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Influence of vegetable shortening and emulsifiers on the unfrozen water content and textural properties of frozen French bread dough

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Abstract

The influence of vegetable shortening (VS) and emulsifiers (calcium stearoyl-2-lactylate (CSL) and polysorbate 80 (PS80)) on frozen French bread dough has been studied. Eight formulations without yeast were used with different quantities of VS, CSL and PS80. Dough was prepared by mixing all ingredients in a dough mixer at two speeds. The fresh dough was divided into 60 g pieces and molded. Fresh dough samples were also collected for water content and textural analyses. The dough pieces were packed, frozen in a freezer at −30°C and stored at −18°C up to 56 days. After 2, 7, 21, 28 and 56 days of frozen storage, samples were removed from the freezer, thawed at ambient temperature and textural analyses were conducted.

The enthalpy of freezable water on fresh bread dough was determined by Differential Scanning Calorimetry (DSC) at the heating rate of 3°C/min, temperature range of −40°C to 20°C. The value of unfrozen water was 0.30–0.34 g H_2O/g solids and additives used during the storage up to 56 days significantly affected the textural properties of frozen dough.

Keywords: Frozen dough; French bread; DSC; Textural properties

1. Introduction

French bread production represents 85% of the total amount of bread produced in Brazil (Nutrinews, 1999). A typical French bread in Brazil should be 12.5 cm long, 5.5 cm diameter, 50 g of final weight, with a brown and glossy crust, a white and soft crumb with a unique cut largely following the length of the dough piece made before baking (Carr & Tadini, 2003).

French bread can be available from frozen part-baked or frozen dough. The rise in popularity of frozen baked goods has been driven mainly by economic attraction of centralized manufacturing and distribution (Best, 1995). These products do not demand specialized workers and have the possibility to make available "fresh" bread at any time at the store. Frozen part-baked French bread has shorter time of preparation in the store (about 12 min) than frozen dough (3–4 h) due to proofing. However, the volume occupied by frozen bread dough in transport and storage is much smaller than frozen part baked bread (Klimaquip, 2003).

The quality of bread made from frozen dough is influenced by dough formulation and also processing parameters. Havet, Mankai, and LeBail (2000) studied the influence of freezing conditions on the baking performance of French bread dough and they reported a decrease in bread quality and dough resistance to extension when freezing rate was increased (1–3 m/s air speed of an blast air freezer at −20°C). LeBail, Havet, and Hayert (2001) verified that short freezing, in a blast air freezer (−30°C, 4 m/s) until the temperature at the center of dough, formulated with a strong wheat flour, just past the freezing plateau (−5°C), produced a higher specific volume on French bread than a long freezing, when the temperature at the center of pieces formulated with weak flour was below the plateau (−15°C). The freezing was completed in a storage cabinet at −20°C and stored for 7 days.

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Rouillé, LeBail, and Courcoux (2000) studied the influence of formulation and mixing conditions on bread-making qualities of French frozen dough. The effects of ascorbic acid, alpha amylase with hemicellulase activity and mixing time were investigated. The bread volume was measured and they concluded that mixing time was the most influential factor conditioning bread quality. The longer mixing time resulted in larger volumes.

Rouillé et al. (2000) cited studies in which an increase of extensigraph resistance and decrease in extensibility of dough subjected to two freezing–thaw cycles was observed.

Wolt and d'Appolonia (1984) studied the influence of dough additives on frozen dough stability. Sodium stearoyl lactylate (SSL) and diacetyl tartaric acid decreased the effects of frozen storage on rheological properties, but they were not effective in reducing the dough proofing time. Ribotta, Léon, and Añon (2001) reported that frozen dough supplemented with diacetyl tartaric acid ester of monoglycerides (DATEM), gluten and guar gum produces bread of greater volume and more open crumb structure than those prepared with the basic formulation. Kenny, Wehrle, Dennehy, and Arendt (1999) verified that frozen dough with SSL, DATEM and ascorbic acid after frozen storage presented higher resistance to extension. The authors verified a decrease in resistance to extension due to freezing.

