Baking bread the German way

Technology – Techniques - Recipes

READING SAMPLE

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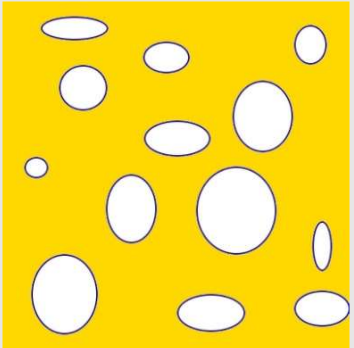
What is bread?

In its simplest form, bread consists of only two ingredients: flour and water. And unless you live in Tuscany, you will usually add salt as the third ingredient. Salt enhances the flavor of bread. But not just that, it is also toughens the gluten network and allows bread dough to hold more water. You will see why that is in my chapter on bread ingredients.

With just flour, water, and salt you can bake tasty unleavened flatbreads like for example tortilla wraps. But once you want to bake a thicker bread you will need to incorporate large air bubbles into your bread dough. Otherwise, the bread will be dense, heavy, and hard to chew. Air is incorporated into bread dough by mixing and kneading it. Yeast is added to bread dough to expand the existing air bubbles during fermentation. The yeast can either be obtained naturally by producing a sourdough or it can simply be added to the bread dough in the form of Baker's yeast.

Yeast produces carbon dioxide as it digests sugar molecules in the bread dough. This carbon dioxide gets entrapped in the dough as it rises. The dough turns into a sponge. Scientists also call it a foam. A foam is a porous material that consist of a

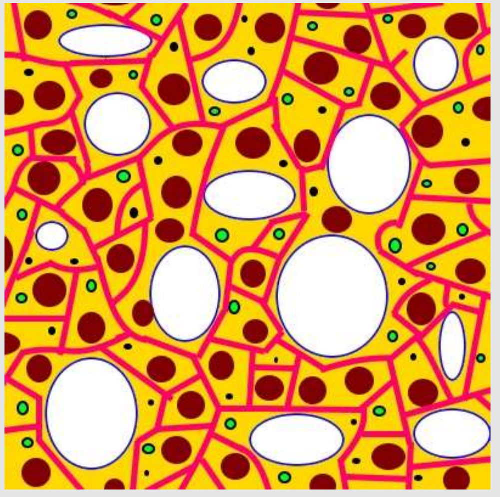
dispersed phase, the air bubbles, which are entrapped in a continuous phase. The continuous phase in bread is an aqueous medium.



Bread dough is a foam that consists of a continuous aqueous phase (in yellow) and a dispersed gas phase (white bubbles).

But not just air bubbles are dispersed in the continuous aqueous medium. In the aqueous medium, the different molecules that you can find in bread dough like gluten, starch, fat, salt, and sugar are also dispersed. By kneading wheat dough, we can form a continuous network within the aqueous medium: the gluten network.

In the picture on the next page, you can see a schematic drawing that displays the structure of a fat-free bread dough.



Dispersed in the continuous aqueous phase (in yellow) are starch molecules (dark red circles), yeast cells (green circles), salt molecules (black circles), and the gluten proteins (pink strands). Notice how the gluten proteins form a continuous network. Entrapped (also dispersed) in this continuous aqueous phase are gas bubbles (in white).

As you can see, bread dough is a complex system. But that shouldn't worry or discourage us. For baking bread, we don't need have an in-depth knowledge about dough structure. However, a little background knowledge can help us to better understand some common observations that we can experience during bread baking.

For example, think about enriched doughs. An enriched dough is a bread dough that has fat added into it. Some very buttery types of bread like a French brioche require you to first knead the lean dough thoroughly before incorporating the butter. When you incorporate fat into a bread dough, you are adding another dispersed phase to the system. A large amount of dispersed fat globules throughout the system hinders the gluten proteins from bonding together to form a continuous network. The fat globules get in between the gluten proteins. So, for enriched doughs, you want to introduce these fat globules after the 3-dimensional gluten network has been developed.

Fat globules which get in between the gluten strands are also the reason why enriched breads have a short bite. You know this from milk bread. It is fluffy and tender, not chewy at all. This is because the fat from butter, eggs, milk, and oil hinders the gluten from forming these ultra-long strands which make the bread chewy.

