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Effect of *trans*-fat free shortening and temperature on the rheological characteristics of pie crust dough and quality of pie crust

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Abstract

This research purpose was to evaluate the effect of *Trans*-fat free shortening and temperature on the rheological characteristics of pie crust dough and quality of pie crust. Lubricated squeezing flow techniques were used to evaluate the rheological characteristics of pie crust dough prepared from *Trans*-fat free shortening and commercial shortening. The relationship between biaxial extensional viscosity and biaxial extensional strain rate of both shortenings can be described by a power-law model with a biaxial consistency coefficient (K_B) of 14.63$\pm$3.07 and 8.13$\pm$2.07 kPa.s as well as a flow behavior index (n) of 0.31$\pm$0.09 and 0.32$\pm$0.07, respectively. The pie crust dough from each shortening prepared at 5 temperature levels (5, 10, 15, 20 and 25 °C) showed all extensional thinning behaviors. The biaxial consistency coefficient of pie crust dough from commercial shortening at every temperature level showed significantly higher than the one from *Trans*-fat free shortening. However the flow behavior index of pie crust dough from commercial shortening prepared at 25°C (0.34$\pm$0.10) was not significantly different from *Trans*-fat free shortening prepared at 10 and 15°C. The hardness and fracturability of pie crust was then evaluated by Texture Analyzer and found that the hardness of pie crust from commercial shortening was greater than from *Trans*-fat free shortening for each temperature from 5-25°C. Nevertheless the fracturability of pie crust with commercial shortening at 5-25 °C was not significantly different from the pie crust with *Trans*-fat free shortening at 10, 15 and 20 °C.

Keywords: pie crust, shortening, *trans*-fat, squeezing flow, rheology

1. Introduction

Pie crust is a kind of pastry which has low moisture content and high fat level. Wheat flour, fat and water are main ingredients which affected overall features after baking pie crust. Protein contents in wheat flour determined the strength of gluten in baking products. If wheat flour has low protein contents, the structure of baked pie crust is weak and easy to crumble and texture is coarse. In the other hand if wheat flour has high protein contents, structure of baked pie crust is compact and texture is dry. Moreover fats contribute tenderness, crispiness and shortness.

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Besides it can improve flavor and texture and extend shelf life of pie crust by coating starch granules thus it inhibits the re-association of starch molecules during retrogradation (Yvonne, 2008). The cold water helps disperse the ingredients thoroughly and also control temperature during mixing thus shortening does not melt which resulted in flakiness of pie crust (Pyler, 1982). The good characteristics of pie crust are tenderness and flakiness hence the production of pie crust has to use low protein flour, increase the amount of fat in formula and minimize added water.

Functions of fat in bakery products are various depending on product types. For instance: In biscuit, fat acts as an aid in lubricating ingredients during mixing and prevents the gluten structure in dough as well (Manohar and Rao, 1999). In puff pastry, fat helps developing and improving properties of dough and also helps to lift the layers of puff pastry (Simovic et al., 2009). In cookie, fat acts as provider in flavor and texture of the product, helps lubricating ingredients during mixing and prevents the gluten structure in dough (Jacob and Leelavathi, 2006). In pie crust, fat acts as provider in tenderness by coating the structure builders such as gluten and starch in order to prevent this contact with water and also helps building the structure (Figoni, 2008). Sudha et al. (2007) reported that the reduction of fat levels in biscuit dough affected dough rheological properties. As the fat level decreased from 20% (control) to 10%, 8% and 6%, the dough hardness increased from 20.78 N to 44.08 N. In addition, the fat replacer such as maltodextrin and polydextrose with glycerol mono stearate and guar gum was found to make the biscuit texture significant decreased the hardness of biscuit ($p \leq 0.05$). Yvonne (2008) studied the properties of mango pie containing a papaya derived fat replacer and found that the reduced-fat treatment was not significantly different ($p>0.05$) from the full-fat control in most sensory attributes. Moreover, the texture profile analysis result indicated that the reduced-fat treatment was not significantly different ($p > 0.05$) in hardness from the full-fat control but the fracturability was significantly different ($p \leq 0.05$).

Fat that usually used to produce pie crust is shortening which is the secondary amount of the wheat flour. Shortening is made from vegetable oils or animal fats or blended with vegetable oils and animal fats that hydrogenated in double bonds of unsaturated fatty acid in order to transfer liquid phases to solid phases at room temperature that called plastic fat.

