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Review on the influence of NaCl on the quality parameters of soft wheat dough

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Abstract
The presence or absence of Sodium Chloride on the quality parameters of soft wheat dough samples was identified. 176 flour samples were analyzed for their protein content, Zeleny sedimentation value and by means of the Chopin Alveograph and Brabender Farinograph, with no salt and with 1.5% salt addition. Aubusson, Boleroand Blasco were studied by means of the Rapid Visco Analyzer at three levels of salt addition (0%, 1.5% and 3.0%). The results of the study confirmed the role of salt in strengthening the wheat gluten network and thus the gas retention of dough and in affecting yeast activity. Protein content, sedimentation value according to Zeleny, Alveograph and Farinograph parameters were analyzed. The protein content (% d.m.) were ranged from 8.2 to 15.0 covering the range of values that are commonly found in wheat commercialized for bakery products manufacturing and Zeleny sedimentation Index value ranges from 18 to 68 mL indicating that values below 20 mL are unsuitable for bread baking. Considering the Alveograph parameters obtained with salt ranges from 72 to 413 whereas values ranged from 42 to 342 in the absence of salt. T-test resulted in significant difference ($p < 0.01$) between all Farinograph and Alveograph parameters with or without salt. Two way analysis of variance showed that all parameters are influenced by the cultivar ($p < 0.01$), but did not confirm an interaction between the two factors (salt × cultivar). Differences between parameters with and without salt resulted to be of quite variable extent between samples.

Keywords: Alveograph, dough, farinograph, quality, salt, rapid visco analyzer, wheat

Introduction
Sodium is essential for the human metabolism. Excess sodium intake is associated with hypertension, which is a major risk factor for cardiovascular diseases; it has been estimated that 62% of strokes and 49% of coronary heart diseases are caused by high blood pressure [1]. Moreover, high sodium intake has also been associated with several other negative health effects, including renal disease, renal stones [2], decreased bone mineral density [3], gastric cancer [4], asthma [5], and possibly obesity [6]. In industrialized countries, 10–15% in average of sodium intake is naturally occurring in foods, 10–15% comes from discretionary use of salt (sodium chloride) during home cooking or at the table and the remaining 70–75% comes from processed foods [7]. WHO recommends a maximum adult salt intake of 5 g/day [8]. Different strategies and policy options have been proposed to achieve this goal and several initiatives have been implemented especially in the European region, aiming at reaching this level of salt consumption [7, 9-11].

Salt reduction in processed products has been proposed as a high-impact intervention for reducing the sodium intake at population level. Amongst processed foods, cereal products contribute the most to the overall salt intake, especially in those countries where they are staple foods [12-15]. Salt has critical technological functions in dough and bread other than sensory contribution and its reduction can create significant processing challenges that the bread manufacturing industry has yet to face, for example, salt influences dough rheological behavior and at reduced salt levels dough handling can be affected due to sticky dough phenomena, creating major processing issues and a poor quality final product [16]. Several salt substitutes have been experimented in bread to reduce sodium, but they often have negative effects on sensory properties [17]. A study on the behavior of wheat doughs belonging to many different genetic backgrounds in the presence or absence of salt and it could be used in guiding food industry and breeders in the selection of suitable genotypes for reduced salt bread and bakery products manufacturing.

Materials and Methods Wheat Samples

176 soft wheat (*Triticum aestivum* L.) grain samples belonging to 41 cultivars of different bread making quality and representing the Italian genetic soft wheat panorama currently used in bakery products, were collected at the farm over the harvest years 2011–2013 in Italy For each cultivar, a minimum of 3 up to a maximum of 6 samples were collected, in different geographical locations whenever possible. Grain samples were tempered to 15.5-17.5% moisture depending on their hardness measured by means of the SKCS 4100 instrument (Perten Instruments, Stockholm, Sweden) and subsequently milled in a Bühler MLU 202 pilot mill (Canton St. Gallen Bühler, Uzwil, Switzerland) equipped with three break rolls, three reduction rolls, and six screens, according to method 26–10.02 of the AACCI [18] to obtain commercial type white flours with an ash content of 0.55–0.65% (flours of 0 type according to the Italian official classification).

