Chicken Breast Contamination Removal Efficiency with Different Cutting Boards Materials and Cleaners

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Abstract

Cutting boards are common tools in the kitchen. Previous studies have shown that different kinds of materials/surfaces have different levels of cleaning difficulties, and different cleaning methods also vary in cleaning efficiency. Here we want to study whether there will be meat contamination after cutting chicken breasts on different materials, including wood, plastic and iron, after applying different cleaning methods, including liquid cleaner, solid cleaner and water. Here we show that only the materials of cutting boards affect the number of meat residuals. Among all three tested, iron cutting boards have the lowest meat residuals. No statistically significant differences were found among different cleaning methods. Our study provides an insight that plastic or wood cutting boards that are commonly used in the home kitchen and restaurant might be a source of cross-contamination.

Introduction

Food safety is a critical global issue, as unsafe food can lead to serious public health consequences and economic losses. Countries around the world have made significant efforts to ensure the safety of their food supply, including implementing regulations and standards, developing food safety management systems, and conducting research and training programs (Chaoniruthisai et al., 2018; Liu et al., 2019; Mensah & Julien, 2011). However, there are still as much as 87% of foodborne disease outbreaks that have been reported are linked to food that was either prepared or eaten at home (van Asselt et al., 2008). Although cases of campylobacteriosis, as one of the foodborne diseases, can be associated with a variety of sources, such as contaminated water and other food products, chicken meat remains the leading cause of this illness, accounting for 20-40% of cases (Humphrey et al., 2007). Thus, chicken breasts, as one of the most popular and accessible raw protein sources, are good samples for studies related to food safety.

Cross-contamination is one of the ways in which people can become ill after consuming chicken meat, in addition to undercooking (Mylius et al., 2007; van Asselt et al., 2008). Various factors including cutting boards, hands and knives have been found strongly correlated to food cross-contamination (Cliver, 2006; van Asselt et al., 2008).

Cutting boards, as one of the commonest tools in both home and restaurant kitchens, are good linking sites for cross-contamination (Cliver, 2006; van Asselt et al., 2008). Especially when multiple kinds of food are needed for one dish, people would ignore thoroughly cleaning them when preparing different materials. Meanwhile, cleaners are also essential tools that help clean up kitchen utensils. As a kind of cleaners, disinfectant wipes have been proven to be useful for avoiding food cross-contamination (Lopez et al., 2015).

Currently, there have been many studies about the modelling of cross-contamination in kitchens with various parameters including cutting boards, and washing conditions (Kusumaningrum et al., 2004; van Asselt et al., 2008). Nevertheless, research is yet to be conducted on the impact of cutting board materials and various methods of quick, rough cleaning of cutting boards with different cleaners on the occurrence of food cross-contamination.

In this study, we examined how cutting raw chicken breasts on cutting boards made of plastic, wood, and iron, and subsequently washing the boards with water, solid or liquid detergents, impacted cross-contamination. We analyzed the residues left on the cutting boards through DNA concentration using spec20 to determine the effects of different types of cutting board materials and cleaners. We hypothesized that cutting boards that are made of different materials will have different affinity to chicken breast contamination and different detergents have different cleaning efficiency and predicted that iron cutting board washed with liquid detergent will have the lowest cross-contamination level compared to other combinations.

Methods

Materials

The chicken breast samples were bought from Save on Food in Wesbrook one day before the experiment and kept in the fridge overnight. A standard kitchen knife, wood cutting board and plastic cutting board were used. Since pure iron is rarely used to make cutting boards, stainless steel plates were bought from Amazon as a replacement. The liquid cleaner used was 800 mL no name® lemon fresh dishwashing liquid. The solid cleaner used was the dishwasher detergent from Kirkland®.

Sample Collection

The chick breast was roughly cut into 3 by 3 cm pieces. The height of the meat pieces was quite similar, so it was considered a constant during the sample preparation process.

For the cutting boards, a 5cm $\times$ 5cm square area was outlined using masking tape. One small piece was cut 10 times horizontally and 10 times vertically in the masking tape-wrapped area. The cutting boards were cleaned thoroughly and wiped with kitchen paper before and after cutting the chicken breast each time.

