BC Centre for Disease Control
An agency of the Provincial Health Services Authority

Environmental Health Services

Food Issue

Notes from the Field

Food Safety Assessment of Kombucha Tea Recipe and Food Safety Plan

Request received from:	Regional Health Authority
Date of request:	January 27, 2015
Issue *(brief description)*:	Assessment of kombucha tea recipe and food safety plan

Summary of search information:

1. Internet sources: general search for "kombucha"
2. OVID and PubMed search "kombucha" AND "illness"

Background information:

Kombucha Tea (*KT*, sometimes called Manchurian tea or Kargasok tea) is a slightly sweet, mildy acidic tea beverage consumed worldwide, which has seen significant sales growth in North American markets from recent years.[1] *KT* is prepared by fermenting sweetened black or green tea preparations with a symbiotic culture of bacteria and yeast (*SCOBY*), often referred to as the "mushroom" (misnamed because of its appearance) or as a "mother" (for its ability to reproduce). The culture comes in different varieties, but is generally made up of a variable amount of *Gluconacetobacter, Lactobacillus,* and *Acetobacter* (genera of acetic acid bacteria) coupled with one or more yeasts, which can include *Saccharomyces, Saccharomycodes, Schizosaccharomyces, Zygosaccharomyces, Brettanomyces, Candida, Torulospora, Koleckera, Pichia, Mycotorula,* and *Mycoderma.*[2] Alcohol produced by the yeasts is further transformed into acetic acid by the bacteria, giving it its acidic composition while limiting the tea's alcoholic content.[3]

Potential health benefits of *KT* consumption, said to alleviate a non-specific range of ailments, have recently generated an increased interest in the product.[4] These benefits are largely based on anecdotal reports, and studies on the claimed antimicrobial (primarily from acetic acid), antioxidant, hepatoprotective, and anticancer effects have only been conducted *in vitro.*[5] There has been no evidence published to date on the biological activities of kombucha in human clinical trials.[6] Furthermore, *KT* consumption has proven to be harmful in several documented instances.[7-9] However, since the scope of attributed health risks are yet to be fully established, some sources[6] advise against drinking *KT* for pregnant or nursing women, as well as children under the age of 4.

Vancouver Coastal Health requested review of a recipe and a food safety plan associated with the commercial production of KT.

General *KT* Process Summary

Prior to the fermentation step, black or green tea leaves (or bagged) is added to hot, boiled water. Sugar (sucrose) may be added at this point or after the tea leaves are removed. The tea is steeped for several minutes (length of time depends on desired final flavour). The tea leaves are subsequently removed and the now hot, sweetened tea is allowed to cool to room temperature. Once cooled, a *SCOBY* and a portion of a previous batch of *KT* (generally 10%) are added to the cooled tea. A commercially purchased culture and starter *KT* can be used on the first batch, but general practice is to re-use *SCOBY*s and a portion of a previous batch of *KT* on subsequent batches.

The tea's pH at the beginning of the fermentation process is generally ≤ 5. During the fermentation process, the yeasts in the mixture metabolize sucrose into glucose and fructose, then into ethanol and carbon dioxide. Ethanol is then oxidized by the bacteria (in the presence of air) to acetaldehyde, then to acetic acid. Typically, the alcohol and acetic acid content of *KT* are both less than 1%, but each can rise to 3% during a long fermentation (~ 30 days).[10] Other studies have demonstrated alcohol (i.e. ethanol) after a 10-day fermentation period, the final product can be variable in residual alcohol, sugars, tea components and bacterial and fungal metabolites.[11] The acetic acid bacteria also utilize glucose to produce gluconic acid to approximately 2%. Fructose is used to a lesser extent, and some remains after the fermentation. Some glucose will also remain unmetabolized, and, together with the remaining fructose, provide sweetness. The entire fermentation step (approximately 7 days, though this can vary significantly) results in a finished pH of ≥ 2.5. At this point, the *KT* should be refrigerated or pasteurized to stop additional alcohol and acid production prior to consumption or packaging.[12]

What are the potential hazards associated with the commercial production of kombucha tea?

