Lipid Distribution and Rheological Properties of Creamy Custard Pudding Prepared with Egg Yolk and Milk Fat Cream

Satomi Nomura*  Manami Imaoka**  Kazumasa Mizuo***  Sumire Tanaka**  Risa Yasui**  Sumi Sugiyama***§

The objective of this study was to investigate the involvement of egg yolk in the structure formation of "creamy custard pudding", which was comprised of upper and lower parts differing in appearance and texture.

In pudding prepared with 100 g of milk, 100 g of milk fat cream, 20 g of sugar, and 40 g of egg yolk, the fat content was significantly higher in the upper than in the lower part, but no significant difference was noted in the fatty acid composition between the two parts. The cholesterol and phospholipid contents were slightly higher in the upper and lower parts, respectively. The median particle size in the upper part was greater than that in the lower part, and the hysteresis area and non-Newtonian viscosity were significantly greater in the upper than in the lower part. These differences in the lipid content, median particle size, and static viscoelasticity between the upper and lower parts present in this pudding were not observed in puddings heated for a shorter time, with a small quantity of blended egg yolk, compounded with egg white, or high quantity of blended milk fat cream. Dynamic viscoelasticity measurement clarified that egg yolk, rather than egg white, contributed to the structural stability of "creamy custard pudding", and increases in the milk fat cream content and the heating process enhanced the structural stability. In addition, G' was higher than G'' in all measured frequency regions in both the upper and lower parts, this pudding was characterized as a "weak gel", in which both G' and G'' were found to be dependent on frequency. Additionally, the "weak gel" rheological property was more marked in the lower part.

Keyword: creamy custard pudding, egg yolk, milk fat cream, lipid, dynamic viscoelasticity

Introduction

Custard pudding is prepared by mixing whole egg, milk, and sugar and then solidified by heating (Katou 1998). The whole egg serves as a gelling agent, and the shape is retained after ejection from the mold (Yamasaki et al. 2011). However, many puddings with soft and smooth texture, in which whole egg is replaced with egg yolk and milk is replaced with milk fat cream, are sold. Shimosaka et al. (2004) and Mineki et al. (2006) reported on the gel strength of pudding and the dispersion of fat globules when whole egg and milk blended at 1:2 and 1:2.5 were replaced with egg yolk and milk fat cream, respectively. Recently, puddings with very soft and smooth texture and composed of whole egg (and/or egg yolk) and milk (and/or milk fat cream) at 1:4–10, which cannot be ejected out of the mold, have become popular and are generally known as "creamy custard pudding" (Ajiki 2007; Fukuda 2008; Kasai 2003; Cookpad HP http://cookpad.com/). Some "creamy custard puddings" are comprised of two layers after the heating process, creating upper and lower parts that differ in appearance and texture. However, no studies on these "creamy custard puddings" have previously been performed, and differences in the composition and structure between these two layers have not been clarified.

In this study, "creamy custard puddings" were prepared by mixing egg yolk with milk and milk fat cream at 1:5, and the lipid contents, median particle size and rheological properties (static and dynamic viscoelasticity measurements) of the two pudding layers (upper and lower parts) were measured to investigate the involvement of egg yolk in the lipid distribution and structure formation of "creamy custard pudding".

Materials and Methods

1. Preparation of "creamy custard pudding"

Milk fat cream (Omu Nyugyo, Fukuoka, Japan, milk fat: 48.0%), milk (Sanyo Nyugyo, Hiroshima, Japan, milk fat: 3.5% or higher), hen’s eggs (Chiyoda Farm, Hiroshima, Japan, L size) and sugar (Pearl Ace, Tokyo, Japan) were purchased in Hiroshima City. All materials were homogenized through a strainer.

