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EFFECTS OF VARYING TOTAL PROTEIN AND FAT CONTENT ON THE RHEOLOGICAL AND PHYSICO-CHEMICALS PROPERTIES OF ICE MILK

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ABSTRACT

Whey protein isolates (WPI) 91.5 % proteins were used in the preparation of ice milk mixes: a) by replacing 12.5 to 50% of added skim milk powder (SMP) to the control mix or: b) as a fat replacer by replacing 25 to 100% of its milk fat. The control mix formula had 4% fat, 14% SNF, 15% sugar and 0.5% gelatin. The mixes were examined for flow properties (rheological parameters), acidity and pH, specific gravity, weight per gallon and freezing point. Overrun and melt down percent were also tested and carried out in the resultant ice milk.

The results showed that there was no effect of replacing SMP of control mix with WPI on acidity, pH, specific gravity (SG), and weight per gallon (W/G), while the viscosity values increased, and the consistency improved. The overrun of the ice milk also increased and the product showed lower ability to melt down and became smoother and more acceptable. Replacing milk fat with WPI led to a slight increase in acidity, specific gravity and weight per gallon, and slight decrease in freezing point. An increase in viscosity and consistency of the mixes were observed up to50% replacement Improvement in mouthfeel, better melting resistance and high overrun were also observed in the resultant ice milk.

From the attributes studies, it was evident that ice milk could be successfully prepared by substituting SMP or milk fat in control mix with WPI to an extent of 50%.

Keywords: ice cream, ice milk, SMP, WPI, additives, rheological parameters.

Abbreviations: WPI: Whey protein isolate, SMP: Skim milk powder, TS: Total solids, SG: Specific gravity, W/G: Weight per gallon

INTRODUCTION

Whey and whey products have been used successfully in ice cream and other frozen dairy desserts for years. Sweet whey, modified whey, whey protein concentrates (34~80% protein), and whey protein isolates (>90% protein) are among the most commonly used whey products. Delactosed and demineralized wheys can also be used. Cost efficiency and quality improvement are key drivers in using whey products. The nutritional value of whey products is also important (Yaung, 1999). Whey ingredients are an excellent source of high quality protein, and thus are highly valued as components in a variety of weight management foods. The scientific community is increasingly recognizing that diets higher in protein may indeed provide a key to weight loss (Gerdes, 2003). Relative to other protein sources, whey proteins have high concentration of branched chain amino acids- leucine, iso- leucine and valine. These amino acids, particularly leucine, are important factors in tissue growth and repair (Marshall, 2004). Leucine has been identified as key amino acids in protein metabolism during the translation – initiation pathway of protein synthesis (Daenzer, *et al.*, 2001). Whey proteins are also rich in the sulfur containing amino acids; cysteine and methionine. With a high concentration of these amino acids, immune function is enhanced through intracellular conversion to glutathione (Marshall, 2004).

Whey protein concentrate (WPC) has been included in ice cream mix formulations for its contribution to favorable sensory and textural qualities (Tirumalesha and Jayaprakasha, 1998; Hofi, *et al.,* 1993; Parsons, *et al.,* 1985). Functional characteristics such as water binding, emulsification, and foaming are important in ice cream. Water binding is a property of WPC that can be utilized in frozen desserts to delay development of coarseness (Morr, 1989). Whey proteins bind high amounts of water through physical and chemical means and become more hydrated during aging. This tends to increase mix viscosity and aids in achieving finished goods freeze/thaw stability by limiting water-ice-water movement. The water-binding capacity of WPC is influenced by protein concentration, mineral content, and the extent of heating during manufacture (Sienkiewicz and Riedel, 1990). Whey protein concentrates can also be utilized for their emulsifying properties. Whey proteins are very efficient emulsifiers of fat and oil. They easily form stable emulsions and can be used totally or partially to replace chemical emulsifiers in frozen dairy desserts (Young, 1999).