Key concepts to remember:

! Bread is a foam.

! Bread is a complex system consisting of multiple phases that are dispersed in an aqueous medium.

! The gluten network is a continuous phase that gets created during kneading. It is dispersed within the continuous aqueous medium.

! Other dispersed phases like fat globules can get in between the gluten molecules and thus hinder the gluten proteins from forming long strands. This gives bread a short bite and soft texture.

Which grains can be used to bake bread?

A grain is suitable for bread baking if a dough made from it has the ability to entrap and hold gas bubbles. There are only two types of grains that can do so:

- Wheat and its family members
- Rye

The wheat family

Wheat dough can hold gas because of the gluten proteins which can form a continuous 3-dimensional network. The most prominent members of the wheat family are:

- Bread wheat
- Durum wheat
- Spelt
- Emmer
- Einkorn

The by far most important member of the wheat family is bread wheat. Most bread in this world is made from bread wheat flour. Durum wheat is mostly used to produce pasta whereas bread made from spelt, emmer, or einkorn is a niche product.

Rye

Just as wheat grains, rye also contains gluten proteins. But it can’t form a continuous gluten network because rye flour is full of pentosans. Rye flour has a pentosan content between 6-8 % whereas wheat flour only contains 2-4 % pentosans. Pentosans are fiber molecules which can hold up to eight times their weight in water. We can distinguish between water-insoluble and water-soluble pentosans. The water-soluble pentosans are the structure-giving element in rye bread because they can form a gel that stabilizes the air bubbles in rye dough. Rye flour is rich in insoluble pentosans. These insoluble pentosans can be broken down into water-soluble pentosans by acidifying rye dough. This is why most rye bread is baked with sourdough. Sourdough rye bread contains more structure-giving water-soluble pentosans and can thus entrap more air than rye bread that has not been acidified.

Other cereals

Besides rye and wheat there are many other cereals that can be added to bread dough. You might’ve eaten a bread that contained:

- Barley
- Oats
- Corn
- Rice
- Millet

What all these cereals have in common is that flour made from them doesn’t have the ability to form a bread dough that can entrap air bubbles. They can only be used in combination with wheat flour to produce an airy loaf of bread.

The same is true for the group of pseudo cereals. Among the most common pseudo cereals are:

- Amaranth
- Buckwheat
- Chia
- Quinoa

It’s delicious to add buckwheat flour to bread dough but you can’t bake an airy loaf of bread out of 100 % buckwheat. The way to incorporate buckwheat flour into bread is to mix the buckwheat flour with wheat flour.

Key concepts to remember:

! Cereals that are suitable to produce bread are wheat, spelt, einkorn, emmer, and rye.

! The flour of other cereals and pseudo cereals can only be used in combination with wheat flour to bake an airy loaf of bread.

The composition of wheat

The water content of whole wheat grains lies between 12-14 %. The remaining 86-88 % are dry matter. In the table below, you can see the dry matter composition of whole wheat grains.

Component	Content in the dry matter
Protein	12-18 %
Fat	3 %
Starch	67-70 %
Ash	2 %
Fiber	10-13 %

As you can see, the main component of wheat flour is starch. Starch can bind water and a part of it gets broken down during the bread fermentation into simple sugars that serve as food for the yeast.

Much more interesting for a bread baker is the protein content of wheat flour. We can distinguish two kinds of proteins in wheat flour:

- Gluten proteins
- Non-gluten proteins

About 20 % of the proteins in wheat flour are non-gluten proteins. The remaining 80 % are part of the gluten which consists of two components:

- Gliadins
- Glutenins

Gliadins are monomers that can't form crosslinks with each other. They are responsible for the extensibility of a dough. The glutenins, on the other hand, have the ability to form an extensive network through disulfide bonds. Therefore, the glutenins are responsible for the elasticity and firmness of bread dough.

Durum wheat, spelt, emmer, and einkorn all contain more gluten than bread wheat. But the gluten network they form is inferior to that of bread wheat. That is because the ratio between gliadins and glutenins is an important factor.

