Investigation on the Cold Temperature Retention Capacity of the 1.5 Liter Thermos® Double Wall Vacuum Stainless Steel Thermal Container when Filled to Different Volumes and with Different Types of Milk

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ABSTRACT

Introduction: Customers sometimes question the freshness of milk inside thermal containers in coffee shops. Milk that is kept between 4°C to 60°C can support the growth of pathogens, hence it should be kept below 4°C. Thermal containers are often advertised as being able to retain the temperature of their contents for a prolonged period of time. Yet, the extent of their temperature retention capacity is not clearly defined by the manufacturers. This study investigated the effectiveness of the 1.5 Liter Thermos® Double Wall Vacuum Stainless Steel Serving Carafe thermal container in keeping milk at ≤4°C when it was filled to different volumes and with different types of milk over a nine hour period.

Methods: Four tests were carried out in this study: The 1.5L Skim Milk, The 1.5L Creamo, The 0.75L Skim Milk and The 0.75L Creamo Test. For each test, the milk was placed into the 1.5L Thermos® Double Wall Vacuum Stainless Steel Serving Carafe with the initial temperature between 3.1°C to 3.4°C. Change in temperature was recorded for nine hours using the Thermocouple data logger.

Results: The descriptive data demonstrates that the mean temperatures over the nine-hour period for The 1.5L Skim Milk Test, The 1.5L Creamo Test, The 0.75L Skim Milk Test and The 0.75L Creamo Test were 4.41±0.88°C, 4.51±0.95°C, 5.59±1.52°C and 6.05±1.77°C, respectively. MANOVA results suggested that “volume”, “time”, “type of milk”, “volume and time”, “volume and type of milk”, “time and type of milk”, and “volume, time and type of milk” did have effects on the temperature retention capacity of the thermal container with p-values <0.05. The temperatures of all samples were <4°C at hour zero. All of the samples’ temperatures began to increase once they were inside the thermal container and all of the samples entered the danger zone (>4°C) after four hours. A Chi Square test was conducted to determine whether Creamo or skim milk was safer (≤4°C) from hour one to four. Results showed that 123/240 (51%) skim milk and 110/240 (46%) Creamo samples were safe, but the result was not statistically significant.

Conclusion: This study’s results indicate that the tested thermal container had a better cold temperature retention capacity when it was filled up (1.5L) compared to when it was only half filled (0.75L). In addition, when the thermal container was filled with skim milk, it also had a better cold temperature retention capacity compared to Creamo. Finally, this specific thermal container was not successful in maintaining the temperature of milk out of the danger zone (≤4°C) after four hours. These results should be disseminated to Environmental Health Officers whose job it is to keep the public safe from foodborne illnesses. As well, policies should be established pertaining to time permitted to keep milk in thermal containers.

Keywords: Thermos, thermal container, milk, Creamo, coffee, temperature

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INTRODUCTION

Coffee is one of the most popular hot beverages in North America. Because coffee is bitter, many coffee drinkers like to add milk to obtain a rich and creamy flavor. For customers' convenience, coffee shops usually put the milk in thermal containers and leave the milk on the self-serve counter. The turn-over rate of milk in busy coffee shops is high, however, this is simply not the case for less busy coffee shops. Although thermal container manufacturers have asserted that their products have the capacity to keep liquid cold for an extended period of time (Thermos®, 2014a), there is not enough evidence to support this claim. Therefore, it remains unknown as to whether thermal containers in less busy coffee shops can keep the temperature of their milk at a low enough temperature. This is a concern because milk is considered as a potentially hazardous food that can easily support the growth of pathogenic microorganisms under temperature abuse conditions (Nada, Ilija, Igor, Jelena & Ruzica, 2012).

PURPOSE OF STUDY

The purpose of this study was to determine the effectiveness of the Thermos® Double Wall Vacuum Stainless Steel Serving Carafe thermal container in keeping milk and Creamo out of the danger zone at ≤4°C for twelve hours. The container's cold temperature retention capacity when it is filled up to different volumes was assessed because the amount of air inside the container can play a role in determining the speed of heat exchange. As well, in coffee shops, since customers are constantly pouring out the milk, the thermal containers at the self-serve counter are not necessarily full at all time. This study simulated the realistic situation in coffee shops and evaluated the cold temperature retention ability of the 1.5 Liter Thermos® Double Wall Vacuum Stainless Steel Serving Carafe when it is filled to different volumes and with different types of milk.

LITERATURE REVIEW

Pasteurized Milk

The nutrient contents, water activity, and pH of milk are ideal for the rapid growth of pathogenic microorganisms. Because milk has the potential to cause sickness in humans, all milk sold in Canada has to be pasteurized (Milk Industry Act, 2014). Nevertheless, pasteurization is different from sterilization, where all microorganisms are killed. A small amount of microorganisms can still survive after pasteurization (Angulo, LeJeune, & Rajala-Schultz, 2009). As a result, it is important for thermal containers in coffee shops to hold milk at ≤4°C in order to prevent the multiplication of pathogens.

