THE HOT LUNCH DILEMMA:

EVALUATING HEAT RETENTION ABILITY OF

INSULATED CONTAINER WITH MACARONI AND CHEESE

by

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ABSTRACT

More child care facilities are refraining from helping children to microwave their lunches because of inadequate staffing and time. As a result, parents have to pack hot lunches using thermal insulated containers. For food safety purposes, temperature of food should be kept above 60˚C or below 4˚C. Improper hot holding temperature (i.e. 4˚C to 60˚C) can provide an ideal condition for bacteria to thrive and can possibly lead to foodborne illnesses in children.

The true heat retention ability of insulated containers has rarely been studied and tested. Information of proper use is also not comprehensive. When children are sent to school with lunch packed in a thermal container, there is typically a period of five to six hours from preparation of food to actual consumption of it. Food inside can therefore possibly be held at inadequate temperature within that period of time. The purpose of the study was to monitor the temperature changes of macaroni and cheese that was packed in three commonly used thermal containers over six hours. Whether preheating those containers with boiling water would result in increase heat retention abilities was also assessed.

Using SmartButton, a temperature data logger, temperature change of macaroni and cheese over six hours was collected thirty times from each preheated thermal container and another thirty times from each non-preheated thermal containers. Data collected was analyzed to generate descriptive and inferential outputs. The results showed that none of the containers can keep food hot above 60˚C for more than three hours whether subjected to preheating with boiling water or not ($p=0.000$). Regardless, results indicated that preheating the container provided an extra level of food safety by slightly enhancing the heat retention abilities for all containers. Based on these results, parents must preheat thermal containers when preparing lunches for their children and child care facilities should arrange lunch hour to be at an earlier time to provide an extra level of food safety by limiting potential bacterial growth within the food.

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INTRODUCTION

People have relied on insulated thermal containers to keep their food fresh and hot for decades. Since the first invention of "vacuum flask" in 1892 by Sir James Dewar, many have adapted the innovative technology to produce this silver, double-walled vacuum vessel product. The industry is still expanding and companies today are claiming their products to be able to maintain food integrity and safety. Insulated food containers are very popular among parents and are commonly used to pack school lunches for children. In fact, parents are encouraged by child care facilities to pack hot lunches using insulated containers because some facilities do not provide lunches nor do they have adequate staffing or time to microwave lunches daily. However, little is known about heat retention ability of these containers because only a limited number of studies have been conducted.

Concerns were raised when the author talked to Rosa Wai, an Early Childhood Educator from St. Francis Xavier Montessori Child Care Centre in Vancouver. She mentioned that it is common practice for parents to prepare hot lunches for their children and store the food in an insulated container. As such, there is usually a period of five to six hours from preparation of food to actual consumption of it (Wai, 2012). The author believes that parents and staff of child care facilities need to be well-educated on food safety and the risks associated with improper hot holding temperature of lunches. Food that undergoes time and temperature abuse will favour the survival and growth of pathogens, and when children consume it they can contract foodborne illnesses, which can be detrimental to their lives. The author considers the project as an opportunity to conduct a study that would add to scientific knowledge on heat retention ability of thermal insulated containers. Completion of the project can provide useful information for parents, staff and health professionals on how to choose and properly use insulated containers.

LITERATURE REVIEW

Public health significance

Improper food handling. Foodborne illness occurs when a person consumes food or beverage that has been contaminated with a particular type of bacteria, virus, mould or parasite (HealthLinkBC, 2011). Improper food handling has been identified to be the major cause of food poisoning. When food is not prepared or stored safely, it can become contaminated which allows the survival and growth of pathogens (HealthLinkBC, 2011). Common practices that can cause foodborne illness include advance preparation, inadequate reheating for hot holding and improper hot holding (British Columbia FOODSAFE Secretariat, 2006).

Foodborne illness in children. Each year throughout British Columbia, it is estimated that foodborne illnesses strike between 200,000 and 650,000 residents (BC Ministry of Health, 2006). Foodborne illness is especially dangerous to young children (one to five years old) because they do not have a fully developed immune system and are more susceptible to illnesses (Canadian Food Inspection Agency [CFIA], 2011a). Severe symptoms, illnesses and complications are more likely to develop among them and some cases can be fatal (Ontario Ministry of Health and Long Term Care, 2011).

Campylobacter jejuni, *Clostridium botulinum*, *Cyclopora*, *Escherichia coli* O157:H7, Heptatis A, *Listeria monocytogenes*, Norovirus, *Salmonella*, *Shigella* and *Vibiro* are the top ten pathogens that Canadian Food Inspection Agency, CFIA (2011a) has identified to cause most foodborne illnesses in Canada. According to the Center for Disease Control and Prevention (2011), Norovirus, *Salmonella* and *Campylobacter*, were also ranked the top pathogens contributing to foodborne illnesses and deaths from 2000 to 2008. Among these, Norovirus and *Campylobacter* are pathogens that cause common childhood diseases and can lead to severe signs and symptoms such as diarrhea, nausea and vomiting (BC Centre for Disease Control [BCCDC], 2009). Moreover, as with Norovirus and *Campylobacter*, the Canadian Integrated Surveillance Report also stated that the highest infection rates of *Salmonella* and verotoxigenic *E.coli* (in particular serotype O157) were observed in infants and young children (Public Health Agency of Canada, 2009). Young children who are infected with *Salmonella* and *E.coli* are likely to develop severe diarrheal illnesses that may lead to hospitalization. In more serious cases of *E. coli* infection, children between 6 months and 4 years may develop hemolytic uremic syndrome which is characterized by kidney failure and blood disorder, leading to a 5% to 10% mortality rate (Public Health Agency of Canada, 2009).

Child care facilities

High risk setting. According to the Community Care and Assisted Living Act, any child care facilities that provide care to three or more children who are not related to the operator by blood or marriage must apply for licensing and follow the Child Care Licensing Regulation (Community Care and Assisted Living Act, 2002; Fraser Health, 2011). Based on a food safety evidence review published by the BC Ministry of Health (2006), health institutions (e.g. long term care and child care facilities) are ranked as the third most common source of foodborne illness outbreaks and cases, with primary sources being food service establishments, followed by private residences. More recently, Toronto Public Health also concluded that the average number of infectious gastrointestinal illness cases attributed to food was highest among long term care homes and child care facilities between 2003 and 2007 (Arthur, Gournis, Mckeown &Yaffe, 2009). The nature of daycare environments, where children often come in close contact with one another and the high occurrence of enteric disease transmission has categorized child care facilities as high risk settings (BCCDC, 2011).

From microwave to insulated thermal container. Any childcare facility that has a kitchen and is using it to prepare food for children falls under definition "food premises" and "food service establishment" of Food Premises Regulations (2009). Categorized as high risk setting, Food Safety Plans should be available and used at child care facilities to avoid young children from consuming contaminated food and getting sick (Food Premises Regulations, 2009). Staff should also practise proper food handling and be familiar with food safety issues such as time and temperature abuse. However, some child care facilities neither have kitchens nor do they have refrigeration units (Frumkin, Geller, Rubin & Nodvin, 2006; Wai, 2012). Although some child care centers have microwaves, parents are still encouraged by staff to pack hot lunches for their children using insulated containers (Wai, 2012). This is because microwaving numerous lunches each day is very time-consuming, and the waiting time to have all lunches heated to be ready to eat would be lengthened (Wai, 2012). Foods that are reheated in a microwave may sometimes cook food unevenly resulting in cold spots where harmful microorganisms may not be sufficiently killed and will therefore survive in food (Florida Department of Health, 2012). Over-microwaving can also overheat food making it too hot and too dry to be consumed by young children. Therefore, insulated thermal containers become popular among parents when they want their children to have hot lunches at daycare facilities.

The "Thermos"

Technology. The vacuum insulated container is an innovative product invented in 1892 (Thermos®, 2011a). The design is comprised of two flasks: an outer and an inner vessel (Thermos®, 2011b). The air gap between the two flasks is evacuated to create a vacuumized space (Thermos, 2011b). This airless space prevents heat transfer by conduction or convection and can eliminate temperature change, so food stored in it can stay hot (Thermos, 2011b).

