PRODUCTION OF LOW AND FREE FAT ICE MILK USING SODIUM CASEINATE AND BUTTER MILK POWDER

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Abstract

Performance of butter milk powder (BMP) and sodium caseinate (SC) as a partial or total replacement of milk fat in ice milk formulas were investigated. All mixes and resultant ice milk samples were evaluated for their chemical, physical and rheological properties as well as their sensory quality attributes. Total protein and ash contents were significantly affected with adding BMP and SC as partial or total replacement of milk fat on total solids or fat percentages. Specific gravity was increased with adding BMP and SC in both mixes and in the resultant ice milk and therefore the overrun percent was significantly increased. Addition of BMP and SC in ice milk recipes led to slightly higher acidity with lowering the freezing point and the product showed lower ability to meltdown with replacement of milk fat by BMP and SC compared to full-fat treatment (control).Apparent viscosity as well as flow time of mixes was significantly increased with substitution of milk fat by BMP and SC. The ice milk became smoother and highly acceptable by partial replacing of milk fat with BMP and SC. Therefore, fat ice milk can be produced with high quality by partial substitution of milk fat with BMP and SC.

Key words: Ice milk, butter milk powder (BMP), sodium caseinate (SC), substitution, rheological properties, sensory evaluation.

INTRODUCTION

Milk fat as a constituent is of major importance to the quality of ice cream. The high fat content tends to retard whipping and reduces the melting resistance and increases the cost of production of ice cream (Marshall et al., 2003). The high fat content may limit the consumption of ice cream due to its high caloric value (Arbuckle, 1986).

In recent years, the awareness of the harmful effects of excess dietary fat on human health increased the demand for low-fat or non-fat dairy products. High fat diets have been linked to high serum cholesterol levels, digestive disorders, heart burn and stress. A low-fat diet has the potential of reducing the risk of heart disease, diabetes and cancer. Over the past decade, there has been substantial interest in the development of a new range of dairy products which are similar to the existing products but in which the fat content is substantially reduced to avoid the health problems associated with increased fat composition. Using fat substitutes to replace fat in food while keeping the same functional and sensory properties of high fat products had great attention in the past few years. Available fat substitutes can be classified as carbohydrate-based, protein-based and fat-based fat replacers. Reduced and low fat foods have relied on a combination of fat replacers because for a single fat replacer it has not been possible to replace all functions of fat (Giese, 1996).

Sweet butter milk was used successfully in many dairy products such as yoghurt (El-Batawy et al., 1987) Kariesh cheese (Ibrahim et al., 1990) and ice milk (Mahran et al., 1976 and Fikry et al., 1994). Incorporation of ultrafiltered buttermilk into reduced fat Mozzarella and Cheddar cheese enhanced the mouthfeel or body of the cheeses by improving meltability (Poduval and Mistry 1999). The composition of butter milk solids (BMS) is similar to that of nonfat dried milk (NFDM), with the exception that a higher fat content and the presence of milk fat globule membrane (MFGM) exist with BMS (Malin et al., 1994, Mistry et al., 1996). During butter churning fat globule membrane is disrupted from the globules and goes into the butter milk. Dried buttermilk has the advantage of improving melting resistance, texture, body and foam properties of the ice cream product leading to smooth body and better overrun. The components that are responsible for effects are of interest of many scientists (Rajore et al., 1983). It is usually assumed that phospholipids are responsible components through their emulsification power.

Proteins from traditional sources are being increasingly utilized as ingredients in a growing number of formulated foods. The benefits of milk proteins as ingredients in other food stem from their excellent nutritional properties and their ability to contribute unique and essential functional properties to the final foods (Morr, 1979, Morr, 1982, Dewit,1989 and Fox, 2001). The caseinates (sodium and calcium) are very soluble and extremely heat stable over a wide range of conditions. Because of their amphiphilic structure, these proteins are useful for emulsification, water binding, thickening, whipping, foaming and gel formation and found wide acceptance as emulsifiers and water binders in different formulated food preparation (Mulvihill, 1992). So, the objective of this study was to investigate the possibility of using dried butter milk and sodium caseinate as natural fat replacers in the manufacture of low or free-fat ice milk.

