Sous Vide Salmon Pasteurization Temperature

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ABSTRACT

Objectives: Cooking foods to a specific temperature and temperature control are often very difficult due to the frequent fluctuation of heat during the traditional dry heat (oven) cooking process. "Sous vide" cooking of vacuum-packaged foods immersed in water provides constant and controllable time and temperature measurements throughout the process. Some sous vide style foods are cooked at temperatures that are lower than 60ºC for short periods of time. This presents a recognizable food safety concern including the survival of harmful bacteria as well as conditions that do not achieve pathogen reduction during either the sous vide cooking or finishing (searing) process. This research project investigated the time and temperature relationship for sous vide salmon in order to examine if pasteurization temperature was achieved if an additional searing step was performed.
Methods: Temperature values were measured using data-loggers (SmartButton) for 30 samples of vacuum-packed salmon and cooked sous vide inside a circulating water bath at 50ºC for 20 minutes. A one sample one tailed t-test was conducted to assess whether the internal temperature of salmon reached instantaneous pasteurization temperature of 70ºC after a final searing step was performed at 220ºC for 45 seconds.
Results: Five out of the 30 (16.7%) salmon samples achieved 70ºC after the final searing step. Statistical analyses were statistically significant, and the null hypothesis (H_o: measured internal temperature of salmon $\geq$ target temperature) was rejected with 100% power and a p-value of 0.00.
Conclusion: These results indicate that salmon cooked sous vide style under 50ºC for 20 minutes with a final searing step of 220ºC for 45 seconds will likely not achieve pasteurization providing adequate pathogen reduction according to guidelines set out by BCCDC. For sous vide style cooked salmon cooked at lower temperatures for short periods, freezing for control of parasite hazards is recommended.
Key words: Sous vide, salmon, temperature, SmartButton, public health

INTRODUCTION

For hundreds of years, chefs and food critics around the world have been in search of better ways of preparing, cooking, serving and preserving food. In order to create the perfect food item, precise control of time and temperature is often required. Traditional ways of cooking often involve high and fluctuating temperatures, with little tolerance of error. Constant temperature control is often very difficult due to the frequent fluctuation of heat during the cooking process. "Sous vide" cooking evolved as an attempt to provide constant and controllable time and temperature measurements throughout the process. This research topic was brought forward by Lorraine McIntyre at the British Columbia Centre for Disease Control (BCCDC) as a continuation project from a previous student project on sous vide cooking that investigated whether safety objectives were achieved during the sous vide cook step.

LITERATURE REVIEW

History of Sous vide

Sous vide is defined as the "raw materials or raw materials with intermediate foods that are cooked under controlled conditions of temperature and time inside heat-stable vacuumed pouches". Vacuum style of cooking was first developed in 1969 in Europe. In the early 1970s, a French chef named George Pralus discovered that the vacuum style of cooking is able to better preserve food's texture and taste (Schellekens, 1996). It has since been further developed through experimentations in order to determine the appropriate cooking time and temperature for various food items.

Sous vide is a new way of cooking that has only been actively studied and used since the 1990s in North America (Meyer, 2008). Some researchers and food scientists have analyzed the safety of sous vide cooking through various temperature monitoring and microbiological analyses. The results of these studies vary depending on the food item and temperature which foods are cooked under. It is important to note that in the 1990s, sous vide techniques were used primarily as a means of preserving food in order to extend shelf life. However, in the past 20 years, sous vide has evolved as a cooking style to make dishes that are served immediately at restaurants, catering events or homes (Stringer, Fernandes & Metris, 2012). In order to determine the safety of cooking sous vide style, it is important to examine its techniques, advantages, microbiological and temperature concerns, relevant legislation and public health significances.

Techniques of Sous Vide Cooking

Sous vide, literally meaning "under vacuum" in French, involves slow cooking food items in vacuum packages, submerged in hot water baths, with the purpose of preserving the food's taste, texture and tenderness. The raw food is first put into food grade plastic pouches, then vacuum-sealed. The vacuum-sealing step is important as removing air prevent the pouches from floating in the water bath, providing an even distribution of heat across the food item while cooked in the circulating water bath under low heat. It also eliminates risks of recontamination during storage and therefore increases the food's shelf life (Baldwin, 2011). In addition, the juice and seasonings are guaranteed to stay in the bag while the food is being cooked to preserve flavor. In food establishments, sous vide foods are generally cooked in water baths with immersion circulators or a combination of steam or forced convection oven in order to precisely control temperature of the water bath (NSW Government Food Authority, 2012). There are several ways sous vide food items can be prepared. Details on the steps involved can be found in later sections of this paper.

Advantages of Sous Vide

Tenderness. In order to assess the necessity of putting foods at more risk by cooking sous vide style, it is important to note the advantages of this technique. Collagen, the "major insoluble fibrous protein in the extracellular matrix and in connective tissue", shrinks at 60ºC to 70ºC and is converted to its denatured form, gelatin, at 80ºC in meat (Lodish, Berk, Zipursky et al. 2000). Research has shown that tenderness of cooked meat products is directly related to heating to temperatures that disrupts collagen. This disruption, along with moisture loss and myofibrillar hardening, are the major contributors in decreased tenderness of meat products (Turner & Larick, 1996). As a result, sous vide cooking is being adopted by chefs to produce desirable tender food items through minimum disruption of collagen at low heat and preservation of moisture with vacuum packaging.