Being one of the world's most renowned insulated container manufacturers, Thermos® has always been on the cutting edge in inventing and improving children's lunch kits, and expanding its variety of food jar products. In 2007, Thermos® entered the children-food and beverage storage category with a new line of stainless-steel insulated products called Foogo™, which are specifically designed for children aged 6 months and up (Sharyn, 2007). Thermos® declares that with the new double-wall vacuum-insulation and TherMax technology, food can be kept warm for up to five hours (Thermos®, 2011b). Since the launching of Foogo™, Thermos® online sales have been dominated by this product line (Thermos®, 2008).

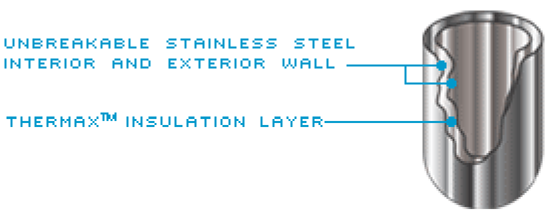

Fig 1. TherMax vacuum insulation (Thermos®, 2011b).

Depending on the filling materials of the vacuum-insulation panels, effectiveness of thermal conductivity of different types of containers can vary, thus affecting the ability to adequately hold food hot above 60˚C (Kwon, Jang, Jung & Song, 2009).

Deceptive messages and potential health risk associated with insulated containers. Many companies claimed that their insulated food containers are able to hold food "hot" or "warm". However, the key word "hot" is often not clearly defined on manufacturers' website. Information on heat retention ability of most insulated containers also cannot be found. On a typical day, parents usually drop off their children at daycare facilities as early as 7 a.m., and lunchtime could be as late as 1p.m., so food may remain in the insulated container for as long as 6 hours before consumption (Wai, 2012). Therefore, when children are sent to school with lunch packed in a thermal container, parents have no way of ensuring that the food remains at an adequate temperature , or some parents may assume containers can always keep food “hot”. According to the FoodSafe training program, foodborne disease-causing bacteria can rapidly grow and multiply to an unacceptable number if food is left at any temperature between 4˚C and 60˚C (40˚F and 140˚F) known as the “danger zone” (British Columbia FOODSAFE Secretariat, 2006). This is especially dangerous for children because thermal containers that cannot hot hold food to adequate temperatures can act like an incubator, providing an ideal environment for microorganisms to grow. The situation can escalate if potentially hazardous foods (PHF) such as dairy products, meat, cheese, rice, potatoes and soy protein foods are packed because these food are known to have caused foodborne illness outbreaks (Frumkin, Geller, Rubin & Nodvin, 2006).

Non-comprehensive public information. Various government and health resources recommend the use of a thermal insulated container to keep foods hot. For example, HealthLinkBC (2011) recommends “parents should pack hot food in a thermos” to pack food safely but “hot” is not clearly defined. “Lunches to Go” created by the Community Nutritionists Council of BC (2008) which was included as a healthy eating resource on the BC Ministry of Education website also did not define the key word “hot”: the document only states to “use a wide mouth thermos to keep hot food hot. Pre-heat the thermos with hot water before filling”. On the other hand, CFIA (2011b) website provides parents a better picture of what “hot” is by stating that “to be safe, hot food like soup, chili and stew must stay hot-at or above 60˚C (140˚F).”

Scott (2003) stated that many cases of foodborne illness occur as a result of improper food handling and preparation by consumers in home kitchen. Non-comprehensive information can possibly act as a barrier to public awareness of food safety and could provide parents with inadequate knowledge on thermal effectiveness, improper care and use of these containers.

Lack of published literature. Limited studies have been conducted to test heat retention ability of thermal insulated containers. A comparative study conducted by Cornell University in 2006 has concluded Foogo™ by Thermos® has a better insulating efficiency and less growth rates of potential foodborne pathogens, but the author was only able to get access to the summary of test result posted on Thermos® website (2009) and could not locate the full article online.

In 2011, Jackson Kwok, a previous ENVH student conducted a research project on heat retention ability of three thermal containers. He found that none of the containers tested was able to maintain chicken noodle soup above 60˚C for more than 4 hours and concluded that those containers are unable to keep hot lunches safely and may lead to foodborne illness if young children consume the food packed in them (Kwok, 2011). A similar study performed by the Good Housekeeping Research Institute (2009) determined that out of nineteen thermal containers being tested only one could keep food hot and out of danger zone for up to six hours, while others failed. Young children should not consume food that has been out in the danger zone for anytime more than two hours because there is an increased risk of contracting foodborne illness.

Role of Environmental Health Officers (EHOs)

EHOs, also known as public health inspectors, are responsible for inspecting the food facilities of child care centers that have lunch program and ensuring compliance to the Food Premises Regulations (Interior Health, 2010). EHOs also review and approve their menu items (Interior Health, 2010). However, childcares that are not equipped with kitchens and in situations where lunches are provided by the parents, inspections will only be conducted by delegated licensing officers and not EHOs (Vancouver Coastal Health, 2013; Vancouver Island Health Authority, 2012). Nevertheless, EHOs should always coordinate with licensing officers to educate staff at child care facilities and parents on safe food handling and answer concerns and questions that they might have regarding food safety. However, non-comprehensive resources on the safety of thermal containers may make EHOs less able to educate them on proper care and use of thermal insulated containers. Questionable heat retention ability of thermal containers may also be potential contributors to foodborne illness outbreaks which EHOs, licensing officers, parents and staff need to be aware of.

Purpose of study

Improper food handling practices have been identified as one of the major causes of foodborne illnesses, so whether food is prepared in a child care facility or brought from home, safe food handling is the key to avoiding food poisoning in young children (BC Ministry of Health, 2006; HealthLink BC, 2011).

The purpose of this research project was to monitor the internal temperature of macaroni and cheese in three different thermal containers over six hours and to determine hot holding time of each container. The study monitored the temperature of macaroni and cheese in each container, with and without preheating, using a real time temperature recorder. The data collected were statistically assessed to determine whether preheating reduces or increases heat retention ability on thermal containers.

METHODOLOGY

Materials & equipment

The following were used for the study:

1. Thermos® Foogo food jar x 2
2. Thermos® FUNtainer food jar x 2
3. President's Choice thermal food jar x 2
4. Kraft Dinner Original macaroni & cheese
5. President's Choice electronic water kettle
6. Pyrex® 400ml beakers
7. Durac® digital thermometer
8. Microwave
9. Microwavable bowl
10. Spatula
11. Weigh balance
12. Non-hydrogenated margarine
13. Skim milk
14. Small plastic zip-lock clear bags
15. Timer
16. Measuring spoon
17. ACR SmartButton temperature datalogger[2K readings/-40 to 85˚C]x6
18. SmartButton USB adapter
19. ACR TrendReader for SmartButton Software (Version 3)
20. Crushed ice
21. Water
22. Detergent
23. Pen
24. Logbook
25. NCSS (Version 8.0.11)
26. Microsoft Excel
27. Computer

ACR Systems Inc. SmartButton Temperature Recorder

Datalogging is a well-established technology that has been widely used in different studies to monitor time-temperature history, for example meteorological investigations and Hazard Analysis Critical Control Point program implementation (Whiteman, Hubbe & Shaw, 2000; Walker, Pritchard & Forsythe, 2003). The internal sensor of the datalogger is able to sample temperature at fixed time intervals and store measurements within for later analysis (Whiteman, Hubbe & Shaw, 2000).

SmartButton (See Appendix 1 for product specifications) is the datalogger that was used in this experiment. It is a miniature temperature datalogger that is made up of food grade stainless steel (ACR Systems Inc., 2012). It has an internal silicon semiconductor that senses and measures temperature of food items ranging from -40˚C to 85˚C (±1.0˚C from -30˚C to 45˚C; ±1.5˚C from 45.5˚C to 85˚C), and records those data at specific intervals ranging from once every 1 minute, to once every 255 minutes (ACR Systems Inc., 2012). In this research project, time-temperature monitoring helped in assessing the heat retention ability of three thermal insulated containers on solid food.

