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Safety Aspects and Guidance for Consumers on the Safe Preparation, Handling and Storage of Kombucha — A Fermented Tea Beverage

ABSTRACT

Kombucha tea is a non-alcoholic beverage that has gained popularity in the health-food industry because of its alleged potential to optimize human health and act as a functional food. The distinctive flavors of kombucha are a result of the fermentation of sugared black tea with a symbiotic culture of bacteria and yeast (SCOBY). Recent research identifying the potential health benefits associated with kombucha, as well as the composition of the fermented beverage, will be summarized. Kombucha is available for purchase at retail outlets; however, preparation of the beverage at home has risen in popularity. The preparation of kombucha presents unique risks because of the fermentation process, and although food safety issues are not common, previous case reports of such issues associated with kombucha have been published. In this review, the steps involved in kombucha preparation are outlined, along with a discussion of the potential biological, chemical, physical and allergenic hazards associated with the preparation and consumption of kombucha at home. From a public health perspective, there is a need to address these potential hazards to provide individuals preparing kombucha at home with a scientifically based hazard assessment and guidelines for safe production of the fermented beverage.

INTRODUCTION

Kombucha is a uniquely prepared tea beverage that has been consumed since 220 BC *(20)*. Kombucha's growing popularity has allowed this traditional tea blend to extend beyond its reported birthplaces of China and Japan, and it is now prepared and readily available for purchase in many countries, including Canada, Germany, Russia and the United States *(20, 43)*. Globally, its rise in popularity can be attributed to the publicity surrounding kombucha's purported beneficial health effects *(13)*. Unlike many teas, prepared by pouring boiling water over the leaves of *Camellia sinensis,* kombucha is prepared by a process that involves fermenting sugared black tea with a symbiotic culture of yeast and acetic acid bacteria *(16, 20, 38)*. This unique process utilizing a symbiotic culture of bacteria and yeast (SCOBY) produces a desirable acidic and sweet combination, which

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is a differentiating characteristic of kombucha from other teas and tea blends *(24, 30)*. The resulting product is a non-alcoholic beverage that has similarities to apple cider *(16)*.

Kombucha has different names around the world, such as Champignon de longue vie, tea fungus, Chainii grib, etc. *(43)*. The beverage has been highly praised in the literature as "the ultimate health drink" and conversely has been referred to as "the unsafe medicinal tea" in other studies *(21, 24)*. These conflicting viewpoints, as well as the lack of focus on the potential for food safety concerns for consumers, is notable. With kombucha's growing popularity, there is a definite need to understand the potential health hazards of this beverage in more detail. The British Columbia Centre for Disease Control recently published a non-comprehensive food safety assessment of a kombucha tea recipe *(4)*. However, a peer-reviewed, more detailed assessment of the preparation, handling and storage of kombucha, using a hazard analysis critical control points (HACCP)-based approach, is required for accurate dissemination of information to consumers in Canada as well as globally *(4)*. Currently, no comprehensive food safety hazard analysis plan exists for the preparation of kombucha in Canada, and this paper aims to close this gap. In addition, alleged health effects associated with the consumption of kombucha, the unique processing steps involved in its preparation, and recent scientific evidence substantiating the reported health benefits of the fermented tea will be examined.

Potential kombucha health benefits

Health Canada defines a functional food as a food that is "similar in appearance to, or may be, a conventional food, is consumed as part of a usual diet, and is demonstrated to have physiological benefits and/or reduce the risk of chronic disease beyond basic nutritional functions" *(19)*. Many of the claims associated with kombucha claim that the beverage has health-promoting benefits aligned with Health Canada's definition of a functional food. The lay literature promotes kombucha as a beverage that is a 'probiotic-rich immunity booster,' 'can improve depression and anxiety,' and possesses the ability to 'aid in digestion and weight loss'; however, scientific substantiation of these claims is lacking *(17, 42)*.