Temperature Control. In addition, sous vide cooking guarantees the control of temperature throughout the whole cooking process through the use of reliable immersion circulator in hot water baths. Immersion circulators are usually equipped with precious time and temperature controls that can achieve desired final cooking temperature, therefore chefs do not have to worry about overcooking the food item even if it is left in the water bath for extended periods of time. A circulating water bath can also increase cooking contact surfaces so that heat can evenly distribute through oddly shaped or very thick food items (Baldwin, 2014). Through the use of immersion circulators, temperature swings of the circulating water baths are usually less than 0.1ºC, which contributes to precise temperature measurements and control (Baldwin, 2011).

Economic Advantages. In addition to providing tenderness in food and precious time and temperature control, sous vide cooking also presents with noticeable economic advances. Due to the nature of sous vide cooking, it can provide "better use of labor and equipment through centralized production" (Schellekens, 1996). It also requires less kitchen space for food production and adds variety and diversification to the restaurant (Meyer, 2008). If an establishment has well trained staff with good knowledge of sous vide cooking and adequate equipment, savings can be observed in labor cost of staff needed for food preparation.

Sous vide products cost slightly more to prepare than food items that are prepared using traditional methods. However, savings in labor and overhead can counterbalance this increased cost. When sous vide products are used in restaurants and banquets, because employees do not need as much culinary skills, resources can be allocated to providing better service instead of production (Meyer, 2008). As a result, higher standards of services can help achieve increase in revenue and popularity among other establishments.

Risks and Concerns

Microbiological. Similar to traditional cooking methods, bacterial hazards can be introduced through raw material, improper temperature control or poor food handling practices. Examples of common bacteria involved are *Staphylococcus aureus*, *E. coli,* and *Salmonella spps* (Foodsafety.gov, 2014). Bacteria can multiply exponentially under the right conditions, which usually require warm temperature, moisture, and nutrients from the food. For food items that are cooked sous vide style, chilled, and reheated before service, pathogens such as *Clostridium botulinum, Bacillus cereus* and *Clostridium perfingens* are of most concern in sous vide food items due to its ability to form spores (Gilani & Media, 2014). Spore forming bacteria have the capability of surviving under hostile environmental conditions, such as heat and freezing, so harmful bacteria will continue to proliferate inside food items even after the initial cooking process.

Cooking foods under vacuum provides the perfect environment for anaerobic bacteria to grow and thrive. *Clostridium botulinum* is of particular concern due to the anaerobic environment of vacuum packaged food and its dangerous neurotoxicity in human when consumed (Hyytia-Trees et al, 2000). Botulism, the condition caused by the *C. botulinum* bacteria, is known to block nerve functions and lead to respiratory and muscular paralysis. Foodborne botulism resulting from contaminated and improperly processed food can cause fatal conditions if not diagnosed immediately (WHO, 2013). As a result, bacterial hazards are assumed to be present in any of the sous vide cooking steps, and critical control points must be in place to reduce and eliminate pathogens as well as possibilities of recontamination.

Time and Temperature. Due to the nature of sous vide cooking, food is usually cooked at lower temperatures in order to preserve and enhance its quality. However, this practice raises food safety concern as it puts food at more risk while in the "danger zone". Danger zone, described as the temperatures between 4^{o}C and 60^{o}C (40F to 140F), is when bacteria can grow and multiply rapidly if left in that range for prolonged periods of time (PHAC, 2012). In addition, *Clostridium botulinum* can grow and proliferate even at 4^{o}C (BCCDC 2014). Therefore, it is important that sous vide food is kept either below 3^{o}C or above 60^{o}C before and after cooking to prevent bacteria growth. In order to reduce pathogenic organisms in food, a safe internal temperature must be achieved. For example, beef, veal and lamb are required to cook to at least 63^{o}C in order to consider it to be safe for human consumption (PHAC). Pork and poultry requires a slightly higher minimum internal temperature. In the case of sous vide, food is usually cooked at temperatures that are lower than 70^{o}C. As a result, the heating step, referred to as "mild heat pasteurization", requires enough time held at sufficient temperatures in order to achieve pasteurization and kill all vegetative bacteria. Therefore, time and temperature control is extremely important in the process of sous vide pasteurization.