MATERIALS AND METHODS

Materials

Raw and skimmed buffalo's milk were obtained from the herd of Faculty of Agriculture, Ain Shams University and used for preparing the ice cream mixes.

Skimmilk powder (SMP) made in USA was obtained from Misr for Milk and Food Co., Cairo, Egypt. Commercial grade cane sugar was purchased from sugar and integrated industries company, Giza, Egypt. High viscosity carboxymethyl cellulose (CMC) produced by TIC gums, MD, USA was used as a stabilizer and soy Lecithin was used as an emulsifier. Vanilla was obtained from the local market and used to flavour the ice milk. Butter milk powder used in this study was obtained from Dairy Farmers of America, Inc. Spring field, MO, USA. Sodium Casienate produced by Benser Bridel Alimentare-Bener Industrie-SNC France was obtained from Misr for Milk and Food Co. Cairo Egypt.

The gross composition of both butter milk and caseinate powder is illustrated in Table(1).

Table 1 . Composition of butter milk powder (BMP) and sodium caseinate (SC) used in the preparation of ice milk mixes.

Component %	Butter milk powder(BMP)	Sodium caseinate (SC)
Protein	30.19	86.82
Lactose	52.85	4.74
Ash	7.00	3.33
Fat	5.85	0.90
Moisture	4.11	4.21
Acidity	0.22	0.32
pH	6.43	6.08

Manufacture of ice milk

Ice milk batches were prepared from the forementioned ingredients with quantities calculated as shown in Table (2). The control mix was standardized to contain 4% fat, 12% SNF, 15% sugar, 0.25% CMC and 0.1% Lecithin. A mixture of butter milk powder and sodium caseinate was used to replace part or whole fat mixture of ice milk as shown in Table (2). However, six batches of ice milk were made as follows:

Control : Adjusted to 4% milk fat

T_2 : Adjusted to 1% milk fat + 1% sodium caseinate +2% butter milk powder

T_3 : Adjusted to 1% milk fat + 1.5% sodium caseinate +1.5% butter milk powder

T_4 : Without milk fat + 1% sodium caseinate +3% butter milk powder

T_5 Without milk fat + 2% sodium caseinate +2% butter milk powder

All prepared mixes were heat treated up to 85±1°C for about 30 sec., then rapidly cooled to 5±1°C and aged at same temperature for 4hr. After ageing, 0.01% vanilla powder was directly added to the mixes before freezing in a horizontal batch

freezer (Taylor Co. USA). The frozen ice milk was drawn in plastic cups (120 ml) and hardened at -26ºC for 24 hr
before analysis. All treatments were of three replicates.

Table 2. Composition of low or free fat ice milk recipes.

Ingredients	Con.	T_1	T_2	T_3	T_4	T_5
Sugar	15	15	15	15	15	15
CMC	0.25	0.25	0.25	0.25	0.25	0.25
Lecithin	0.1	0.1	0.1	0.1	0.1	0.1
Sod. Caseinate	---	0.5	1.0	1.5	1	2
Butter milk powder	---	2.5	2.0	1.5	3	2
Skim milk powder	4.89	4.89	4.89	4.89	4.89	4.89
Fresh milk (whole 6%)	66.42	16.63	16.63	16.63	0	0
Fresh milk (skim)	13.29	60.13	60.13	60.13	75.76	75.76

Analysis

Moisture, fat, ash and total protein percentages were determined according to AOAC (2000). Titratable acidity of mixes was determined in duplicate according to Richardson (1986) by titration with NaOH 0.1N. Specific gravity was determined as described by Winton (1958) at 20ºC for mixes and resultant ice cream using a pycnometer. The freezing point was tested for mixes as mentioned in FAO Laboratory manual (1977). Lactose was determined according to Lawrence (1968). Values of pH were measured using a digital laboratory pH meter (HI 93 1400, Hanna instruments) with glass electrode. Flow time of the mixes was measured as the time in seconds required to discharging a 50 ml pipette at 5ºC under atmospheric pressure (Arbuckle, 1986). The overrun in ice cream was calculated according to Marshall et al., (2003) as the difference in volume between resultant ice cream and original mix. Melting rate of the resultant ice milk samples was determined as mentioned by Segall and Goff (2002). Ice milk samples were allowed to melt at room temperature (23±1ºC) and the melted portion was weighed every 10 min. the percent mass loss/min in the linear region (slope) was used to compare the meltdown rate of different samples. Hardness of frozen ice milk was examined by adapting the method recommended by Bourne and Comstock (1986). Puncture test was based on using a (0.27) inch diameter of Chatillon Fruit and Vegetables Tester Precission Instrument model ATL 719-10. The yield point force was measured as lb/in2 in ice milk samples hardened in a deep freezer at -26ºC for 24hr before testing.

