

Pasteurisation Is a Pair of Temperature and Time, Not a Temperature

— **3.5** hours at **55** degrees and **3.38** seconds at **75** achieve the same seven-decade reduction — The ratio of times is **3727.5937**, which is the closed form $10^{20/5.6}$ — “How hot did it get” does not settle whether it is safe

— [Paper 369]

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— *From thinking to syncing.* —

Abstract

The safety of cooking is spoken of as “what core temperature was reached”. This paper asks whether that settles it —the answer is that it does not: a pair of temperature and time settles it. No new mathematical theorem and no new law is claimed. First, the D value is the time to cut the count by one decade and the z value the temperature shift that changes D by one decade (Section 2). Second, this is the core of the paper. **210** minutes at **55** degrees and **3.38** seconds at **75** are the same seven-decade reduction (Section 2). Third, the ratio of times is **3727.5937**, exactly $10^{20/5.6}$ (Section 2). Fourth, at **60** degrees it is **26.8758** minutes, agreeing with the accepted “chicken at 60 for about 30 minutes” (Section 2). Fifth, solved the other way, “seven decades in 60 minutes” requires **58.0468** degrees (Section 3). Sixth, the separator is whether one reports a temperature or a temperature and a time (Section 5).

Scope of this paper (scope note): No new mathematical theorem and no new law is claimed— D values, z values, and low-temperature pasteurisation are all standard. We do not build microbiology—the mechanism of heat resistance by species, and the treatment of spores, are not entered. They are named and no more. We give no safety standard—the numbers here must not be used as cooking guidance. $D = 30$ minutes and $z = 5.6$ degrees are stated assumptions; real values vary with species, food, and water activity. Heat conduction is not treated—the time for the interior to reach the set temperature is not the subject. Only the case of the centre held at the target is computed. Quality is not discussed—texture, flavour, and protein denaturation are not the subject. Regulation is not discussed—national standards and labelling are not the subject. Relation to earlier papers: Paper 352 showed a transition temperature moving with the speed of measurement—there time moved a temperature; here time and temperature are interchangeable. Paper 346 showed half-life ceasing to be a constant for some reaction orders—there too the question was whether one number suffices. Paper 300 showed whether two things share a root is decidable—by that test, “the temperature was reached” and “it was pasteurised” have distinct roots. Paper 358 showed a convention fixing a number—here the convention is how many decades to remove. What is added is giving the required time at five temperatures, showing the ratio to be the closed form $10^{20/5.6}$, checking against the accepted “60 degrees for about 30 minutes”, solving backwards for 58.0468 degrees and confirming the formula closes, and putting the separator on what is reported.

1. Notation and the Question

Setting: Write thermal inactivation with D and z values.

$$D(T) = D_{\text{ref}} \cdot 10^{(T_{\text{ref}} - T)/z}, \quad t_{n \text{ decades}} = n D(T)$$

Take $D_{\text{ref}} = 30$ minutes (at $T_{\text{ref}} = 55$ degrees), $z = 5.6$ degrees, and a target of $n = 7$ decades.

Observation 1.1

The D value is the time to reduce the count to a tenth. The reduction is exponential, so counting in decades is natural—seven decades is one part in 10^7 , a ten-millionth.

Observation 1.2

The z value is the temperature shift that cuts D to a tenth. Raise the temperature by 5.6 degrees and the required time falls tenfold—temperature and time are linked logarithmically.

Observation 1.3

So one safety level is reachable by many pairs.Hot and brief, or cool and long——this paper gives the values of those pairs.

Question: Does “how hot did it get” settle safety?

2. 3.5 Hours and 3.38 Seconds Are the Same

Calculation 2.1: *D* value and the time for seven decades against temperature (computed in this paper).

Temperature [deg]	<i>D</i> [min]	Time for seven decades
55	30.000000	210.0000 min (3.5 h)
60	3.839407	26.8758 min
65	0.491368	3.4396 min
70	0.062885	0.4402 min
75	0.008048	0.0563 min (3.38 s)

Observation 2.2

This is the core of the paper.3.5 hours at 55 degrees and 3.38 seconds at 75 are the same seven-decade reduction——20 degrees apart and 3727 times apart in time, and the safety achieved is identical.

Observation 2.3

The ratio has a closed form.3727.5937 is exactly $10^{20/5.6}$ ——independent of D_{ref} and of the number of decades. It is fixed by the temperature gap and *z* alone.

Observation 2.4

It agrees with accepted practice.26.8758 minutes at 60 degrees——matching the sous-vide guidance of “chicken at 60 for about 30 minutes”. Neither the formula nor the constants are off.

Observation 2.5

Even 55 degrees gets there.210 minutes, well inside a day——there is no “temperature too low to be safe”; there is only a longer required time.

Observation 2.6

But it cannot be lowered without limit.The *z* value is constant only over a limited range——at low temperature the organisms grow instead, so it must not be extrapolated. This paper has not computed that lower bound.

3. Fix the Time and the Temperature Follows

Calculation 3.1: Solving “seven decades in 60 minutes” backwards (computed in this paper).

Quantity	Value
Target	seven decades in 60 minutes
Required temperature	58.0468 degrees
Check (time for seven decades there)	60.000000000 min

Observation 3.2

The formula closes.Putting the temperature back gives 60.000000000 minutes——not an arithmetic error.

Observation 3.3

So either quantity may be fixed. Fix the temperature and the time follows; fix the time and the temperature follows——only one of the two can be chosen independently.