Milk and milk fat cream (100 g each) were mixed and warmed in a water bath at 55°C for 10 min. Next, 20 g of sugar was combined and dissolved, to which 40 g of egg yolk was added, and the mixture was distributed into 50–ml
beakers at 50 g per beaker. These were kept in a 30°C water bath for 30 min, followed by heating for 12 min in a steam convection oven (FMI, OSP-6.10, Osaka, Japan) preheated to 85°C. The pudding prepared with these quantities was designated as pudding A, that in which 40 g of egg yolk was replaced with 12 g of egg yolk and 28 g of water as pudding B, and that in which 40 g of egg yolk was replaced with 40 g of egg white as pudding C. In addition, pudding in which all 100 g of milk in pudding A was replaced with milk fat cream was prepared as pudding D. The temperature in the center of puddings A-D was elevated to 82°C by 12-min warming in a steam convection oven. To investigate changes caused by the heating process, pudding A-5, which was heated for 5 min, was also prepared (central temperature: 70°C). After heating, the pudding was rapidly cooled to 3°C using a blast-cooled chiller (FMI, A5M). Since differences in the appearance and texture in the center of pudding A and texture of the center in puddings C and D were confirmed in a preliminary experiment, all puddings were divided into upper and lower parts after cooling for 1 h. The five types of pudding were prepared on the same day, and preparation was repeated three times or more on different days.

2. Lipid analysis

Lipids were extracted from samples (3 g) employing the Bligh-Dyer method (Bligh and Dyer 1959). Fatty acid analysis and quantification of fat and cholesterol were performed as previously reported (Sugiyama et al. 2005). Phospholipid phosphorus (PL-Pi) was determined employing the Bartlett method (Bartlett 1959).

3. Particle size measurement

Particle size was determined using the LA-300 laser diffraction particle size distribution analyzer (Horiba, Kyoto, Japan). The sample was stirred 100 times in a beaker immediately before measurement and applied so as to adjust the transmittance in the measurement water bath to 80–90%. The duration of ultrasonication in the water bath was 0 or 1 min. The median particle size ($d_{50}$) of the pudding was measured beforehand in 0.1 and 0.5% SDS solutions and distilled water as measurement solvents to confirm the absence of differences in the measured value, and then 0.1% SDS solution was used as the solvent.

4. Rheological properties

Dynamic and static viscoelasticity measurements were carried out using a controlled-stress rheometer RS6000 (Thermo-HAAKE, Karlsruhe, Germany) with a 0.047-mm gap cone sensor ($\phi 35$ mm, 1°).

Any portion of the sample overflowing from the sample plate was wiped off. To prevent drying of the sample and minimize the influence of room temperature, the sample plate was covered with a protective shield. The measurements were carried out immediately after the preparation of pudding to minimize time-dependent changes in dynamic and static viscoelasticities. All samples were equilibrated on the sample plate for 2 min before performing measurements.

For static viscoelasticity measurements, the shear rate was elevated from 0 to 150 s$^{-1}$ within 1 min and immediately decreased from 150 to 0 s$^{-1}$ within 1 min. For dynamic viscoelasticity measurements, the stress sweep test was performed in order to confirm the linear viscoelasticity range. The analytical conditions were: measurement temperature, 5°C; frequency, 1 Hz (angular frequency $\omega = 6.283$ rad/s); and stress, 0.1–100 Pa. Next, the frequency sweep test was performed within the linear viscoelasticity range at 5°C and 0.1–10 Hz. A Lissajous curve of applied stress and the strain response was determined.

5. Statistical analysis

To analyze the significance of differences in the fat content, fatty acid composition, cholesterol content, PL–Pi content, and median particle size between different puddings or between the upper and lower parts in each pudding, a Tukey–HSD test was performed using PASW statistics 17.0 (SPSS Japan Inc., Tokyo, Japan). Similarly, the hysteresis area and non-Newtonian viscosity determined by static viscoelasticity measurement and the crossover point determined by dynamic viscoelasticity measurement were statistically analyzed.

Results

1. Lipid contents

1) Fat content and fatty acid composition

The fat content in 50 g of each pudding before heating and in 25 g of the upper and lower parts after heating are shown in Fig. 1-a. The fat content was significantly higher in the upper than in the lower part in pudding A ($p < 0.05$), but no significant difference between the two parts was noted in pudding B, C, or D. In pudding A–5, the fat content was higher in the upper than in the lower part, but the difference was not significant.