A 2016 study conducted with Wistar rat brains has proposed that kombucha tea could have beneficial neuroprotective effects as a result of its antioxidant properties *(26)*. Bellassoued et al. *(6)* assessed kombucha's alleged antioxidant potential, and results from this study suggested that kombucha tea has potential remedial properties in Wistar rats *(6)*. There was a decrease in lipid peroxidation, an evident hypercholesterolemic effect and an improved antioxidant defense, which demonstrates a potential link between kombucha tea and prevention of cardiovascular diseases *(6)*. Aloulou et al. *(1)* compared kombucha tea and black tea to determine the potential therapeutic effects of these two beverages on diabetes. A 5 ml/kg dose of either kombucha tea or black tea was orally administered, daily, to alloxan diabetic rats, and blood samples were collected to assess various biomarkers (cholesterol, blood glucose, triglycerides, etc.). In addition, the effects of kombucha and black tea on α-amylase and lipase activities were measured. Results suggested that kombucha tea had considerable beneficial effects on liver and kidney functions, slowed the rise in blood glucose levels, and inhibited the activity of the pancreatic enzymes that were measured *(1)*. The authors suggested that with more targeted research, the beverage could potentially be used in the future for the treatment of diabetes *(1)*. A study published in the 2015 in *Bali Medical Journal* used Wistar rats to determine if kombucha tea could be used as a treatment for hyperuricemia *(39)*. Curative effects were observed, following a 4 ml dose of kombucha that was fermented for a 12-day period, through the inhibition of xanthine oxidase *(39)*. From these recent scientific studies, it is evident that kombucha tea, at least in the models chosen, appears to demonstrate some potential curative functions for multiple conditions. However, additional studies in different animal species are needed to fully assess the safety and health benefits of kombucha before human clinical trials can be considered.

In earlier research, two *in vitro* studies were conducted using human cells *(10, 32)*. The first study, by Cavusoglu and Guler *(10)*, used human peripheral blood lymphocytes and kombucha tea at various doses and demonstrated that the fermented tea may have some radio-protective effects. Compared to the control group, which received γ-radiation alone, the lymphocytes exposed to kombucha tea as well as γ-radiation demonstrated a reduction in chromosomal aberrations *(10)*. The second *in vitro* study compared the effects of kombucha produced from two different substrates, from *Camellia sinensis* and *Satureja montana (31)*. The authors concluded that kombucha from *Camellia sinensis* had a greater influence than that from *Satureja montana* on the parameters studied, i.e., micronuclei development and the rate of sister chromatid exchange increased *(32)*. To our knowledge, no additional studies on kombucha using human cells have been reported in the scientific literature.

Despite these seemingly beneficial effects seen in the rat and human peripheral lymphocyte studies, the responses are not necessarily predictive of human responses. There is a substantial need for human clinical research to be conducted to elucidate the potential for beneficial health effects in humans.

Composition of kombucha

As previously mentioned, the SCOBY is responsible for the distinctive flavor of kombucha *(43)*. Each batch of kombucha is unique, and therefore the microbial composition of kombucha is never reported in the literature in a general sense. However, researchers have discovered that particular bacteria and yeast species are abundant in kombucha *(24)*. Several studies throughout the years have reported use of different strains of both bacteria and yeasts in

the fermentation process *(16, 24, 43)*. A review conducted by Watawana and colleagues *(43)* regarding therapeutic effects, functionality and safety aspects of kombucha consumption reported that *Acetobacter xylinoides*, *A. pausterianus*, *A. xylinum*, *A. aceti* and *Bacterium gluconicum* are the most common species of bacteria found in kombucha cultures *(43)*. These researchers also reported the predominant yeast species to be the following: *Schizosaccharomyces pombe*, *Torulaspora* spp., *Kloeckera* spp., *Saccharomyces ludwigii*, *S. erevisiae*, *Pichia* spp. and *Zygosaccharomyces bailii (43)*. A review conducted previously by Dufresne et al. *(16)* stated that additional yeast strains had also been identified from microbial composition analyses, i.e., *Brettanomyces lambicus*, *B. bruxellensis*, *B. custersii* and *Candida* species.

