



Thermal Profiling for Bread Products

How to control the baking process for a better product

What is thermal profiling?

Thermal profiling or thermal logging is the process of recording the internal temperature of baked goods during the baking cycle. This form of data collection during the baking cycle produces an S-curve, with time on the x-axis and temperature on the y-axis. Rather than relying on the loaf color, exit temperature and time to determine baking conditions, using the S-curve to determine the bake out is a better way to determine a good bake. Deploying this level of process control removes the guesswork with baking conditions and provides real-world data that improves product quality.

Thermal profiling uses a combination of thermocouple sensors inserted into the dough and pointed into the air above the product. The temperature and duration is recorded to make necessary oven zone adjustments. Using this method, changes to the S-curve parameters will result in product quality consistency.

Baked Goods
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Making sense of a thermal profile

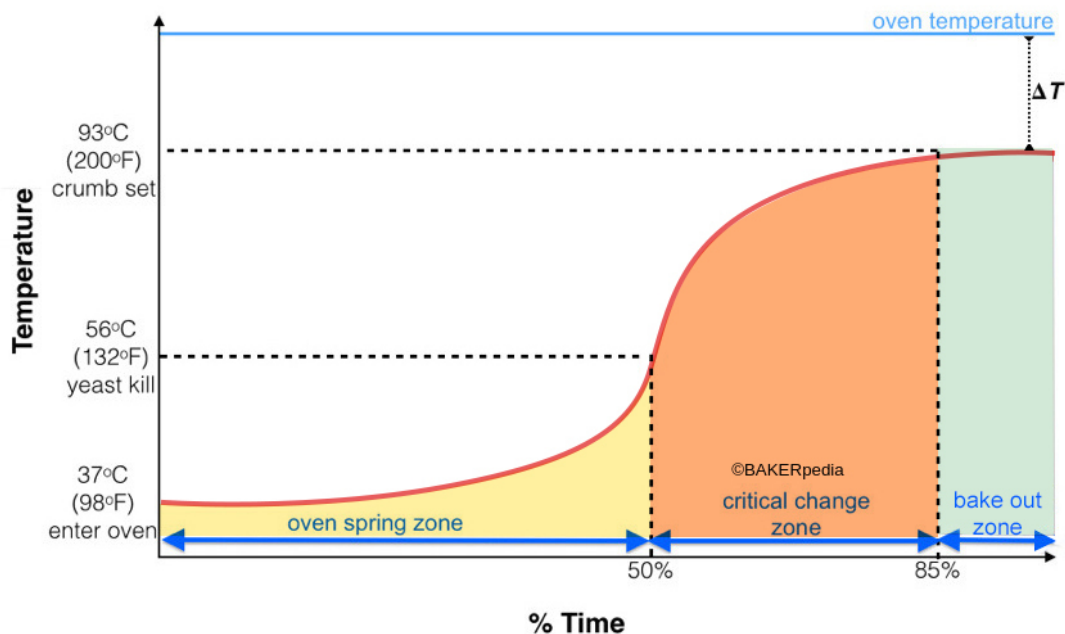
Leveraging this process approach to optimizing baking conditions,¹ the data is displayed as a temperature/time plot known as the thermal S-curve. There are hundreds of physiochemical changes during baking, but to simplify it, we have broken the S-curve into three major zones:

1. Oven spring zone: the final stage of fermentation in the oven, ending at about 56°C (132°F).
2. Critical change zone: the stage where yeast is killed, starch gelatinizes and protein denatures. The continuous dough becomes a porous crumb. The continuous dough becomes a porous crumb.
3. Bake-out zone: After the arrival point, where the internal temperature reaches above 93°C (200°F) and water starts escaping the product



Other important points include:

- Temperature entering oven
- Starch gelatinization time
- ΔT : difference between oven air and internal temperatures
- Final exit time and temperatures
- Energy under the S-curve



WHAT IS YEAST KILL?

The point where all fermentation activity ends: 56°C (132°F)

At this temperature, the yeast will stop producing gas. Therefore, all oven spring will halt. A high oven spring will be experienced if the product takes a longer time to reach this temperature. Therefore, to control oven spring, yeast kill precision at 50% or less of the baking time is essential.

What is arrival and why is it important?

