Assessment of Consumer Flour Thermal Treatments on the Reduction of *Salmonella*

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Abstract

Introduction: Increased public awareness of risks associated with raw flour and products containing raw flour, such as raw cookie dough, has resulted in online consumer resources offering home-scale solutions for reducing pathogens in such foods. However, there is limited evidence validating the efficacy of these treatments.
Purpose: The purpose of this study was to determine the efficacy of home-scale raw flour heat treatments on the reduction of *Salmonella* in a variety of flour types.
Methods: An online search for home-scale instructions for flour heat treatment informed the experimental design. All-purpose, whole-wheat, and gluten-free (rice-based) varieties of flour were inoculated with *Salmonella* Enteritidis PT 30 (~8.65 log CFU/g), and conditioned to a water activity (a_w) of ~0.45 for ≥ 2 days. Samples (three replications with triplicate 4-8 g subsamples) were spread into a uniform layer ~ 0.5 cm thick, heat-treated in a convection oven at 177°C up to 10 min, then transferred to sterile bags, cooled, serially diluted, and plated on differential media. Temperature profiles and a_w also were measured.
Results: After a 10 min treatment, *Salmonella* in all-purpose, whole wheat, and gluten free flours resulted in log reductions (mean ± standard deviation) of 3.28 ± 0.52, 4.09 ± 0.46, and 4.13 ± 0.67, respectively. There were significantly less *Salmonella* reductions in all-purpose than in whole-wheat and gluten-free flour. Similar a_w trends were observed for all products, with values < 0.1 by 7.5 min. Samples did not achieve greater than an average 5 log reduction after a 10 min treatment ($P < 0.05$).
Significance: Awareness of microbial hazards associated with low-moisture products is increasing; however, none of the home-scale solutions evaluated were scientifically supported. While treated flour resulted in less *Salmonella*, it is currently unknown whether this is a sufficient or best practice for consumers.

Objectives

→ Test the efficacy of internet-sourced flour heat treatments for raw-cookie dough recipes.
→ Utilize *Salmonella* to model a hypothetical flour contamination scenario.
→ **Goal:** reach an average 5 log reduction in pathogen populations as a benchmark.

Introduction

Recent instances of pathogen contamination in flour-based baking products has increased public awareness of risks associated with flour and other minimally-processed foods. On June 21st, 2018, the US Food & Drug Administration issued a recall on Brand Castle and Sisters Gourmet cookie and brownie mixes due to possible *E. coli* contamination [1]. To avoid these risks, many consumers have taken to the internet to find methods for heat-treating flour as a "kill-step" [5] in residential settings for use in popular recipes such as raw cookie dough [3, 7, 9, 11, 13, 16]. Such sources are not related to kinetics and thermal inactivation studies; some baselines for a "safe flour temperature" are misconstrued from recommended internal meat temperatures such as chicken [17]. While well intentioned, the disconnect between popular belief and scientific method can be detrimental to the flour product and for the consumer—improper heat treatments can lead to decreased gluten extensibility within the flour [10] and foodborne illness [4] if the product is contaminated.

An internet search provided potential thermal treatments used in the experimental design.

TABLE 1. *Proposed thermal treatments for raw flour, sourced from consumer-based internet web pages*

Source	Temperature (°C)	Treatment Duration (min)	Baking Surface
Tomlan, *TODAY* Food [16]	149	2[a]	Baking Pan
Tane, *Cooking Light* [15]	177	5	Baking Pan
Bogacki, *Liv For Cake* [2]	177	5 to 10	Baking Pan
Sprinkle Some Fun [14]	93	10	Baking Pan
Sobjack, *Baked By An Introvert* [12]	177	5	Baking Pan

[a] Treatment involved 2 min heating intervals until internal product temperature reached 74 °C.

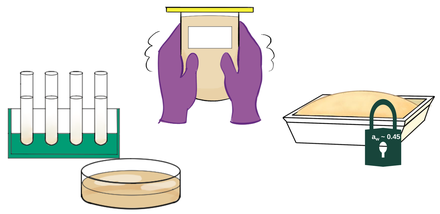
From Table 1, an isothermal treatment (Table 2) was chosen for application. The treatment was applied to flour inoculated with *Salmonella* Enteritidis PT 30; the variable treatment duration allows for an analysis of *Salmonella* population reductions over time.

TABLE 2. *Chosen thermal treatment for raw flours*

Flour Products	Temperature (°C)	Treatment Duration (min)	Baking Surface
All-purpose, gluten-free, whole-wheat	177	[0, 2.5, 5.0, 7.5, 10]	Baking Pan

Methods and Materials

All-purpose flour (AP) | Whole-wheat flour (WW) | Gluten-free flour (GF)

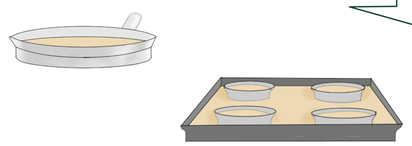


Inoculum Preparation

- Inoculation protocols followed previously published "lawn-liquid method" [8].
- *Salmonella* Enteritidis PT 30 cultured in Tryptic Soy Broth, then grown on Tryptic Soy Agar with Yeast Extracts media.
- 1 mL of buffered peptone water added to lawn culture plate, agitated, and harvested as liquid inoculum.
- 1 mL of inoculum added to bagged 200 g flour in a sterile bag and hand massaged for 3 min.

