Microbial Modeling and Monte Carlo Simulation to Determine Microbial Performance Criteria on Wooden Cutting Boards

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Abstract

This study used simulation modeling to evaluate the microbial performance over time for four types of meat and the effect on the frequency of changing cutting boards. The results revealed that pork chopping boards can be used up to time $t = 9$ minutes, that is, with the corresponding bacterial counts of $19 \text{ CFU}/4\text{cm}^2$. Beef chopping boards can be changed or clean beyond the time $t = 7$ minutes since the bacterial growth already exceeds the standard sanitary requirement of using wooden cutting boards. On the other hand, chicken cutting boards can be used only for up to $t=10$ minutes out of a 20–minute period of chopping chicken meat to meet the sanitary guidelines. Wooden cutting boards used to chop fish meat can be used for a maximum of $t= 9$ minutes to meet the acceptable sanitary requirement. These findings suggest that wet market meat vendors can be constrained to the allowable time in minutes of using the wooden cutting boards in order to meet the sanitary guidelines that guarantee safe meat cutting boards utilized in most wet market settings.

Keywords: Bacterial growth, simulation modeling, sanitary guidelines

1.0 Introduction

According to the Food Safety Act of 2013, food safety refers to the guarantee that food will not cause harm to the consumer when it is prepared or eaten according to its intended use. Therefore, any individual employed in the preparation, manufacture, packing, storing and sale of food must keep such food from contamination. In most Philippine local wet market, vendors make use of wooden cutting boards in cutting raw fish, chicken, beef and pork meats. Specifically, the researchers became interested on how frequently a wooden cutting board for each type of meat would need to be changed to meet the guidelines shown in Table 1. It has been found that bacteria are of utmost concern as cross contaminants on kitchen cutting boards are primarily of animal origin, which are significant causes of human contagious disease (Ak, N. et al, 1993). Contamination experiments revealed that plate counts from wood were higher than boards that are made of plastic or metals (Kelch and Palm, 1958; Rodel et al., 1994). Moreover, increasing number of bacterial counts was observed after several cleaning procedures from the wooden surfaces, which indicate that those surfaces could not be decontaminated efficiently (Gilbert & Watson, 1971; Kampelmacher et al., 1971; Borneff et al., 1988; Abrishami et al.,...
known as porous material that can absorb and keep bacteria and thus, it is regarded as impossible to be maintained as completely clean and decontaminated.

A number of scientific studies have determined the hygienic potential of wood compared to plastics and stainless steel and resulted in completely various observations. Thus, this study was carried out to gather further knowledge and to quantify the increase in microbial contamination, over time, on wooden cutting boards used in a wet market setting.

2.0 Conceptual Framework

Wood has been a long tradition natural material used by humans. One of the many uses of it is the chopping board. Wood then is well

Diagram of the Conceptual Framework

Figure 1: Conceptual Framework Diagram
3.0 Research Design and Methods

The study utilized an experimental design using simulation modeling. The experimental criterion measured the length of time that the wooden cutting board meets the sanitary quality while the simulated experimental treatment is the types of meat namely beef, pork, chicken and fish.

At the beginning of the simulation (t = 0 minute) each of the four meats is assumed to be chopped into its assigned wooden chopping board for 20 minutes. Then the bacterial growth (in CFU / 4cm²) is computed using the formula:

\[ Bacterial\ Growth\ (in\ CFU/4cm^2) = Time\ (in\ minutes) \times \log_{10}(colony\ forming\ unit\ per\ 4cm^2) \]

Assumptions:

The simulation model is based on the following assumptions:
1. The cutting board is sterile before the simulation.
2. Four wooden cutting boards are tested at 1 minute interval, over a 20 minute period.
3. Each type of meat is chopped on one wooden cutting board within the 1-minute interval for 20 minutes.
4. The known respective average colony forming units per 4 square centimeters and its corresponding standard deviations of a wooden chopping boards for each type of meat are used to generate 20 normal randomly distributed CFU per 4 square centimeters (Food Science Department, Rutgers University).