Food Safety

The Canadian Food Inspection System Implementation Group's Food Retail and Food Services Code (2004a) defines a potentially hazardous food as any food or beverage that can support the growth or multiplication of disease-causing microorganisms. Acidity, moisture contents (water activity) and nutrient contents of a food are factors that determine whether or not the food is considered as a potentially hazardous food. Any food with a pH of >4.6 and water activity (Aw) of >0.85 is categorized as potentially hazardous food (Canadian Food Inspection System Implementation Group, 2004a). Based on this definition, milk, which has a pH of 6.3 – 8.5 and a water activity of 0.98, is a potentially hazardous food (US Food and Drug Administration, 2012). In addition, the rich nutrient contents of milk can support the rapid growth of microorganisms. For example, a glass (250mL) of 2% milk contains 5 grams of fats, 12 grams of carbohydrates and 9 grams of proteins along with various vitamins and minerals (Dairyland, 2013). This clearly suggests that milk has very high nutrient contents and such nutrient composition is ideal for the multiplication of pathogens. Even though milk has the perfect acidity, moisture contents and nutrient contents to support the growth of pathogens, if the temperature of the milk is maintained properly, the multiplication of pathogens can be inhibited.

Legislation and Guidelines

According to Section 11 of the BC Food Premises Regulation (2013), coffee shop operators must obtain the milk from an approved source. This will ensure that the milk is being handled, pasteurized, packaged and transported properly before reaching the coffee shops. Because milk is a potentially hazardous food, operators must also follow section 14 of the BC Food Premises Regulation (2013) which requires food handlers to store the milk at ≤ 4°C or ≥ 60°C to prevent the growth of pathogens. While the milk is being served to customers, operators should regularly monitor and keep record of the temperature of milk in the thermal containers (Canadian Food Inspection System Implementation Group, 2004b). The Food Retail and Food Services Code (2004b) states that "potentially hazardous foods that are intended for immediate consumption, may be displayed or held for service at room temperature but for no more than 2 hours, after which, they should be discarded". In other words, if milk, which is used for immediate consumption, has been left at > 4°C or < 60°C for more than 2 hours, then it should be discarded (Canadian Food Inspection System Implementation Group, 2004b).

Growth of Microorganisms

When milk is still in the mammary gland of the cattle, the milk is normally sterilized unless the cow has mammary gland infection (Angulo et al., 2009). If milk is sterilized, it contains no microorganisms. Milk can become contaminated with bacteria and microorganisms during and after milk extraction (Angulo et al., 2009). For example, the normal bacterial flora that is within the cow's milking ducts can get into the raw milk during extraction. As well, feces, soil and unsanitary equipment in the dairy farm can contaminate the raw milk after the milk has been extracted (Nada et al. 2012). Milk pasteurization is a process by which milk is heat treated at 72°C for ≥16 seconds in order to reduce the concentration of pathogens to a level that is insufficient to cause diseases in human. However, pasteurization is different from sterilization, where milk is heated to 100°C to kill all microorganisms (Dairy Farmers of Manitoba, 2013). Milk that is served in commercial settings in Canada is typically only pasteurized but not sterilized. Therefore, under temperature abuse conditions, the microorganisms that survive pasteurization can begin to multiply in milk and eventually achieve a disease-causing concentration. All of these studies confirm that it is crucial to keep milk out of the danger zone at or below 4 °C because the warm temperature, the rich nutrient contents and the pasteurized characteristic of milk are ideal for pathogens to grow and multiply efficiently.

Escherichia. coli family

Escherichia coli O157:H7 is a pathogen that is originated from the gut of cattle. This organism is mostly associated with inadequately cooked ground beef and raw milk. E. coli O157:H7 is a concern for milk because on the dairy farm, milk can easily become contaminated by fecal matters, a major source of E. coli O157:H7 (Doyle, 1991). E. coli O157:H7 is one of the most virulent types of E. coli bacteria (Mead & Griffin, 1998) Despite the fact that some E. coli bacteria are considered as the normal flora in human gastrointestinal tract, E. coli O157:H7 bacteria can lead to hemorrhagic colitis (bloody stools) and perhaps hemolytic uremic syndrome (HUS) which is characterized by kidney failure and sometimes neurological damage (Doyle, 1991). Fortunately, E. coli O157:H7 and other E. coli bacteria are not heat resistant. These bacteria are usually not presented in pasteurized milk unless there is post-pasteurization contamination such as fecal contamination by food handlers (Mead & Griffin, 1998).

