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# USING WHEY PROTEIN ISOLATE AS A SUBSTITUTE OF MILK SOLID NOT FAT ON CHEMICAL AND PHYSICO-CHEMICAL PROPERTIES OF ICE CREAM

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## ABSTRACT

Effect of whey protein isolate (WPI) as a partial substitution of milk solids not fat (MSNF) in ice cream formula was investigated by replacing 1, 2, 3 and 4% of mix solid not fat. Mixes and resultant ice cream samples were evaluated for their chemical, physico-chemical, as well as the sensory quality attributes. There was no remarkable effect of adding WPI as partial substitution of skim milk powder (SMP) on total solids or fat percentages, while total protein, ash, and lactose content were significantly affected. Specific gravity was affected with the ratio of substitution in both mixes and resultant ice cream and therefore the weight per gallon and overrun percent was significantly changed in the samples. Also, freezing point of resultant ice cream was affected by implementing WPI in ice cream mix.

However, the ice cream became smoother and highly acceptable by replacing MSNF with WPI up to 3%. From the data obtained, it could be recommended that ice cream can be produced with high quality by substituting MSNF with WPI up to 3%.

**Keywords**: Ice cream, whey protein isolate (WPI), Skim milk powder (SMP).

## INTRODUCTION

Ice cream composes of four distinct phases: a continuous serum phase known as a matrix, and three distinct dispersed phases corresponding to fat droplets, ice crystals and air cells (Goff, 1997). Ice cream is a complex matrix of fat globules, ice crystals, air cells, protein-hydrocolloid structures, and an unfrozen water with dissolved sugars, proteins and salts.

Increase of protein content in ice cream boosts nutritional value, but it can also have a considerable effect on structural elements, particularly the formation of partially coalesced fat during freezing (Segall & Goff, 1999).Ice cream usually contains about 4% protein, initially stabilize the lipid emulsion after homogenization by forming a dense adsorbed layer on the fat globule interface, which prevents the droplets from coalescing (Dickinson, 2003). However, each milk protein are of differt adsorption properties, and functions at the interface, how much they reduce the interfacial tension, how densely packed they can become, and their typical surface coverage. (Zhang and Goff, 2005; Dickinson, 2003; Goff, *et al.*, 1989).

Whey protein is usdually used in ice cream making to develop a better quality due to its good water binding property. However, whey protein isolate (WPI) delays the development of coarseness, and increases ice cream mix viscosity. The presence of WPI, on the other hand, in ice cream may enhance fine dispersion of air cells and lower the ice crystal size in ice cream owing to its foaming property.

Concentrated whey protein also lowers the surface tension, stabilizes the fat emulsion, controls fat destabilization and enhances partial coalescence due to the emulsifying properties of protein (Ruger *et al.*, 2000, Patel *et al.* 2006), However, the presence of WPI in ice cream could improve its physical and sensory properties of the resultant product by resisting changes in ice cream during storage, increasing its nutritional value, and increasing its balatibility and acceptance.

The objective of this study was to investigate the physical, rheological and sensory characteristics of resultant ice cream with whey protein isolate (WPI).

## MATERIALS AND METHODS

Fresh buffalo's skim milk (90.9 % moisture, 0.1% fat, 3.4% protein, 4.9% lactose and 0.7% ash) and fresh isolated cream (29.4% moisture, 67% fat, 1.3% protein, 1.7% lactose and 0.6% ash) were obtained from the herd of Faculty of Agriculture, Cairo University and used as an ingredient for preparing the ice cream mixes. Low heat skim milk powder (3.8% moisture, 0.8% fat, 33.4% protein, 54.1% lactose and 7.9% ash) was obtained from Abou El-Hool-Import/Export Co., Cairo, Egypt. Whey protein isolate powder (4.7% moisture, 0.1% fat, 92.92% protein, 0.18% lactose and 2.1% ash) was supplied by Davisco Foods International, Inc, USA. Commercial grade sugar cane was obtained from the local market, Sodium carboxymethyl cellulose (CMC) as a stabilizer was obtained from Mifad Company; Giza, Egypt Vanilla was obtained from the local market and used to flavor final ice cream.

Ice cream mix contained 8% fat, 12% milk solid not fat, 15% sucrose, 0.25% stabilizer. Skimmed milk powder was substituted with WPI at 1.0, 2.0, 3.0 and 4.0% of dried milk solids not fat in the base mix (Table 1).

