

Effect of egg yolk substitution by sweet whey protein concentrate on some Gelato ice cream physical properties during storage

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Summary

Changes in physical properties of Gelato vanilla ice cream during four weeks of storage using different levels of sweet whey protein concentrate (WPC) substitutions of two levels of egg yolk (4.5% and 9%) were studied. For each level, one control sample with no WPC addition and four levels of WPC substitutions (three replications of each treatment) were made. Determinations of texture, stability and colour were made. Results showed a significant ($P < 0.05$) difference in hardness (N) among 4.5% and 9% egg yolk samples during four weeks of storage. However, increasing WPC level led to a significant ($P < 0.05$) decrease in the melting rate between 9% egg yolk samples with increased storage time. On the other hand, there was no significant ($P > 0.05$) effect on melting rate among 4.5% egg yolk samples with increasing WPC levels. Addition of WPC did not affect whiteness (L) values within 4.5% egg yolk samples, whereas L values were significantly ($P < 0.05$) affected among 9% egg yolk samples, after one week storage. The results indicated that it is possible to substitute egg yolk with WPC in Gelato, particularly on the 4.5% egg yolk samples, allowing for a cheaper product, without any detrimental change in physical quality parameters.

Keywords:

Gelato; whey protein concentrate; egg yolk; texture; stability; colour

Gelato ice cream is a frozen Italian dessert that contains a minimal amount of whipped air. It is prepared using a low butterfat cream containing less than 10% milk, while the typical premium ice cream contains between 16% and 18% fat [1, 2]. Whey protein concentrate (WPC) is a milk product that has gained popularity as a food ingredient in the past 40 years. Its emerging use stems from nutritional and affordable qualities [3]. Commercially prepared WPC are available at a range of proteins contents (34–80% protein content on a dry weight basis). Furthermore, basic mechanisms for preparation of these general products are based upon ultrafiltration and diafiltration [4]. A number of WPC functional properties such as hydration, solubility, viscosity, gelation, emulsifying, foaming and flavour binding are discussed in length according to their function in the ice cream by numerous researchers [3–8]. In the context of Gelato, the most important properties of WPC are its emulsifying ability, as well as its foaming aptitude and formation; both those properties are im-

proved during the final processing step known as ultrafiltration [6, 8].

The preparation of ice cream incorporates a variety of egg yolks in various forms such as pasteurized fresh egg yolk or frozen sugared pasteurized egg yolk, whereas the usage of egg yolks solids is around 0.5–3% [9–11]. Gelato ice creams contain high levels of egg yolk that produce an often favourable egg flavour that is highly demanded in some markets [9]. Egg yolks play numerous roles in the formulation of foods, and there are no equitable replacements for them [10]. The composition of egg yolks promotes coagulation upon heating, they also act as emulsifiers in oil and water formulations and they make rich foams when strongly beaten [11]. Egg yolks, however, can be a costly ingredient, while WPC is much more economical (currently in Australia WPC is almost 20% cheaper than dried egg yolk) and is widely available. The aims of this study were to explore and evaluate the use of whey protein concentrate as a substitute of egg yolk in Gelato ice cream.

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MATERIALS AND METHODS

Materials

Spray-dried egg yolk powder (32.9 g/100 g protein, 5.5% maximum moisture) was obtained from Pace Farms Egg Production (Warabrook, New South Wales, Australia) and stored in a dry place at $(17 \pm 1) ^\circ\text{C}$. A commercial sweet whey protein concentrate (100% WPC80) was supplied by Top Nutrition Company (Newcastle, New South Wales, Australia) and stored at $(17 \pm 1) ^\circ\text{C}$. Sucrose, vanilla extract (natural), skim milk powder (0.1% fat), commercial whole full cream milk (3.4% fat) and thickened cream (35% fat) were purchased from local supermarket. Milk and cream were stored at $(4 \pm 1) ^\circ\text{C}$. The amounts of dried egg yolk and WPC80 used in the Gelato formulations are presented in Tab. 1.

