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Ozonation as an alternative to chlorination for soft wheat flours☆

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ABSTRACT

High ratio cakes made from ozonated flour attained volumes and other quality characteristics comparable to those from chlorinated flours at 36 min ozonation time. Ozone thus appears to be a viable and more environmentally acceptable alternative to chlorine. Extraction of lipids from flour caused deterioration of cake quality which was not restored by ozonation, indicating that lipids were involved in the improving effects of ozonation. Oxidation by ozone led to higher molecular weights of polymeric proteins.

1. Introduction

Chlorination of soft wheat flour has been used since the 1930s (Gough et al., 1978) to make them suitable for manufacture of high ratio cakes; i.e. cakes that use high proportions of shortening and sugar. Chlorine treatment has two main beneficial effects on flours. It prevents collapse of cakes after removal from the oven, giving rise to higher volumes, and acts as a bleaching agent to produce a whiter colour of the product. The chemistry of the effects of chlorine has not been clearly explained although studies have implicated its influence on gluten, prime starch (Sollars and Rubenthaler, 1971) and lipids in flour (Kissell and Yamazaki, 1979; Clements and Donelson, 1982).

Chlorination of flour is usually carried out in flour mills and, as chlorine is a poisonous gas, this has raised safety issues. Also, the use of such chemicals in food processing is of public concern (Thomasson et al., 1995). As a result, alternatives to chlorination have been sought (Donelson et al., 2000). For example, heat treatment has been used to reduce shrinkage of cake during baking and increase cake volume, effects similar to those of chlorination (Russo and Doe, 1970; Thomasson et al., 1995).

Ozone is a strong oxidizing agent similar to chlorine. It does not have the poisonous properties of chlorine. However, ozone is reported to be an effective alternative to conventional fumigants against a range of pests, micro-organisms and mycotoxins (Tiwari et al., 2001). When used for tempering of wheat grain prior to milling, it has been shown to reduce the required energy for milling (Desvignes et al., 2008). When flour was treated with ozone, its dough gave higher alveograph force and tenacity and lower extensibility (Violleau et al., 2012). In a study of breadmaking, flour treated with ozone gave larger specific bread volume and better crumb characteristics, suggesting that ozone could be a viable alternative to potassium bromate (Sandhu et al., 2011).

The purpose of this study was to assess whether ozone treatment could improve the properties of soft wheat flour for cakemaking and thus offer a more environmentally acceptable alternative to chlorination. Following this, a second aim was to try to throw light on the mechanism by which ozone modified flour (and thus cake) properties. Two variables that were studied were the effects of flour lipid removal and the changes in protein measured by Size-exclusion High Performance Liquid Chromatography (SE-HPLC).

2. Materials and methods

2.1. Materials

Unchlorinated and chlorinated flours from the same soft wheat were provided by ConAgra Foods (Alton, IL). All vegetable shortening was donated by ADM packaged oils (Decatur, IL). Non fat

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dried milk was provided by Ryt-way Industries Inc. (Northfield, MW). Double acting baking powder was obtained from Clabber Girl (Terre Haute, IN). Fine granulated sugar was obtained from Domino Foods Inc. (Baltimore, MD).

2.2. Methods

2.2.1. Analytical determination

Protein contents of flour samples were analysed by the combustion method using a LECO FP2000 Nitrogen/Protein Analyzer. A factor of 5.7 was used to convert nitrogen (N) to protein. Moisture content was determined according to AACC method 44-15A (AACC, 2000).

2.2.2. Ozone production

Ozone gas was generated by a pilot scale ozone generator (Clear Water Tech. Inc., San Luis Obispo, CA). The rate of ozone production was measured by an iodometric method for determination of ozone in a process gas. Ozone gas was passed through three sets of glass wash bottles containing 250 ml distilled water as a detector for ozone transfer and reaction, 4 g of potassium iodide, and 15 ml of 0.3 M sulphuric acid and then the solution was titrated against 0.01 N sodium thiosulphate containing starch indicator solution. Ozone concentration was calculated from ml of sodium thiosulphate usage.

2.2.3. Production of ozone treated flour

The ozone gas was tumbled in the chlorination box filled with 5 lb (2.27 kg) of non chlorinated soft wheat flour. The ozone was introduced at the rate of 0.06 L/min for times of 10, 20, 30, 36, and 40 min. A tube from the box allowed gas to be expelled to the open air, preventing build up of gas inside the room. Ozone production, measured by the iodometric method increased linearly with time and was given by the equation:

$$\text{conc} = 0.08\,t - 0.45$$

where conc is the concentration of ozone (mg/kg flour) and t is the time in min.