Experimental procedure

Kraft Dinner Original macaroni and cheese was placed into 3 different thermal insulated containers (See Appendix 2 for product descriptions) and its temperature change in each container was monitored over 6 hours using SmartButton. The study was designed to determine the amount of time that each container could hold macaroni and cheese at above 60˚C and to evaluate whether preheating containers would have an effect on hot holding temperature and time. Interactions between time, types of containers and method of preparation (preheating or not) were analysed. Therefore two experiments were performed for each type of container:

A: Containers were preheated with boiling water for 5 minutes before filling with food (Step 1-5 was followed)

B: Containers were not preheated before filling with food (Step 1 & 2-5 were followed)

Note: See Appendix 3 for flowchart of experimental procedure

Step 1: Measuring instrument preparation and calibration

Prior to the experiment, SmartButton was calibrated by connecting to the software using the USB adapter and removing any residual readings, thus zeroing the logger. New start time setting was applied and logger was disconnected from the computer and put in a clear plastic bag. As SmartButton could not withstand temperature above 85˚C, a calibrated digital thermometer was used as a secondary standard to ensure logger's reading for hot temperatures would be accurate.

Step 2: Food sample preparation

Hands were washed with mild soap and warm running water before food preparation. Macaroni and cheese was then prepared according to the microwave direction (Appendix 4) on the package.

Step 3: Preheating procedures (Note: this step was followed when performing Experiment A)

Boiling water was poured into containers to one inch below opening and lids were put back on tightly. Containers were preheated for five minutes and a timer was used to monitor the duration.

Step 4: Time-temperature monitoring

250g of cooked macaroni and cheese was accurately measured into a tare beaker and microwaved for another minute. The researcher then immediately transferred the food from beaker to container. For preheated container, water was poured out before putting in the food. Initial food temperature was measured with the secondary standard and recorded to ensure food had reached between 77˚C and 85˚C. Using a spatula, the researcher pushed the logger to the centre of the container and securely closed the lid. Food was held in the container for six hours.

Step 5: Retrieving data

After the six hour period, the SmartButton logger was taken out and removed from plastic bag. It was connected to the computer to retrieve the data. After each run, the container was cleaned with warm and soapy water, and allowed to air dry.

Alternate methods

The temperature of the macaroni and cheese could be measured by the calibrated digital thermometer. Initial temperature would be recorded when food is put into the container. For every one, two, three, four, five and six hours, the lid of the container would be removed and temperature of the food would be taken and recorded. One disadvantage of this alternative would be the loss of heat when lid of container is opened for temperature measurement.

Justification for proposed methodology

For this study, the amount of time the food container to be tested was adapted from Kwok's methodology (2011). Based on Kwok's report, his experimental design was able to give predictable and consistent results with a confidence level of 99% (2011).

Measuring instrument. Miniature temperature datalogger was the preferred measuring instrument because it was small enough to be submerged in food to perform real-time recording and was an established instrument used in Kwok's study (2011). Also, six loggers were readily available at the Food Technology laboratory.

Types of containers and food. The three types of containers used in this study were the Foogo, FUNtainer and President Choice's thermal insulated food jar. According to Wai (2012), these containers are used most commonly by children in the establishment she works at. For the purpose of this study, other containers available in the market were not assessed due to budget and time constraints. Macaroni and cheese is one of the most common lunch items brought to Wai's child care centers, and therefore it was a representable solid food to be used in this study. Instant macaroni and cheese was also relatively inexpensive to purchase and only minimal cooking preparation was required.

Experiment location. The study was conducted in a home kitchen environment which enabled reconstructing conditions typically exist in preparing macaroni and cheese for children.

Six hour duration. Potentially hazardous food such as macaroni and cheese should not be left at any temperature between 4˚C and 60˚C (known as the "danger zone") for more than two hours (British Columbia FOODSAFE Secretariat, 2006). However, when children bring lunch using a thermal insulated container, the typical length of time from preparation of food to actual consumption of it can be as long as five to six hours. For the purpose of this study, it was essential to observe temperature change of food over six hours.

Preheating. The procedure of preheating containers with boiling water is recommended by the Canadian Food Inspection Agency (2011b). Five minutes preheating duration is based on care and use instruction of Thermos® food jars (Thermos®, 2011c).

Inclusion and exclusion criteria

Only macaroni and cheese packed in Foogo, FUNtainer and President Choice's thermal insulated food jar were eligible for the experimental procedures. Other solid foods that were stored in the three containers, or keeping macaroni and cheese in containers other than the three being specified were excluded from the study.

Reliability and validity of measures

Reliability/ repeatability. The established measuring instrument, SmartButton, came factory calibrated, and for every run, the calibrated digital thermometer, used as a secondary standard, showed that logger's readings were accurate. Also, the equipment was used and was administered by only one researcher in a consistent fashion (Heacock & Crozier, 2011a). The same food item and amount were used for every run, so composition and volume were consistent. Each container contained a food item that had initial temperature ranging from 77˚C to 85˚C at the beginning of each run to ensure similar amount of heat energy was contributed to each container. For each type of container, thirty runs of each experiment (A and B) were performed to increase power and strengthen repeatability (Heacock & Crozier, 2011a).

Validity/ accuracy. The secondary standard was calibrated using the standard fixed point method, where temperature readings were calibrated with ice bath and boiling water to ensure recorded values during experiment were valid (Kwok, 2011; ASTM, 2011). The manufacturer's instructions of SmartButton were strictly followed by the researcher to increase accuracy of data collected. Generalizability may be increased because experiment was conducted in a home kitchen environment and results may better reflect real-life setting (Heacock & Crozier, 2011a).

Pilot study

With the same materials and conditions, 2 runs of experiment A and B were performed for all three types of container. The pilot study allowed the researcher to:

- test for potential experimental errors
- be familiar with the use of SmartButton and treatment of data collected

The results obtained from the pilot study confirmed that the experimental procedure, the materials and equipment were capable of measuring heat retention ability of each container, both preheated and not-preheated.

STATISTICAL ANALYSIS

In this study, temperature changes of macaroni and cheese over time were monitored and the length of time that each container could hold food above 60˚C was determined. The type of data collected during the experiment was continuous, numerical data being the temperature of macaroni and cheese obtained from SmartButton. Nominal data collected were the time at specified intervals (0, 30, 60, 90, 120, 150, 180, 210, 240, 300, 330 and 360 minutes), container type (Foogo, FUNtainer and PC) and method of preparation (preheated or not-preheated). Microsoft Excel (Microsoft Corporation, 2010) was used to generate descriptive analysis while Number Cruncher for Statistical Systems (NCSS) (Version 8.0.11) (Hintze, 2012) was used to produce inferential analysis.

Descriptive statistics

Mean and standard deviation of temperature of macaroni and cheese in each container (not preheated and preheated) were obtained. In Table 1, the means during the six hour period in not preheated Foogo, FUNtainer and President' Choice (PC) were 59.3±11.3˚C, 59.9±11.5˚C and 57.3±12.9˚C, respectively. The means for preheated Foogo, FUNtainer and PC are 60.8±11.5˚C, 60.7±11.8˚C and 57.5±12.8˚C, respectively.

Table 1. Descriptive statistics on temperature (˚C) of macaroni and cheese in each container (preheated or not) during six hours of testing

	Without preheating			**With preheating**		
	Foogo	FUNtainer	PC	Foogo	FUNtainer	PC
Maximum	82.0	83.0	85	83.5	84.5	85.0
Minimum	41.5	42.5	34.5	42.0	41.0	38.5
Mean	59.3	59.9	57.3	60.8	60.7	57.5
Standard Error	0.6	0.6	0.7	0.6	0.6	0.7
Median	58.0	58.0	55.0	59.5	59.5	55.3
Mode	45.0	54.5	49.0	47	51.5	49.0
Standard Deviation	11.3	11.5	12.9	11.5	11.8	12.8
Count	360	360	360	360	360	360

Inferential Statistics

In this project, two hypotheses were tested:

1) ***H_o**: There is no difference in the mean temperature of macaroni and cheese temperature within each container as holding time increases, i.e. slope = 0*

   ***H_a**: There is a difference in the mean temperature of macaroni and cheese temperature within each container as holding time increases, i.e. slope ≠ 0*

Temperature change of macaroni and cheese over time were collected. Linear regression was performed to determine correlation between time and temperature. The holding time (in minutes) before the food content in each container, both preheated and not, fell to below 60˚C and reached the temperature "danger zone" was also determined.