With regard to analysis of the fermentation process on a molecular level, the monosaccharides, glucose and fructose are produced by the breakdown of sucrose by specific yeast enzymes. Following this, the yeasts ferment glucose into carbon dioxide gas (CO_2) and ethyl alcohol, a process carried out by use of a range of enzymes *(16, 20)*. The oxidation of ethanol, which occurs as a result of the dominant bacterial species in the kombucha culture, produces acetaldehyde, which then undergoes a second oxidation reaction to yield acetic acid *(16, 20)*. Another product of this fermentation is gluconic acid, produced as a by-product from the bacteria oxidizing glucose *(16, 20)*. Previous chemical analyses have demonstrated the diversity of each kombucha batch and how factors such as the fermentation period and the tea substrate chosen can directly impact the concentration of the main components *(25)*. Predominant metabolites, some mentioned previously, consist of acetic acid (4.69 – 8 g/L), glucuronic acid (0.0026 – 1.17 g/L), gluconic acid (39 g/L), glucose (12 – 179.5 g/L), fructose (5.40 – 76.9 g/L), and sucrose (2.09 – 192.8 g/L) *(24)*. In addition to chemical analysis, mineral composition and water soluble vitamin analyses have also been conducted *(3, 24)*. Bauer-Petrovska and Petrushevska-Tozi *(3)* outlined the following minerals and their respective concentrations: cobalt 0.004 $\mu g\ ml^{-1}$, copper 0.237 $\mu g\ ml^{-1}$, chromium 0.001 $\mu g\ ml^{-1}$, iron 0.353 $\mu g\ ml^{-1}$, lead 0.005 $\mu g\ ml^{-1}$, manganese 0.462 $\mu g\ ml^{-1}$, nickel 0.346 $\mu g\ ml^{-1}$ and zinc 0.154 $\mu g\ ml^{-1}$ *(3)*. These researchers also determined that thiamin, vitamin B6, vitamin B12 and vitamin C (0.74 $mg\ ml^{-1}$, 0.52 $mg\ ml^{-1}$, 0.84 $mg\ ml^{-1}$ and 1.51 $mg\ ml^{-1}$, respectively) were present in the kombucha *(3)*. Because of the fermentation that occurs throughout the preparation of kombucha, it is imperative to be aware of all the by-products produced in order to do an accurate health hazard assessment along with developing science-based educational material for consumers.

Food safety issues associated with kombucha

Kombucha is prepared in commercial kitchens and sold in retail stores, although this beverage is also prepared in consumers' homes. In fact, the average consumer can learn the processing steps for kombucha from many sources, such as online blogs, social media outlets and advertisements, which may not be reliable sources of safe and accurate information.

Kombucha is often promoted as a healthful beverage; however, as already stated, human clinical evidence to substantiate these claims is lacking *(16, 17)*. Conversely, several case reports have linked the consumption of kombucha to adverse health effects in humans *(Table 1)*. For example, after consumption of 1 liter of unpasteurized kombucha tea, a 22-year old man who had recently been diagnosed with human immunodeficiency virus (HIV) began exhibiting symptoms including shortness of breath, fever, and intense bouts of shaking *(27)*. After he was admitted to the hospital, further testing took place and the patient exhibited signs of lactic acidosis, hyperthermia and acute renal failure as a result of kombucha ingestion *(27)*. In 2014, Kovacevic et al. *(28)* reported a case of a patient who had initially demonstrated symptoms including jaundice, nausea and fatigue, which then progressed to toxic hepatitis. These symptoms were linked to the daily consumption of kombucha *(28)*. In other case reports, patients have complained of neck and head pain, signs of allergic reactions, discoloration of the skin and nausea *(37)*. These adverse effects were reasonably attributed to kombucha consumption, as abnormal laboratory results returned to "normal" levels upon cessation of kombucha drinking *(37)*. Although a sub-acute oral toxicity test conducted in rat models has deemed kombucha tea to be non-toxic *(41)*, scientific evidence to verify the safety of the drink when prepared at home is lacking. These case reports are suggestive of the fact that susceptible individuals and the consumption of high doses of kombucha can lead to detrimental health impacts. Consequently, from a public health perspective, there is a need to address the potential hazards of consuming kombucha, especially for potentially at-risk populations (i.e., individuals with allergies to mold, immunosuppressed individuals, those who are susceptible to acidosis and those who are sensitive to alcohol, such as pregnant women).