4.0 Results and Discussions

Table 1 shows the guidelines on allowed levels of microbial contamination of surfaces (CFU/4 cm²) adopted from Current Rutgers Division of Dining Services.

| Status          | Stored (CFU/4cm²) | In Use (CFU/4cm²) |
|-----------------|-------------------|-------------------|
| Acceptable      | Less than 5       | Less than 20      |
| Some concern    | Between 5-10      | Between 20-40     |
| High concern    | Greater than 10   | Greater than 40   |

Table 2 Shows the Number of Runs and the Corresponding Bacterial Growth for a Pork Chopped on a Wooden Cutting Board

| Time t (in minutes) | Num of Runs | Mean CFU / 4 sq. cm | Variance | \( \log_{10}(CFU / 4\ sq.\ cm) \) | Bacterial Growth (in CFU / 4 sq. cm) | Running Sum for Bacterial Growth (in CFU / 4 sq. cm) |
|---------------------|-------------|---------------------|----------|-----------------------------------|--------------------------------------|---------------------------------------------------|
| 1                   | 100         | 2.7575              | 1.6061   | 0.4405                            | 0.4405                               | 0.4405                                            |
| 2                   | 100         | 2.4290              | 1.4881   | 0.3854                            | 0.7709                               | 1.2114                                            |
| 3                   | 100         | 2.8359              | 1.7517   | 0.4527                            | 1.3581                               | 2.5694                                            |
| 4                   | 100         | 2.7664              | 1.5669   | 0.4419                            | 1.7676                               | 4.3371                                            |
| 5                   | 100         | 2.5767              | 1.5906   | 0.4111                            | 2.0553                               | 6.3924                                            |
| 6                   | 100         | 2.5950              | 1.7234   | 0.4141                            | 2.4848                               | 8.8772                                            |
| 7                   | 100         | 2.7028              | 1.5804   | 0.4318                            | 3.0227                               | 11.8998                                           |
| 8                   | 100         | 2.4214              | 1.5904   | 0.3841                            | 3.0726                               | 14.9724                                           |
| 9                   | 100         | 2.5958              | 1.4981   | 0.4143                            | 3.7284                               | 18.7009                                           |
| 10                  | 100         | 2.6020              | 1.4734   | 0.4153                            | 4.1530                               | 22.8539                                           |
| 11                  | 100         | 2.6036              | 1.6047   | 0.4156                            | 4.5713                               | 27.4252                                           |
| 12                  | 100         | 2.6644              | 1.6868   | 0.4256                            | 5.1073                               | 32.5325                                           |
| 13                  | 100         | 2.6066              | 1.5717   | 0.4161                            | 5.4090                               | 37.9415                                           |
Bacterial growth in wooden cutting board used to chop a bulk of pork revealed an increasing CFU per 4 square centimeters after 1 – minute interval of use and steadily grows over a 20 – minute period. The simulated results further depicts that pork chopping boards in wet market setting can only be use up to time $t = 9$ minutes, that is, with the corresponding bacterial counts of 18.7009 or 19 CFU which satisfies the sanitary acceptable standards before a pork cutting boards be replaced or washed to avoid bacterial contamination and the risk of food poisoning.

Table 3 Presents the Number of Runs and the Corresponding Bacterial Growth for a Beef Chopped on a Wooden Cutting Board

| Time $t$ (in minutes) | Num of Runs | Mean CFU / 4 sq. cm | Variance | $\log_{10}$(CFU / 4 sq. cm) | Bacterial Growth (in CFU / 4 sq. cm) | Running Sum for Bacterial Growth (in CFU / 4 sq.cm) |
|------------------------|-------------|---------------------|----------|-----------------------------|--------------------------------------|---------------------------------------------------|
| 1                      | 100         | 3.6157              | 4.6908   | 0.5582                      | 0.5582                               | 0.5582                                           |
| 2                      | 100         | 4.0771              | 6.1981   | 0.6104                      | 1.2207                               | 1.7789                                           |
| 3                      | 100         | 3.8214              | 5.3415   | 0.5822                      | 1.7467                               | 3.5255                                           |
| 4                      | 100         | 3.3209              | 5.1202   | 0.5213                      | 2.0850                               | 5.6106                                           |
| 5                      | 100         | 3.8645              | 6.0415   | 0.5871                      | 2.9355                               | 8.5460                                           |
| 6                      | 100         | 3.5635              | 4.3820   | 0.5519                      | 3.3112                               | 11.8573                                          |
| 7                      | 100         | 3.6707              | 4.8247   | 0.5647                      | 3.9532                               | 15.8105                                          |
| 8                      | 100         | 3.6086              | 5.9925   | 0.5573                      | 4.4587                               | 20.2692                                          |
| 9                      | 100         | 3.9256              | 5.7099   | 0.5939                      | 5.3451                               | 25.6143                                          |
| 10                     | 100         | 3.9590              | 4.9683   | 0.5976                      | 5.9758                               | 31.5901                                          |
| 11                     | 100         | 3.6053              | 4.2092   | 0.5569                      | 6.1263                               | 37.7164                                          |
| 12                     | 100         | 3.5120              | 4.1750   | 0.5456                      | 6.5467                               | 44.2631                                          |
| 13                     | 100         | 3.3414              | 4.7351   | 0.5239                      | 6.8111                               | 51.0742                                          |
| 14                     | 100         | 3.6370              | 5.5450   | 0.5607                      | 7.8505                               | 58.9246                                          |
| 15                     | 100         | 3.7911              | 5.0090   | 0.5788                      | 8.6814                               | 67.6060                                          |
| 16                     | 100         | 3.7522              | 5.4407   | 0.5743                      | 9.1885                               | 76.7946                                          |
| 17                     | 100         | 3.7971              | 5.7759   | 0.5794                      | 9.8506                               | 86.6452                                          |
| 18                     | 100         | 4.0040              | 6.8675   | 0.6025                      | 10.8450                              | 97.4902                                          |
| 19                     | 100         | 3.7595              | 5.3771   | 0.5751                      | 10.9275                              | 108.4177                                         |
| 20                     | 100         | 3.3055              | 4.3983   | 0.5192                      | 10.3848                              | 118.8025                                         |
Meanwhile, a wooden cutting board being used to chop a piece of beef showed a progressively increasing colony forming units per 4 square centimeters throughout a 20 – minute period. However, the simulated results suggested that beef chopping boards in wet market be changed or cleaned beyond the time $t = 7$ minutes since, the bacterial growth already contaminates and exceeds the standard sanitary requirement of using cutting boards. Extended use of a wooden chopping board in cutting beef beyond 7 minutes may contaminate the meat and may cause foodborne illness.

