Sushi rice acidification

Request received from:	Fraser Health Authority
Date of request:	Aug 17, 2015
Issue *(brief description)*:	Current guidance for sushi white rice is to acidify below pH 4.6, and to refrigerate acidified brown rice. Should pH be lowered to control for pH paper and why is refrigeration needed for brown rice?

Disclaimer: The information provided in this document is based on the judgement of BCCDC's Environmental Health Services Food Safety Specialists and represents our knowledge at the time of the request. It has not been peer-reviewed and is not comprehensive.

Summary of search information:

1. Internet sources: general search for sushi HACCP plans of government sites
2. PubMed: [sushi AND outbreak;25 hits-5 relevant] Google Scholar: [sushi AND outbreak OR illness; over 6900 hits, reviewed 1st 5 pages] Web of Science [rice AND acid* AND (penetrat* OR migrat*); 227 hits, none relevant]
3. Contacted Drs. O. Peter Snyder, Jr. and K.R. Schneider via e-mail for further clarification and advice.

Background information:

When reviewing the available information about sushi HACCP plans from on-line sources, an Environmental Health Officer (EHO) noticed that some jurisdictions in the U.S. request operators to acidify sushi rice to a pH of 4.0 to 4.4, a value much more stringent than the normal pH barrier quoted to render foods non-potentially hazardous, which is a pH value of 4.6. The rationales in these jurisdictions was this was a control for the inherent inaccuracies of pH paper[1-3] as pH paper is only accurate to a value of ± 0.2 to 0.3 log units. To allow room temperature storage of the rice, therefore, the recommendation was that the pH must read below the possible inaccuracy of the pH strip paper.

Other concerns raised included a rationale for the different behaviour of brown rice, and a review of the bacterial hazards associated with sushi rice, specifically research that indicates bacterial hazards are tolerant to acidic conditions.

What are the risks associated with sushi rice

The principal hazards associated with room temperature storage of cooked rice include *Bacillus cereus* and *Staphylococcus aureus* bacterial growth and toxin production. *B. cereus* is a ubiquitous soil bacterium commonly associated with grain products and any foods grown in soil.[4] *S. aureus* is principally a concern with extensively handled foods from food handlers carrying this bacterium. Healthy people can carry *S. aureus* in their nasal cavity, estimated at 20 to 50% of the population.[5]

If food handling practices are poor, contamination of food left unrefrigerated may lead to growth and production of toxin. Both *B. cereus* and *S. aureus* can produce heat-stable toxins in sushi rice that has not been adequately acidified. It is important to point out that once toxins are formed, further heating will not inactive them.

A literature search for outbreaks and illnesses associated with sushi revealed issues associated with (1) poor hygiene and handling, (2) with contaminated ingredients other than the rice, and (3) with rice. Poor hygiene and worker handling was linked to an outbreak of norovirus involving prosciutto wrapped sushi in New Zealand[6]; to enterotoxigenic *E. coli* in sushi restaurants in Nevada[7]; and to Hepatitis A in a revolving sushi bar in Japan, although it is not known whether this was linked to a food handler.[8]

Salmonella illnesses associated with contaminated ingredients include a large outbreak in over 28 U.S. states affecting 425 people with *S.* Bareilly and *S.* Nchanga caused by imported tuna scrape from India[9,10] and contaminated mayonnaise in sushi rolls made with raw shell eggs in Australia.[11] Fish and shellfish used in sushi foods can be contaminated with *Bacillus cereus, Campylobacter, Clostridium perfringens* and parasites.[12-14] *Bacillus* spp. have been found in surveys of take-away cooked ready-to-eat rice, and are the principal hazard of concern in (un-acidified) rice cake manufacture.[15,16] *Staphylococcus aureus* contaminated rice products have caused many illnesses in Japan and Korea.[17,18] Unfortunately, we could find no outbreaks of sushi that reported on the pH of the rice.