10 mL of liquid cleaner and diluted in 100 mL using dH_2O. One pod of the solid cleaner was diluted into 1000 mL so that they were smooth and could be quantitatively measured using pipettes. For each cleaning, the square area used for cutting was rinsed with 600 µL of cleaner 3 times and then rinsed with water for 6 seconds. Sterile Q-tip swabs were used to collect samples

on the cutting board by swabbing the square area after cleaning. The head of the sterile Q-tip swab was placed in separate 1.5 mL microcentrifuge tubes. 500 µL of dH_2O was added to each microcentrifuge tube to dissolve the samples on the sterile q-tip swab. Three replicates were done for each material-cleaner combination.

Spectrophotometric Analysis of DNA Samples

The Eppendorf BioPhotometer (Spec 20) was used to identify the concentration of DNA in each sample. The blank sample was set by running a clean cuvette with 1000 µL of dH_2O under dsDNA mode. For each sample, 50 µL of sample and 950 µL of dH_2O were added to a clean cuvette, which was then mixed thoroughly. The cuvettes were wiped with a Kimwipe before loading to remove possible dust and fingerprints. The machine was set to know the dilution ratio by setting 50 µL of sample in a microcentrifuge tube and 950 µL of dH_2O. For each test, DNA concentration and 260/280 ratio were recorded for further investigation.

Data Analysis

A Two-way Analysis of Variance (Two-Way ANOVA) test was conducted using R (version 4.2.2) to compare if the means of DNA concentration varied between the two categorical variables, i.e., materials and cleaners (R Core Team, 2023). To further check which pairwise comparison of means contributes to the overall significant difference that was observed in the computation of the F statistic, the Tukey HSD test was conducted using R (R Core Team, 2023). The significant level was set at 0.05. CRAN package ggplot2 (Version 3.4.1) was used for visualisation purposes (Wickham, 2016).

Results

Figure 1 shows that there are obvious differences among means with different materials of cutting boards, where iron is the lowest, plastic is intermediate, and wood is the highest. All three cleaning methods have the same trend. The result of the two-way ANOVA test also supports that the material variable was found to have a significant effect on the dependent variable, $F(2, 18) = 7.119$, $p = 0.00527$, which is statistically significant. On the other hand, the cleaner variable did not have a significant effect on the dependent variable, $F(2, 18) = 0.270$, $p = 0.76609$. Furthermore, the interaction between material and cleaner was not significant, $F(4, 18) = 0.686$, $p = 0.61119$. These results suggest that the material of the cutting surface is a significant predictor of the dependent variable, but cleaners as well as the interaction between materials and cleaners do not have significant effects.