Proteins interact at the oil/water interface during homogenization to stabilize the fat emulsion, and during freezing, proteins function to control destabilization of fat (Goff, 1997; Goff, *et al.,* 1989; Mangino, 1992). Increased amounts of whey proteins at the oil/water interface lower surface tension and slightly increase mix viscosity that produces a drier ice cream and enhances partial coalescence in the freezer (Goff *et al.,* 1989). The tremendous foaming properties of whey proteins allow fine dispersion of air cells (Zayas, 1997), which will lower the ice crystal size in ice cream (Flores and Goff, 1999). The whipability and foaming function of whey proteins add to desirable performance during freezing and enhances air incorporation.

Whey proteins add body to frozen desserts and have been shown to improve chew and bite. Texture improvements can be achieved through the addition of whey proteins: the mouthfeel of frozen desserts tends to be smoother, creamier, and icy or coarse textural problems minimized. Depending on the mix type, whey products can add opacity, whiteness, and milkiness to mixes and finished products. Whey proteins play a key role in managing ice crystal growth during heat shock and other distribution abuses. Superior freeze-thaw stability can be achieved through the use of whey proteins (Young, 1999). The rheology and melting rate are markedly influenced by mix composition, processing treatments and the addition of hydrocolloids and both have major impacts on consumer perception of the final product quality.

Therefore, the main objectives of this study are evaluating the effects of varying total protein and fat content of the mixes on the rheological and physico-chemicals properties of ice milk.

MATERIALS AND METHODS

Materials:

Cow's milk was obtained from herds of Faculty of Agriculture, Suez Canal University, and skimmed in dairy department. Skim milk powder 95% TS is a product of Holland. Cane sugar and vanillin were obtained from local market, gelatin solution (10%) was prepared from gelatin powder (ADWIC, El-Nasr Pharmaceutics Chemicals Co. Egypt). Whey protein isolate (WPI 91.5 % protein) is of Bio-Pharma Co .Egypt.

Preparation of different mixes:

The ice milk mixes were prepared according to Arbuckle (1986). The control mix contained of 4% fat, 14% SNF, 15% sugar, 0.5% gelatin and 0.03 % vanilla. The mixes were prepared using the formulation in (Table 1) and processed as shown in Figure (1).

Table (1): Composition of ice milk mixes containing different level of whey protein isolates (g/100g mix)

Ingredients \ Treatments	T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
Sugars	15	15	15	15	15	15	15	15	15
Gelatin solution	5	5	5	5	5	5	5	5	5
Cream (20 % fat)	20	20	20	20	20	15	10	5	0
Skim milk	52	52	52	52	52	56	60	64	68
Skim milk powder	8	7	6	5	4	8	8	8	8
(WPI)	0	1	2	3	4	1	2	3	4
Substitute ratio	0	12.5	25	37.5	50	25	50	75	100

T_0: (control)
T_1: WPI substitute 12.5% of added skim milk powder to the control mix.
T_2: WPI substitute 25% of added skim milk powder to the control mix.
T_3: WPI substitute 37.5 % of added skim milk powder to the control mix.
T_4: WPI substitute 50% of added skim milk powder to the control mix.
T_5: WPI substitute 25% of milk fat in the control mix.
T_6: WPI substitute 50% of milk fat in the control mix.
T_7: WPI substitute 75% of milk fat in the control mix.
T_8: WPI substitute 100% of milk fat in the control mix.

Methods of analyses:

The total solids, fat, protein and acidity were determined according to (AOAC, 1990), pH by using digital pH meter. The specific gravity of the mix was determined using the method described by Winton (1958), weight per gallon according to (Burke, 1947), freezing point due to FAO, (1977). The viscosity, consistency and flow index of the mix were carried out as described by Petersen *et al.*, (2000) by using a Brookfield viscometer (Brookfied Engineering Laboratories. Inc., MA, USA), equipped with a SC 4-21 spindle running at 25 rpm. Measurements were made at the temperature of 5°C in shear rate ranging from 9.3 to 93.