Seafood. Due to the delicacy of seafood, it is one of the most easily overcooked food items with traditional cooking techniques. Therefore, sous vide styled seafood has gained wide popularity in recent years as it better preserves moisture, flavor and color of the seafood, especially fish. However, due to vulnerability of most fish items, restaurant chefs recommend cooking at temperatures of around 40-50ºC in order to obtain optimal texture and flavor of the fish (Picouet et al., 2010). This temperature will not achieve sufficient pasteurization, as pathogens such as *Salmonella spp.* will not be destroyed in the process. *Clostridium botulinum* is also a concern as it is a naturally occurring marine organism. As stated previously, *C. botulinum* can grow and proliferate anaerobically even in low temperatures, therefore poses a great risk to sous vide seafood items if proper temperature control is not in place. In addition to bacterial concerns, certain fish species are also at risk for parasites from their natural environment. Parasites are heat sensitive organisms; however, as sous vide fish does not usually achieve temperatures required to inactivate parasites, additional freezing controls are generally required (BCCDC, 2014).

Special Concerns Traditionally, solid cuts of meats such as beef, are considered to be safe on the "inside" because microorganisms only reside on the outside of the meat slice and will be destroyed during the cooking or searing process. However, new techniques such as mechanically tenderizing meat have recently been introduced. This technique uses machines or tools specifically designed to pierce meat and break connective tissues in order to improve the tenderness of meat when it is cooked (Government of New Brunswick, 2013). However, this practice allows surface contamination to enter the inside of the meat. Due to increased risks of contamination for mechanically tenderized meat, Health Canada and Public Health Agency of Canada recommends cooking temperature of minimum 71ºC for mechanically tenderized meat (2014). Sous vide cooking style rarely achieves a high enough temperature to kill the pathogens as per recommendations. In addition, Maillard Reaction is a well-known process used to produce flavor in cooked meats and seafood. This involves cooking meat at around 150ºC or higher to denature proteins on the surface of the meat, which is then recombined with the sugars present to produce color change and a "meaty" flavor (Exploratorium, n.d.). Many chefs will using this method to achieve rare, or medium-rare steak, as this process was thought to kill pathogenic organisms which only resided on the outside of the meat. However, due to the process of meat tenderization, this step is no longer effective in destroying surface pathogens that are traditionally the only concern in solid cuts of beef.

Legislations & Guidelines

There is currently no legislation regulating sous vide cooking in BC or Canada. However, the BC Centre for Disease Control Environmental Health Services and the BC Sous Vide Working Group developed the "Guidelines for Restaurant Sous Vide Cooking Safety in British Columbia" in 2014 in order to provide restaurant operators and chefs guidance on safe sous vide cooking. The guideline is based on recommendations and is not enforceable. However, under the Public Health Act, it specifies that "a person must not willingly cause a health hazard, or act in a manner that the person knows, or ought to know, will cause a health hazard" (2008). As a result, the guideline provides chefs and operators safe procedures on sous vide cooking that could prevent causing harm to the public.

Guidelines for Restaurant Sous Vide Cooking Safety in British Columbia. Due to the nature of the sous vide technique, operators proposing to serve sous vide food in their establishments are required to ensure that processes meet public health requirements. The facility needs to be properly equipped to handle and monitor the steps and processes involved in preparation, cooking, chilling and serving of sous vide food. Equipment onsite may include immersion circulators, water tanks, appropriate thermometers, sous vide vacuum packaging bags, and vacuum packaging machines. Operators must consult with their Environmental Health Officer before offering any food items cooked sous vide style (BCCDC, 2014).

According to the guideline, the minimum acceptable sous vide cooking temperature is 55ºC for all meats, with the exception of 60ºC for all poultry, held at an established amount of time. As with other food establishments, the food service intending to serve sous vide style food must have a food safety plan outlining the following criteria:

- Time & temperature settings of the immersion circulator
- Internal temperature of food for the sous vide cook step and duration of hold time during pasteurization
- Description of sous vide process in a food flow chart
- Temperature and time combinations must provide a $6.5\log_{10}$ reduction for bacteria for all sous vide pasteurized foods (poultry requires $7\log_{10}$ reduction)

In addition, temperature must be measured after food is removed from pouches and before being served to customers to account for any temperature changes (BCCDC, 2014).

Minimum Log Reduction. For all meats cooked sous vide style, a recommended minimum of $6.5\log_{10}$ reduction is required (minimum $7\log_{10}$ for poultry) (BCCDC, 2014). This means that the number of microorganisms needs to be reduced by approximately 3,200,000 to 10,000,000 in order to be safe for consumption (Cleaning Industry Research Institute, n.d.). For this to happen, food must be cooked to a certain temperature for a set period of time. For example, beef cooked sous vide style in the water bath at 60ºC will need to first reach the temperature of the water bath, then be held at that temperature for at least 12 minutes to achieve full sous vide pasteurization. Similar standards apply to seafood such as fish. Furthermore, fish that does not meet the $6.5\log_{10}$ reduction requirement during heating will require additional freezing controls before cooking in order to be control for parasite hazards (BCCDC).

Time and Temperature Relationship. Equilibrium cooking is the point at which “the internal temperature of sous vide food in an immersion circulator is at the same temperature as the water in the immersion circulator”. Equilibrium cooking can also be referred to as the Come Up Time (CUT), which is the “period of time it will take for food to reach a specific internal core temperature” (BCCDC, 2014). After the internal temperature of the food reaches CUT, it then needs to be held for a specified period of time long enough to reach log reductions of bacteria to achieve pasteurization. This is referred to as the “pasteurization time”. It is important to record both CUT and pasteurization time as this will determine if pasteurization was achieved after the food reached equilibrium cooking.

