Figure S1. Analysis of Cooling Data with a Focus on Food Depth

The table below presents an analysis of the cooling data collected by the City of Minneapolis in retail restaurants. The temperature of each cold-holding unit was captured at one point in time during the cooling process and ranged from 34-40°F (average 38.1° F). The data are sorted in order of decreasing food depth. The second column indicates whether the cooling profile met the FDA Food Code or not. In those cases where the answer was "almost" or "no" we ran these data through the ComBase perfringens Predictor and the predicted log increases are shown in the third column. Where the predicted log increase was greater than one, this text has been indicated in bold. The name of the food is shown in the fourth column.

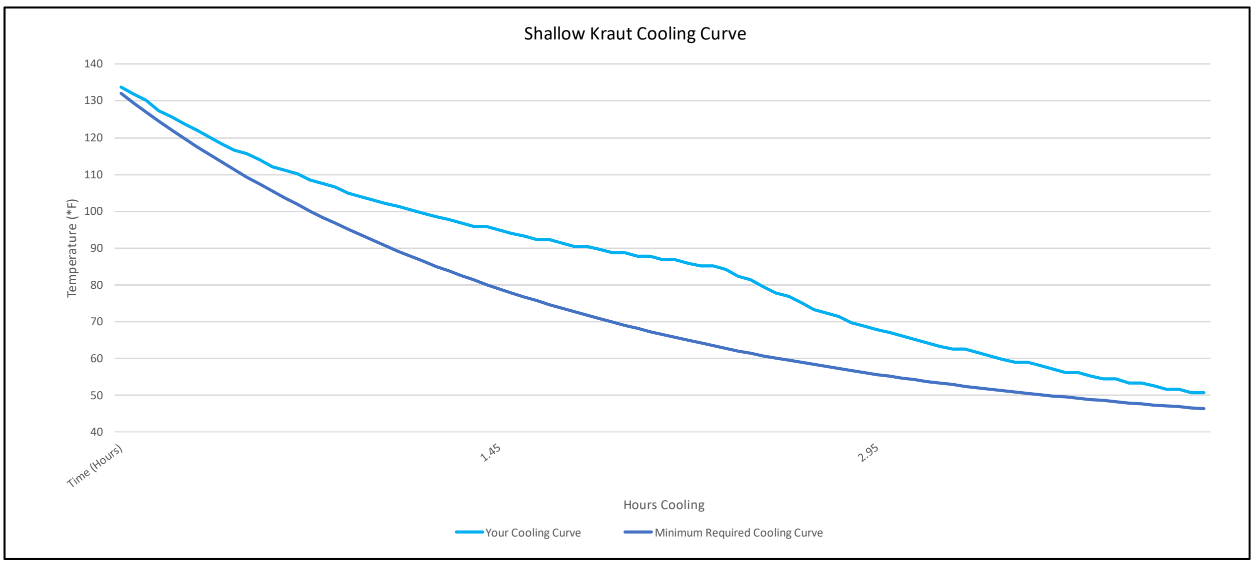
There are two instances where 2-inch cooling would appear be "risky" but are explained by mitigating circumstances. These two instances are for Sausage Gravy and Shallow Kraut. The cooling curve for Shallow Kraut is biphasic, which indicates that the ambient temperature changed during the cooling process. The cooling curve is pictured below, and we have included notes from the inspector on what may have happened. The Sausage Gravy was cooled with the ambient temperature of the cooler at 45.2° F, which would not be compliant with cooling in cold holding equipment maintaining an ambient temperature of 41°F or less. All other food items at a depth of 2 inches would result in a less than 1 log increase of *Clostridium perfringens*.

Food Depth (Inches)	Meets code	Perf predictor Log Increase	Recipe
2.5	Yes	0.029	Chicken Wings
2.5	Almost*	0.241	Shallow Potatoes
2.5	**No**	**1.332**	**Deep Kraut**
2.5	Almost	0.559	Cheese Sauce Deep
2.5	Almost	0.271	Squash Soup Deep
2.5	Almost	0.576	Spinach in Metal Pan
2.5	**No**	**1.094**	**Spinach in Plastic Pan**
2.5	Yes	0.019	Tomato Sauce
2.5	Yes	0.004	Diced Chicken
2.5	No	0.942	Chili Verde
2.5	**No**	**1.181**	**Refried Beans 2.5-inch pan**
2.25	**No**	**1.374**	**Chicken Pot Pie Mix**
2.25	Yes	0.038	Chicken Breasts
2	**No**	**1.870**	**Sausage Gravy**
2	Almost	0.652	Garden Veggie Soup
2	Yes	0.180	Chicken Curry Walk-In 2 Inches
2	Yes	0.081	Tomato Soup 2 Inch Metal Walk-In
2	Almost	0.242	Corn Chowder Plastic No Cover 2"
2	Almost	0.479	Chorizo 2"
2	Yes	0.028	Cherry Compote
2	Yes	0.028	Black Beans
1.75	Almost	0.110	Chicken Rice
1.5	Yes	0.020	Empanadas
1.5	Yes	0.011	Ground Beef
1.5	Yes	0.018	Mushroom Sauce Bottom Pan
1.5	Yes	0.013	Mushroom Sauce Top Pan
1.5	**No**	**1.280**	**Shallow Kraut***