2.2.4. Flour properties

The pH of flour samples was measured by AACC method 02-50 (AACC, 2000). Ten grams of flour were added to 100 ml distilled water. The flour suspension was placed on a stirring plate and stirred for 15 min. It was then stood for 10 min and the supernatant decanted and used for pH measurement.

Flour colour was measured with a Minolta colorimeter (Minolta Corp., Ramsey, NJ) and the L^*, a^* and b^* values were recorded.

2.2.5. Lipid extraction

Unchlorinated flour was extracted with chloroform according to MacRitchie and Gras (1973). Three extractions were performed using 200 g of flour and 400 ml of chloroform for each successive extraction. The flour was filtered through a Whatman No. 1 filter paper and placed in a fume hood for 12 h at room temperature to allow evaporation of the chloroform.

2.2.6. Size exclusion High Performance Liquid Chromatography (SE-HPLC)

SE-HPLC was performed using a Hewlett Packard 1100 system with a UV detector set at 214 nm. A BioSep-Sec-S4000 column 300 × 7.8 mm (Phenomenex, Torrance, CA) was used for protein fractionation. The elution solvent was deionized water and acetonitrile (1:1), both containing 0.05% trifluoroacetic acid (TFA) with a flow rate of 0.5 ml/min.

Procedures were based on those of Gupta et al. (1993). For total protein determination, 10 mg of flour was suspended in 1 ml of 0.05% sodium dodecyl sulphate (SDS) and 0.05 mM dibasic sodium phosphate buffer, pH 6.9. Samples were vortexed for 5 min and sonicated at an output of 6 W for 15 s. Samples were centrifuged at 12,000 × g for 20 min, the supernatants were filtered and transferred to HPLC glass vials. For unextractable protein, the same extraction procedure was followed without sonication. After removal of the supernatant (containing extractable polymeric protein), 1 ml of SDS-buffer solution was added to the residue and the dispersion sonicated for 25 s to give the solution for measurement of unextractable polymeric protein (UPP). Areas under the chromatograms were integrated in three parts. The first peak contained polymeric proteins (mainly glutenins). The second peak contained mostly gliadins and the third peak was albumins and globulins. The proportion (%) of total polymeric protein (TPP) was calculated as (peak 1 area/total area) × 100. The percentage of unextractable polymeric protein (UPP) in the total polymeric protein was calculated as peak 1 area (unextractable)/peak 1 area (total). Peak 1 area (total) is the sum of peak 1(extractable) and peak 1(unextractable).

2.2.7. Viscosity of cake batter

Cake batter viscosity was determined according to Kim and Walker (1992) using a Brookfield Synchro-lectric viscometer model LVt (VS4) (Brookfield Engineering Laboratories, Inc., Stoughton, MA). Spindle number 4 was used and the viscosity measured in centipoises. These measurements were done on a flour that had been tumbled in a metal box as part of a study of the effects of temperature and ozonation time on flour properties (Chittrakorn, 2008).

2.2.8. Baking test

All cakes were baked according to AACC method 10-90 (AACC, 2000). The optimum level of water and double acting baking powder were first determined by adjusting these variables in order to obtain a maximum cake volume, consistent with a satisfactory texture. Three different levels of distilled water, 250, 270, and 290 ml were tested and the optimum water level was determined to be 270 ml of water, which gave the highest cake volume. All dry ingredients were sifted and transferred to the mixing bowl. Shortening and 60% of distilled water were added. The ingredients were mixed at a low speed for 30 s using a Hobart mixer, scraped down and mixed at medium speed for 4 min. One half of the remaining water (20%) was added to the batter and mixed at low speed for 30 s and then at medium speed for 2 min. The remaining water (20%) was added to the batter and mixed at low speed for 30 s and then at medium speed for 2 min. 425 g of cake batter was transferred into each of two greased pans and baked in an electrical oven at 190C (375F) for 22 min.

2.2.9. Cake quality

Volumes of cakes were measured by a plastic measurement template according to AACC method 10-91 (AACC, 2000) and volume index was calculated based on the following equation: Volume index $= B + C + D$ where B, C, and D are heights of cake corresponding to vertical lines of the plastic template designated for cake volume calculations.

A texture analyzer (TA.XT2, Stable Micro Systems Ltd) was used to measure hardness, springiness and cohesiveness of cakes. Texture profile analysis (TPA) was performed using a 1 inch (2.5 cm) diameter cylinder probe. The TPA test setting was as follows: pre-test, test and post test speeds were 2.0 mm/s, a distance of 10 mm was used to compress the sample, and the time between each stroke was 3.0 s. For sample preparation, each cake was cut into 4