During the cooking process, sous vide food items immersed in water baths undergo gradual increase in temperature until they achieve the same temperature as the water bath. For example, the temperature profile of chicken breasts cooked sous vide style for 23 minutes at 66ºC, shows a mathematical relationship between time and temperature. The most rapid changes in temperature usually occur in the middle of the curve. The internal temperature rises steadily once the food is warmed up in the water bath, then plateaus and slows down as food approaches the target temperature in the immersion circulator (BCCDC, 2014). When low temperature sous vide food is cooked for a short time, it sometimes does not reach the target temperature due to plateauing of temperature at the end. Therefore, it is essential for temperature to be monitored throughout the cooking process to ensure food has time to reach the target pasteurization temperature before it is removed from the heat.

Pathways and Critical Control Points. Sous vide cooking require precisely controlled procedures and monitoring of Critical Control Points (CCPs) throughout the process. Critical control points are the “steps in food preparation processes where a hazard can be controlled" (BCCDC, 2009). The common CCP among all pathways is to chill the food after vacuum packaging (prior to cooking in circulating water bath). When all of the CCPs are met and controlled throughout cooking steps, the chance of sous vide preparation procedure causing foodborne illnesses is greatly minimized.

Additional Requirements for Seafood. The BCCDC Sous Vide Working Group recommends all sous vide style seafood to be cooked to full pasteurization to meet a $6.5\log_{10}$ reduction of bacteria. However, most seafood will not stand up well to higher temperatures, so chefs will choose to cook seafood in lower temperatures. In this case, two additional controls are required to be in place:

1. Fish, with the exception of certain species of tuna and farmed fish, must be pre-frozen for parasite reduction. (BCCDC, 2010).
2. Consumer disclosures are recommended via menu warnings, posted signs, and verbal disclosure by staff or the chef (BCCDC, 2014).

Public Health Significance

Informed Customers. Sous vide style cooking done incorrectly poses a food safety issue because (1) foods cooked at lower temperatures for extended periods of time (LTLT) potentially leads to growth of microbial pathogens, and (2), foods cooked at lower temperatures for shorter periods of time (LTST), may not achieve pathogen reduction requirements. Individuals at increasing risk of food-borne illnesses should be informed of food cooked sous vide style when dining to avoid developing serious complications. These individuals include: young children, the elderly, pregnant women and any individual with lowered immunities (Ministry of Primary Industries, n.d.). The NSW Food Authority's Sous Vide Guideline states that patrons can only request to have their food cooked essentially raw using the sous vide method if they are informed, healthy adults willing to accept the risks associated (2012). In BC, the guideline states that customer should be able to obtain disclosure in the form of menu warnings, label statements, table tents and verbal instruction by staff or the chef (BCCDC, 2014). Restaurants should take initiative in providing disclosure to its patrons in order to protect public health and avoid possible liability issues.

Roles and Responsibilities. In terms of food safety, both EHOs and restaurant staffs are responsible for keeping food safe for the public because inspection alone will not eliminate risks and hazards from facilities. A written food safety plan is required for sous vide products in order to aid EHOs and restaurant staff in understanding the procedures and precautions of food processing in sous vide cooking. Proper food safety precautions should be taken at every step along with regular monitoring of time and temperature during preparation in order to minimize any risks associated with sous vide cooking. Restaurants serving sous vide food should also offer frequent training to all employees who come in contact with sous vide food to ensure that all staff are aware of the steps of the food safety plan and critical control points are being met.

PURPOSE OF STUDY

A previous experiment was conducted in 2013 by formal BCIT student using chicken breast to examine if temperature reached pasteurization after cooking sous vide style. Results showed that the chicken breasts required an additional searing step in order to achieve the target pasteurization temperature (Do, 2013). However, seafood is usually cooked at lower temperatures and shorter cooking time than other types of meat. Therefore, the purpose of this research project was to monitor the internal temperature of a type of seafood (salmon) cooked from raw using the sous vide technique in order to examine if combined effects of sous vide cook step will achieve the desired temperature for sufficient pasteurization if a finishing (searing) step was performed.

METHODS

Methods

ACR SmartButtons. In order to setup Smartbutton for this experiment, TrendReader® for SmartButton software was installed on a PC computer. Following the TrendReader® for SmartBotton Software Reference Guide, SmartButton set up was as follows:

Data collection interval: 1 minute

Memory usage: Stop when full

Start time: For the purpose of this project, start time was set to 30 minutes prior to start process.

Fish Preparation. Large packages of whole salmon were taken out of the cooler, de-skinned, cut into portion sizes, scaled, placed in plastic bags and put into an ice bath until used. A small incision (approximately ½ inch) was made on each salmon portion and SmartButton was inserted into the thickest part of the fish. Time of insertion was recorded in the notebook.