Melting down percent and overrun were determined according to Arbuckle (1986). The sensory evaluations were assessed by the staff of the Dairy Department., Suez Canal University using the following scale for flavour, (50 points), body and texture (40 points) and appearance (10 points) according to Arbuckle (1986).

Figure (1): Processing steps for production of ice milk

Mixing the ice milk ingredients (Table 1)

↓

Heat treatment (72 ˚C /5min)

↓

Cooling 4-5 ˚C

↓

Ageing at (4-5 ˚C / 24 hrs)

↓

Freezing (62-75% overrun)

↓

Filling

↓

Hardening and Storage at (-18 ˚C)

RESULTS AND DISSECTION

Mix composition and Characteristics:

As shown in Table (2) fat content of ice milk mix was about 4% for treatments T0,T1 ,T2, T3 and T4, in which WPI substituted part of SMP. On the other hand, in T5, T6, T7 and T8, WPI substituted 25-100 % of the milk fat in the control mix, the milk fat ranged from 3.15 to 0.1 %, respectively. Keeney and Kroger, (1974) reported that an increase in fat content have been shown to reduce ice crystal size and affect sensory evaluation by causing a lubricating sensation in the mouth (Arbuckle, 1986; Keeney, 1979). Often fat is Added to the ice cream mix at the expense of water and this lowers the ice phase volume of the ice cream, which provides a smoother product (Hartel, 1996).

Total protein content (T.P) in control mix was 5.04 %, Table (2). Substituting SMP of the control mix by different levels of WPI, while maintaining the fat content constant, increased the protein content to 4.6, 6.16, 6.72 and 7.28 % in T1, T2 T3 and T4, in the same order. When WPI gradually substituted the milk fat (T5, T6, T7, and T8) the protein content also increased to 5.96, 6.88, 7.8 and 8.72 %, respectively. Milk proteins are the main functional ingredients of the incorporated milk products. Caseins form high molecular weight aggregates in solutions due to their distinct molecular structures. The uneven distribution of hydrophilic and hydrophobic amino acids, gives them a detergent likes structure, therefore the ability of caseinates to form foams and form stabilized emulsions has a long tradition in use of the processing of food (Mehrens and Reimerdes 1991). Whey proteins show a relatively globular structure, the solubility of undenaturated whey proteins is high over a wide pH range, but changes dramatically if denaturation has taken place (Mehrans and Reimerdes 1991).Functional properties of whey proteins include emulsification, gelation, water-binding, solubility whipping /foaming and viscosity development. In general, the higher the protein content, the more functional ingredient.

Table (2): Some physico-chemical properties of ice milk mixes containing different levels of WPI

Treatments	TS (%)	Fat (%)	TP (%)	Acidity (%)	pH	SG	W/G Kg	F.P (°C)
T0	33.58	4.17	5.04	0.25	6.4	1.12	5.09	-2.6
T1	33.58	4.17	5.60	0.27	6.4	1.12	5.10	-2.6
T2	33.43	4.14	6.16	0.27	6.4	1.12	5.10	-2.6
T3	33.50	4.14	6.72	0.27	6.3	1.12	5.10	-2.5
T4	33.45	4.09	7.28	0.27	6.3	1.12	5.10	-2.5
T5	33.60	3.15	5.96	0.27	6.3	1.124	5.11	-2.6
T6	33.60	2.14	6.88	0.29	6.3	1.128	5.122	-2.6
T7	33.55	1.14	7.8	0.31	6.3	1.136	5.163	-2.7
T8	33.47	0.1	8.72	0.32	6.2	1.140	5.181	-2.7

Total solids ranged from 33.43 to 33.60 % and were similar among treatments. Keeney, (1979) reported that mix with lower total solids has proportionately more water to freeze than a higher TS mix hardened to the same storage temperature. Variation in solids content of just a few percent greatly influences ice crystal growth. These reasons make uniformity in total solids content among treatments essential.