Researchers have attempted to simulate post-pasteurization contamination by inoculating E. coli O157:H7 into milk in order to investigate the organism's ability to grow in milk at different temperatures. In one study, E. coli O157:H7 was able to multiply to a significant concentration at 8°C but was incapable of multiplying or producing toxin when the milk was stored at 5°C (Massa, Goffredo, Altieri, & Natola, 1999). In another study, it was found that both pathogenic E. coli O157:H7 and non-pathogenic E. coli strains were unable to multiply significantly in whole milk stored at 4°C for 24 hours. However, both E. coli O157:H7 and non-pathogenic E. coli strains were able to grow from 4-5 log CFU/mL to 8-9 log CFU/mL after 24 hours of storage at 20°C (Mamani, Quinto, Simal-Gandara, & Mora, 2003). Finally, the study by Wang, Zhao, & Doyle (1997) indicates that E. coli O157:H7 inoculated in milk increased by 1-2 log CFU/ml at 8 °C after 4 days and 1.0 x 10^8 log CFU/mL at 15°C after 7 days. Their study also showed that inoculated E. coli O157:H7 multiplied more rapidly in pasteurized milk compared to unpasteurized milk because of the lack of other competitive bacteria in pasteurized milk.

Listeria. monocytogenes

Listeria. *monocytogenes* is an organism that is normally associated with cheese products and raw milk but this organism can also be associated with pasteurized milk in some instances (Fleming et al., 1985). In 1983, fourteen people died in Massachusetts after consuming a certain brand of pasteurized milk. The health department stated that the pathogen was originated from listeriosis infected cows at the dairy farm. Although pasteurization was done properly, the organism survived the heat treatment. Investigators concluded that the outbreak occurred because L. *monocytogenes* is somewhat heat resistant, is a psychrophile that can multiply to a significant amount at <4°C and is infectious at a low dosage (Fleming et al., 1985). This outbreak demonstrates that pasteurization is sometimes incapable of killing all pathogenic microorganisms. As a result, consumers and food handlers must keep the milk at the adequate temperature to avoid the reactivation or multiplication of pathogens.

The use of Thermal Containers

In order to fulfill the food safety requirements, coffee shops often keep their milk in thermal containers aiming to keep the milk within the safe temperature range. Although manufacturers of thermal containers advertise that their containers can retain temperature of food and beverage for as long as 6-24 hours (Thermos®, 2014a), the actual meaning of temperature retention is not clearly defined. As well, the manufacturers usually do not provide in the description of their products a clear definition or measurement on what they mean by hot and cold. Does temperature retention mean that liquid that is 4°C when it is transferred into the thermal container will remain at 4°C after 12 hours? Or does it mean that the liquid will merely remain cool at around 10°C after 12 hours? The temperature of the milk in the refrigerator is around 2-3 ºC. When the milk is taken out from the refrigerator, the temperature of the milk can rapidly raise. If the thermal container cannot effectively retain temperature, the temperature of the milk can quickly increase from 2 - 3 ºC to 4 ºC. If this is the case, the milk will then reach the danger zone where microorganisms can start to multiply and cause illnesses in humans.

Thermos® Technology

Normally, when a cold item is placed in a hotter environment, the cold item raises its temperature quickly because of thermal energy exchange. The cold item will lower the temperature of the hotter environment while the hotter environment will raise the temperature of the cold item until they reach equilibrium meaning that they have the same temperature (NASA, 2014).

With the help of a good thermal container, the process of thermal energy exchange can be slowed down. Depending on the design and the material, different thermal containers have different temperature retention capacities (Thermos®, 2014a). A double wall foam vacuum design thermal container can retain the temperature of cold items for as long as 6 hours and hot items for as long as 3 hours while the double wall glass vacuum and the double wall stainless steel vacuum thermal container can maintain the temperature of cold and hot items for as long as 24 hours (Thermos®, 2014a). This heat retention technology utilizes no electricity. Instead, it is simply the double wall vacuum insulation design that helps to retain the temperature and the freshness of the food and beverage. The airless environment between the internal and external wall of the thermal container prevents air exchange from happening (Thermos®, 2012). As a result, the temperature of food or beverage inside the thermal container will not be lost to the surrounding environment.