1.5	Yes	0.138	Marinara 1.5" V1
1.5	Yes	0.202	Marinara 1.5" V2
1.5	Almost	0.123	Au Jus
1.5	Almost	0.115	Cheese Sauce Shallow
1.5	Almost	0.089	Squash Soup Shallow
1.5	Yes	0.008	Butternut Squash Soup
1.5	Yes	0.005	Mashed Potatoes
1.5	Almost	0.004	Turkey Chili
1.5	Almost	0.167	Refried Beans 1.5 Inch Pan

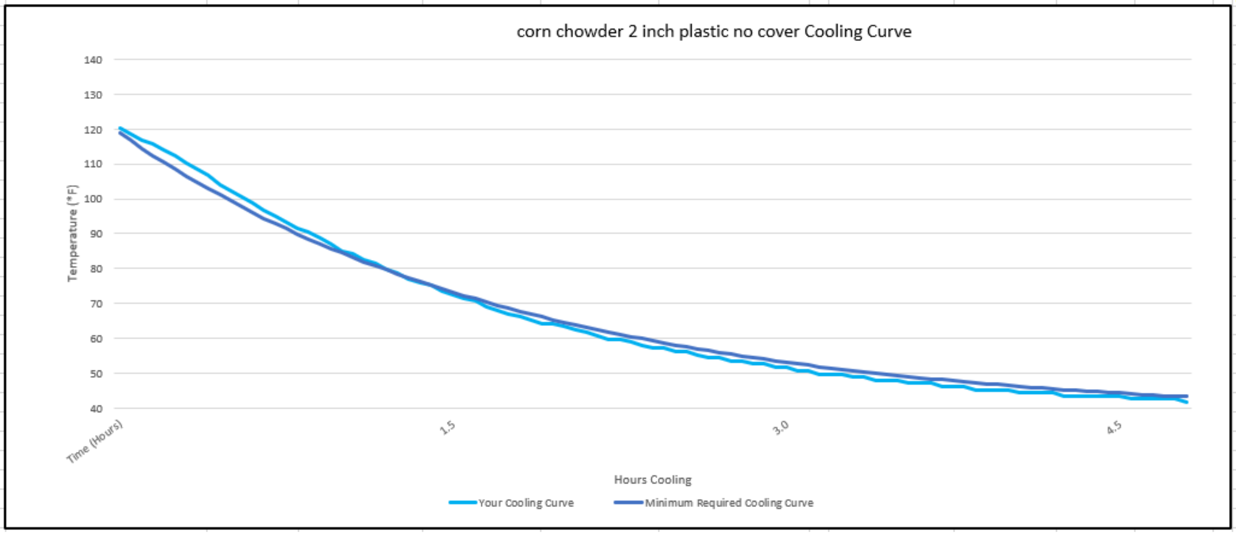
* The determination of cooling curves that "almost" meet the food code is somewhat subjective but these are curves where (a) the first phase of cooling happens more rapidly than the food code allows while the second part happens more slowly, (b) where the first part of the curve matches the food code and the second part more cools more slowly, or (c) where the entire curve is just slightly slower than the food code recommendation.

Shallow Kraut Cooling Curve:



The overall shape of the curve (a spike increase in the middle of the curve) suggests that the cooling method measurements were not maintained for the duration of the cooling curve. It is likely that the operator removed the data logger mid cooling, or the food was re-panned.

Corn Chowder (plastic no cover, 2in) Cooling Curve:



This food item didn't meet the FDA minimum time and temperature parameters for adequate cooling, and was labeled "almost" on the table above. You can see how close the curve is to the minimum required cooling curve. When this curve was run through the ComBase perfringens Predictor, there was only a 0.22 log increase.

Figure S2. Summary of Cooling Rates in relation to Food Code Requirements

The temperature change of cooling foods is not linear. Hot foods cool faster at first then more slowly as the temperature difference with the environment (and thus the driving force) is less.