Chemical composition analyses

Grain samples were analyzed for moisture by means of the Aquasearch P600 instrument (Kett Electric Laboratory, Tokyo, Japan). Flours were analyzed for moisture according to the ICC Method N.110⁄1 [19], for total protein by the Kjeldahl method according to AOAC Official Method 2001.11 [20] using 5.70 as conversion factor and for Zeleny sedimentation index according to the ICC Method 116/1 [19]. Ash content in flours was checked in a muffle furnace according to ICC Method N. 105/2 [19]. The effect of salt addition on the rheological properties of dough produced from the flour samples was investigated by means of the Chopin Alveograph (Chopin Technologies, Paris, France) and the Brabender Farinograph, equipped with a Sigma mixer S50 (50 g of flour) (Brabender, Duisburg, Germany). The Brabender Farinograph test was run a first time according to the standard ICC Method n. 115/1 [19] without salt addition, then it was repeated by modifying the procedure in this way: a sodium chloride solution was used instead of pure distilled water, to obtain a dough containing 1.5% salt with respect to flour weight. The measured parameters were: water absorbance 14%, development time, stability and softening. The flours of Aubusson, Bolero and Blasco, which are widely used in bread making in Italy and considered respectively as possessing weak, intermediate and strong gluten were also tested for their pasting properties by means of a RVA (Rapid Visco Analyzer) (Perten Instruments, Stockholm, Sweden) according to ICC Method n. 162, Standard 1 profile [19]. The test was repeated according to a modified Standard by using 1.5% or 3.0% salt and the parameters of peak time, peak viscosity, through viscosity, viscosity breakdown, set back and final viscosity were measured.

Results

Protein content, sedimentation value according to Zeleny, Alveograph and Farinograph parameters were analyzed. The Alveograph and the Farinograph parameters were reported for salt-free dough and for dough containing 1.5% salt. The protein content (% d.m.) were ranged from 8.2 to 15.0 covering the range of values that are commonly found in wheat commercialized for bakery products manufacturing and Zeleny sedimentation Index value ranges from 18 to 68 mL and values below 20 mL are indicative of a flour unsuitable for bread baking. Considering the Alveograph parameters obtained with salt ranges from 72 to 413 whereas values ranged from 42 to 342 in the absence of salt. Farinographic water absorbance (14% m.b.) is reported for a dough without salt and with 1.5% salt; values ranged respectively from 48.6 to 62.8% and from 47.5 to 61.5%. The development time was also measured under the same conditions and it was between 1.0 and 20.0 min for the dough without salt and between 0.9 and 22.0 min for the dough with salt. The stability was also measured in the Farinograph curve and it ranged between 0.9 and 21.4 min in the dough without salt and between 0.7 and 20.5 in the dough with salt.

Considering the Farinograph parameters, salt addition produced a decrease in water absorption of a few percent points in 95% of samples. It also resulted in an increase generally small, but high for certain samples of development time (78% of samples and stability (70% of samples). This was accompanied by a decrease in softening (72% of samples). The farinogram of strong flours like Blasco looked as if it was not affected that much by salt addition, whereas the curve of medium bread making quality flours as Aubusson was clearly improved and the curve of poor-quality flours was only slightly improved. Aubusson, Bolero and Blasco were selected to study the behaviour of flours in the Rapid Visco Analyzer (RVA), with three levels of salt addition i.e., 0%, 1.5% and 3.0%. Aubusson and Bolero are classified in Italy as bread-making quality and the Blasco as superior bread-making quality, with Bolero being intermediate between Aubusson and Blasco. Total proteins of these flours were Aubusson 11.6% d.m., Bolero 10.0% d.m. and Blasco 9.9% d.m. The Alveograph with salt was 367 for Blasco, 192 for Bolero and 110 for Aubusson whereas it was 336, 147 and 73 respectively, without salt. At each salt concentration, viscosity at peak, through and end, together with breakdown and setback, were higher for Aubusson, intermediate for Bolero and lower for Blasco. Progressive increase of salt concentration induced in all three cvs. A corresponding increase of viscosity at peak, through and end and a slight delay of peak. The highest peak and final viscosities were reached for the maximum salt addition (i.e., 3.0%) whereas the 1.5% salt addition produced noticeable differences in the RVA curve with respect to no salt addition only for the Aubusson and Bolero whereas in the Blasco the strongest quality one, the 0% salt curve and the 1.5% salt curves were almost superimposed. Salt addition to the dough resulted in a decrease of gas production during fermentation and the dropping was much more pronounced at 3.0% salt concentration than at 1.5%. For the Aubusson flour, dough made without salt produced a total gas volume of 1518 mL. The addition of 1.5% NaCl led to a total volume of 1487 mL, whereas at 3.0% salt total volume dropped to 1272 mL. Similarly, for the Blasco flour, total volume was 1584 mL without salt, 1519 mL with 1.5% NaCl and 1242 mL at 3.0% NaCl, respectively.

