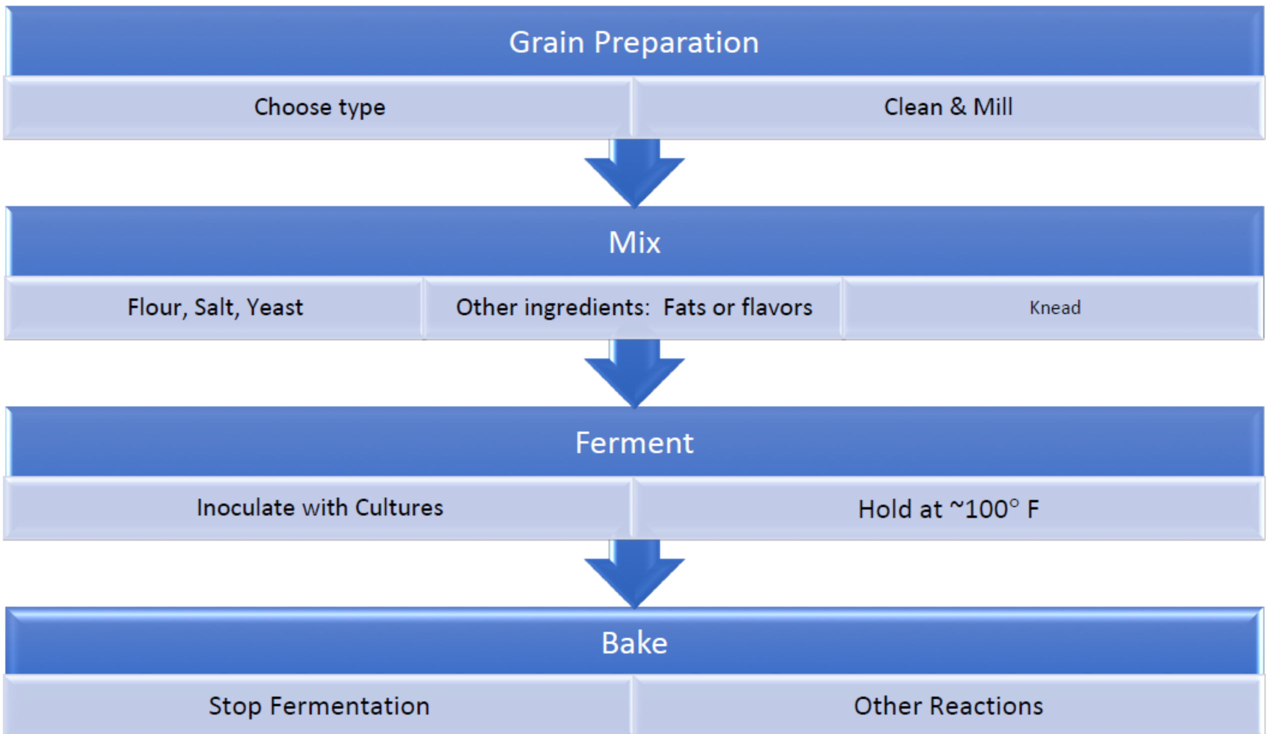
1.12: Bread

Bread Production

Bread is a staple food in many cultures. The key ingredients are a grain starch, water, and a leavening agent. However, there are some breads without leavening agents (tortillas or naan), but these are flat breads.

Typical Steps in Bread Production:



Leavening Organisms and Fermentation

Saccharomyces cerevisiae, also known as baker's yeast, is the primary leavening agent in the production of most breads. Yeast cells consume the sugars present in dough and generate carbon dioxide (CO_2) and ethanol that are responsible for dough leavening during the fermentation phase and the oven rise.