The FDA Food Code recommends that hot foods be cooled 135 °F to 70 °F within two hours and then from 70 °F to 41 °F within another four hours, for a total cooling time of six hours.

According to Newtons law of cooling, the rate of cooling of an object can be described by a linear relationship if the logarithm of the difference between the object and the environment is plotted versus cooling time.

If we use the time and temperature parameters from the FDA Food Code and assume and an environmental temperature of 37°F this gives the highest R^2 value for cooling rate. The slope of this log linear plot is -0.23.

We also have validated computer models for predicting the growth rate of the two most likely spore forming pathogens found in cooling foods (*C. perfringens* and *B. cereus*). Those models are Perfringens Predictor https://browser.combase.cc/Perfringens_Predictor.aspx and Juneja, et al 2019 (Predictive model for growth of *Bacillus cereus* during cooling of cooked rice). The predictions below use pH 7, 0.5% salt for Perfringens Predictor, and assume cooked rice for *B. cereus*.

The predicted log increases assuming a food code cooling rate are 0.33 for *C. perfringens* and 0.10 for *B. cereus* and are shown in the table below. It is commonly accepted that a less than one logarithm increase for either of these pathogens constitutes a tolerable risk given the typical levels found in food and the levels needed to cause illness for these pathogens.

Linearized rate	*C. perfringens*	*B. cereus*
	log CFU increase	
-0.30	0.15	
-0.23	0.35	0.10
-0.20	0.56	0.16
-0.15	1.27	0.37
-0.10		1.13

This shows that the food code cooling rate is protective of public health, and that slightly slower cooling rates might also represent a negligible risk. For example, if we assume a log linear cooling rate of 0.20, this also results in less than a one logarithm increase for either pathogen.

If we convert this cooling rate back to an arithmetic scale this represents a food that is cooled according to this profile:

time (hr)	temp °F
0	135.0
1	98.8
2	76.0
4	52.5

6	43.2
12	37.4

As shown in the first table, a cooling rate of 0.15 would result in an unacceptable (1.26 log) increase in the concentration of *C. perfringens*.

If we convert this cooling rate back to an arithmetic scale this represents of food that is cooled according to this profile:

time (hr)	temp °F
0	135.0
1	106.4
2	86.1
4	61.6
6	49.3
12	38.6

The slowest cooling rate which results in an acceptable (e.g., approximately 0.99 log) increase in the concentration of *C. perfringens* is 0.165, which corresponds to a food cooled according to this profile:

time (hr)	temp °F
0	135.0
1	104.0
2	82.8
4	58.4
6	47.0
12	38.0

Thus, if the “2 inch food depth uncovered” protocol results in cooling slower than what is specified in the FDA Food Code this does not necessarily result in a risk to public health.

Table S1. Summary of Washington State Outbreak Data

When Washington state adopted the FDA Food Code in 2005, it added language allowing for 2 inch cooling as an alternative to time and temperature monitoring. From 2010-2021 there were 408 foodborne disease outbreaks of all types reported in Washington State.

Some of these outbreaks, 42 of 408 (10.2%) were listed as *Clostridium perfringens*, *Bacillus cereus*, or other bacterial toxin, and thus could have been caused by cooling deficiencies.

- 4/42 Laboratory confirmed outbreak
  - All *C. perfringens*
- 38/42 Suspected outbreak
  - 8/38 *B. cereus*
  - 19/38 *C. perfringens*
  - 11/38 Bacterial toxin

<u>**Cooling method utilized in outbreaks from 2010 – 2021**</u>

Grouping	Category	*Deep Pan Cooling	2 Inch Cooling, Uncovered	Room Temperature Storage	Deep Pan & Room Temperature Storage	Unknown Methods	Total
By agent status	Confirmed	1	0	1	1	1	**4**
	Suspected	21	0	5	7	5	**38**
	Total	**22**	**0**	**6**	**8**	**6**	**42**
By agent type	*B. cereus*	4	0	1	1	2	**8**
	C. perfringens	13	0	3	5	2	**23**
	Bacterial toxin	5	0	2	2	2	**11**
	Total	**22**	**0**	**6**	**8**	**6**	**42**

*Deep Pan cooling is cooling foods at a depth of greater than 2 inches.

In summary, 30/42 (71%) of the above outbreaks had Deep Pan Cooling listed as the primary Contributing Factor. Fewer 6/42 (14%) listed Room Temperature Storage as the Primary Contributing Factor. The same number 6/42 (14%) listed either Hot-holding or Cold-holding as the Primary Contributing Factor <u>and</u> the cooling method was not identified/evaluated. **None of 42 outbreaks was linked to use of 2 inch cooling.**