2) ***H_o**: Time, type of container and method of preparation do not have an effect on the length of time (in minutes) before food falls below 60˚C*

   ***H_a**: Time, type of container and method of preparation have an effect on the length of time (in minutes) before food falls below 60˚C*

Time in intervals, type of containers and method of preparation were three independent variables which may affect the dependent variable (length of time before macaroni and cheese falls below 60˚C); therefore, an extension to one-way analysis of variance (ANOVA), three-way ANOVA was performed.

Interpretation of results

Table 2 showed that there is a very good to excellent negative linear relationship (r > -0.75) between time and temperature for each type of containers (both preheated and not preheated). As holding time increases from 0 to 360 minutes, the temperature of food inside each container decreases. Change in food temperature can be predicted from the change in time using the intercepts and coefficients from Table 2 or by the linear regression equations in the detailed linear regression report presented in Appendix 5. For instance, regression equation for Foogo (not preheated) was: Food temperature in ˚C = 76.02 + (-0.0969) x Time in minutes

Therefore, after 1 minute, the macaroni and cheese in the container would drop to 75.92 ˚C.

Table 2. Linear regression and correlation coefficients of time (minutes) on temperature (˚C) of macaroni and cheese from preheated and not-preheated thermal containers

Type of containers	Slope	Y-intercept	Correlation of coefficient
Foogo (not preheated)	-0.0969	76.0228	-0.9751
Foogo (preheated)	-0.0977	76.8954	-0.9739
FUNtainer (not preheated)	-0.0980	76.9045	-0.9733
FUNtainer (preheated)	-0.0987	77.2216	-0.9729
PC (not preheated)	-0.1082	76.2080	-0.9656
PC (preheated)	-0.1025	76.9471	-0.9614

According to the t-tests for correlation (Table 3), we reject the null hypothesis and conclude that there is a statistically significant correlation between time and temperature. Food temperature decreases significantly as holding time increases, i.e., the longer the food is held in a container (preheated or not), the colder the food gets.

Table 3. t-test results for slope of each containers (H_o: slope = 0 and H_a: slope ≠ 0)

Type of containers	T-value	Probability level	Reject H_o	Power (alpha = 0.05)
Foogo (not preheated)	-83.7748	0.0000	Yes	1.0000
Foogo (preheated)	-81.1264	0.0000	Yes	1.0000
FUNtainer (not preheated)	-80.2518	0.0000	Yes	1.0000
FUNtainer (preheated)	-79.5617	0.0000	Yes	1.0000
PC (not preheated)	-70.2580	0.0000	Yes	1.0000
PC (preheated)	-66.0753	0.0000	Yes	1.0000

Using the same linear equation, the mean holding time for each container before the food dropped below 60˚C was calculated and is presented in Diagram 1 (also indicated in each corresponding plot in Appendix 4): Foogo (not preheated: 2.75 hours; preheated: 2.88 hours), FUNtainer (not preheated: 2.86 hours; preheated: 2.9 hours) and President's Choice (not preheated: 2.5 hours; preheated: 2.75 hours).

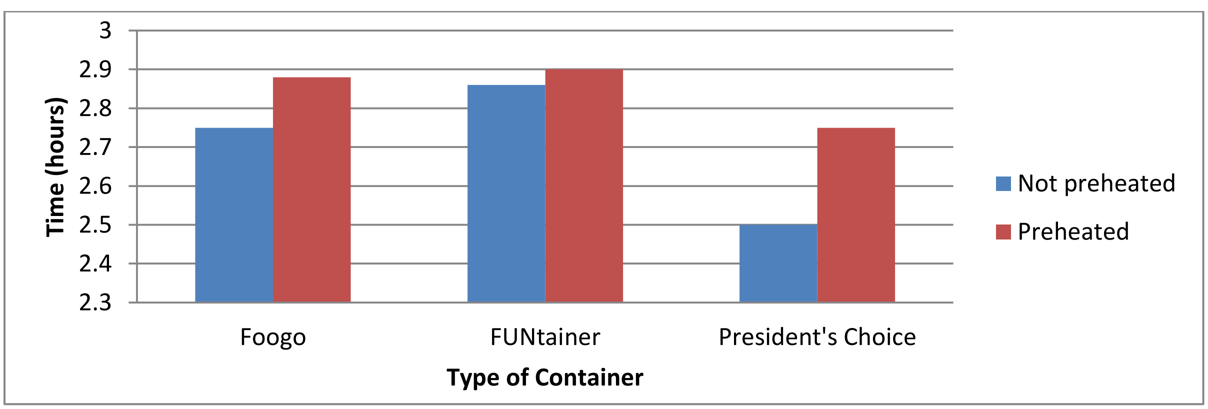

Diagram 1. The mean holding time for each container before the food dropped below 60˚C

3-way ANOVA result in Table 4 and Appendix 6 showed that difference between mean at individual level (container type, time and method of preparation) and 2-way interactions (container vs time; container vs method of preparation; time vs method of preparation) were significant (i.e. all $p<0.05$). However, 3-way interactions (container vs time vs method of preparation) was not significant (i.e. $p>0.05$). Therefore, we can only conclude that time, type of container and method of preparation has an effect on the length of time (in minutes) before food falls below 60˚C only in 2-way interactions.

Table 4. 3-way ANOVA. Interactions of time, type of container and method of preparation on mean temperature of macaroni and cheese

				Difference			
	Container	Time	Preparation	Container vs Time	Container vs Preparation	Time vs Preparation	Container vs Time vs Preparation
Probability level	0.000000	0.000000	0.000000	0.000000	0.000000	0.001874	0.978471
Power (alpha = 0.05)	1.000000	1.000000	1.000000	1.000000	1.000000	0.999993	0.148051

Alpha and Beta error

The probability for all independent variables and 2-way interactions between them was 0.000000 or 0.001874. With such low p-value, there is almost no chance of an alpha error. The power at alpha level 0.05 was either 100% or 99.9%, indicating that failure to reject null hypothesis when alternate hypothesis is true is extremely low (Helen & Crozier, 2011b). However, in the case of 3-way interactions, power was below 80%, therefore there is a high chance of beta error, indicating that there is a need of increasing sample size to conclude that there is a difference when in fact there is one (Helen & Crozier, 2011b).

DISCUSSION

The popularity of using thermal insulated containers to pack hot lunches for children has raised concerns because of the limited studies conducted to determine the true thermal effectiveness of these containers. This is because improperly keeping food at temperature less than 60˚C for more than 2 hours can accelerate growth of disease-causing bacteria to a hazardous level. It is believed that temperature of food packed in a thermal insulated container may decrease and reach the temperature "danger zone" over time, and the results from this study support the belief. The temperatures of macaroni and cheese in all containers (whether preheated or not) dropped after the six hour testing period, and were lower than the initial food temperatures (as indicated in Table 1, maximum starting temperatures were well above 80˚C but they are decreased to temperatures ranging between 34.5˚C and 42.5˚C after six hours). The negative linear relationship ($r > -0.75$) between time and temperature also suggests that the longer the food is held in a container (whether preheated or not), the colder the food gets. This finding is expected and can be explained by heat exchange between the warmer food and cooler container, and the loss of kinetic energy of food over time.