Water, as ice, separates out during freezing and the solute concentration of the unfrozen phase in contact with it increases when temperature decreases. After a certain concentration of unfrozen phase, no more ice separates. This is the maximum freeze concentration of unfrozen phase and it becomes so viscous that it turns into a glass. The glass transition temperature is a time-dependent change in physical state from glassy to a rubbery viscous liquid, and it occurs in a temperature range (Laaksonen, 2001) and can be determined by differential scanning calorimetry (Harwalkar & Ma, 1990). Unfrozen water content is the water present in the unfrozen phase.

Roman-Gutierrez, Guilbert, and Cuq (2002) determined the unfrozen water in two different flours and their main components, gluten and starch, using DSC. The calculated unfrozen water was 29–32% (db) in flour, 38–47% in gluten and 38–42% in starch. The simple summation of the contribution of each component cannot be used to estimate the overall behavior of flour. Bhattacharya, Langstaff, and Berzonsky (2003) verified the effects of prolonged frozen storage on frozen dough and repeated partial freeze–thaw cycles on the rheological and baking properties of wheat cultivars. The dough was subjected to frozen storage at $-23^{\circ}C$ for 4–12 weeks with and without freeze–thaw cycles. The enthalpy of freezable water was significantly affected by initial freezing, whereas the rheological properties of the dough were more susceptible to freeze–thaw cycles than to frozen storage. Lu and Grant (1999) studied the effects of prolonged frozen storage on the rheological and baking properties of dough from four wheat cultivars. The freezable water was determined in DSC for 16 weeks. The authors suggested that the initial freezing and subsequent frozen storage of the dough changed the amount of freezable water. The amount of freezable water increased as frozen storage time increased until the 8th week, then it began to decrease slowly until the 16th week for most wheat cultivars. Migration of water, which occurs during freezing process and continues during frozen storage, would offer an opportunity for additional intermolecular and intramolecular protein bounding that might change irreversibly the gluten structure.

The objective of this project was to study the influence of vegetable shortening (VS), calcium stearoyl-2-lactylate (CSL) and polysorbate 80 (PS80) on unfrozen water of French bread dough and on textural parameters of frozen bread dough stored up to 56 days at $-18^{\circ}C$, after freeze–thaw cycle.

2. Materials and methods

Eight formulations were used to produce French bread dough with different vegetable shortening (VS), polysorbate 80 (PS80) and calcium stearoyl-2-lactylate (CSL) quantities, as listed in Table 1. A commercial bakers' flour with water content of 14.3% and farinograph water absorption of 63.0% was used for all formulations.

All ingredients, except the salt, were mixed in a mixer for complete water absorption at low speed. After that, salt was added and the dough was mixed at a high speed until its complete development. The final temperature of the dough was monitored. Yeast was not added because the goal of this study was to determine only the influence of selected additives on dough.

After mixing, the dough was divided into 60 g pieces, molded and packed in polyethylene bags, immediately frozen in a freezer (FANEN 349FV, Brazil) at $-30^{\circ}C$ and stored at $-18^{\circ}C$ for 56 days.

Samples of fresh bread dough were collected for DSC, textural and water content analysis. After 2, 7, 21, 28 and 56 days of frozen storage, samples removed from the freezer were thawed at ambient temperature for textural analyses.

2.1. Water content determination

The water content of the French bread dough was determined according to AACC 44-15A in replicates

Table 1
Ingredients used to produce frozen French bread dough from eight different formulations

Ingredients	Formulation (g)							
	0	1	2	3	4	5	6	7
Wheat flour	2500.0	2500.0	2500.0	2500.0	2500.0	2500.0	2500.0	2500.0
Water	1425.0	1425.0	1425.0	1425.0	1425.0	1425.0	1425.0	1425.0
Salt	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
VS	0.0	50.0	0.0	0.0	25.0	25.0	0.0	50.0
CSL	0.0	0.0	12.5	0.0	6.3	0.0	6.3	12.5
PS80	0.0	0.0	0.0	7.5	0.0	3.8	3.8	7.5

VS: vegetable shortening; CSL: calcium stearoyl-2-lactylate; PS80: polysorbate 80.