Methods

Texture

Texture analysis of Gelato samples was conducted using a microprocessor-controlled texture analysis system in conjunction with data collection and analysis software (TMS-Pro, S. I. Instruments, Hilton, South Australia, Australia). Texture characteristics were determined according to the method of LIM et al. [12] with slight modifications [13]. The conditions for analysis in this study were as follows: a 2 mm diameter probe penetrated the ice cream to a depth of 10 mm. The analysis used a 250 N load cell; while the probe speeds during and after penetration were $25 \text{ mm}\cdot\text{min}^{-1}$ and $400 \text{ mm}\cdot\text{min}^{-1}$, respectively. The maximum force was recorded.

Stability (melting rate)

Melting rate characteristics were measured using previously described methods [14, 15]. The dimensions of the sample varied slightly from one Gelato ice cream to another (4.5 cm to 5 cm \times 4 cm to 4.5 cm \times 3 cm to 3.5 cm) due to the differences in physical characteristics (e.g. overrun). The sample was placed (at room temperature, $17 ^\circ\text{C} \pm 1 ^\circ\text{C}$) on a wire screen (56 holes per 1 cm^2) on top of a funnel that was attached to a 100 ml graduated cylinder underneath. The volume of the

melted ice cream was recorded after 40 min and one measurement was taken per sample.

Colour

A Chroma Meter (model CR-131, Minolta Camera, Osaka, Japan) was used to measure Gelato ice cream colour whiteness (L) and yellowness (b). After melting, the sample ($10 ^\circ\text{C} \pm 1 ^\circ\text{C}$) was collected and its L and b values were measured at room temperature ($17 ^\circ\text{C} \pm 1 ^\circ\text{C}$) using the Chroma Meter. Three measurements were taken per single sample and the average was calculated.

Statistical analysis

Analysis of Variance (ANOVA) using Excel software (Microsoft, Redmond, Washington, USA) was used to evaluate the effect of egg yolk substitution by WPC80, on texture, stability and colour properties of Gelato vanilla ice cream during the storage period. Significant differences were determined at $P < 0.05$.

RESULTS AND DISCUSSION

Texture

The findings from this study indicate a significant ($P < 0.05$) effect on hardness (N) among 4.5% and 9% egg yolk samples during four weeks of storage. The increase in hardness during weeks three and four of storage with increasing levels of WPC80 by 4.5% egg yolk is shown in Fig. 1. Moreover, extending the storage time resulted in decreased hardness in the 9% egg yolk samples. The only exception to this was with a one-week storage period. Fig. 1 also highlights that the formulation closest in behaviour to the control, during the storage period studied, was the one containing 50% WPC80. Several factors impact the hardness of Gelato ice cream such as the overrun, ice phase volume and fat destabilization levels. For the purpose of this study, a control sample with 4.5% egg yolk was less hard and had greater overrun than the 9% egg yolk control sample. The contrast between overrun and hardness was notable by several researchers [16–18]. WILBEY et al. [19] discovered a direct relationship between the hardness

Tab. 1. Amounts of dried egg yolk and WPC80 added per 100 g of base formulation of Gelato.

Samples	4.5% egg yolk					9% egg yolk				
	Control	20%	50%	80%	100%	Control	20%	50%	80%	100%
Dried egg yolk [g]	4.50	3.60	2.25	0.90	-	9.00	7.20	4.50	1.80	-
WPC80 [g]	-	0.90	2.25	3.60	4.50	-	1.80	4.50	7.20	9.00