Hazards most likely to be associated with *KT* include:

Biological:

Pathogenic microorganisms can contaminate the *KT* just after the water boiling step, and throughout the entire subsequent process. However, the period of greatest vulnerability, from a food safety viewpoint, is after the tea has cooled, until a pH of ≤ 4.2 has been achieved by fermentation. Until this pH is reached, contamination by pathogens would potentially be exacerbated by outgrowth of the contaminants. Reported symptoms of possibly contamined *KT* consumption include dizziness, nausea, vomiting, headache, and jaundice.[6] There has even been a case of unhygienic *KT* exposure that led to cutaneous anthrax.[13] Mold contamination on *SCOBY* cultures, predominantly with *Penicillium*[10] or *Aspergillus*[8] organisms, is also seen in homemade instances of *KT* brewing. Although not yet reported in a *KT* setting, some toxin-producing *Aspergillus* species could be of concern, especially for immunocompromised individuals[14], because of their known toxigenic and carcinogenic effects.[15]

Chemical:

The other potential hazard begins from the end of fermentation through to consumption. Unless the production of acid is controlled, over-fermentation can result in excessive acetic acid production. The resulting low pH environment has the potential to leach out some of the chemical contaminants that may be present in the fermentation vessel and packaging materials. For example, cases of lead poisoning were observed with *KT* brewed or stored in glazed earthenware.[2]

On a similar note, over-consumption of *KT* increases the likelihood of acidosis. *KT* consumption has proven to be harmful in a few documented instances.[9] Some reports suggest exercising caution if regularly drinking *KT* while taking medical drugs or hormone replacement therapy, in part because of the reduced absorption rates of drugs that are sensitive to stomach pH levels. [16] The possibility of toxic effects when *KT* is consumed in large quantities also became a concern with the report of two incidents occurring in 1995.[8] One individual, who died of cardiac arrest, was found to have perforations of the intestinal tract and severe acidosis. It was speculated that *KT* might have been the cause of death, since she had consumed 4 oz per day of homemade *KT* for two months prior to the incident. The surviving victim, whose *KT* came from the same initial *SCOBY*, also suffered cardiac arrest and severe acidosis. She mentioned that she increased her daily consumption from 4 oz to 12 oz and the fermentation time length from 7 days to 14 days, and that she consequently could hardly manage swallowing the very acidic tea, but did so anyway. It was later determined that the individuals had pre-existing conditions that made them susceptible to acidosis. These two cases of illness were investigated to determine if *KT* played a role in the development of metabolic acidosis or other toxic effects.

Control of Potential Hazards at Various Steps in the Process [12]

1. Biological Hazards

- **Hygiene and sanitation:**

Contamination by other microorganisms, and subsequent outgrowth during the fermentation period, are potential risks. Clean and sanitized utensils and vessels should be used throughout the process. Moreover, the preparation and fermentation areas should also be clean and sanitary. The fermentation vessel should be covered with a clean and sanitized porous cloth (e.g., cheese cloth).

- **Cooling of heated tea:**

The initial tea infusion starts at pH ~ 5. As such, after cooling to 60°C and before fermentation, the tea is vulnerable to outgrowth by potential contaminants. As such, the tea should be cooled from 60°C to 20°C within 2 hours, at which point the *SCOBY* should be added as soon as possible so as to begin the fermentation step and subsequent acid production.