Table 2
Values of water content (w_{tot}), enthalpy, T_{onset}, T_{peak} and unfrozen water content (UFW) from ice-melting curves of frozen dough according to formulation

	Formulation								
	0	1	2	3	4	5	6	7	Tukey HSD 5%
w_{tot} (g H_2O/100 g sample)	43.93^{d}	43.01^{a}	43.51^{bcd}	43.62^{cd}	43.26^{abc}	43.47^{abcd}	43.17^{ab}	43.08^{a}	0.37
Enthalpy (J/g)	−85.62	−87.09	−89.61	−90.08	−88.24	−88.87	−84.72	−78.41	
T_{onset} (°C)	−5.72	−5.54	−5.47	−5.53	−5.23	−5.37	−5.40	−4.24	
T_{peak} (°C)	−1.21	−1.41	−1.17	−1.07	−1.36	−1.32	−1.09	−0.75	
UFW (g H_2O/g solids)	0.326	0.297	0.295	0.296	0.297	0.298	0.314	0.344	

Averages with the same letter, in the same row, are not significantly different at 95% confidence interval.

(AACC, 1995). This analysis provided the total amount of water of the dough (w_{tot}).

2.2. Thermal analysis

Ice-melting curves were obtained using a DSC. The fresh dough samples were frozen up to −40°C at a freezing rate of −3°C/min and then heated at a rate of 3°C/min from −40°C to 20°C in a medium pressure pan (120 μl) (DSC 822^{e} Module—Mettler Toledo, Switzerland). The DSC apparatus was calibrated with In metal (m.p. 156.61°C; $\Delta H = 28.54$ J/g).

Unfrozen water content, UFW (g H_2O/g solids) was obtained from the relationship between the latent heat of ice melting (ΔH_m, J/g solids) and total water content (g/g solids) using Eq. (1) (Laaksonen & Ross, 2000):

$$UFW = \frac{w_{tot} - \Delta H_{tot}/\Delta H_{mw}}{C_{tot}}, \quad (1)$$

where w_{tot} is the total amount of water (g), ΔH_{tot} is the total heat of melting of ice (J), ΔH_{mw} is the latent heat of ice melting (334 J/g), and C_{tot} is total amount of solids (g). $\Delta H_{tot}/\Delta H_{mw}$ is the amount of ice (g) in the sample.

2.3. Textural analyses

A texture analyzer TA-XT2i (SMS, England) equipped with A/KIE dough and gluten extensibility rig accessory was used to measure the extensibility and resistance to extension of fresh and frozen dough. Pieces of frozen dough were removed from the freezer and thawed at ambient temperature. The analyses were carried out according to the *Extensibility of Dough and measure of Gluten quality* method (SMS, 1995). The thawed dough was placed into a Teflon-coated block, and cut into dough strips using the appropriate mold. The test was conducted under the following conditions: pre-test speed 2 mm/s, test speed 3.3 mm/s, post-test speed 10 mm/s, distance 75 mm and trigger type auto 5 g.

3. Results and discussion

Analysis of variance (ANOVA) was applied within 95% confidence interval to the results obtained for water content, and they are presented according to the formulation in Table 2.

The total water content (w_{tot}) was influenced significantly by VS and CSL and formulations 1 and 7, with higher quantities of VS presenting lower w_{tot}, as expected. The values obtained for enthalpy, T_{onset} and T_{peak} for ice melting on DSC curves (Fig. 1) and unfrozen water are also presented in Table 2. The enthalpy varies from −78.41 J/g for formulation 7 to −90.08 J/g for formulation 3. T_{onset} and T_{peak} presented similar results and no other transition, such as glass transition, was observed on DSC curves; the same was observed by Laaksonen et al. (2000). However, Levine and Slade cited by Laaksonen et al. (2000) reported that glass transition temperature for different frozen dough systems occurred in the −10°C to −30°C temperature range. The method (heating rate, initial temperature of analysis) or equipment used could not be adequate for the glass transition determination. DSC is not the best choice in thermal analysis to determine glass transition in foods, but it is much used because it is easier than dynamic thermal mechanic analysis (DTMA).