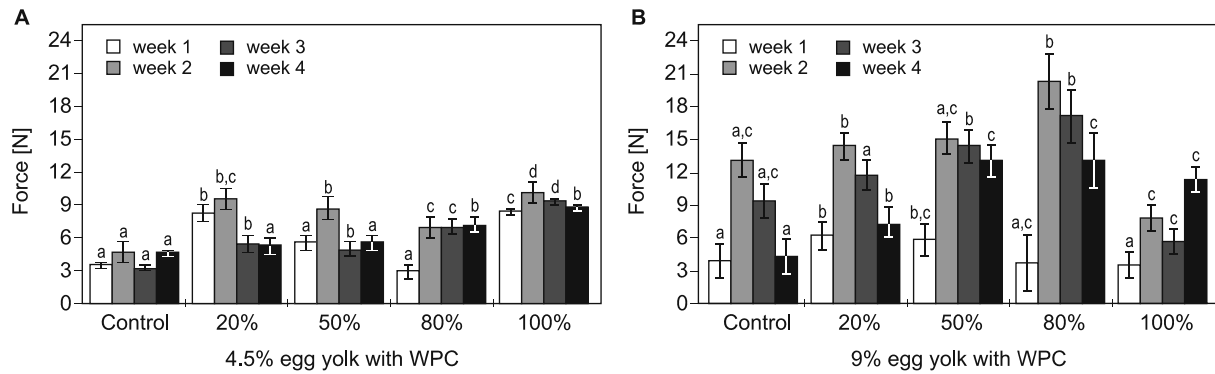


Fig. 1. Comparison of hardness (N) values in Gelato ice creams, stored for four weeks, with different levels of WPC substitutions using (A) 4.5% and (B) 9% egg yolk. Values are the means of three replicates. Same colour columns with different superscripts differ significantly ($P < 0.05$).

of ice cream and the level of ice phase volume. The fat network was also found to impact hardness. However, THARP et al. [20] determined that as the amount of destabilized fat increased, the hardness of the ice cream was greater. Another factor that impacts the texture of Gelato ice cream is viscosity. Increasing viscosity levels resulted in a Gelato with firmer texture. Viscosity increases are the overall effect from a large quantity of fat [21, 22]. However, at the protein concentration level that is required to form a three-dimensional network of aggregated protein molecules, a gel is generated. This network holds water by means of capillary forces and, therefore, its firmness increases [21].

Stability (melting rate)

During four weeks of storage, the melting rate qualities of Gelato ice cream were observed. Increasing WPC80 levels resulted in a significant

effect ($P < 0.05$) in the melting rate among 9% egg yolk samples during increased storage time. However, there was no significant ($P > 0.05$) impact on melting rates among 4.5% egg yolk samples with increasing WPC80 levels. The only exception was among the samples after four weeks of storage as shown in Fig. 2. The control Gelato ice cream containing 9% egg yolk melted much more rapidly than other samples. On the other hand, the control samples containing 4.5% egg yolk melted at a similar speed as other Gelato ice cream samples among the same level. Many factors impact the melting rate of Gelato ice cream, such as incorporated air, the character of the ice crystals, and the network of fat globule formations during the processing and freezing processes [16, 23, 24]. Moreover, GOFF et al. [25] discovered that whey proteins reached a better level of emulsion than the caseins in the absence of emulsifiers, which was egg yolk in our

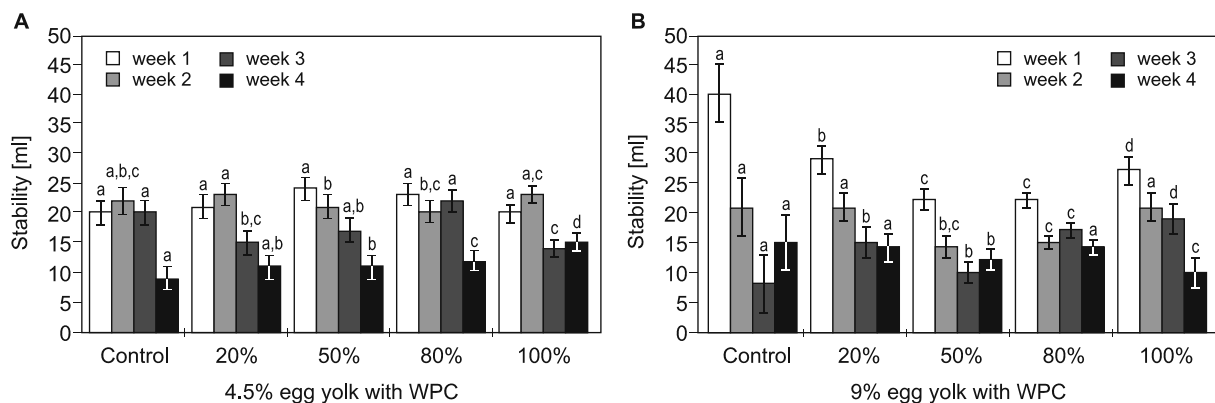


Fig. 2. Effect of WPC substitution on the stability (ml) of Gelato ice creams, stored for four weeks, with different levels of WPC substitutions using (A) 4.5% and (B) 9% egg yolk. Values are the means of three replicates. Same colour columns with different superscripts differ significantly ($P < 0.05$).