Arrival temperature occurs at 93°C (200°F) under standard atmospheric conditions. This is the temperature at which all areas of the doughpiece have reached a solid state, thus beginning a mass movement of water out of the bread. The bake-out zone is the time between the arrival temperature and the exit of the oven.

Texture, mouth-feel and moisture content for a desirable shelf-life continue to develop during this critical period. The longer the product remains in this zone, the more moisture it loses, firming up the product.

TIP: If arrival happens at 80% of a baking profile, it means that 20% of that time is in the bake-out zone. For example, if the total baking time is 20 mins., 4 mins. of that time is in the bake-out zone.



Should all bake-out zones target 20%?

There haven't been any studies that recommend a universal bake-out zone for all baked products. However, the following zones are typical for achieving a soft interior without excessively drying up the crumb:

Product	Bake-out	Arrival
Hamburger buns	18-20%	78-80%
White pan bread	15-18%	82-85%
Whole wheat bread	10-15%	85-90%
Multigrain bread	2-7%	93-98%
Rye bread	20-25%	75-80%
Sourdough bread	10-15%	85-90%

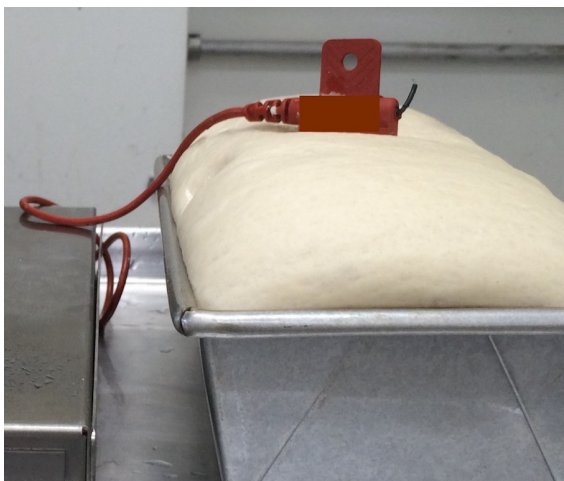
The bake-out zone should be manipulated accordingly to the final quality of the product. If the product is too gummy for slicing, increase the bake-out zone by 3%. If excessive molding is present, increase the bake-out zone by 5% as long as it doesn't affect the dryness of the crumb.

How do you know if you're over-baking?

Customers are generally vocal about bread dryness or crumbliness the day after it is baked. Usually, this is indicated by the hinge test. Fold a slice of bread over on itself, and if it completely breaks at the hinge, the product is most likely over-baked. Check to see if the bake-out is over 20%. If it is, reduce it by cutting down the time and temperature in the oven.

What if the bake-out zone is between 15-20% of baking time, and it still fails the hinge test the day after it is baked? Then, it's time to look at shelf-life extension enzymes and emulsifiers to slow down the staling effect. For now, keep the bake-out zone below 20% of the baking time, and don't let it go higher than that if dryness issues are occurring.





Using thermal profile equipment

1. Connect sensors to data logger inputs
2. Insert sensors inside the test product
3. Turn on data logger and press record button to start recording data
4. Place the thermal profiler inside the insulation box
5. Place the protected profiler and test products inside the oven
6. Collect data during baking cycle
7. Connect data logger to computer
8. Open profiler software to analyze the S-curve

CASE STUDY:

Why a step profile is better than just using one temperature throughout the baking process

A step profile refers to taking advantage of baking oven designs to individually control oven zone temperatures. Common with conveyerized tunnel ovens, many rotating rack ovens also feature programmable time regimes among thermal setup parameters.

Most industrial high-speed bakeries take advantage of this oven feature, yet it is often overlooked by many wholesale bakeries—especially when rotary or single deck ovens are used. The truth is that step profiles provide the best efficiencies with high throughput bakeries, and the following example indicates why this is the case.

Both breads were baked at a total time of 23 mins. The bread in Figure 1 baked at 218.3°C (425°F) for 23 mins., experienced a yeast kill at 62%, with a bake-out of 18% and an exit temperature of 97.8°C (208°F). When a step profile was introduced with the same baking time of 23 mins., the bread in Figure 2 saw a quicker yeast kill at 59%, a longer bake-out of 25% and an exit temperature of 98.9°C (210°F). The S-curve in Figure 2 shows that we can reduce the bake out from 25% to 18% simply by cutting the baking time by 2 minutes.