- **Monitoring and control of the pH during the fermentation step:**

There are two potential hazards of concern regarding pH during the fermentation step: the production of acetic acid in a timely manner, so as to transform the initial tea infusion from a potentially hazardous food (PHF) to a non-PHF, and, at the opposite end, the over-production of acetic acid to hazardous levels. These hazards are mitigated through the monitoring and control of pH levels during the fermentation step. Acceptable monitoring includes using a calibrated digital pH meter for accuracy (versus using paper pH strips). The control of these hazards is described below:

1. Production of acetic acid in a timely manner:

   The initial tea infusion typically starts at pH ~ 5. Per the *2013 US Food Code*[17], the initial tea infusion isn't a PHF if the pH is ≤ 4.6. At this point, the heated tea is at a pH greater than 4.6 but not yet packaged, therefore it may be subject to contamination. Since *KT* fermentation

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.

is targeted to finish below pH 4.2, this process would require food safety monitoring to ensure the finished pH corresponds to recommended pH levels. The main corrective action, if the pH is > 4.3, would be to continue fermentation and re-measure the pH. If the pH does not reach pH ≤ 4.2 in seven days, the culture is most likely contaminated or the fermentation temperature is too cold. In either case, discarding the *KT* is recommended. Start a new batch with a newly purchased commercial culture. Written pH records of batches of *KT* should be kept to verify that safe pH levels are consistently reached.

2. Overproduction of acetic acid:

This hazard is controlled by stopping the further development of acetic acid when the pH approaches 2.5. This is accomplished by refrigerating the fermented tea (now *KT*) and keeping the product refrigerated until consumed.

- **Packaging of *KT*:**

KT can be packaged after it is fermented, if the finished product has a pH ≤ 4.2. However, if not controlled, a potential effect of packaging can be the persistent production of alcohol. It may be debatable whether the production of alcohol is a hazard per se, but, at a minimum, it is a quality issue that must be addressed. Some US commercial producers of bottled *KT* were forced to recall unpasteurized *KT* from grocery store shelves when the alcohol content exceeded 0.5% for legislative reasons. Some bottled brands continued to ferment, and produced up to 3% alcohol in the package. [12] This can happen because yeast continues to ferment sugars, producing alcohol and carbon dioxide. In a sealed container (i.e. bottled *KT*), the build-up of carbon dioxide inhibits the conversion of alcohol to acetic acid, therefore acid hazard is unusual at that point. However, carbon dioxide formation may in extreme cases lead to excess pressure and the leakage of bottles.

Options to prevent over-production of alcohol and carbon dioxide after packaging include:

- Pasteurizing the finished *KT*. This pasteurized and subsequently bottled *KT* would be considered shelf stable at room temperature.
- Adding 0.1% sodium benzoate and 0.1% potassium sorbate to the finished *KT*, and refrigerating until use. Benzoate and sorbate will prevent mold growth and minimize yeast and acetic acid bacteria growth in the sealed container.
- Using refrigeration alone to minimize hazards and spoilage.

With the last two options, a refrigerated shelf life will need to be determined based on eventual yeast growth. If this technique proves difficult, the operator may need to find a commercial *KT* culture with yeasts selected to not grow well at refrigeration temperature.

- **Adequate cleaning and sanitation of packaging containers:**

If using returned bottles, assume that the returned bottles are contaminated. If this is adequately managed, then subsequent refrigerated retail storage of the bottled *KT* would be low risk provided the pH is ≤4.2.

- **Knowing when the *SCOBY* may be contaminated:**

Discard all *KT* produced that

- show signs of mold contamination (fuzzy concentric patches that can be colored green, black, brown, blue, gray, or white; not to be confused with the sometimes irregularly shaped surface of the *SCOBY*), or,
- does not develop a pH of ≤ 4.2 during the fermentation period.

If one of these conditions occurs, do not reuse the *SCOBY* for a subsequent batch. Start a new batch with a newly purchased commercial culture.

2. Chemical Hazards

- **Appropriate materials to use:**

Because the potential exists for the acidic product to leach out chemical contaminants such as lead, the sweetened tea should be fermented and packaged in food-grade glass. Other acceptable container types reported include china, lead-free glazed earthenware, food-grade stainless steel, and food-grade high density polyethylene (HDPE) and polypropylene (PP).