In the table below, you can see the approximate ratio of gliadin to glutenin in different wheat cultivars:

Wheat cultivar	Gliadin to glutenin ratio
Bread wheat	2.5 to 1
Spelt	3 to 1
Durum wheat	4 to 1
Emmer	4.5 to 1
Einkorn	6 to 1

The lower the gliadin to glutenin ratio, the better a grain is suited for baking bread. By looking at the table above, it becomes obvious why bread wheat and spelt are by far the two most popular wheat cultivars to bake bread with. They form strong gluten networks that can entrap a lot of air bubbles.

The problem with spelt, durum wheat, emmer, and einkorn is that they all have a much higher gliadin content than bread wheat. Spelt is the best alternative to bread wheat because it makes up for its high gliadin content with an even higher glutenin content than bread wheat. All the other wheat cultivars have a lower glutenin content than bread wheat. Gliadin makes the dough extensible whereas glutenin makes the dough firm and elastic. If you've ever worked with durum wheat, emmer, or einkorn then you know that they all produce a bread dough that is very soft.

Key concepts to remember:

! Whole wheat grains are rich in starch, fiber, and proteins.

! The gluten proteins are the most important component in wheat flour when it comes to bread making.

! The lower the gliadin to glutenin ratio of a wheat cultivar, the better it is suited for bread making.

The composition of rye

Rye has a water content of about 13-14 %. The remaining 86-87 % are dry matter. In the table below, you can see the dry matter composition of whole rye grains.

Component	Content in the dry matter
Protein	10-15 %
Fat	2-3 %
Starch	55-65 %
Ash	2 %
Fiber	15-17 %

The main difference between rye and wheat grains is that rye has a higher fiber and lower starch content than wheat. Because of its high fiber content, rye flour can hold more water than wheat flour.

Rye contains gluten proteins, but they can't form a continuous network. The main structure giving element in rye bread is a gel of water-soluble pentosans. Pentosans are part of the fiber fraction of rye flour. The pentosan content of whole rye grains lies between 6-9 % of which only 12-15 % are water-soluble.

By lowering the pH of the bread dough by addition of sourdough, buttermilk, or vinegar, the water-insoluble pentosans can be broken down into water-soluble pentosans that enable the dough to hold onto air bubbles.

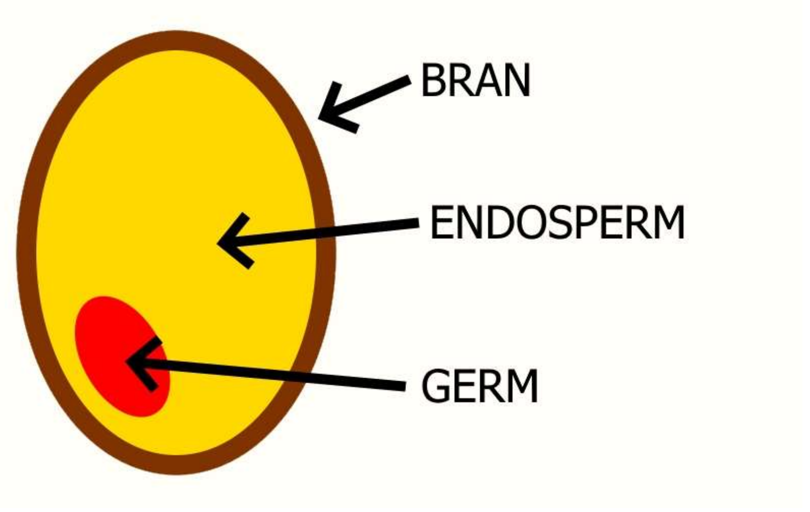
Key concepts to remember:

! Water-soluble pentosans enable rye dough to stabilize air bubbles.

! Because of its high fiber content, rye can hold onto more water than wheat.

Milling to produce different types of flour

If we look at the basic structure of a cereal grain, then we can recognize three main components: bran, endosperm, and germ.



The endosperm consists mainly of starch and makes up for about 80-85 % of the weight of a grain. The other components of a grain are the germ which is rich in proteins and the bran which is rich in fiber and minerals.

We can mill the whole grain and then use this flour to bake whole grain bread.