Unfrozen water content (UFW) varied from 0.295 g H_2O/g solids for formulation 2 to 0.344 g H_2O/g solids for formulation 7 and the ANOVA indicated that additives (VS, CSL and PS80) did not significantly influence the results, as expected, because none of them took part in the remaining solution. Usually, ingredients that take part in UFW in dough are sugars and salts.

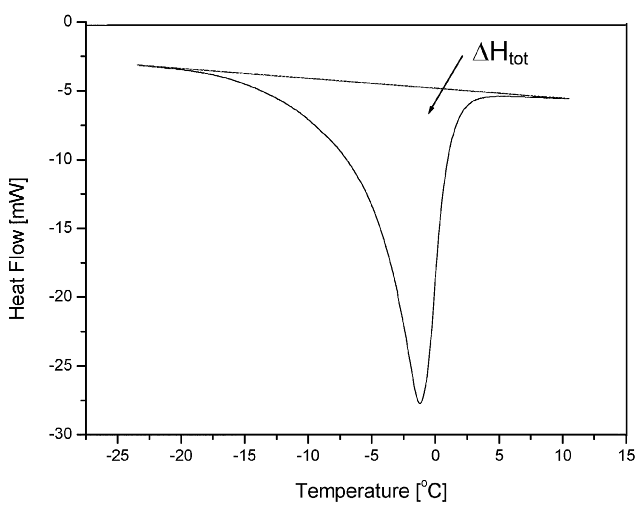

Fig. 1. A DSC thermogram for formulation 0.

UFW contents obtained in this work were similar to those obtained by Roman-Gutierrez et al. (2002), which were 0.29–0.32 g H_2O/g solids for two different flours, as expected because dough is formed mainly by flour and water and these results are expressed in dry base, and by Laaksonen et al. (2000), which verified an UFW of 0.35 g H_2O/g solute for frozen dough.

Analysis of variance (ANOVA) was applied within 95% confidence interval to the results obtained in textural analyses, and they are presented according to formulation and storage time in Table 3.

Tendency of resistance to extension and extensibility for each formulation were not totally clear like those described by Bhattacharya et al. (2003); these authors studied nine flours selected for their high gluten strength and verified an increase in resistance to extension during the frozen storage at −23°C up to 4 weeks, while extensibility had no statistically significant difference on the same period. Lu et al. (1999) verified that resistance to extension of four hard spring wheat cultivars, determined by farinographic method, decreased after 4 weeks of frozen storage at −23°C. These authors also reported that there was migration of water during the frozen storage that might change the gluten structure.

In this work, the ANOVA was applied to textural parameters as a function of storage time. It can be observed in Fig. 2 that resistance to extension increased after 2 days of frozen storage and after day 7. The extensibility of dough has increased with increasing storage period up to 56 days. Probably some change of gluten structure occurred due to water migration.

Resistance to extension was influenced by CSL, PS80 and storage time and extensibility was influenced by VS,

Table 3
Resistance to extension and extensibility of frozen French bread dough according to formulation and frozen storage up to 56 days