Kombucha preparation

When preparing kombucha at home, the following steps are taken *(Table 2)*: The first step involves boiling 1 liter of water at 100°C for approximately 1 min and adding approximately 50 g of sugar as sucrose *(20, 33, 43)*. Once the sugar is dissolved, the chosen tea substrate (black, green, oolong tea, etc.) is infused into the mixture (5 g of tea/liter) for the recommended time of 10 min *(20)*. Traditionally, a black tea base combined with white sugar is used as the base for kombucha; however, green tea has also been used *(16)*. Processing techniques, resulting in varying levels of oxidation of *Camellia sinensis*, is the differentiating factor between a green and black tea *(22)*. Green tea leaves are heated, known in the tea industry as "firing," to prevent oxidation, whereas

TABLE 1. Kombucha tea food safety issues – case reports from the literature

Reference	Description of Patient	Onset	Symptoms
Gedela, 2016 *(18)*	58-year-old female; history of hypothyroidism and diabetes mellitus	5 days prior to admission to the hospital	Pain in the upper abdomen, discolored stool and urine
Kole, 2009 *(27)*	22-year-old male; one month prior was diagnosed with HIV	15 h following consumption of 1L of unpasteurized kombucha	Severe hyperthermia, acute renal failure, and lactic acidosis
Kovacevic, 2014 *(28)*	47-year-old female patient	Symptoms appeared four days prior to hospitalization and the patient consumed daily amounts of kombucha over a two-year period	"Nausea, fatigue, yellow discoloration of the skin and visible mucous membranes, dark discoloration of urine and discrete neurological problems (anxiety, agitation)" *(28)*
Morbidity and Mortality Weekly Report, 1995 *(11)*	48-year-old woman	Consumed 4 oz of kombucha tea within two months; received starter culture from 59-year-old patient described above and on the day of admittance to hospital increased fermentation time of tea to 14 days and consumption to 12 oz	Admitted originally for shortness of breath; further testing indicated respiratory distress and increased levels of lactic acid
Morbidity and Mortality Weekly Report, 1995 *(11)*	59-year-old woman (was on medication for anemia, hypertension and renal insufficiency)	Consumed approximately 4 oz in the two months before the incident (determined that the fermentation period during the kombucha at home brewing was approximately 14 days in length)	Found unconscious; determined to have severe metabolic acidosis and eventually died
Phan, 1998 *(35)*	A married couple	Consumed kombucha tea for six months (brewed in a ceramic pot)	Lead poisoning
Srinivasan, 1997 *(37)*	55-year-old woman with a history of alcoholism	Two glasses of kombucha were consumed daily for a 2-month period	Jaundice
Srinivasan, 1997 *(37)*	51-year-old woman	Half a glass of kombucha consumed daily for months	"Xerostomia, dizziness, nausea, vomiting, headache, and neck pain" *(37)*
Srinivasan, 1997 *(37)*	Woman	No specific details provided however, onset occurred following the consumption of kombucha tea	Shortness of breath, agitation and shaking
Srinivasan, 1997 *(37)*	No description; referred to as Patient 4 in case report	An hour following kombucha tea consumption and 5 min after ephedrine	Tightness in throat and shortness of breath