Review:

Exercise 1.12.1

1. What is the biochemical pathway for the formation of CO_2 and ethanol in yeast?
2. Why doesn't bread contain alcohol?

Fermentable Sugars

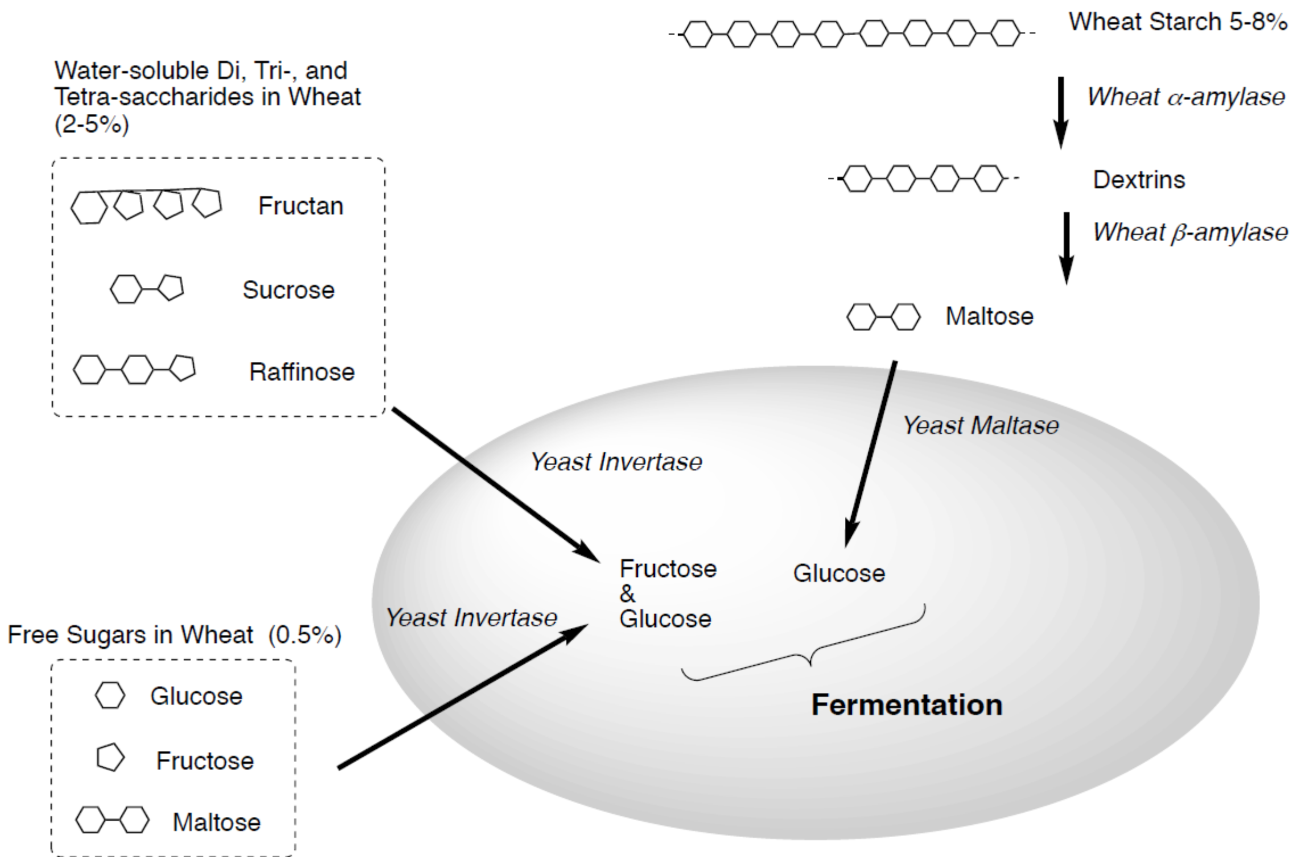
After flour, yeast and water are mixed, complex biochemical and biophysical processes begin, catalyzed by the wheat enzymes and by the yeast. These processes go on in the baking phase. The primary starches found in most cereal plants are the polymers amylose and amylopectin.

Review:

Exercise 1.12.2

What are the monosaccharides in these polysaccharides? What are the linkages?

These starches in the flour provide most of the sugar for fermentation, but the starch must be broken down into monosaccharides before it can be fermented by the yeast. Here is an overview of the sugars utilized by the yeast for the fermentation process:



Amylases: Two types of amylases are present in wheat flour: α-amylases and β-amylases.

- α-Amylases hydrolyze the α-(1,4)-linkages inside the starch chain randomly, thereby generating shorter oligosaccharides.
- β-Amylases cleave maltose from the non-reducing end of the starch chain.

