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Effects of chemical leavening system and processing conditions on the opacity and other quality characteristics of whole-wheat flour tortillas

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ABSTRACT

Chemical leavening is a neutralization reaction that can affect not only the opacity but also other physical and chemical properties of tortillas. Whole-wheat flour (WWF) tortillas is often associated with lack of sufficient opacity, generally considered as quality defect in tortillas. The objectives of this research were to evaluate the effects of types and amounts of leavenings (acids and base), hot press and dough temperature on the quality attributes of WWF tortillas. Three leavening acids, three levels of sodium bicarbonate (SBC) (1%, 1.5%, and 2%), hot-press temperatures of 160 °C, 177 °C, and 193 °C, and two dough temperatures (25 °C and 35 °C) were used. Sodium aluminum phosphate (SALP) produced more opaque tortillas than sodium acid pyrophosphate-28 (SAPP-28), followed by sodium aluminum sulfate (SAS). Increased amount of SBC and lower dough temperature improved opacity. Higher hot-press temperature produced lighter weight, thinner, and bigger diameter tortillas. Higher amount of SBC produced smaller, thicker, and brighter color tortillas. WWF tortillas made with SAS had the largest breaking force, while tortillas with SALP had the smallest breaking force as determined by TA-XTPlus Texture Analyzer. After 45 days of storage at room temperature, all tortillas showed decreased breaking force and extensibility.

1. Introduction

Considerable epidemiologic evidence suggests that whole grains are associated with reduced risk for certain chronic diseases (Marquart, Jacobs, Mclntosh, Poutanen, & Reicks, 2007). The 2010 Dietary Guidelines for Americans (USDA & USDHHS, 2010), via MyPlate, is designed to encourage people to eat at least three whole grain servings per day as part of a healthy meal plan. In step with these recommendations, the food industry has been incorporating whole-wheat flour (WWF) into a variety of grain-based foods to meet consumer taste preferences and provide more whole grains in the U.S. diet (Marquart et al., 2006).

Incorporating WWF into tortillas is one approach to deliver whole grains into the American diet. Tortilla is a thin Mexican flatbread made from wheat flour or corn, with the versatility to be used in many dishes. The Tortilla Industry Association (TIA) reported tortillas were more popular than other types of ethnic breads in the U.S., as approximately 85 billion tortillas were consumed in 2000 (TIA 2015). Given current trends toward healthier food and the popularity of tortillas, manufacturers are striving to provide customers with healthier, more varied, and flavored tortillas. Although the use of WWF can significantly improve the nutritional profile of tortillas, WWF tortillas have encountered more quality issues compared to refined wheat flour tortillas.

Translucency, a lack of opacity, is generally considered a quality defect in tortillas because consumers perceive translucency as a characteristic of tortillas that are undercooked or high in fat (Alviola & Awika, 2010). A 'translucent' tortilla is dark or yellowish in color, while 'opaque' tortilla is bright white (Dann, 2014). The absence of small air bubbles in the baked tortilla is likely related to translucency since the tortilla appears opaque when light reflects on the surface of small air bubbles (Cepeda, Waniska, Rooney, & Bejosano, 2000). Thus, the formation of air bubbles in the dough and retention of air bubbles in the tortilla are critical factors for producing uniformly opaque tortillas (Casso, 2003; Cepeda et al., 2000). Leavening agents help to form fluffy, thick, and opaque tortilla products.

Unlike many bread products that use yeast as leavening agents,

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flour tortillas are produced using a chemical leavening system. Chemical leavening is a neutralization process where bicarbonate is neutralized by an acid or acids yielding carbon dioxide in the presence of moisture and heat (Heidolph, 1996). A chemical leavening system contains two components: a base (bicarbonate) and an acid or acids (Adams & Waniska, 2002). The most commonly used leavening bases in baked foods are sodium bicarbonate (SBC), potassium bicarbonate (KBC), and ammonium bicarbonate (ABC). The different types, amounts, and grades of bicarbonates have been studied relative to tortilla properties (Bejosano & Waniska, 2004; Casso, 2003). Leavening acids vary in the neutralization value (NV) and the rate of reaction (ROR). Based on ROR, leavening acids can be divided into three categories. Nucleating agents release acids during mixing such as calcium phosphates (monocalcium phosphate [MCP]) and organic acids (fumaric, citric, lactic, and tartaric). Time-released agents release acids after a period of time (sodium acid pyrophosphate [SAPP] and calcium acid pyrophosphate [CAPP]). The third category, a heat-activated agent, reacts when triggered by heat. Sodium aluminum sulfate (SAS) and Sodium aluminum phosphate (SALP) are included in this category (Cepeda et al., 2000; Casso, 2003). Nucleating agents are seldom used as a leavening by themselves. Instead, the combinations of fast and slow leavening acids are used to produce a double reaction (Heidolph, 1996; La Baw, 1982).

