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The Fundamentals of Bread Baking Science

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Abstract

So how do I transform flour, salt, water, and leaven into bread? This is a crash course led by Peter Reinhart in the process of that transformation through the act of baking (baking is defined (textbook) as the application of heat to a “product” in an enclosed environment for the purpose of driving off moisture). But a lot of drama occurs both before and during this act, so we’ll examine all that occurs within the “baking triangle” that causes grain to be transformed into flour, flour transformed into dough and, finally, dough transformed into bread.

Peter is the author of The Bread Baker’s Apprentice and Peter Reinhart’s Artisan Breads Every Day and many other books. He is also the executive director of the Johnson & Wales University International Symposium on Bread.

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The Fundamentals of Bread Baking Science | Fermentology mini-seminars

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Introduction

We’ve focused a lot on microbes and the work of yeast and bacteria, which are at the heart of fermentation,[1] whether for beer, bread, cheese, and more. Now, I'd like to broaden the scope and focus on the process that transforms this microbial and biological process into a finished product. In this instance: bread. We can call this the fundamentals of bread baking science, or the journey from wheat to eat.[2]

Baking is Transformation

We call it the bread baking science so let's talk about baking first. We've got to lay down a couple of key terms here.

Baking, as in all cooking, is an act of transformation. All cooking is transformational, and by transformation I mean a radical change in an object from one thing into something totally new and different. Since I'm going to be using this word a lot, I want to ensure that we all understand what I mean by that: a radical change from one thing into something else. The key here is this notion of *transformation*. How do we explain why this radical change happens?

We'll start with a definition that is fundamental and textbook:

> **The definition of baking is the application of heat to a product in an enclosed environment, meaning an oven, for the purpose of driving off moisture.**

There's nothing in that definition that talks about transformations or anything else, but it's this process of baking that allows for transformation to take place at the baking level. As we go through our journey of bread baking, when we get to the baking stage, this is where a lot of transformations and the final transformations actually occur. Yet, the way baking is very different from other processes, like roasting, which is also done in an oven, but in the definition of roasting you use moist heat. The purpose is not necessarily to drive off moisture, but driving off moisture is very critical in the bread baking process because if you put a loaf of bread in the oven that weighs approximately 18 ounces, it's more likely to come out of the oven weighing about 15 or 16 ounces due to the evaporation of moisture. We're driving off moisture.

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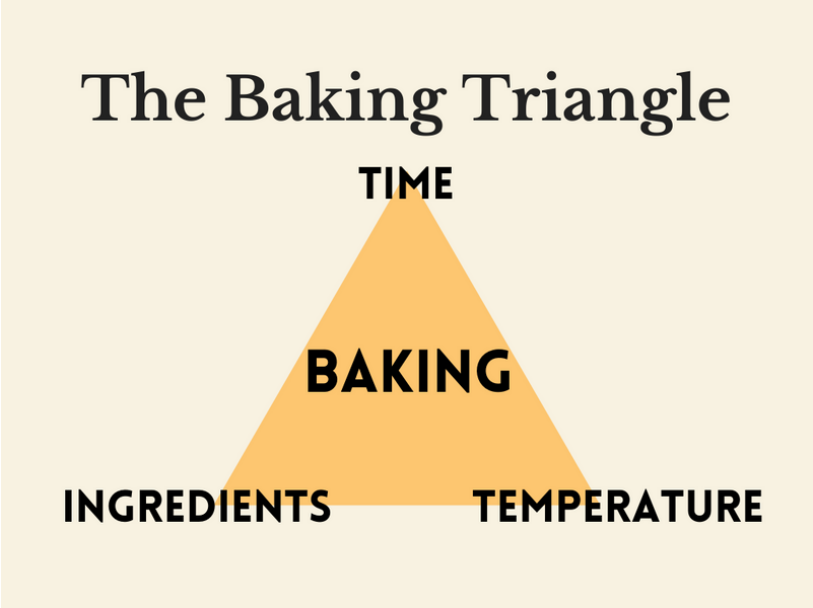
The Baking Triangle

All the transformations that happened during the baking process occur within the triangulation of time, temperature, and ingredients. Anything that happens at one of these points on the triangle affects the other two points. An example would be if you raise the temperature of the oven when you're baking; it's going to make the loaf faster, but it also may affect the ingredients on how they bake, how they caramelize, and, importantly, whether the outside gets done too quickly. Our goal in baking, especially baking bread, is we want the outside and the inside of the loaf to get baked and finish at the same time. There's an awful lot that's going to be going on to make that happen.



Peter Reinhart's Baking Triangle

The craft of baking really comes down to:

- managing time, temperature, and ingredients
- understanding through practice
- following instructions and figuring it out
- eventually balancing those three, time, temperature, and ingredients, to give you the best product possible

The difference between an average baker and a craft or artisan baker, as well as the quality of the breads that they produce, is not the ingredients, but that some have a much better sense of how to control these factors. I call this the baking triangle, and everything discussed below is going to happen within the context of that.