The pH value of ice milk mix is related to SNF content, as the SNF portion of a mix increases the normal acidity elevated, and the pH lowered (Arabuckle,1986).The pH of ice milk mix can be used as an indicator of mix quality. From Table (2) increasing the protein content with the range 5.04 to 7.28 % while maintaining the fat content constant at 4% had no effect on pH values and titratable acidity. Increasing the protein content within the range 5.96 to 8.72 while decreasing the fat content led to increase in acidity of T6, T7 and T8 due to the increase in the SNF content of the mix. No effect was reported for the specific gravity (SG) of the mixes due to replacing of SMP with WPI. Substituting the milk fat in the control mix by WPI led to slight increase in (SG). This may be due to increase of the SG of WPI than the SG of the fat. Weight per gallon (W/G) of different mixes closely related to the SG.

Freezing point (F.P) of ice milk mix is a reflection of the molecules in solution, the most prevalent constituent being sugar (Arbuckle, 1986). Freezing point will detect variation in samples assuring that solute is found in proper quantity (Baer and Czmowski, 1985). Variation in mix freezing points can alter the recrystalization rate at a specific storage temperature in ice milk (Hagiwara and Hartel, 1996). Freezing point of the ice milk mix increased as the substitution level with WPI increased Table (2), this mainly due to the composition of WPI, which free from sugar. Substituting the fat with WPI led to slight decrease on freezing point.

Rheological properties:

The rheology of mix generally describes and measures the texture and includes such terms as viscosity and consistency. Importantly the rheology is markedly influenced by mix composition and addition of hydrocolloids. Variation in total fat, protein and the ratio of casein to whey protein had major effects of the rheological properties (Arbuckle, 1986). Marshall and Arbuckle (1996) stated that a certain level of viscosity is necessary for suitable whipping and retention of air in the ice cream freezer, as the viscosity is raised, the resistance to melting and the smoothness of body increases. Generally, ice cream mix with high viscosity accompanies good textured. To achieve the desired mix viscosity, the mix must be properly balanced for composition, concentration and quality of ingredients and then appropriately processed (Ruger, *et al.,* 2002).

Rheological parameters (consistency index, flow behavior index, and yield stress) of mixes during ageing are presented in Table (3). Differences in yield stress and consistency index can be noticed between control mix, and WPI mix treatments.

Increased the level of WPI increased the consistency index and yield stress, and they increased during ageing. The same Table shows that the flow behavior index of all treatment was lower than the control. Thus it is quit clear from the above results that consistency index and flow behavior index was inversely related. The determined flow behavior indexes in all treatments were low, exhibit a non Newtonian character. Almost all treatments were pseudoplastic fluids (structural-viscous behavior) expect the control mix before ageing that exhibited dilatants properties.

Differences were observed in mixes viscosity Fig (2). Mixes with WPI as a substitute of SMP had higher viscosity than the control mix. By increasing the substitution level, the viscosity increased. Also replacing the fat with WPI increased the viscosity than the control up to 50% substitution. This could be attributed to the fat/ protein ratio, and the considerable increase in water binding capacity of ice cream mixes with high protein content (Abbas 2006).

Figure (2) shows the viscosity-shear rate of ice milk mixes during ageing. Addition WPI increased the mix viscosity, however T0 and T8, in which the WPI substitute 0 and 100% of the fat content, respectively, showed lower viscosity than mixes that made by substituting the SMP or milk fat by WPI. This relation and trends sustained in the mixes during the whole ageing period.

The viscosity of mix continuously decreases with increasing shear rate. In addition, the steeped of the slope decreases with increasing shear rat, due to break up of the gel structure. Eventually, when the gel and all aggregate are broken up and only colloidal particles are present, hydrodynamic forces dominate all other forces and sample-become Newtonian, i.e. has a constant viscosity (van Marle, *et al.*, 1999).