Most of the components in shortening are *Trans*-fat which is harmful to the body (Rattanapanon, 2005). Craig-Schmidt (1992) reported that shortening that produced from vegetable oil has amount of *Trans*-fat 8-23% of total fatty acid. *Trans*-fatty acid is unsaturated fatty

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acid which compounded with one double bond or more than one bond in structure. *Trans*-fatty acid found in hydrogenated oil which characteristic is semi-solid, high ability to oxidation. Generally Hydrogenated oil is used in food industry such as margarines, fried products and baking products (Kuhnt et al., 2011) which is dangerous to the body. When the body has got in large quantities, it leads to the risk of heart diseases since *Trans*-fatty acid will increase levels of Low Density Lipoprotein Cholesterol (LDL) and decrease levels of High Density Lipoprotein Cholesterol (HDL). Additionally *Trans*-fatty acid will increase Lipoprotein and levels of Triglycerides which caused an increase in the risk of heart disease (Simovic et al., 2009).

Pie crust contains 30-40% shortening (Jammek and Naiwikul, 2011) which contributes especially to *Trans*-fat (8-23%) to consumers. If the hydrogenated shortening can be totally replaced with *Trans*-fat free shortening in pie crust, it would help reduce in the risk of coronary heart disease. Therefore, was working on the application of *Trans*-fat free shortening in biscuit (Handa et al., 2010). The result showed that the hardness of biscuit using interesterified *Trans* free bakery shortening was significantly ($p \leq 0.05$) less hard, had a higher spread ratio and was rated higher on all sensory attributes. Their overall acceptability score on a nine point hedonic scale was 8.2 ± 0.8 as compared to 7.3 ± 0.7 for control biscuits from hydrogenated shortening.

Although there was a limited work on the application of Trans fat free shortening in biscuits, none of the reviewed work was found on the application of *Trans*-fat free shortening in pie crust. Since the *Trans*-fat free shortening from rice bran oil has lower melting point of 39-40 °C and different solid fat index as compared to hydrogenated vegetable shortening whose melting point was 43-52 °C (Figoni, 2008), the application of *Trans*-fat free shortening in pie crust was then needed for further studying especially the effect of temperature during dough preparation on the pie crust quality. The objectives of this study were then to study the rheological properties of *Trans*-fat free shortening comparing with hydrogenated vegetable shortening and to study the effect of temperature on the rheological characteristics of pie crust dough and quality of pie crust.

2. Materials and Methods

Materials

Commercially Bread flour (White swan®) and Cake flour (Royal fan®) were obtained from United Flour mill Public Co., Ltd., Thailand. Hydrogenated Shortening (Zest®) was provided by Lam soon Public Co., Ltd., Thailand. *Trans*-fat free shortening from rice bran oil (King®) was

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provided by Thai Edible Oil Co., Ltd., Thailand (36.8% of Saturated fat, 0 gram of *Trans*-fat and 0% of Cholesterol) Salt, Cold water

Preparation of pie crust dough

Pie crust dough was prepared according to Jammek and Naiwikul (2011). The dough formulation consisted of 100% Flour (Bread flour: Cake flour=1:1 by weight), 50% Shortening, 1.5% Salt and 30% Cold water. The bread flour and cake flour were sifted to break up any clumps and to add air to the flour in order to produce lighter pie crust. Cut the shortening into mixed flour using pastry blender until it is the size of green bean. Added the chilled water with dissolved salt one tablespoon at a time and mixed gently with pastry blender after each addition.

Preparation of sample for squeezing flow analysis

The sample was moulded to cylindrical shape (50 mm diameter and 25 mm height). After the cylindrical sample was removed from the mould, let the stress in the sample relaxed for 10 minutes before applying the squeezing flow analysis.

Squeezing flow method

The sample was placed on the platform of a Texture Analyzer (Stable Micro System, TA-XT2i) directly under an aluminum plate (50 mm. in diameter). The samples were lubricated with vegetable cooking oil to minimize frictional effects, to ensure extensional deformation only and compressed 70% of their initial height. The force F in Newton was measured. Test conditions were a pre-test speed of 1 mm. s^{-1}, post-test speed of 10 mm.s^{-1} and the cross head speed of 0.1 mm.s^{-1} (Limanond et al., 1999).

Pie crust production

The dough was sheeted to 5 mm thickness and cut to 55 mm diameter by circular cutter. The dough sheet was then baked for 15 min at 200 °C in a baking oven (Union Progress Ltd., E100, Thailand). The pie crusts were left at 25 °C to cool down for 15 min and then evaluated for hardness and fracturability by a Texture Profile Analyzer (Stable Micro System, TA-XT2i).

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Texture measurement of pie crust

Three-point bend test was performed to measure the hardness and fracturability of pie crust using Texture Analyzer (Stable Micro System, TA-XT2i), equipped with the three-point bending rig (HDP/3PB) (Mamat and Hill, 2012). The span between the supports was 40 mm. Test conditions were a pre-test speed of 1.0 mm/s, test speed of 3.0 mm/s, post-test speed of 10.0 mm/s and distance of 10 mm. The load cell used was 1 kg. The maximum force and the distance to break off the sample were recorded and were referred to as the hardness of pie crust. The distance at the point of break is the resistance of the sample to bend and so relates to the fracturability of the pie crust. An average value of 5 replicates was reported.