Yeast Invertase and Maltase

- Invertase hydrolyzes several small oligosaccharides.
- Maltase cleaves maltose into the 2 monosaccharides.

Exercise 1.12.3

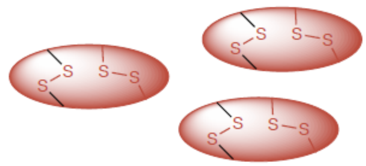
- Draw Maltose. It is a disaccharide made of which two monosaccharides?
- Draw Sucrose. Label the monosaccharides that compose this structure.
- Draw Raffinose. Label the monosaccharides that compose this structure.
- Draw a Fructan. Label the monosaccharides that compose this structure.

Sometimes, α-amylases are added to dough as part of a flour improver.

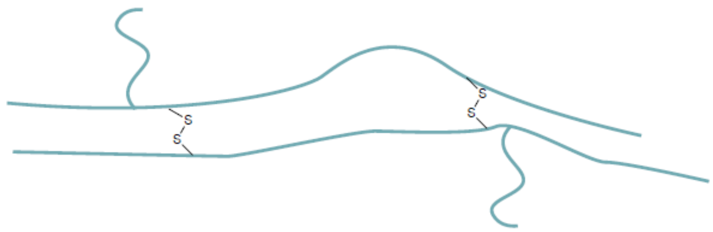
- Explain the benefits of additional amylase enzymes to the bread production process.
- Explain the benefits of adding sugar (sucrose) to the bread production process.

Gluten Formation

Amongst the most important components of the flour are proteins, which often make up 10-15% of the flour. These include the classes of proteins called glutenins and gliadins. **Gliadins** are globular proteins with molecular weights ranging from 30,000 to 80,000 kDa. Gliadins contain intramolecular disulfide bonds.



Glutenins consist of a heterogeneous mixture of linear polymers with a large molecular weight sections and low molecular weight branches (LMW). Disulfide bond cross-link the glutenin subunits.

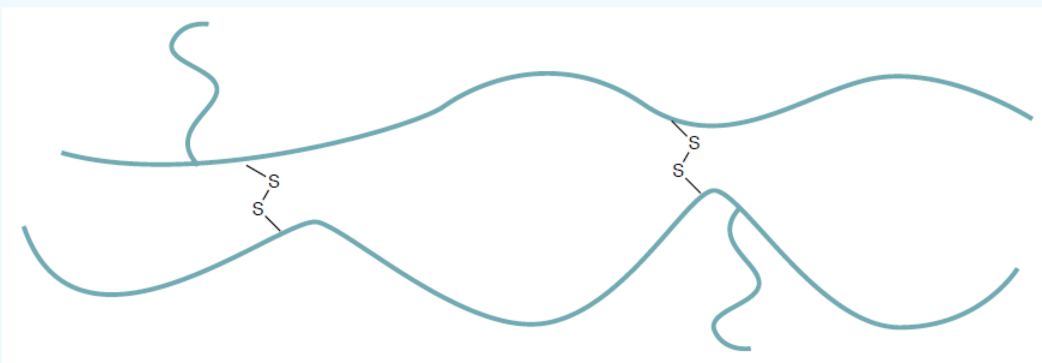


Exercise 1.12.4

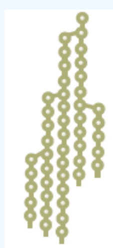
- Define chemical cross-links and physical cross-links in polymers.

In the bread-making process, water is added to flour, where it hydrates the glutenin proteins, causing them to swell and become stretchy and flexible.

- Add water molecules to this hydrated glutenin picture.