Table (3): Some rheological parameters of ice milk mixes containing different levels of WPI

Treatment / Ageing time	T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
					Consistency index (m Pa. S^n)				
Zero time	1.79	2.61	1.87	3.07	3.98	1.85	2.16	2.33	2.27
3 h	98.4	113.9	175	180.8	182.2	152.1	189.8	73.9	97.7
6 h	119	160.7	175.3	180.7	195.4	205.6	262.6	180.1	138.8
24 h	219.7	330.6	439.8	455.5	495.7	477.4	499.7	440	259.3
					Flow index (n)				
Zero time	1.02	0.95	0.94	0.94	0.91	0.99	0.98	0.99	0.98
3 h	0.66	0.61	0.61	0.61	0.61	0.63	0.63	0.64	0.65
6 h	0.63	0.61	0.61	0.61	0.58	0.47	0.47	0.61	0.61
24 h	0.57	0.57	0.47	0.45	0.46	0.46	0.45	0.49	0.58
					Yield stress				
Zero time	0.02	0.05	0.05	0.06	0.08	0.03	0.05	0.04	0.03
3 h	3.04	5.18	5.30	5.56	5.29	4.27	5.62	5.27	4.20
6 h	3.94	5.23	5.21	6.21	5.73	4.57	5.56	5.12	4.59
24 h	4.23	7.97	8.02	8.03	8.97	6.75	8.25	8.13	5.13

Figure (3) show shear stress-shear rate of mixes during ageing condition.Shear stress of control mix was lower than mixes from other treatments. Addition of WPI increased the shear stress. The shear stress of all samples continuously increased at first with increasing shear rate but then leveled constant. It was mentioned that WPI have an influence on the flow behavior. The increase of the WPI content in the mix mad the pseudoplastic - characteristics more apparent, and it also increased the viscosity. These results are in agreement with those obtained by (Jayaprakasha, *et al.*, 1990).