2.1 Studying the rheological properties of *Tran*s-fat free shortening and commercial shortening

The biaxial consistency coefficient (K_B) and flow behavior index (n) of commercial shortening and *Trans*- fat free shortening were analyzed by squeezing flow method. The experimental design was a completely randomized design (CRD) with three replications for each. Statistical analysis was performed using software SPSS 17 for windows version to calculate means$\pm$SD of values measured for each sample. Analysis of variance (ANOVA) with the least significant difference test (LSD-test) was applied. The level of significance used was 95% ($P < 0.05$).

2.2 Studying the effect of temperature on the rheological characteristics of pie crust dough and quality of pie crust

The pie crust dough prepared from commercial shortening and *Tran*s-fat free shortening were incubated in a refrigerator so that it reached the temperature of 5, 10, 15, 20, and 25 °C. The biaxial consistency coefficient (K_B) and flow behavior index (n) of the pie crust dough were analyzed by squeezing flow method in three replications. The hardness and fracturability of pie crust prepared from baking pie crust dough at each temperature was further evaluated using three-point bend test as mentioned above. The experimental design was a 2×5 Factorial in CRD with three replications for each. Statistical analysis was performed using software SPSS 17 for windows version to calculate means$\pm$SD of values measured for each sample. Analysis of variance (ANOVA) with the least significant difference test (LSD-test) was applied. The level of significance used was 95% ($P \leq 0.05$).

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3. Results and Discussion

3.1 Studying the rheological properties of *Trans*-fat free shortening and commercial shortening

According to the analysis of the relationship between σ_B (biaxial stress, Pa) and $\acute{\varepsilon}_B$ (biaxial strain rate, 1/s) of *Tran*s-fat free shortening and commercial shortening, the parameters K_B and n as calculated from Eqn [3] are shown in Table 1.

Table 1. Biaxial consistency coefficient (K_B) and flow behavior index (n) of *Tran*s-fat free shortening and commercial shortening.

Shortening	Mean $\pm$ SD	
	K_B (kPa.s)	n [ns]
Commercial shortening	14.63±3.07[b]	0.31±0.09
Trans- fat free shortening	8.13±2.07[a]	0.32±0.07

[a, b…] Values with the different letter within the same column are significantly different (p < 0.05).

[ns] Not significantly different (p>0.05).

As seen in Table 1, the biaxial consistency coefficient of commercial shortening is significantly greater than the *Trans*- fat free shortening ($p \leq 0.05$). This result indicated that the consistency of commercial shortening was higher than the *Tran*-fat free shortening. Since the *Trans*-fat free shortening has lower melting point of 39-40 °C as compared to hydrogenated vegetable shortening whose melting point was 43-52 °C, the shortening with higher melting point therefore showed more solid-like behavior than the one with lower melting point at the measurement temperature of 25 °C. However, the flow behavior index (n) of both shortening was not significantly different ($p > 0.05$). Since the flow behavior index (n) represents the change of viscosity at various strain rate. If its value is greater than 0 but less than 1, it means that the material behaves like the extensional thinning fluid. From Table 1, it is clearly shown that both shortenings have the same extensional thinning behavior.

3.2 Studying effect of temperature during relaxing dough in Physical of Dough pie crust and Pie crust

It can be seen from Table 2 that all the pie crust dough from each shortening prepared at 5 temperature levels (5, 10, 15, 20 and 25 °C) showed extensional thinning behavior (0<n<1). The consistency coefficient of pie crust dough from commercial shortening at any temperature showed significantly higher than the one from *Trans*-fat free shortening. However the flow behavior index of pie crust dough from commercial shortening prepared at 25 °C (0.34±0.10) was not significantly different from *Trans*-fat free shortening prepared at 10 and 15 °C

Table 2. Effect of shortening types and temperature on biaxial consistency coefficient (K_B) and flow behavior index (n) of pie crust dough.

Shortening	Mean ± SD		
	Temperature (°C)	**K (kPa.s)**	**n**
Commercial shortening	5	62.42[c]±10.35	0.20[a] ±0.06
	10	62.23[c]±5.31	0.16[a] ±0.03
	15	45.64[b]±3.74	0.15[a] ±0.03
	20	46.89[b]±11.92	0.25[abc]±0.02
	25	47.74[b]±14.00	0.34[cd] ±0.10
Trans- fat free shortening	5	25.44[a]±4.58	0.21[ab] ±0.40
	10	26.79[a]±5.33	0.32[cd] ±0.80
	15	24.47[a]±4.82	0.32[bcd] ±0.60
	20	28.82[a]±5.42	0.40[de] ±0.07
	25	31.87[a]±5.57	0.48[e] ±0.04

[a, b, c…] Values with the different letter within the same column are significantly different ($p \leq 0.05$).