To produce white flour, the fiber-rich outer bran and germ get removed during milling. Thus, refined flour has a lower ash and mineral content than whole grain flour. We are removing the bran and germ so that we are left behind only with the starchy endosperm.

In Europe, we classify flour by its mineral content. Most of the minerals are in the bran and germ. The more refined the flour, the lower the mineral content. In the US, flour gets classified according to its protein content.

In the table below, you can see wheat flour as it is classified in Germany by its mineral content:

Type of Flour	Mineral content (in mg per 100 g flour)
Cake Flour	405
White Flour	550
Semi-White Flour	812
Bread Flour	1050
Bread Flour	1600
Wholewheat flour	1800

And these are the basic types of rye flour that you can find in Germany:

Type of Flour	Mineral content (in mg per 100 g flour)
Refined Rye Flour	815
Light Rye Flour	997
Light Rye Flour	1150
Dark Rye Flour	1370
Dark Rye Flour	1740
Wholegrain Rye Flour	1800-2300

And lasty, a list of the most commons spelt flour varieties:

Type of Flour	Mineral content (in mg per 100 g flour)
White Spelt Flour	630
Semi-White Spelt Flour	812
Spelt Bread Flour	1050
Wholegrain Spelt Flour	1800

In America, the standard classification of wheat flour is according to its protein content:

Type of Flour	Protein content in the dry matter (in %)
Cake Flour	9
All-purpose Flour	11
Bread Flour/ Strong Flour	14
First Clear Flour	15
Whole Wheat Flour	13

The American flours don't correspond to their European equivalents. The grain varieties grown in the US are different cultivars than the European ones. Most of the US wheat production is the hard red wheat variety which has a higher gluten content than European soft wheat cultivars. Hard wheat varieties are ideal for baking airy bread with large air pockets, but the taste of hard wheat is not as good as that of soft wheat. Whenever possible, I recommend you buy soft wheat flour if you can source it.

Having said that, you can of course substitute German cake flour with American cake flour. You can also bake baguettes

with American bread flour instead of French baguette flour. But what you most likely have to adjust is the amount of water you add to your dough. Wheat proteins can bind more than double the amount of water than starch. So, if you are working with an American flour and the recipe is written for a moderate to low protein European flour, please feel free to add more water to the dough so that it is properly hydrated.

In general, I urge you to not rely on recipes when it comes to the amount of water added to a dough. Every type of flour can absorb a different amount of water. While a low-protein flour might start to feel sticky at 60 % hydration, another high-protein flour might just feel very dry and firm at that point. The dough consistency is a far more important parameter than the dough hydration. You can judge if your dough is properly hydrated by how soft it feels and by how sticky it is.

I've baked American bread recipes with German flour and I regularly have to reduce the hydration level a bit because otherwise my dough would be a liquid batter. Don't be afraid to deviate from a recipe when it comes to the amount of water added. If the dough seems unreasonably sticky or dry to you, then there is no reason to not add more flour or water to it.

If you ever misjudge the consistency of your dough, then that is usually not an issue. The more experienced you get, the more comfortable you will get with handling very sticky doughs. Master bakers often try to push the hydration level of their bread doughs as far up as possible.

Key concepts to remember:

! White flour consists only of the starchy endosperm.

! American and European wheat are different cultivars and are classified differently. The American and European flour types are no equivalent.

! You can substitute European with American flour, but you will then most likely have to adjust the hydration level of your dough.

Main bread ingredients besides flour

Baker's Yeast

Baker's yeast is a living microorganism. It serves two main functions in bread dough:

- Yeast is a biological leavening agent. It consumes sugars in bread dough and converts them into carbon dioxide. This creates gas bubbles in the dough that give the bread volume.
- Besides carbon dioxide, the yeast also produces organic flavor compounds which lend the bread a unique aroma.

Baker's yeast can either be sold fresh or dried. The most common forms that you will find in grocery stores are:

Form of yeast	Water content	Shelf-life
Fresh yeast	70 %	2-3 weeks in the fridge
Active dry yeast	5 %	1 year
Instant dry yeast	5 %	1 year

Fresh yeast has the highest activity level and can be weighed very accurately on a kitchen scale because of its high-water content. I prefer to work with fresh yeast. However, I also know that many people outside of Europe have no access to fresh yeast. In that case, you have to work with dried yeast.