TABLE 2. Recommended process for kombucha preparation for consumers at home

Step	Recommendations for Consumers	pH log**
1	• Boil 1 liter of water at 100°C (allow water to stay at a rolling boil for approximately one min) and add 50 g of sugar. - **Rationale:** designed to protect the health of consumers through pathogen reduction *(12)*.	Not required
2	• Infuse 5 g of tea substrate chosen (i.e., black tea substrate instead of a green or oolong tea base*) for approximately 10 min *(12, 20)*. - **Rationale:** lactic acid concentration is higher in a kombucha batch when a green tea substrate was used instead of a black tea base *(25)*.	Not required
3	• Withdraw tea leaves from the mixture.	Not required
4	• Allow the remaining liquid to cool to room temperature (approximately 20–25°C).	
5	• Inoculate the cooled liquid mixture with approximately 100 ml of a microbial mat and visually examine the recycled or store bought SCOBY prior to adding the culture to the mixture*. - **Rationale:** any discoloration (i.e., green, white, black or gray) or abnormal odor (i.e., putrid odor) could be attributed to the presence of molds and the SCOBY should be discarded to avoid any potential health issues *(4)*.	
6	• Place a clean cloth over the glass storage vessel to cover the kombucha tea mixture. - **Rationale:** prevents biological cross-contamination *(33)*.	
7	• Allow the mixture to ferment for approximately 7 and up to 10 days in the food-grade glass container and ensure the temperature range throughout fermentation is between 18°C and 26°C *(4, 16, 35, 43)*. • On day 7, measure the pH using a digital pH meter or pH strips. - **Rationale:** glass storage containers can reduce the risk of chemical contamination *(4, 16, 35, 43)*. During the fermentation, the pH decreases from around less than or equal to 5 to a final pH of approximately 2.5. If the pH has not reached less than or equal to 4.2 by day 7 of fermentation, continue fermentation until the desired pH is reached, stopping fermentation at day 10. If desired pH has still not been reached by this day, restart the process from the beginning to avoid over fermentation of the batch. Fermenting for a longer time period could result in an increased acetic acid concentration in the tea broth *(43)*. Measuring the pH throughout this step is critical to ensure the inhibition of microorganisms *(43)*. Use food-grade glass containers for storage.	
8	• Remove the top layer of the tea fungus and refrigerate the remaining liquid tea broth at 4°C for consumption. - **Rationale:** this storage temperature can inhibit the growth of mesophilic foodborne pathogens and slow down the growth of the psychrotrophs *(33)*.	
9	• Only consume approximately 125 ml (or ½ cup) a day. - **Rationale:** a previously established recommendation in the scientific literature *(20)*. Refrigerate at 4°C.	Not required
All Steps	• Proper handling procedures • Clean utensils and equipment - **Rationale:** avoid biological cross-contamination.	Not required
	• Visual examination at each step - **Rationale:** prevents chemical and physical cross-contamination	Not required

(Source: Adapted from *20, 24, 33, 43*)

*Note: * = At-risk consumers (i.e., individuals with allergies to mold, immunosuppressed individuals those who are susceptible to acidosis and those who are sensitive to alcohol such as pregnant women). It is important to note that all of the precautions described above are directed at both healthy and at-risk consumers. However, the descriptions targeting at-risk consumers are especially critical to ensure that these individuals avoid health risks that have been identified in previous case reports (Table 1). ** Log the pH throughout steps 4, 5, 6, 7 and 8. If brewed under these recommendations and all precautions are taken, kombucha tea should be safe to drink. However, at-risk consumers should consult with a health professional before they consider making and consuming kombucha tea in their home.

black tea is produced by complete oxidation of the leaves *(22)*. The leaves are withdrawn from the mixture and the tea blend is left until room temperature (20–25°C) is reached *(20, 24, 33, 43)*. Approximately 100 ml of a microbial mat (often referred to as the kombucha "mushroom") from an earlier kombucha preparation is inoculated into the room temperature tea blend *(20, 24, 33, 43)*. A starter culture can be purchased for the initial kombucha preparation *(4)*. A clean porous cloth is placed over the storage container (glass jar, glass bottle, etc.) and the fermentation process occurs over a 7- to 10-day period at a temperature ranging from 18°C to 26°C *(20, 24, 33, 43)*. It is highly recommended that the preparation occur in some type of food grade glass container to avoid adverse effects from chemicals that can leach into the brewed mixture *(4, 16, 35, 43)*. Following this fermentation period, a film will have been created on the surface of the mixture; this pellicle is excised, and the remaining liquid tea broth is prepared for consumption *(20, 24, 33, 43)*. Kombucha should be refrigerated at 4°C; a recommended amount of approximately 125 ml (½ cup) can be consumed daily by healthy individuals *(20)*.

