

BETTER MODELING OF HIGH-SPEED COMMERCIAL DOUGH MIXING

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Dough-mixing characteristics have been an important part of assessing wheat quality for more than 60 years. Most methods are based on assessing the physical properties of the gluten network that is formed after mixing and the properties' correlation with some end use baking property. The precise specification for dough rheology parameters will depend on many factors, including the breadmaking process, the recipe used, and the required qualities of the final bread.

There are several different standard methods and instruments used to assess protein quality in flours. They have originated in different countries and markets at different times and are applicable to different baking contexts (5).

Standard physical dough-test-measuring equipment is comprised of a mixer bowl of specified geometry in which mixer blades or mixer pins rotate. Methods are based on mixing flour and water with sigma-arm mixing blades (e.g., Farinograph, C. W. Brabender Instruments, Inc., New Jersey, U.S.A.; Valorigraph, INTER_LABOR, Hungary; and doughLAB, Perten Instruments, Kungens Kurva, Sweden), augers (e.g., Consistograph, Lab Synergy, New York, U.S.A.; Mixolab, Lab Synergy, New York, U.S.A.), or a system of rotating and fixed pins (Mixograph, National Manufacturing Co., Nebraska, U.S.A.). The mixer blades or pins are matched to the geometry of the bowl and as mixing proceeds the changing resistance of the dough ingredients is measured as torque on the mixing arms. The measured torque is continuously recorded; the curves indicate the amount of torque or strength required to mix the dough to a defined consistency and the length of time the torque stays steady. This process indicates the resilience of the gluten protein matrix that develops (5).

Another purpose of the test is to estimate the water-absorption capacity of the flour,

- High-energy-input dough development tests that mimic high work rate commercial dough-mixing conditions can be used to more accurately predict product quality and processing characteristics of bread. Such tests adequately mix strong wheat flour doughs of different quality, providing more rapid, accurate, relevant, and easy-to-interpret results.
- Low-water-addition physical dough test methods that correspond to the optimum consistency of pasta and noodle doughs provide information that is relevant to the manufacturing process.
- Physical dough tests with two-stage (low speed followed by high speed) mixing enable the incorporation of fat in a test that provides process-relevant information for the manufacture of laminated baked products.

that is, the amount of water required for the dough to reach a defined consistency. Standard mixing speed is slow and the energy input rate is low. Standard mixing protocols bear little or no resemblance to mixing and processing techniques used in a modern commercial bakery (5).

Starting with the Standards

Bowl geometry, mixing blade/pin design, and mixing speed determine the mechanical energy input to the dough. Rotating pins deliver the lowest energy input, augers deliver intermediate energy input, and sigma-arms deliver the highest energy input. Low energy input and slow-speed (63 rpm) standard methods originated when weak soft wheat was the major part of the crop in Europe; they worked well on this type of wheat. Many studies have shown that very strong wheat is not developed using low-energy-input standard methods (2). Pin mixer action does not mix dough sufficiently or transfer energy rapidly enough to simulate many modern processes, particularly the rapid dough process (1).

What Is Meant by "Dough Development"?

Dough mixing has three main objectives: blending the flour and ingredients, hydrating the ingredients, and developing a gluten structure (1).

When water is added to the flour particles, the surfaces of the particles hydrate. Hard wheat flour particles are dense and water penetrates the particles slowly. Diffusion moves the water within the particle, water hydrates and mobilizes the proteins, and mixing shears and disrupts the hydrat-

ed particles, allowing the protein network to form. Additional mixing delivers additional energy to the system and the dough now develops to its optimum elastic and viscous properties for the retention of gas that is essential to the breadmaking process. Dough development involves the alignment and entanglement of the gluten fibrils over the starch to form a continuous, highly organized network. Optimum dough development may be related to the point of maximum resistance of the dough, or to some point 10 or 20% beyond the time when maximum resistance occurs to a point when maximum bread volume has been determined to occur. The gluten network retains the gas bubbles entrained during mixing that then grow and set during leavening and baking (3,5,9).