Observation 3.4

That is the practical freedom. Cool and long to preserve texture; hot and brief when speed matters——one can choose for another purpose while holding safety fixed.

Observation 3.5

“How many decades” is a convention too. Seven is a target set in this paper——six would give six sevenths of the time. The same shape as the circle of confusion fixing the number in Paper 358.

4. A Temperature Alone Is Not Enough

Observation 4.1

“It reached 75 degrees” contains no time. Taken off the moment it arrives, it has not had 3.38 seconds——that report cannot say whether it is enough.

Observation 4.2

“60 degrees for 30 minutes” is complete. Both the temperature and the time are there——that it exceeds seven decades can be computed.

Observation 4.3

Distinct roots by the criterion of Paper 300. “The temperature was reached” is settled by a thermometer; “it was pasteurised” by an integral——taking a report of one as a guarantee of the other is the confusion.

Observation 4.4

To be stated honestly——inactivation also proceeds during the heat-up.This paper computed only the case of the target being held——including the heat-up shortens the required time. The estimate errs on the safe side.

Observation 4.5

The numbers here must not be used as cooking guidance. $D = 30$ minutes and $z = 5.6$ degrees are assumptions——real values vary with species, food, and water activity.

5. The Separator: What Is Reported

Observation 5.1

The separator——whether one reports a temperature alone or a pair of temperature and time.

Report	Enough information	Reaches seven decades	Decidable
“reached 75 degrees”	no	unknown	no
“60 degrees, 30 minutes”	yes	yes	yes
“55 degrees, 3.5 hours”	yes	exactly	yes

Observation 5.2

The first row has the highest temperature and cannot be decided.The hottest of the three carries the least information——the size of a number and the amount of information in it are different things.

Observation 5.3

The separator can be moved. Give the thermometer an integrating function and the report moves from the first row to the second—change the instrument and the same cooking becomes decidable.

Observation 5.4

This is a problem of measurement design. What can be said afterwards was fixed when it was decided what to record—the same shape as recording the dropouts in Paper 364.

Observation 5.5

To be stated honestly—210 minutes and 3727.5937 are values under stated assumptions of $D = 30$ minutes, $z = 5.6$ degrees, and seven decades. Another organism gives other numbers—what does not move is the structure: temperature and time are logarithmically interchangeable.

Observation 5.6

One last thing—when two quantities are linked logarithmically, a habit of reporting only one throws information away. Temperature is easy to measure and time is easy to forget—that only the easily measured one gets reported is not because it is the important one.

6. The Census and the Close

1. D is the time for one decade (Section 1): seven decades is a ten-millionth.
2. $z = 5.6$ degrees cuts D tenfold (Section 1): a logarithmic link.
3. 210 minutes at 55 degrees (Calculation 2.1): 3.5 hours.
4. 3.38 seconds at 75 degrees (Calculation 2.1): the same seven decades.
5. Ratio 3727.5937 (Observation 2.3): exactly $10^{20/5.6}$.
6. 26.8758 minutes at 60 degrees (Calculation 2.1): agrees with practice.
7. 58.0468 degrees for 60 minutes (Calculation 3.1): solvable backwards.
8. Back-substitution gives 60.0000000000 (Observation 3.2): the formula closes.

9. “Reached 75” cannot be decided (Observation 4.1): no time in it.

10. Heat-up inactivation not counted (Observation 4.4): an estimate on the safe side.

Closing: The safety of cooking is spoken of as “what core temperature was reached”——but that single number does not settle it. The D value is the time to cut the count by one decade; the z value the temperature shift that cuts D by one——raise the temperature 5.6 degrees and the required time falls tenfold, so temperature and time are linked logarithmically. So one safety level is reachable by many pairs——on $D = 30$ minutes at 55 degrees with $z = 5.6$, removing seven decades (a ten-millionth) takes **210** minutes (3.5 hours) at 55 degrees and **3.38** seconds at 75. Twenty degrees apart, **3727.5937** times apart in time, and the safety achieved is identical. That ratio is exactly $10^{20/5.6}$, independent of D and of the number of decades. At 60 degrees it is **26.8758** minutes, agreeing with the sous-vide guidance of “chicken at 60 for about 30 minutes”. Either quantity may be fixed——solving “seven decades in 60 minutes” backwards gives **58.0468** degrees, and putting it back returns 60.0000000000 minutes. Only one of the two can be chosen independently, and that is the practical freedom——cool and long to preserve texture, hot and brief when speed matters, with safety held fixed. So a temperature alone is not enough——“it reached 75 degrees” contains no time, and taken off the moment it arrives it has not had 3.38 seconds. That report cannot say whether it is enough. “60 degrees for 30 minutes” is complete and can be computed. The hottest of the three reports carries the least information. One thing separates them——whether one reports a temperature alone or a pair of temperature and time. Give the thermometer an integrating function and the same cooking becomes decidable, so this is a problem of measurement design — the same shape as recording the dropouts in Paper 364. To be said honestly——inactivation also proceeds during the heat-up, so these values err on the safe side. And $D = 30$ minutes, $z = 5.6$ degrees and seven decades are all stated assumptions; real values vary with species, food and water activity. The numbers here must not be used as cooking guidance. One last thing——when two quantities are linked logarithmically, a habit of reporting only one throws information away. Temperature is easy to measure and time is easy to forget. That only the easily measured one gets reported is not because it is the important one.

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