In the tortilla dough system, previous research demonstrated that chemical leavening showed effects on end-product opacity. Time-released and heat-activated leavening acids yield more opaque tortillas compared with nucleating agents (Adams & Waniska, 2002; Cepeda et al., 2000). Slower acids partially dissolve during mixing and nucleate the dough with a sufficient yield of gas bubbles to produce opaque tortillas. During dough resting, dividing, and rounding, some insoluble leavening compounds need to be retained to allow for later chemical neutralization and reactions during the baking process (Adams, 2001). In addition, the tortilla opacity is generally associated with the amount of leavenings used (Adams, 2001; Adams & Waniska, 2002; Bejosane & Waniska, 2004). However, Cepeda et al. (2000) observed small or insignificant improvements in opacity when using more SALP, SAS, and SAPP, while adverse effects were observed when using more MCP. Furthermore, the effects of leavening systems on other tortilla attributes (moisture, pH, diameter, texture, etc.) have been investigated (Adams & Waniska, 2002; Adams, 2001; Bejosano & Waniska, 2004; Book, Brill, & Heidolph, 2002; Cepeda et al., 2000).

With higher dough temperature, less mixing time is required to form dough (Hlynka, 1962). However, more acid solubilizes and reacts faster with the base in tortilla dough; thus, the leavening reaction increasingly occurs in warmer dough, which reduces the potential for bubble enlargement during tortilla processing and yields more translucent tortillas (Cepeda et al., 2000). Cepeda et al. (2000) studied the effect of dough temperature (34 °C and 38 °C) and determined that at 38 °C, more leavening acid and base were needed to compensate for the loss of carbon dioxide incurred during mixing and resting to yield tortillas with comparable opacity.

Other than dough temperature, hot-press conditions of pressure, time, and temperature directly affect the tortillas. Typical hot-press operating conditions range from 300 to 2000 psi pressure, 0.7–3.5 s time, and 149–232 °C temperature (TIA 2014). Adams and Waniska (2005) examined the effects of dwell time and pressure on tortilla quality. However, the hot-press temperature has not yet appeared in the literature to determine its influence on flour tortilla characteristics.

Although considerable research has focused on the chemical leavening system for wheat flour tortillas, there is little research on WWF tortillas. Barros, Alviola, and Rooney (2010) compared the quality of refined and WWF tortillas and found that the WWF tortillas had lower opacity scores than their corresponding refined flour tortillas. The high fiber content in WWF weakens the gluten network and results in dough less resistant to hot pressing (Barros et al., 2010). Therefore, WWF tortillas have weaker dough structure and integrity to retain the air bubbles created during baking. Thus, it is necessary to modify the chemical leavening system and processing conditions in WWF tortilla production to improve opacity and overall quality characteristics.

The objectives of this study were to examine the effects of varying types of leavening acids, amounts of leavening base, hot-press temperature, and dough temperature on the opacity and other quality properties of WWF tortillas.

2. Materials and methods

2.1. Materials

A 100% hard white WWF with 9.6% moisture content, 13.3% protein (14% mb) and 1.4% ash (14% mb) was kindly provided by Bay State Milling Company (Minneapolis, MN). The leavening acids, SALP, SAS, and SAPP-28 were provided by ICL Food Specialties (St. Louis, MO). Encapsulated fumaric acid was kindly provided by Clabber Girl Inc. (Terre Haute, IN). SBC (powder ACS) was purchased from ChemProducts (Portland, OR). Sodium stearoyl lactylate (SSL) was obtained from Corbion (Kansas City, KS). Salt, Crisco vegetable shortening and sugar were purchased from a local supermarket (Portland, OR). Potassium sorbate and calcium propionate were obtained from Muhlenchemie GmbH & Co KG (Ahrensburg, Germany).

2.2. Preparation of WWF tortilla

The WWF tortilla formula is listed in Table 1. The ingredients were weighed and added to a Horbart 5-Quart Mixer (Model A-120, Hobart MFG. Co, Troy, OH) with water jacket and constant temperature circulator (Model 1165, PolyScience, Div. of Preston Industries, Inc. Niles, IL) and mixed for 4 min at the 1st speed and 2–8 min at the 2nd speed until the dough was fully developed. The dough temperature was measured using a thermometer. After resting for 15 min at room temperature, 1400 g dough was flatted on the Dutchess Divider/Rounder tray (model JN-3, Dutchess Baker's Machinery Co. Inc. Superior, WI) with uniform thickness. The dough was divided and rounded into pieces of dough balls (40 g each) after resting for 5 min. The dough balls were then placed in a covered box and proofed for 20 min. Finally, each dough ball was hot-pressed by using an automatic Tortilla Press (Model Wedge Press, Bakery Equipment & Service Co. San Antonio, Texas) and baked on a griddle (model TW2025, DoughPro, Perris, CA) for 30 s

Table 1
Whole-wheat flour tortilla formulation.

Ingredients	Dough	
	%	g
Whole-Wheat Flour	100	1000
Water	58	580
Salt	1.5	15
Sugar	0.5	5
Shortening	7	70
Sodium bicarbonate	1/1.5/2	10/15/20
Leavening acids	Varied per trial	
Encapsulated fumaric acid	0.5 5	
Sodium stearoyl lactylate	0.5	5
Potassium sorbate	0.4	4
Calcium propionate	0.5	5