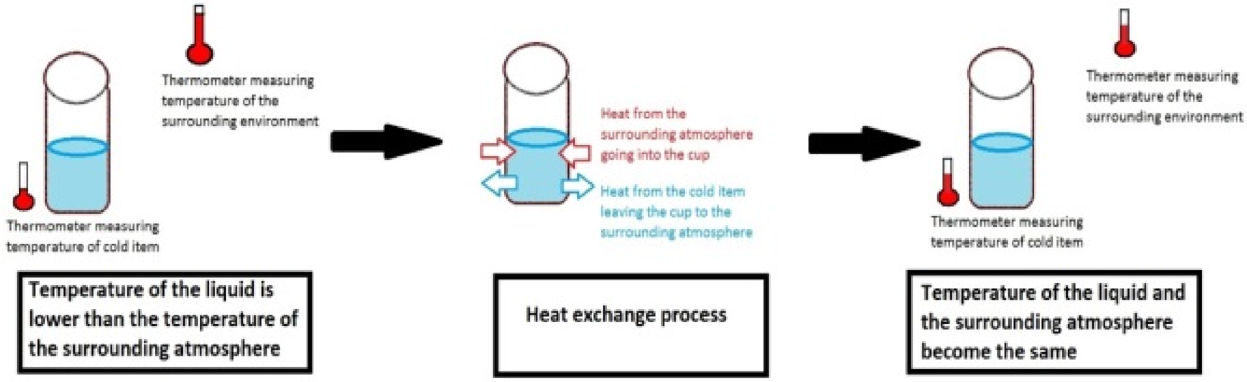

Figure 1. Heat Exchange Illustration

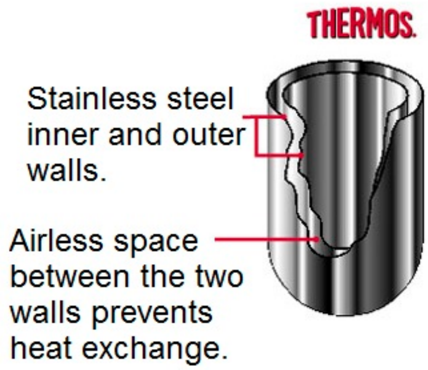

Figure 2. Thermos® Heat Retention Technology (Thermos®, 2012)

Manufacturer's Claim

Reviews and studies on the effectiveness of thermal containers can sometimes yield very different results. For example, Schindel's (2014) online review has confirmed the claim made by Thermos® that their products can retain the temperature of food and beverages for a prolonged period of time. This Thermos® user showed that her Double Wall Stainless Steel thermal beverage container could keep an ice drink cold for 12 hours with ice remaining in the container even at the end of the experiment (Schindel, 2014). In contrast, scientific research studies by previous BCIT Environmental Health students do not support the claim made by Thermos®. In one study, the researcher discovered that the Thermos® Double Wall Stainless Steel Vacuum thermal food container could not keep the temperature of food above 60ºC for more than six hours (Chu, 2013). Another study also reported similar results where experimented thermal containers failed to keep food at above 60ºC for more than four hours (Kwok, 2011). All of the studies mentioned above utilized the same Thermos® Double Wall Stainless Steel technology but results were contradicting. Although Schindel focused on evaluating the cold temperature retention capacity of the container while Chu and Kwok conducted their experiment on hot food, the different results from these studies make it logical to question whether the Thermos® containers truly have the same level of performance as advertised. Furthermore, Schindel's review was a consumer feedback where no temperature measurement standard procedures were employed. On the contrary, Chu's and Kwok's studies were done using standard procedures and statistical analysis. With this in mind, consumers and food handlers are encouraged to test their thermal containers and see if they can live up to the performance as suggested by the manufacturers.

The thermal container that will be used in this study is the Thermos® Double Wall Vacuum Stainless Steel Serving Carafe. This specific product is said to have a hot and cold temperature retention capacity of 24 hours (Thermos®, 2014b). This study will investigate whether the true cold temperature retention capacity of this thermal container live up to the performance as suggested by Thermos®.

Role of Environmental Health Officers (EHO)

Every year Health Authorities in British Columbia are required to give each restaurant a food premises inspection priority ranking (Fraser Health, 2008). This ranking will determine the number of times per year that EHOs will be going to the premises for inspection. Because of the minimum preparation work that is required to make beverages and baked products, coffee shops are generally given a low priority ranking which means that EHOs will only perform one inspection per year. Although EHOs do check the temperature of milk in thermal containers during the coffee shop inspection, EHOs simply cannot capture every temperature abused incident. It may be more effective if EHOs can ask operators of coffee shops questions such as:

- How long does it take them to finish the milk in the self-serve counter?
- What type of thermal container do they use?
- Do they know how effective the container is at keeping the temperature of milk?
- How often do they replace the old milk in the self-serve counter with fresh milk?
- Do they keep a time-temperature log for the milk?
- What do they do with the milk that has become "warmed"?

The answers to these questions will help EHOs determine whether the operator at the coffee shops is handling the milk properly. If EHO suspects that the operator is mishandling the milk, the EHO can educate the staff about correct handling procedures such as having a time-temperature log, placing only a small amount of milk on the self-serve counter, installing a small refrigerator on the self-serve counter or simply keeping the milk behind the counter in the cooler for slower coffee shops (S. Joseph, personal communication, October 5 2014). By doing the above, coffee shops will be able to better preserve the quality of milk and avoid foodborne illnesses related to milk.

METHODS

Standard Procedures

In this study, the 1.5 Liter Thermos® Double Wall Vacuum Stainless Steel Serving Carafe thermal beverage container was used to test its temperature retention capacity. This thermal container can be purchased in most Canadian supermarkets, drugstores or online at the Thermos website. It was claimed by the manufacturer to have 24 hours of hot and cold temperature retaining capacity (Thermos®, 2014a). In addition to the thermal container, 1.5 liters of Foremost skim milk and Creamo were purchased at a local supermarket. Both types of milk were placed inside a home refrigerator to achieve an initial temperature of 3.1°C – 3.4°C.

The initial temperature and the change in temperature of the milk in the thermal container were measured using a probe thermometer and the Cole Parmer Model Thermocouple thermometer, respectively. The Thermocouple is an automatic temperature recorder consisting of two thin wires which join together at the sensor end (Omega, 2014). The specific wire that was used for this study was the Type K wire. Both thermometers were calibrated using the ice water mixture. Refer to the “Calibration” section for detailed descriptions.

