## **Explaining Gluten**

One question I hear a lot is "what is gluten? Can you please explain it to me?" It's not surprising that people have a difficult time understanding gluten, because it doesn't exist in nature. Gluten is a water-insoluble *protein* that is formed when water is mixed with wheat flour. Proteins are very large molecules composed of amino acids. Two of the naturally occurring proteins in flour are called *glutenin* and *gliadin*. When sufficient water is added to dry flour the two proteins emerge from a "frozen state" and become flexible and able to move about. It's not too different from stiff, dry spaghetti becoming flexible when it is cooked in water.

The process of wetting the proteins is called *hydration*. As water and flour are mixed the hydrated proteins are brought together and begin to interact. They literally begin to stick to each other through the formation of chemical bonds. These new chemical bonds are called *cross-links*. Again, it's not unlike a pot of cooked spaghetti that has been poured into a colander and allowed to drain. After a few minutes the strands of spaghetti stick together unless they are separated by the addition of a little oil. In the case of gluten a number of different types of chemical bonds form between the proteins, with some (disulfide bonds) being stronger than others (ionic bonds and hydrogen bonds).

Continued mixing causes more cross-links to form between the proteins until a large *network* of chemically linked proteins is formed. Mixing can be done with a stand mixer, or by hand, such as when dough is *kneaded*. When dough is mixed or kneaded the hydrated flexible proteins are stretched and aligned in the direction of kneading providing more opportunities to form cross-links between the proteins. Kneading also incorporates air, which helps to form strong disulfide bonds. As kneading continues the protein networks combine to form *sheets* of proteins. Think of this step in the process as being similar to unraveling thread (proteins), and weaving the straightened thread into pieces of cloth (networks), and then pieces of cloth being stitched together to form large sheets of cloth similar to a quilt (see figures on following page).

The chemical cross-linking of glutenin and gliadin forms gluten, a very *elastic* substance. Neither protein alone is as elastic and stretchable as gluten. But when chemically linked together the new protein becomes elastic and stretchable like a rubber balloon. The gluten becomes stronger and stronger as more bonds form between the proteins, like a weak thin rubber balloon becoming a strong thick rubber balloon. Like a balloon, gluten can be inflated with gas and steam as dough rises and bread is baked in the oven. Think of an inflated balloon covered with paper mache. This is how we made puppets when I was young. When the paper mache dries the balloon can be popped and removed leaving a rigid sphere. In the same way, as bread bakes the inflated gluten dries turning into a strong but flexible structure that creates the holes in chewy bread (Note that freshly baked bread still contains about 35% moisture by weight, which is sufficient to keep the starch soft and the gluten elastic)

Below is a series of *scanning electron micrographs* (SEMs) of different stages of gluten development reproduced from the German journal *Zeitschrift fur Lebensmittel-Untersuchung und-Forschung* (1990) 190: 401-409. These photos taken under high magnification may help you envision the formation of gluten from flour and water. Dimension bars at the bottom of each photo show distance in microns (one micron is one-millionth of a meter).



Figure 1. Shows the protein network formed after water is added to flour with no mixing. Starch granules have been removed by washing (the starch granules normally fill the holes). Figure 2. Shows how the protein strands begin to stretch and bond together after a few seconds of kneading. Starch granules have been removed by washing.



Fig. 3

Fig. 4

Figure 3. Shows under-kneaded dough with stretched aggregated strands of protein. Starch granules have been washed away at the surface but remain trapped within the protein matrix. Figure 4. Shows the protein network resulting from optimally kneaded dough. Starch granules have been washed away at the surface.

Figure 5. On the following page shows a higher magnification of optimally kneaded dough with the starch granules still in place. When the dough bakes the starch granules will absorb water and swell many times larger filling most of the gaps. Figure 6. On the following page shows under higher magnification an exploded view of how sheets of gluten layer upon each other to form a flexible membrane capable of holding in gas.



Many factors affect the development and strength of gluten. If too much gluten develops it can make baked goods, like pie crust, tough rather than tender. The extent of gluten development also affects how high leavened baked goods will rise, and if the crumb is tender or chewy. Weaker gluten is more extensible (stretchable) and doesn't shrink as much. Here are some factors that affect gluten development.

- 1) Variety of wheat: Soft wheat contains less protein (6-8%), less glutenin, smaller proteins, forms weaker gluten. Hard wheat contains more protein (10-14%), more glutenin, larger proteins, forms stronger, more cohesive, elastic gluten.
- 2) Amount of water: Hydration is essential for gluten development. Glutenin and gliadin absorb about twice their weight in water (hydration). Less water results in less gluten development (reduces protein mobility), but too much water also reduces gluten development by diluting the proteins so much that their interaction is restricted.
- 3) Water hardness: Calcium and magnesium in hard water strengthen gluten. Water in Boston, MA is soft containing only 0-60 ppm of calcium and magnesium.
- 4) Water pH: The ideal pH for gluten development is 5-6. Above and below pH 5-6 reduces gluten strength producing more extensible (easier to stretch) dough. Adding baking soda raises pH producing more cookie spread, and more porous, tender crumb.
- 5) Leavening: Expanding air bubbles strengthen gluten, increasing cohesiveness, and elasticity, producing higher volume and finer crumb.
- 6) Enzymes: Enzymes that break down proteins are naturally present in flour, but inactive when dry. Enzymes break down gluten into smaller pieces so dough becomes softer and more extensible. The process known as autolyse (resting dough for 15-30 minutes), allows time for enzymes to break down gluten to produce more extensible dough, providing more volume and open crumb.
- 7) Salt: Bread dough contains 1.5-2.0% salt by weight of flour. Salt slows enzyme activity and rate of fermentation. Salt strengthens gluten, producing bread with higher volume and finer crumb.
- 8) Fat, oil, emulsifiers, and sugars tenderize dough. Fat and emulsifiers coat proteins reducing hydration and gluten development (like oil coating spaghetti). Shortening shortens gluten strands producing more tender baked goods. Sugar competes for water reducing protein hydration and gluten development.