Bread

Basic Structure: Three main components

- Water
- Gluten proteins
- Starch granules

The texture of breads and pastries are 100% dependent on how these components interact with the "other stuff"

- Breads and cakes = light and fluffy. This is because the starch granules are separated by millions of tiny air bubbles
- Pastries = flaky and tender. This is because the layers of protein/starch is broken up by millions of layers of fat

Ration of water : starch/protein dictates properties:

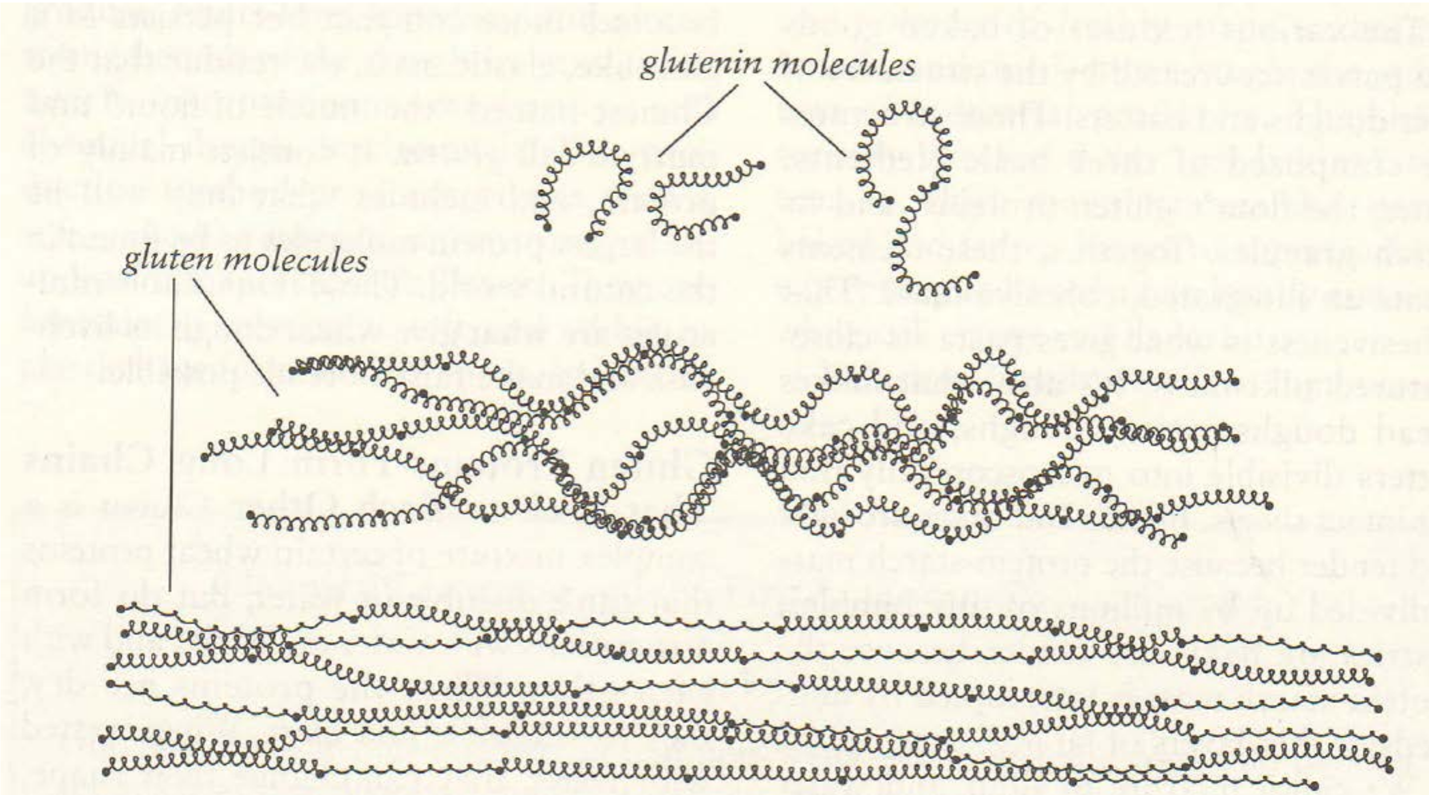
- More water = batters
    - Starch granules and gluten protein is dissolved in the water. Lots of the water is "free" (not bound to the gluten or starch). This make the mixture more pourable.
- More starch/protein = dough
    - All water is tightly bound to the gluten protein or the outside of the starch granule. These are embedded in the semisolid gluten-water matrix.

