Food Research International 88 (2016) 10–15

Contents lists available at ScienceDirect

Food Research International

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

Salt reduction in sheeted dough: A successful technological approach

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ARTICLE INFO

Article history:
Received 9 October 2015
Received in revised form 1 March 2016
Accepted 6 March 2016
Available online 9 March 2016

Keywords:
Sheeted dough
Salt reduction
Sheeting
Dough rheological properties
Spatial distribution

ABSTRACT

The challenge of reducing the salt content while maintaining shelf life, stability and acceptability of the products is major for the food industry. In the present study, we implemented processing adjustments to reduce salt content while maintaining the machinability and the saltiness perception of sheeted dough: the homogeneous distribution of a layer of encapsulated salt grains on the dough during the laminating process. During sheeting, for an imposed deformation of 0.67, the final strain remained unchanged around 0.50 for salt reduction below 50%, and then, increased significantly up to 0.53 for a dough without salt. This increase is, in fine, positive regarding the rolling process since the decrease of salt content induces less shrinkage of dough downstream, which is the main feature to be controlled in the process. Moreover, the final strain was negatively correlated to the resistance to extension measured with a texture analyzer, therefore providing a method to evaluate the machinability of the dough. From these results, a salt reduction of 25% was achieved by holding 50% of the salt in the dough recipe to maintain the dough properties and saving 25% as salt grains to create high-salted areas that would enhance the saltiness perception of the dough. The distributor mounted above the rollers of the mill proved to be able to distribute evenly salt grains at a calculated step of the rolling out process. An innovative method based on RX microtomography allowed to follow the salt dissolving and to demonstrate the capability of the coatings to delay the salt dissolving and consequently the diffusion of salt within the dough piece. Finally, a ranking test on the salted perception of different samples having either an even distribution of encapsulated salt grains, a single layer of salt grains or a homogeneous distribution of salt, demonstrated that increasing the saltiness perception in salt-reduced food product could be achieved by a technological approach.

1. Introduction

Daily salt intakes of population in Europe are in excess of dietary needs with more than twice the recommended value of 3–4 g of salt/day. The main source of salt in the diet is processed foods (about 70–75% of the total intake). However besides its flavoring effect, salt controls the water activity and influences the protein structure therefore playing a significant role in the food preservation and structure, respectively. The challenge of reducing the salt content while maintaining shelf life, stability and acceptability of the products is major for the food industry.

Because of its affinity for water, salt competes with the other constituents of the flour and the dough to hydrate during the mixing step, delays consequently the formation of the gluten network and the development of the dough, and accordingly, lengthens the duration of mixing (Danno & Hoseney, 1982; Farahnaky & Hill, 2007; Hlynka, 1962; McCann & Day, 2013). Na$^+$ and Cl$^-$ ions released at the onset of dough mixing (salt dissolution) interact with the flour and dough ingredients and particularly create ionic bonds with proteins. Wheat proteins have positive charges to their surface which will be neutralized by the presence of anions, reducing therefore the repulsive forces between proteins and their interaction with water (Beck, Jekle, & Becker, 2012; Miller & Hoseney, 2008). This explains the reduction in absorption of water (Beck et al., 2012; Hlynka, 1962), as well as the increase of free water in the dough (Farahnaky & Hill, 2007; Larsson, 2002), observed in the presence of salt. This could also explain the increase of the stickiness of dough in the presence of salt observed by Beck et al. (2012) and Jekle and Becker (2012). The second consequence of the neutralization of the surface charges of proteins is an increase of the hydrophobic bonds between them, resulting in a better stability of the gluten network (Chiotelli, Rolee, & Le Meste, 2004; McCann & Day, 2013; Tolstoguzov, 1997). Lynch, Dal Bello, Sheehan, Cashman, and Arendt (2009) observed by CLSM that gluten fibers have larger diameter in the presence of salt.

This effect of salt on the gluten has a straightforward impact on the properties of texture of dough; however the reported effects are sometimes contradictory. Some authors showed an increase of the consistency of the dough after addition of salt (Beck et al., 2012; Danno & Hoseney, 1982). Whereas others showed its reduction (Farahnaky & Hill, 2007; Hlynka, 1962; McCann & Day, 2013). Moreover, according

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http://dx.doi.org/10.1016/j.foodres.2016.03.013

to some authors the salt seems to decrease slightly the elastic modulus G′ without affecting tan δ (Jekle & Becker, 2012; Lynch et al., 2009; McCann & Day, 2013) whereas other authors observed rather an increase of G′ (Larsson, 2002). Lynch et al. (2009) and McCann and Day (2013) attributed these differences to the content and the nature of the flour proteins. The extensional properties of the dough are also affected by salt. In the presence of salt, the dough appears more stretchable but also more resistant to extension (Beck et al., 2012; Casutt, Preston, & Kilborn, 1984). Moreover, the salt increases the relaxation time of the dough (McCann & Day, 2013).

The effects of salt content reduction in dough are expected to be significant; a first positive effect reported in the literature is an increase in water absorption (Beck et al., 2012; Hlynka, 1962) and a shorter mixing time because of the faster development of the gluten network (Danno & Hoseney, 1982; Farahnaky & Hill, 2007; Hlynka, 1962; McCann & Day, 2013). A rather negative effect is a lower consistency and a reduction in stability (Chiotelli et al., 2004; McCann & Day, 2013), a decrease in extensibility, i.e. ability to be stretched, and in resistance to extension, i.e. force needed to stretch (Beck et al., 2012; Casutt et al., 1984). One advantage of this decreased consistency of the dough will be a lower energy demand to laminate the dough (Raghavan, Babu, Chand, & Rao, 1996).