Table 4 Shows the Number of Runs and the Corresponding Bacterial Growth for a Chicken Chopped on a Wooden Cutting Board

| Time $t$ (in minutes) | Num of Runs | Mean CFU / 4 sq. cm | Variance | $\log_{10}(\text{CFU / 4 sq. cm})$ | Bacterial Growth (in CFU / 4 sq. cm) | Running Sum for Bacterial Growth (in CFU / 4 sq. cm) |
|-----------------------|-------------|---------------------|----------|-----------------------------------|---------------------------------------|-----------------------------------------------------|
| 1                     | 100         | 1.9714              | 1.663101 | 0.2948                            | 0.2948                                | 0.2948                                              |
| 2                     | 100         | 2.3269              | 1.97064  | 0.3668                            | 0.7336                                | 1.0283                                              |
| 3                     | 100         | 2.4751              | 2.101967 | 0.3936                            | 1.1808                                | 2.2091                                              |
| 4                     | 100         | 2.4074              | 2.451258 | 0.3816                            | 1.5262                                | 3.7353                                              |
| 5                     | 100         | 2.1289              | 1.870883 | 0.3282                            | 1.6408                                | 5.3761                                              |
| 6                     | 100         | 2.3851              | 2.151852 | 0.3775                            | 2.2650                                | 7.6411                                              |
| 7                     | 100         | 2.1415              | 2.171089 | 0.3307                            | 2.3150                                | 9.9561                                              |
| 8                     | 100         | 2.1934              | 2.53249  | 0.3411                            | 2.7290                                | 12.6851                                             |
| 9                     | 100         | 2.1911              | 2.115217 | 0.3407                            | 3.0660                                | 15.7510                                             |
| 10                    | 100         | 2.3739              | 2.637039 | 0.3755                            | 3.7547                                | 19.5057                                             |
| 11                    | 100         | 2.5224              | 2.198475 | 0.4018                            | 4.4199                                | 23.9257                                             |
| 12                    | 100         | 2.2345              | 2.302345 | 0.3492                            | 4.1902                                | 28.1159                                             |
| 13                    | 100         | 2.1418              | 2.420585 | 0.3308                            | 4.3002                                | 32.4160                                             |
| 14                    | 100         | 2.4372              | 3.120159 | 0.3869                            | 5.4164                                | 37.8325                                             |
| 15                    | 100         | 2.3202              | 2.4202   | 0.3655                            | 5.4830                                | 43.3155                                             |
| 16                    | 100         | 2.3035              | 2.425129 | 0.3624                            | 5.7983                                | 49.1138                                             |
| 17                    | 100         | 2.3916              | 3.366928 | 0.3787                            | 6.4377                                | 55.5515                                             |
| 18                    | 100         | 2.4090              | 2.467027 | 0.3818                            | 6.8730                                | 62.4245                                             |
| 19                    | 100         | 2.1854              | 2.345265 | 0.3395                            | 6.4511                                | 68.8756                                             |
| 20                    | 100         | 1.8606              | 1.822624 | 0.2697                            | 5.3932                                | 74.2688                                             |