The dough development profiles during fermentation of the Aubusson and Blasco flours show that without salt, the dough made from the weak Aubusson cv. rose to a maximum height first and then deflated sensibly. The dough made from the strong Blasco cv. rose continuously, with a pause (shoulder) but without deflating and reached a final height that was also its maximum height. The addition of 1.5% salt strengthened the Aubusson dough, that did not deflate sensibly anymore and its maximum height, which was like the one without salt, occurred later. On the contrary, there was no appreciable effect on the final height of the Blasco dough (The shoulder was slightly delayed and increased). At 3.0% salt addition, the profile of the Aubusson dough changed completely and became like that of the Blasco dough with no salt or 1.5% salt, whereas the Blasco dough became too tenacious and rose less than with no salt or 1.5% salt.

Discussion

By using Farinograph and Alveograph instruments flours coming from 41 different genotypes were analyzed in the absence and in the presence of 1.5% salt to understand how the presence of such an amount of salt influences the flour behavior compared to no salt. The Zeleny index spanning a wide range of values was a clear confirmation of the different bread making quality of our flours. The comparison of rheological parameters determined with varying salt content in the dough suggests that the presence or absence of salt does influence these parameters. T-test resulted in significant difference ($p < 0.01$) between all Farinograph and Alveograph parameters with or without salt. Two-way analysis of variance confirmed this result and as expected showed that all parameters are influenced by the cultivar ($p < 0.01$), but did not confirm an interaction between the two factors (salt × cultivar). Differences between parameters with and without salt resulted to be of quite variable extent between samples.

Several authors have investigated on the addition of salt to wheat dough and how it affects its Farinograph parameters. Kojima *et al.* [21] reported a decrease in water absorption and an increase in the development time of the dough at a 1.5% salt level. When salt was added to the dough the protein association was increased, water absorption decreased but resistance to extension and extensibility increased. Beck at al. [22] also report that their Farinograph studies indicated that decreasing NaCl concentration increased water absorption and explained that this tendency confirms the assumption of decreasing protein hydration capacity due to the competition of sodium and chloride ions and water molecules on the protein surface. When salt is added to dough, Na^+ and Cl^- ions can interact with polar binding sites of gluten protein and compete with water for them. When salt was added as a solid to dough ingredients before mixing, the first part of the farinogram (dough development) was less smooth than when salt was previously dissolved in water, indicating that salt participates to the process of dough formation. Full-charged ions Na^+ and Cl^- probably establish strong polar interactions with gluten proteins that lead to a stabilized gluten network, so that strength and machinability of dough is improved. It seems, however, that this effect can improve technological quality of flours of medium strength, but cannot change too weak flour, whereas strong flour would not need it.

Tuhumury *et al.* [23] studying two commercial wheat flours with different levels of total proteins in the presence or absence of NaCl by using transmission electron microscopy and chemical analysis of disulfide bond linkages and the ratio of polymeric glutenins and monomeric gliadins, confirmed the fact that NaCl caused gluten to form fibrous structures and NaCl presence increased non-covalent interactions and β-sheet structure in gluten proteins.

So, the presence of salt during dough mixing results in different molecular conformation and network structure of gluten proteins which contributed to the differences in the rheological properties. Recently, Chen at al. [24] investigated on the disulfide, sulfhydryl groups, surface hydrophobicity, secondary structure and extractable gliadin and glutenin of gluten in hard wheat flour doughs prepared with five different levels of NaCl. They found that the presence of salt decreased the free sulfhydryl content but increased the β-sheet structure of gluten. The extractable level of gliadin greatly decreased while glutenin increased with NaCl implying that more polymeric and less soluble protein networks were formed. More recently a paper by Avramenko *et al.* [25] investigated on the role of NaCl level on the handling and water mobility in dough prepared from four different wheat cultivars.

Conclusions

176 samples from 41 different genotypes were studied possessing a wide range of qualities. Salt influences dough behavior and in general all flours improve their baking quality. Salt is used in strengthening the gluten network and thus the gas retention of dough and in affecting yeast activity. Part of this dough strengthening effect is due to the decrease in the water absorption of the flour when NaCl is present. A small quantity of salt (1.5%) is enough to improve the technological quality of medium bread making quality flours, so that they can sustain longer fermentations and can be mixed for a longer time. Strong flours perform well without adding salt and too much salt (3.0%) can make them too tenacious. This certainly opens to the reduction of salt use in bread making, in line with recommendations to improve public health by reducing salt intake in the diet.

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