Figure 1: Immersion circulator with vacuum packaged salmon in circulating water bath

Vacuum Packaging. Salmon portions were put into specific food grade plastic bags and placed into the Komet Plusvac 20 for vacuum packaging. The vacuum setting was set to maximum suction, as enough air must be evacuated to prevent air bubbles from developing during the heating process, which will cause the package to float in water bath. Sealed salmon packages were labeled and stored in the ice water bath until needed (MacDonald, personal communication, 2014).

Immersion Circulator. Calibration of immersion circulator was carried out before initiating the cooking process using a probing thermometer as the control. After calibration was completed, the immersion circulator was clamped onto the short side of the water tank filled with water. Temperature was set to 50.8°C as calibration showed that the immersion circulator was 0.8 degrees off from the control thermometer. Fish packages were not placed inside the tank until display on immersion circulator showed a temperature of 50.8°C.

Experiment Procedure. Vacuum packaged salmon packages were removed from ice and put directly into the hot water tank after immersion circulator displayed the target temperature of 50.8°C (Figure 1). Throughout the cooking process, the water bath was monitored to make sure that the packages were circulating in the water bath in order to achieve consistent cooking temperature. After the timer went off, salmon packages were removed from the tank and time of removal was recorded on the notebook. Time was recorded again as packages were opened and the fish samples were transferred to a pan for the searing step (Figure 2). Each sample of salmon was seared in the pan 220°C for 45 seconds. Fish samples were then transferred to a plate and allowed to sit for another 3 minutes before SmartButtons were removed. At the end of the experiment, SmartButtons were connected to the computer via USB interface cable for data retrieval.

Figure 2: Searing step setup with searing pan, gas stove, salmon, and infrared thermometer

RESULTS AND STATISTICAL ANALYSES

Data collected throughout this experiment were temperature values and were therefore continuous numerical data. All samples reached an internal temperature equivalent to the water bath (50ºC) within 20 minutes. However, only five out the 30 samples reached the target temperature of 70ºC after the final searing step. Figure 3 illustrates the temperature of the SmartButton as it a) drops when the fish is put into a ice bucket, b) rises as the salmon is cooked in the circulating water bath (at 50ºC), c) peaks and holds at the temperature of the water bath, d) rises abruptly when the fish is put into a frying pan for searing (at 220ºC), e) falls abruptly when fish is removed from the pan and set aside to cool to room temperature.

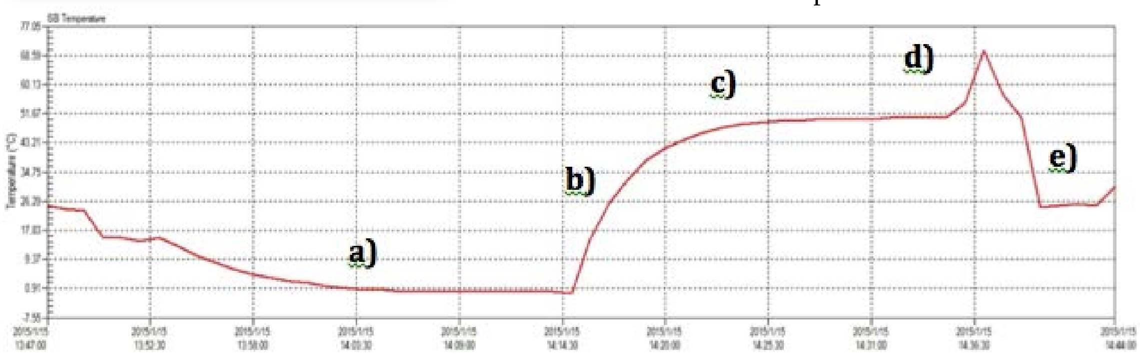

Figure 3: Temperature data graph extracted from SmartButton (Small 30g serving size)

Descriptive Statistics

Below are descriptive statistic values:

Descriptive Statistics	Values
Mean	61.7 ºC
Median	61.25ºC
Standard Deviation	5.90ºC
Mode	N/A

Inferential Statistics

Null and alternate hypotheses of this experiment were as follows:

H_o: Salmon cooked sous vide at 50ºC for 20 minutes will reach greater or equal to 70ºC (≥ 70ºC) after final searing step to achieve instantaneous pasteurization.

H_a: Salmon cooked sous vide at 50ºC for 20 minutes will not reach 70ºC (< 70ºC) after final searing step to achieve instantaneous pasteurization.

All 30 temperature data points were compared to a standard temperature as specified in the sous vide guideline to see if adequate temperature was reached. Therefore, a **one-sample one-tailed t-test** was used to determine if null hypothesis can be rejected (NCSS, 2012). A one tailed t-test was used because the temperature values collected were not expected to exceed the target value. The p-value was set at 0.05. Data collected was normal (cannot reject normality) for all three tests of assumption based on a sample size of 30.