KOMBUCHA HAZARD ANALYSIS

The Hazard Analysis Critical Control Point (HACCP) approach is a universally recognized food safety management system that critically evaluates hazards associated with food: biological, chemical, physical and allergenic *(14)*. Food safety hazards are identified and controlled when HACCP is implemented successfully *(14)*. In fact, research suggests a positive correlation between good food safety records and tea establishments that have implemented HACCP *(29)*. Lokunarangodage et al. *(29)* noted that the fermentation and oxidation steps of tea processing are vulnerable to contamination by improper hygienic protocols and that these steps were often overlooked throughout processing prior to HACCP implementation. The CFIA defines a food safety hazard as "any agent with the potential to cause adverse health consequences for consumers" *(9)*. Using the principles of HACCP, a hazard analysis for at-home preparation of kombucha is outlined with the goal of informing consumers about the safe practices that they should follow when preparing kombucha in the home. In terms of kombucha preparation and consumption, the biological, chemical, physical and allergenic hazards will be discussed, along with recommended preventative measures. Food safety hazards related to commercial production, packaging and shipping will not be addressed in this hazard assessment.

Biological hazards

Although one does not commonly think of tea, specifically kombucha tea, as a potential cause of foodborne illness, the fermented beverage can become contaminated with pathogens if certain steps throughout the preparation are not conducted properly *(33)*. Common biological hazards associated with food include foodborne pathogens such as *Clostridium botulinum*, *Salmonella* spp. or *Listeria monocytogenes*, which can enter the food chain at many different points *(12)*. Several other pathogens have been reported to survive and be associated with outbreaks associated with low-moisture foods such as dried spices, nuts and tea. For example, *Bacillus* spp. and *Clostridium perfringens* were implicated in several outbreaks in the EU in which paprika, white pepper, turmeric, ground cumin, cinnamon, barbecue spice, red pepper and dried chilis were the contaminated food sources *(34)*. In addition, *Cronobacter* spp., previously known as *Enterobacter sakazakii*, *Escherichia coli*, and *Staphylococcus aureus*, were isolated from several food items of plant origin, including spices, nuts and tea *(15, 34, 40)*.

The first step in the preparation of kombucha consists of boiling 1 liter of water at 100°C for 1 min *(12, 20, 24, 33)*. This boiling step acts as a preventative, initial critical control point by removing or inactivating any potential pathogens (i.e., *Campylobacter*, *Salmonella*, etc.) in the water *(12)*.

The second critical control point for preparation of kombucha is fermentation, wherein the pH decreases from around ≤ 5 to a final pH of approximately 2.5 within a 7–10 day fermentation period *(20, 23, 33)*. Another beverage that undergoes fermentation during preparation is beer, and, as is the case for kombucha, the low pH that beer has throughout and at the end of the fermentation process is a key factor in controlling microbiological contamination *(5)*. Therefore, having the proper equipment to reliably measure pH throughout the fermentation process is crucial to ensuring safety *(20, 33)*. Both pH strips and a digital pH meter are tools that consumers can purchase to measure the pH at home. However, digital pH meters are more accurate and are a more objective measurement tool. By logging the pH value at each step of the fermentation process *(Table 2)*, an accurate representation of any potential hazards can be established. Step 4 *(Table 2)*, which involves allowing the broth to cool to room temperature and Step 7 *(Table 2)*, the fermentation period, are the most susceptible to contamination *(4)*, and as such are both critical control points. In the 2015 BC Centre for Disease Control food safety assessment of kombucha, the authors suggested that cooling kombucha to room temperature should take no longer than 2 h to prevent the growth of unwanted contaminants such as *C. perfringens (4, 33)*. Corrective action by day 7 of fermentation may be necessary if the desired pH of ≤ 4.2 (qualifies as a non-potentially hazardous food) has not been reached. Allowing for further fermentation until day 10 is one of two options. The second option is to discard the product if the desired pH is not attained by day 10, and consumers should restart the process from the beginning to ensure that the tea broth has not been contaminated with foodborne pathogens such as *C. botulinum (4, 33)*. In addition to pH, temperature plays a key role in ensuring the safe preparation of kombucha *(4, 33)*.

The optimal temperature for the fermentation process ranges from 18°C to 26°C, while the finished product must be refrigerated at a temperature of 4°C to avoid the potential for the growth of foodborne pathogens *(4, 33)*. The use of a digital pH meter or pH strips, as well as a thermometer, are essential tools that the consumer can use to prepare kombucha safely.

