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

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Summary

Changes in physical properties of Gelato vanilla ice cream over 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 during four weeks of storage.

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, allowing for a cheaper product, without any detrimental effect of physical quality parameters.

Keywords:
Gelato, WPC, egg yolk, texture, stability, colour
Introduction

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 ice cream has between 16% to 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 with either: 34%, 50%, 60%, and 75% protein content on a dry 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 on 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 improved 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 pasteurised fresh egg yolk or frozen sugared pasteurised 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 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.
Materials and Methods

Materials

Spray dried egg yolk powder (32.9 g/100 g protein, 5.5% maximum moisture) was obtained from PACE Farms Pty. Ltd. Egg Production (Warabrook, NSW, Australia) and stored in a dry place at 17±1°C. A commercial sweet whey protein concentrate (100% WPC) was supplied by Top Nutrition Company, (Newcastle, NSW, Australia) and stored at 17±1°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±1°C.

Methods

Texture

Texture Analysis was conducted using a microprocessor controlled texture analysis system in conjunction with data collection and analysis software (TMS-Pro, S.I. Instruments, S.A, 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 25 and 400 mm/min, 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 to 5 cm × 4 to 4.5 cm × 3 to 3.5 cm) due to the differences in physical characteristics (e.g., overrun). The sample was placed (at room temperature, 17±1°C) on a wire screen (56
holes/cm²) 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 minutes and one measurement was taken per sample.

**Colour**

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

**Statistical Analysis**

Analysis of Variance (ANOVA) (using Microsoft Excell software) was used to evaluate the effect of egg yolk substitution by WPC, on texture, stability and colour properties of Gelato vanilla ice cream over 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 over four weeks of storage. The increase in hardness during weeks three and four of storage with increasing levels of WPC by 4.5% egg yolk is shown in Figure 1. Moreover, extending the storage time resulted in decreased hardness in the 9% egg yolk samples. The only exception to this is with a one-week storage period. Several factors impact the hardness of Gelato ice cream such as the overrun, ice phase volume, and fat
destabilisation 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 is notable by many researchers [16-18]. WILBEY et al. [19] discovered a direct relationship between the hardness of ice cream and the level of ice phase volume. The fat network also impacts hardness. However, THRAP et al. [20] determined that as the amount of destabilised fat increased, the hardness of the ice cream is greater. Another factor that impacts the texture of Gelato ice cream is viscosity. As the samples’ viscosity levels are increased, Gelato was resulting firmer texture. The overall effect from a large quantity of fat is apparent and the viscosity increases [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; therefore, its firmness increases [21].

**Stability (melting rate)**

Over four weeks of storage, the melting rate qualities of Gelato ice cream are observed. WPC levels are increased, which resulted in a significant effect ($P<0.05$) in the melting rate among 9% egg yolk samples over increased storage time. However, there was no significant ($P>0.05$) impact on melting rates among 4.5% egg yolk samples with increasing WPC levels. The only exception is among the samples after four weeks of storage as shown in Figure 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
more optimal level of emulsion than the caseins in the absence of emulsifiers; which was egg yolk in our 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 homogenised globules. Coupled with ice crystals and air bubbles, the fat globules contribute to ice cream’s stiff and arid qualities [20, 27]. 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 smoother texture in the frozen ice cream, which is proven by many researchers [20, 26, 27].

**Colour**

The mean $L$ (whiteness) and $b$ (yellowness) values are displayed in Table 1. There were slight differences in colour between the 4.5% and 9% egg yolk observed and recorded. Addition of WPC (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. Four weeks post-storage, the differences in colour are markedly evident. Generally, Gelato ice cream with added WPC in 9% egg yolk samples slightly had 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. 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 WPC at different levels. In general, hardness of the samples was lower for 4.5% egg yolk samples compared with 9% egg yolk. Therefore, increasing WPC levels in both 4.5% and 9% egg yolk samples improved the texture characteristics of the Gelato ice creams. Additionally, data showed that increasing WPC levels and storage time led to increased Gelato ice cream samples stability when using 9% egg yolk. This is probably due to the higher fat content, and the foaming ability and stability of whey protein concentrate. Furthermore, adding WPC significantly affected the 9% egg yolk samples $L$ values (whiteness) while no effect in 4.5% egg yolk samples was recorded. 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 WPC substitution appears to be most advantageous for Gelato ice cream samples, as it would allow for the production of a cheaper alternative to Gelato without a compromise to the functional properties of the product.
References:


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.

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.
Table 1: Mean $L$ and $b$ values of Gelato ice cream with different concentrations of WPC over four weeks of storage\textsuperscript{a}.

<table>
<thead>
<tr>
<th>WPC (%)</th>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
<th>Week 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$L$</td>
<td>$b$</td>
<td>$L$</td>
<td>$b$</td>
</tr>
<tr>
<td>0%</td>
<td>42.72</td>
<td>12.32</td>
<td>47.53</td>
<td>9.21</td>
</tr>
<tr>
<td>(control)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20%</td>
<td>47.07</td>
<td>13.21</td>
<td>44.59</td>
<td>12.05</td>
</tr>
<tr>
<td>50%</td>
<td>46.58</td>
<td>11.94</td>
<td>49.49</td>
<td>12.49</td>
</tr>
<tr>
<td>80%</td>
<td>42.89</td>
<td>10.05</td>
<td>49.09</td>
<td>10.81</td>
</tr>
<tr>
<td>100%</td>
<td>46.81</td>
<td>9.81</td>
<td>47.48</td>
<td>10.40</td>
</tr>
</tbody>
</table>

\textit{4.5\% egg yolk}

<table>
<thead>
<tr>
<th>WPC (%)</th>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
<th>Week 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$L$</td>
<td>$b$</td>
<td>$L$</td>
<td>$b$</td>
</tr>
<tr>
<td>0%</td>
<td>51.72</td>
<td>10.82</td>
<td>51.37</td>
<td>10.18</td>
</tr>
<tr>
<td>(control)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20%</td>
<td>48.09</td>
<td>14.61</td>
<td>55.11</td>
<td>10.50</td>
</tr>
<tr>
<td>50%</td>
<td>48.26</td>
<td>12.11</td>
<td>48.69</td>
<td>12.95</td>
</tr>
<tr>
<td>80%</td>
<td>46.00</td>
<td>10.76</td>
<td>46.96</td>
<td>10.82</td>
</tr>
<tr>
<td>100%</td>
<td>49.39</td>
<td>10.51</td>
<td>46.60</td>
<td>9.78</td>
</tr>
</tbody>
</table>

\textit{9\% egg yolk}

\textsuperscript{a} Values represent the mean of 3 replicate trials, $L$ - Measure of whiteness, $b$ - measure of yellowness.
4.5% Egg yolk with WPC

Control 20% 50% 80% 100%

Force (N)
Control 20% 50% 80% 100%

9 % Egg yolk with WPC

Force (N)

week-1
week-2
week-3
week-4
Stability (ml)

Control  20%  50%  80%  100%

Week-1  Week-2  Week-3  Week-4

4.5% Egg yolk with WPC