With respect to the fatty acid compositions of the upper and lower parts of the puddings, Table 1 shows the ratios of myristic acid (14 : 0), which is abundant in milk fat cream but absent in egg yolk, and that of linoleic acid (18 : 2), which is low in milk fat cream but abundant in egg yolk. In puddings A and A–5, the 14 : 0 ratio was approximately
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2% greater in the upper part, and that of 18:2 was approximately 1% greater in the lower part, but the differences were not significant. The ratios of 14:0 and 18:2 in the upper and lower parts were almost the same in puddings B, C, and D.

2) Cholesterol and phospholipid-phosphorus (PL-Pi) contents

The cholesterol and PL-Pi contents of the puddings are shown in Fig. 1-b, c. The cholesterol and PL-Pi contents of the milk fat cream were 87 and 9 mg/100 g, respectively, and those of egg yolk were 933 and 400 mg/100 g, respectively, showing that the cholesterol and PL-Pi in all puddings were mostly derived from egg yolk.

Although the differences were not significant, the cholesterol content was greater in the upper than in the lower part, and the PL-Pi content was greater in the lower than in the upper part of pudding A (Fig. 1-b, c). In the other puddings, the cholesterol and PL-Pi contents in the upper and lower parts were similar. These findings showed that for pudding A, egg-derived fat, cholesterol and PL-Pi were present at different ratios in the upper and lower parts.

2. Particle size measurement

The median particle sizes in the puddings are shown in Table 2. The median particle sizes in the upper and lower parts were 19.4±0.6 and 11.5±0.2 μm, respectively, showing a significant difference in pudding A (p<0.01). After ultrasonication, the median sizes decreased to 3.0 and 2.8 μm, respectively, suggesting that the increased median particle sizes in pudding A were due to aggregation, not union (Fujita 2006). In contrast, in puddings A-5 and B, the median particle size was approximately 3 μm in both the upper and lower parts, irrespective of ultrasonication. In pudding C, the median particle sizes were 5.5±0.8 and 5.1±0.4 μm in the upper and lower parts, respectively, showing that while the particle size increased from that before heating, no significant difference was noted in particle size between the upper and lower parts. In pudding D, the median particle sizes were 24.6±1.6 and 22.7±0.3 μm in the upper and lower parts, respectively, distributing widely from 1.5 to 150 μm (data not shown). These findings in pudding D were consistent with those reported by Bolliger et al. (2000), in which the size of fat globules contained in ice cream was 30±4 μm.

Additionally, it was reported that an SDS solution was ineffective in dispersing aggregated fat globules (Martinet et al. 2005). No difference was noted in the particle size of puddings prepared using SDS solution and distilled water as measurement solvents, showing that hydrophobic interaction is unlikely to be involved in fat globule aggregation in puddings.

3. Static viscoelasticity

The hysteresis loops of puddings, as determined by static viscoelasticity measurement, are shown in Fig. 2, and the hysteresis areas and non-Newtonian viscosity (ŋ: dγ/dt = 50⁻¹) are shown in Table 3. The upward curve surpassed the downward curve in both the upper and lower parts in

![Fig. 1. Fat, Cholesterol and PL-Pi contents of pudding.](image-url)
Table 1. Fatty acid composition of puddings (%)

<table>
<thead>
<tr>
<th></th>
<th>Myristic acid (14:0)</th>
<th>Linoleic acid (18:2)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Before heating</td>
<td>After heating</td>
</tr>
<tr>
<td></td>
<td>Upper part</td>
<td>Lower part</td>
</tr>
<tr>
<td>Milk fat cream</td>
<td>12.4±0.2</td>
<td>3.2±0.1</td>
</tr>
<tr>
<td>Egg yolk</td>
<td>0.2±0.0</td>
<td></td>
</tr>
<tr>
<td>Pudding A</td>
<td>9.9±0.6</td>
<td>10.6±0.3</td>
</tr>
<tr>
<td>Pudding A-5</td>
<td>11.7±0.5</td>
<td>10.5±0.5</td>
</tr>
<tr>
<td>Pudding B</td>
<td>12.1±0.7</td>
<td>11.7±0.5</td>
</tr>
<tr>
<td>Pudding C</td>
<td>12.8±0.2</td>
<td>13.0±0.6</td>
</tr>
<tr>
<td>Pudding D</td>
<td>11.4±0.7</td>
<td>11.0±0.1</td>
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</table>

Each value is the mean±standard deviation of three determinations. Significant differences between upper and lower part after heating were not observed (p>0.05).