Rheological properties

Rheological data were determined in all mixes using a coaxial cylinder viscometer (Brookfield Engineering Labs. DVIII Ultra Theometer and COM1 or COM2 of our host computer) at rpm 20, 40, 60, 80, 100 and 120 as suggested by

Arbuckle(1986). All samples were adjusted to 20±1ºC before loading in the viscometer device.

Sensory evaluation

Samples of ice milk after 24hr. of hardening at -26ºC were judged by a panel of 10 judges selected on the basis of their consistency in scoring. The samples scored for flavour (45), body and texture (35), melting properties (10) and colour (10) as suggested by **Arbuckle (1986)**.

Statistical analysis

All data (mean of three replicates) were analyzed by the General Linear Models procedure of **SAS (1990)**. Least significant difference test was performed to determine differences in means at P≤0.05.

RESULTS AND DISCUSSION

Properties of ice milk mixes.

Chemical composition of ice milk mixes with BMP and SC as a substitution of fat in the base formula is shown in Table (3).Total solid contents in all treatments were from 31.96 to 32.84%. It is shown from the data that there were slight differences in the total solid contents of mixes. The fat content showed also the figure adjusted before mix preparation.

The total protein of ice milk mixes was significantly affected by addition of BMP and SC as a substitution of milk fat. Replacement of milk fat with SC and BMP together resulted in higher protein content of treatments .Also, ash content showed higher ratio in treatments with BMP and SC as a fat substitution compared to control treatment. This is due to the higher ratio of protein and ash in BMP and SC (Table, 1).

Table 3. Chemical composition (%) of ice milk mixes with sodium caseinate and butter milk powders as a fat substitution.

Treatments*	Total solids	Fat	Total protein	Ash	Carbohydrate (by differences)
Control	32.44	4.10^{A}	5.812^{D}	1.06^{B}	21.468
T_1	32.18	1.26^{B}	7.599^{C}	1.28^{A}	22.041
T_2	31.96	1.21^{B}	7.595^{C}	1.2^{A}	21.815
T_3	32.45	1.17^{B}	8.406^{B}	1.23	21.644
T_4	32.57	0.37^{c}	9.208^{A}	1.20	21.992
T_5	32.84	0.46^{c}	9.603^{A}	1.15^{B}	21.627

* : See Table (2) for details

Effect of butter milk powder (BMP) and sodium caseinate (SC) as a fat substitution on some properties of ice milk mixes is shown in Table (4). Titratable acidity values tended to increase and the pH values slightly decreased with adding BMP and SC in ice milk formula compared to control treatment. These changes in acidity and pH values may be due to the higher protein and ash contents related to the use of BMP and SC instead of fat as fat source. These components contribute in the natural acidity of ice milk mix. Similar trends were obtained by Shenana, et al., (2007).

Specific gravity (sp.gr.) of ice milk mixes was increased with adding BMP and SC as a substitution of milk fat (Table,4). From the same table it could be noticed that the freezing points were significantly affected by adding BMP and SC in the mixes. The mixes showed higher freezing points in treatments T_1 and T_2 than that of other treatments. The control treatment showed the lowest freezing point among all treatments. The freezing point is affected by the amount, type and molecular weight of the solutes in the mix. Partial or total replacement for milk fat with BMP and SC in ice milk recipes has significantly affected the flow time (Table,4). The data indicated that the control treatment without substitution possessed the lowest flow time compared to the treatments with BMP and SC. Values of flow time significantly increased with adding BMP and SC in the formula being highest in treatment (T_5) with 2% BMP and 2% SC. Treatment (T_1) showed the lowest flow time among treatments. The differences in flow time values between control and other treatments could be due to the differences in composition of the base formula of mixes.. Sodium caseinate contains a high amount of protein which may increase the viscosity and flow time under the processing condition of ice milk mix. The results are in accordance with **Awad and Metwally, (2000)** who found an increase in viscosity of ice cream mixes with adding total milk proteinate powder.