What is the difference between active dry and instant dry yeast? It's the particle size. Instant dry yeast particles are smaller than active dry yeast particles. This allows the instant dry yeast particles to dissolve in water more quickly. Thus, instant dry yeast doesn't have to be bloomed in water before adding it to bread dough. It will rehydrate much quicker than active dry yeast.

The advantage of using active dry yeast that has to be bloomed in water with a little sugar before adding it to bread dough is that you can check if your yeast is still alive. If the yeast water starts to produce air bubbles after 10 minutes, then you know that your yeast hasn't died during storage.

If a recipe calls for another form of yeast than you have at home, you can use the equations below to convert the amount of fresh yeast into dry yeast equivalents.

$$\text{Active dry yeast [in grams]} = \frac{\text{Fresh yeast [in grams]}}{2.5}$$

$$\text{Instant dry yeast [in grams]} = \frac{\text{Fresh yeast [in grams]}}{3}$$

To convert the amount of dry yeast to fresh yeast equivalents you can use the following equations:

$$\text{Fresh yeast [in grams]} = \text{Active dry yeast [in grams]} \cdot 2.5$$

$$\text{Fresh yeast [in grams]} = \text{Instant dry yeast [in grams]} \cdot 3$$

To convert the amount of active dry yeast and instant dry yeast to the corresponding dry yeast equivalent you can use the following equations:

$$\text{Active dry yeast [in grams]} = \text{Instant dry yeast [in grams]} \cdot 1.25$$

$$\text{Instant dry yeast [in grams]} = \frac{\text{Active dry yeast [in grams]}}{1.25}$$

Below you can find a table for quick conversions. 40 grams of fresh yeast is roughly equal to one block which weighs 42 grams exactly.

Fresh yeast (in grams)	Active dry yeast (in grams)	Instant dry yeast (in grams)
5	2	1.7
10	4	3.3
15	6	5
20	8	6.7
25	10	8.3
30	12	10
35	14	11.7
40	16	13.3

Good bread contains no more than 2-3 % of fresh yeast in relation to the flour weight. This means that you should ideally use no more than half a block of fresh yeast per kilogram of flour. In bread, it is undesirable if you can taste the yeast. Instead, you want to slow-ferment the dough so that there is enough time for the formation of organic flavor compounds.

Sourdough bread can be baked without the addition of Baker's yeast. Sourdough contains wild yeast strains which are much less potent than Baker's yeast. Sourdough bread can be just as airy as Baker's yeast bread, but it takes more time to rise. Baker's yeast is therefore often added to sourdough bread to speed up the fermentation. In such a bread, the sourdough provides the organic flavor compounds whereas the Baker's yeast provides the carbon dioxide. I will cover baking with sourdough in detail in the chapter about sourdough bread.

Chemical Leavening Agents

Chemical leavening agents are typically not used to produce bread. They are common in cakes and cookies. In Germany, we are horrified by things like soda bread. But it is certainly an option to use one of the following leavening agents to bake bread:

- Baking powder
- Baking soda
- Cream of tartar
- Ammonium bicarbonate

Bread that is leavened with one of these substances doesn't need to be fermented before baking. Baking powder consists of sodium bicarbonate and acid salts which react instantly with each other in an acid-base reaction to produce carbon dioxide once they both come into contact with water. The other leavening agents shown in the list above decompose at high oven temperatures. The most important decomposition product of these substances is carbon dioxide.

Physical Leavening Methods

Puff pastry doesn't contain any yeast or chemical leavening agent and yet it is light and airy. It puffs up the in the oven. That is because puff pastry is leavened by steam. Puff pastry is a laminated dough consisting of many layers of butter in between layers of dough. When baking bread in the oven, water will start to evaporate. The steam that is being generated escapes from the bread and while it evaporates it will cause the small gaps in between the dough layers to puff up.

If you've ever made German semolina dumplings from scratch, then you have already encountered another method to aerate a dough with steam. To produce semolina dumplings, flour and milk are combined in a pot and cooked until the flour has gelatinized. The high temperature causes the water from the milk to start evaporating. This generates many small air bubbles

that get entrapped in the dough. In France, they call this type of dough choux pastry.