Figure 3. Set-up of the thermal container

A probe thermometer was used to measure the initial temperature of the milk to ensure that it was within 3.1°C – 3.4°C. If the temperature did not achieve the ideal range, the milk was placed back into the refrigerator until the ideal temperature was achieved. After the ideal temperature was achieved, an appropriate amount of milk (1.5L or 0.75L) was measured using the Pyrex® two liter beaker. The thermal container was rinsed with cold tap water and the milk was transferred in subsequently.

The temperature of the milk inside the thermal container was measured using the Thermocouple. The sensor wire of the Thermocouple was inserted into the thermal container through the small pouring mouth which was part of the cap of the container (Figure 3) while the other end was plugged into the data logger. The wire end of the Thermocouple was adjusted so that it was submerged to the bottom of the container. The data logger was set to record the temperature of the milk hourly. The timer began after the cap of the thermal container was securely locked. Meanwhile, the Thermocouple also began to record the first measurement at hour zero. Temperature was recorded hourly for nine hours. Afterwards, the set-up was disassembled and data were printed using the Thermocouple infrared printer.

Four different temperature measuring tests were carried out in this research study: "The 1.5L skim milk test", "The 1.5L Creamo test", "The 0.75L skim milk test" and "The 0.75L Creamo test". For each test, the above steps were repeated. In addition, thirty runs were conducted for each of the four tests to ensure reliability. Finally, data obtained were entered into Microsoft Excel and NCSS for statistical analysis.

Note: Two 1.5 Liter Thermos® Double Wall Vacuum Stainless Steel Serving Carafes and Thermocouple data loggers were used so that two runs could be carried out simultaneously to increase the efficiency of the experiment. Although the two thermal containers were of the same brand and model, they had slightly different temperature retention capacities. This confounding factor was addressed by swapping the containers half way through the thirty runs. For example, if the first fifteen runs of the "1.5L skim milk test" were carried out using container A then next fifteen runs would be carried out using container B.

RESULTS

The purpose of this study was to measure the change in the temperature of milk inside the double wall vacuum thermal container under different conditions (ie. different types of milk and volumes) over a nine-hour period. This research was a quantitative study. Temperature, the information that was gathered from the experiment using the Thermocouple, was considered as a continuous numerical data because the measurement was on a continuum

(Heacock & Sidhu, 2014a). The Thermocouple was used to record the temperature of milk inside the thermal container hourly for nine hours while the container was filled with “1.5L skim milk”, “1.5L Creamo”, “0.75L skim milk” or “0.75L Creamo”. Thirty runs were conducted for each of the four tests and results were entered into Microsoft Excel and NCSS to generate descriptive and inferential statistical data, respectively.

Descriptive Statistics

The Thermocouple data logger was used to record the hourly change in temperature over the nine hour duration of each run and a total of thirty runs were carried out. An infrared printer was used to receive and print out the data collected. Finally the data were manually transferred to Microsoft Excel to generate the following descriptive data:

The nine-hour mean temperatures for the “1.5L skim milk test”, “1.5L Creamo test”, “0.75L skim milk test” and “0.75L Creamo test” were 4.41±0.88°C, 4.51±0.95°C, 5.59±1.52°C and 6.05±1.77°C, respectively.

From hour zero to two, the mean temperatures for the “1.5L skim milk test”, “1.5L Creamo test”, “0.75L skim milk test” and “0.75L Creamo test” were 3.46±0.26°C, 3.45±0.24°C, 3.75±0.24°C and 3.87±0.56°C, respectively

From hour three to four, the mean temperatures for the “1.5L skim milk test”, “1.5L Creamo test”, “0.75L skim milk test” and “0.75L Creamo test” were 4.09±0.32°C, 4.15±0.29°C, 5.08±0.39°C and 5.49±0.4°C, respectively

From hour five to seven, the mean temperatures for the “1.5L skim milk test”, “1.5L Creamo test”, “0.75L skim milk test” and “0.75L Creamo test” were 4.84±0.55°C, 4.98±0.55°C, 6.42±0.57°C and 7.03±0.57°C, respectively

From hour eight to nine, the mean temperatures for the “1.5L skim milk test”, “1.5L Creamo test”, “0.75L skim milk test” and “0.75L Creamo test” were 5.53±0.43°C, 5.76±0.41°C, 7.6±0.47°C and 8.39±0.38°C, respectively.

