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The effect of superheated steam on the inactivation kinetics of *Enterococcus faecium* inoculated in peanut butter at different water activities

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Introduction

- Superheated steam is an emerging sanitation technology for treatment of food plant surfaces that offers minimal water and chemical utilization.
- Superheated steam is a form of steam at a temperature higher than its liquid's boiling point under a given pressure.
- However, limited data is available on the mediating effects of food soil residues present on environmental surfaces as they impact microbial inactivation.
- The objective of this study was to investigate the inactivation kinetics of *Enterococcus faecium* in peanut butter as a function of superheated temperatures and peanut butter water activity (a_w).

Materials & Methods

- **Sample preparation**
  - *E. faecium* NRRL B-2354 was inoculated in peanut butter (7.96 log CFU/g ± 0.63) adjusted to different aw (0.18, 0.40, 0.60, and 0.80) and kept at 25°C for 48 h for adaptation.
  - The samples were coated (31.5 mm × 20.0 mm × 0.60 mm) onto aluminum foil of 0.016 mm thickness.
- **Superheated steam treatment**
  - Steam temperature: 125, 175, 225, and 250 °C
  - The coated samples were placed in a custom coupon holder inside the treatment chamber.
  - After treatment, the samples were immediately transferred to peptone water to stop the thermal process.

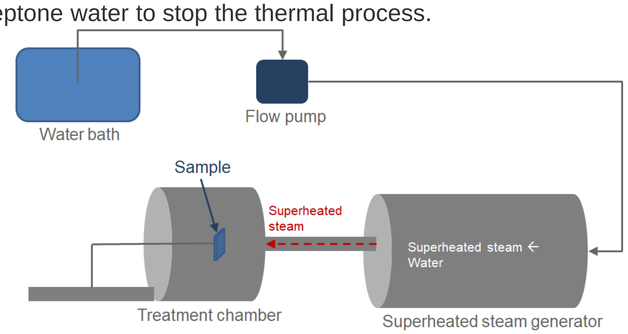


Fig 1. The schematic diagram of the superheated steam equipment.

- **Inactivation kinetics**
  - Survivors after treatment were enumerated by plating on tryptic soy agar

$$D = \frac{-\Delta t}{Log(N/N_o)} \qquad z = \frac{C_2 - C_1}{\log D_1 - \log D_2}$$

D: decimal reduction time (sec); *t*: time (sec); *N*: survivor after treatment (CFU/g); N_0: initial population (CFU/g); *z*: temperature (z_T) or water activity (z_{aw}) sensitivity of the bacterial culture; *C*: temperature (°C) or water activity

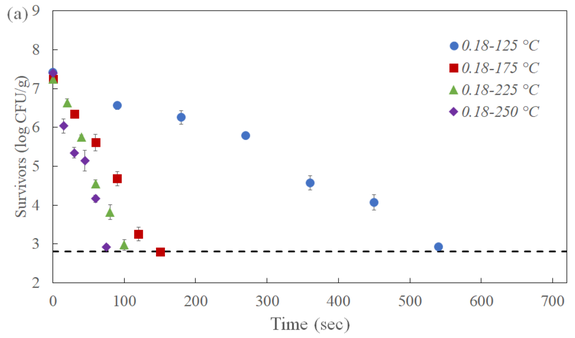
  - All the experiments were triplicated in this study.
  - Coefficient of determination (R^2) was used to quantify the goodness-of-fit of linear regression models.
  - Standard error of the estimate (*SEE*) was used to estimate the accuracy of predictive models.

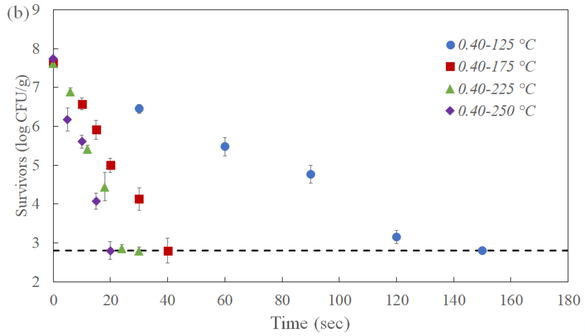
$$R^2 = 1 - \frac{SS_{Regression}}{SS_{Total}} \qquad SEE = \sqrt{\frac{\sum(N - N_p)^2}{n}}$$