Chicken cutting boards on the other hand, can be utilized only for 1 to 10 minutes out of a 20 – minute period of chopping chicken meat since the bacterial counts still conforms to the sanitary guidelines allowed for the level of microbial contaminations on the surfaces of the chopping board. The result further suggests that prolonged use of the wooden cutting board in chopping chicken meat may pose a serious health risk to the consumer.
Table 5 Depicts the Number of Runs and the Corresponding Bacterial Growth for a Fish Chopped on a Wooden Cutting Board

| Time $t$ (in minutes) | Num of Runs | Mean CFU / 4 sq. cm | Variance | $\log_{10}$ (CFU / 4 sq. cm) | Bacterial Growth (in CFU / 4 sq. cm) | Running Sum for Bacterial Growth (in CFU / 4 sq. cm) |
|-----------------------|-------------|---------------------|----------|-----------------------------|-------------------------------------|---------------------------------------------------|
| 1                     | 100         | 2.5958              | 2.582913 | 0.4143                      | 0.4143                              | 0.4143                                            |
| 2                     | 100         | 3.0520              | 3.849114 | 0.4846                      | 0.9692                              | 1.3834                                            |
| 3                     | 100         | 2.3725              | 2.49742  | 0.3752                      | 1.1256                              | 2.5091                                            |
| 4                     | 100         | 2.3830              | 3.565624 | 0.3771                      | 1.5085                              | 4.0175                                            |
| 5                     | 100         | 2.4086              | 2.621235 | 0.3818                      | 1.9088                              | 5.9263                                            |
| 6                     | 100         | 2.8158              | 4.030451 | 0.4496                      | 2.6976                              | 8.6239                                            |
| 7                     | 100         | 2.6803              | 3.886865 | 0.4282                      | 2.9973                              | 11.6213                                           |
| 8                     | 100         | 2.6251              | 3.079972 | 0.4191                      | 3.3532                              | 14.9744                                           |
| 9                     | 100         | 2.7231              | 3.832845 | 0.4351                      | 3.9156                              | 18.8900                                           |
| 10                    | 100         | 2.5682              | 3.24877  | 0.4096                      | 4.0963                              | 22.9863                                           |
| 11                    | 100         | 2.5057              | 3.029716 | 0.3989                      | 4.3833                              | 27.3745                                           |
| 12                    | 100         | 2.4497              | 3.219893 | 0.3891                      | 4.6693                              | 32.0439                                           |
| 13                    | 100         | 2.3584              | 3.919837 | 0.3726                      | 4.8441                              | 36.8879                                           |
| 14                    | 100         | 2.9003              | 3.98965  | 0.4624                      | 6.4743                              | 43.3622                                           |
| 15                    | 100         | 2.4939              | 3.321204 | 0.3969                      | 5.9532                              | 49.3153                                           |
| 16                    | 100         | 2.6141              | 2.983025 | 0.4173                      | 6.6771                              | 55.9924                                           |
| 17                    | 100         | 2.5697              | 2.798504 | 0.4099                      | 6.9679                              | 62.9603                                           |
| 18                    | 100         | 2.9947              | 4.265596 | 0.4763                      | 8.5742                              | 71.5345                                           |
| 19                    | 100         | 2.7988              | 3.616362 | 0.4470                      | 8.4925                              | 80.0270                                           |
| 20                    | 100         | 2.8658              | 3.806048 | 0.4572                      | 9.1448                              | 89.1718                                           |

Consequently, the bacterial counts on a wooden cutting board used to chop a fish meat were found to be increasing with colony forming units per 4 square centimeters of 18.8900 at $t = 9$ minutes. This guarantees fish wooden chopping boards in wet markets to be safe for use up to 9 minutes since its microbial contamination are still acceptable. The result further suggests that the use of wooden chopping boards on fish beyond 9 minutes may contain harmful bacteria which can seriously affect the health of meat consumers.

5.0 Conclusion

The results of this simulation can be used as a tool to investigate cutting board policy changes for wet market. Simulation results revealed that a wooden chopping board used in cutting pork and fish respectively, can be used up to 9 minutes; while wooden chopping board used in cutting beef be changed or clean beyond 7 minutes. Wooden chopping board used in cutting chicken can be used for 10 minutes to conform to the sanitary guidelines allowed for the levels of microbial
contamination on the surfaces of the chopping board. Moreover, the result of this simulations and observations in real wet market operations further reveals that most wet markets have unsafe wooden cutting boards, which suggest bacterial contamination and may pose health threats and risks of food borne illnesses to meat consumers.

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