Clearly, sushi is a potentially hazardous food, and contamination of sushi can occur from poor handling and contact with other contaminated ingredients used to make sushi. Sushi, once assembled, must be either served or held refrigerated as a ready-to-eat food. Sanitary handling and care to avoid cross-contamination of cooked rice with raw ingredients prior to sushi assembly will limit the possibility of pathogens contaminating cooked sushi rice. Proper acidification of the cooked rice is a critical step to ensure that this ingredient can be safely held at room temperature during sushi making. What is the minimum pH to limit conditions for pathogen growth? According to one FDA source, *B. cereus* can be controlled at a minimum pH of 4.3, *S. aureus* and *E. coli* at a minimum pH of 4.0, and *Salmonella* requiring a pH of 3.7.[19]

Previous guidance on sushi rice from British Columbia

BCCDC guidance for operators making sushi rice is summarized in a food safety note[20] that recommends (1) to acidify white rice to a pH of ≤ 4.6; (2) to make sushi rice fresh daily, and discard at the end of the day (acidification allows for room temperature storage); and (3) to refrigerate brown sushi rice regardless of acidification.

Previous guidance on sushi rice from elsewhere

Brown rice acidification and refrigeration. This latter recommendation, to acidify brown rice, was based on a document from 2004, *Guidance for Processing Sushi in Retail Operations* by AFDO,[21] which stated "Brown Rice. Typically this rice is not acidified since the harder surface coating on the brown rice is difficult to penetrate with typical acid solutions. In the non-acidified condition, cooked rice is considered

Disclaimer: The information provided in this document is based on the judgement of BCCDC's Environmental Health Services Food Safety Specialists and represents our knowledge at the time of the request.
It has not been peer-reviewed and is not comprehensive.

a potentially hazardous food….". This document appears to be quoted in many on-line sources that recommend brown rice be refrigerated.

We investigated the literature to review this belief, including contacting the author of this statement. There is no peer-reviewed research that suggests brown rice is more resistant to acidification than white rice. The source of this information was based on an operator application that found their process of acidification was inconsistent, therefore to control for the hazard, they chose to supplement with an additional barrier of refrigeration.[22] In the U.S., variances for foods are submitted to outline the process to allow for room temperature storage, termed non-TCS, or non-Time/Temperature controlled for Safety Food. In subsequent variances received by our source (Dr. K.R. Schneider), operators also chose to acidify to a pH of less than 4.2 to ensure an adequate acidification barrier.[22] In one unpublished report from 2009, Dr. O. Peter Snyder Jr., who is a process authority in the U.S., validated acidification of multi-grain and brown sushi rice, and reported "this experiment has shown that multi-grain rice and brown rice can be treated in the same way as white rice for the production of sushi. The pH equilibrium of the rice is not significantly affected by the protein in the rice, and the cooked multi-grain rice and brown rice are very stable products that can be stored at room temperature with no hazard."[23]

Sushi rice acidification. Neither *Bacillus cereus* nor *Staphylococcus aureus* are particularly acid-tolerant organisms. One experiment found acetic acid (vinegar) inhibited growth of *S. aureus* at a pH of 4.5, and another experiment found that acid-tolerant *S. aureus* strains would not survive in a variety of foods stored at room temperature at a pH of 4.[24,25] Similarly, *B. cereus* vegetative cells rapidly decrease when exposed to a pH of 4.2 in simulated gastric fluids, and were unable to grow at pH of <4.5 in carrot juice.[26,27] Specific peer-reviewed literature for rice acidification and microbial tolerance was not found. One study that assessed Seattle area restaurant sushi found pH in rice samples were all below 4.6, and although *B. cereus* and *S. aureus* were detected in some samples, counts were less than 100 CFU/g.[28] In an unpublished survey of pH tests on sushi rice conducted between 1997 and 2002 at BCCDC, the median pH of sushi rice found in 53 samples was 4.3. Of these, four samples exceeded a pH of 4.6, and 22 exceeded a pH value of ≥4.4. A more recent review in Burnaby, BC found a median pH of 4.1 in 30 samples of sushi rice, with 100% compliance with acidification below pH 4.6.[29] This appears to be an improvement in practice and compliance.

The standard practice for most sushi recipe HACCP documents (of U.S. sources) is to acidify sushi rice to a pH that is less than 4.2 to control for a few strains of *B. cereus* that begin growing at this condition, in addition to acid tolerant *Salmonella* and *Listeria* (pers. comm. Dr. Snyder).[30]

pH paper and operator verification of acidification. Commercial suppliers of pH paper provide wide range paper (read between pH 0 to pH 14) and narrow range paper (for e.g., pH 0 to pH 6 or pH 2.9 to pH 5.2). Increments, depending on the paper chosen vary between 0.3 to 1.0 pH units. No matter what type of pH paper is chosen, pH paper is not an accurate tool, at best it will vary between 0.2 to 0.3 units. pH paper may provide a quick spot check, and is suitable to verify an existing process. However, it should not be relied upon to validate a process or recipe. pH meters with an accuracy of ±0.01 pH units are recommended to validate a sushi rice recipe.