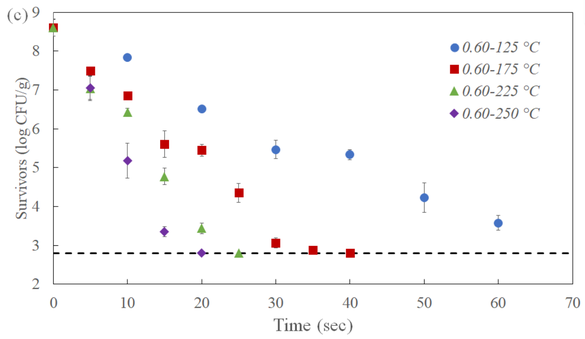
$SS_{Regression}$: sum squared regression error; SS_{Total}: sum squared total error
N_p: predicted survivor after treatment (CFU/g); *n*: number of data point

Results and Discussion

- **Uniformity of superheated steam**
  - During superheated steam treatment, the steam temperature was uniform and stable at the steady state for each target temperature (SEE < 1.34).







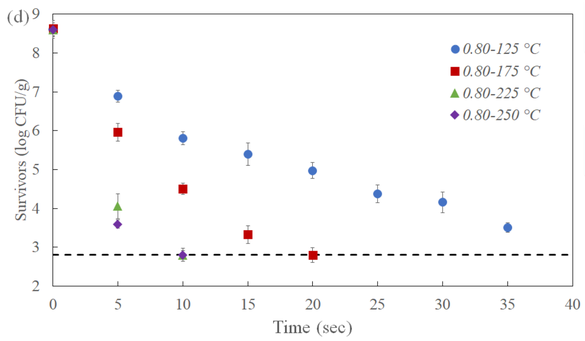


Fig 2. The inactivation kinetics of *Enterococcus faecium* inoculated in peanut butter at (a) 0.18, (b) 0.40, (c) 0.60, and (d) 0.80 a_w.

Table 1. *D*-value of *Enterococcus faecium* in peanut butter at different superheated steam temperatures.

a_w		Temperature (°C) 125	175	225	250
0.18	*D-value* (sec)	123.46	29.94	21.88	18.83
	R^2	0.97	0.98	0.99	0.95
	SEE	0.55	0.37	0.36	0.66
0.40	*D-value* (sec)	28.25	7.49	4.93	4.02
	R^2	0.97	0.97	0.98	0.97
	SEE	0.33	0.45	0.52	0.43
0.60	*D-value* (sec)	11.92	6.01	3.97	2.65
	R^2	0.98	0.98	0.98	0.96
	SEE	0.58	0.75	0.38	0.45
0.80	*D-value* (sec)	8.13	2.98		
	R^2	0.90	0.95	< 0.58	< 0.58
	SEE	1.07	1.39		

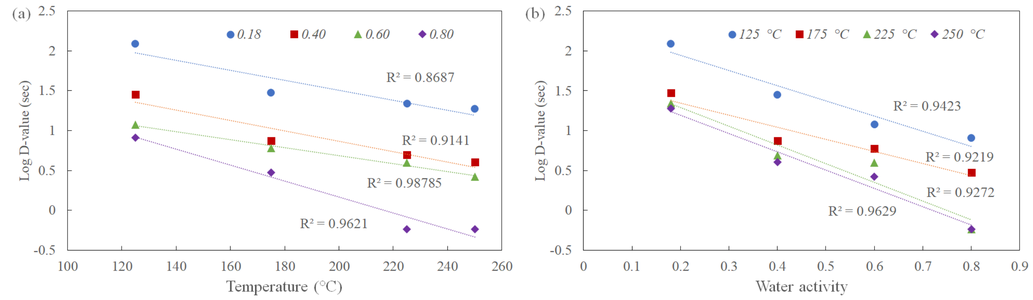


Fig 3. The effect of (a) temperature and (b) water activity on changed in *D*-value.

Conclusions

- *D*-value was estimated (*SEE* < 1.39) in the wide ranges of temperature (125-250°C) and water activity (0.18–0.80).
- As a_w increased from 0.18 to 0.80, *D*-value at each temperature significantly decreased.
- The z_{aw}-value and z_T-value were 0.52 ± 0.12 and 157.71°C ± 40.76, respectively (R^2>0.90).
- While low a_w food matrixes offer a protective effect and minimizes sanitizer efficiency, superheated steam may be an effective alternative technology achieving up to 5 log reduction on peanut butter in 94.15 s at 250 °C.

Acknowledgement

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References

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