To achieve this, the M.O.L.E.® software should be manipulated by cutting back on the baking time (reduce bake time in the oven model by manipulating the Process End line till you reach an arrival of 82%). Therefore, this shows that a step profile provides an opportunity to reduce baking time, allowing for a higher oven throughput.

CONT.

CASE STUDY

Figure 1: A loaf of bread baked at 218.3°C (425° F) for 23 mins.

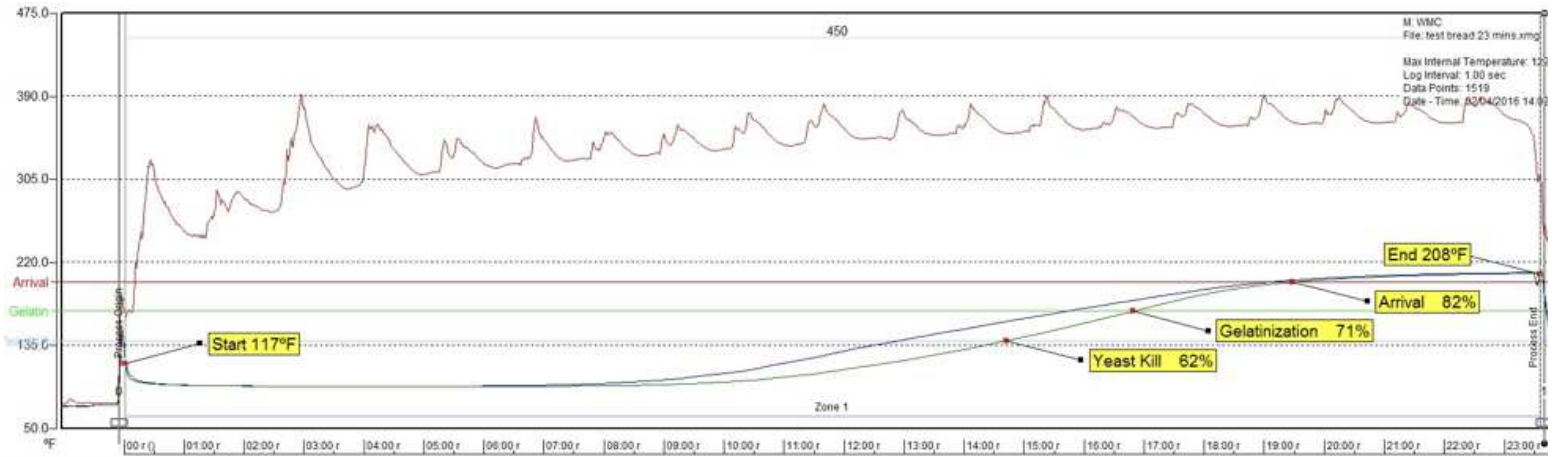
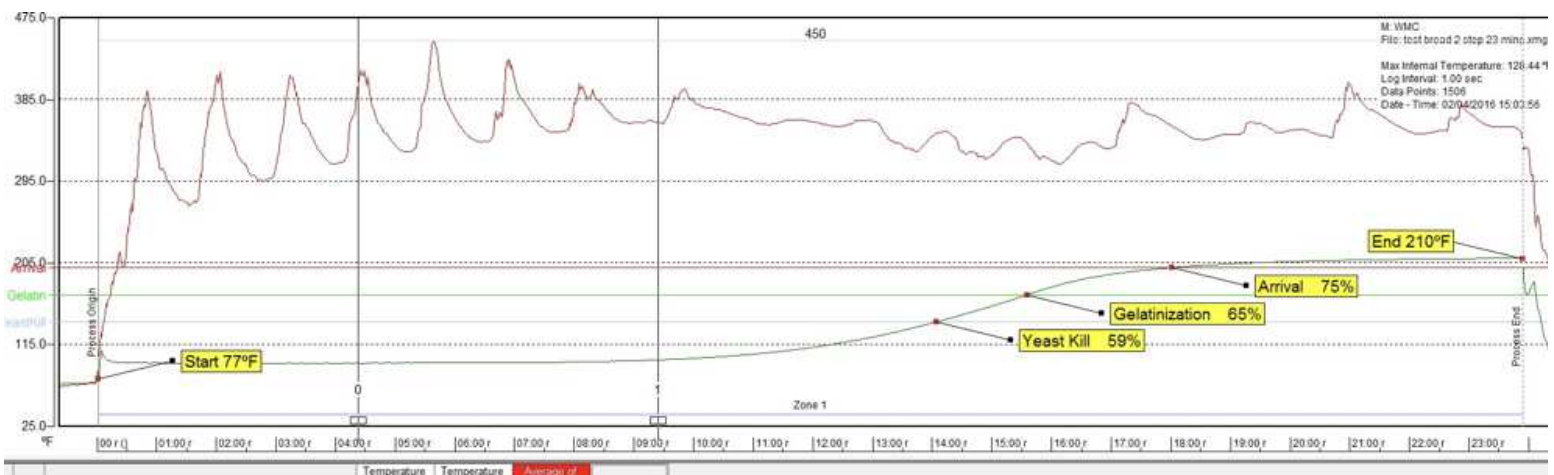