Interpretations of Data. One-sample T-test report was generated from NCSS for peak temperatures AFTER final searing step. Test of assumptions showed that data was normally distributed under all assumption tests. Therefore, the One Sample T-Test was read (Heacock, 2014). The probability level (p-value) of median <70ºC was 0.00 with power of 1.00, which suggest that the results were statistically significant (null hypothesis was rejected). Therefore, it can be concluded that salmon cooked sous vide style at 50ºC for 20 minutes was not sufficient to achieve instantaneous pasteurization of 70ºC with an additional searing step for 45 seconds.

DISCUSSION

Sous vide and Foodborne Illnesses (FBI). Based on the results of this study, salmon cooked at the specific conditions of this experiment did not achieve pasteurization temperature even with a finishing (searing) step. Although the author did not find any documented outbreaks related to sous vide salmon, there are outbreaks associated with restaurant sous vide food currently under investigation. Concerns regarding these outbreaks mostly revolve around time and temperature abuse of sous vide prepared foods (McIntyre, L., personal communication, Feb 12, 2015). According to a previous study by Vipin Vikraman, salmon cooked at 53ºC for 20 minutes only achieved approximately 1.0log reduction in inoculated bacteria (2011). Another study by Gonzalez-Fandos, E., et al noted that *Staphylococcus aureus, Bacillus cereus, Clostridium perfringens* and *Listeria monocytogenes* were not found in any samples of salmon cooked sous vide at 90ºC for 15 minutes and stored at 2ºC for 45 days. However, the sensory characteristics and quality of the salmon were greatly diminished (2005). Seafood, among all other food items, is of special concern as it is often cooked at lower temperature for shorter time in order to preserve its quality. During an interview with a chef who is familiar with the procedures of sous vide, it was noted that even at the specific time and temperature of this experiment (50ºC for 20 minutes), the salmon was considered to be "overcooked" and not aesthetically appealing for service to customers (MacDonald, personal communication, January 2015). According to the Restaurant Sous Vide Guideline by BCCDC, the minimum temperature requirement for sous vide is 55ºC (2014), but chefs may be putting food items at risk by cooking at much lower temperatures in attempt to achieve aesthetic appealing appearances.

In relevancy to the results of this experiment, sous vide fish failing to achieve pasteurization temperature during cooking is required to comply with BCCDC's seafood controls. Although these standards have been proven to destroy parasites in fish for the service of sushi and sashimi products, it does not account for bacteria and other pathogens that may contaminate the fish during preparation (BCCDC 2014). Vikraman's study of sous vide salmon cooked under similar conditions observed bacteria numbers reducing from four million (4,677,351) to only two million (2,187,761) after cooking (2011). If pathogenic bacteria were among the two million bacteria left on the salmon after cooking, it is likely that this will cause foodborne illnesses in patrons consuming this fish. Contrasting to sushi and sashimi products, sous vide fish usually does not appear to be raw or undercooked. This may mislead consumers in thinking that the food they consume is fully cooked.

Fluctuation of Water Bath Temperatures. In Vikraman's study, it was noted that the water bath temperature fluctuated as much as 8-10^{o}C in 15-20 minutes interval while food was cooked in the circulating water bath. This was mainly due to adding large amount of refrigerated foods during the process of cooking items already in the water bath (2011). Similar effects were noted during the process of this experiment, although temperature fluctuations were only between 0.5-1.5^{o}C, as this experiment was done under a controlled environment to minimum fluctuation of temperature. However, during rush hours at busy establishments, chefs may be unintentionally lowering the temperature of the water bath by cooking too many refrigerated items at once in the circulating water bath.

The immersion circulator used for this experiment was widely used by professional chefs and some food processing establishments. However, other equipment frequently used for sous vide cooking may also play a role in the fluctuation of water bath temperature, as steamer ovens have shown to provide relatively less even heat distribution compared to immersion circulators (Sherd & Rodger, 1995). As mentioned in the literature review, one of the main advantages of the sous vide process is that the food item can be cooked at a specific lower temperature to achieve pasteurization as well as tenderization (BCCDC, 2014). Variation in equipment and adding of refrigerated samples may result in failure to achieve pasteurization as restaurants may not be measuring temperature constantly, or at all, while more frozen food items are added in an effort to speed up the production process. Therefore, it is important that restaurant operators and chefs maintain constant temperature in the circulating water bath in order to achieve appropriate come-up and pasteurization time for the food items. It is important to note that both come-up time and pasteurization time must be satisfied in order to consider the food to be fully pasteurized.

Research on Restaurant Sous Vide. Although sous vide has risen in popularity around the world, it has yet to become a customary cooking style for most restaurants. However, it is predicted that with increasing numbers of establishments adding sous vide food items to their menus, risks of foodborne illness outbreaks are also on the rise (McIntyre, personal communication, Feb 12, 2015). As more and more restaurants are adopting sous vide style recipes for their menus, the demand for knowledge on the risks and safe handling procedures of sous vide cooking is also increasingly high. Currently, many of the restaurants serving sous vide food items are higher quality, fine-dining establishments. Whether these establishments have better food safety standards in cooking sous vide is yet to be determined. Many of the past research studies on sous vide were microbiological ones based on cook-chill-store pathway after cooking food at high heat. There is very limited research available on the effects of sous vide cooking in the context of restaurant served foods. Do's research on sous vide chicken breast showed that chicken breast cooked sous vide at 66^{o}C for 23 minutes only achieved pasteurization temperature after a searing step (2013). However, the results of the current experiment indicated that salmon cooked at 50^{o}C for 20 minutes with an additional searing step was not able to achieve pasteurization. It is evident that more research is required to determine the specific time and temperature relationship and risks associated with each food item in order to remediate for possible food safety concerns.