Another method to aerate dough physically that is usually not used in bread making but more common in pastries is to incorporate whipped egg whites into the dough. Whipped egg whites are a protein-stabilized foam. The air bubbles are incorporated into the egg whites by whipping them.

Salt

Salt is a key ingredient in bread because it serves multiple functions.

Salt is a flavor enhancer

Without salt, bread is tasteless. Salt increases our sweetness perception and masks metallic, bitter, and other off-flavors.

Salt is a fermentation stabilizer

Salt stabilizes the fermentation rate of the yeast by decreasing the rate of gas production. Without the addition of salt, bread dough ferments excessively which results in a sour loaf with poor texture. Salt increases the osmotic pressure in the system. The salt draws out moisture from the yeast cells which results in shrinkage and a reduced yeast metabolism rate.

Salt strengthens the gluten network and increases the mixing time of bread dough

Adding salt to a dough before kneading increases the time it takes for the gluten proteins to hydrate. A simple flour and water mixture has a pH level of about 6. At pH 6, the gluten proteins have a positive net charge. This leads to the situation, that the positively charged regions of the gluten proteins repulse each other. This allows for them to hydrate more quickly but it also results in a weaker dough because of the repulsion between the positively charged protein chains. Salt is an ionic compound consisting of positively charged sodium ions and negatively charged chloride ions. The negatively charged chloride ions can shield the positively charged regions of the gluten proteins and thus allow them to come into close contact with each other to form a strong dough. However, as indicated before, adding salt to the dough increases the mixing time because it takes longer for the gluten proteins to hydrate.

Salt binds water

Salt is a hygroscopic material that absorbs water. Salted doughs can thus hold more water than non-salted doughs.

The optimum level of salt in bread dough is 1.5 to 2 % in relation to the flour weight. At this salinity level, the salt brings

out the natural flavor of the bread without imparting a salty taste. From a technological point of view, it is also not recommended to add higher levels of salt to bread dough. Salt decreases the solubility of gluten proteins. If you have higher levels of salt than recommended in your dough, the gluten proteins won't hydrate properly, and you will end up with a dense and salty loaf of bread.

Sugar

Just as salt, sugar serves multiple functions in bread dough:

Sugar adds sweetness

The more sugar is in your dough, the sweeter it will taste.

Sugar is a fermentation stabilizer

Just as salt, sugar increases the osmotic pressure on the yeast cell walls which leads to the shrinkage of yeast cells and slows down the yeast metabolism. Levels of up to 22 % sugar in relation to the flour weight are acceptable in sweet doughs. If you go higher than that, the yeast activity gets reduced to an absolute minimum so that your dough won't rise properly.

Sugar gives bread a caramelized, dark crust

Sugar in combination with proteins produces brown flavor compounds via the Maillard reaction. In the Maillard reaction, reducing sugars such as glucose, fructose, lactose and maltose react with the proteins in flour when baked at high temperatures in the oven to form dark flavor compounds. This reaction gives bread an appetizing caramelized crust.

Table sugar (sucrose) is no reducing sugar but is a source of the reducing sugars glucose and fructose. Baker's yeast contains enzymes that can invert the sucrose molecule into glucose and fructose. Another source of glucose is starch. Flour naturally contains starch-cleaving enzymes that can cleave the starch molecule into the reducing sugars glucose and maltose. These reducing sugars are also present in baking malt which I will discuss in more detail in the enzyme section. Another major source of reducing sugars in bread dough are dairy products which contain the milk sugar lactose.

In the table below, you can see the main reducing sugars in bread dough and their source of origin:

Reducing sugar	Source in bread dough
Glucose	Enzymatically inverted table sugar, enzymatically cleaved starch molecules, baking malt
Fructose	Enzymatically inverted table sugar
Lactose	Milk
Maltose	Enzymatically cleaved starch molecules, baking malt

Sugar binds water

Sugar is a hygroscopic material that absorbs water. A dough made with sugar can hold more water than a dough made without sugar.