**Table (1): Formulation of different ice cream mixes with WPI as a substitute of milk solid not fat (g/ kg mix).**

| Ingredients | Control | Level of substitution (g/kg mix) | | | |
|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ |
| Sugar | 150 | 150 | 150 | 150 | 150 |
| Stabilizer | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| Fresh skim milk | 670.38 | 670.38 | 670.38 | 670.38 | 670.38 |
| Cream | 117.69 | 117.69 | 117.69 | 117.69 | 117.69 |
| Dried skim milk | 59.43 | 48.95 | 38.47 | 27.98 | 17.50 |
| WPI | 0.00 | 10.50 | 21.07 | 31.61 | 42.15 |
| Total | 1000 | 1000.02 | 1000.11 | 1000.17 | 1000.22 |

**$T_1$, $T_2$ $T_3$, $T_4$ :Corresponding to 1, 2, 3 and 4% WPI substitution of milk solid not fat.**

Moisture content, total solids, total protein and ash were determined according to AOAC (2006). Titratable acidity of mixes was determined according to Arbuckle (1986) by titration with NaOH 0.1 N. Lactose content was determined according to Lawrance (1968). Fat content was determined according to Divide (1977). Values of pH were measured using a digital laboratory pH meter (HI 93 1400, Hanna instruments). Overrun of ice cream samples was calculated by using the method given by Arbuckle (1986).

$$\textbf{Overrun(\%)} = \frac{\textbf{weight of mix- weight of the same volume of ice cream}}{\textbf{weight of the same volume of ice cream}} \times 100$$

The specific gravity of the ice cream mix was measured by using of a bottle pyconometer as described by Winton (1958) at 20°C, while in resultant ice cream a cool cup (with known weight and volume) was filled with ice cream mix, and weighted. Finally, specific gravity was obtained by dividing the weight of the frozen ice cream by the cup volume. The weight per gallon (lb) of ice cream mixes and the final frozen products were calculated according to Kessler (1981) by multiplying the specific gravity by the factor of 8.34. Freezing point of ice cream mix was measured as described in FAO report (1977), using digital thermometer (Digitemp D 200/20), Germany. 75 ml of ice cream mix was transferred to test tube (100-120 ml) and placed in the prepared freezing solution (100g NaCl/L water, freezing point -6.7ºC). About 2Kg small ice flakes was added to the brine solution. Thermometer (differences of 1/10ºC) was placed in the mix. The change on the thermometer at first a steady decrease in the temperature, thus a sudden rise and the temperature will be constant for same time, this constant temperature is the freezing point of the mix. Meltdown of frozen ice cream for each sample was determined according to Arndt and Wehling (1989). Ice cream samples (~75 gm), were placed into wire mesh (6 holes/cm) over a glass funnel fitted on conical flask at ambient temperature (28±1ºC). The time at which the first drop of ice cream dripped was recorded. Then, melted ice cream was weighed every five min. resultant ice cream were judged by 10 staff members of the Food Technology and Research Center. Dairy Department. The evaluation comprised of flavor (45 points), body & texture (35 points) melting properties (10) and colour (10) as suggested by Arbuckle (1986).

Data were analysed statistically using the MSTAT-C (ver 2.10, MSU, USA.) package on a personal computer. All experiments were carried out in triplicates. Differences were considered significant at P< 0.05.

# RESULTS AND DISCUSSION

Chemical composition of ice cream mixes with whey protein isolate as a substitution of SMP in base formula is shown in Table (2)

**Table (2).Chemical composition (%) of ice cream mixes with different ratios of WPI as apartial substitution of milk solid not fat**

| Treatments | Total solids | Fat | Total protein | Ash | Lactose content |
|---|---|---|---|---|---|
| Control | 36.96 | 8.23 | 4.37[e] | 1.073[a] | 7.98[a] |
| T1 | 35.18 | 8.20 | 4.82[d] | 0.949[b] | 6.20[b] |
| T2 | 35.21 | 8.21 | 5.41[c] | 0.889[c] | 5.70[c] |
| T3 | 35.17 | 8.22 | 5.91[b] | 0.840c[d] | 5.20[d] |
| T4 | 35.11 | 8.22 | 6.36[a] | 0.780[d] | 4.75[e] |

**Means designated with the same letter in the same column are not significantly different at P ≤ 0.05 level of probability. $T_1$, $T_2$, $T_3$, $T_4$ : Corresponding 1, 2, 3 and 4% WPI**

Fat was adjusted in all mixes to almost 8% for recipe formula during the procedures.