There is typically a period of five to six hours from preparation of food by parents to actual consumption by their children at child care facilities. Since food cannot be kept in the "danger zone" for more than two hours, it is crucial to maintain food temperature above 60˚C for at least four hours. As such, there will still be a two-hour window before the food is deemed unsafe to be consumed. Diagram 1 shows that none of the containers can keep food above 60˚C for more than three hours whether subjected to preheating or not (2.5 to 2.9 hours). Therefore, according to this study, containers (Foogo and FUNtainer) that claim to keep food "hot" for up to five hours have failed to perform. This result is similar to Kwok's (2011) and Good

Housekeeping Research Institute’s (2009) findings, where none of the containers tested were able to maintain food temperature above 60˚C for more than four and six hours, respectively. If lunch time is five to six hours from preparation of food, it is very likely that children would have eaten food that has undergone time and temperature abuse for over two hours and may possibly contract foodborne illness as a result.

Regardless, Diagram 1 shows a slightly better heat retention ability (2.75 to 2.9 hours) when containers were preheated with boiling water for five minutes. Although the difference in thermal efficiency between preheated and not preheated containers over time seems small (only 10 to 15 minutes), it is significant ($p=0.000$ as indicated in Table 4). The better thermal efficiency can be explained by the smaller heat difference between the hot food and warmed container resulting in a lesser extent of heat exchange and heat loss, and thus temperature can be maintained for a longer period of time. This finding suggests that heat retention ability may improve even more if containers are preheated for longer, such as for 10, 20 and 30 minutes.

Table 4 shows significant differences at individual levels and that each variable (time, type of container and method of preparation) has an effect on the length of time before food falls below 60˚C in 2-way interactions. This result is expected and may be explained in two ways: the first being that containers are made of vacuum-insulation panels with different filling materials, thus thermal conductivity and heat retention quality can vary. The alternative explanation would be the difference in holding capacity (Foogo and FUNtainer - 250mL; President’s Choice - 290mL). Unfortunately, the design of the experiment limits the explanation of 3-way interactions (container vs time vs method of preparation) due to insufficient sample size. Nevertheless, this study proves that different insulated containers have different heat retention ability. Preheating container lengthens hot holding time and may enhance food safety.

Limitations

Time and budget restraints are one of the major limitations to this research. The power of the study for all independent variables and 2-way interactions between them is extremely high (either 100% or 99.9%), but the small sample size introduced a high chance of beta error for the 3-way interactions (power of less than 80%). In order to generalize the results for larger groups, more types of containers commonly used by children at different child care centres should be tested. One can truly extrapolate to Kraft Dinner Original macaroni and cheese from the results obtained, although given similar results with chicken noodle soup (Kwok, 2011), the author is confident that her results can be generalized to all or most hot pasta dishes packed in thermal insulated containers. Out of the numerous brands and types of containers available in the market the researcher could only test three of them. Biases may have been introduced as the types of containers and food tested are based on the most commonly used and eaten ones at Wai's (2012) child care center. Furthermore, SmartButton cannot withstand temperature above 85˚C and results may be different if food is placed into the containers at a higher initial temperature.

Conclusion

The data shows that none of the containers (preheated or not) can hold food above 60˚C for more than 3 hours, indicating that young children who consume food kept in thermal insulated containers may be at increased risk of contracting foodborne illnesses. Data also shows that time, type of container and method of preparation each individually has an effect on the length of time before food falls below 60˚C. Although the experiment failed to conclude that there is a 3-way interaction between container type, time and preparation method, from a public health perspective, preheating containers with boiling water significantly improves heat retention ability and may reduce the level of bacterial growth.

Recommendations

Parents. Preheating insulated thermal containers slightly improves heat retention ability of containers and may provide an extra barrier to bacterial growth. Children under the age of five have a developing immune system that puts them at increased risk for complications from food poisoning; therefore parents are recommended the following:

1. Preheat insulated thermal container with boiling water for at least five minutes.
2. Cook or reheat food to at least 74˚C (165˚F).
3. Use a food thermometer to ensure food has reached at least 74˚C (165˚F).
4. Empty the water in the container.
5. Transfer food into preheated container.

Child care facilities. Different types of containers have significantly different heat retention ability, and therefore staff from daycare facilities could advise parents on the exact lunch time to allow parents to choose the most appropriate insulated thermal containers for their children. Staff can ensure food safety in children by asking them whether their food is hot or cold. In the case where food, especially potentially hazardous food, may seem lukewarm or cold, staff could provide information to parents with regards to proper food handling, including the importance of preheating insulated thermal containers.

EHOs. As one of EHOs' major roles is to educate the public regarding food safety issues, parents and operators of child care facilities should be informed that the three tested containers were unable to hold food above 60˚C for more than three hours and may contribute to potential foodborne illnesses if lunch time is five to six hours from preparation of food. EHOs should coordinate with Licensing Officer to suggest facilities to schedule an earlier lunch hour, ideally at 11am, to minimize the time period between preparations of food to actual consumption. EHOs should also be familiar with the various types of containers available and new studies like this to answer public concerns and questions, promote and ensure food safety.

Furthermore, information on various government and health resources such as "Food Safety in Child Care Facilities" (HealthLink BC, 2011) and "Lunches to go" (Community Nutritionists Council of BC, 2008) should be updated, and include recommendations to:

1. Preheat insulated containers with boiling water for at least five minutes before filling.
2. Ensure food to be at least 74˚C or steaming hot (if a food thermometer is not used) just prior to transfer into containers.

Suggestions for Future Studies

1. Same physical testing but with different types of containers, food items and/or containers with different times of uses;
2. Physical testing to determine differences in thermal efficiency if containers are preheated with boiling water for a longer period of time;
3. Microbiological testing to determine changes in the level of bacteria over time within food that is packed inside thermal containers;
4. Conduct a survey to determine information such as the knowledge of parents in regards with food safety issues and proper food handling/packaging, the most commonly used thermal food containers and food types and the typical time period from preparation of food to actual consumption of it.

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APPENDICES

1. ACR Systems Inc. SmartButton Data Logger Specifications
2. Materials & Equipment
3. Flowchart of Experiment
4. Kraft Dinner Microwave Directions
5. Statistical Analysis – Linear Regression
6. Statistical Analysis – 3-way ANOVA

APPENDIX 1
ACR Systems Inc. SmartButton Specifications

Product Specifications
PROVEN DATA LOGGING SOLUTIONS

ACR SmartButton Temperature Data Logger

The ACR SmartButton is a miniature-sized temperature logger that is extremely low-cost and easy to use. Because of its small size and low-cost, you can purchase tens or hundreds of them for multiple-site temperature monitoring. To get you started, purchase the SmartButton Starter Pack. It includes one SmartButton, Interface cable, and TrendReader for SmartButton Software. So simple and easy to use, anyone can start data logging today!

APPLICATIONS

Food processing verification, pharmaceutical storage, laboratories, transportation of temperature sensitive goods, equipment run time, HVAC system testing and balancing , etc.

GENERAL SPECIFICATIONS

Size:	17.35mm diameter x 5.89mm height (0.68" x 0.23")
Weight:	4 grams (0.14 ounces)
Case Material:	Stainless Steel
Battery:	3.0 volt Lithium – Approximate 10 year battery life using 20 min sample rate at 15°C (*See product lifetime table for more information)
Resolution:	8-bit (1 part in 256)
Mounting	User selectable (magnetic backing, plastic hard plastic or self-adhesive backing material)
Clock Accuracy	±2 minutes per month from 0° to 45°C (32° to 113°F)
Sampling Methods:	Continuous (First-in, First-out) or Stop When Full (Fill-then-stop)
Operating Limits:	-40°C to 85°C (-40°F to 185°F)
PC Requirements:	Windows PC with at least one free USB Port
Software Requirements:	ACR TrendReader for SmartButton Software (Compatible with Windows XP, Vista, Windows 7 and Windows 8 [32 bit and 64 bit])
Communication:	USB/ACR SmartButton Interface

TEMPERATURE SENSOR SPECIFICATIONS

Type:	Silicon
Range:	-40°C to 85°C (-40°F to 185°F)
Accuracy:	±1.0°C from -30°C to 45°C (± 1.8°F from -22°F to 113°F) ±1.5°C from 45.5°C to 85°C (± 2.7°F from 114°F to 185°F)