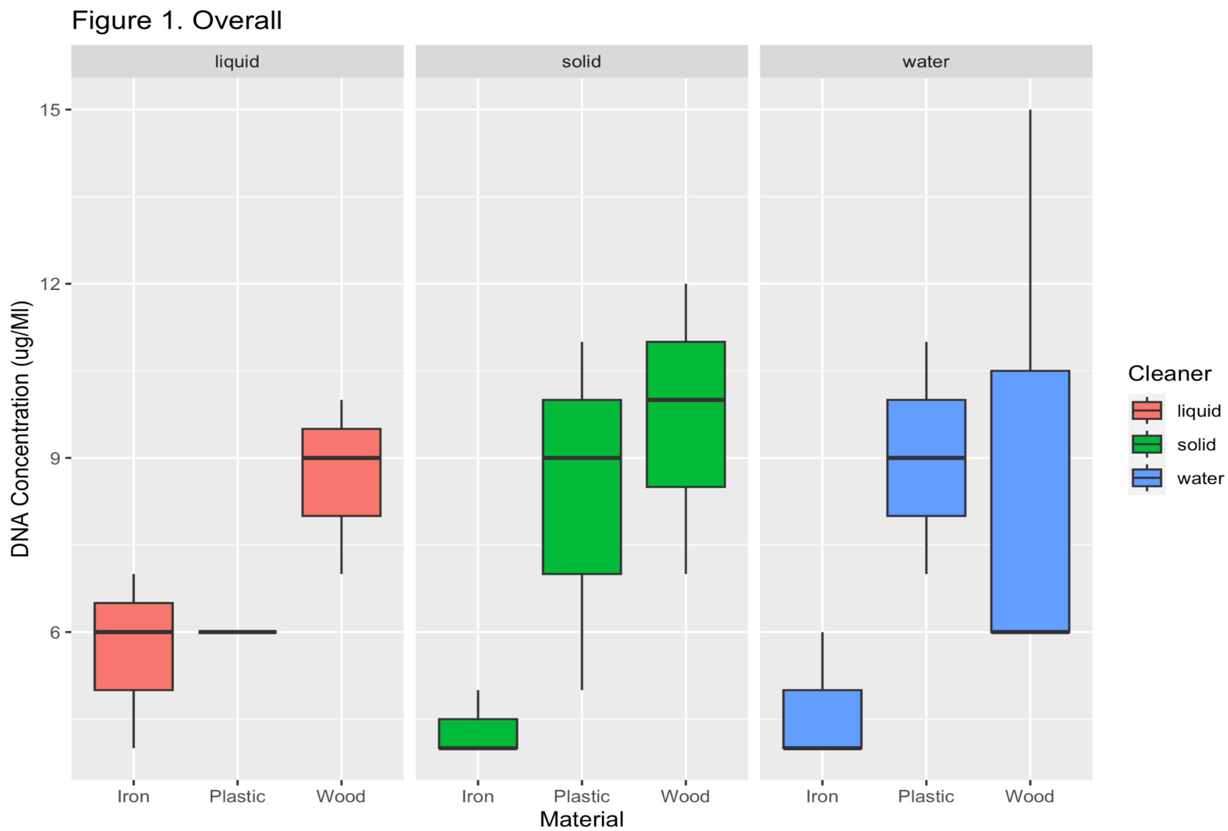
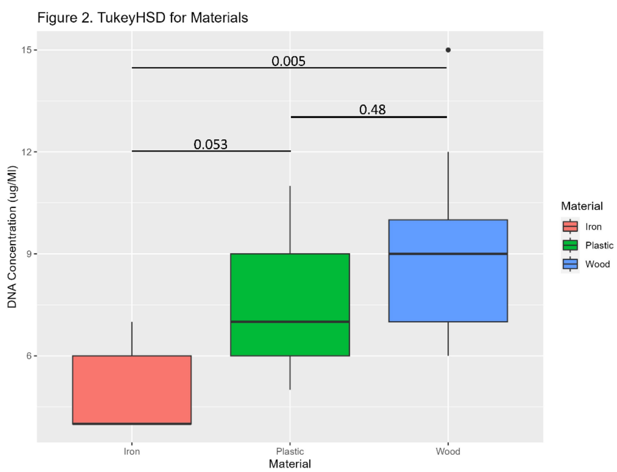


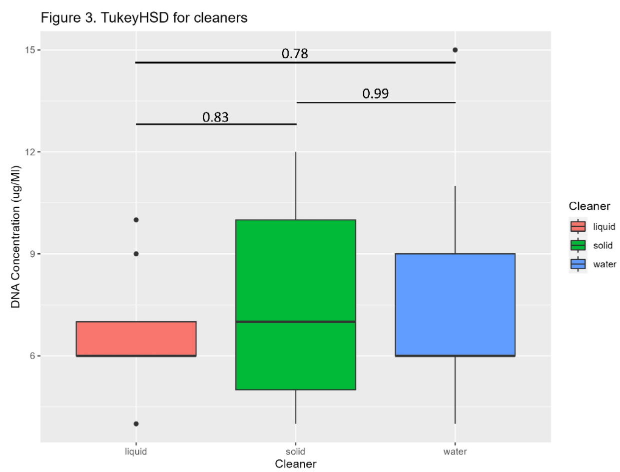
Figure 1, Overview of all the collected data, clustered by the materials of the cutting boards and the cleaning methods, with response to DNA concentration. Sample size N=27. Each of them has five summary statistics (the median, two hinges and two whiskers), and all "outlying" points individually.

To further investigate which specific groups or treatments differ significantly from each other, a posthoc Turkey HSD test was conducted. The results are shown in Figures 2 and 3.

Figure 2 illustrates the results of Tukey HSD among different materials of cutting boards. For the comparison between wood and plastic, the p-value was 0.48, which was not statistically significant with a significance level set at 0.05. The p-value between wood and plastic was 0.053, which was a bit higher than 0.05, suggesting non-statistical significant comparing the means. But the p-value between wood and iron was 0.005, showing there was a significant difference between the means of the two groups.

As for the results among different cleaners, the result showed no statistical difference in mean DNA concentration between treatment groups, which aligned with the results of the two-way ANOVA test (Figure 3).





Figures 2 & 3. Post-hoc TukeyHSD for cleaners and materials. The numbers above the lines connecting two different groups are adjusted p-values given by Tukey HSD. Each bar has five summary statistics (the median, two hinges and two whiskers), and all "outlying" points individually.