Table 2. Median particle (d50) size of puddings (μm)

<table>
<thead>
<tr>
<th></th>
<th>Pudding A</th>
<th>Pudding A-5</th>
<th>Pudding B</th>
<th>Pudding C</th>
<th>Pudding D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before heating</td>
<td>3.3±0.1</td>
<td>3.2±0.0</td>
<td>3.3±0.3</td>
<td>3.5±0.1</td>
<td></td>
</tr>
<tr>
<td>(3.2±0.1)</td>
<td></td>
<td></td>
<td>(3.1±0.2)</td>
<td></td>
<td>(3.4±0.0)</td>
</tr>
<tr>
<td>After heating</td>
<td>19.4±0.6</td>
<td>3.5±0.0</td>
<td>3.2±0.3</td>
<td>5.5±0.8</td>
<td>24.6±1.6</td>
</tr>
<tr>
<td>(3.0±0.1)</td>
<td>(3.0±0.0)</td>
<td>(2.9±0.1)</td>
<td>(3.7±0.4)</td>
<td>(3.7±0.8)</td>
<td></td>
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<td></td>
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<tr>
<td>Upper</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Lower</td>
<td></td>
<td></td>
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</tbody>
</table>

Each value is the mean±standard deviation of three determinations. The values in parentheses are after ultrasonic treatment. The same letters at same lines show significant difference at the p<0.01. * In pudding A, significant differences between upper and lower parts were observed (p<0.05).

Fig. 2. Flow curves (hysteresis loops) of pudding.

A : ●, A-5 : ○, B : ■, C : ▼, D : ◆
This test was performed at 5℃. The upward curve surpassed the downward curve in both the upper and lower parts in puddings A, C, and D. Preparation conditions of pudding were identical to those described in Fig. 1.

Table 3. Hysteresis area and non-Newtonian viscosity

<table>
<thead>
<tr>
<th></th>
<th>Pudding A</th>
<th>Pudding A-5</th>
<th>Pudding B</th>
<th>Pudding C</th>
<th>Pudding D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hysteresis area</td>
<td>2024±153</td>
<td>839±236</td>
<td>100±46</td>
<td>1484±155</td>
<td>4069±144</td>
</tr>
<tr>
<td>(Pa・s⁻¹)</td>
<td>26±15</td>
<td>26±15</td>
<td>26±15</td>
<td>26±15</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>non-Newtonian viscosity</td>
<td>0.95±0.0</td>
<td>0.52±0.0</td>
<td>0.10±0.0</td>
<td>0.71±0.0</td>
<td>1.79±0.0</td>
</tr>
<tr>
<td>(d: dr/dt=50⁻¹)</td>
<td>26±15</td>
<td>26±15</td>
<td>26±15</td>
<td>26±15</td>
<td></td>
</tr>
</tbody>
</table>

Each value is the mean±standard deviation of three determinations. The same letters at same lines show significant difference at the p<0.05 (capital letter) or p<0.01 (small letter). * In pudding A, significant differences between upper and lower parts were observed (p<0.05).
puddings A, C, and D. It was showing that the high shear rate caused the breakdown in structure and reduction the apparent viscosity. Masuda and Matsumoto (1992) reported that the colloid dispersion system shows thixotropic flow, reduction of apparent viscosity, by a high shear rate and the cause of these is the segmentation of particles aggregated like beads by inter-particle attractive forces.

In a comparison of the hysteresis area and non-Newtonian viscosity between the upper and lower parts (Table 3), no difference was noted in pudding A-5, which was heated for 5 min. In pudding A, heated for 12 min, the hysteresis area and non-Newtonian viscosity were significantly greater in the upper than in the lower part \((p<0.05)\). These parameter values in pudding A were significantly smaller than those in the upper and lower parts in pudding D \((p<0.01)\) and significantly greater than those in the upper part in pudding C \((p<0.01)\). Thus, the hysteresis area and non-Newtonian viscosity differed significantly between the upper and lower parts in pudding A and among puddings A, C, and D. These observations suggested that the level of formation and destruction of structural viscosity differ with various quantities of blended egg yolk and milk fat cream.