Starch:

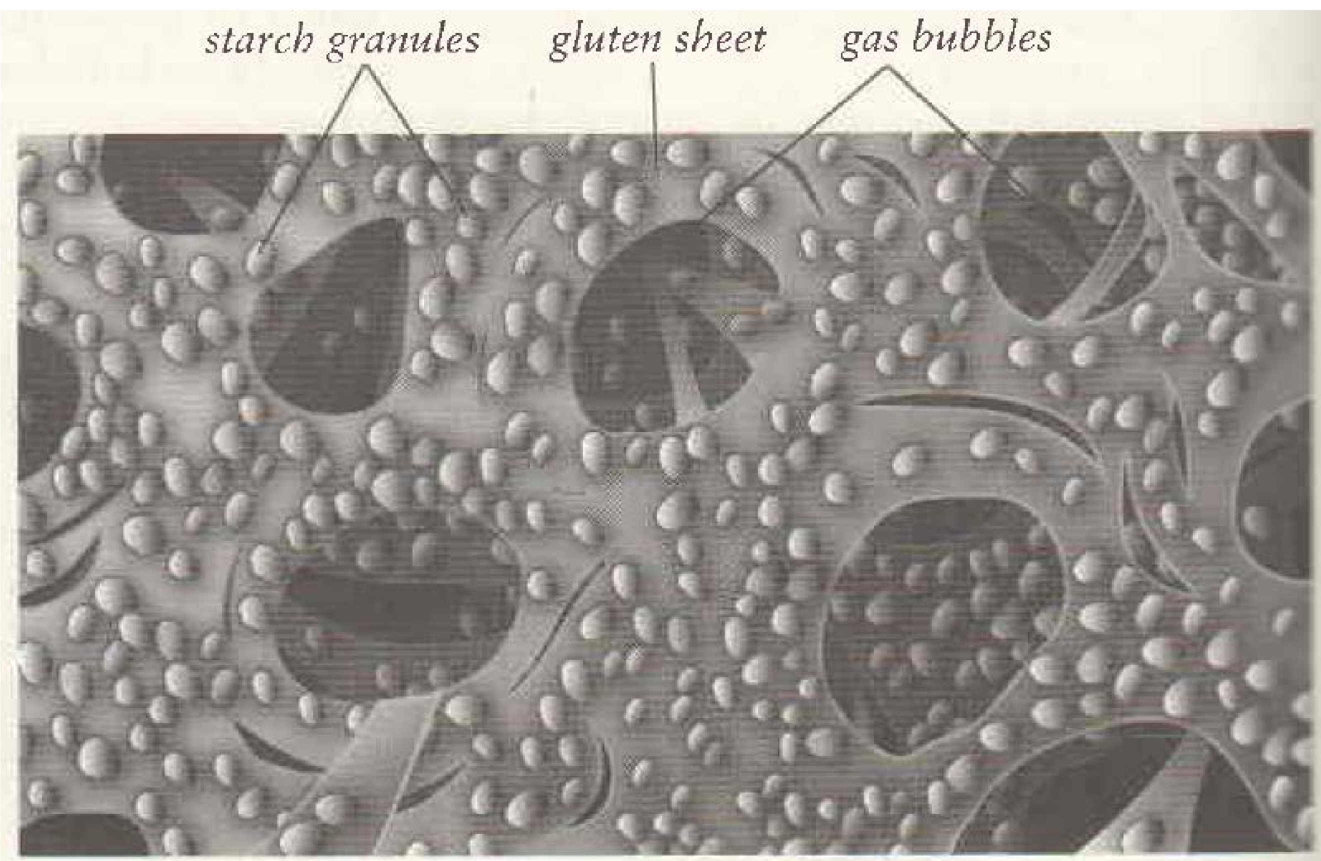
Gluten:

