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S-Curve Management: It's in Your Hands

How Bread Thermal Profiling Can Improve Quality and New Technology is Making Bakers' Jobs Easier

There's an art to baking the perfect loaf. And there's a lot of science, too. Thorough data about dough transformation is key. Read on to find out how to optimize your baking operation for the BEST results and how new technology may make it even easier to achieve.

Monitoring internal dough temperatures during a baking cycle is a crucial element of process control to ensure consistent, repeatable quality products. Known as bread thermal profiling, dough temperatures are measured using thermocouple sensors placed at various locations inside and outside the dough. By collecting and understanding this data, the baking step can be optimized, shelf-life improved, and plant-wide consistency ensured. Plus, with the latest advancements in thermal profiler designs, viewing S-curve data is easier and more immediate than ever before.

Understanding Thermal Profiling and the Infamous S-Curve

During the bread baking step, dough passes through three key stages, noted below. The functional properties of these steps depend on the baking time and control over the internal dough temperature throughout the process.

1. Yeast Kill: Produces gas in the dough and raises the product volume.
2. Gelatinization: Starch undergoes gelatinization and protein denatures, solidifying the crumb.
3. Arrival Point: This phase is when the majority of the internal dough reaches actual baking temperature, such that oven exit minus arrival equals bake out to achieve optimum quality control. The impact on final bread moisture content has a significant effect on texture and shelf life.

To precisely analyze and control these phases, a thermal profiling routine is highly recommended. A thermal profiler attached to a sensor device provides a log of the internal product temperature during a baking cycle and generates a graphical time-temperature representation of the baking process.

While the dough undergoes many physicochemical changes during baking, time and temperature have the most significant impact on the quality, characteristics, and repeatability of these transformations. Therefore, time and temperature are considered standard control variables for bread quality. Figure 1 below illustrates these phases. The Y-axis shows the temperature (internal product and oven temperature), and the X-axis displays the baking time as the product passes through multiple zones and temperatures. Because this graph is typically in an S-shape, it is commonly called the S-curve.