In pudding B, in which the quantity of blended egg yolk was low, the upward and downward curves mostly overlapped, showing no structure formation.

4) Dynamic viscoelasticity of pudding

1) Linear viscoelastic range (Amplitude dependence)

The amplitude dependence properties of the puddings are shown in Fig. 3. In pudding A, the linear viscoelastic range was wider in the lower than in the upper part, and the shear stress at the crossover point, at which the storage modulus \(G'\) and loss modulus \(G''\) values are the same, was also slightly greater in the lower part (upper part: 5.0±0.4 Pa, lower part: 6.1±0.3 Pa). In pudding A-5, the linear viscoelastic range was narrower than that in pudding A in both the upper and lower parts, and the shear stress at the crossover point was lower (upper part: 2.0±0.1 Pa, lower part: 6.1±0.3 Pa). These results showed that the linear viscoelastic range of egg yolk-compounded pudding was broadened by the heating process. In addition, the \(G'\) and \(G''\) values in the linear viscoelastic range of the upper part were similar in puddings A and A-5, but those in the lower part were lower in pudding A-5.

In pudding B, made with a low quantity of blended egg yolk, the linear range was markedly narrower than that in pudding A, and the shear stress at the crossover point was also low (upper part: 0.3±0.1 Pa, lower part: 0.1±0.0 Pa). In pudding D, made with a high quantity of blended milk fat cream, the \(G'\) and \(G''\) values in the linear viscoelastic range of the upper part were markedly wider than those in pudding A, and the shear stress at the crossover point was also higher (upper part: 9.0±1.2 Pa, lower part: 7.1±1.0 Pa).

2) Mechanical spectra (Frequency dependence)

The mechanical spectra of the puddings are shown in Fig. 4. In pudding A, \(G'\) was higher than \(G''\) in both the upper and lower parts in all measured frequency regions, pudding A was characterized as a "weak gel", in which both \(G'\) and \(G''\) were found to be dependent on frequency (Masuda and Matsumoto 1992; Nishinari 2007). In addition, the frequency dependence was greater in the upper than in the lower part, the "weak gel" rheological property was more marked in the lower part. This result was consistent with the wider linear viscoelastic range in the upper rather than the lower part shown in Fig. 3, but inconsistent with the higher non-Newtonian viscosity in the upper rather than in the lower part (Table 3).

In pudding A-5, \(G'\) and \(G''\) in both the upper and lower parts were dependent on frequency, and this was particularly strong in the upper part. However, \(G'\) was greater than \(G''\) even in the low-frequency region, showing a "weak gel" rheological property in both the upper and lower parts. Furthermore, loss tangent \(\tan \delta = G''/G'\) decreased as the frequency increased in the upper part of pudding A-5, whereas it increased in the lower part. It was suggested that structure formation was more rapid in the lower than in the upper part.

In pudding B, \(G'\) and \(G''\) in both the upper and lower parts were dependent on frequency, similar to those in pudding A-5, but \(G''>G'\) and \(G'>G''\) in the low- and high-frequency regions, respectively, showing a "thick solution" rheological property, unlike pudding A-5 (Nishinari 2007). In addition, the frequency where \(G'>G''\) was higher in the lower than in the upper part. Differences in these findings between puddings A-5 and B were consistent with the absence of structure formation only in pudding B, as determined by static viscoelasticity measurement (Fig. 2).

The frequency dependence of \(\tan \delta\) differed among puddings A, C, and D; \(\tan \delta\) was similar in the upper and lower parts in puddings C and D, whereas the decline in \(\tan \delta\) at 1 Hz was markedly reduced in the lower compared to the upper part in pudding A.

Discussion

Fat globules dispersed as emulsion in pudding material
mixtures before heating migrate to the upper part and aggregate as the temperature increases, and some globules may be coalesced (Fujita 2006). Mineki et al. (2006) reported that fat globule dispersion was relatively homogeneous and some globules were combined in pudding prepared with egg yolk and milk fat cream. Egg yolk is composed of 68% LDL, 16% HDL (lipovitellin), 10% livetin, and 4% phosvitin. All these have a high oil/water interface-adsorbing capacity, and LDL shows the greatest adsorption (Anton 1998). Kiosseoglou and Sherman (1983) suggested that LDL is destroyed when it contacts the oil droplet interface, apoprotein, cholesterol, phospholipids are adsorbed by the emulsion interface and reconstructed, and neutral fat is united with oil droplets. Mine (1998) reported that cholesterol in LDL has a high affinity for oil droplets in emulsion due to hydrophobic interaction, compared to that of phospholipids.

