Kneading and Gluten Formation in Dough

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Abstract
Gluten in wheat-based bread can both benefit and harm consumers and thus is an important factor in consumers' food choices. The effect of kneading time on the gluten content of bread was studied. Relative gluten content was determined by measuring the force needed to puncture both the kneaded dough and the baked bread. It was found that the force needed to puncture both the dough and the bread increased with increasing kneading time up to 12 minutes. Kneading for longer than 12 minutes resulted in a decrease in the measured force. The gluten content of the dough was also measured directly and found to follow a trend similar to the force.

Keywords: gluten, kneading time, wheat dough, pound bread

I. INTRODUCTION

Gluten is an important protein in wheat grains. It has the ability to act as a binding and expanding agent and is often used as an additive in processed foods to improve texture, taste and moisture retention.[1] Gluten is formed from a complex combination of hundreds of proteins, although it is mostly a combination of glutenin and gliadin proteins. When water is added to flour, the proteins come out of the 'frozen state', which makes them flexible, a process called 'hydration'. The two types of protein attach to each other chemically with disulfide bonds, as shown in Figure 1, forming gluten, which is tough, flexible and insoluble.[2]

Since gluten has a complex structure of large molecules that are tangled together (Figure 2), it forms a strong network which is both flexible and extensible, enabling the dough to capture the carbon dioxide gas produced by the yeast, which causes the dough to rise.[4] Gluten also helps make bread fluffier and gives it a soft, chewy texture. Wheat is rich in gluten proteins, with up to 23 grams per 100 grams of wheat, but consuming too much gluten can affect your immune system, leading to gluten intolerance for some.[6]

The amount of time for which wheat flour dough is kneaded affects the gluten content of the dough due to the time it takes for the glutenin and gliadin proteins to hydrate and then react with each other to form gluten.[7] Since gluten forms a strong molecular network that is flexible and extensible, the gluten content of dough and baked bread will affect its elasticity and resilience, meaning that the force needed to puncture dough and bread can be used as a measure of relative gluten content.[8]

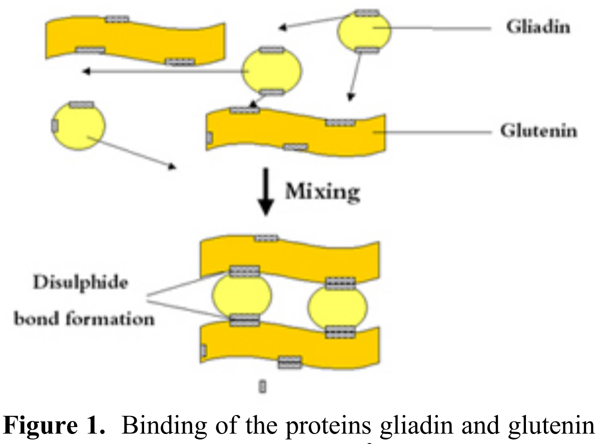

Figure 1. Binding of the proteins gliadin and glutenin by disulfide bonds to form gluten.[3]

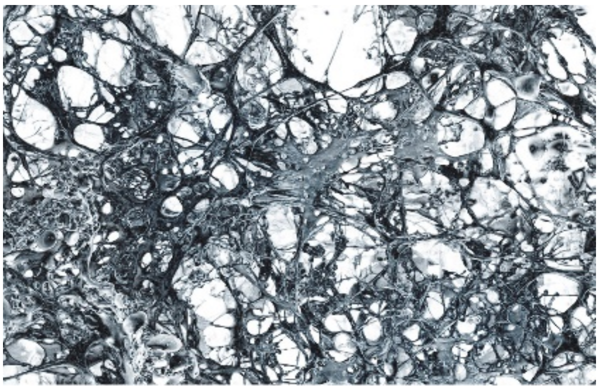

Figure 2. An image of gluten proteins taken with a scanning electron microscope.[5]

Here the effect of wheat dough kneading time on gluten content is studied. The relative gluten content of both the dough and the baked bread was determined by measuring the force needed to puncture the dough and bread. The gluten content in the dough was also determined by dissolving the dough in water and measuring the mass of the insoluble solids, which will be mainly the gluten proteins. It is hoped that the results of this study will be helpful for others in the food industry wanting to understand gluten levels in kneaded bread.

II. METHODS

Preparation of Pound Bread Dough

Bread flour (160 g) and cake flour (40 g) was sifted together, then yeast (3.0 g) was added and mixed well. Eggs (17 g), salt (2.0 g), sugar (30 g), and water (102 g) were then added and mixed well with the flour mixture.

Kneading the Dough

Unsalted butter (30 g) was put in a kneading machine, along with the dough mixture and set to mix at medium speed for 50 seconds. Seven batches of dough were made and kneaded for times ranging from 0 minutes to 20 minutes. Each batch was then taken out of the kneading machine and placed in a covered bowl for 45 minutes to allow it to rise. The risen dough was kneaded briefly to expel excess air, and then divided into three 100 g portions, with the remainder (74-76 g) reserved for the insoluble solids testing. The 100 g portions were put into three bread molds which were placed on the left (A), center (B) and right (C) of the oven and baked for 30 minutes. The baked bread was removed from the mold to cool for 30 minutes, then placed back in the mold for testing. This process was repeated for a total of four batches for each kneading time tested.