The salt reduction in dough and cereal product seems possible from a technological point of view and can be easily compensated with an adjustment of the moisture content and the temperature (Farahnaky & Hill, 2007; Lynch et al., 2009). McCann and Day (2013) show that the bad effects of a reduction of salt on the dough consistency and the properties of the bread can be partially overcome by the strength of the flour used. Lynch et al. (2009), also point out that the major problem of the reduction of salt in bread lies in the sensory acceptance of the product. The reduction or the omission of the salt gives a less tasty, bland, even insipid product. However according to some authors, the reduction of the salt can be acceptable from a sensory point of view if it is progressive: a reduction of 25% of the salt content in 6 weeks (Bolhuis et al., 2011; Girgis et al., 2003), or even of 52% over 4 weeks do not affect the acceptability and the consumption of breads by the consumers nor the choice of the spreading for a possible compensation (Bolhuis et al., 2011).

A strategy to enhance saltiness intensity using an inhomogeneous spatial distribution of sodium has been proposed for bread (Noort, Bult, Stieger, & Hamer, 2010). It was achieved by baking bread made of different layers having different salt contents; in such a configuration, the spatial modulation of salt content (sensory contrast) could allow reducing the sodium content in bread without loss of saltiness intensity. However, the salt tends to dissolve and diffuse from the highly concentrated towards the less concentrated regions. An alternative strategy based on spatial modulation has been proposed by the same author using encapsulated salt grains distributed in dough reduced in salt (Noort, Bult, & Stieger, 2012). In the present study, we implemented processing adjustments to reduce salt content while maintaining saltiness perception in two types of sheeted dough, a puff pastry and a pizza dough. On one hand we created highly salted spots by encapsulating salt grains, and, on the other hand, we optimized a dusting system to achieve a homogeneous distribution of encapsulated salt grains on the dough during the laminating process.

2. Material and methods

2.1. Dough recipes

2.1.1. Reference recipes

The dough recipe 1, a simplified puff pastry without fat layers, was made of flour (100 g), tap water (50.9 g), and 2.1 g sodium chloride (Groupe Salins, Levallois-Perret, France). The dough recipe 2, a simplified pizza dough, was made of 100 g flour, 43.6 g of water, 2.1 g of salt and 14.8 g fat. Flour contains 11.8% of proteins, 14.3% of water (Rettenmeier, Horb, Germany).

2.1.2. Experimental modalities

- Salt reduction study

Various amounts of salt were studied:

- 0%, 0.4%, 0.7%, 1.0%, 1.4%, 1.8% and 2.1% in recipe 1;
- 0%, 1.1%, 1.5%, 2.2% in recipe 2.

- Saltiness compensation study

For the dissolution tests, 4 following distributions have been tested:

1. raw salt grains added during mixing;
2. raw salt grains mixed with fat prior to mixing to create an hydrophobic coating around the salt grains;
3. raw salt grains encapsulated with fatty compound A (30% d.b.) added during mixing;
4. raw salt grains encapsulated with wax B (40% d.b.) added during mixing.

For the modalities 3 and 4, salt grains with a diameter in the range of 1.25 mm to 2 mm were encapsulated with either a fatty compound A (85% of saturated fatty acids, 15% of unsaturated fatty acids) or a wax B (85% of fatty acids esters, 15% fatty alcohols), having respectively a melting temperature of 70 °C and 80 °C.

2.2. Dough processing: mixing, sheeting and salt distribution

The ingredients were mixed for 4 min at slow speed (spiral 50 rpm, bowl 6 rpm) and 8 min at fast speed (spiral 120 rpm, bowl 10 rpm) in a SP11 spiral mixer (VMI, Montaigu, France). The power developed by the mixer is recorded during the mixing step and the optimal mixing time is chosen as the time where the power reaches a maximum (t_{peak} on Fig. 1).

After a resting time of one hour in a plastic film to avoid dehydration, the dough was sheeted with a rolling mill (Rondo Doge, Burgdorf, Switzerland) equipped with a duster located downstream of the rollers which has been modified to distribute salt during sheeting. The quantity of salt distributed was being controlled by the vibration speed of the duster and by the opening of drawers inside the duster. Two laser sensors (IL S-065, Keyence, Osaka, Japan), located upstream to and downstream of the rollers, allowed the measurements of dough thickness along the rolling out process steps (Fig. 1). The initial thickness is measured (H_{in}), then the sheeting is done by adjusting the space between the rollers (H_0) and the final thickness is measured (H_{out}). A series of 10 decreasing gaps (nip between the rollers equal to H_0) from 45 mm to 1 mm is followed; the dough goes back and forth for every gap.

The distribution of salt grains by the duster fitted downstream is followed by image analysis. The initial surface of the dough sample is colored in green and the salt grains are colored in black to increase the contrast with the dough as illustrated by Fig. 2. The images are thresholded at two gray levels; one to select the darkest pixels corresponding to the salt grains and another to select the green surface area corresponding to the surface area of the dough sample at the time of the salt distribution.

2.3. Dough physical properties

2.3.1. Stickiness properties

The stickiness of the dough was measured with a texture analyzer TAXTPlus (SMS, Swantech, France) equipped with a dough stickiness rig as described by Chen and Hoseney (1995). The principle of the test is to measure the adhesive force of a piece of dough extruded through a grid to a cylinder in polished Plexiglas (diameter 25 mm). Dough