ORDERING INFORMATION

Item	Cat#:
SmartButton USB Starter Pack*	01-0182
SmartButton (Single)	01-0180

*Starter Pack includes:
One SmartButton Data Logger
TrendReader for SmartButton Software CD
USB interface Cable, Magnetic Backing,
Plastic ID Tag, Adhesive Backing
Quick Start Guide

Actual Size

WARRANTY: 1 YEAR

ACR Systems Inc
Toll-Free: 1.800.663.7845
Tel: 1.604.591.1128
sales@acrsystems.com

www.acrsystems.com
ISO 9001 Certified
ISO9000\SPECIFICATIONS\SMARTBUTTON.pdf

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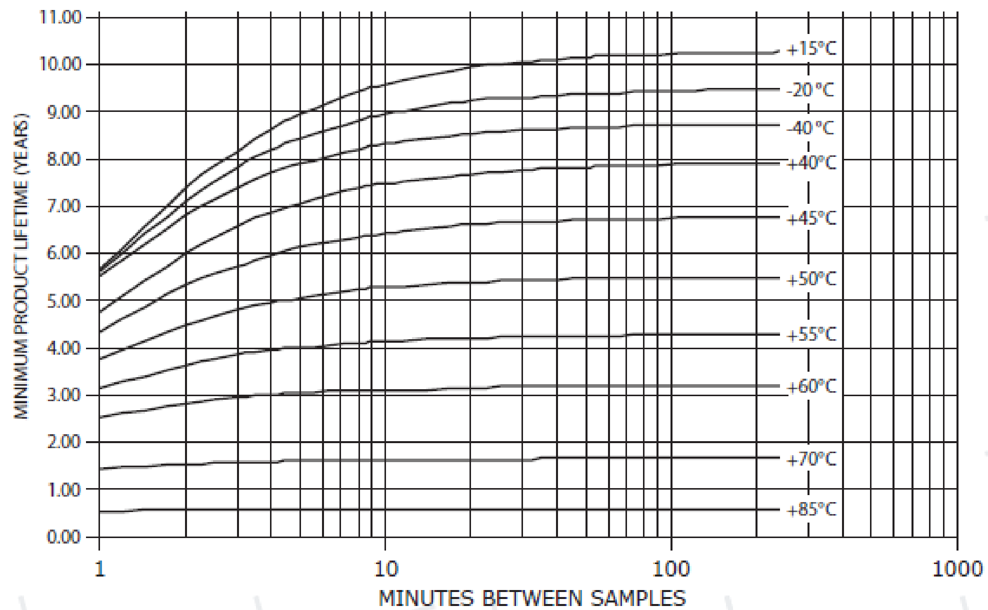
ACR SYSTEMS INC.

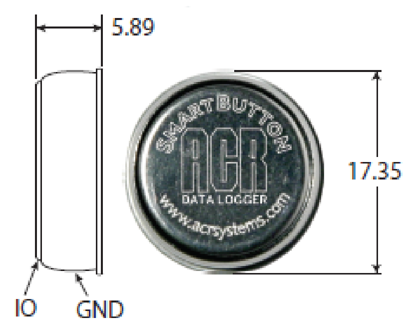
Product Specifications
PROVEN DATA LOGGING SOLUTIONS

MINIMUM PRODUCT LIFETIME vs SAMPLE RATE AT DIFFERENT TEMPERATURES



SPECIAL FEATURES

- ACR SmartButton measures temperature in 0.5°C increments
- Logs up to 2048 consecutive temperature measurements in internal memory
- Programmable temperature-high and temperature-low alarm trip points
- Records up to 24 time stamps and durations when temperature leaves the range specified by the trip points (12 periods for too hot and 12 for too cold)
- Automatically wakes up and measures temperature at user-programmable intervals from 1 to 255 minutes
- Unique, factory-lasered and tested 64-bit registration number (8-bit family code + 48- bit serial number + 8-bit CRC tester) assures absolute traceability because no two parts are alike
- Chip-based data carrier compactly stores information
- SmartButton can be accessed while affixed to an object



All dimensions shown are in millimeters

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APPENDIX 2

Materials & Equipment

1. Insulated Thermal Containers
2. Durac® Digital Thermometer

President's Choice **Foogo** **FUNtainer**

1. *Insulated Thermal Containers*

Container (volume)	Manufacturer	Price	With Care & Use Guide?
Foogo **(290mL)**	Thermos LLC *Made in China*	$19.99	**Yes** For maximum thermal efficiency, preheat (food jar only) or prechill (food jar or beverage bottle) prior to use. Fill hot/cold tap water, attach lid, let stand 5 to 10 minutes
FUNtainer **(290mL)**	Thermos LLC *Made in China*	$13.99	**Yes** Same as above
President's Choice **(350mL)**	Loblaws Inc. *Made in China*	$7.00	**No**


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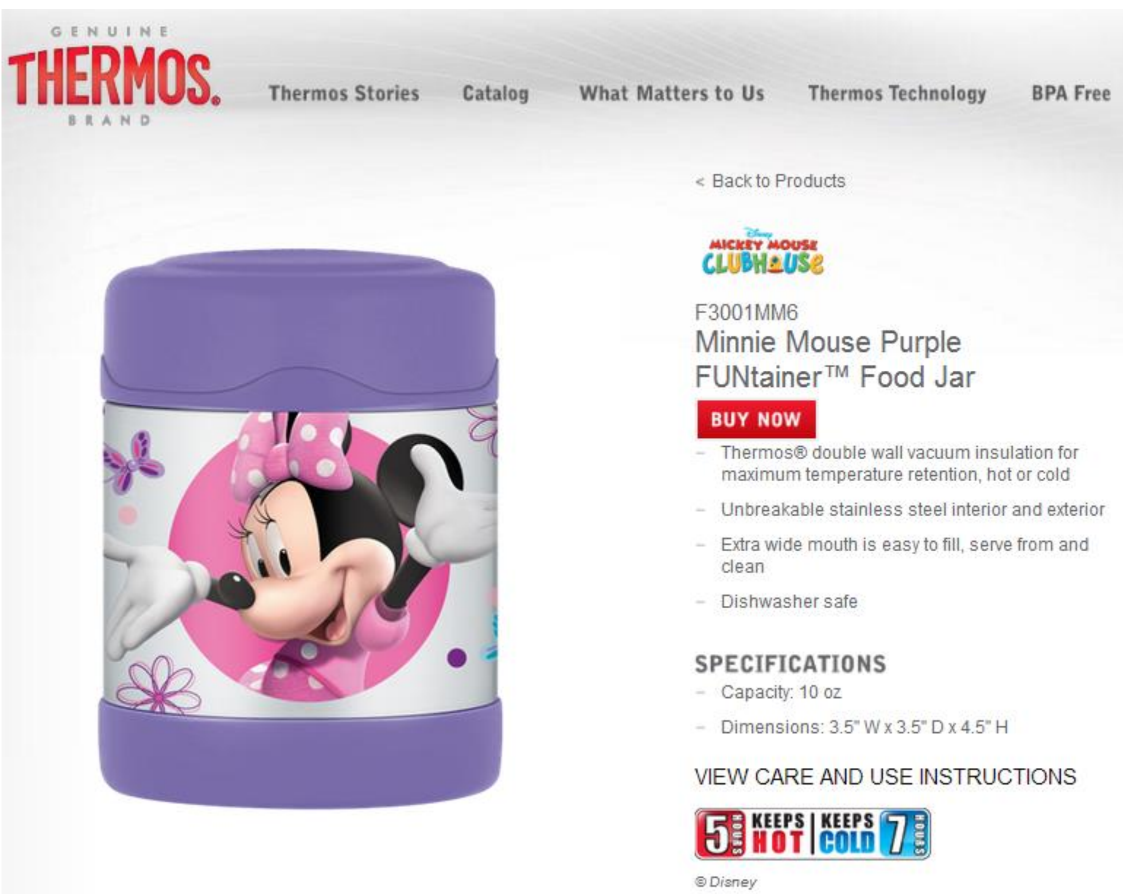
Blue Foogo® Vacuum Insulated 10 oz Food Jar
BUY NOW
AVAILABLE IN
Product Tutorial
- Thermos® double wall vacuum insulation for maximum temperature retention
- Unbreakable stainless steel interior and exterior
- Wide mouth is easy to fill, eat from, and clean
- Ergonomically designed lid with rubber grip
- Dishwasher safe
- Non-slip, scratch resistant base, cool to the touch with warm foods
- Light, compact and portable
SPECIFICATIONS
- Capacity: 10 oz
- Dimensions: 3.8" W x 3.8" D x 4.8" H
VIEW CARE AND USE INSTRUCTIONS
5 KEEPS WARM
KEEPS COLD 7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F3001MM6
Minnie Mouse Purple FUNtainer™ Food Jar
BUY NOW
- Thermos® double wall vacuum insulation for maximum temperature retention, hot or cold
- Unbreakable stainless steel interior and exterior
- Extra wide mouth is easy to fill, serve from and clean
- Dishwasher safe
SPECIFICATIONS
- Capacity: 10 oz
- Dimensions: 3.5" W x 3.5" D x 4.5" H
VIEW CARE AND USE INSTRUCTIONS
5 KEEPS HOT
KEEPS COLD 7
© Disney