- **Risk of over-consumption and acidosis:**

An investigation by the *US FDA* concluded that *KT* is not harmful at a consumption of 110 ml (4 oz) per day for healthy individuals. [8] However, potential risks can be associated with excessive consumption or consumption by individuals with pre-existing health problems.

Recommendations from BCCDC:

The Food Safety Plan and support materials submitted by the operator were comprehensive. The operator has done extensive research on the subject, and is knowledgeable of the process and potential hazards. Recommendations are as follows:

1. Hygiene and Sanitation

- **Fermentation and preparation areas:**

The operator proposes the fermentation and packaging to be done in a commercial kitchen. Provided the areas are kept clean and sanitary, and cross traffic during processing is minimized, these should be acceptable locations.

- **Utensils and vessels including kegs for packaging:**

There is minimal information provided regarding the cleaning and sanitizing of the utensils, vessels and kegs. From a food safety evaluation viewpoint, the same basic principles for cleaning and sanitizing utensils/vessels/kegs in a food service establishment can be applied to the production of *KT*.

2. Appropriate Materials Used

The operator proposes using a stainless steel vessel for the fermentation step and a stainless steel keg for packaging the finished *KT*. Provided these are confirmed to be food-grade, these should be acceptable.

3. Monitoring and Control of the pH During the Fermentation Step

The operator proposes to monitor the pH using a calibrated pH meter during the fermentation step (10-12 days) to ensure acetic acid production to a pH of ≤4.2. The operator's target pH is ≤ 3.2. The operator is aware that a pH of < 2.5 may be hazardous. This is acceptable, provided adequate records of each batch are kept for future reference, and the manufacturer's calibration procedures for the pH meter are followed.

4. Packaging of KT

After the fermentation step is complete, but prior to packaging, the operator will add pasteurized, commercially produced juice for flavour. The operator will re-check the pH at this point to ensure it is less than 4.2 and greater than or equal to 2.5. This should be acceptable.

The operator proposes to then package the finished *KT* into a clean and sanitized keg. The filled keg is afterwards refrigerated and carbonated. The filled kegs are kept refrigerated until dispensed to customers for immediate consumption. Provided that

- the cleaning and sanitizing of the re-used kegs are adequate, and,
- the kegs and carbon-dioxide are food-grade, and,
- the kegs are kept under refrigeration at all times after filling and prior to being dispensed for immediate consumption,

then this procedure should be acceptable.

5. Further recommendations

While the various legislated requirements for the labelling of packaged KT are beyond the scope of this assessment, to minimize the risk to public health, a written label should accompany each keg with the following information:

- Clearly identifies the product;
- A list of the ingredients should a consumer ask (for allergenic reasons);
- A product shelf life;
- Storage instructions (product to be kept refrigerated at ≤4°C at all times);

Because of the potential risk of over-consumption, it is also recommended that the operator also include a serving size suggestion on the label to state serving amounts should be no more than 110 ml (4 oz) per day.

Over-fermentation of products has been an issue with past kombucha products.[18] As the microbes (yeast and bacteria) are not inactivated, when the kombucha and juice are placed under anaerobic conditions, there is the possibility that fermentation of the added sugars (from the juice) will resume if the product is taken out of temperature control.[19] According to the BC Liquor Control and Distribution

Act, a maximum of 1% ethanol is permitted in beverages before they are defined as a liquor, and subject to the regulations of this Act.[20] Further, in a pressurized enclosed vessel, should temperature rise to allow fermentation to resume, there is the possibility that the tank would be under increasing pressure from release of CO2, with a potential explosion hazard. Therefore, as previously recommended we stress that the keg remain refrigerated at all time during distribution and dispensing to prevent these hazards, and that batches of kombucha be periodically monitored for ethanol content to ensure that the process is not producing an alcoholic beverage.

In conclusion, the recipe and food safety plan provided by the operator can be reasonably assumed to be safe, provided the above recommendations are followed.