Tab. 2. Mean *L* and *b* values of Gelato ice cream with different concentrations of WPC during four weeks of storage.

WPC [%]	Week 1		Week 2		Week 3		Week 4	
	<i>L</i>	<i>b</i>	<i>L</i>	<i>b</i>	<i>L</i>	<i>b</i>	<i>L</i>	<i>b</i>
4.5% egg yolk								
0% (control)	43.32 ^a	11.97 ^a	47.51 ^a	9.89 ^a	50.98 ^a	9.77 ^a	54.13 ^a	10.37 ^{a,c}
20%	47.04 ^a	12.83 ^a	44.79 ^a	11.72 ^b	52.53 ^a	12.16 ^b	56.40 ^a	8.86 ^a
50%	45.58 ^a	11.85 ^a	47.91 ^a	11.99 ^b	49.04 ^a	11.96 ^b	54.65 ^a	12.71 ^b
80%	44.50 ^a	10.12 ^b	48.77 ^a	11.01 ^{a,b}	51.33 ^a	11.15 ^{a,b}	49.42 ^a	11.05 ^c
100%	46.51 ^a	9.71 ^b	47.88 ^a	10.58 ^{a,b}	49.51 ^a	11.36 ^{a,b}	52.67 ^a	9.86 ^{a,c}
9% egg yolk								
0% (control)	51.70 ^a	10.96 ^a	51.38 ^a	10.29 ^{a,b}	54.05 ^a	11.91 ^{a,b}	50.95 ^a	16.77 ^a
20%	49.20 ^a	14.41 ^b	52.34 ^a	11.09 ^{a,b}	55.88 ^a	12.14 ^{a,b}	54.93 ^b	16.65 ^a
50%	47.93 ^a	11.60 ^a	48.95 ^{a,b}	12.99 ^a	54.05 ^a	14.05 ^a	53.88 ^{a,b}	14.70 ^b
80%	46.60 ^a	10.67 ^a	45.23 ^b	10.46 ^{a,b}	53.81 ^a	11.58 ^b	50.03 ^{a,c}	12.03 ^c
100%	48.21 ^a	10.33 ^a	46.27 ^b	9.79 ^b	47.92 ^b	10.26 ^b	48.57 ^c	10.62 ^d

Values represent the mean of 3 replicate trials. *L* – measure of whiteness, *b* – measure of yellowness. a, b, c, d – means with different superscripts in the same column differ significantly ($P < 0.05$).

study. Additionally, fat is highly contributing to ice cream's structure in the freezing process where it forms a partially coalesced, three-dimensional network of homogenized globules. Coupled with ice crystals and air bubbles, the fat globules contribute to ice cream's stiff and arid qualities [20, 26]. Alongside milk, fat decreases heat transfer rates in Gelato ice cream samples. As a result, Gelato ice creams containing more fat (9% egg yolk) are expected to melt at a slower rate than those containing less fat (4.5% egg yolk). This also contributes to melt resistance and to smoother texture in the frozen ice cream, which was proven by several researchers [20, 26, 27].