Time (days)	Formulation								
	0	1	2	3	4	5	6	7	Tukey HSD 5%
Resistance to extension (N)									
0	0.488^{aB}	0.396^{aA}	0.478^{bB}	0.545^{cC}	0.578^{bC}	0.460^{bB}	0.461^{aB}	0.640^{bD}	0.043
2	0.589^{bC}	0.498^{bAB}	0.404^{aA}	0.717^{dD}	0.452^{aAB}	0.520^{cBC}	0.536^{bBC}	0.774^{dE}	0.079
7	0.453^{aB}	0.379^{aA}	0.482^{bB}	0.380^{aA}	0.574^{bD}	0.494^{bcBC}	0.542^{bCD}	0.539^{aCD}	0.046
21	0.592^{bDE}	0.354^{aA}	0.654^{cE}	0.446^{bB}	0.454^{aB}	0.545^{cdCD}	0.490^{abBC}	0.725^{cdF}	0.061
28	0.561^{bC}	0.384^{aA}	0.487^{bB}	0.470^{bB}	0.474^{aB}	0.574^{dC}	0.504^{abB}	0.753^{dD}	0.049
56	0.501^{aB}	0.484^{bB}	0.653^{cC}	0.655^{dC}	0.499^{ab}	0.355^{aA}	0.689^{cC}	0.660^{bcC}	0.054
Tukey HSD 5%	0.043	0.062	0.043	0.060	0.056	0.046	0.064	0.066	
Extensibility (mm)									
0	17.837^{bcB}	15.339^{aA}	18.791^{bcB}	13.654^{aA}	14.649^{aA}	18.988^{bcB}	18.163^{aB}	18.689^{bB}	1.861
2	16.052^{abA}	16.372^{aA}	21.585^{cdB}	15.144^{abA}	20.346^{bcdB}	16.312^{abA}	16.429^{aA}	16.384^{abA}	2.683
7	14.614^{aA}	23.124^{cD}	19.159^{bcC}	23.001^{dD}	17.364^{abABC}	14.830^{aAB}	18.332^{aC}	17.817^{abBC}	3.159
21	15.031^{aAB}	18.173^{abC}	14.011^{aA}	16.706^{bcABC}	23.247^{dD}	17.346^{abABC}	17.660^{aBC}	15.597^{aAB}	2.880
28	16.611^{abA}	22.903^{cC}	18.058^{bAB}	19.600^{cABC}	21.267^{cdBC}	16.766^{abA}	17.836^{aAB}	17.147^{abA}	2.945
56	19.930^{cAB}	21.168^{bcB}	22.433^{dB}	19.292^{cAB}	19.994^{bcAB}	22.088^{cB}	16.635^{aA}	16.618^{abA}	3.682
Tukey HSD 5%	2.275	3.715	2.669	2.599	2.857	3.072	2.604	2.284	

Averages with same letter, in the same column and with the same capital letter, in the same line, are not significantly different at 95% confidence interval.

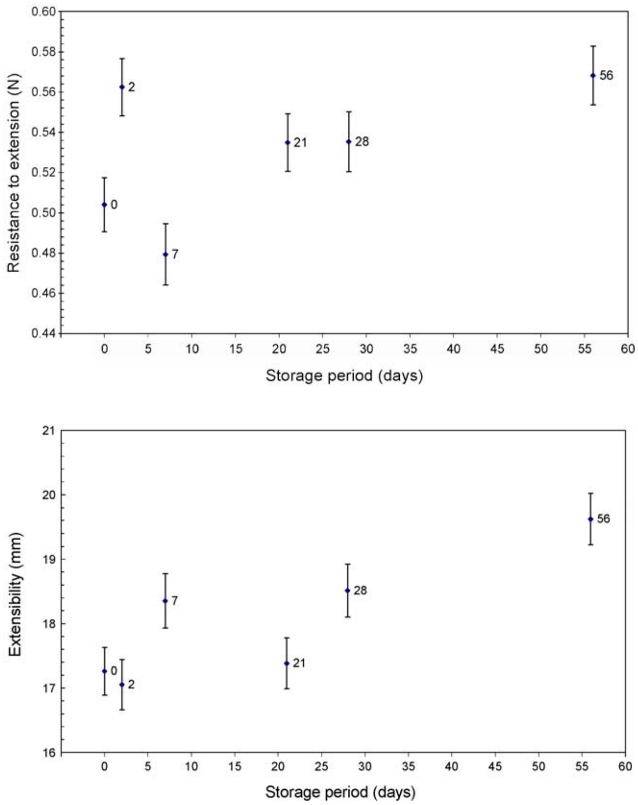

Fig. 2. Resistance to extension and extensibility of French bread dough according to frozen storage up to 56 days.

PS80 and storage time. Even VS did not influence resistance to extension; this parameter was slightly related to dough strength and it should be used because it is a important ingredient to give good results on bread texture, like firmness (Carr et al., 2003).

4. Conclusions

The influence of vegetable shortening (VS), calcium stearoyl-2-lactylate (CSL), polysorbate 80 (PS80) and frozen storage time on frozen French bread dough was studied.