Hour	1.5 skim	1.5 cream	0.75 skim	0.75 cream
Hour 0-9				
Mean	4.411	4.510	5.579	6.072
Standard Deviation	0.878	0.947	1.517	1.777
Count	300	300	300	300
Hour 0 -2				
Mean	3.456	3.453	3.749	3.880
Standard Deviation	0.259	0.235	0.460	0.573
Count	90	90	90	90
Hour 3-4				
Mean	4.085	4.145	5.085	5.523
Standard Deviation	0.324	0.286	0.386	0.382
Count	60	60	60	60
Hour 5-7				
Mean	4.837	4.979	6.406	7.062
Standard Deviation	0.555	0.546	0.567	0.554
Count	90	90	90	90
Hour 8-9				
Mean	5.530	5.758	7.580	8.422
Standard Deviation	0.432	0.415	0.484	0.382
Count	60	60	60	60

Figure 4 - Descriptive Statistic for Skim Milk and Creamo temperatures over the nine-hour period

Inferential statistics

There were three independent variables (time, volumes and types of milk) and one dependent variable (temperature of milk) in this study. Data for the dependent variable was obtained from the Thermocouple. They were entered into Microsoft Excel and then transferred to NCSS. Multivariate analysis of variance (MANOVA) and the Chi square contingency test were used to analyze the data.

The hypothesis was that volumes, time and type of milk have an effect on the temperature retention capacity of the 1.5 Liter Thermos®

Double Wall Vacuum Stainless Steel Serving Carafe.

Statistical Package Used

Microsoft Excel and NCSS were used for this research study.

Interpretation of Results

Statistical data presented in this report were obtained using the Thermocouple data logger and transferred to Microsoft Excel and NCSS. Results from NCSS (Appendix B) showed that the separated effects of “volume”, “time” and “type of milk” on the temperature of milk inside the thermal container were significant with P values<0.05. As well, the cumulative effects of “volume and time”, “volume and type of milk”, “time and types of milk”, and “volume, time and type of milk” on the temperature of milk were also significant. The powers of “volume”, “time”, “type of milk”, “volume and time”, “volume and type of milk”, “time and types of milk” were 100% whereas the power for “volume, time and type of milk” was 96.5%. Since the power for all variables were either 100% or very high, it was unlikely that chance played a role in the findings for the above factors (ie. these factors resulted in statistically significant differences in milk temperature) (Heacock & Sidhu, 2014b).

Throughout the study, the temperatures of milk from most of the four tests exceeded the danger zone (4°C) after four hours. An additional statistical test, the Chi Square Contingency Test, was conducted to determine whether skim milk or Creamo was safer (ie. <4°C) during hour one to hour four. This time frame was considered because this was the time period with both <4°C (safe) and >4°C (unsafe) samples. Therefore, the data could be used to determine which type of milk had better cold temperature retaining capacity. The results from the Chi Square Contingency Test (Figure 6) showed that 123 skim milk samples were safe (≤4°C) while only 110 Creamo samples were safe (≤4°C) between hour one to hour four. However, the result was not significant as the p-value was greater than 0.05.

Analysis of Variance Table for Temp			
Source		**Prob Level**	**Power**
Term	**DF**		**(Alpha=0.05)**
A: Vol	1	0.000000*	1
B: Time	9	0.000000*	1
AB	9	0.000000*	1
C: Type_of_milk	1	0.000000*	1
AC	1	0.000000*	1
BC	9	0.000000*	1
ABC	9	0.002518*	0.965339
S	1160		
Total (Adjusted)	1199		
Total	1200		
* Term significant at alpha = 0.05			

Figure 5. MANOVA Report

Counts Table					
	Safe	Unsafe	Total		
cream	110	130	240		
skim	123	117	240		
Total	233	247	480		
Tests for Row-Column Independence (skim_cream by safe_or_not)					
H0: "skim_cream" and "safe_or_not" are independent.					
H1: "skim_cream" and "safe_or_not" are associated (not independent).					
Test	Type	Chi-Square Value	DF	P-Value	Reject H0 at α = 0.05?
Pearson's Chi-Square	2-Sided	1.4095	1	0.23513	No
Yates' Cont. Correction	2-Sided	1.201	1	0.27312	No
Likelihood Ratio	2-Sided	1.4102	1	0.23502	No
Fisher's Exact	2-Sided			0.2731	No
Fisher's Exact (Lower)	1-Sided			0.13655	No
Fisher's Exact (Upper)	1-Sided			0.8995	No

Figure 6. Chi square contingency Report

DISCUSSION

All of the thirty samples from each of the four tests in current study had an initial temperature of 3.1°C to 3.4°C when they were transferred to the 1.5 Liter Thermos® Double Wall Vacuum Stainless Steel Serving Carafe thermal container. The results showed that the thermal container could not maintain the temperature of milk at below 4°C for more than four hours. This can be a food safety concern because milk is a potentially hazardous food that can support the multiplication of disease-causing microorganisms when its temperature is within the danger zone (4°C -60°C). The data obtained from the current study is consistent with similar studies done by previous BCIT Environmental Health students. In the study conducted by Kwok (2011), the experimented thermal food containers failed to maintain the temperatures of chicken noodle soup out of the danger zone at above 60°C after four hours. Similarly, Chu (2012) found that the tested thermal containers could not maintain the temperatures of macaroni and cheese at above 60°C for more than three hours. Although the tested thermal containers were claimed by the manufacturers to have more than twelve hours of hot and cold temperature retention capacities, results from current and previous studies indicated that the tested containers could merely slow down by a certain extent the heat exchange between the contents inside and the environment outside.