2. *Durac® Digital Thermometer*

H-B Instrument Company
102 West Seventh Ave
P.O. Box 26770
Collegeville, PA 19426 USA

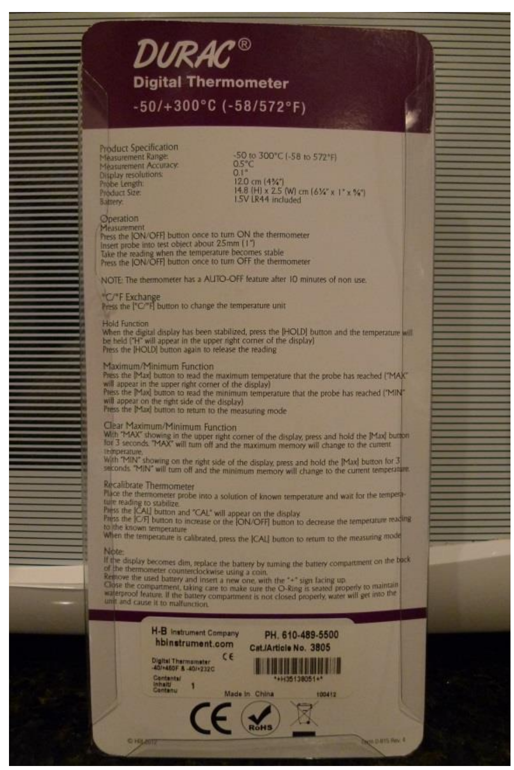
Toll Free Phone:	800-4 TEST-Lab (USA & Canada only)
Worldwide Phone:	610-489-5500
Toll Free Fax:	800-HBI-FAX2 (USA & Canada only)
Worldwide Fax:	610-489-9100
Email:	info@hbinstrument.com

DURAC® Waterproof Electronic Thermometers

Feature a stainless steel temperature probe, probe cover with pocket clip, 0.1 resolution, CE mark, RoHS compliant. Supplied with multi-language (English, French, German, Italian, Portuguese and Spanish) instructions and Statement of Traceability indicating accuracy traceable to NIST and DAkkS. All thermometers are tested and calibrated in H-B's exclusive triple accredited/ registered ISO/IEC 17025:2005, A2LA accredited laboratory against equipment whose calibration is traceable to NIST and DAkkS. Ideal for field studies, cuvettes, test tubes, flasks and beakers. Will read temperatures in sample reagents, water baths, semi-solids and gases.

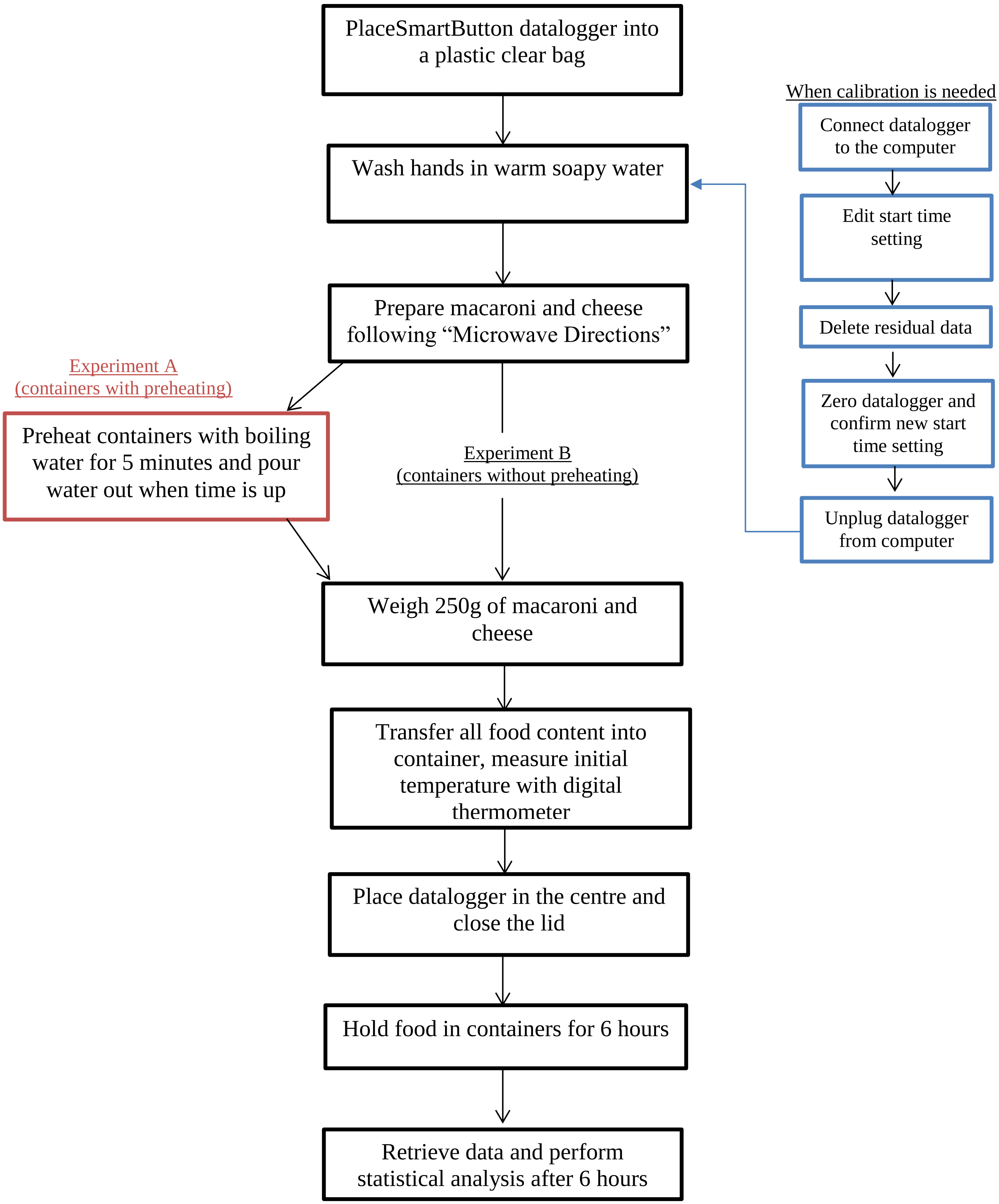
Results 1 - 4 of 4

Item #	Item Image	IP Rating	Range	Probe Length	Accuracy	Instruction Sheet
3805	 3805 Durac Digital Thermometer	IP68	-40/232 °C -40/450 °F	5 in 127 mm	2ºC; 0.5ºC from 54/82ºC; 4ºC above 176ºC	Instruction Sheet



APPENDIX 3

Flowchart of Experiment


PlaceSmartButton datalogger into a plastic clear bag
Wash hands in warm soapy water
Prepare macaroni and cheese following "Microwave Directions"
Experiment A (containers with preheating)
Preheat containers with boiling water for 5 minutes and pour water out when time is up
Experiment B (containers without preheating)
Weigh 250g of macaroni and cheese
Transfer all food content into container, measure initial temperature with digital thermometer
Place datalogger in the centre and close the lid
Hold food in containers for 6 hours
Retrieve data and perform statistical analysis after 6 hours
When calibration is needed
Connect datalogger to the computer
Edit start time setting
Delete residual data
Zero datalogger and confirm new start time setting
Unplug datalogger from computer

APPENDIX 4

Kraft Dinner Microwave Directions

1. Empty pasta into 6-cup microwavable bowl. Add 1 ¾ cups HOT water, stir.
2. Microwave on HIGH for 8 to 9 minutes, or until water is adsorbed, stirring everyyy   3 minutes
3. Add 1 Tbsp. non-hydrogenated margarine, 1/3 cup skim milk and the Cheese Sauce Mix.
4. Mix well.