Table 4. Effect of sodium caseinate and butter milk powder as fat substitutes on some properties of ice milk mixes.

Treatments*	Acidity %	pH values	Specific gravity	Freezing point (°C)	Flow time (sec)
Control	0.22^{B}	6.52	1.1321^{B}	-2.51^{A}	79.84^{E}
T_1	0.26^{AB}	6.47	1.1399^{B}	-2.21^{B}	88.64^{DE}
T_2	0.29^{AB}	6.49	1.1460^{AB}	-2.19^{B}	99.91^{CD}
T_3	0.31^{A}	6.48	1.1498^{AB}	-2.24^{AB}	116.75^{BC}
T_4	0.33^{A}	6.45	1.1528^{A}	-2.36^{AB}	122.34^{AB}
T_5	0.35^{A}	6.33	1.1586^{A}	-2.31^{AB}	135.11^{A}

* see table(2)

Flow behaviour

Flow behaviour (shear stress/shear rate curve) for ice milk mix treatments is shown in Fig. (1). It could be noticed that pseudoplastic behavior was exhibited in all treatments with the existence of a yield stress. Addition of BMP and SC to the ice milk mixes resulted in an upward shifting of the flow curve (building up of structure leading to increase in the samples viscosity). Shear stress values for all treatments with BMP and SC were higher than that of control without addition. This trend was independent of shear rate. The shear stress increased in the treatments with increasing the ratio of BMP and SC added. These results are in agreement with Fayed et al., (1996), Awad and Metwally (2000) and Awad (2007).

Apparent viscosity values at a constant shear rate (12.604 sec^{-1}) are presented in Fig (2). The results revealed that addition of higher amounts of BMP and SC led to increase the apparent viscosity of ice milk mixes. From the data given in Fig. (2) it appeared that partial or total replacement of milk fat with BMP and SC had affected the apparent viscosity values that fell in the range of 0.13 to 0.28 $pas.sec^{-1}$. It could be also noticed that free fat ice milk mixes (T_4 and T_5) showed the highest viscosity 0.24 and 0.28 $pas.sec^{-1}$ respectively with almost 2 times more than that of control treatment. All treatments with BMP and SC exhibited higher viscosity than that in the control. The higher viscosity values in the treatments with BMP and SC could be due to the greater proportion of such altered proteins in these mixes. Similar results were reported by Awad and Metwally (2000) and Awad (2007).

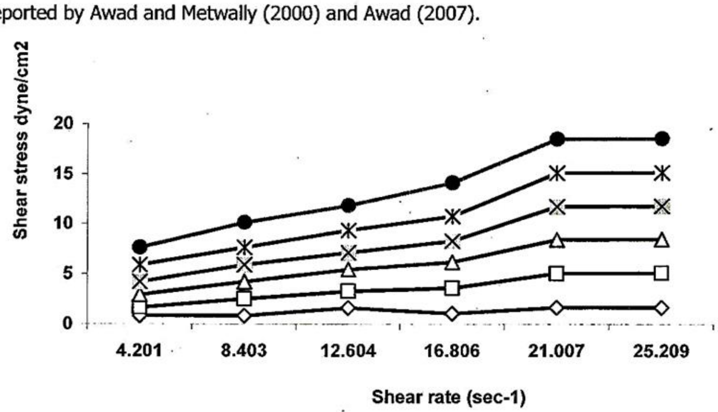

Fig. 1. Flow behaviour of ice milk mixes with sodium caseinate and butter milk powder as fat substitutes.

