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# Soy ingredients stabilize bread dough during frozen storage

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ABSTRACT

Bread with 48.5% soy ingredients was assessed for quality during frozen storage of the dough. Soy protein was hypothesized to prevent water migration during frozen storage, thereby producing dough that would exhibit fewer structural changes than traditional wheat bread. Wheat and soy bread were baked from dough that was fresh or frozen (−20 °C, 2 or 4 wks). Dough and bread were assessed for physical properties including moisture content, percent "freezable" and "unfreezable" water, dough extensibility, and bread texture. The bread was subjected to an untrained sensory panel. The soy bread was denser, chewier, and had a higher moisture content than wheat bread. When baked from fresh or frozen dough, soy bread was rated "moderately acceptable" or higher by 70% of panelists. Soy minimized changes in dough extensibility and resistive force to extension, leading to minimal changes in bread hardness. Although consumers could distinguish between bread baked from soy dough that was fresh or frozen for 4 wks, sensorial and textural data suggested that the rate at which the quality of the soy dough deteriorated was slower than that of wheat dough. In conclusion, the dough of consumer-acceptable soy bread retained quality characteristics during frozen storage slightly better than wheat dough.

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## 1. Introduction

Bakery products prepared from frozen dough are typically of lower quality than bread prepared from fresh dough. The loaves have smaller volume and require a prolonged proofing time (Berglund et al., 1991; Nilufer et al., 2008). During frozen storage, water irreversibly migrates from an "unfreezable" state, a state in which the molecules are strongly associated with protein or starch or are simply impeded translationally or rotationally, to the "freezable" state in which they are capable of forming ice crystals (Berglund et al., 1991; Lu and Grant, 1999). Migration occurs until the unfrozen phase reaches a maximum concentration of solute. The freeze-concentrated phase often vitrifies and the water in the amorphous, glassy phase comprises the "unfreezable water" (UFW) population. The ratio of "freezable water" (FW) to UFW tends to increase with frozen storage time until the maximum concentration is reached, about 4 weeks (Lu and Grant, 1999). The changes occurring in the water distribution during frozen storage can irreversibly damage the yeast and the starch and gluten ultrastructure, impacting functionality of the matrix (Berglund et al., 1991; Lu and Grant, 1999; Ribotta et al., 2003).

Detrimental changes that occur during frozen storage can be circumvented to various degrees by the addition of food additives or specialty flours. For example, dough made with 15% low-amylose, waxy wheat flour has been shown to increase specific volume of loaves produced from frozen dough (Yi et al., 2009), likely due to the increased water absorption of the dough and a reduction in syneresis associated with the amylopectin fraction. Soy protein has similarly demonstrated increased water holding capacities and interruption of normal packing of dough macromolecules such as gluten protein (Kinsella, 1979; Zhang et al., 2003) since soy protein can bind covalently (ex. disulfide bonds) and non-covalently (ex. hydrogen bonds) to wheat protein (Ribotta et al., 2005). Because soy protein is involved in tight binding to water instead of other protein molecules, these interactions are more elastic and possibly less prone to damage by freezing. Soy proteins, specifically glycinin and β-conglycinin, are globular in structure and the amino acid composition is more hydrophilic than that of wheat

*Abbreviations:* AUP, area under the peak; cc, cubic centimeter; Δ*H*, the change in enthalpy; DSC, differential scanning calorimetry; DTG, derivative of thermogravimetric analysis; $Ext_{Rmax}$, the extension of the dough at the maximal resistant force; FW, "freezable" water; $T_{final}$, the ending temperature of the phase transition; TGA, thermogravimetric analysis; $T_{onset}$, the starting temperature of the phase transition; TPA, texture profile analysis; $T_{peak}$, the temperature at the peak of the phase transition; $T_{range}$, the range of the phase transition (in °C); $R_{max}$, the maximal force the dough resists pull; UFW, "unfreezable" water.

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gluten and, since protein molecules in soy flour exist in a dehydrated state (Kinsella, 1979), they quickly bind water when the dough is moistened. Thus, soy proteins have greater water-binding capacities and formulations require increased hydration when incorporating them into baked goods (Zhang et al., 2003). Moreover, a previous study on frozen parbaked dough has shown that soy addition prolongs fresh-like qualities in microwave applications (Serventi et al., 2011).

Among bakers, the addition of soy flour or soy protein isolate to wheat bread at 2–3% has been performed in order to increase the quality of wheat bread from frozen dough in regard to loaf volume and appearance of the crust (Stauffer, 2005). Ribotta et al. (2003) assessed the effects of the addition of 10% soy flour to wheat dough for frozen storage. However, the goals of their experiment directed them to compare bread made from frozen dough with added soy to fresh wheat dough, and the difference between bread with added soy from fresh vs. frozen dough was not compared. Moreover, differences in the quality of bread made from frozen dough have not yet been evaluated for high soy containing products (about 25% soy ingredients; Vodovotz and Ballard, 2009) compared to the wheat counterpart.

Hence, the purpose of this investigation was to characterize the effect of soy addition on the physiochemical properties of frozen dough before and after baking. We hypothesized that, due to the high water-binding properties of soy, water migration would occur at a slower rate in the soy dough during frozen storage compared to traditional wheat dough, resulting in a higher quality product.