The average value of protein contents in different ice cream treatments was stated in Table (2). A proportional replacement of MSNF with WPI resulted in a significant increase (P<0.001) of protein contents of ice cream mixes. Obtained data agreed with the findings of Awad and Metwally (2000), Suneeta-Pinto *et al.*, (2007) and Shenana *et al.*, (2007).

The usage of WPI as a MSNF replacer leaded to a significant difference (P<0.001) in ash content as shown in Table (2). Ash contents decreased in ice cream mixes with the addition of WPI ratio. This decrease could be due to the differences in ash contents of WPI and SMP. The obtained results are in a harmony with the findings of Awad and Metwally (2000) and Patel *et al.,* (2006). Lactose values decreased by increasing the substitution level of WPI in mixes due to a less content of lactose in WPI than in SMP. However, WPI with low lactose content can be safely used at higher levels without concerning of sandiness development defect in ice cream (Parsons *et al.,* 1985).

Titratable acidity of ice cream mix increased gradually as shown in (Table 3). However, acidity values increased proportionally with increasing WPI ratio. The differences in acidity values among treatments are due to the differences in chemical composition and mainly the protein content. Obtained results were in agreement with those of Tirumalesha, and Jayaprakasha (1998), Patel *et al.,* (2006), Shenana *et al.,* (2007).

The pH values of ice cream mixes with WPI in base formula are presented in Table (3). A reverse proportion of pH and WPI% was obtained for ice cream samples. The pH values of ice cream mixes decreased significantly by substituting MSNF by WPI in the base formula ($P<0.001$). The differences in pH values of ice cream mixes are related to the original composition and acidity. The obtained results were in harmony with those obtained of Patel *et al.,* (2006) and Pandiyan *et al.,* (2010).

**Table 3. Physicochemical and rheological properties of ice cream mixes with different ratios of WPI.**

| Treat. | Acidity | pH | SG (-) | W/gal (lb) | FP (ºC) |
|---|---|---|---|---|---|
| Control | 0.21$^{a}$ | 6.72$^{a}$ | 1.1085$^{a}$ | 9.2448 | -2.47$^{a}$ |
| $T_1$ | 0.21$^{a}$ | 6.70$^{b}$ | 1.0827$^{b}$ | 9.0297 | -2.45$^{ab}$ |
| $T_2$ | 0.22$^{a}$ | 6.56$^{c}$ | 1.0741$^{b}$ | 8.9579 | -2.33$^{bc}$ |
| $T_3$ | 0.23$^{a}$ | 6.49$^{d}$ | 1.0653$^{bc}$ | 8.8846 | -2.29$^{c}$ |
| $T_4$ | 0.23$^{a}$ | 6.42$^{e}$ | 1.0535$^{c}$ | 8.7861 | -2.11$^{d}$ |

The effect of replacing skim milk powder with WPI at different ratios on specific gravity (SG) of ice cream mixes was shown in Table (3). The specific gravity values of ice cream mixes decreased by substituting skim milk powder with WPI in the recipe. Obtained results are harmony with Awad and Metwally (2000) and Awad (2007). However, Weight/gallon of mix follow the same manner of SG.

The freezing point of ice cream mixes was significantly affected by adding WPI to ice cream recipes ($P<0.001$). The mixes showed higher freezing points with substituting skim milk powder by WPI. The high freezing point in treatments with WPI could be due to its lower lactose and other true solutions solutes with high protein contents Muse and Hartel (2004). The results obtained are in line with those of Patel *et al.,* (2006), Awad (2007), Shenana, *et al.,* (2007).

The effect of WPI as a substitution of MSNF on some of physicochemical properties of resultant ice cream is presented in Table (4).

Specific gravity (sp.gr.) is one of the important physical properties of ice cream. It gives some information about the quality of the resultant ice cream such as body and texture, incorporated air and melting quality of ice cream. These data indicated that the sp.gr. of resultant ice cream decreased with incorporating WPI in the formula.