LIMITATIONS

Salmon Portions. Due to budget and time constraints, this experiment was done with salmon portions of approximately 30 grams each, which were relatively smaller than normal serving sizes. As such, smaller pieces of salmon may have heated up faster in the water bath, reaching Come-Up Time faster than larger pieces. However, smaller portions of salmon still resulted in under-cooked (not fully pasteurized) salmon after the searing step, which suggests that bigger pieces of salmon under the same conditions will also not reach the target pasteurization temperature. The researcher was able to test two samples of salmon weighting 120 grams each as an additional experiment. Figure 4 shows a data collection graph for a larger portion salmon cooked under the same condition of the smaller pieces. The graph indicates that the maximum temperature only reached 48ºC after being in the water bath for 20 minutes (a), comparing to the target temperature of 50ºC. In addition, while the salmon piece was prepared to be transferred onto the frying pan for the final searing step, the temperature dropped slightly (b), and the subsequent searing step (c) was not long enough for the temperature to rise to higher than around 46ºC. This suggested that the larger portions of salmon would need to be in the water bath for longer than 20 minutes in order to reach the target temperature of the water bath. Also, further testing is required in order to examine if the searing step will make a statistically significant difference in pasteurization temperature for larger portions of salmon.

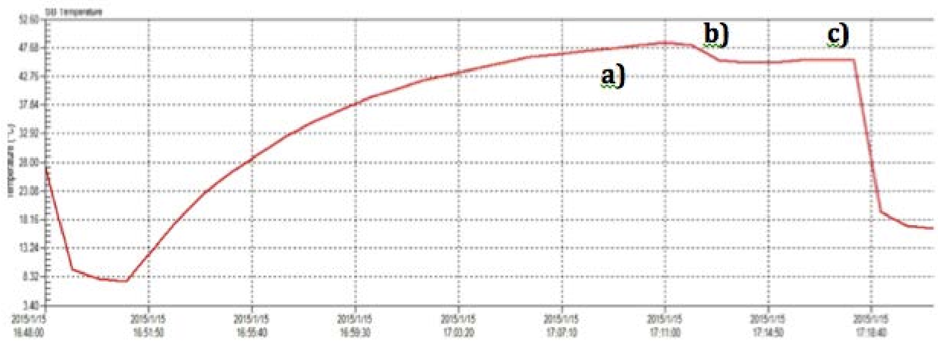

Figure 3: Temperature data graph extracted from SmartButton (Regular 120g serving size)

Minimum Data Collection Interval of SmartButtons. SmartButtons were chosen for their compact size and accurate temperature measurements. However, the shortest interval of data collection that can be set-up on the *TrendReader®* program was in 1-minute intervals. Because the searing step was only performed for 45 seconds, there may have been discrepancies during peak temperature recording. For example, if the salmon was put into the searing pan at 21:50, and taken out of the pan at 22:35 (after 45 seconds of searing), the SmartButton would have measured the temperature of the salmon only after 10 seconds of searing (SmartButtons takes the reading at 22:00 for 1-minute intervals). This could have been avoided if the searing time was increased to one minute instead of only 45 seconds, but this may result in overcooking of the salmon. As an attempt to minimize this limitation, each piece of salmon was seared for 45 seconds, and then taken out of the pan and set aside for at least 3 minutes before the SmartButton was removed from the salmon. This was done to minimize inconsistencies in temperature recording, as temperature will continue to rise for a few seconds after each sample is removed from the heat.

Final Searing Step. The final searing step was completed on a small pan on a portable gas stove. As such, there may have been temperature fluctuations during this step. Although an inferred thermometer was used to ensure that the pan was at 220ºC prior to placing each sample onto the pan, the position of where the sample was placed could have made a difference in transfer of heat. The researcher attempted to minimize temperature differences by placing samples as closely to the center of the pan as possible, however, limitations in equipment and personnel could have caused unintentional temperature fluctuations during the experimental process.

RECOMMENDATIONS

Based on this study, salmon cooked at the specific conditions did not achieve pasteurization with an additional searing step. Therefore, it is recommended that restaurant serving sous vide items take measures to prevent foodborne illness from occurring in their establishments. As such, Environmental Health Officers have the duty of helping operators throughout this process so that public health can be protected.