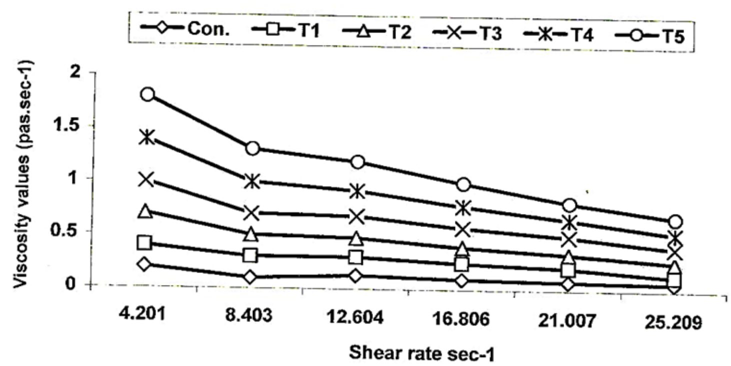

Fig. 2. Viscosity of ice milk mixes with sodium caseinate and butter milk powder as fat substitutes.

Resultant ice milk properties

Effect of partial or total replacement of milk fat with BMP and SC is shown in Table (5). Specific gravity of all resultant ice milk recipes was lower in all treatments than that in the control treatment (Table,5). Treatment 3 with BMP and SC in ratio 1.5 and 1.5% respectively in the base mix, showed the lowest specific gravity value among all treatments. The specific gravity depends on the formula components as well as the mix ability to hold the air bubbles and overrun percent in the resultant ice milk. The overrun differed significantly among the treatments and treatment (T_3) showed the highest. Control treatment exhibited lowest overrun percent. The time required for freezing the mix decreased in all treatments with BMP and SC(16-17min) compared to 19 min in control treatment. The decrease in freezing time could be due to the decrease in freezing point of the mixes. The hardness values (Table,5) indicated that treatment (T3) was the softest while control treatment was the hardest. The different hardness values could be related to the freezing point, the amount of free water in the sample, overrun percent and consistency of the treatment. Ice milk samples showed different melting resistance as a function of adding sodium caseinate (SC) and butter milk powder (BMP) to ice milk mix (Table,5). The control treatment exhibited higher melting ability, i.e. lower resistance among all treatments. Partial replacement of milk fat in ice milk samples as in treatments (T_1, T_2 and T_3) led to lower melting rate (higher melting resistance). Treatments of free milk fat (T_4 and T_5)

showed the highest melting resistance with lowest melting rate among all ice milk treatments. The differences in melting resistance could be due to the differences in the mix composition especially the protein content and freezing point of recipes (Awad and Metwally 2000).

Table 5. Effect of sodium caseinate and butter milk powder as fat substitutes on some properties of ice milk.

Treatments*	Specific gravity	Overrun %	Freezing time (min.)	Hardness (lb/m²)	Loss percentage after (min)			
					15	30	45	60
Control	0.6833 A	65.68 B	19 A	13.78 A	16.61	48.58	91.09	98.28
T_1	0.6759 AB	68.65 AB	16 B	12.57 AB	9.13	31.74	72.40	95.61
T_2	0.6682 AB	71.51 A	16 B	12.19 AB	7.9	28.48	68.47	93.38
T_3	0.6604 B	74.11 A	17 AB	11.96 B	8.4	29.97	70.46	99.56
T_4	0.6760 AB	70.53 A	18 A	12.14 AB	7.1	26.27	60.28	97.39
T_5	0.6717 AB	72.49 A	17 AB	12.06 B	6.0	23.65	54.18	95.06

* see Table (2)

sensory properties of ice milk

Sensory panel evaluation is an important indicator of potential consumer preferences. Differences in sensory quality attributes of ice milk with BMP and SC as a partial or total substitution of milk fat are presented in Table (6). Ice milk flavour was slightly affected in treatments with adding BMP and SC showing lowest flavour score in treatments T_4 and T_5. On the other hand, body and texture of resultant ice milk were improved with partial substitution of milk fat in the formula with BMP and SC (T_1, T_2, T_3). There were no differences in melting properties as well as appearance score of treatments with fat replacement (T_1 and T_2) and control. Ice milk treatments with BMP and SC as a partial substitution of milk fat were not significantly different in total organoleptic score than that of control without substitution. The panel could not be able to detect any significant differences in sensory quality attributes during the course of judging. On the other hand, treatments (T_4 and T_5) scored the least and were significantly different in all quality attributes. Resultant ice milk became more smoother and had creamy appearance with improving flavour intensity by adding BMP and SC as a partial substitution of milk. Treatments T_4 and T_5 with total fat substitution resulted in lower quality properties. In another term, presence of 1% milk fat in formula (T_1, T_2 and T_3) produce ice milk with higher acceptability were similar to that of control.