**Table 4. Effect of WPI% on specific gravity and overrun ice cream properties**

| Treatments | Specific gravity (-) | Weight per gallon (lb) | Overrun % |
|---|---|---|---|
| Control | 0.9133$^{a}$ | 7.622 | 47.64$^{e}$ |
| $T_1$ | 0.8992$^{a}$ | 7.499 | 56.14$^{d}$ |
| $T_2$ | 0.762$^{b}$ | 6.358 | 64.87$^{c}$ |
| $T_3$ | 0.6755$^{c}$ | 5.634 | 68.55$^{b}$ |
| $T_4$ | 0.6112$^{d}$ | 5.098 | 72.45$^{a}$ |

Specific gravity depends on the formula components as well as the ability of the mix to retain air cells in ice cream matrix. Ice cream treatment with 4% WPI in the formula T4 showed the lowest SG as the total protein was the highest in comparison to the control mix, which meant more air incorporation in the body of ice cream with more protein membranes constructed. The results obtained are in line with those of Awad and Metwally (2000), Shenana *et al.,* (2007), Badawi, *et al.,* (2013). Values of weight per gallon Table (4) follow the same trend as SG.

Substituting skim milk powder as a source of milk solids in the base formula of ice cream with WPI led to higher overrun. The high overrun percentages in treatments containing WPI could be related to the high foaming ability of ice cream mixes. However, our findings agreed with those reported by Tomer and Kumar (2013), Pandiyan *et al.,* (2012), Alfaifi, and Stathopoulos, (2010) and Tirumalesh and Jayaprakasha (1998) who pointed out that there was a significant improvement in both whipping rate and overrun by increasing the replacement of skim milk solids with the admixture of butter milk powder and WPI. Alvarez *et al.,* (2005) mentioned that the presence of WPC may facilitate the initial stabilization of newly formed air bubbles in the freezer better than UF retentates of NDM.

Sensory evaluation is an important indicator of potential consumer preferences. Among all treatments (Table 5) T3 with 3% WPI substitution of milk MSNF was the best to panelists and scored the highest. However, Prindiville *et al.,* (2000) reported that *Simplesse* was more similar to milk fat than was Dairy

Lo in its effect on sensory and textural stability of low-fat ice cream. Also, Yilsay, *et al.*, (2006) reported that, the addition of *Simplesse* to fat free ice cream mix improved the overall sensory characteristics with the rating of ice creams resembling that of the regular fat ice cream

**Table 5. Sensory quality attributes of ice cream samples with WPI as a partial substitution of milk solid not fat.**

| Properties | | Treatments | | | | |
|---|---|---|---|---|---|---|
| | | Control | $T_1$ | $T_2$ | $T_3$ | $T_4$ |
| Flavour | (45) | $42.11^{bc}$ | $42.59^{b}$ | $43.84^{a}$ | $44.20^{a}$ | $41.51^{c}$ |
| Body& texture | (35) | $33.50^{a}$ | $33.52^{a}$ | $33.56^{a}$ | $34.11^{a}$ | $31.99^{b}$ |
| Melting properties | (10) | $8.16^{c}$ | $8.30^{bc}$ | $8.44^{ab}$ | $8.50^{a}$ | $7.95^{d}$ |
| Appearance | (10) | $8.2^{c}$ | $8.4^{bc}$ | $8.5^{b}$ | $8.9^{a}$ | $8.5^{b}$ |
| Total | (100) | 90.97 | 92.81 | 94.34 | 95.71 | 89.95 |

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## تأثير استخدام معزول بروتينات الشرش كبديل لجوامد اللبن اللادهنية على بعض الخواص الكميائية والطبيعية للمثلوجات القشدية

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تم في هذا البحث دراسة استخدام معزول بروتينات الشرش كبديل جزئى لجوامد اللبن اللادهنية في صناعة المثلوجات القشدية وذلك بإضافتها بنسب ١، ٢، ٣ ، ٤% من جوامد اللبن اللادهنية. واختبرت المخاليط والمثلوجات الناتجة من حيث خواصها الكميائية والطبيعية وكذلك الخواص الحسية وأشارت النتائج إلى أن إضافة معزول بروتينات الشرش بدلا من جوامد اللبن اللادهنية لم يكن لها تأثير على نسبة الجوامد الكلية أو الدهن في المثلوجات الناتجة في حين تأثرت معنويا قيم البروتين الكلى والرماد وسكر اللاكتوز. وأدت زيادة نسب الاستبدال إلى اختلافات في قيم الكثافة النوعية والوزن بالجالون لكل من المخاليط والمثلوجات الناتجة وبناء علية كان هناك اختلاف معنوي في الريع الناتج. أظهرت مخاليط المثلوجات زيادة طفيفة فى حموضة المخاليط مع ارتفاع في نقطة التجمد كما أدى الاستبدال بمعدل ٣% إلى انتاج مثلجات ذات نسبة قبول مرتفعة