Effects of Emulsifier on Mixing Properties and Glass Transition Temperature of Zein-Starch Doughs

Murdiati¹, Lumdubwong, N.² and Kuakpetoon, D.¹

Abstract

When mixed maize protein (zein) with starch and water above room temperature (e.g. 35°C) can form a viscoelastic dough like wheat flour. The effects of emulsifiers (PATCO® and sodium stearoyl lactylate (SSL)) on mixing properties and glass transition temperature (T_g) of zein-starch dough were studied. Corn starch (90%, w/w), zein (10% w/w), emulsifier (4-6% PATCO® or 2-3% SSL) and water were mixed at 35°C into dough. The optimum water amount for dough mixing was determined using farinograph. The T_g of doughs was measured using a rheometer by small amplitude test at a cooling rate of 1°C/min from 35°C to 10°C. Doughs with emulsifiers showed a lower optimum water amount and T_g. Depression of optimum water amount and T_g by SSL were higher compared to PATCO®. The more emulsifier addition, the lower the optimum water amount and the greater T_g depression. This study may help to mix viscoelastic gluten-free dough at room temperature.

Keywords: zein, starch, dough, glass transition temperature, viscoelastic

Introduction

Corn flour does not form a viscoelastic dough when hydrated. However, zein protein, mixed with starch and water at above room temperature, can participate in viscoelastic dough formation similar to wheat dough that is thought by far as the best dough properties to other cereal products (Lawton, 1992; Mejia, Oom et al., 2008). Up to now, one of the limiting factor of zein-starch dough formation is that mixing temperature at above room temperature is not a practical condition in regular food processing environments. Sodium stearoyl lactylate (SSL) and calcium stearoyl lactylate (CSL) are commonly used as dough and bread improver (Nunes et al., 2009). Its amphiphilic nature and emulsifying properties as emulsifier might influence the properties of zein dough. Despite a few publications regarding their application in gluten-free cereal products (Lai, 2001; Nunes et al., 2009), di Gioia and Guilbert (1999) showed that the addition of di-acetyl tartaric ester of monoglyceride (DATEM) as emulsifier in corn-protein based thermoplastic resins could depress the glass transition temperature (T_g). The objective of the research was to study the effects of emulsifiers (PATCO®, SSL) on mixing properties and T_g of zein-starch dough.

Materials and Methods

Commercial zein was purchased from Flo Chemical Corporation (Ashburnham, MA, USA). Native maize starch was donated by Friendship Corn Starch Co., Ltd. (Thailand). Sodium stearoyl lactylate (SSL) was provided by Danisco Co., Ltd. (Thailand) and PATCO® was purchased from UFM Food Centre Co. Ltd. (Thailand). Distilled water was used for all experiments. The control was blended zein-starch added with water. Each treatment was employed in three levels based on dry flour weight (w/w); PATCO® at 4, 5 and 6% (P-4, P-5, P-6 respectively) and SSL at 2, 3 and 4% (S-2, S-3, S-4 respectively).

Mixing properties: Dough mixing properties for all treatments were investigated by using a 150-g Brabender farinograph (Brabender® GmbH & Co. KG, Duisburg, Germany). Starch (90%, w/w), zein (10%, w/w), emulsifier and distilled water were mixed into a dough for 16 min at 35°C. All ingredients were pre-mixed in a glass jar with a spatula and incubated to 35°C for 24 hr before dough formation. Mixing properties were evaluated in terms of water absorption and dough development time. Mixing in farinograph was conducted

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according to AACC (American Association of Cereal Chemist) standard method 54-21 and was based on dough consistency at the 475-500 FU (Farinograph Unit) line.

**Determination of T_g**: For sample preparation, a modified hand mixer (Kenwood HM320, from Kenwood Limited, Havant, UK) was used to prepare all dough samples. The mixer was modified into a single kneader mixer with a flat-bottom glassware as the mixing bowl (dimension was 3 cm diameter and 10 cm height). The mixing speed was set at 28 rpm by using power inverter. The 12-g composite flour (as shown in Table 1) was pre-mixed inside glassware and incubated at 35°C for 24 hr before dough formation. Then, distilled water (35°C) was added gradually in a glassware sitting in water bath. The amount water added were based on water absorption from farinogram, while the mixing time was adopted from the dough development time from farinogram.

Small amplitude oscillatory testing (Schober et al., 2008) was performed to determine the T_g of zein doughs. Measurements were made in a rheometer (Bohlin C-VOR rheometer, from Bohlin Instruments Ltd., Gloucester, UK). Triplicate samples were analyzed with parallel plate geometry (20 mm diameter plate) at 35°C. After mixing at 35°C, dough samples were transferred to the plate with the gap of 3 mm. Sample trimming using spatula was done to excessive sample and the exposed edges were covered with grease to reduce water loss from the sample. In addition, coating was used to cover sample and plate. The tests were performed in two modes: (a) stress sweep test and (b) temperature sweep test. The temperature sweep tests were conducted to investigate changes in the sample as function of glass transition. Stress sweep tests were conducted at a constant frequency of 1 Hz and stress range between 1 and 1 x 10^3 Pa to determine the linear viscoelastic region. Based on the stress sweep test results, temperature sweep tests for all samples were performed at 3 x 10^{-3} at 1 Hz. The measurements were started at 35°C and decrease to 10°C at the cooling rate of 1°C/min. Results were expressed in terms of storage modulus (G'). The T_g was determined from the temperature where the slope in G' changed significantly, as described by Laaksonen and Labuza (2007). The T_g was reported as the onset temperature where the slope of G' just began to increase significantly, indicated by the highest correlation coefficient (R2), from the linear regression line of the initial storage modulus. The moisture contents of doughs were determined according to AACC Method 44-15 A (at 130°C for 60 min).

