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Coating development with modified starch and tomato powder for application in frozen dough

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ABSTRACT

The Central Composite Rotatable Design (CCRD) with variables developed modified ascorbic acid (AA) starch coating added with tomato powder (TP): ascorbic acid and tomato powder. The CCRD verified the effects on the coating's properties: surface tension, electrical conductivity, viscosity and ζ-potential. Specific volume, hardness and Scanning Electron Microscopy with Energy-Dispersive Spectroscopy evaluated the optimized coating efficiency on the frozen dough in storage. A significant ($p < 0.05$) influence of AA and TP was observed in all parameters, as there was an increase in surface tension, viscosity and electrical conductivity with an increase in the independent variables. The optimized edible coatings were EC1 – 1.8% AA/4.0% TP and 2.2% AA/5.0% TP. The coated frozen dough promoted breads with a greater specific volume and less hardness than the breads produced by uncoated frozen dough. The EDS analysis showed the presence of K, S, Ca and P minerals, proving coating mobility into the dough.

1. Introduction

Bread is a product of wheat flour fermentation by yeast, and is widely consumed as a staple food across many cultures and countries worldwide (Arendt & Zannini, 2013). Dough is a comprehensive network containing wheat flour, water, and other ingredients. Gluten in wheat flour is a crucial protein to form a viscoelastic structure in dough and bread (Peng, Li, Ding, & Yang, 2017). The functionality of the gluten network developed through mixing is crucial for gas retention and the final structure of bread (Gao, Koh, Tay, & Zhou, 2017).

For economic reasons, the dough-freezing technique is commonly employed in bakery businesses (Halagarda, 2017). As such, bakery products can be prepared quickly and on demand, thus minimizing the cost of unsold products (Giannou, Kessoglou, & Tzia, 2003). Nevertheless, there are several issues connected with this technology, i.e. loss of dough strength caused by the formation of ice crystals, decreased retention capacity of CO_2, longer fermentation time, reduced viability and yeast activity. These may lead to reduced volume and deterioration in the texture of a baked product (Steffolani, Ribotta, Perez, Puppo, & Leon, 2012). During proofing, the gas production rate depends on the activity of baking yeast (Saccharomyces *cerevisiae*), while the dough expansion rate is determined by both the gas production and the gas transfer rate (Gao et al., 2017). In this way, frozen storage can reduce the yeast population which affects the final quality of the bread, making it necessary to develop technologies that reduce the impact of freezing on the structure and quality of bread dough.

Research on edible coatings and films has been intense in recent years. Application of edible coatings (EC) confers a more natural appearance to food products, and environmental impact reduction by decreasing the use of oil-derived plastic packaging materials (Dangaran, Tomasula, & Qi, 2009). EC can offer biocompatibility, aesthetic appearance, barrier properties, no toxicity, low cost, and can be used as additive carriers such as colorants, flavors, antioxidants, or antimicrobials (Vásconez, Flores, Campos, Alvarado, & Gerschenson, 2009). Starches are attractive biopolymer candidates for replacing a part of synthetic polymers in coatings since starch will increase the biodegradability of the final products and lower the material costs (Rahmat, Rahman, Sin, & Yussuf, 2009). Starch-based films are widely used because they are transparent, odorless, tasteless, and good CO_2 and O_2 barriers (Jiang, Neetoo, & Chen, 2011; Neetoo, Ye, & Chen, 2010). Modified starches have been used to develop biodegradable films for food packaging because they present better physical, optical, morphological, mechanical, and barrier properties when compared to native starch films (Fonseca et al., 2015). Coatings with modified corn starch by the action of ascorbic acid and added with powder tomato, when applied in frozen bread dough are able to improve physical properties

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and characteristics in the crust color. The use of ascorbic acid on the starch modification promotes improvements in the starch technological quality. Thus, the addition of functional powder components, such as tomato, can provide improvements in the general aspects of product quality (Galvão, Zambelli, Araújo, & Bastos, 2018).

The consumption of tomato and tomato-based products have been associated with a lower risk of developing certain types of cancers such as digestive tract and prostate cancer, which may be due to the ability of lycopene and other antioxidant components (Beecher, 1998). The increasing interest in the antioxidant activity of lycopene (the most abundant carotenoids in tomatoes), its bioavailability in the heating process (Alvarenga et al., 2017), and other functional components have been promoting tomato and tomato-based product consumption (Tapiero, Townsend, & Tew, 2004). Thus, the aim of this study was to develop edible corn starch coatings modified with ascorbic acid and added tomato powder for application on frozen bread dough to improve quality.

2. Materials and methods

2.1. Tomato powder preparation

Freshly harvested tomato (*Solanum lycopersicum* L.) fruit at the mature stage of ripening was purchased from a local market in Fortaleza. The fruits were chosen considering uniformity in color, size, and absence of blemishes, mechanical damage, or fungal infection. After washing, the tomatoes were dried (Quimis Corporation, São Paulo, Brazil) in an oven at 50 °C for 16 h. The dried tomatoes were then pulverized using an electric grinder and particles smaller than 149 µm were separated by passing through a standard sieve (U.S. No. 100). The obtained tomato powder was used to make the edible coating solution.