Recommendations from BCCDC:

As there are many hazards of concern with sushi-based products, and as the most recent survey of BC sushi restaurants suggests that compliance with achieving a sushi rice pH of below 4.2 is achievable, we believe that increasing the hurdle by lowering the pH requirement is supportable. This would also align our approach with U.S. sushi processing and guidance. Based on the above information, BCCDC recommends the following:

1. All sushi rice varieties, white rice, brown rice and multi-grain rice may be managed in the same way, as there is no evidence to suggest acid penetration varies between types;
2. Acidification of rice should achieve a pH of less than 4.2 to control for hazards to allow for room temperature storage. This represents 4X more acidic conditions. Acidified sushi rice should be made fresh daily (no leftovers).
3. All operators should validate their recipe for making sushi rice. This would include providing a result with a method capable of accuracy to 0.01 log units (i.e. with a pH meter). Daily verification of the recipe may be conducted using pH paper.
4. BCCDC should review this recommendation with Food Safety managers.
5. BCCDC should update the sushi safety note and other educational documentation accordingly.
6. We recommend that a BCIT student project could verify the work done in 2009 by Dr. Snyder, and ensure there is no variation between white rice and brown rice. A future project could repeat the survey of sushi rice acidity in restaurants to assess compliance if the recommendation to lower pH requirements is accepted.

References

1. Minnesota Department of Agriculture. Evaluation tool for acidified rice HACCP plans. St. Paul, MN:MDA, 2006; Available from: http://www.mass.gov/eohhs/docs/dph/environmental/foodsafety/retail/evaluation-tool-rice.pdf.

2. South Carolina Department of Health and Environmental Control. Retail food establishments: sushi rice guidelines. Columbia, SC: DHEC, 2015; Available from: https://www.scdhec.gov/library/CR-011393.pdf.

3. Southern Nevada Health District. Is your sushi rice safe to eat? SNHD: Las Vegas, NV, 2013; Available from: http://www.southernnevadahealthdistrict.org/download/eh/food-regs-append-d.pdf.

4. Ceuppens S, Boon N, Uyttendaele M. Diversity of Bacillus cereus group strains is reflected in their broad range of pathogenicity and diverse ecological lifestyles. FEMS Microbiol Ecol. 2013;84(3):433-50.

5. Adams M, Moss M. Food microbiology, 2nd ed. Royal Society of Chemistry, Cambridge, 2000.

6. Thornley C, Hewitt J, Perumal L, et al. Multiple outbreaks of a novel norovirus GII. 4 linked to an infected post-symptomatic food handler. Epidemiol Infect. 2013;141(08):1585-97.

7. Jain S, Chen L, Dechet A, et al. An outbreak of enterotoxigenic Escherichia coli associated with sushi restaurants in Nevada, 2004. Clin infect dis. 2008;47(1):1-7.

8. Tominaga A, Kanda T, Akiike T, et al. Hepatitis A outbreak associated with a revolving sushi bar in Chiba, Japan: Application of molecular epidemiology. Hepatol Res. 2012 Aug;42(8):828-34.

9. Hoffmann M, Luo Y, Monday SR, et al. Tracing origins of the Salmonella Bareilly strain causing a food-borne outbreak in the United States. J Infect Dis. 2016 Feb 15, 2016;213(4):502-8.

10. Centers for Disease Control and Prevention. Multistate outbreak of Salmonella Bareilly and Salmonella Nchanga infections associated with a raw scraped ground tuna product (final update). Atlanta, GA: U.S. Department of Health & Human Services,; 2012 [updated 2012 Jul 26; cited 2016 Feb 18]; Available from: http://www.cdc.gov/salmonella/bareilly-04-12/.

11. Barralet J, Stafford R, Towner C, et al. Outbreak of Salmonella Singapore associated with eating sushi. Commun Dis Intell Q Rep. 2004;28(4):527-8.