Typical sugar levels in yeast-leavened baked goods are:

Baked Good	Sugar content in relation to the flour weight
Savory Bread	0.5-4 %
Milk Bread	6-12 %
Sweet Bread	14-22 %

Lipids/ Fats

Bread dough typically contains lipids from various sources:

- Lipids naturally present in flour
- Added fats like lard, shortening, butter, or vegetable oil
- Added surfactants (emulsifiers)

Lipids naturally present in flour and added fats bind to the gluten proteins during mixing of the dough and thus improve the gluten proteins ability to align themselves at the interface of gas bubbles. This synergy stabilizes gas bubbles within bread dough. But this is only the case if you add a solid fat like lard, shortening, or butter to your dough. Solid fat contains fat crystals. A neutral vegetable oil that is liquid at room temperature doesn't have the ability to stabilize gas bubbles because it contains no solid fat crystals. You know this from

whipped cream. It is much easier to whip fridge-cold cream with a high crystalline fat content than it is to whip lukewarm cream. That is because the fridge-cold cream contains more solid butter fat crystals which stabilize gas bubbles. If you bring heavy cream up to a light simmer, the fat crystals in the cream have melted completely. You can't whip the cream anymore.

Surfactants (emulsifiers) are added to bread dough because, even in tiny quantities, they are very potent at stabilizing air bubbles. Besides the gluten-binding emulsifiers, there are also emulsifiers that can bind to the starch molecules in bread dough. This prevents the recrystallization of the starch after baking. The recrystallization of starch is the reason why bread loses moisture and goes stale. Hindering the starch from recrystallizing keeps bread fresh for longer.

Because fat binds to the gluten proteins and gets in between the strands, it hampers the formation of the gluten network. Therefore, bread with a high fat content above 5 % has a short bite. Hence the name shortening. We call it that because shortening creates a short texture when we add it to bread and pastries. This is because the gluten strands are shorter in bread with a high fat content. But bread with a high fat content can still be airy because both fat and gluten can stabilize air bubbles.

Besides creating a short bite and stabilizing air bubbles, fat is also added to bread dough because it tastes good and gives baked goods a moist mouthfeel.

In the table below, you can see the typical fat content of various baked goods:

Baked Good	Fat content
Crusty Bread	up to 2 %
Soft Bread	5-15 %
Croissants	45 %
Brioche	up to 50 %

Enzymes

Every bread dough contains enzymes. That is because flour naturally contains enzymes. But we can, of course, also add additional enzymes to our dough. Enzymes play a key role in bread baking and serve many purposes.

Enzymes can keep bread fresh for longer

Maltogenic alpha-amylases decrease the starch retrogradation and starch-protein interactions. The main reason for bread staling is that the starch components recrystallize during bread storage. We call this process retrogradation. Maltogenic alpha-amylases cleave maltose molecules off the wheat starch. This alters the structure of the starch molecules and hinders them from recrystallizing. Another minor reason for bread staling is that gluten and starch like to from gluten-starch complexes with a decreased water-holding capacity during bread storage. Starch that has been modified by enzymes is less likely to bind to gluten proteins.

Enzymes can strengthen bread dough

Phospholipases can be used to strengthen bread dough. That is because they can modify the structure of the phospholipids which are naturally present in wheat flour to improve their ability to act as an emulsifier. Emulsifiers can bind to gluten proteins or starch molecules. If they bind to gluten proteins, they help to stabilize gas bubbles within the dough. If they bind starch molecules, they prevent recrystallization of the starch.

Glucose-oxidase is an enzyme that catalyzes the oxidation of glucose to gluconic acid and hydrogen peroxide. Hydrogen peroxide is a strong oxidant that oxidizes the gluten proteins. This leads to an increased formation of disulfide bonds within the gluten network. The more disulfide bonds are formed between the gluten molecules, the stronger the gluten network, and the more gas a dough can hold. A less effective way to oxidize the gluten proteins to encourage the formation of disulfide bonds is to add Vitamin C (ascorbic acid) to the dough.

Fiber molecules in flour compete with gluten proteins for water. This makes it harder for the gluten proteins to properly hydrate and form a strong gluten network. In rye doughs, fiber molecules are the structure-giving element but in wheat doughs they are often undesirable. This is why industrial manufacturers sometimes add cellulases and xylanases to wheat doughs. These enzymes break down cellulose, arabinoxylans, and pentosans.