- Mainly protein. Gives dough the "liveliness". Makes raised breads possible.
- Complex mixture of a number of wheat proteins that cannot dissolve in water but WILL form strong associations with water.
- Main protein classes (both around 1000 amino acids long):
    - Gliadins
        - fold onto themselves in a compact mass
        - only weakly interact with other protein
    - Glutenins
        - Bond with each other in a number of ways
        - Form extensive tightly knit network
        - Coiled structure that can act like a spring
        - Interactions are relatively weak (so can be broken and reformed)
        - Each Glutenin protein has sulfur at the end of the chain
            - This allows glutenins protein to link up end to end through sulfur-sulfur bonds
            - Requires oxidants (electron acceptors) - O_2, yeast compounds, or bread additives
- Plastic and Elastic
    - Elastic = can change its shape in response to pressure
        - Due to structure of glutenins
        - Coiled structure allows weak bonds to be broken in response to pressure
        - Bonds reform with the pressure is removed
        - New bonds will form if they are "found" first
    - Plastic = will revert back to the original shape
        - Result of gliadin
        - Act like ball bearing – allow glutenins to glide past each other without bonding

Schematic of gluten proteins



Close-up depiction of gluten network. Note the starch granules suspended in the gluten network.



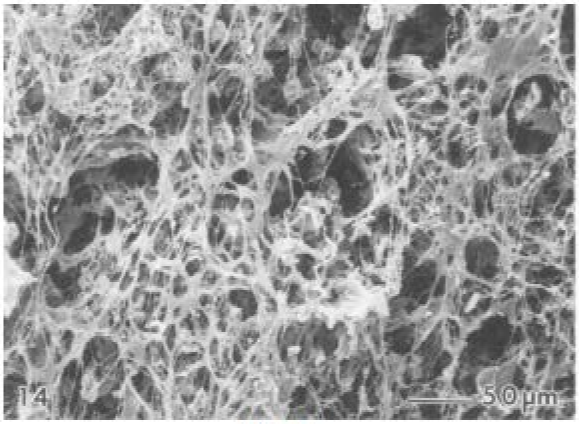


Fig. 1

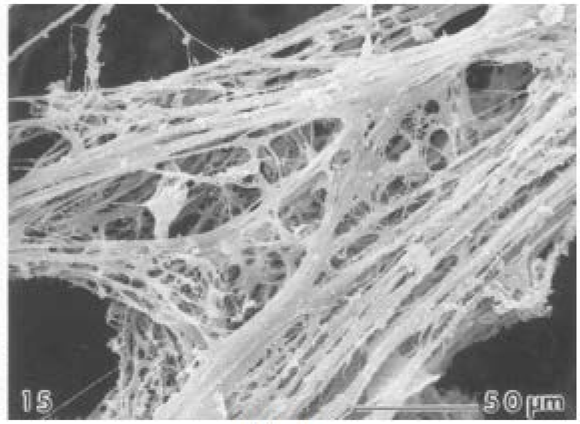


Fig. 2

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.

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.