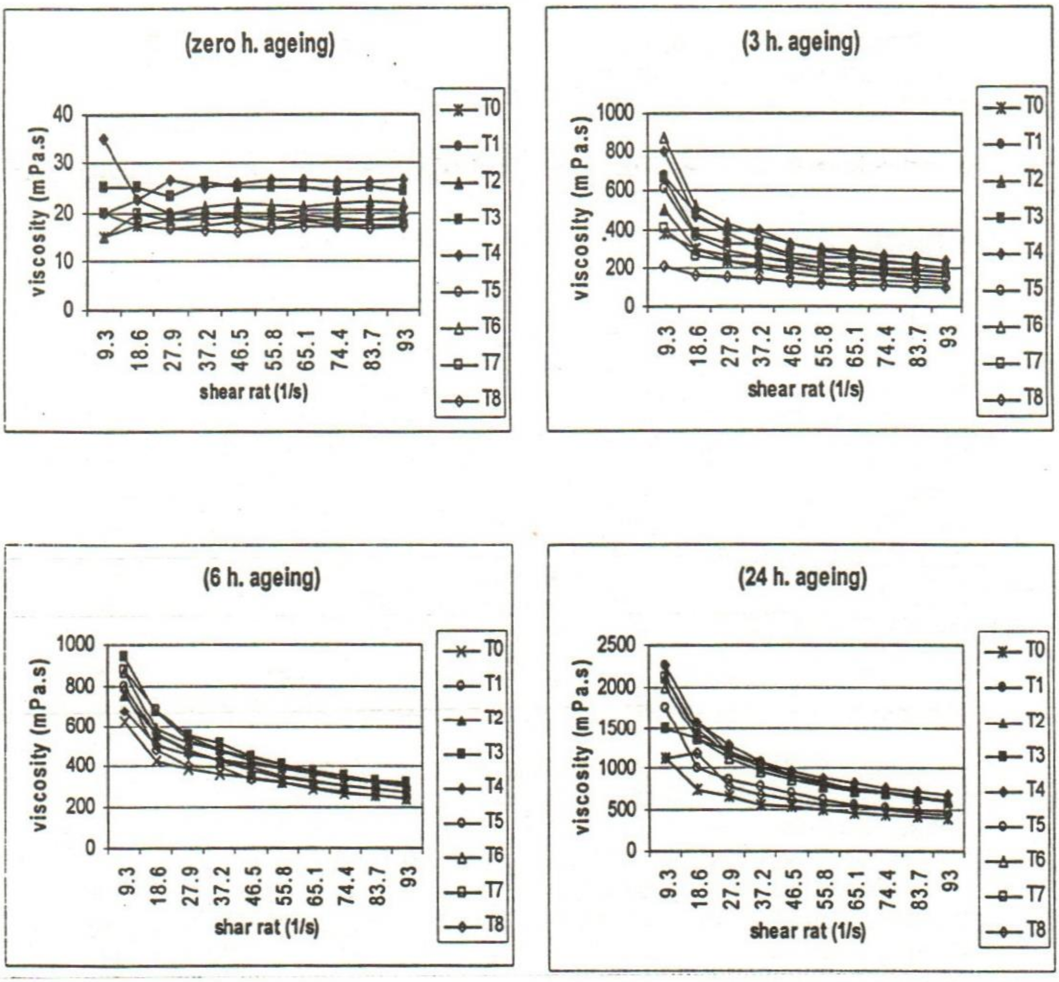

Fig (2):Viscosity-shear rate of ice milk mixes during ageing

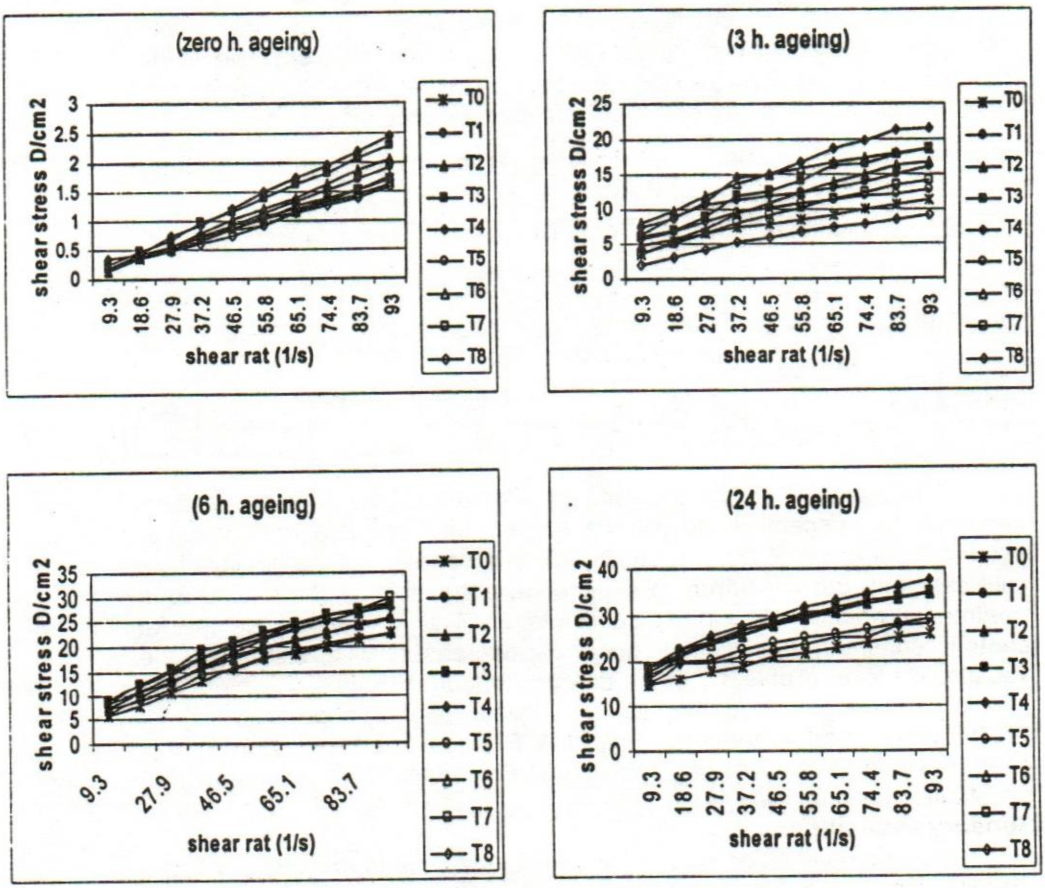

Fig (3): Flow curves of ice milk mixes during ageing(Shear stress - shear rate)

Ice milk characteristics:

Overrun is the increase in volume of ice cream over the volume of ice cream mix due to the incorporation of air (Marshall and Arbuckle, 1996). Slight differences were seen among treatments for overrun which ranged from 62-75% (Table 4).An increase in overrun will decrease the SG and weight per gallon (W/G). Mahran *et al.,* (1984) reported that the SG of the ice cream is inversely proportional to changes occurring in the overrun. Goff, *et al.,* (1989) run a series of experiments incorporating different milk proteins isolate combination into ice cream mix. These researchers determined that a 95% WPI used at 3% provided proper ice cream mix viscosity, allowed for adequate incorporate of air, the ice cream had acceptable test and fat destabilization was at a rate that made inclusion of emulsifier unnecessary.

Table (4): Some physico-chemical properties of ice milk containing different levels of WPI

Treatment / Property	T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
Overrun (%)	62	70	70	75	75	65	75	75	72
Specific gravity	0.69	0.66	0.66	0.64	0.64	0.68	0.65	0.65	0.66
Weight / gallon (kg)	3.14	3.00	3.00	2.91	2.91	3.10	2.93	2.95	3.00
Melt- down									
% after 30 min	17	13	13	12	10	17	13	12	14
% after 60 min	40	36	35	33	30	38	35	35	35
% after 90 min	100	95	90	90	90	95	90	90	92

