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Behavior of wheat flour dough at different pretreated temperatures through rheological characteristics and molecular interactions of proteins

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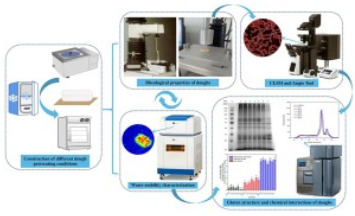
Highlights

- The low-moisture doughs were pretreated at low or high temperatures.
- The pretreatment promoted the formation of a rigid structure in the dough.
- Preheating weakened the mechanical properties of doughs.
- Non-covalent interaction was the main reason of dough processing ability in actual processing.
- The conversion of SH to SS was enhanced by high preheating temperatures.

Abstract

Rheological properties and chemical interactions of doughs prepared at different temperatures were evaluated. The results showed that the rigidity of pretreated doughs was enhanced, and the processing performance of doughs was weakened. Preheating resulted in the polymerization of gluten through the conversion of sulfhydryl groups to disulfide bonds. The noncovalent interaction of dough played a dominant role and further led to the production of glutenin macropolymers (55.77 mg/g). CLSM images verified that preheating promoted the formation of the coarse and scattered gluten network, while preheating at 80 °C led to a higher gluten area percentage (40.27%) and lower lacunarity (6.74×10^{-2}) structure. The migration of water promoted changes in hydrogen bond and hydrophobic interaction in doughs, which directly affect the processability of doughs. The study provides information for predicting the rheological behavior of dough in actual production and makes it possible to modify gluten by preheating treatment without complicating existing operations.

Graphical abstract



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Introduction

Wheat flour and products are widely used in the diet of consumers and play an irreplaceable role. A large number of literature have reported the extensive application of thermal treatment in the quality improvement of wheat flour, including superheated steam treatment (Ma et al., 2022, Ma et al., 2022), repeated wet heat pretreatment (Xie, Li, Chen, & Zhang, 2019), dry heat treatment (Gou, Wu, Saleh, Jing, Liu, Zhao, et al., 2019), etc. Gluten aggregation occurred through disulfide bond formation and molecular rearrangement of hydrogen bonds, as well as gelatinization of protein and starch, and their interactions, lead to changes in dough rheological properties and final product quality (López-Barón et al., 2017, Wang et al., 2021, Zhang et al., 2021).

In general, the main research object of thermal treatment technology is wheat kernels or flour. The direct heat treatment of wheat flour doughs is more concerned with bread and biscuit doughs because of the baking process. Pulatsu et al. (Pulatsu, Su, Kenderes, Lin, Vardhanabhuti, & Lin, 2021) found the preheated cookie dough system can form a more stable structure during 3D printing, resulting in more attractive cookies with a neat and unbreakable shape. The proofing of bread dough assisted by ohmic heating allowed the yeasts to quickly reach the optimum temperature of their activity, and led to lower temperature gradients, meaning a potential improvement of dough quality

(Gally, Rouaud, Jury, Havet, Ogé, & Le-Bail, 2017). The mixture (1:1) of preheated dough and fresh dough enhanced the interaction between water and starch-gluten matrix, and effectively reduced the damage of the matrix in frozen dough, which ultimately proved that the method was innovative in improving the quality of frozen dough (Yuan, Hong, Ma, Xu, Zhang, Jin, et al., 2021).

In the processing of noodles, more attention should be paid to the practical application of heat treatment rather than just the cooking. Research had showed that shortening the cooking time of noodles can better meet the needs of the fast-paced consumer market. Xue et al. (Xue et al., 2010, Xue et al., 2008) used microwave heating to produce quick-cooked noodles, and further predicted to achieve accurate control of intermittent microwave heating on starch gelatinization. In fact, the noodles dough is mostly exposed to cold or hot weather conditions, which is completely different from the high temperature processing that leads to an increase in the internal temperature of wheat dough. Turksoy et al. (Turksoy, Erturk, & Kokini, 2021) explored the non-linear rheological properties of fresh dough changed during the aging process of 108 h at 4 or 25 °C. However, due to the decisive role of water, the processing performance of the dough sample is almost completely different from that of the noodle dough with low water content. The comparative study of rheological properties and their effects on protein structure between low-temperature treated and preheated white salt noodles dough is rare. The results obtained in the study will provide additional information for predicting the processing behavior of wheat dough and the effect of preheating treated noodle dough at temperatures closer to the processing conditions. Specifically, this study focuses on the comparison of the rheological changes of dough at a wide range of pretreated temperatures to guide for white salt noodles processing. The objective was to evaluate and compare the effect of low-temperature and preheating treatment on the changes of the processing characteristics of the dough. The changes in rheology were also molecularly explained using the solubility and structure of glutenin. The results of this study can provide an interesting reference for the processing of wheat flour products with low moisture content.

Section snippets

Preparation of dough samples

The raw wheat was ground into flour with a Buhler experiment mill (Buhler Group., Uzville, Switzerland). The water content of the flour was 12.8% (determined by the Oven drying method), and the protein content was 13.8% (determined by the Kjeldahl method). The doughs were prepared with a pin mixer. The total amount of added water (60% of the water absorption measured by the Farinograph) and the time of mixing (7 min) were unified. The resulting floc doughs were sheeted to 4 mm and incubated …

Rheological properties of dough with large deformation

Uni-axial tensile test of dough was one of the most conventionally used methods for evaluating dough processing performance. The dough tensile resistance decreased significantly ($P<0.05$) and elongation increased ($P>0.05$) after pretreated, with no distinct change in the tensile area (Fig. 1 A). The pretreatment process promoted water regulation between proteins and starch, and the gluten network changed to a more ordered structure. The dough becomes softer, less stretchable and more …

Conclusion

The water distribution, rheological properties and the composition of gluten protein were analyzed under different pre-treating temperatures. In general, the cold-pretreated increased the hardness of the dough sample and weakened the movement of the gluten polymer chains, resulting in low deformation recovery ability. The higher pretreatment temperatures also led to the increase in dough rigidity and the deterioration of elongation. The composition and subunit structure of gluten protein showed …

CRediT authorship contribution statement

Yu-ling Yang: Conceptualization, Methodology, Investigation, Formal analysis, Writing - original draft, Writing - review & editing. **Er-qi Guan:** Supervision, Project administration. **Ting-jing Zhang:** Data curation, Methodology. **Fei Xu:** Writing - review & editing. **Meng-meng Li:** Data curation, Writing - review & editing. **Ke Bian:** Conceptualization, Resources, Project administration, Funding acquisition, Supervision, Writing - review & editing. …

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. …

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