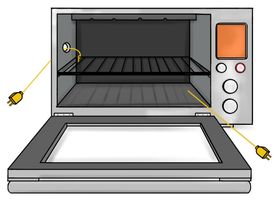
Inoculation and Conditioning

- Inoculated samples conditioned for 48 h in custom conditioning chamber.
- Target a_w ~ 0.45
- Mean initial inoculation levels for AP, WW, and GF: ~8.65 log CFU/g



Sample Preparation

- 1 tablespoon of inoculated and conditioned sample placed into four aluminum trays.
- Trays nested in bed of unconditioned flour to model proposed home-scale treatments.

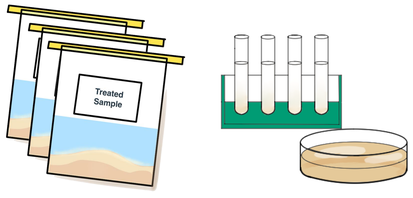


Thermal Treatment Preparation

- Breville © oven outfitted with k-type thermocouples to measure oven and sample temperature profiles.
- One probe permanently secured to one aluminum tray.
  - Thermocouple attached 2mm above bottom of tin and beneath the flour sample.
- Oven preheated to 177 °C with convection mode **OFF.**

Thermal Treatment

- Batches of samples baked at one of five chosen durations.
- Duration of treatment chosen at random from 0, 2.5, 5.0, 7.5, 10.0 min. Temperature profiles recorded concurrently with treatment.
- Sample flour depth: ~ 0.5 cm.



Post Treatment

- Immediately post treatment, flour samples aseptically poured into bag with chilled Buffered Peptone Water.
- Samples bags stomached, serially diluted, and plated on differential media (Modified Tryptic Soy Agar) for further analysis.

Results

Temperature Profiles Vs. Water Activity (a_w):
All-Purpose (AP), Whole-Wheat (WW), and Gluten-Free (GF) Flours
Over A Ten Minute Treatment at 177 °C

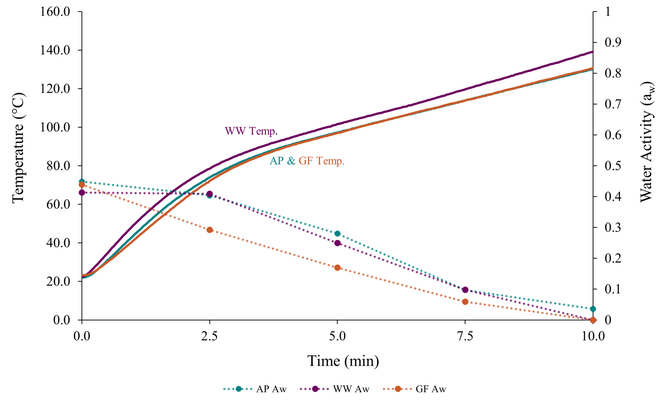


Figure 1: Temperature vs. water activity of all-purpose, whole-wheat, and gluten-free flours.

Log Reductions of *Salmonella* Enteritidis PT 30 In All-Purpose, Whole-Wheat, and Gluten-Free Flours

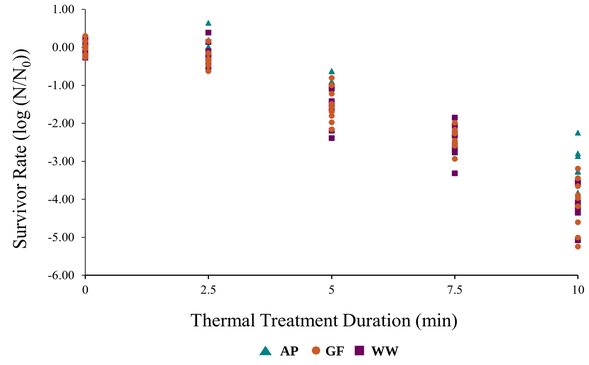


Figure 2: Log reductions of *Salmonella* in inoculated flour samples.

- Average log reductions for AP, WW, and GF flours were 3.28 ± 0.52, 4.09 ± 0.46, and 4.13 ± 0.67, respectively. No flour samples achieved greater than an average 5 log reduction, missing the target. Samples were not significantly greater than a 4 log reduction. *Salmonella* had higher survival rates in AP flour than WW and GF when compared using ANCOVA ($P<0.05$).

Significance

- The lack of concrete, scientifically supported heat treatment methods accessible to consumers is a public health issue that requires further investigation.
- Research is needed to test the effectiveness of home-scale thermal treatments regarding the survival of pathogens.
- Increasing treatment duration to achieve a 5-log reduction is possible, but may negatively affect the functional properties of flour [10].

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