Table 6. Sensory evaluation attributes of low or free fat ice milk samples with sodium caseinate and butter milk powder as fat substitutes.

Properties		Treatments*					
		Con.	T_1	T_2	T_3	T_4	T_5
Flavour	(45)	45	44	44	43	42	40
Body&texture	(30)	25	26	26	26	25	25
Melting properties	(10)	9	9	9	8	8	7
Appearance	(15)	14	14	13	13	12	11
Total	(100)	93^{A}	93^{A}	92^{A}	90^{AB}	87^{B}	83^{C}

* see table (2)

CONCLUSION

It could be concluded that the partial substitution of milk fat with a mixture of BMP and SC produced ice milk without any significant differences and high acceptability compared to control of full fat such products can be applied in the industry particularly for whom of health concise and care of milk fat.

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انتاج مثلج لبنى منخفض وخالى الدهن باستخدام كازينات الصوديوم واللبن الخض البودرة

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٢. معهد بحوث تكنولوجيا الاغذية – مركز البحوث الزراعية – الجيزة

تم في هذا البحث دراسة استخدام اللبن الخض وكازينات الصوديوم المجففة كبديل جزئى لدهن اللبن في صناعة المثلوجات اللبنية منخفضة, خالية الدهن. حيث تم ضبط الدهن في عينة المقارنة إلى ٤% وتم استبدال ٣% من هذا الدهن بخليط من الكازينات واللبن الخض على النحو التالي:معاملة١ (٠,٥+٢,٥) ،معاملة٢ (١ + ٢) ،معاملة٣ (١,٥+١,٥) على الترتيب كماتم تصنيع معاملتين باستخدام لبن فرز خالي تماما من الدهن مع أضافة خليط الكازينات واللبن الخض البودرة على النحو التالي معاملة٤(١ + ٣) ،معاملة٥ (٢ + ٢) على الترتيب.

ولقد اختبرت المخاليط وكذلك المثلوجات الناتجة من حيث خواصها الكميائية والطبيعية والريولوجية وكذلك الخواص الحسية وأشارت النتائج أن إضافة اللبن الخض والكازينات المجففة كبديل لدهن اللبن لم يكن لها تأثير على النسبةالمئوية للجوامد الكلية في المثلوجات الناتجة في حين تأثرت معنويا قيم البروتين الكلى والرماد .وأدى استبدال دهن اللبن بمخلوط من اللبن الخض وكازينات الصوديوم المجففة إلى اختلافات في قيم الوزن النوعى لكل من المخلوط والمثلج الناتج كماوجد اختلاف معنوي في الريع الناتج. أظهرت مخاليط المثلوجات زيادة طفيفة في الحموضة وزادت قيم اللزوجة ووقت السريان زيادة معنوية وكذلك زيادة نقص الانخفاض في نقطة التجمد مع إضافة كلا من اللبن الخض وكازينات الصوديوم المجففة. اظهر التحكيم الحسى للمثلوجات الناتجة أن استبدال الدهن جزئيا بمخلوط من اللبن الخض وكازينات الصوديوم لم يؤثر معنويا على الصفات الحسية وكانت العينات بنفس درجة القبول لعينة المقارنة المحتوية على الدهن كله مع تفضيل اكبر للعينات من حيث القوام والتركيب واظهرت العينات المصنعة من اللبن الخض والكازينات قوام وتركيب أكثر نعومة وأكثر تفضيلا لدى المحكمين. أما العينات التى صنعت باستبدال كلى للدهن فكانت اقل تفضيلا ولذلك يمكن التوصية بتطبيق صناعة المثلوجات اللبنية منخفضة الدهن باستبدال الدهن جزئيا بمخلوط من اللبن الخض والكازينات المجففة كما في المعاملات معامله١ومعامله ٢.