High-Energy Dough Tests

Typical bread-making wheat is strong or very strong, with very long dough development times using standard dough test methods. Some very strong wheat produces a dough development graph with two peaks, with the second peak taken to be the true dough development peak. In some cases, dough will not develop because the energy delivered by the standard method is below the critical mixing energy required (6).

Clearly, there is a need for testing at a higher energy input that will produce more rapid, accurate, relevant, and easier to interpret results. Higher energy mixing would be capable of adequately mixing strong wheat flour doughs to differentiate between samples of different quality. Methods that can mimic commercial mixing conditions offer considerable advantages

when specifying flour for different baking processes, bread products, and other wheat flour products such as pasta and noodles.

The doughLAB is a relatively new instrument for testing dough-making properties. It was designed to emulate the high work rates of modern dough mixers. High-speed (180 rpm) mixing can be used to screen wheat samples for suitability in bread production, mixing at torques around 7.8 Nm, yielding high-energy input rates. This feature is especially useful for samples such as hard wheat and durum semolina that are difficult to develop (7,8). Tests at higher speeds not only mimic process relevant conditions, but also reduce test time for the miller. By programming the energy input rate to the dough, new specific tests that better mimic the variety of final product processing conditions and better predict final product or processing characteristics can be developed.

The doughLAB can be programmed to detect the dough development peak while the test is running so it can be automatically terminated after the peak has been found at a point when maximum bread volume has been determined to occur. This enables a typical bakery practice to be mimicked.

Bread Has Ingredients and Improvers

Flour additives play an important role in the modern bakery. Recent advances in enzyme technology, particularly, opportunities for new product types and some regulatory changes, have led to the development of new and improved additives with a wide range of functionality. These include imparting tolerance to variation in raw materials and process conditions, and improving dough handling properties, loaf volume, taste, texture, nutrition, and shelf life. Bakeries are actively seeking improved methods to assess the effects of additives such as oxidants, reducing agents, emulsifiers, hydrocolloids, salt, sugar, soy flour, and enzymes, to check efficacy and dosage levels for a wide range of yeast-leavened products. By altering mixing speed and temperature regimes, methods to suit a variety of products, processes, and additive properties have been developed (4).

What About the Water?

Physical dough-testing methods are used to estimate how much water is required for the dough to reach a target consistency.

The optimum consistency for the physical dough test should correspond to the optimum consistency of the dough for processing in post-mixer operations. This will depend on the bread-making method and the dough-processing equipment used. In no-time bread-making processes, such as the Chorleywood Bread Process, there is no significant softening of the dough in the short time before dividing and molding, so higher water-addition levels are optimum. In hearth or oven-bottom breads, optimum water-addition levels are lower to limit the flow of the dough and retain product shape (5).

For cookie, cracker, pastry, pasta, and noodle manufacturing, water addition to the flour may be as low as 30–35% (9). There is a need to be able to test at these low-water-addition levels, to an optimum consistency that will produce more process-relevant information about the production and behavior of these types of dough. Water-ladder type experiments were run in the doughLAB with flour and semolina down to 30% water addition, demonstrating that practical methods can be developed to handle the type of low-water doughs used for these products.

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Fat in the Formula?

Laminated baked products such as puff pastry, croissant, Danish, and brioche, require a reasonable degree of gluten development and the incorporation of fat. Standard low mixing energy test protocols are not able to adequately develop the dough or incorporate the lipid. In commercial production, the flour is typically first mixed at a low speed to homogenize the ingredients, then at a high speed to develop the gluten matrix. In the latter step, the work rate must be high enough to overcome the lubricating effect of the fat.

A two-stage doughLAB mixing method uses low speed (63 rpm) to blend the ingredients (flour and sugar), followed by high-intensity, high-speed (110 rpm) mixing to develop the dough and incorporate 30% lipid (oil) (4).

Summary

Standard low-energy dough rheology methods have limited relevance to the very strong wheats and high-energy input processes now used for breadmaking. New high-speed tests have been developed to better mimic the variety of final product processing conditions encountered in the bakery and better predict final product and processing characteristics. Low-water-addition tests have also been developed that are relevant to pasta and noodle manufacturing.

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