Figure 2: A loaf of bread baked using a step temperature profile of 232.2°C (450°F) for 10 mins. and 204.4° C (400°F) for 23 mins.



If using a logger like the SuperM.O.L.E.® Gold 2 thermal profiler with a Breadometer® sensor from ECD, channel 1 is an ambient temperature probe (red curve near top of graph). This sensor tells the software where oven entrance and exit occur to accurately position the oven model. The multiple dough insertion sensors are embedded in a stainless steel shaft, which is inserted into the dough up to a stop plate. This provides repeatable data from multiple depths, profile after profile.

“ Why do bakers go over 20% in the bake-out zone on their thermal profile?

Many bakers have been taught to bake until a certain golden brown color is achieved. Consequently, many bakers will leave bread in the oven longer than necessary to obtain that color. Depending on the moisture and type of bread, it's safe to say that a bake-out of 15% produces a bread product with a moist interior that would perform well in the hinge test. Targeting an arrival above 80% is only reasonable for most white bread products.

“ How can I make the rollout of a new product across plants more consistent?

Having actual data from a top performing plant for NPI (new product introduction) is the key to consistency across bakeries using different ovens. Multiple profile runs will provide an “optimized profile” which can be shared across all plants baking the same product. Share yeast kill and arrival data from the software (or bring the profiles along on laptop or hardcopy). [M.O.L.E.® Map software](#) features the overlay tool for a detailed comparative analysis of all profile features that are enabled. With this information, benchmarked by a known quality profile, implement the same yeast kill and arrival at the other lines or bakery locations by manipulating the oven zones with the aid of the software analysis.

To achieve adequate bake, the arrivals should target 80%. For single oven bakeries, benchmarking the old oven prior to purchasing a replacement is vital for retaining product consistency. This also holds true for a multi-rotating rack oven conversion to production with a tunnel oven.

“ What if I meet a 20% bake-out, but I do not get the color I want? Do I bake until I get my golden brown?

There is no correlation between bake-out and color. They can be controlled separately. If bake-out parameters are met, browning of the product can be controlled in the final zone of the oven. In most cases, increasing the final zone temperature at the desired bake-out will brown the product adequately.

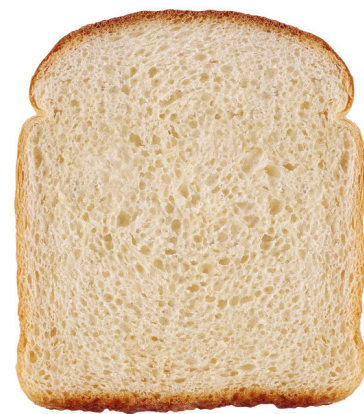
“ How do I get rid of white smiles on my hamburger buns?

The break and shred on one side of the hamburger bun produces a sloped crown that makes the bun look like it is smiling on one side. This is often observed with an increased strength in the dough, especially if the heel is white as well. While adjusting the oxidation strength for the formulation may be one way to solve this situation, the fastest way is to use thermal profiling and target an early yeast kill of 45%.

Increase the front zone temperatures to make sure that the interior of the bun reaches yeast kill, 56°C (132°F) at 45% of the baking time. This will ensure minimal oven spring and prevent occurrence of the one-sided break and shred.

References

1. Thermal profile for baking.
<https://bakerpedia.com/processes/thermal-profiling/>
2. How to determine adequate baking by using thermal profiling.
<https://bakerpedia.com/how-to-determine-adequate-baking-by-using-thermal-profiling/>. Last accessed by Mar 16. 2020.



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