Melting down refers to tendency of the ice milk to melt at room temperature, susceptibity to melting have major impacts on consumer perception of the final product quality. Indeed, variation in the quality of ice milk can lead the consumer to experience either thin or thick texture. In treatments which WPI partially substitute SMP while maintaining the fat content constant, the melting down % decreased with increased the substitution level (Table 4), which can be attributed to the increase in ice milk mix viscosity and hydration ability and water binding of protein.

On the other hand, in treatments which WPI substituted milk fat of mix at different levels, the melting down % decreased with increase the substitution level up to 75 %.

Sensory evaluation:

Sensory evaluation scores for ice milk treatments are listed in Table (5). The ice milk made by substituting different levels of SMP in the mix with WPI characterized by smoother textuer, softer body and higher melting resistance and gained a higher score points than the control for flavour and body and textuer. Panelists found no differnces in appearance. Increase the replacement level, increased the score points. Goff, *et al.,* (1989) reported that a 95% WPI used at 3 % provided acceptable taste ice cream. Jayarakasha, *et al.,* (1999) used WPC to replaced SMP and observed improvement mouthfeel and better melting resistance with increasing level of substitiution. Awad and Metwally (2000) used total milk protein as a milk solids source in ice cream manufacture. They found that the ice cream became smoother and more acceptable. On the other hand, treatments (T5, T6, T7 and T8) which WPI substitited the milk fat at different levels, the ice milk gained a slight lower score points for flavour. Increase substitution levels led to deceased of flavour score points. The substitution of milk fat with WPI improved the body and textuer of ice milk up to 50%.