Results from this study revealed that the 1.5 Liter Thermos® Double Wall Vacuum Stainless Steel Serving Carafe thermal container failed to maintain the temperature of both skim milk and Creamo at <4°C for more than four hours; however, the container was capable of keeping the milk at a reasonably cold temperature over the nine-hour period. For the samples with full contents (1.5L), the mean temperatures for skim milk and Creamo at hour nine were 5.68±0.43°C and 5.89±0.40°C, respectively. On the other hand, for the samples with half contents (0.75L), the mean temperatures for skim milk and Creamo at hour nine were 7.8±0.46°C and 8.68±0.27°C, respectively. The observed results from this study were consistent with a non-scientific consumer's feedback that was posted online by Schindel. Both the current study and Schindel's experiment on the Thermos® Double Wall Vacuum Stainless Steel thermal containers resulted in liquid contents that were still considered cold after nine and twelve hours, respectively. (Schindel, 2014).

Results from the four tests conducted in this study indicated that there was a difference between the mean temperatures of skim milk and Creamo. For both of the 1.5L and the 0.75L Skim Milk Tests, their nine-hour mean temperatures were lower than the 1.5L and the 0.75L Creamo Tests. Observed differences could be explained by the term "Specific Heat Capacity". Specific heat capacity refers to the amount of energy required to raise the temperature by 1°C. According to Spreer (1998), skim milk has specific heat of 3977.5 J/Kg°K while Creamo has specific heat of 3516.9 J/Kg°K, meaning that less energy is required to heat up or cool down the Creamo by 1°C compared to skim milk. The patterns observed in this study were the same as the trends predicted by the specific heat capacity rule where Creamo, which had a lower specific heat capacity, warmed up faster than skim milk, which had a higher specific heat capacity, even though both types of milk were placed under the same conditions.

Results from this study revealed that the Thermos® Double Wall Vacuum technology was incapable of keeping milk out of the danger zone at <4°C for the period of time advertised by the manufacturer. Since many coffee shops use thermal containers with the same double wall technology, there are possibly food safety concerns regarding whether these containers have the capacity to maintain temperature of milk within the safe zone. As mentioned previously, milk has the pH, water activity and nutrient contents that are ideal to support the growth of pathogens. Pathogens can multiply if the milk is not maintained at temperatures out of the danger zone (<4°C or >60°C). Coffee shop operators rarely monitor the temperature of the milk inside the thermal containers because staff are often busy serving customers. This is a risky practice because milk in thermal containers are meant to be used for immediate consumption meaning that there will be no further cooking steps to kill pathogenic microorganisms. Customers consuming milk with significant amounts of microorganisms are at risk of getting foodborne illnesses. The older food safety guideline, Food Retail and Food Services Code, states that potentially hazardous foods that are used for immediate consumption should be discarded two hours after the foods have been placed at room temperature (Canadian Food Inspection System Implementation Group, 2004). In contrast, a newer and less stringent guideline developed by the BC Center for Disease Control (BCCDC) indicates that operators may be allowed to keep their ready-to-eat potentially hazardous foods for up to four hours if the following conditions are met:

1.) The premises are reasonably clean to protect the food from contamination
2.) The ambient temperatures are less than 24°C
3.) The food has to be time labelled
4.) The food has to be less than 4°C when it leaves the refrigerator

The guideline from BCCDC permits for a longer holding period than the Food Retail and Food Services Code because various studies have shown that microorganisms multiply slowly at temperatures below 24°C. Therefore, BCCDC is confident that under given circumstances, microorganisms in potentially hazardous foods may not be able to multiply to disease-causing concentrations. At the discretion of the Environmental Health Officers, coffee shops with good sanitary practices could be allowed to follow the four-hour rule instead of the two-hour rule given that the milk in the thermal container is maintained at less than 24°C, is time labelled as well as less than 4°C when removed from the refrigerator (BC Center for Disease Control, 2014).

LIMITATIONS

Due to time constraint, two 1.5 Liter Thermos® Double Wall Vacuum Stainless Steel Serving Carafe thermal containers and two Thermocouples data logger were used so that two runs could be performed simultaneously to speed up the data collection process. Pilot tests were performed on both of the thermal containers, namely “Container A” and “Container B”. Results from the pilot studies revealed that the two thermal containers had different temperature retention capacities. For instance, when both containers were filled with 1.5L of 3°C skim milk, skim milk in “Container A” would reach 9 °C while skim milk in “Container B” would reach 10°C after nine hours. The differences in the temperature retention capacities between Container A and B were likely due to less than ideal quality control during production. This major confounding factor was addressed by performing fifty percent of the trials of each test in “Container A” and the other fifty percent of the trials using “Container B”. This issue can also be controlled if the study was performed on higher quality thermal containers such as those ones with NSF approvals.