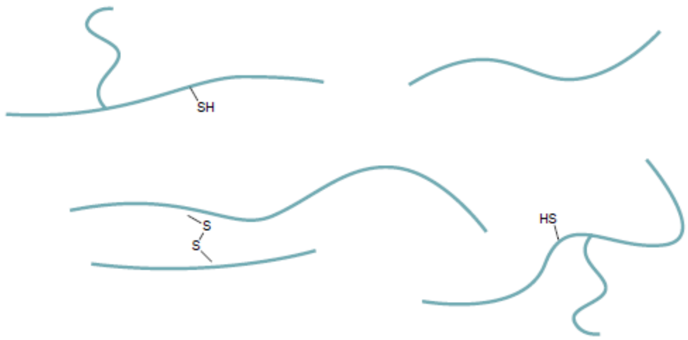


- What IMF changes might be occurring to cause this conformational change?
- Addition of water increases the flexibility of the protein strands and decreases the chain entanglement. This hydration [**increases / decreases**] the flexibility of dough. Explain what is happening on a molecular level to the flexibility.
- Starch granules will also begin to associate with these glutenin proteins. Add some of these to the picture indicating the IMFs involved.



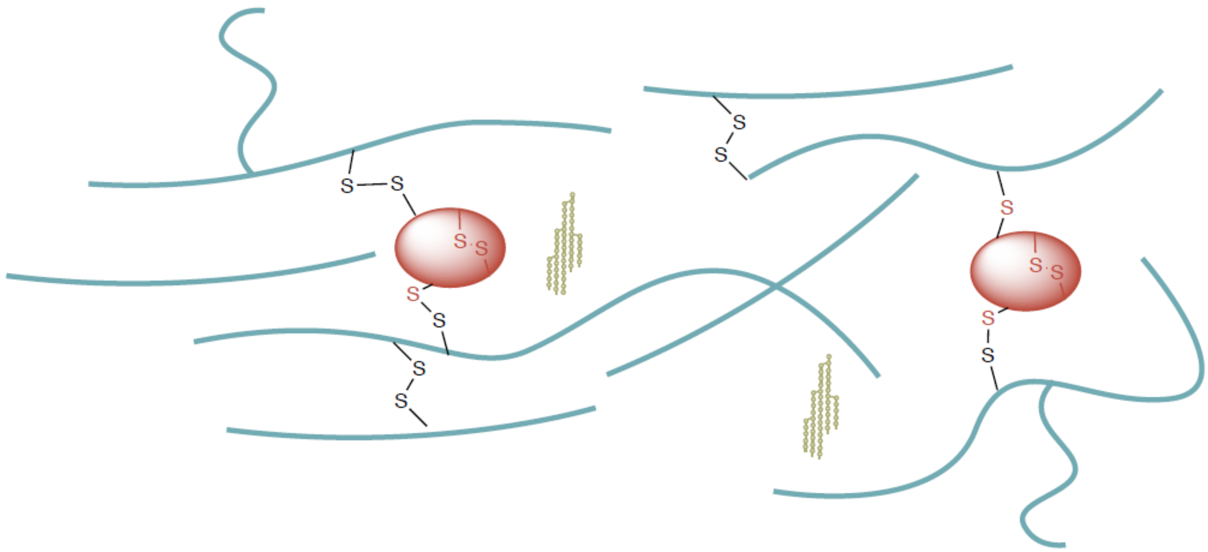
Prior to kneading, the two main protein types, gliadin and glutanin, remain separate on a molecular level. However, as the dough is mixed and kneaded several things begin happening:

The protease enzymes from the wheat begin to break the glutenin into smaller pieces.



The glutenin and gliadin begin to form chemical crosslinks between the proteins. A complex network of proteins, ***gluten***, is formed.

> **? Exercise 1.12.5**
>
> - Predict whether gluten is [**more / less**] elastic than the individual starting proteins.



Starch granules are trapped in the dough and air is incorporated into the dough during kneading. The dough needs to be elastic enough to relax when it rests and expand and hold CO_2 when it rises — while still maintaining its shape.

> **? Exercise 1.12.6**
>
> 1. If too much gluten forms (over-kneaded), what will happen to the texture of the bread?
> 2. As the bread rises, where does the CO_2 come from?
> 3. As the bread bakes, the yeast will continue to ferment the sugars causing the dough to [**expand / shrink**].

Eventually, the heat of the baking will kill the yeast.

Effect of Other Ingredients on Gluten Formation

Fat and emulsifiers coat proteins.

Exercise 1.12.7

1. The presence of fats (butter, oil, etc.) will [**increase / decrease**] hydration.
2. The presence of fats (butter, oil, etc.) will [**increase / decrease**] gluten development

Salts (table salt, NaCl, or hard water salts such as Ca^{+2} or Mg^{+2}) can strengthen the gluten network.