Mold is another potential source of contamination that kombucha preparers need to be concerned about *(4, 43)*. The naturally carbonated beverage may be susceptible to mold growth through the SCOBY cultures that are added in Step 5 *(Table 2)* of the preparation. Two examples of fungi found in kombucha mixtures are *Aspergillus* and *Penicillium (27, 43)*, both of which produce toxins that are commonly referred to as mycotoxins. The former primarily produces a mycotoxin known as aflaxtoxin, while the latter produces a mycotoxin known as ochratoxin *(31)*. Both toxins have been linked to acute and chronic toxicity in humans and animals *(31)*. Although these mycotoxins are not commonly reported in case studies for kombucha, it is imperative that safety precautions be taken to prevent the growth of molds that produce them.

The ingredients used in the kombucha formulation, especially the SCOBY cultures, which are sometimes recycled, should be routinely inspected for spoilage. Upon visual examination of the SCOBY cultures, if abnormal colors (e.g., green, white, black or gray) or other forms of surface contamination appear, the cultures should be discarded immediately to avoid potential illness *(4)*. Proper hygiene and sanitation procedures, even when preparation occurs at home, can aid in preventing potential health hazards *(8)*. The area in which kombucha is prepared should be thoroughly cleaned before and after use, and clean utensils should be used at each step to prevent cross-contamination *(33)*. In addition, a clean porous cloth should be used in Step 6 *(Table 2)* to cover the glass jar *(4, 33)*.

Chemical hazards

To prevent chemical contamination, Step 6 *(Table 2)* specifies the use of a glass storage vessel (i.e., glass jar or glass bottle). A case report from 1998 describes two individuals suffering from symptomatic lead poisoning following consumption of kombucha over a period of six months, as the fermented tea was prepared in a ceramic pot *(35)*. The storage vessel was coated in a lead-based glaze, and because the beverage developed a high pH following the fermentation period, lead leached into the brewed tea *(35)*. This particular incident, however, appears to be a medical anomaly, as it has been reported only once in the literature *(35)*. Food-grade glass containers would allow consumers to avoid this chemical contamination and are also recommended for storing the final tea broth *(4, 16, 35, 43)*.

Kombucha tea is not exempt from Paracelsus's concept of the "dose makes the poison," as excess-consumption of the fermented beverage is a considerable concern in terms of chemical hazards *(7, 36)*. The recommended daily consumption of kombucha tea is approximately 125 ml (or ½ cup) for individuals with no known pre-existing health concerns *(20)*. The potential chemical hazard associated with excess consumption is the risk of chemical acidosis *(33)*. The fermentation period causes the tea to become acidic in nature, and one of the known components found in kombucha tea through chemical analysis is L-lactic acid *(25)*. Drinking more than the suggested amount of kombucha tea could lead to accumulation of this organic acid in the blood, thus causing life-threatening lactic acidosis, specifically in individuals who are susceptible to acidosis *(25)*. Individuals with weakened immune systems or a history of heavy drinking, and pregnant women, are at risk for acidosis *(27, 35)*. Consuming the recommended daily amount is the greatest form of preventative measure for this chemical hazard. Notwithstanding this, Jayabalan et al. *(25)* experimentally determined that the lactic acid concentration was higher in a kombucha batch when a green tea substrate was used in place of a black tea base. For individuals vulnerable to acidosis, choosing a black tea substrate for Step 2 *(Table 2)* would appear to be a better choice. Drinking water following kombucha consumption is another recommendation to promote the excretion of acids that may accumulate if an individual suffers from any form of kidney disorder *(43)*.

Alcohol, produced as a result of the production of alcoholic metabolites in the preparation, can also be considered a potential chemical hazard *(33)*. Pasteurization of the final kombucha tea product, along with the addition of 0.1% sodium benzoate and 0.1% potassium sorbate, can stop yeast activity and thus prevent the excess production of alcohols and carbon dioxide *(33)*. The alleged functional beverage, under normal conditions, has only traces of alcohol (lower than 0.5% alcohol), but in some instances overproduction of alcohols can occur *(43)*. In 2011, Whole Foods recalled GT Kombucha products for misleading consumers by labeling products as non-alcoholic, when in fact the alcohol content exceeded the maximum allowed for a product to be considered non-alcoholic *(2)*. The greatest concern is for individuals who should not be consuming beverages containing alcohol, such as pregnant women, individuals abstaining from alcohol for health reasons, and children *(4)*. Precautions should therefore be taken by these individuals, and it may prudent for them to avoid kombucha completely.