Statistical analysis: One-way ANOVA with Post-Hoc LSD spss test was used to form statistical grouping (α=0.01) using SPSS Statistics 22.0 (IBM Corp., New York, USA) was used to evaluate the difference among means.

**Results and Discussion**

**Mixing properties**

When mixed at 35°C by using a farinograph, addition of emulsifier was as expected affected the mixing properties of zein-starch doughs (Table 1). Water absorption decreased for all dough with emulsifiers and the change was greater with higher emulsifier addition. The development time of doughs with added SSL was more prolonged than that of with added PATCO®. Previous finding in wheat dough also showed the same evident of decreasing in water absorption due to addition of SSL (Gómez et al., 2004).

The time needed to dough development was prolonged by SSL and PATCO®, and the effect was more pronounced with increasing emulsifier concentration. This result agrees with previous findings showing that SSL increased the mixing time of wheat dough (Lang et al., 1992, Gómez et al., 2004). In the case of ionic surfactants, this effect could be attributed to their ability to form complexes with proteins through their charge interaction, inducing protein-protein aggregation that could retard the dough development (Keller et al., 1997). PATCO® is commercial emulsifier containing SSL and CSL in ratio of 50%:50% (as informed by the supplier).
Likewise SSL, CSL is categorized as ionic surfactant, it is therefore assumed to have the same effect in water absorption and dough development as SSL.

Table 1 Effect of emulsifier on mixing properties

<table>
<thead>
<tr>
<th></th>
<th>Water absorption (%)</th>
<th>Development Time (min)</th>
<th>Water absorption (%)</th>
<th>Development Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>75</td>
<td>2.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P-4</td>
<td>64.5</td>
<td>4</td>
<td>S-2</td>
<td>56.3</td>
</tr>
<tr>
<td>P-5</td>
<td>63.2</td>
<td>4.7</td>
<td>S-3</td>
<td>54.1</td>
</tr>
<tr>
<td>P-6</td>
<td>60.3</td>
<td>4.7</td>
<td>S-4</td>
<td>51.9</td>
</tr>
</tbody>
</table>

Glass transition profiles were obtained for each sample to study the influence of emulsifier on zein-starch dough’s glass transition behavior (Figure 2 and Table 3). Figure 2 shows typical changes in the dynamic-mechanical properties of the zein-starch dough. A significant increase in the G’ can be observed by looking at the linear regression line. This change in G’ expressed the T_g of the material as when the material is cooled down, at the glass transition, a material becomes hardened and its ability to store energy is partially increased resulting in higher G’ (Nikolaidis and Labuza 1996; Laaksonen and Labuza 2001).

Both PATCO® and SSL clearly showed the plasticizing effect of emulsifier, as shown by lower T_g (Table 3), and the greater effect was more obvious with higher level of emulsifier. Those observations mentioned above were also in line with the finding of di Gioia and Guilbert (1999) showing that the addition of di-acetyl tartaric ester of monoglyceride (DATEM), which is also anionic emulsifier, in corn-protein based thermoplastic resins could depress the T_g. Furthermore, the control and all samples containing emulsifiers exhibited significantly different dough moisture contents (P<0.01) (Table 2). With a significant decrease (P<0.01) in moisture content between the control, P-4 and P-5 doughs, the T_g of those samples occurred at close temperatures while for the rest of samples (P-6, S-2, S-3 and S-4), lower T_g were observed with decreased moisture contents (P<0.01). The T_g depression was more pronounced at substantial decrease in moisture content. Water is an important plasticizer of many biopolymers and the glass transition of various cereal polymers have been widely studied as a function of water content which is typically that the lower water content, the higher the T_g (Laaksonen and Labuza 2001). However, in this case, the similar T_g occurred at lower water content, thus, this finding still demonstrated the decreasing T_g as a function of water.

Table 2 Glass transition temperatures (T_g) of zein-starch doughs with different

<table>
<thead>
<tr>
<th>% dough moisture (wb)</th>
<th>T_g (°C)</th>
</tr>
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<tbody>
<tr>
<td>Control</td>
<td>46.35 ± 1.12  a</td>
</tr>
<tr>
<td>P-4</td>
<td>43.62 ± 0.18  b</td>
</tr>
<tr>
<td>P-5</td>
<td>42.90 ± 0.22  b</td>
</tr>
<tr>
<td>P-6</td>
<td>41.13 ± 0.49  c</td>
</tr>
<tr>
<td>S-2</td>
<td>40.88 ± 0.30  c</td>
</tr>
<tr>
<td>S-3</td>
<td>38.90 ± 0.21  d</td>
</tr>
<tr>
<td>S-4</td>
<td>37.34 ± 0.07  e</td>
</tr>
</tbody>
</table>

Means followed by different letters within the same column were significant differences (P≤0.01)

Figure 2 Example rheometer profile for zein-starch dough containing emulsifier (P-6).
Summary

The emulsifiers influenced the mixing properties of zein-starch doughs, as indicated by distinctly lower water absorption and longer mixing time. While effects of emulsifier on the Tg of zein-starch doughs confirmed that zein-starch doughs are plasticized by emulsifier, resulting in a decrease in Tg. The study could help to mix viscoelastic gluten-free dough at room temperature.

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Literature cited