The Stages of Bread Baking

On the transformational journey of the loaf of bread, there are 12 distinct stages that take us from wheat to eat.

I'm using 12, but I've seen in other books 10 or 8 because everyone has a different way of describing it. While this is not the only way of giving context to what goes on in this journey, but this is the way I define it and I think it helps us to get our mind around it and give us a sense of structure as we think about all the things that are going on in the loaf.

Stage One: *Mise en place*

As in all cooking, we use the term *mise en place*, which in French means: everything in its place. I call it the organizational principle, get organized, but in baking we call it scaling. This means weighing, scaling out, or even measuring your ingredients. In this case, with bread, I want to go back and say that *mise en place* really goes way back to the field itself. Our *mise en place* really begins with wheat or grain, but here we're going to focus on wheat because that is the primary grain for bread, mainly because it has the most gluten of any grain — and it also tastes great.

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Wheat Fields with art from The MET by Vincent van Gogh, Winslow Homer, Jacob van Ruisdael, Jean Jacques de Boissieu, Mathew B. Brady, Ma Hezhi, Pieter Bruegel the Elder, and Jean-François Millet.

Wheat growing in the field is essentially a grass that puts out seeds. It's alive. It's a living thing. Thus, the first transformation in this journey is going to be moving from a state of being alive to a state of dead because when we harvest that wheat, gather its seeds, and take it to the mill where it is crushed into flour, we kill the life-giving

properties of that seed. It is destroyed. We've just taken a living thing and made it dead. I always say that harvesting is just a euphemism for killing, but that's what we've done. Then what we do with that flour is we combine it with other ingredients that we've scaled up to begin the dough-making process.

Stage Two: Mixing

We've got our ingredients. We gathered them and there are three distinct objectives that have to happen during the mixing process:

1. We want to evenly distribute the ingredients. We don't want little clumps of salt, yeast, or any other things that we're adding. We need to get them properly spread, and that happens automatically just by mixing by hand or by machine. There's no rule about this, but it's mostly done by machine production because the human body just can't handle a big piece of dough. Yet, if you're making it at home, there's no reason why a machine should be any better than doing it by hand, and hand mixing actually is in many ways more satisfying.

2. Another objective is the activation of the yeast. Now, yeast can come in a lot of forms. It could be powder, dry yeast, it could be a sort of a soft cakey yeast, it could be a liquid yeast, it could be sourdough yeast, which is what we're going to be mainly using as we progress through this fermentology series of webinars, but we have to activate it because, until we put it into the dough, it's basically lying dormant, waiting to be activated. Sourdough starter is already active, but it's kind of sitting there waiting to be deployed. So once we hydrate the dough, because one of the ingredients is going to be water or some liquid, the yeast wakes up and begins seeking out food.

3. Then we have to develop the gluten — and that again goes back to the wheat. Wheat has more gluten than any other grain. Rye comes in second. Barley, a distant third. There may be traces of gluten in some other grain but mostly other grains are essentially gluten-free, unless they've been cross-pollinated or cross-contaminated. Yet, the problem is with gluten is that there is no such thing as gluten in wheat. A lot of people think that gluten exists in wheat, but really wheat just has the potential to make gluten. What it does have are two partial proteins, or small proteins, called gliadin and glutenin, and these two proteins, neither of which are strong enough to make a dough both extensible and elastic. When they get hydrated, they seek out each other and they bond, they form together a new protein, and that new protein is

what we call gluten, and gluten does have the properties of both extensibility and elasticity, and that is in a sense one of the magic things about wheat and why it's the most desired grain for bread making. And it's also one of the most problematic aspects, especially for people who have gluten sensitivities.

The local baker since 1885. Image contributed by Tjoffe to Europeana's **Europe at Work** collection day, through the Kiviks Museum.

These are the three things that have to happen in Stage Two, the mixing process. We're making a piece of clay and then we are bringing it to life through the injection of

leaven, in the form of yeast. Importantly, the word leaven derives from the word to *enliven*, which means to bring to life, to vivify. The second transformation takes place as we're taking something that was dead, a piece of clay, and we're bringing it back to life by injecting it with leaven. These microorganisms, yeast mainly but also bacteria, especially in our sourdough breads where we have a lot of lactic bacteria also living in that piece of clay that we've made, seek out food, and the food they seek, as we learned last week, is mainly glucose, possibly some maltose and other sugars, but glucose is the primary food source. They digest it, and then they create, as a byproduct, carbon dioxide, alcohol, and acids, as a byproduct of fermentation.

Stage Three: Bulk Fermentation

This bulk fermentation[3] is taking our big dough and raising it anywhere from 90 minutes to three or four hours, depending on the dough and how much leaven we put in it. Meanwhile there's also nonliving enzymes that come in with the flour, they're part of the flour base, and sometimes they're even added by millers in production bakeries as additional enzymes, mostly amylase and protease enzymes. Amylase that act on starches, proteins that act on proteins, and they begin to break the carbohydrates and put proteins into smaller digestible chains.