Public Health Significance. In recent years, efforts were put into encouraging disclosures when consuming undercooked or essentially raw food items and the potential for increased risk of foodborne illnesses. An example of a successful initiative is the customer disclosure program for raw or undercooked oysters implemented within the Vancouver Coastal Health Authority region since 2007 (VCH, 2007). However, the effort was not successful for sous vide items, as restaurants are generally reluctant in putting disclosures on their menus (McIntyre, L., Personal communication, Feb 12, 2015). As such, Environmental Health Officers (EHO) should work with restaurant operators and educate them in the specific risks associated with sous vide food items. Each category of food item prepared using sous vide (ie. meat, poultry, seafood, eggs) should have a food safety plan dedicated to the specific procedure of that item. The critical control points (CCPs) which contain specific time and temperature combinations that are required for achieving adequate pasteurization should be clearly identified and adhered to by the chef or other parties responsible. For cook-chill-reheat sous vide foods, the reheat temperature and duration should also be recorded, as it may be the sole pasteurization step. EHOs should also familiar themselves with the Restaurant Sous Vide Cooking Safety Guideline produced by BCCDC in order to better serve the restaurant operators throughout this process.

If food items do not achieve pasteurization throughout the sous vide cook step, in addition to ensuring that the fish comes from approved sources that meet the corresponding seafood control requirements, restaurant operators should also take the responsibility of informing its customers they may be consuming undercooked or essentially raw foods. This is of utmost importance for the "at risk" group, which includes young children, the elderly, pregnant women and people who are immune-compromised, as they are at more risk of developing adverse health effects resulting from foodborne illnesses. Advisories can be communicated through verbal communication, menu labels or table tents. It was also noted that some restaurants serving sous vide food items do not label food item as "sous vide" on their menus (Heacock, personal communication, Feb 5, 2015). The researcher noted a restaurant in Vancouver serving sous vide sablefish only labeled the menu as "Smoked Sablefish". This may be misleading to customers as they are not aware that the fish was prepared sous vide. Having customers informed will not only give customer information regarding the risks they are taking with the food they consume, it can also help the restaurant to avoid legal issues regarding foodborne illnesses caused by potentially under-cooked foods.

It was noted throughout the study that restaurants are often not up-to-date on their equipment calibrations. The immersion circulator used in this experiment was never calibrated, nor did the chef know the procedures of calibration. As sous vide cooking requires strict time and temperature control in order to ensure food safety throughout the process, chefs and restaurant owners are strongly encouraged to obtain and use accurate temperature measurement devices throughout the cooking process. Written procedures should be available for all staff as references when it comes to pasteurization temperatures for different food items. Good resources may include the Internal Temperature Holding Times for Meats and Poultry chart produced by BCCDC and other food safety plans produced for specific food items. In addition, it is important that chefs are constantly monitoring internal temperature of foods to ensure adequate pasteurization was achieved.

Lastly, the most effective approach to minimizing foodborne illness in restaurants and other establishments is adequate cleaning, sanitation, and safe food handling practices. Even when food is cooked at adequate temperature for sufficient amount of time, it is still prone to cross-contamination from multiple handling procedures. Most of the time, foodborne illnesses are not caused by one inadequate cooking step, but rather a combination of poor cleaning and sanitation, as well as a lack of knowledge or awareness on safe food handling. Therefore, it is important that restaurant owners and operators work together with the local health authority to actively prevent causing harm to the public by complying with food safety procedures and adapting relevant food safety recommendations.

FUTURE RESEARCH SUGGESTIONS

Due to time and resource constrains, this experiment was conducted on smaller pieces of salmon (30g) compared to regular serving sizes (approximately 120g). Further research can be performed on larger sizes of salmon to examine the come-up time and pasteurization time and temperatures in order to confirm the results of this study.

As this study examined the time and temperature relationship of sous vide salmon, other types of meat or vegetable can be examined to see if the results of this study is transferrable for other food items cooked sous vide under similar conditions.

Sous vide usually involve vacuum packaging the food item of interest and cooking in hot water bath. There are concern regarding the plastics that are used and whether it poses a chemical risk to the food if cooked in the water bath for long periods of time. Future research can be conducted to examine alternative methods of sous vide, for example, examining heat transfer for fish cooked in a sealed jar compared to vacuum-sealed bags.

As technology advances, better temperature monitoring equipment may be available. Future research can be conducted to compare the efficiency and appropriateness of different temperature monitoring devices to better obtain accurate internal temperature of sous vide food.

CONCLUSION

According to the results of this study, salmon cooked at 50ºC inside a circulating water bath for 20 minutes with an additional searing step at 220ºC for 45 seconds did not achieve appropriate target pasteurization temperature (70ºC). Therefore, salmon served under this condition must undergo adequate freezing control for parasite reduction (-35ºC for 15 hours or -20ºC for 7 days) (BCCDC, 2014). Safe food handling procedures should be emphasized to minimize cross contamination of the fish as the condition of the sous vide process favors microbial survival and multiplication. Also, restaurants serving sous vide food items are encouraged to inform their customers, especially the “at risk” group, about the risks associated with consuming undercooked or essentially raw food.

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COMPETING INTEREST

The authors declare that there are no competing interests.

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