Exercise 1.12.8

Suggest how the presence of salts might strengthen gluten.

Cookie: Usually quite crumbly and doesn't rise very much.

Exercise 1.12.9

What would you need for a cookie dough?

- [**Low or High**] gluten formation
- [**Low or High**] fat content
- [**Low or High**] salt content

Pizza: To pull dough as thin as a pizza without breaking, there must be a very strong gluten network.

Exercise 1.12.10

What would you need for a pizza dough?

- [**Low or High**] gluten formation
- [**Low or High**] water content
- [**Low or High**] salt content

Bread: A network is tight enough to trap the yeast's CO_2 allowing it to rise, but not so tight that it is free to expand.

Exercise 1.12.11

• What would you need for a bread dough?
o [**Low or Medium or High**] gluten formation
o [**Low or Medium or High**] water content

Baking

Flavors and Aromas: Maillard Reactions

Brewer's Journal, Science/Maillard Reaction

In food chemistry, any heating steps involving the presence of sugars and amino compounds lead to a series of reactions called the Maillard reactions. These Maillard reactions are nonenzymatic 'browning reactions' that lead to the formation of a wide range of flavorful compounds which include; malty, toasted, bready and nutty flavors.

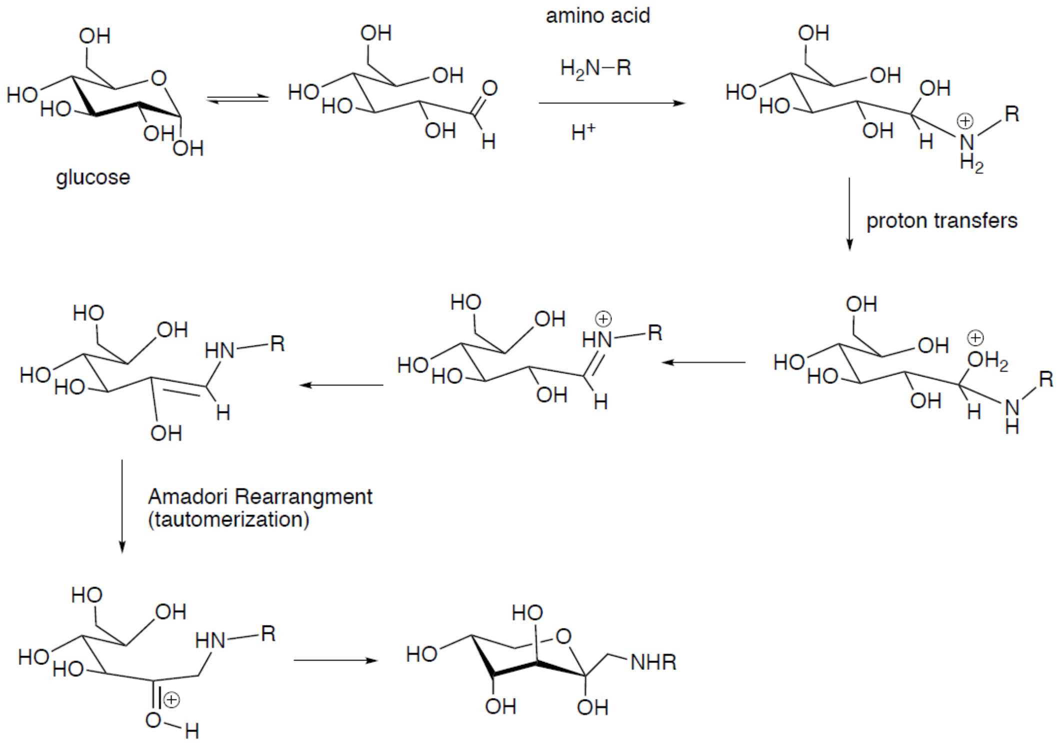
There are three stages to the Maillard Reactions:

Stage I: A condensation between the sugar and amine followed by the Amadori rearrangement.
Stage II: Formation of Strecker Aldehydes
Stage III: Formation of heterocyclic nitrogen compounds.