Fig. 5

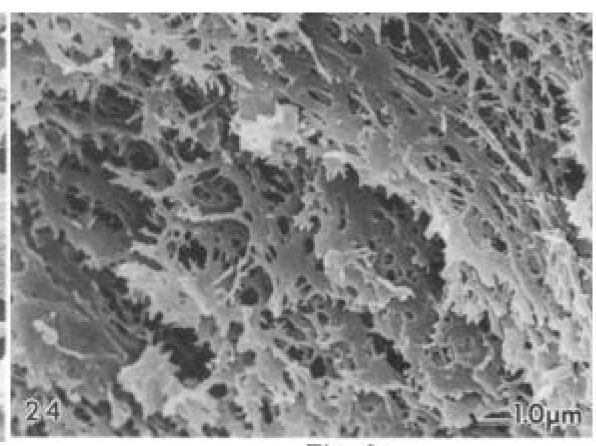


Fig. 6

- Controlling Gluten Strength:
    - Type of flour
        - High protein = strong gluten (good for bread)
        - Low protein = weak gluten (good for pastry)
        - Durum flour = strong but plastic (good for pasta)
    - Presence of oxidizing agents in flour
        - Affects S-S bonds. More bonds = higher dough strength
    - Water content
        - Controls gluten concentration (low concentrations = low bonding potential)
        - Little water = poorly developed gluten and crumbly texture
    - Kneading – promotes organization into a network
    - Salt – strengthens network through ionic interactions with glutenin proteins (prevents charged parts from repelling)
    - Sugar – limits gluten development by taking up space and discouraging protein interactions
    - Oil – coats gluten proteins and prevents gluten development. Shortening literally means that it shortens the gluten strands so that the dough is short – not stretchy (long).
    - Eggs
        - Water – dilute the gluten making a lower bonding potential
        - Oil – see above
        - Emulsifiers in the egg coat protein
            - same effect as shorteners
            - Stabilize bubbles and starch
        - Egg proteins
            - coagulate during cooking – contributes to the firmness of bread.
            - Egg proteins are softer and more chewy then gluten protein (more tender product)
    - Milk
        - Water, protein, fat and emulsifiers have similar results as eggs.
        - Mild acidity – increases the total negative charge on the gluten proteins and promotes protein repulsion. This weakens the network.

Leaveners – adding air bubbles

- Natural = yeast.
    - The gluten network is extensive enough that it limits the amount of oxygen that gets to the yeast. Anaerobic respiration
    - Yeast uses the nutrients provided by the flour as energy. Gaseous CO_2 is produced.

$$C_6H_{12}O_6 \rightarrow 2\ C_2H_5OH + 2\ CO_2$$

- Chemical leaveners:
    - Baking soda – requires acidic conditions to work best

$$NaHCO_3 + H^+ \rightarrow Na^+ + H_2O + CO_2$$

    - Baking powder – contains the acid so just add water

$$NaHCO_3 + KHC_4H_4O_6 \rightarrow KNaC_4H_4O_6 + H_2O + CO_2$$

$$3\ NaHCO_3 + NaAl(SO_4)_2 \rightarrow Al(OH)3 + 2\ Na_2SO_4 + 3\ CO_2$$

"Resting" the dough – letting it sit for some time

- Enzymes are naturally present in the flour (inactive when dry)
- Resting gives the enzymes time to work.
- Break gluten into smaller pieces – dough becomes softer and more extensible.
- Think about a pizza chef preparing the crust of pizza.

Baking the bread:

- Heat kills the yeast. Why does the bread still rise? Gas Laws: $\frac{V_1}{T_1} = \frac{V_2}{T_2}$. Or in plain English – as the temperature of a gas rises, so does the volume.
  - There are a certain number of gas molecules trapped in the gas bubble.
  - When the temperature rises:
    - The yeast dies (so no more CO_2 can be made)
    - The volume of the bubble expands
    - Water evaporates from the gluten network resulting in the gluten losing its elasticity.
    - The alcohol that is made by yeast also evaporates (sorry, you lush).
    - Starch granules swell and burst (similar to boiling potatoes – you know that white foam that's produced is exploding starch)
    - The dehydrated gluten gets rigid – this prevents the air pockets from collapsing when the bread cools.
    - The bread is done when the internal temperature reaches the point that all water can evaporate. If the internal temp is too low, the inside will remain "gooey".
  - The outside of the bread is much harder than the inside.
    - The heat penetrates from the outside to the inside (i.e. the outside heats up first).
    - The water from the exterior of the bread evaporates first.
    - The outside of the bread reaches the same temperature as the oven. It gets very dry and turns brown.
      - Brown color is from the Mallard Reaction. Basically, special sugars that are produced from heating the starch react with proteins. A few more chemical transformations happen resulting in a brown color. This happens at temperatures above 160 °C.
  - Baking with steam is beneficial
    - Increases the rate of heat transfer
    - Coats the surface of the bread to slow the rate of the surface becoming rigid. This gives the bread enough time to rise before the outside becomes rigid. Prevents cracking of the surface.