2.2. Corn starch modification

Corn starch was dissolved in distilled water in proportions of 1:1 until complete homogenization, containing different concentrations of ascorbic acid through a Central Composite Rotatable Design (CCRD) (Table 1). The solution was dried at 50 °C for 8 h in the forced air circulation oven. The modification that occurs in the starch is chemical, according to the review of Masina et al. (2017) with adaptations.

2.3. Preparation of coating solutions

Coating solutions were prepared according to Choulitoudi et al. (2016). First, Modified Corn Starch (MCS) was dissolved in distilled water (15 g/L) under magnetic stirring at 80 °C. The MCS solution was mixed by magnetic stirring with 20.2% glycerol (v/v). Emulsions were obtained by adding tomato powder in MCS solutions according to CCRD. Homogenization of the emulsions was performed by a high-speed homogenizer (CAT Unidrive 1000, Paso Robles, California) at 200 rpm for 5 min at room temperature. The emulsions remained for 15 min at room temperature to exhaust air bubbles formed during homogenization. The amounts of ascorbic acid and tomato powder used in the preparations of each formula were selected according to Table 1.

Table 1
Central Rotating Compound Project (CCRD) with uncoded and coded variables, these are presented in parentheses.

Edible Coatings	Independent Variables	
	Ascorbic Acid (mL/100 g of Starch) - X_1	Tomato Powder (g/100 g of starch) - X_2
1	1.0 (−1)	5.0 (−1)
2	1.0 (−1)	10.0 (+1)
3	2.0 (+1)	5.0 (−1)
4	2.0 (+1)	10.0 (+1)
5	0.80 (−1.41)	7.5 (0)
6	2.20 (+1.41)	7.5 (0)
7	1.5 (0)	4.0 (−1.41)
8	1.5 (0)	11.0 (+1.41)
9	1.5 (0)	7.5 (0)
10	1.5 (0)	7.5 (0)
11	1.5 (0)	7.5 (0)

2.4. Coating quality analysis

2.4.1. Surface tension

The surface tension of the coating solution was measured by the pendant drop method using the Laplace-Young approximation (Song & Springer, 1996) using a Du Nouy tensiometer (Lauda Command model TD 1 C). After insertion of the ring in the tensiometer, the samples were transferred to chemical cells, which were embedded in the equipment platform. This platform was then suspended until the ring became immersed in the liquid. The platform was slowly lowered and the value recorded on the equipment display.

2.4.2. Electrical conductivity

Solution conductance was analyzed using the mCA-150 conductivity meter, with cell constant k = 1.0504. The measurement consisted of inserting the electrolytic cell in the coating solutions.

2.4.3. Rheological properties

The rheological properties of the edible coating solutions were studied to investigate the flow behavior of blends, which is an important factor for food coating materials. Rheological parameters (shear stress, shear rate, apparent viscosity) of edible coating solution blends were measured using a Brookfield Engineering lab DV-III Rheometer. The edible coating solution was placed in a small sample adapter. The viscometer was operated between 10 and 50 rpm and shear stress, shear rate, apparent viscosity data were obtained directly from the instrument. The SC4-21 spindle was selected for measurement. Rheological measurements were made at different concentrations of ascorbic acid and tomato powder.

2.4.4. The ζ-potential

The ζ-potential (mV) was measured by phase-analysis light scattering (PALS) with a Zetasizer Nano-ZS laser diffractometer (Malvern Instruments Ltd, Worcestershire, UK). It determines the electrical charge at the interface of the droplets dispersed in the aqueous phase.

2.4.5. Statistical analysis

The CCRD was performed to obtain a second order model to predict the quality of the dough and bread as a result of ascorbic acid and tomato powder addition into the edible coating formulas. This model can be observed by the following equation:

$$y = \beta_0 + \sum_{i<j} \beta_{ij} x_i x_j + \sum_{j} \beta_{jj} x_j^2 + \varepsilon \tag{1}$$

Where y is the predicted response (dough and bread quality variables), β_0 is the global mean, β_j is the linear coefficient, β_{ij} is the coefficient of interaction, β_{jj} is the quadratic coefficient, ε is the error of the model, and x_i and x_j are the coded values of the independent variables.

The experimental data were analyzed using Statistica software version 9.0 (Statsoft, Inc., Tulsa, OK, USA). Analysis of variance (ANOVA) tables were generated, and the effect and regression coefficients of individual linear, quadratic and interaction terms were determined. The quality-of-fit of the equation model was expressed by the coefficient of determination (R^2), and its statistical significance was determined using the F-test. For validation of the statistical results, the observed values of edible coatings variables were compared with the predicted values obtained by the experimental models. The optimized