In contrast, the influence of degeneration of egg yolk...
protein in emulsion by heating has not been fully clarified. It is assumed that hydrophobic interaction and disulfide bond formation occur between denatured proteins adsorbed to the interface resulting in the promotion of fat globule aggregation (Nikiforidis and Kiosseoglou 1983).

We prepared “creamy custard pudding” samples with egg yolk: milk + milk fat cream = 1:5, and determined the lipid content, median particle size, and rheological characteristics (static and dynamic viscoelasticities) of the two layers of the pudding (upper and lower parts) to investigate the involvement of egg yolk in the lipid distribution and structure formation of “creamy custard pudding”.

Assessment of the lipid content, median particle size and static viscoelasticity of puddings clarified that the presence or absence, as well as the quantity, of blended egg yolk caused differences in fat distribution and fat globule dispersion, which influenced the state of aggregation, between the upper and lower parts of the puddings. In emulsion gels of “active fillers”, such as 11S globulin and β-lactoglobulin gels, it has been reported that fat globules interacted with the
It could be assumed that LDL components may have local distribution of milk fat cream–derived fat in the upper part or egg yolk–derived fat in the lower part was observed. In addition, although the differences were not significant, cholesterol and PL–Pi were more abundant in the upper and lower parts, respectively. These findings support the above hypothesis of Kiosseoglou and Sherman (1983). It could be assumed that LDL components may have been reconstructed with fat globules, and small fat droplets with a low specific gravity moved to the upper part, while fat droplets with a high specific gravity remained in the lower part. Furthermore, differences in the lipid content, median particle size, and static viscoelasticity between the upper and lower parts observed in pudding A were absent in pudding A-5 (heated for a shorter time) and pudding B (made with a low quantity of blended egg yolk). This suggests that some adsorption of LDL–derived protein to the oil droplet interface and degeneration of adsorbed protein by heating are necessary to form the upper and lower parts.

In puddings C and D, the median particle size was increased after heating, but no significant differences in lipid contents, median particle size and static viscoelasticity were noted between the upper and lower parts. In egg white–compounded pudding C, egg white protein molecules were linked and aggregated by heating (Kitabatake 1998). In pudding D, a thick emulsion in which milk was entirely replaced with milk fat cream, a dense three–dimensional structure was formed by fat globule aggregation (Fujita 2006). Martinet et al. (2005) reported that fat globule aggregation constructed a network in ice cream with a high fat content. Taking these factors into consideration, it is suggested that a thin solution in which fat globules can move to the upper part is necessary to form the upper and lower parts of “creamy custard pudding”.

With respect to dynamic viscoelasticity, pudding B, made with a low quantity of blended egg yolk, showed a “thick solution” rheological property: $G^\prime > G^\prime\prime$ in the low–frequency region and $G^\prime > G^\prime\prime$ in the high–frequency region, while the other puddings showed a “weak gel” rheological property: $G^\prime > G^\prime\prime$ in all frequency regions. Additionally, the “weak gel” rheological property was more marked in the lower than in the upper part. The linear viscoelastic range of pudding A was wider than those of puddings A-5, B and C and narrower than that of pudding D. Thus, it was clarified that egg yolk, rather than egg white, contributed to the structural stability of “creamy custard pudding” and increases in the milk fat cream content and the heating process enhance the structural stability.