Ultimately, the function of the enzymes is to begin to break it all apart and make this essentially indigestible piece of clay digestible by breaking it down. In doing so, it also frees up more natural sugars as it breaks the carbohydrates, the sugar chains break off of the starch chains, and they become available to the yeast and the bacteria for food — thus also available to our palates for sweetness and to the oven for caramelization later on.

Stage Four: Degassing and Dividing

Fermentation is going on from this point on all the way till we take it to the oven. Once our dough gets to the size we want, we're going to take it out of the container and divide it. In dividing it, it also is going to knock out some of the gas that's been created, the carbon dioxide, through fermentation, so sometimes it's referred to as

degassing. Some people call it punching, but you don't really have to punch the dough unless you want to, and some people like to punch the dough. But we're really dividing it into smaller units that will be the individual pieces of bread that we're going to bake.

Stage Five: Pre-Shaping/Rounding

The next stage is to pre-shape it, sometimes called rounding. Sometimes rounding can also be in the form of a torpedo. It doesn't have to be a round shape, it just depends on where we're headed with the final shape.

Cliff Teinart Making Sourdough Biscuits. Image from UT San Antonio Libraries Special Collections.

Stage Six: Resting

The dough dividing and rounding has essentially tightened the gluten up. The gluten, being a protein and being the muscle of the bread, gets tense and it becomes very

elastic, but not very extensible. By letting it rest, the gluten will relax and allow us to extend the loaf to its final shape.

Risen Bread Dough. Jones, S. (1978). Image from the Library of Congress, Paradise Valley Folklife Project collection, 1978-1982 (AFC 1991/021), American Folklife Center, Library of Congress.

Stage Seven: Final Shaping

Then we give the dough its final shape. Whether it's a baguette, a sandwich loaf, a round loaf, a boule, or a baguette — any of those shapes happen with this final shaping.

Stage Eight: Panning

Then we go to panning. Panning can be on a sheet pan, in a loaf pan, or in a basket. It could be in any form that we want to use to allow the bread to go to Stage Nine, which is proofing.

Stage Nine: Final Proofing

We call it final proofing because it's really the end of the fermentation cycle.[4] Proofing and fermentation are very synonymous terms, and bakers use them interchangeably. The term proofing refers to the fact that we're proving that the dough is alive, and the proof of that life is growth. We're seeing the dough grow.

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"An Inside Look at Bread Dough Proofing" by Modernist Cuisine

Through proofing, we know that not only has the dough been growing, but it's been developing personality and character through the flavors that have been released through fermentation — including the alcohol flavors and the acid flavors. The breakdown by enzymes of the starches and the proteins releases flavor.

This is all happening through these stages but then we come to the final transformational stage, baking. This is where really it all changes radically again.

Stage Ten: Baking

Remember our definition of transformation? A radical change. It happens through three distinct oven transformations:

1. The sugars caramelize to form the crust, and that happens at about 325° F. The only place in the loaf that can get that hot is the surface, because the crust on the outside actually insulates the inside from ever getting above 200 or 205° F. When the crust does get above 325° F, the sugars begin to turn brown or caramelize.
2. Proteins, on the other hand, coagulate or denature. They open up, they unfold, they line up, and they get organized to form the skeleton interior of the loaf. This happens at about 160° F. Therefore, while the outside is getting very, very hot, the inside is rising to 160 to 165° F, and the proteins are beginning to denature and coagulate.
3. Then, as the loaf continues to cook, at about 180° F the starches (remember, bread is mostly starch because wheat is about 70% to 80% starch) gelatize, meaning they absorb as much water as they can until they can't handle anymore, and then they explode. They burst and they thicken everything around it.

> **An analogy here would be like making gravy, where you put a little bit of flour in some broth and you bring it up to a boil where it gets closer and closer to the boiling point and the gravy thickens. That's gelatinization of starches happening in a liquid form, and here in bread it's happening in a solid loaf form.**

180° F is the magic number here, or 82° C. That's not where we stop, but that's the minimum. If you do a temperature check and the dough at the center is below 180° F, you know that the bread is still doughy and not yet bread, but it's on its way. If you

bake it a little longer, those internal starches will also gel. Typically we're going to bake to at least 190° F, and 200 to 205° F for a crusty bread — even in the center, partly to drive off even more moisture and partly to give us a nice hard crackly crust.

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“Timelapse Compilation | Sourdough Bread, Pizza, Rolls and Cinnamon [sic] Rolls Baked In A Home Oven” by Bread By Rosendahl

Now the yeast, or the leaven, whose mission it was to raise the dough so that it can become bread, dies at approximately 138° F. This is what we call that the thermal death point. This means that the yeast, whose mission it was to raise the dough so that it could become bread, has to sacrifice its life. It dies first. You can't have this transformation from a living dough to a piece of bread without this essentially sacrificial act on the part of the very organism that gave that dough life. This is an important thing and I think one of the factors in why bread has such an important place in many people's lives.[5]

> **In other words: It goes in alive, but it comes out dead. It goes in as dough, but comes out as bread. It's like a caterpillar that goes in and a butterfly that comes out.**