From the physico-chemical and sensory attributes studies,it was evdent that good quality ice milk could be made by replacing up to 50 % of added SMP or the fat content in the control mix with WPI.

Table (5): Organoleptic properties of ice milk containing different levels of WPI

Treatment / Property		T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
Flavour	50	42	44	44	46	46	44	43	43	41
Body & texture	40	33	37	37	39	39	34	39	39	37
Appearance	10	8	9	9	9	9	9	9	9	8
Total	100	83	90	90	94	94	87	91	91	86

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تاثير استخدام نسب مختلفه للبروتين الكلى والدهن على الخواص الريولوجيـــه والكيموطبيعيه للمثلوج اللبنى

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تستخدم منتجات الشرش المختلفه بنجاح فى صناعه المثلوجات اللقشديه مما يؤدى لخفض تكاليف الصناعه وتحسين جوده المنتج وذلك بجانب ارتفاع قيمتها الغذائيه فهى تعتبر مصدر ممتاز للبروتين العالى الجوده ويعتبر عدد من الباحثين ان الوجبات المرتفعه فى محتواها من البروتين عامل أساسى للتغلب علـــى مشكله الوزن الزائد.

وادخال بروتينات الشرش ضمن تركيب مخاليط المثلوجات القشديه كان له تاثير جيد على النواحى الحســيه والريولوجيه فهى لها قدره على التأدرت والاستحلاب وتكوين رغوه مما يزيد الريع فى الناتج.

في هذه الدراسة حضرت مخاليط المثلجات اللبنية بحيث تحتوى على (٤ ٪ دهن ،١٤ ٪ جوا مد لبنيه لا دهنيه، ١٥ ٪ سكر، ٠,٥ ٪ جيلا تين).

وتم أحلال ١٢,٥–٥٠٪ من اللبن الفرز المجفف المضاف لمخلوط المثلوج اللبنى لتجربه المقارنـــه أو ٢٥–١٠٠٪ من محتواه من دهن اللبن ببروتينات شرش معزوله تحتوى على أكثر مـــن ٩٠% بـــروتين بغرض الوصول إلى منتج ذو صفات جودة مرغوبة وقيمه غذائية ووظيفية عالية.

وقد أظهرت النتائج أن استبدال اللبن الفرز المجفف المضاف لمخلوط المثلوج اللبنى لتجربه المقارنه ببروتينات الشرش المعزوله ليس له تاثير على قيم كل من الحموضة والوزن النوعى والوزن لكل جالون- ينما أدى إلى زيادة في اللزوجة وتحسن في الخواص الريولوجيه الاخرى للمخلوط .كما أدى الى تحســن فى الريع والقابليه للانصهار وكان الناتج ذوصفات جوده عاليه.

أما استبدال المحتوى الدهنى لمخلوط المثلوج اللبنى لتجربه المقارنه ببروتينات شرش معزوله أدى الى زياده طفيفه فى الحموضه والوزن النوعى والوزن لكل جالون وانخفاض طفيف فى نقطه التجمد وقـــد لوحظ زياده لزوجه المخاليط وتحسين فى خواصها الريولوجيه حتى نسبه استبدال تصل الـــى ٥٠% مـــن المحتوى الدهنى وكان للناتج خواص حسية جيدة. وبزياده نسبه الاستبدال عن ذلك كان له تـــاثير عكســـي على الخواص الحسيه والريولوجيه.

من النتائج المتحصل عليها أمكن بنجاح إنتاج مثلجات لبنيه ذات جودة عالية باســـتبدال اللـــبن الفرز المجفف المضاف لمخلوط تجربه المقارنه أو محتواه من دهن اللبن ببروتينات الشرش المعزولـــه حتى نسبه استبدال ٥٠ ٪ دون حدوث اى تأثير على خصائص جودة المنتج.