Notably, the 260/280 ratios were well below 1.80 with a mean value of around 1.25 for all collected samples. This suggested that there was protein contamination in all groups of experiments.

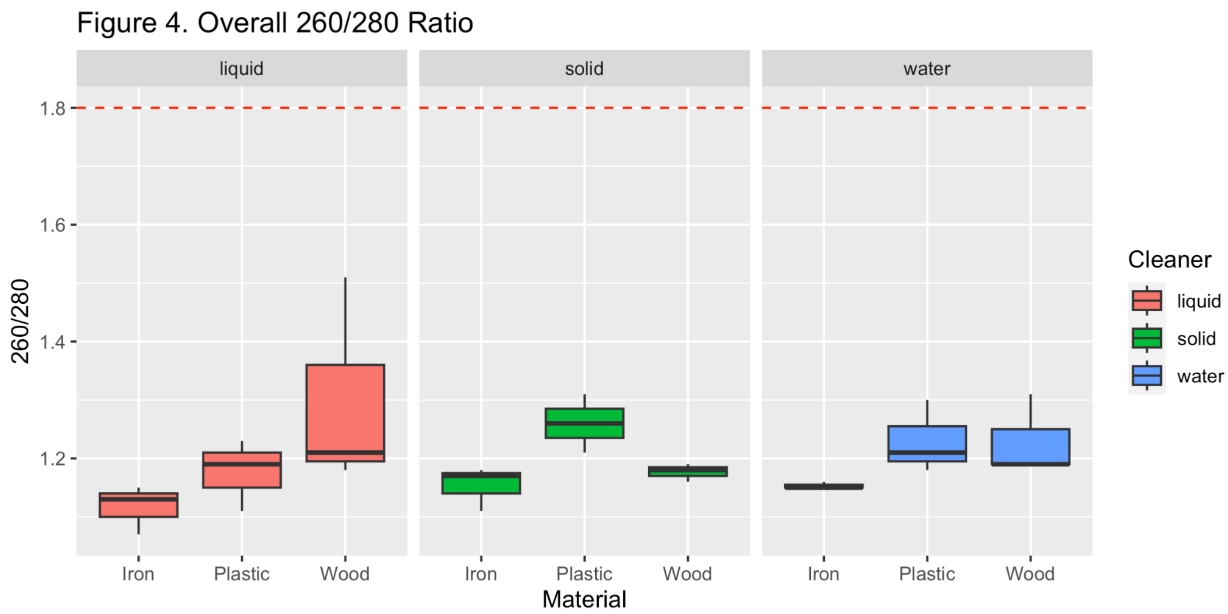


Figure 4. 260/280 ratios for all samples are below 1.80 (red dash line), indicating protein contamination. Each bar has five summary statistics (the median, two hinges and two whiskers), and all "outlying" points individually.

Discussion

This study investigated DNA residues after cutting meat on different cutting boards and washing it with different detergents, in order to determine potential sources which lead to cross-contamination between foods due to bacterial residues. The results of the experiments showed that DNA concentration residues did not differ significantly among cutting boards washed with different detergents (Figure 1). Concentrations of DNA were similar after washing with water, solid detergent, and liquid detergent. Additionally, the Tukey HSD test's result indicated that cutting board materials significantly affected the concentration of chicken DNA residues in the study. Among all kinds of cutting boards, wooden and plastic ones are the most popular and widely used, but the cross-contamination levels were shown to be higher than iron ones according to our results. Therefore, it is recommended to use iron cutting boards to reduce food cross-contamination in home or restaurant cooking.

In the previous study, Campylobacter is readily transferred through transient contact between contaminated meat and unscoring and scoring plastic and wooden cutting boards (Humphrey et al., 2007; Jugé et al., 2016). The scratches caused by the material of the cutting board were more pronounced in the comparison of the three materials for wooden cutting boards and least pronounced for iron cutting boards. Since the cracks in the scratches are more likely to lead to the harboring of bacteria, these cuts also produce hidden food residues and become one of the sources of more cross-contamination. Figure 2 also verifies that wooden cutting boards produce more chicken DNA residues in the crevices than iron cutting boards because of the more scratches created by the knife cuts. The plastic cutting boards and iron cutting boards also had similar properties. Therefore, scratched wooden and plastic cutting boards have a greater risk of cross-contamination than iron cutting boards, and more bacteria from food residues are generated in the gaps between wooden and plastic cutting boards.