Table 3 shows the effect of shortening types and temperature on hardness and fracturability of pie crust. It was found that both of the shortening types and temperature affected the hardness and fracturability of pie crust. As the temperature of pie crust dough increased, the hardness of pie crust from both shortening increased. However, the hardness of pie crust with commercial shortening was greater than the hardness of pie crust with *Trans*-fat free shortening at every temperature level. This result was in agreement with the research work of

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Handa et al.(2010) in that the biscuits made of interesterified *Trans* free bakery shortening were significantly less hard and had a higher spread ratio than the hydrogenated shortening. The fracturability of pie crust with commercial shortening prepared at every temperature was significantly different from the fracturability of pie crust with *Trans*-fat free shortening except at the temperature of 5 and 25 °C.

Table 3. Effect of shortening types and temperature on hardness and fracturability of pie crust.

Shortening	Mean ± SD		
	Temperature (°C)	**Hardness(g)**	**Fracturability(mm)**
Commercial shortening	5	726.807[a]±63.7	1.49[a]±0.47
	10	855.211[a]±70.3	1.62[a]±0.33
	15	1479.812[c]±119.8	1.57[a]±0.11
	20	2607.700[b]±484.4	1.84[a]±0.47
	25	3045.329[d]±495.1	1.88[a]±0.07
Trans- fat free shortening	5	560.690[a] ±29.2	2.94[b] ±1.22
	10	604.105[a] ±98.9	1.66[a] ±0.56
	15	700.906[a] ±113.3	1.71[a] ±0.18
	20	669.414[a] ±37.0	1.91[a] ±0.11
	25	635.104[a] ±18.9	5.07[c] ±0.85

[a, b, c…] Values with the different letter within the same column are significantly different ($p \leq 0.05$).

As of the result from dough rheological properties and pie crust from both shortening types at each temperature level, it can be concluded that the pie crust dough from *Trans*-fat free shortening should be prepared at 10 or 15 °C in order to have the similar flow behavior index as the dough from commercial shortening at 25 °C. However, no pie crust dough from *Trans*-fat free shortening at any temperature had the similar biaxial consistency coefficient as the dough from commercial shortening. Even though the fracturability of pie crust prepared from *Trans*-fat free shortening was not significantly different from the one from commercial shortening, the hardness of *Trans*-fat free pie crust was still less than the commercial one. Therefore, the addition of emulsifier such as lecithin (Manohar and Rao, 1999) or DATEM (Diacetyltartaric Esters of Monoglycerides) (Hadaegh et al., 2011) should be considered to apply to the pie crust formula in

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order to develop the *Trans*-fat free pie crust so that it had almost the similar properties as to the commercial one.

4. Conclusion

The relationship between biaxial stress and biaxial extensional strain rate of commercial shortening and *Trans*-fat free shortening can be described as a power-law model with a biaxial consistency coefficient (K_B) of 14.63±3.07 and 8.13±2.07 kPa.s, respectively. The flow behavior index (n) of both shortenings showed extensional thinning behavior with the value of 0.31-0.32. The pie crust dough prepared from both shortenings at 5 different temperature levels from 5-25 °C was evaluated using squeezing flow method. It was found that the relationship between biaxial stress and biaxial extensional strain rate was also a power-law model with extensional thinning behavior. The biaxial consistency coefficient (K_B) of commercial shortening showed a greater value than *Trans*-fat free shortening at every temperature level. However, the flow behavior index (n) of pie crust dough with commercial shortening at 25 °C was not significantly different from the one with *Trans*-fat free shortening at 10 and 15 °C. As the dough temperature increased from 5 °C to 25 °C, the hardness of pie crust prepared from both shortening increased. The fracturability of pie crust with commercial shortening at 25 °C was almost the same as the one with *Trans*-fat free shortening except at the temperature of 5 and 25 °C.

This study demonstrated that the preparation of pie crust dough from *Trans*-fat free shortening should be done at 10-15 °C in order to obtain the similar flow behavior index of pie crust dough and also the similar fracturability of pie crust from the commercial one at 25 °C. However, the pie crust from *Trans*-fat free shortening was lower in hardness as compared to the commercial shortening at every temperature level of pie crust dough preparation. Therefore the incorporation of emulsifiers in the pie crust formulation will be one of the alternative choices in order to improve the rheological characteristics of pie crust dough and quality of pie crust in the future study.

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