Figure 3. The Force Probe being inserted into the bread to record the force needed to puncture it using Datalogger program.

Force Testing of the Dough and Bread

Before baking, the force needed to puncture the dough was recorded using Datalogger by inserting the Force Probe into the left, center, and right side of the dough in the mold. After baking and cooling, the part of the loaf extending above the edge of the mold was cut off to remove the top crust, and the force needed to puncture the bread was measured in the same way as the dough, as shown in figure 3.

Testing for Gluten Content

The reserved portion of the dough was weighed then soaked in water for 15 minutes and filtered to separate the water. The dough was then soaked in water for another 10 minutes leaving the insoluble gluten as a solid, as shown in Figure 4, then filtered. The insoluble portion (wet gluten) was weighed, then dried in an oven and weighed again to determine the amount of dry gluten formed in the dough.

Figure 4. The insoluble gluten left as a solid after soaking the dough in water.

III. RESULTS AND DISCUSSION

The results of measuring the force required to puncture the dough on the left side, center, and right side of the mold (sample shown in Figure 5), indicated that, on average, there was no significant difference in force between the three points. The results of the tests on the baked bread also showed no difference in the three points tested, indicating that the baking process did not change the reliability of using force as a measure of gluten content.

The results for the means of all the tests for both the dough and the bread are shown in Figure 6. It is clear that the trend is the same for both. For kneading times of 0 – 12 minutes, the force increased, indicating increasing gluten content as the gluten had more time to form. But for kneading times greater than 12 minutes, the force needed to puncture both the dough and bread decreased. This is likely due to the fact that after 12 minutes all the proteins in the dough had formed into gluten networks, and further kneading acted to shear the aligned gluten molecules, reducing the strength of the gluten networks.[4]

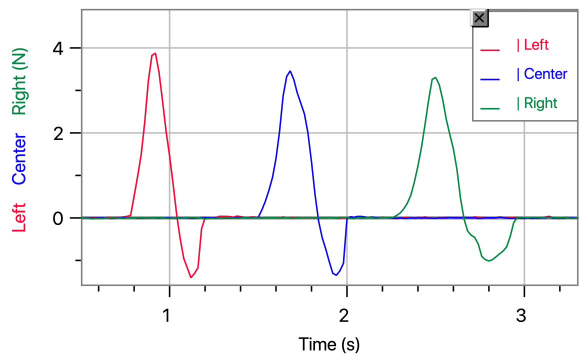

Figure 5. Representative sample of the results of the force measurements on the left, right, and center points of the dough in the mold.

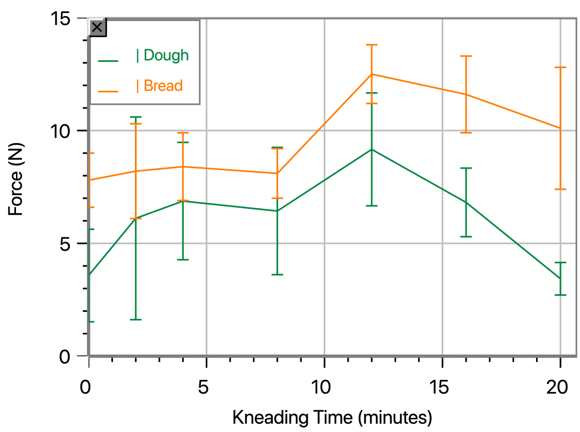

Figure 6. Force needed to puncture dough and baked bread as a function of kneading time.

While the force trends are the same for both dough and baked bread, the force required to puncture the bread was significantly higher. This is likely due to the baking process causing an increase in the resilience of the bread as a result of molecular changes during the baking process unrelated to gluten content.[8]

The results of the testing for gluten content, Figure 7, show a similar trend to the results of the force tests. The proportion of insoluble gluten in the dough increased with increasing kneading time from 0-12 minutes. This is because the kneading causes the particles in the flour to become smaller, allowing water to penetrate to more of the protein molecules and thus enabling the formation of gluten.[8] For kneading times beyond 12 minutes gluten content stayed constant. This is likely because the water had completely penetrated to all the proteins and no more gluten formation was occurring.

IV. CONCLUSION

It has been shown that both the insoluble gluten content and the force needed to puncture the dough and bread increased for the first 12 minutes of kneading time, clearly showing increasing gluten content with increased kneading time up to a maximum of 12 minutes. For kneading times greater than 12 minutes, insoluble gluten content stayed constant, while puncture force declined, likely due to a breakdown in the integrity of the molecular networks of gluten.

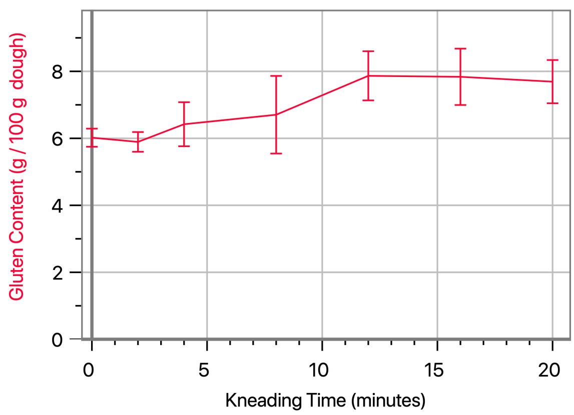

Figure 7. Mean gluten content in the dough as a function of kneading time.

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