## 2. Materials and methods

### 2.1. Dough and bread preparation

A model dough ("wheat dough") and the soy dough were prepared according to the formulae developed by Zhang et al. (2003). The ingredients used included: wheat flour (Magnifico spring wheat flour, 13.0% protein, ConAgra Mills, Omaha, NE), non-toasted, defatted soy flour (Archer Daniels Mills, Decatur, IL), soy milk powder (Devansoy, Inc., Carroll, IA), sugar, shortening (Crisco® vegetable shortening, J. M. Smucker Co., Orrville, OH), vital wheat gluten (Hodgen Mill, Effingham, IL), Saf-Instant yeast (Lesaffre Yeast Corporation, Sil Fala Lesaffre, France), sodium chloride, and dough conditioner (Caravan Products Company, Totowa, NJ). The soy dough used soy milk powder and soy flour in an approximate 1:3 ratio so that soy ingredients comprised 48.5% of the dry weight (Vodovotz and Ballard, 2009). For the dough experiments, yeast was omitted to avoid production of carbon dioxide that would change the dough matrix during experimental analysis. "Fresh dough" was analyzed the day it was prepared. For "frozen dough", the samples filled the majority of the volume of 41.25 mL glass jars sealed with parafilm; dough that was used to make bread was placed in gallon-size polyethylene bags. The dough was flash frozen at −40 °C for 24 h in order to maximize the *rate* of freezing and then transferred to −20 °C for the remainder of the frozen storage period in order to simulate industrial freezing practices (Lu and Grant, 1999). Samples were thawed at ambient temperature the day of analysis. For bread, the dough was placed in a loaf pan and proofed at 39 °C for either 30 min (wheat bread) or 60 min (soy bread; CM2000 combination module, InterMetro Industries Corp, Wilkes-Barre, PA). The dough was then baked at 160 °C for 60 min (Jet air oven, JA14, Doyon, Linière, Québec, Canada). The bread was allowed to cool for 3 h and was placed in a large polyethylene bag overnight. The next morning, the bread was weighed and analyzed for volume using a rapeseed displacement apparatus (method 10-05.01, AACC, 2010). It was then sliced into 16 mm slices (Doyon SM302 bread slicer, Linière, Québec, Canada), stored in sealable bags, and analyzed for moisture content, phase transitions between −50 °C and 200 °C, and texture.

### 2.2. Sensory analysis

Acceptability and difference testing were performed on wheat and soy bread made from fresh and frozen dough. Sensory analyses were approved by the Institutional Review Board at The Ohio State University. All participants were aware of the risks associated with the study and provided written consent. Bread samples were given random, 3-digit numbers and presented in a randomized, counterbalanced fashion at ambient temperature and lighting. Paper-based ballots were collected and results were analyzed using Compusense® software (Compusense, Inc., Guelph, Ontario, Canada).

In order to test the acceptability of the bread samples, 40 untrained panelists (men and women age 18–35) were asked to rate the acceptability of 4 bread samples: 1) soy bread baked from fresh dough, 2) soy bread baked from dough frozen for 2 wks, 3) wheat bread baked from fresh dough, and 4) wheat bread baked from dough frozen for 2 wks. Participants evaluated the samples on a 5-point hedonic scale with the options: "Completely acceptable", "Moderately acceptable", "Marginally acceptable", "Not quite acceptable", or "Not at all acceptable".

To establish if consumers could distinguish between bread baked from fresh or frozen dough, 7 triangle tests were performed, 3 in one panel and 4 in a separate panel. For both panels, 40 untrained panelists (men and women age 18–35) were recruited. The samples were presented in 3-digit, randomly labeled cups in a random, counterbalanced order. The panelists attempted to identify which 1 of the 3 samples was different from the others. The first panel asked the panelists to distinguish between 1) soy or wheat bread baked from fresh dough, 2) soy bread baked from fresh or 1 month frozen dough, 3) wheat bread baked from fresh or 1 month frozen dough, or 4) soy or wheat bread baked from 1 month frozen dough. The second panel repeated triangle tests 2–4 except the frozen dough was frozen for 2 wks.

### 2.3. Thermogravimetric analysis (TGA)

Total moisture content of the dough and bread samples was measured on the Thermogravimetric Analyzer Q5000 (TA Instruments, New Castle DE). Dough samples of 15–20 mg were spread evenly on the bottom of TGA pans and analyzed immediately. The chamber was equilibrated at 25 °C, held isothermally for 2 min, and subsequently heated to 200 °C at 10 °C/min. The weight of the sample at 150 °C was subtracted from the initial weight to yield the percent of weight lost during heating; this loss was attributed solely to water evaporation (Fessas and Schiraldi, 2001). The derivative weight loss (DTG) was calculated by Advantage for the Q Series, version 2.8.0.394 (TA Instruments- Waters LLC, New Castle DE, 2001–2007).

### 2.4. Individual ingredient analysis

Wheat flour, soy flour, soy milk powder, isolated soy protein (PRO-FAM 781, ADM Protein Specialties Division, Decatur, IL), and wheat gluten were individually analyzed for rate of weight loss while undergoing a constant temperature ramp. The ingredients were mixed in a 1:1 ratio (by mass) with water and immediately analyzed by TGA as for the dough samples above.

### 2.5. Differential scanning calorimetry (DSC)

Thermal phase transitions were monitored using a Differential Scanning Calorimeter Q100 with a refrigerated cooling system

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