Colour

The mean *L* (whiteness) and *b* (yellowness) values are displayed in Tab. 2. There were slight differences in colour between the 4.5% and 9% egg yolk observed and recorded. Addition of WPC80 (yellowish powder) did not affect ($P > 0.05$) *L* values within 4.5% egg yolk samples. On the other hand, *L* values were significantly ($P < 0.05$) affected among 9% egg yolk samples, with the exception of those stored for one week. Additionally, a significant ($P < 0.05$) difference on *b* values among 4.5% and 9% egg yolk samples was recorded, with the exception of week two for both egg yolk levels. After four weeks of storage, the differences in colour were markedly evident. Generally, Gelato ice cream with added WPC80 in 9% egg yolk samples had slightly higher *L* and

b values than 4.5% egg yolk samples. This may be due to the innate yellow colour that stems from egg yolk powder. As the fat content of Gelato ice cream samples increased, the amount of yellowness *b* also increased. According to MARSHALL et al. [1], enough yellow colour is usually added to vanilla ice cream to enhance its popular golden colour, it is therefore possible by common commercial practices to counteract this undesirable effect of WPC80 substitution. Furthermore, RONALD et al. [24] and PHILLIPS et al. [28] demonstrated that the colour of ice cream increased in *L* and *b* as the fat content increased.

CONCLUSION

Gelato ice cream with 4.5% and 9% egg yolk substitutions was successfully manufactured by adding WPC80 at different levels. In general, hardness of the samples was lower for 4.5% egg yolk samples compared with 9% egg yolk. Increasing WPC80 levels in both 4.5% and 9% egg yolk samples generally led to an increase in hardness when compared with the control samples. The most desired hardness (as defined by the relevant control) was the sample with 50% WPC substitution for the 4.5% egg yolk containing Gelato. Additionally, data showed that increasing WPC80 levels and storage time led to increased Gelato ice cream samples stability when using 9% egg yolk. This was probably due to the higher fat content,

and the foaming ability and stability of whey protein concentrate. However, adding WPC80 significantly affected the 9% egg yolk samples *L* values (whiteness) while no effect in 4.5% egg yolk samples was recorded then. If the colour of the control samples is taken as optimal, then the change in colour of the Gelato with 9% egg yolk samples was undesirable, but this can be counteracted by applying common commercial practices such as colour addition. In addition, a significant difference on *b* values (yellowness) among 4.5% and 9% egg yolk samples was observed in this study. The use of WPC80 substitution on the 4.5% egg yolk Gelato samples appears to allow for the production of a cheaper alternative to Gelato without a compromise to functional properties of the product such as texture and stability.