At the beginning of the experiment we hoped to observe which method was more effective in removing food residues by the cleaning effect of different detergents on the same cutting boards, but the results showed that none of the three detergents produced a difference in effect. However, this is contrary to the conclusion that in real life, using detergent would be more effective than rinsing with water. We speculate that this is related to the changes brought about by the washing method. In this experiment, the detergent was not used to wipe away the food residue with the aid of a rag or other supplies, but a small amount of water was used directly to clean up. The water did not allow for much friction between the detergent and the cutting board, which allowed the food residue to remain on the cutting board. Later in the experiment, the material of the cutting board was found to be the most important factor in food residue, and the difference between wooden and plastic boards was found to be small. However, this differs from previous studies in that Gough and Dodd (1998) concluded that there was a greater risk of cross-contamination with scored wooden boards than with plastic cutting boards. This discrepancy may be related to the choice of plastic boards that are made with indented material. Thus the difference arising between the uneven plastic cutting board and the scratched wooden cutting board is slightly smaller.

The protein contaminations shown in Fig. 4 were as expected since we did not involve the DNA extraction step in our experimental design. Previous studies have shown that cotton, as a plant product, has DNA and proteins (Paterson et al., 1993; Yao et al., 2006). It is possible that part of the DNA concentration readings might be from the sterile q-tip swabs themselves as they are mainly made of cotton, which also explains why the reading for the blank sample is not zero (Table 2 in Appendix).

A major limitation of this study would be the insufficient number of replicates, which was set to three. By adding more replicates, we believe that the statistical results would be stronger and we would be able to do outlier removal in the data analysis step to reduce possible errors as much as possible. Also, a better sample collection method is needed in order to avoid protein contaminations caused by Q-tip swabs. More standard and stable cleaning methods (ideally automated) would also help reduce the possible human error in this experiment.

Conclusion

The goal of this study was to investigate whether regularly used cleaning methods on different kinds of cutting boards differ from one another in regard to chicken breast contamination removal. Our analysis using two-way ANOVA revealed a significant difference in means of DNA concentrations that represented food residue levels for cutting board materials. However, we did not find evidence of a difference in means for cleaners or an interaction effect between cutting board materials and cleaners. The post-hoc Tukey HSD test showed that there was a significant difference in means between the iron cutting boards and wood cutting boards, and the iron one has the lowest mean, suggesting that iron cutting boards are better for avoiding cross-contamination.

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Appendix

Table 1. Raw data collected

Number	Materials	replicate	cleaner	DNA Concentration (ug/mL)	Ratio Reading (260/280)
W01	Wood	1	water	6	1.31
W02	Wood	2	water	6	1.19
W03	Wood	3	water	15	1.19
W11	Wood	1	liquid	10	1.18
W12	Wood	2	liquid	7	1.51
W13	Wood	3	liquid	9	1.21
W21	Wood	1	solid	7	1.18
W22	Wood	2	solid	12	1.16
W23	Wood	3	solid	10	1.19
P01	Plastic	1	water	7	1.18
P02	Plastic	2	water	9	1.3
P03	Plastic	3	water	11	1.21
P11	Plastic	1	liquid	6	1.11
P12	Plastic	2	liquid	6	1.23
P13	Plastic	3	liquid	6	1.19
P21	Plastic	1	solid	5	1.21
P22	Plastic	2	solid	9	1.26
P23	Plastic	3	solid	11	1.31
F01	Iron	1	water	4	1.15
F02	Iron	2	water	6	1.15
F03	Iron	3	water	4	1.16
F11	Iron	1	liquid	4	1.13
F12	Iron	2	liquid	7	1.15
F13	Iron	3	liquid	6	1.07
F21	Iron	1	solid	4	1.11
F22	Iron	2	solid	4	1.18

F23	Iron	3	solid	5	1.17

Table 2. Blank controls

Number	DNA Concentration (ug/mL)	Ratio Reading (260/280)
CW	7	1.74
CF	4	1.27
CP	5	1.31
BLK	4	1.17

Table 3. Notation in the previous tables

Short Form	Full Form
C	Control
W	Wood
F	Iron
P	Plastic

Position 1 of Number	Position 2 of Number	Position 3 of Number
Material (WPF)	Cleaner (0,1,2)	Replicate (1,2,3)

Cleaner Digit	Cleaner
0	Water
1	Liquid
2	Solid