Journal of Cereal Science 76 (2017) 193–198

Contents lists available at ScienceDirect

Journal of Cereal Science

journal homepage: www.elsevier.com/locate/jcs

Polyethylene glycol as an osmotic regulator in dough with reduced salt content

Aleksandar G. Yovchev [a], Andrea K. Stone [a], Pierre Hucl [b], Martin G. Scanlon [c], Michael T. Nickerson [a, *]

[a] Department of Food and Bioproduct Sciences, University of Saskatchewan, Saskatoon, SK, Canada
[b] Crop Development Centre, University of Saskatchewan, Saskatoon, SK, Canada
[c] Department of Food Science, University of Manitoba, Winnipeg, MB, United States

ARTICLE INFO

Article history:
Received 16 December 2016
Received in revised form
5 June 2017
Accepted 5 June 2017
Available online 7 June 2017

Keywords:
Dough
Wheat cultivar
Osmotic regulator
Low salt
Stickiness
Harvest cultivar

ABSTRACT

In this study, polyethylene glycol (PEG) was used as an osmotic regulator in dough to investigate the effects of reduced NaCl content on dough properties. The effects of water content (±10% of Farinograph absorption) and PEG's molar mass on dough machinability (stickiness, work of adhesion and cohesiveness) were estimated using a full factorial design. PEG with different molar masses (400, ~1600, and 3350 g/mol) was added at a concentration of 1 g/100 g flour. All properties measured were affected significantly by the variation of water content and PEG's molar mass. At lower levels of dough hydration, stickiness increased with an increase in PEG's molar mass, whereas the opposite trend was observed at higher levels of dough hydration, suggesting there may be an optimum between the water restriction effect induced by PEG and dough's physical properties. The interaction effect was significant for both stickiness and work of adhesion, showing interdependence between water content, PEG molecule size and dough physical properties. The effects of PEG's concentration and molar mass on dough machinability were also assessed by full factorial design. Increasing PEG's molar mass and concentration improved dough machinability, that is, dough with reduced stickiness was obtained.

1. Introduction

Processed foods are the primary source of salt in the human diet. Due to the prevalence of bread in the diet, it is considered as one of the main processed foods that requires a reduction in the amount of salt used in its standard formulation. As a staple food, a successful bread reformulation with reduced salt (NaCl) would have a large scale effect on the health of populations worldwide (Belz et al., 2012). Commercial white bread formulations typically contain ~570 mg sodium/100 g (or 2% NaCl, flour weight basis) of bread. To date, salt reduction strategies have focused on lowering the sodium content to ~380 mg/100 g bread through the addition of salt replacers (*e.g.*, KCl). Health Canada's Sodium Working Group targeted sodium levels in bread to reach ~330 mg/100 g (or 1.1%); however a recent study has shown this level has not yet been met (Arcand et al., 2016).

Salt is not only a principal component contributing to the flavour in baked products, but also has a major impact on the physical properties of the dough. The viscoelastic properties of dough are a direct result of the interactions between gluten proteins, the main class of proteins in wheat flour, and salt ions which gives rise to the handling properties of the dough (Danno and Hoseney, 1982; Hlynka, 1962; Tanaka and Tipples, 1969). Dough machinability (dough stickiness) is a major limiting factor of salt reduction. Dough stickiness can be detrimental in a production plant causing a decrease in final product volume, production line stoppages, and equipment wear (Adhikari et al., 2001; Huang and Hoseney, 1999). This surface active phenomenon is related to the balance between cohesive and adhesive forces occurring between the dough and a surface, where stickness arises when the adhesive force becomes much greater than the cohesive force (Dobraszczyk, 1997). Stickiness has been previously associated with differences in protein quality and composition (e.g., high and low molecular weight gluteinins, and gliadins), α-amylase and proteolytic activity, levels of damaged starch and pentosans, presence of ferulic acid esterified to a hexose chain, genetics (e.g., varieties containing the

* Corresponding author. Department of Food and Bioproduct Sciences, University of Saskatchewan, 51 Campus Drive, Saskatoon, S7N 5A8 Canada.
E-mail address: michael.nickerson@usask.ca (M.T. Nickerson).

http://dx.doi.org/10.1016/j.jcs.2017.06.004
0733-5210/

1 B/1 R translocation from rye) and processing parameters (e.g., level of hydration, mixing and formulations) (Miller and Hoseney, 2008; van Velzen et al., 2003; Beck et al., 2012). The explicit mechanism of dough stickiness has not been elucidated, however the hydration state of the gluten phase is known to affect dough stickiness and the hydration state changes as water is redistributed throughout the mixing process (van Velzen et al., 2003). van Velzen et al. (2003) applied Attenuated Total Reflectance (ATR) - Fourier Transform Infrared (FTIR) spectroscopy to characterize the surface stickiness of dough after peeling it off an ATR plate. The technique enables dough components (e.g., starch, water, protein and fat) to be probed with a depth of a few microns from the dough surface, to provide a better understanding of what components are present at the surface participating in the cohesive and adhesive forces, and also to characterize changes in protein conformation that may occur in response to various dough formulations or processing parameters. In the case of proteins, levels of hydration and mixing can greatly affect the intensity of the amide bands within the FTIR spectra. The frequency of infrared light which is absorbed is specific to the functional groups present (e.g., chemical bonds) as well as the environment in which that functional group is. In the case of the amide bonds in gluten, α-helices and β-sheets absorb light at 1650–1655 cm^{-1} and 1620–1640 cm^{-1}, respectively (van Velzen et al., 2003). However, due to the overlapping water band (-OH group), curve integration and fitting is typically done to differentiate contributions within the 1800–1500 cm^{-1} region of the spectra.