References

1. O'Neill M. A Magic Mushroom or a Toxid Fad? The New York Times. 1998 December 28;Sect. 8. Available from: http://www.nytimes.com/1994/12/28/garden/a-magic-mushroom-or-a-toxic-fad.html.
2. Marsh AJ, O'Sullivan O, Hill C, et al. Sequence-based analysis of the bacterial and fungal compositions of multiple kombucha (tea fungus) samples. Food Microbiol. 2014 Apr;38:171-8.
3. Sreeramulu G, Zhu Y, Knol W. Kombucha Fermentation and Its Antimicrobial Activity. Journal of Agricultural and Food Chemistry. 2000;48(6):2589-94.
4. Frank GW. Kombucha: Healthy Beverage and Natural Remedy from the Far East; Its correct preparation and use. 9th ed: Ennsthaler Publishing; 1995.
5. Vina I, Semjonovs P, Linde R, et al. Current evidence on physiological activity and expected health effects of kombucha fermented beverage. Journal of Medicinal Food. 2014 Feb;17(2):179-88.
6. Jayabalan R, Malbaša RV, Lončar ES, et al. A Review on Kombucha Tea-Microbiology, Composition, Fermentation, Beneficial Effects, Toxicity, and Tea Fungus. Comprehensive Reviews in Food Science and Food Safety. 2014;13(4):538-50.
7. Srinivasan R, Smolinske S, Greenbaum D. Probable Gastrointestinal Toxicity of Kombucha Tea: Is This Beverage Healthy or Harmful? Journal of General Internal Medicine. 1997;12(10):643-5.
8. Unexplained severe illness possibly associated with consumption of Kombucha tea--Iowa, 1995. From the Centers for Disease Control and Prevention. JAMA. 1996 Jan 10;275(2):96-8.
9. SungHee Kole A, Jones HD, Christensen R, et al. A Case of Kombucha Tea Toxicity. Journal of Intensive Care Medicine. 2009;24(3):205-7.
10. Mayser P, Fromme S, Leitzmann G, et al. The yeast spectrum of the 'tea fungus Kombucha'. Mycoses. 1995;38(7-8):289-95.
11. Greenwalt C, Steinkraus K, Ledford R. Kombucha, the fermented tea: microbiology, composition, and claimed health effects. Journal of Food Protection. 2000;63(7):976-81.
12. Nummer BA. Kombucha brewing under the Food and Drug Administration model Food Code: risk analysis and processing guidance. Journal of environmental health. 2013 Nov 2014;76(4):8-11.
13. Sadjadi J. Cutaneous anthrax associated with the Kombucha "mushroom" in Iran. JAMA. 1998 Nov 11;280(18):1567-8.
14. Spach DH, Hooton TM. The HIV Manual: A Guide to Diagnosis and Treatment: OUP USA; 1996. Available from: http://books.google.ca/books?id=jzMGnInbkd0C.
15. Bennett JW, Klich M. Mycotoxins. Clinical Microbiology Reviews. 2003 Jul;16(3):497-516.
16. Kombucha--toxicity alert. Crit Path AIDS Proj. 1994 Winter(No 30):31-2.
17. U.S. Food and Drug Administration. FDA Food Code 2013. 2013 [cited 2015 Jan 28]; Available from: http://www.fda.gov/Food/GuidanceRegulation/RetailFoodProtection/FoodCode/ucm374275.htm.
18. Matthews C. High Country Kombucha Shows How Small Businesses Can Capitalize on a Crisis. Time. 2012 Mar 12, 2012. Available from: http://content.time.com/time/specials/packages/article/0,28804,2094921_2094923_2108731-2,00.html.
19. Nummer BA. Secondary kombucha fermentation question. In: McIntyre L, editor. e-mail ed2015.
20. Liquor Control and Licensing Act. Queen's Printer. Sect. (2015). Available from: http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/00_96267_01.