	440.50	.93	.339
HTIME2	638.91	1	638.91	1.34	.251
<u>WPIE2</u>	3360.39	2	1680.19	3.53	<u>.035</u>
<u>WPITS2</u>	3399.59	1	3399.59	7.14	<u>.009</u>
HTEMP2 BY HTIME2	948.28	1	948.28	1.99	.162
HTEMP2 BY WPIE2	585.54	2	292.77	.61	.543
HTEMP2 BY WPITS2	275.20	1	275.20	.58	.450
HTIME2 BY WPIE2	166.03	2	83.02	.17	.840
HTIME2 BY WPITS2	516.90	1	516.90	1.09	.301
WPIE2 BY WPITS2	6972.64	2	3486.32	7.32	.001
HTEMP2 BY HTIME2 BY WPIE2	170.81	2	85.41	.18	.836
HTEMP2 BY HTIME2 BY WPITS2	1.80	1	1.80	.00	.951
HTEMP2 BY WPIE2 BY WPITS2	1223.50	2	611.75	1.28	.283
HTIME2 BY WPIE2 BY WPITS2	435.56	2	217.78	.46	.635
HTEMP2 BY HTIME2 BY WPIE2 BY WPITS2	393.41	2	196.70	.41	.663
(Model)	19529.07	23	849.09	1.78	.033
(Total)	53807.30	95	566.39		
R-Squared =	.363				
Adjusted R-Squared =	.159				

3. Discussion

The objective of this study was to investigate the potential use of WPI as an emulsifier and stabilizer in the manufacture of ice cream, through the process of selective homogenization. Whey protein isolate (WPI) is manufactured from whey which is a by-product of cheese making, therefore is widely available. It has some properties (emulsifying and gelling) which indicates that it could be used as an emulsifier and stabilizer replacer as well as a source of protein in ice cream. Other materials present in milk have a better affinity for the interface than WPI, and if present they will be preferably adsorbed rather than WPI. The adsorption of WPI onto the oil water interface can be done by controlling the material present at homogenization. This was achieved by selective homogenization, which consisted of homogenizing separately an emulsion composed of a fat source, water and small amount of WPI. The rest of the ingredients were prepared as a separate solution with WPI to act as a stabilizer.

The ice cream mix used had the following composition: 10% milk fat, 10% sugar (sucrose), 5% glucose solids(corn syrup solids) and 11% milk solids-not-fat (MSNF). The mix was prepared as two solutions: an emulsion containing the fat, WPI (0.15, 0.275 and 0.4%) and water to create a 25% fat emulsion. This emulsion was pasteurized at 65°C for 30 minutes in a double jacket steam pot followed by homogenization (2500/500 psi) in a two stage homogenizer and cooled at 4°C. The thickening solutions were comprised of the rest of the ingredients (skim milk powder, sucrose, corn syrup solids and WPI) and the remainder of the water to make up the correct composition of the final mix. The thickening solution was pasteurized at 75 or 80°C for 10-20 min depending on the treatment required in a double jacket steam pot, and was cooled directly after pasteurization. The two solutions were aged separately at 4°C for 24 hours. They were then mixed to form a 6 kg ice cream mix (40% emulsion, 60% thickening solution). Then, the ice cream mix was passed through the batch freezer until the correct temperature reached -5°C. The finished product was measured to study the properties of ice cream.

In stability of emulsion test, the emulsion was put into a 100 ml cylinder right after homogenization and stored for two days at 5°C. The percentage of fat was measured in the top and bottom 9 grams of the emulsion using the Pennsylvania Method of the Babcock test. It was shown that increasing the total percentage of protein in the mix maintained the stability but it was separated between fat and oil phases when reducing the total percentage of protein. The emulsions containing 0.275% and 0.4% WPI showed good stability, with the latter being slightly more stable (less creaming and smaller mean size distribution of the fat globules; Table 6). The emulsion containing 0.15% WPI was unstable; significant flocculation was observed after 48 hrs:

A two-litre aliquot of the ice cream mix was frozen in a batch freezer to -5°C and held in the freezer for a total of 15 min of agitation. Samples (40 ml) were removed from the barrel every 2.5 min and analyzed for the percentage of fat destabilization. Samples were diluted 1:500 with deionized water and absorbance was measured at 540 nm. Percent fat destabilized was calculated as $[(A_{\text{mix}} - A_{\text{ice cream}}) / A_{\text{mix}}] \times 100 \%$. Table 12 shows a significant difference in fat destabilization with different values of WPI in emulsion and in thickening solution. The highest degree of fat destabilization was observed in the mix

heated at 75°C for 10 min with the emulsion composed of 0.275% and 0.4% WPI, and either the thickening solution containing 15% or 20% WPI. The increase in heating time of the thickening solution at 75°C from 10 to 20 min seemed to cause a decrease in fat destabilization in all the mixes (0.15%, 0.275% and 0.4% WPI in emulsion). The same effect was observed with the increase of WPI replacement in the thickening solution from 15-20%. Increasing the temperature or increasing the percent of WPI in the thickening solution both caused an increase in viscosity which seems to have the effect of slowing down the rate of coalescence or preventing coalescence to a certain degree. This is supported by the mean size distribution analyses of the ice cream (taken at 15 min).