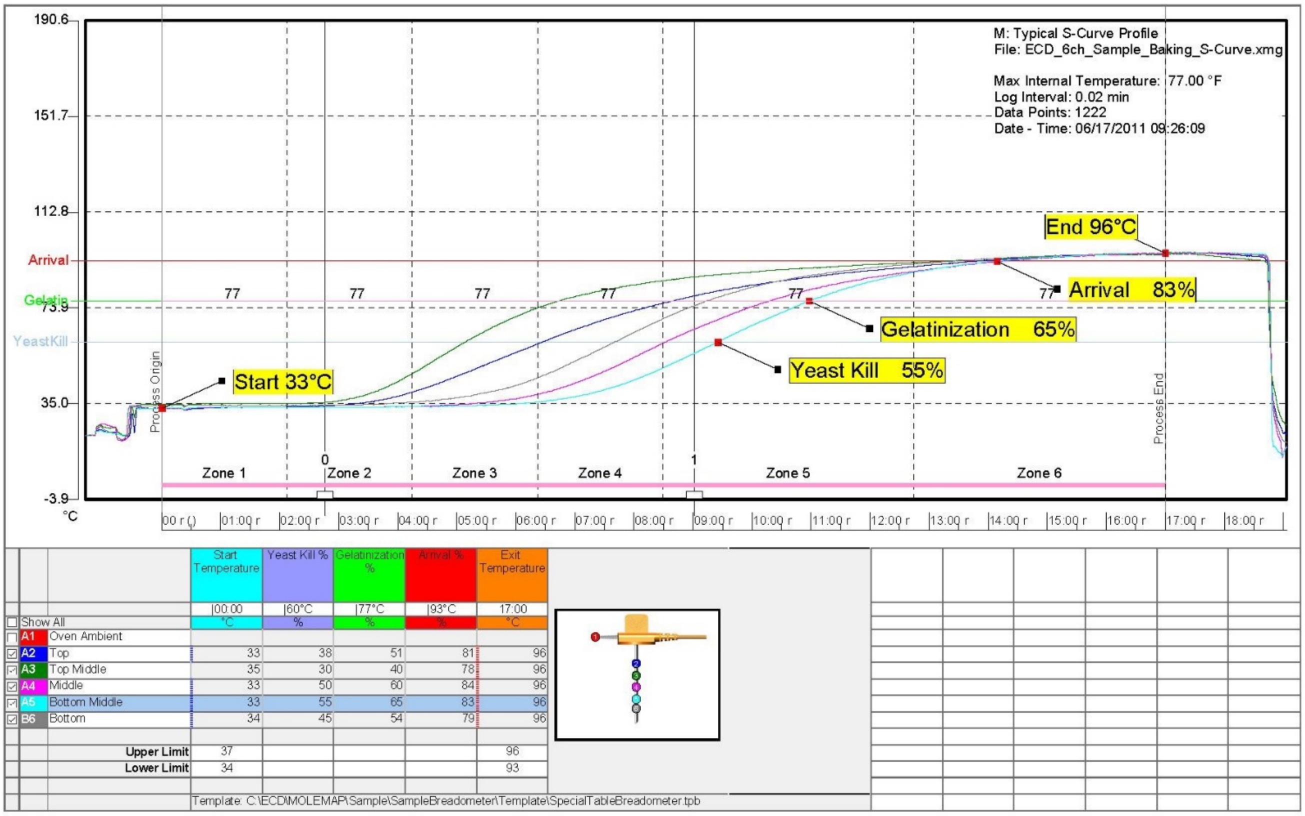

Figure #1: Typical S-curve transformation points. The internal product temperature rises in the oven as it moves inside a continuous oven system, and the product passes through all three phases

S-curve Data Capture and Interpretation

The S-curve is read from left to right like any standard graph. The temperature axis shows internal temperatures measured by the thermocouple and the external (oven) temperatures. The oven temperatures will always be higher than the desired internal temperature. ΔT denotes the difference in the internal temperature and oven temperature. Typical temperatures for an S-curve are shown in Table 1 below.

	Internal Dough Temperature	**Goal % of Bake Time**
Yeast Kill	60°C/140^{O}F	50 - 55%
Gelatinization	77°C/170°F	60 - 65%
Arrival (93°C/200°F)	93°C/200°F	85 - 88%

Table 1: Benchmarks for different phases of baking temperatures and estimated bake times

The target internal product temperature can vary in two ways compared to the achieved temperature. The entire baking process is divided into multiple zones, marked as Z1, Z2, and so on. This is represented on the X-axis. It helps to identify and isolate any specific out-of-specification zones, as in the below.

1. Temperature achieved earlier than desired.
2. Temperature achieved later than desired.
3. Temperature not achieved.

Table 2 below highlights ways the baking process needs to be adjusted for specific problems and illustrates how thermal profiling reduces the guesswork and delivers analytical solutions for most baking issues.

Yeast Kill 140 F	Gelatinization 170 F	Arrival 200 F	Possible Oven Setup or Bake Faults
Early	Early	Early	High Oven Temperature Set Points - All Zones.
			Bake time too long.
			Low formula absorption
			Excessive Oven BTU Capacity.
			High Proofer Exit Temp. (1 degree internal proof temp = 3 degree internal bake temp)
Early	Early	Late / None	First 65% of oven temp too high and last 35% too low.
			First 65% of oven temp too high and bake time too Short.
Early	Late	Late / None	First 50% of oven temp too high and last 50% too low.
			Short bake time with first 50% of oven temp too high.
Late	Early	Early	Short bake time with last 50% of oven temp too high.
			Long bake time with first 50% of oven temp too low.
			Rear Oven Damper closed or incorrectly adjusted.
Late	Late	Early	Excessive bake time with low zone temps.
			High humidity in first 50% of oven.
			Air drafting into oven.
Late	Late	Late / None	Short bake time.
			Low oven heat.
			Lack of BTU availability.
			Possible burner failures.
			Cool proofer exit temps - 1 degree proofer exit temp = 3 degree oven exit temp.
			High oven humidity.
			Air drafting into oven.
			Exhauster imbalance on tunnel ovens.

Table 2: Troubleshooting processing time and temperatures based on the obtained S-curve

The trendline drawn by the information from thermocouples (Figure 2) can provide insight into the baking process and the importance of balanced heat flow in the oven:

- A flat heating line across various zones shows balanced zone burner control.
- Maximum acceptable variance shows a slight bell-shaped heat line with minimal heat variation from zone to zone. It helps achieve the desired oven spring and target crust color.
- Excessive variance and unbalanced heat lines reveal poor burner control and poor product bake quality. This can result in undesirable properties such as late yeast kill, low product volume, no arrival, or unsuitable (very dark or very light) color due to low or high heat in the oven.