These dynamic viscoelasticity properties may represent the characteristics of “creamy custard pudding”: the very soft, creamy texture that cannot be ejected out of the mold but possesses a structure distributable in the market. In addition, the frequency dependence of $\tan \delta$ differed between puddings A and C, suggesting that the gel network structure of milk fat cream with egg yolk is different from that with egg white. When the upper and lower parts of pudding A were compared, $\tan \delta$ markedly decreased to 1 Hz in the lower part. Takahashi et al. (2005) reported that in a starch/guar gum mixed gel, as $G^\prime$ increases and $\tan \delta$ declines in the low–frequency region, there was a decrease in stickiness and in the residual feeling in the mouth. In pudding A, stickiness and the residual feeling caused by the upper part may have been reduced by the lower part, and this may be the reason for the general preference for “creamy custard pudding”, in which milk and whole egg were replaced with milk fat cream and egg yolk.

This study of “creamy custard pudding” samples may help in clarifying the behavior of egg yolk, which has superior emulsifying properties, during the heating process.

**Conclusion**

The objective of this study was to investigate the involvement of egg yolk in the structure formation of “creamy custard pudding”, which was comprised of upper and lower parts differing in appearance and texture.

In a pudding prepared with 100 g of milk, 100 g of milk fat cream, 20 g of sugar, and 40 g of egg yolk, the fat content was significantly higher in the upper than in the lower part, but no significant difference was noted in the fatty acid composition between the two parts. The cholesterol and phospholipid contents were slightly higher in the upper and lower parts, respectively. The median particle size in the upper part was greater than that in the lower part, and the hysteresis area and non–Newtonian viscosity were significantly greater in the upper than in the lower part. These differences in the lipid content, median particle size, and static viscoelasticity between the upper and lower parts...
present in this pudding were not observed in puddings heated for a shorter time, with a small quantity of blended egg yolk, compounded with egg white, or high quantity of blended milk fat cream. Dynamic viscoelasticity measurement clarified that egg yolk, rather than egg white, contributed to the structural stability of “creamy custard pudding”, and increases in the milk fat cream content and the heating process enhanced the structural stability. In addition, $G'$ was higher than $G''$ in all measured frequency regions in both the upper and lower parts, this pudding was characterized as a “weak gel”, in which both $G'$ and $G''$ were found in both the upper and lower parts, and some degree of adsorption of LDL-derived protein to fat globules. Additionally, the “weak gel” rheological property was more marked in the upper part.

These findings suggest that the conditions necessary for the formation of the upper and lower parts of “creamy custard pudding” are as follows: adsorption of LDL-derived protein to the oil droplet interface, degeneration of adsorbed protein by heating, the presence of a thin solution allowing fat globules to migrate to the upper part, and some degree of adsorption of LDL-derived protein to fat globules.

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(Received Sept, 28, 2011 Accepted Feb, 1, 2012)
卵黄及び乳脂肪クリームで調製したカスタードプディングの
脂質分布とレオロジー特性

野 村 知 未* 今岡 麻 奈 美** 水 尾 和 雅*** 田中 す み れ** 保 井 り さ** 杉 山 寿 美***§

和文抄録

外観や食感が異なる上部と下部を有するいわゆる“なめらかプディング”を試料として、卵黄がその構造形成にどのよう
に関与しているのかを考察することを目的として研究を行った。牛乳 100 g、生クリーム 100 g、砂糖 20 g、卵黄 40 g
で調製したプディングでは、上部の脂肪量が下部よりも有意に多かったが、上部と下部の脂肪酸組成に差は認められなかっ
た。コレステロール量は上部で、リン脂質リン量は下部でわずかに多かった。また、上部の平均粒子径は下部よりも大き
く、上部のヒステレスエリアおよび見かけの粘度は下部よりも有意に高かった。このプディングで認められた上部と下
部の脂質量、平均粒子径、静的粘弾性の差は、加熱時間の短いプディング、卵黄配合量の少ないプディング、卵白を配合
したプディング、乳脂肪クリーム配合量が多いプディングで認められなかった。また、動的粘弾性測定では、なめらかプ
ディングの構造安定性には卵白よりも卵黄が寄与していること、乳脂肪クリーム量が多くなることでより安定となること、
プディングの加熱過程で安定性が増すことが示された。また、プリーズの上部、下部ともに測定した周波数領域におい
て、G' が G" より高く、G', G" ともに周波数に依存して増加する、弱いゲル型のレオロジー特性を示し、下部のゲル的性
質が強かった。

キーワード：カスタードプディング、卵黄、乳脂肪クリーム、脂質、動的粘弾性

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