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

[1]Roramie V. Arco, [2]Ricky B. Villeta, and [3]Marisa A. Mahilum

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 CFU/4cm2. 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.,

[1, 2]College of Arts and Sciences
[3]College of Information, Computer and Communications Technology

1994; Rodel et al., 1994).

Researches about the occurrence of various species of bacteria proved the bacterial contaminations in wooden, plastic and steel cutting boards. However, data about the number of times a wooden cutting board be used for each type of meat that need to be changed does not exists.

Thus, the objective of this research was to simulate and quantify the increase in microbial contamination, over time, on wooden cutting boards used to chop four types of meat 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 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 wet market setting for each type of meat; namely pork, beef, chicken and fish. Separate simulation for each type of meat was performed to determine the different microbial contamination rates, over time, on wooden cutting boards being used in a wet market setting.

Diagram of the Conceptual Framework

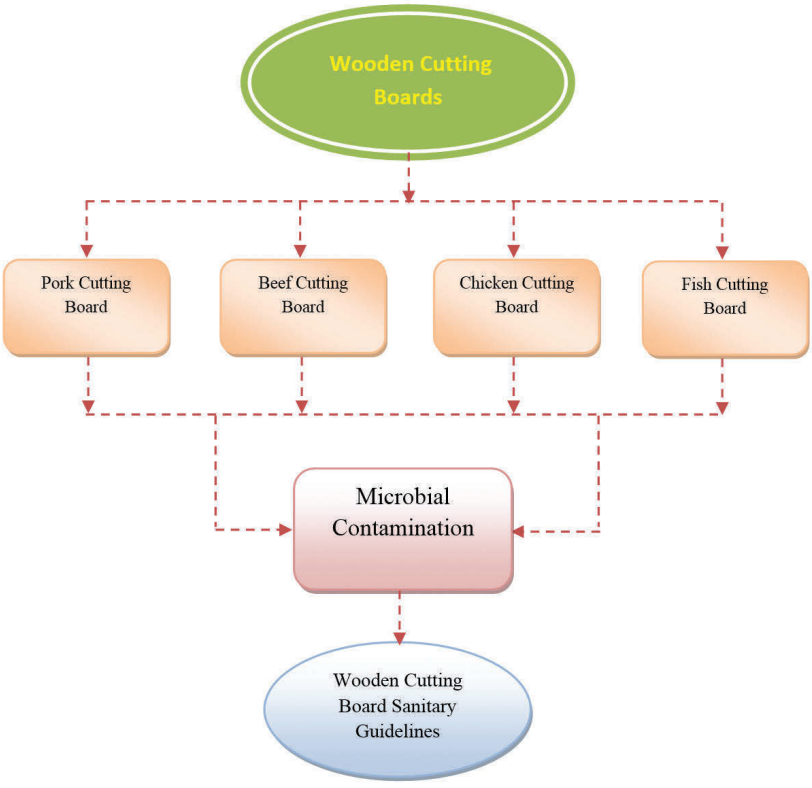

Figure 1: Conceptual Framework Diagram

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 / 4cm^2) 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 cm^2) adopted from Current Rutgers Division of Dining Services.

Table 1

Status	Stored (CFU/4cm^2)	In Use (CFU/4cm^2)
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

14	100	2.5639	1.5728	0.4089	5.7246	43.6660
15	100	2.6643	1.5616	0.4256	6.3837	50.0497
16	100	2.7699	1.7478	0.4425	7.0794	57.1291
17	100	2.5961	1.6875	0.4143	7.0436	64.1726
18	100	2.6222	1.7405	0.4187	7.5361	71.7087
19	100	2.6132	1.6259	0.4172	7.9262	79.6349
20	100	2.8527	1.6277	0.4553	9.1050	88.7399

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}(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	2.467827	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	4.3883	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.

References

Abrishami, S. H., B. D. Tall, T. J. Bruursema, P. S. Epstein, and D. B. Shah. 1994. Bacterial adherence and viability on cutting board surfaces. J. Food Safety. 14:153–172.

Ak, N. O., D. O. Cliver, and C. W. Kaspar. 1994. Decontamination of plastic and wood cutting boards for kitchen use. J. Food Prot. 57:23–36.

Buckalew, J. J., D. W. Schaffner, and M. Solberg. 1996. Surface sanitation and microbiological food quality of a university foodservice operation. J. Food Serv. Syst. 9:25–39.

Gilbert, R. J., and H.M. Watson. 1971. Some laboratory experiments on various meat preparation surfaces with regard to surface contamination and cleaning. J. Food Technology. 6. 163-170.

Kampelmacher, E.H.,D. A. A. Mossel, M. Van Schoethorst, and L. M. Van Noorle-Jansen, 1971.

Quantitative investigations on the efficacy of methods for decontaminating wooden surfaces used in meat preparation. Alimenta 1971:70-76.

Rödel, W., Hechelmann, H. and J. Dresel (1994) Hygieneaspekte zu Schneidunterlagen aus Holz und Kunststoff. Fleischwirtsch. 74 (8):814–821