Enzymes can weaken doughs

In pastries, you often don't want to have a well-developed gluten network. You most often want pastries to be flakey, not chewy. For that purpose, you can add proteolytic enzymes to your dough that attack the gluten proteins and thus weaken the gluten network.

Enzymes can enhance the crust caramelization

As I have already pointed out in the part about sugar, the Maillard reaction is responsible for the development of a dark and caramelized bread crust. In the Maillard reaction, reducing sugars react with proteins to from dark flavor components at high oven temperatures. These reducing sugars get formed during the fermentation of bread dough. If we ferment bread dough for only a few hours, there are usually not enough reducing sugars in it to produce an aromatic crust. Glucoamylases and alpha-amylases cleave the reducing sugars glucose and maltose off the starch molecules. In flour, alpha-amylases are naturally present. However, if we increase the concentration of starch-cleaving enzymes in the dough, we speed up the process. Another option besides adding enzymes, is to add reducing sugars directly to the dough. The reducing sugar lactose is naturally present in milk which is why milk bread always has a beautiful crust. Adding table sugar also helps because Baker's yeast produces an enzyme to invert table sugar into the reducing sugars glucose and fructose. Honey doesn't even need to get inverted by enzymes because it already consists mainly of glucose and fructose. Baking malt also contains a large amount of the reducing sugars glucose and maltose.

Enzymes can reduce the acrylamide content of bread

Acrylamide is a carcinogenic byproduct of the Maillard reaction. The darker the crust, the higher the acrylamide content in bread. Asparaginases can lower the acrylamide content of bread by up to 95 %. That is because asparaginases convert the amino acid asparagine into aspartic acid. If there is no asparagine in the dough, the reducing sugars can't react with it to form acrylamide. The bread will still develop a golden-brown crust, but it will contain almost no acrylamide.

The two most common ways to add enzymes to bread dough are:

- enzymatically active baking malt
- commercial dough improvers

To produce baking malt, wheat, barley, or rye berries are allowed to germinate. During germination, the activity of the natural-occurring enzymes in the grains increases. This leads to the formation of reducing sugars like maltose and glucose. The germinated wheat, barley, or rye berries get dried and milled to produce baking malt. The enzymes in baking malt are still active unless it is heated above 100 °C (212 °F). Baking malt can either be sold enzymatically active or enzymatically inactive.

The enzymatically active version contains alpha-amylase enzymes and reducing sugars whereas the enzymatically inactive version only contains the reducing sugars. The enzymes have been inactivated.

Commercial dough improves contain a whole range of enzymes, reducing sugars, emulsifiers, and oxidizing agents. They are perfectly engineered products. They are no necessity in artisanal bread baking. A lot of artisanal bakers' frown upon commercial dough improvers. However, I think they are a great additive to improve the taste and texture, especially of bread rolls. A packet of commercial dough improver is a great ingredient to keep in your pantry. If you are ever short on time or want your bread to last longer, then there is no shame in adding a few grams of dough improver to your bread dough.

In the table below, you can find an overview of ingredients that are typically part of commercial dough improvers.

Ingredient	Technological function
Baking enzymes	
Alpha-amylases	Improve the crust color Provide food for the yeast and thus speed up the fermentation Slow down the staling of bread
Phospholipases	Turn natural-occurring phospholipids into emulsifiers that can stabilize gas bubbles
Glucose-oxidase	Strengthens the gluten network
Cellulases and Xylanases	Break down fiber molecules that hinder the gluten network development
Proteases	Weaken the gluten network
Asparaginases	Lower the acrylamide content of bread

Other dough improvers	
Emulsifiers	Stabilize gas bubbles Slow down the staling of bread
Oxidizing agents	Strengthen the gluten network
Reducing sugars	Improve the crust color Provide food for the yeast and thus speed up the fermentation

Key concepts to remember:

! The main ingredients in bread dough are flour, yeast, salt, sugar, fat, and enzymes.

! Ingredients not only influence the aroma but also the texture of bread.