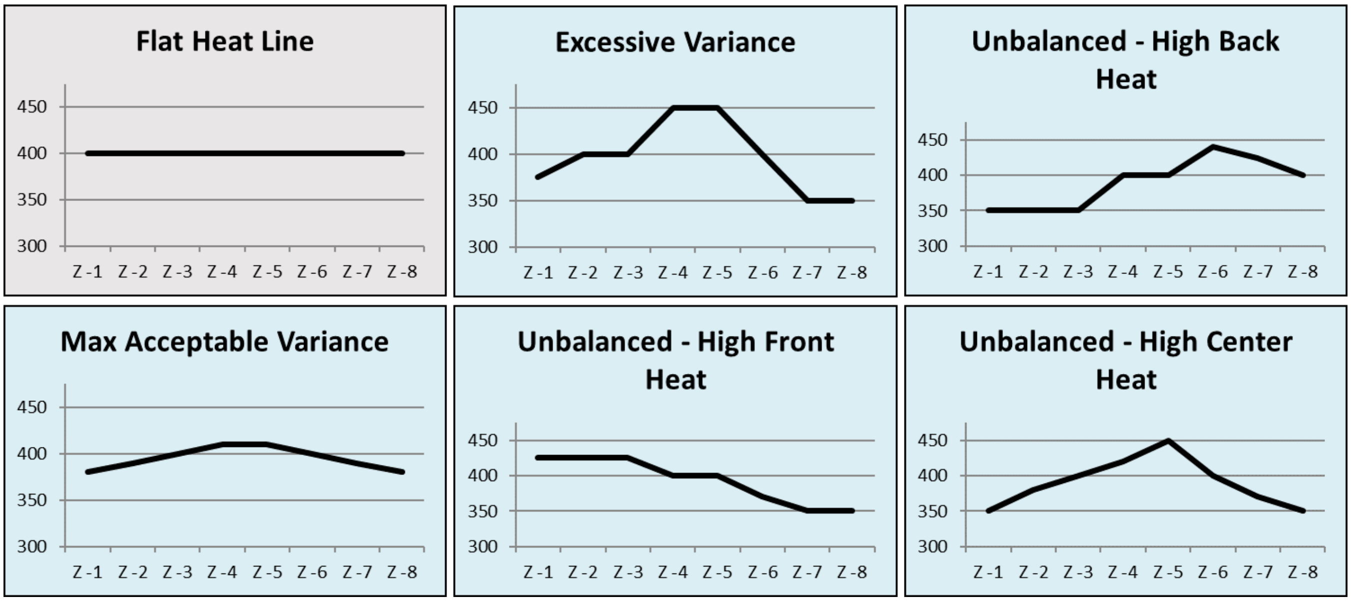

Figure 2: Different possible trendlines for zone temperature settings.

Accurate Data with Thermal Profiling, Now with Immediate S-Curve Viewing

To ensure precise, actionable data, it is essential to get accurate and consistent readings with thermal profiling equipment. Sensors connected to an electronic data recorder (thermal profiler) are used on the product during baking, moving within the oven. For the most thorough readings, six thermocouple sensors should be used in a combination of ambient and dough insertions.

Figure 3: Instrumenting the thermal profiling rig.

Tips for setting up sensors and equipment for accurate readings:

- Secure the thermocouples into the geometric center of each dough piece.
- Pinch the dough around the entrance point of each ‘wire’ so as not to promote excessive heat or moisture loss.
- For the ambient sensors, elbow them into and back out of the dough so the tip is at least 1” above the pan and off the edge of adjacent pans so as not to be directly above a pan to optimize accuracy.

(Figures 3 - 5 illustrate the dough-to-bread steps using a sensor attached to a data logger. In this case, BreadOMETER® with the latest M.O.L.E®. thermal profiler, the M.O.L.E. ® EV6, were used.)