Stage 1:

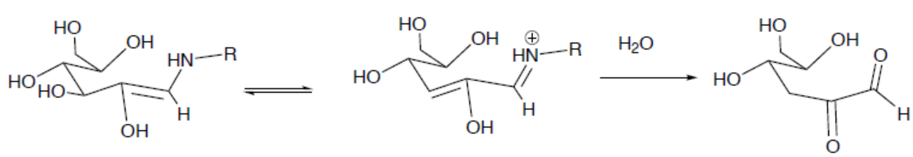
? Exercise 1.12.12

- Add curved arrows for the mechanism of the condensation and subsequent Amadori Rearrangement.



Stage 2:

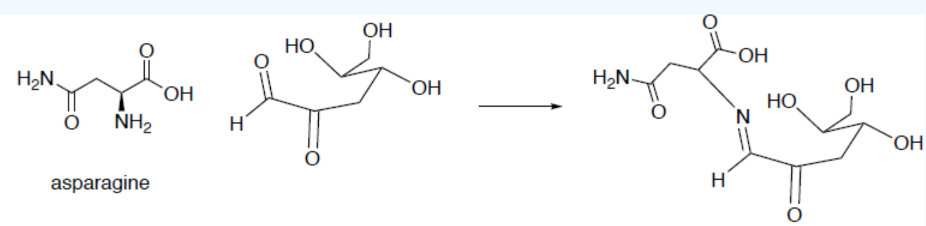
Tautomerizations can convert the Amadori Product to a dicarbonyl.



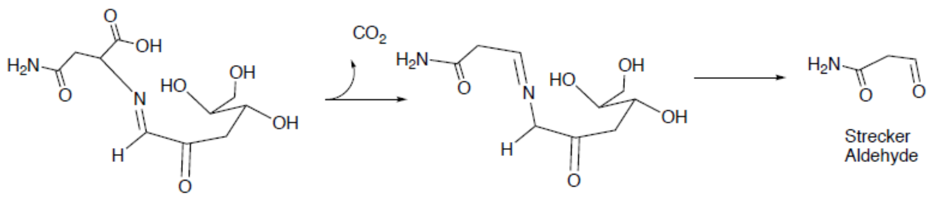
? Exercise 1.12.13

The dicarbonyl reacts with an amino acid (asparagine in this example) to form an imine.

- Draw the curved arrow multi-step mechanism for the formation of an imine. You can use abbreviations.



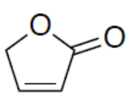
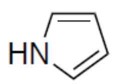
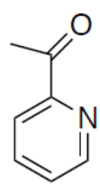
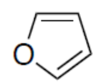
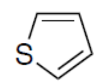
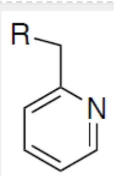
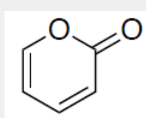
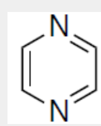
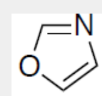
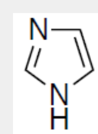
In the Strecker degradation, the imine product undergoes a decarboxylation and is hydrolyzed to an aldehyde.



> **Exercise 1.12.14**
>
> • Complete the table with the Strecker aldehyde formed from these amino acids.
>
> | Amino Acid | Strecker Aldehyde | Aroma |
> | --- | --- | --- |
> | Leucine | | Malty, toasted bread |
> | Isoleucine | | Fruity, roasted |
> | Valine | | Green, unripe fruit |
> | Phenylalanine | | Floral |
> | Methionine | | Vegetable |

Stage 3:

In this stage, the Strecker aldehydes form complicated heterocycles in a variety of molecular families.

 furanones ‘sweet, caramel’	 pyrroles ‘nutty’	 Acylpryidines ‘cracker’	 furans ‘meaty, burnt’	 thiophenes ‘meaty,roasted’
 Alkylpryidines ‘bitter, burnt’	 pyranones ‘maple, warm, fruity’	 pyrazines ‘roasted, toasted’	 oxazoles ‘nutty, sweet’	 imidazoles ‘chocolate, bitter, nutty’

The molecules can also form polymers and precipitates.