Another limitation of this study was due to financial constraint: The researcher was only allocated one hundred Canadian Dollars to perform the study. The two thermal containers cost sixty dollars. As a result, there was only forty dollars left to purchase milk. In order to lower the expense, the researcher had to re-use one batch of milk for a number of runs before getting the next batch. Re-using milk was a limitation because milk that had been warmed and cooled multiple times could support the growth of microorganisms. When these microorganisms multiply and ferment, they could produce heat and increase the temperature of the milk. Two batches of milk were purchased at the beginning and half way through the study. This confounding factor could be improved by using a new set of milk after every few runs to prevent the growth and multiplication of microorganisms.

CONCLUSION

Data collected from the study was entered into Microsoft Excel and NCSS for statistical analysis. Descriptive statistics from EXCEL revealed that the 1.5 Liter Thermos® Double Wall Vacuum Stainless Steel Serving Carafe thermal container had a better cold temperature retention capacity when it was filled (1.5 Liter) compared to when it was half filled (0.75 Liter). The experimental container also had a better cold temperature retention capacity when it was filled with skim milk compared to Creamo. Overall, "The 1.5L Skim Milk Test" resulted in milk with the lowest temperature after the nine-hour test period, followed by the "The 1.5L Creamo Test", "The 0.75L Skim Milk Test" and finally "The 0.75L Creamo Test". Results from all of the four tests showed that the thermal container failed to maintain the temperature of milk at <4°C for more than four hours. Over the nine-hour test period, temperature of skim milk and Creamo in the thermal container increased in a linear pattern. Statistical analysis from NCSS revealed that individually, "volume", "time" and "type of milk" inside the container had significant effects on the temperature retention capacity of the 1.5 Liter Thermos® Double Wall Vacuum Stainless Steel Serving Carafe. For example, less volume of skim milk or Creamo in the container resulted in higher temperatures overtime. Increasing time also resulted in higher temperatures for both milk types and volumes. Similarly, Creamo appeared to warm up faster than skim milk. As well, cumulatively, "volume and time", "volume and type of milk", "time and type of milk", and "volume, time, and type of milk" had significant effects on the temperature retention capacity of the tested thermal container.

RECOMMENDATIONS

Results from this study showed that thermal containers can only keep its content out the danger zone (<4°C) for less than four hours. After that, microorganisms are capable of multiplying. As a result, coffee shop operators are recommended to take precaution steps to ensure that they understand the temperature retention capacity of their specific thermal container and follow appropriate handling and discarding procedures so that customers can enjoy milk that is fresh and safe.

As proven by this study, thermal containers that are the same brand and same model can have different temperature retention capacities. Therefore, in order to determine the retention capacity of their thermal containers, coffee shop operators are recommended to conduct a simple experiment every time they purchase new thermal containers. By knowing the temperature retention capacity of the specific thermal container, operators can estimate the time when contents inside the thermal containers have to be discarded. Operators should keep in mind that the type and volume of contents inside the container greatly affect its temperature retention capacity. As a result, operators should adjust the time that the milk is placed on the self-serve counter according to how much and what type of milk is in the thermal container.

For coffee shops that do not wish to carry out the testing experiment, operators should monitor the temperature of the milk frequently to ensure that the milk is not maintained within the danger zone for more than the allowable time. In fact, monitoring the temperature of milk inside the thermal container should be included as part of the food safety plan so that this practice becomes the operators' routine duty. Furthermore, the food safety plan should list out the cooling, holding and serving procedures of the milk to ensure that staff understand and follow the proper way of handling the milk and thermal containers.

The guideline from BCCDC states that under circumstances when the foods are permitted to follow the four-hour guideline, the food should always be labelled with the time that that it was taken out from the refrigerator and the time that it must be discarded. This practice will allow both the staff and the customers to identify the freshness of the milk inside thermal containers on self-serve counters. This guideline is extremely beneficial for coffee shops that are less busy as operators are now given more time to finish the milk that would otherwise require to be disposed of under the old guideline from the Food Retail and Food Services Code.

It may be difficult for coffee shops that are very quiet to finish the whole thermal container of milk within the allowable time period. As a result, operators in extremely quiet coffee shops should consider placing the milk inside the refrigerator and serving the milk to the customers after each order. By keeping the milk in the refrigerator and serving them to the customer on an order-by-order basis, the less busy coffee shops can prevent the milk from entering the danger zone and prolong the shelf-life.

FUTURE STUDIES

Lower the initial temperature of the milk (eg. 1-2°C) to test if it will change the cold temperature retention capacity of the thermal container

Prepare ice cube using milk and place the milk cube along with milk inside the thermal container to determine if the ice will improve the cold temperature retention capacity

Place the thermal container (with cap off) in the refrigerator before milk is transferred inside to determine if a cooled container will result in better temperature retention capacity

Carry out the same study with thermal containers of different brands or models

Perform the same experiment using different contents such as soy milk, 2% milk, 3.25% milk or lactose free milk.

Perform same experiment with different volumes of contents inside (eg. 1 liter, 0.5 liter etc.)

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COMPETING INTERESTS

The authors declare that they have no competing interests.

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