Unfrozen water content (UFW) was not influenced by additives as expected, because the additives that had their quantities varied (VS, CSL and PS80) do not take part in UFW. Melting transition was verified but no other transition, such as glass transition, was observed on DSC curves.

Textural parameters changed during the period of frozen storage and according to formulation. Resistance to extension was also influenced by CSL and PS80.

To continue this research, it would be interesting to study different heating rates and lower initial temperature on DSC or other techniques should be used, such as Dynamic Thermal Mechanic Analysis, to determine glass transition and the study of baking process to obtain a correlation between rheological properties of dough and bread quality such as specific volume, textural and sensorial analysis.

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References

AACC (American Association of Cereal Chemists) (1995). *Approved methods of the American Association of Cereal Chemists* (9th ed.). Saint Paul.

Best, D. (1995). Economic potential of frozen and refrigerated doughs and batters. In K. Kulp, K. Lorenz, & J. Brümmer (Eds.), *Frozen and refrigerated doughs and batters* (pp. 1–18). Saint Paul, MN: AACC.

Bhattacharya, M., Langstaff, T. M., & Berzonsky, W. A. (2003). Effect of frozen storage and freeze–thaw cycles on the rheological and baking properties of frozen doughs. *Food Research International*, *36*, 365–372.

Carr, L. G., & Tadini, C. C. (2003). Influence of yeast and vegetable shortening on physical and textural parameters of frozen part baked French bread. *Lebensmittel-Wissenschaft und-Technologie*, *36*(6), 609–614.

Harwalkar, V. R., & Ma, C.-Y. (1990). *Thermal analysis of food* (pp. 500). Amsterdam: Elsevier Applied Science.

Havet, M., Mankai, M., & LeBail, A. (2000). Influence of the freezing condition on the baking performances of French frozen dough. *Journal of Food Engineering*, *45*, 139–145.

Kenny, S., Wehrle, K., Dennehy, T., & Arendt, E. K. (1999). Correlations between empirical and fundamental rheology measurements and baking performance of frozen bread dough. AACC. *Cereal Chemistry*, *76*(3), 421–425.

Klimaquip (2003). *Guia Klimaquip, Frio profissional*. Available in <http://www.klimaquip.com.br/guia_klimaquip.htm>, captured in Mach 2003.

Laaksonen, T. J. (2001). *Effects of ingredients on phase and state transition of frozen doughs*. Academic dissertation, University of Helsink.

Laaksonen, T. J., & Ross, Y. H. (2000). Thermal, dynamic-mechanical, and dielectric analysis of phase and state transitions of frozen wheat doughs. *Journal of Cereal Science*, *32*, 281–292.

LeBail, A., Havet, M., & Hayert, M. (2001). *Improvement of the baking performance of frozen dough by short freezing method*. Application to French baguette. IIF-IIR-Commission C2-BRISTOL-GB-2001.

Lu, W., & Grant, L. (1999). Effects of prolonged storage at freezing temperatures on starch and baking quality of frozen doughs. *Cereal Chemistry*, *76*(5), 656–662.

Nutrinews (1999). *Semi assados, a nova era da panificação*. Available in <http://www.nutrinews.com.br/edicoes/9905/mat01.html>, captured in January 2002.

Ribotta, P. D., León, A. E., & Añón, M. C. (2001). Effect of freezing and frozen storage of doughs on bread quality. *Journal of Agriculture and Food Chemistry*, *49*, 913–918.

Roman-Gutierrez, A. D., Guilbert, S., & Cuq, B. (2002). Frozen and unfrozen water contents of wheat flours and their components. *Cereal Chemistry*, *79*(4), 471–475.

Rouillé, J., LeBail, A., & Courcoux, P. (2000). Influence of formulation and mixing conditions on breadmaking qualities of French frozen dough. *Journal of Food Engineering*, *43*, 197–203.

SMS, Stable Micro Systems (1995). *TA-XT2 application study, extensibility of dough and measure of gluten quality, Texture expert guide contents*.

Wolt, M. J., & d'Appolonia, B. L. (1984). Factors involved in the stability of frozen dough. II. The effects of yeast type, flour type, and dough additives on frozen-dough stability. *Cereal Chemistry*, *61*(3), 213–221.