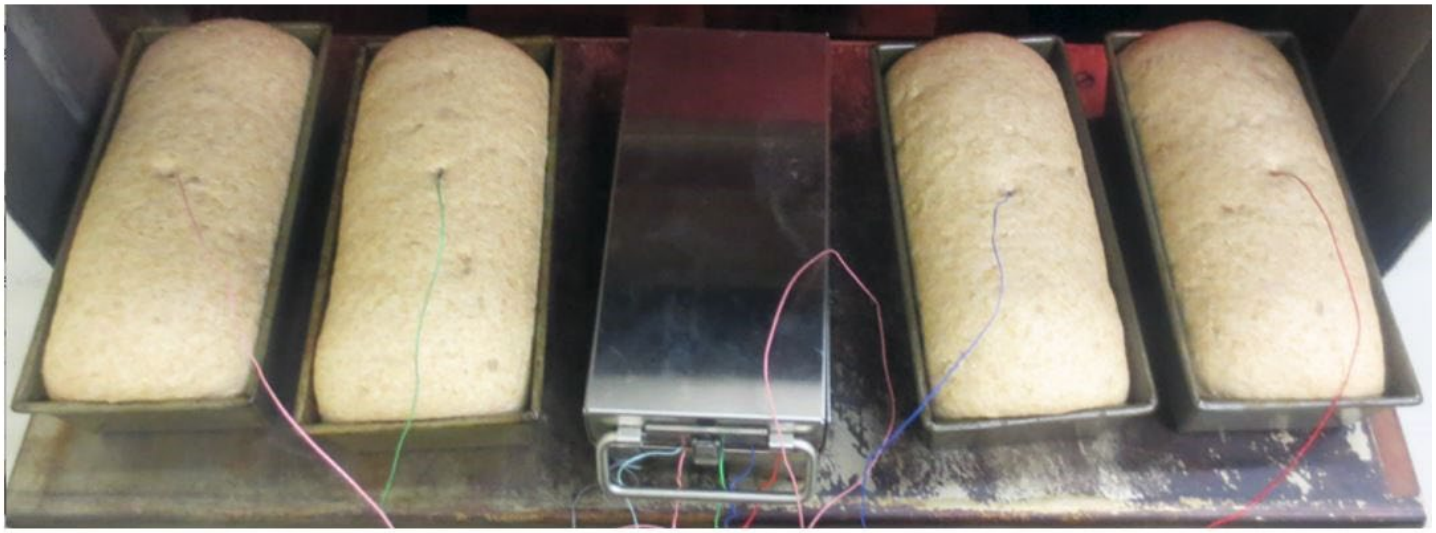

Figure 4: Multiple runs are typically required across the oven to discern if the oven is balanced left-to-right across the conveyor, or if it’s consistent between upper, middle, and lower shelves. Variations in thermocouple sensor placement (i.e., location, depth, angle, etc.) and even dough placement in the oven can also cause alterations in the data. There are models available, like the [BreadOMETER from ECD](), that have fixed positions for the ambient and insertion sensors up to the stop plate.

Figure 5: The BreadOMETER simplifies S-curve management with a patented all-in-one sensor design, allowing a single probe insertion for multi-depth dough measurements. The ambient sensor measures accurate oven line and delineates oven entrance and exit. The M.O.L.E. EV6 touchscreen thermal profiler displays S-Curve data and allows control from the handheld device; no PC download is required to view the profile

Improving Product Quality with Thermal Data Recording, Now with Instantaneous S-Curve Viewing

Baking is a science, so lack of tight process control can result in overbaking, a shorter shelf-life, and poor product texture. Thermal profiling helps reduce overbaking, which enables high product quality and reduced energy consumption. By accurately measuring time and temperature impact, the process can be modified to achieve desired results.

For example, reducing the bake-out time to less than 15% is the first step to avoid overbaking products. If there are shelf-life issues, the thermal profile can be used to achieve more than 15% bake-out. The bake-out time for a gummy product needs to be increased by 3%. The bake-out zones need to be manipulated depending on the final product quality. (Table 3)

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%

Table 3: Time duration for bake-out and arrival to achieve a soft interior without excess crumb drying.

For operational efficiency and maximum yield, regular thermal profiling routines should be standard bakery process control protocols. It is a relatively simple process that can help bakers save time, preserve profitability, drive brand loyalty, and streamline baking parameters. Moreover, the thermal profiler has been radically improved to make S-curve viewing immediate so real-time adjustments can be made. Learn more about the handheld, full-color, touchscreen M.O.L.E. EV6 here. It makes data logger control simple and intuitive and results instantaneous. (Figure 6)

Figure 6: Thermal profiler innovation with touchscreen M.O.L.E. EV6 allows S-curve viewing and data-informed process adjustments on the fly. No PC download is required for data viewing and analysis.

References

1. https://bakerpedia.com/specialties/bread/
2. https://bakerpedia.com/processes/thermal-profiling/

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