12. Labbé R, Rahmati T. Growth of enterotoxigenic *Bacillus cereus* on salmon (*Oncorhynchus nerka*). J Food Prot. 2012;75(6):1153-6.

13. Tan Y, Haresh KK, Chai LC, et al. Prevalence of Campylobacter spp. in retailed ready-to-eat sushi. Int Food Res J. 2008;15(3):331-6.

14. Rahmati T, Labbe R. Levels and toxigenicity of *Bacillus cereus* and *Clostridium perfringens* from retail seafood. J Food Prot. 2008;71:1178-85.

15. Nichols GL, Little CL, Mithani V, et al. The microbiological quality of cooked rice from restaurants and take-away premises in the United Kingdom. J Food Prot. 1999;62(8):877-82.

16. Wang J, Park J-H, Choi N-J, et al. Microbiological analysis of rice cake processing in Korea. J Food Prot. 2016;79(1):157-62.

17. Kim NH, Yun AR, Rhee MS. Prevalence and classification of toxigenic Staphylococcus aureus isolated from refrigerated ready-to-eat foods (sushi, kimbab and California rolls) in Korea. J Appl Microbiol. 2011 Dec;111(6):1456-64.

18. Shimizu A, Fujita M, Igarashi H, et al. Characterization of Staphylococcus aureus coagulase type VII isolates from staphylococcal food poisoning outbreaks (1980–1995) in Tokyo, Japan, by pulsed-field gel electrophoresis. J Clin Microbiol. 2000 Oct 1, 2000;38(10):3746-9.

19. Food and Drug Administration 4th ed. Fish and fisheries products hazards and controls guidance Gainesville, FL: FDA; 2011 [cited 2016 Feb 18]; Available from: http://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/Seafood/ucm2018426.htm.

20. B.C. Centre for Disease Control. Sushi safety. Vancouver, BC: BCCDC, 2010; Available from: http://www.bccdc.ca/resource-gallery/Documents/Educational%20Materials/EH/FPS/Fish/SushiHandout_Dec2010.pdf.

21. Association of Food and Drug Officials. Guidance for processing sushi in retail operations. 2004 [cited 2016 Feb 16]; Available from: https://www.vdh.virginia.gov/EnvironmentalHealth/FOOD/FoodSafety/GuidanceDocs/GuidanceFiles/Food/AFDO%20sushi%20rice%20model%20recipe.pdf.

22. Schneider KR (University of Florida). Guidance for processing sushi in retail operations. Personal communication with: Pablo RomeroBarrios (Senior Scientist with the Environmental Health Services Division at the BC Centre for Disease Control), 2016 Jan.

23. Snyder OP. Validation of safe acifidification of multi-grain and brown sushi rice. Hospitality Institute of Technology and Managment. St. Paul, MN, 2009. p. 1-2.

24. Erdoğrul Ö, Erbilir F, Toroğlu S. Survival of acid-adapted and non-adaptedStaphylococcus aureus in various food samples. Ann Microbiol.56(1):25-7.

25. Rode TM, Møretrø T, Langsrud S, et al. Responses of Staphylococcus aureus exposed to HCl and organic acid stress. Can J Microbiol. 2010;56(9):777-92.

26. Clavel T, Carlin F, Lairon D, et al. Survival of Bacillus cereus spores and vegetative cells in acid media simulating human stomach. J Appl Microbiol. 2004;97(1):214-9.

27. Opinion of the scientific panel on biological hazards on Bacillus cereus and other Bacillus spp. in foodstuffs. European Food Safety Auth J [serial on the Internet]. 2005; 175: Available from: http://www.efsa.europa.eu/sites/default/files/scientific_output/files/main_documents/175.pdf.

28. Adams AM, Leja LL, Jinneman K, et al. Anisakid parasites, Staphylococcus aureus and Bacillus cereus in sushi and sashimi from Seattle area restaurants. J Food Prot. 1994;57(4):311-7.

29. Lee CJ, Heacock H. Safety and pH measurements of sushi rice in Japanese restaurants in Burnaby BC, Canada. Burnaby, BC: British Columbia Institute of Technology, 2014; Available from: http://www.ncceh.ca/sites/default/files/BCIT-Lee-2014.pdf.