Aliquots (40 ml) of ice cream were taken after freezing and were thawed overnight at 5°C. A few drops were put into the Mastersizer X for particle size analysis. The values obtained were the average diameter ($D_{(3,2)}$) and the specific surface area $Sp.A.S., m^2/g$) of the particles. A decrease in mean size distribution by an increase of WPI replacement from 15 to 20 % was shown. However, there was no significant variation when the heating time was increased from 10 to 20 min (Table 11). Heating the thickening solution at 80°C caused a dramatic increase in viscosity. The thickening solution with 15 % WPI formed a gel when heated at 80°C for 20 min, and the thickening solution with 20 % WPI gelled when heated at 10 and 20 min. Samples (500 ml) of the thickening solution and ice cream mix were sampled after aging for viscosity. The viscosity was measured with a Brookfield synchro-electric viscometer model LVT. Ideal range of viscosity was 30-180 mPa.s which was used a standard (medium viscosity); it gave a characteristic of ice cream mix that can flow and not melt too rapidly. Table 9 shows the test of significance for viscosity using Unique sums of squares that presents a significant difference in viscosity with different heating time of thickening solution.

The highest degree of overrun was observed in the ice cream made with thickening solution heated at 75°C for 10 min (~71% overrun for 0.275% and 0.4% WPI emulsion; Table 8). The increase in heating time and temperature caused a decrease in overrun, but there was no significant difference in overrun when the % WPI replacement was increased in the thickening solution. From these basic sensory analysis, it was shown that the ice cream made with 0.275% WPI in the emulsion, 20% WPI replaced, heated at 75°C for 10 min, showed good meltdown properties, good body and chew resistance and was smooth and creamy. The ice cream made with 0.4% WPI in the emulsion showed similar properties but not as much.

4. Conclusion

An increase in the total percentage of protein in the mixture maintained the stability in a standard formulation; whereas a reduction in percentage of protein caused the separation of water and oil phases. The protein is acting as an emulsifying agent. The mixture was composed of two solutions: emulsion and thickening solution. Selective homogenization proved to be advantageous to allow the whey protein to act at the interface. It was observed that at a certain concentration, WPI can act as an emulsifier; it showed good emulsion stability after 48 hrs, good partial coalescence of the fat measured by fat destabilization and good overrun. A concentration of 0.275% WPI in the emulsion showed the best properties. Replacing a portion of the milk solids by WPI proved to be beneficial on the structure of the ice cream: 20% replacement showed less partial coalescence than 15% and showed improved texture, body, chew resistance and melt down properties. The heating time and temperature affected the viscosity of the thickening solution but did not affect significantly the characteristics of the ice cream. This study suggests that WPI is a potential replacer of stabilizers and emulsifiers currently in use.

5. References

1. Charalambous,G. and Doxastakis,G. 1989. A brief Introduction to food Emulsions and Emulsifiers. Food Emulsifiers. p.6., New York.
2. Charalambous,G. and Doxastakis,G. 1989. Milk Proteins. Food Emulsifiers. p.28., New York.
3. Charalambous,G. and Doxastakis,G. 1989. Protein Emulsifiers from Waste Byproducts. Food Emulsifiers. 323-346 pp., New York.
4. Dewit,J.N. 1990. Thermal Stability and Functionality of Whey Proteins. J.Dairy Sci. 73: 3602-3612 pp.
5. Fox,P.F. 1982. Functional Properties of Whey Proteins. Development in Dairy Chemistry-4. 310-312 pp., New York and London.
6. Fox,P.F. 1982. The Use of Whey Protein Products. Development in Dairy Chemistry-4. , New York and London, 323-346 pp.
7. Goff,H.D. and Caldwell,K.B. 1991. Stabilizers in the ice cream: How do they work?. Modern Dairy. 70(3): 14
8. Goff,H.D. and Jordan,W,K. 1989. Action of Emulsifiers in Promoting Fat Destabilization During the Manufacture of Ice Cream. J.Dairy Sci. 72: 18-29 pp.
9. Goff,H.D. 1988. Emulsifiers in ice cream : How do they work. Modern Dairy. 65(4): 15
10. Goff,H.D. 1996. The composition of and ingredients in ice cream. Finding Science in Ice Cream. Ontario,University of Guelph, 2-5 pp.
11. Kanekanian,A.D.A. and Lewis,M.J. 1986. Protein isolation using ion exchangers. Developments in Food Proteins-4. , New York,135-173 pp.
12. Labropoulos,A.E. and Hsu,S.-H. 1996. Viscoelastic Behavior of Whey Protein Isolates at the Sol-Gel Transition Point. J. Food Sci. 61: 65-67 pp.
13. Lampert,L.M. 1970. Ice Cream and Related Products. Modern Dairy Products. , New York, 233 p.
14. Ross,N. 1989. Principles of Ion Exchange Application to Recovery of Whey proteins. A Report Presented to The Department of Food Science of The University of Guelph. , Canada, 1-7 pp.