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REFERENCES

- Schelling, S.: Australian dairy: The comprehensive reference to the dairy industry. Australia: Morescope Publishing, 1996 pp. 103–124.
- Ferrari, L.: The art of Gelato, Sorbetto and Semifreddo. In: Word Pastry Forum [online]. Phoenix, USA: Word pastry forum, 2005 [cit. 15 March 2008]. <<http://www.konditorforum.dk/fundanemt/files/2005%20Luciano%20Ferrari.pdf>>
- Tunick, M.: Whey protein production and utilization: A brief history. In: Onwulata, C. – Huth, P. (Ed.): Whey processing, functionality and health benefits. Ames, Iowa: Wiley-Blackwell, 2008, pp. 2–15.
- Kilara, A.: Whey protein functionality. In: Hettiarachchy, N. – Ziegler, G. (Ed.): Protein functionality in food systems. New York: Marcel Dekker, 1994, pp. 325–356.
- Morr, C.: Functionality of heated milk proteins in dairy and related foods. *Journal of Dairy Science*, 68, 1985, pp. 2773–2781.
- Lorient, D. – Cayot, P.: Structure-function relationship of whey proteins. In: Damodaran, S. – Paraf, A. (Ed.): Food proteins and their applications. New York: Marcel Dekker, 1997, pp. 225–256.
- Hui, Y.: Handbook of food science, technology and engineering. 3rd ed. Boca Raton: CRC Press, 2006. 712 pp. ISBN 1-57444-552-9.
- Farrag, A.: Emulsifying and foaming properties of whey proteins concentrates in the presence of carbohydrates. *International Journal of Dairy Science*, 3, 2008, pp. 20–28.
- Clarke, C.: The science of ice cream. USA: Royal Society of Chemistry, 2004. 187 pp. ISBN 0-85404-629-1.
- Hatta, H. – Kapoor, M. – Juneja, L.: Bioactive components in egg yolk. In: Mine, Y. (Ed.): Egg bio-science and biotechnology. New York: John Wiley & Sons, 2008, pp. 185–238.
- Stadelman, W. – Schmieder, H.: Functional uses of eggs. An overview. In: Watson, R. (Ed.): Eggs and health promotion. Ames, Iowa: Wiley-Blackwell, 2002, pp. 3–7.
- Lim, S. – Swanson, B. – Ross, C. – Clark, S.: High hydrostatic pressure modification of whey protein concentrate for improved functional properties. *Journal of Dairy Science*, 91, 2008, pp. 1308–1316.
- Szczesniak, A.: Texture is a sensory property. *Journal of Food Quality and Preference*, 13, 2002, pp. 215–225.
- Specter, S. – Setser, C.: Sensory and physical properties of a reduced-calorie frozen dessert system made with milk fat and sucrose substitutes. *Journal of Dairy Science*, 77, 1994, pp. 708–717.
- Ohmes, R. – Marshall, R. – Heymann, H.: Sensory and physical properties of ice cream containing milk fat or fat replacers. *Journal of Dairy Science*, 81, 1998, pp. 1222–1228.
- Muse, M. – Hartel, R.: Ice cream structural elements that affect melting rate and hardness. *Journal of Dairy Science*, 87, 2004, pp. 1–10.
- Tanaka, M. – Pearson, A. – DeMan, J.: Measurement of ice cream with a constant speed penetrometer. *Food Science Technology*, 5, 1972, pp. 105–110.
- Sofjan, R. – Hartel, R.: Effects of overrun on structural and physical characteristics of ice cream. *International Dairy Journal*, 14, 2004, pp. 255–262.
- Wilbey, A. – Cooke, T. – Dimos, G.: The effects of solute concentration, overrun and storage on the hardness of ice cream. In: Buchheim, W. (Ed.): Ice Cream: Proceedings of the International Symposium held in Athens, Greece, 18–19 September 1997. Brussels: International Dairy Federation, 1998, pp. 186–187.
- Tharp, B. – Forrest, B. – Swan, C. – Dunning, L. – Hilmoe, M.: Basic factors affecting ice cream meltdown. In: Buchheim, W. (Ed.): Ice Cream: Proceedings of the International Symposium held in Athens, Greece, 18–19 September 1997. Brussels: International Dairy Federation, 1998, pp. 54–64.
- Damodaran, S.: Inhibition of ice crystal growth in ice cream mix by gelatin hydrolysate. *Journal of Agriculture and Food Chemistry*, 55, 2007, pp. 10918–10923.
- Leighton, A. – Leviton, A. – Williams, O.: The apparent viscosity of ice cream: I. The sagging beam method of measurement. II. Factors to be controlled. III. The effects of milk fat, gelatin and homogenization temperature. *Journal of Dairy Science*, 17, 1934, pp. 639.
- Prindiville, E. – Marshall, R. – Heymann, H.: Effect of milk fat on the sensory properties of chocolate ice cream. *Journal of Dairy Science*, 82, 1999, pp. 1425–1432.
- Ronald, A. – Phillips, L. – Boor, K.: Effects of fat

- content on the sensory properties, melting, color and hardness of ice cream. *Journal of Dairy Science*, 82, 1999, pp. 32–38.
25. Goff, H. – Kinsella, J. – Jordan, W.: Influence of various milk protein isolates on ice cream emulsion stability. *Journal of Dairy Science*, 72, 1989, pp. 385–397.
26. Bolliger, S. – Goff, H. – Thrapp, B.: Correlation between colloidal properties of ice cream mix and ice cream. *International Dairy Journal*, 10, 2000, pp. 303–309.
27. Campbell, I. – Pelan, B.: The influence of emulsion stability on the properties of ice cream. In: Buchheim, W. (Ed.): *Ice Cream : Proceedings of the International Symposium held in Athens, Greece, 18–19 September 1997*. Brussels : International Dairy Federation, 1998, pp. 25–36.
28. Phillips, L. – McGiff, M. – Barbano, D. – Lawless, H.: The influence of fat on the sensory properties, viscosity and color of lowfat milk. *Journal of Dairy Science*, 78, 1995, pp. 1258–1266.

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