Osmotic regulators such as polyethylene glycol (PEG) represent an experimentally useful means of altering water availability to gluten. PEG is a flexible non-ionic surfactant, with a repeating group (-O-CH_2-CH_2-) that separates the oxygens (hydrophilic) and ethylene (hydrophobic) units, and consists of a terminal H and an OH end group (Crupi et al., 1994). PEG is soluble in water and can produce very high osmotic pressures, as such it dehydrates the gluten network, allowing investigation of the effects of gluten hydration caused by low salt levels.

According to the rheological study of Dobraszczyk (1997), stickiness is primarily a function of the rheological properties of the dough, which in turn relates strongly to the hydration of the gluten network. The objective of this study therefore was to investigate the effects of water availability on dough rheology using PEG as an osmotic regulator in doughs prepared with reduced NaCl content. The effect of water content was also taken into consideration. An attenuated total reflection (ATR) Fourier transform infrared (FTIR) spectroscopy was used as an analytical tool to probe dough surfaces of different degrees of stickiness as a result of PEG addition.

2. Materials and methods

2.1. Flour quality

Canada Western Red Spring wheat cultivar, Harvest, was used for all analyses. Wheat was tempered to 15.5% moisture for approx. 18 h prior to milling on a Buhler experimental mill MLU-202 according to AACC Approved Method 26-21.01. Quality parameters for Harvest flour included protein (13%, on 14% w.b.), falling number (486 s), damaged starch content (7.1%), and farinograph absorption (65.5%, on 14% w.b.) as measured according to the American Association of Cereal Chemistry International (AACCI) approved methods 46-30.01, 56-81.03, 76-31.01 and 44-15.02, respectively (AACC, 2010). The flour moisture content was 10.6% (w.b.) as measured according to AACC Approved Method 44-15.02 (AACC, 2010).

2.2. Experimental designs and dough preparation

i) The effect of water content and PEG's molar mass on dough machinability was assessed by a randomized full factorial design, arranged in three blocks. Design was repeated and three additional center points were added (one per block) (Table 1a). The center point for water content was Farinograph absorption (FAB), and the low and high levels were ±10% FAB. PEGs with different molar mass (400, ~1600, and 3350 g/mol) were added at a concentration of 1 g/100 g flour. NaCl was added at a level of 1 g/100 g flour;
ii) The effect of PEG's concentration and molar mass on dough machinability and freezable water content was assessed by a randomized full factorial design (Table 1b). Design was repeated once. PEGs with different molar mass (400, ~1600, and 3350 g/mol) were added at concentrations of 1, 2 and 3 g/100 g flour. For all samples water was added according to the FAB value of the flour without added PEG. NaCl was added at a level of 1 g/100 g flour.

To reduce the number of variables that could affect dough machinability, yeast was not used. For all analyses dough samples were mixed to peak development using a 10 g mixograph (TMCO National Mfg., Lincoln, NE). Statistica 10 (StatSoft Inc., Tulsa, OK, USA) was used to design, estimate effects and obtain the response surfaces. Note, the 1 g/100 g NaCl was selected to represent suggested targets of Health Canada for salt reduction; PEG levels of 1–3 g/100 g were selected based on findings of Yovchev et al. (2017) where they found at low levels PEG improved dough strength, but at high levels it had a weakening effect; and water levels (±10% FAB) were selected to represent conditions of under and over hydration of the gluten network.

2.3. Dough stickiness

Dough stickiness was measured using a TA.XT*Plus* texture analyzer with a Chen-Hoseney dough stickiness cell (Chen and Hoseney, 1995), 25 mm perspex cylinder probe and 5 kgf load cell (Texture Technologies, Stable Micro Systems, Ltd., Surrey, UK). The compression force was 40 gf, pre-test and test speed 0.5 mm/s, post-test speed 10 mm/s, return distance 15 mm, contact time 0.1 s, trigger force 5 gf, and a force vs time curve was generated. From the curve three values for dough stickiness were obtained: the maximum positive force (gf) is a measure of stickiness/adhesive force; the positive area under the curve (gf.s) is the work of adhesion; and the distance the sample travels upon probe return is a measure of dough cohesiveness (mm).

2.4. Differential scanning calorimetry

Freezable water content (FWC) was measured with a DSC Q2000 (TA Instruments, New Castle, DE, USA). Approximately 10 mg dough samples were sealed in aluminum DSC pans. The samples were scanned at a cooling or heating rate of 10 °C/min using an empty pan as reference. The temperature profile consisted of: 1) equilibration at 30 °C for 5 min, 2) cooling to −40 °C, 3) equilibration at −40 °C for 5 min, 4) heating to 40 °C. The enthalpy (ΔH) of melting peak was determined with Universal Analysis 2000 version 4.5A (TA Instruments, New Castle, DE, USA). Freezable water content was calculated directly from the measured enthalpy divided by the enthalpy of pure water, and expressed per gram of dry matter.

2.5. Infrared measurements

All infrared spectra were collected on a Smiths Detection