Physical hazards

The primary physical hazards from the preparation of kombucha are foreign matter presented by the individual making the tea, extraneous material from the tea substrate chosen, and foreign material from the container chosen for at-home storage. To prevent foreign matter (i.e., jewelry) intrusions, proper handling procedures are recommended,

even for at-home preparation. Visual examination of the tea (i.e., black, green or oolong tea) substrate is highly recommended, as unwanted leaves or twigs may be present from processing. Again, visual inspection of the storage vessel is essential to ensure the structure of the glass container is intact and that there are no breaks or cracks in the glass from previous use *(33)*. It is apparent that there are fewer potential physical hazards in the at-home preparation process than in a commercial kitchen; however, precautions and preventative measures should be employed as safeguards.

Allergenic hazards

A few of the case reports presented earlier involved individuals who showed signs of allergic reactions, such as tightness of the throat and shortness of breath *(17)*. Other symptoms reported include diarrhea, nausea and vomiting. However, these are also commonly attributed with food poisoning, and it is therefore difficult to definitively conclude whether these case reports represent allergic reactions or food poisoning. Individuals who are sensitive to any of the ingredients used in preparation of kombucha or to the by-products produced during fermentation are advised to avoid consuming the beverage. Many individuals have allergies to mold, and the visual inspection preventative measure discussed in the biological hazard section of this review paper is therefore crucial to avoid adverse effects in vulnerable populations.

CONCLUSIONS

As consumer trends continue to shift towards nutritionally beneficial foods, it is likely that preference for foods with potential curative and health-promoting properties will increase. Kombucha tea may be one of these options for many consumers pursuing a healthy lifestyle. Much of the scientific research on kombucha's potential health effects have been conducted using animal models such as rats, which may not accurately represent what occurs in humans. To investigate the human response to kombucha tea, well-conducted, ethical and approved human trials could provide scientific insight into the reported health effects.

With respect to kombucha tea and food safety, understanding the potential adverse effects of the fermented tea is important for consumers. *Table 2* provides consumers, both healthy and at-risk individuals (i.e., individuals with allergies to mold, known to have immunodeficiency conditions, susceptible to acidosis and sensitive to alcohol), with recommendations to follow in the preparation of kombucha. In view of the fact that preparation of kombucha can occur in consumers' homes, the steps and guidance provided in the paper are necessary to educate consumers on the safe handling and storage of kombucha. Considering the popularity and accessibility of the beverage, further efforts should be directed at providing safe food preparation, storage and handling practices to consumers, especially for those who are at risk.

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Association of Food and Drug Officials Leadership Changes

After years of leading the transformation of the Association of Food and Drug Officials to a key force in food and medical products regulation, Joe Corby is stepping down as executive director of AFDO. Stepping into the position is Steven Mandernach, currently Bureau Chief for Food and Consumer Safety at the Iowa Department of Inspections and Appeals. These changes are effective October 8, 2018.

"Steve brings the spirit of collaboration and innovation I have used to support our growth," says Corby. "His experience at the state level and collaborating with local officials will be instrumental to expanding our reach to the front line members who make a difference every day in their own geographic locations."

"AFDO has a history that predates any kind of food and drug regulation at the national level," Steve Mandernach says, noting that AFDO is older than the predecessor to the FDA itself by nearly ten years. "It's a very great opportunity to bring together partners at the state and local level with our federal partners to discuss, implement and deploy food and medical products policy while being able to answer the needs for new areas and technologies that will impact what our regulators do on a daily basis."

Mr. Mandernach notes that produce regulation, stabilizing the number of restaurant illness incidents, the regulation of cannabis, and the use of artificial intelligence are the kinds of issues that face the profession and he says AFDO wants to be pivotal in encouraging innovation but helping with the application of it at the state and local levels where most policy is carried out.