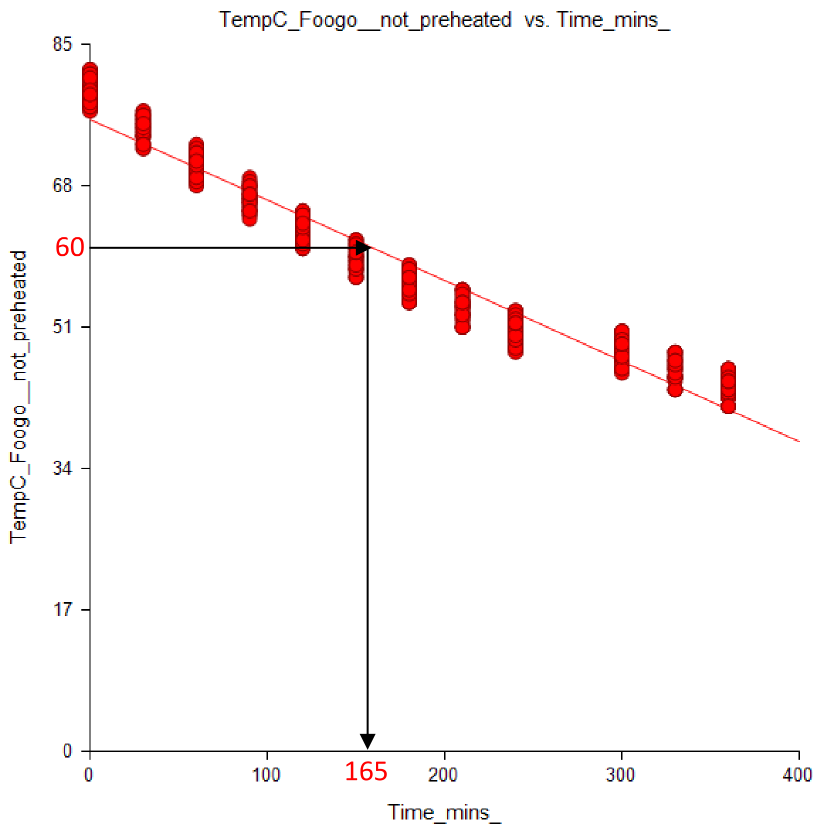
FRONT

BACK

APPENDIX 5

Statistical Analysis – Linear Regression Report

1. Foogo – not preheated
2. Foogo – preheated
3. FUNtainer – not preheated
4. FUNtainer – preheated
5. PC – not preheated
6. PC – preheated



Run Summary Section

Parameter	Value	Parameter	Value
Dependent Variable	TempC_Foogo__not_preheated		Rows Processed
	2160		
Independent Variable	Time_mins_	Rows Used in Estimation	360
Frequency Variable	None	Rows with X Missing	1800
Weight Variable	None	Rows with Freq Missing	0
Intercept	76.0228	Rows Prediction Only	0
Slope	-0.0969	Sum of Frequencies	360
R-Squared	0.9508	Sum of Weights	360.0000
Correlation	-0.9751	Coefficient of Variation	0.0424
Mean Square Error	6.315935	Square Root of MSE	2.513152

Summary Statement

The equation of the straight line relating TempC_Foogo__not_preheated and Time_mins_ is estimated as: TempC_Foogo__not_preheated = (76.0228) + (-0.0969) Time_mins_ using the 360 observations in this dataset. The y-intercept, the estimated value of TempC_Foogo__not_preheated when Time_mins_ is zero, is 76.0228 with a standard error of 0.2407. The slope, the estimated change in TempC_Foogo__not_preheated per unit change in Time_mins_ , is -0.0969 with a standard error of 0.0012. The value of R-Squared, the proportion of the variation in TempC_Foogo__not_preheated that can be accounted for by variation in Time_mins_ , is 0.9508. The correlation between TempC_Foogo__not_preheated and Time_mins_ is -0.9751.

A significance test that the slope is zero resulted in a t-value of -83.1748. The significance level of this t-test is 0.0000. Since 0.0000 < 0.0500, the hypothesis that the slope is zero is rejected.

The estimated slope is -0.0969. The lower limit of the 95% confidence interval for the slope is -0.0992 and the upper limit is -0.0946. The estimated intercept is 76.0228. The lower limit of the 95% confidence interval for the intercept is 75.5494 and the upper limit is 76.4963.

Descriptive Statistics Section

Parameter	**Dependent**	**Independent**
Variable	TempC_Foogo__not_preheated	Time_mins_
Count	360	360
Mean	59.3028	172.5000
Standard Deviation	11.3141	113.8189
Minimum	41.5000	0.0000
Maximum	82.0000	360.0000

Regression Estimation Section

Parameter	**Intercept B(0)**	**Slope B(1)**
Regression Coefficients	76.0228	-0.0969
Lower 95% Confidence Limit	75.5494	-0.0992
Upper 95% Confidence Limit	76.4963	-0.0946
Standard Error	0.2407	0.0012
Standardized Coefficient	0.0000	-0.9751
T Value	315.7912	-83.1748
Prob Level (T Test)	0.0000	0.0000
Reject H0 (Alpha = 0.0500)	Yes	Yes
Power (Alpha = 0.0500)	1.0000	1.0000
Regression of Y on X	76.0228	-0.0969
Inverse Regression from X on Y	76.8881	-0.1019
Orthogonal Regression of Y and X	76.0309	-0.0970

Notes:
The above report shows the least-squares estimates of the intercept and slope followed by the corresponding standard errors, confidence intervals, and hypothesis tests. Note that these results are based on several assumptions that should be validated before they are used.

Estimated Model

(76.0228430898242) + (-.0969279148524431) * (Time_mins_)

Analysis of Variance Section

Source	**DF**	**Sum of Squares**	**Mean Square**	**F-Ratio**	**Prob Level**	**Power (5%)**
Intercept	1	1266055	1266055			
Slope	1	43693.89	43693.89	6918.0400	0.0000	1.0000
Error	358	2261.105	6.315935			
Lack of Fit	10	1578.721	157.8721	80.5112	0.0000	
Pure Error	348	682.3834	1.960872			
Adj. Total	359	45955	128.0083			
Total	360	1312010				

s = Square Root(6.315935) = 2.513152

Notes:
The above report shows the F-Ratio for testing whether the slope is zero, the degrees of freedom, and the mean square error. The mean square error, which estimates the variance of the residuals, is used extensively in the calculation of hypothesis tests and confidence intervals.

Tests of Assumptions Section

Assumption/Test	**Test Value**	**Prob Level**	**Is the Assumption Reasonable at the 0.2000 Level of Significance?**
Residuals follow Normal Distribution?			
Shapiro Wilk	0.9824	0.000221	No
Anderson Darling	1.3815	0.001419	No
D'Agostino Skewness	1.0702	0.284514	Yes
D'Agostino Kurtosis	-5.0337	0.000000	No
D'Agostino Omnibus	26.4832	0.000002	No

Constant Residual Variance?

Modified Levene Test	1.9874	0.159481	No

Relationship is a Straight Line?

Lack of Linear Fit F(10, 348) Test	80.5112	0.000000	No

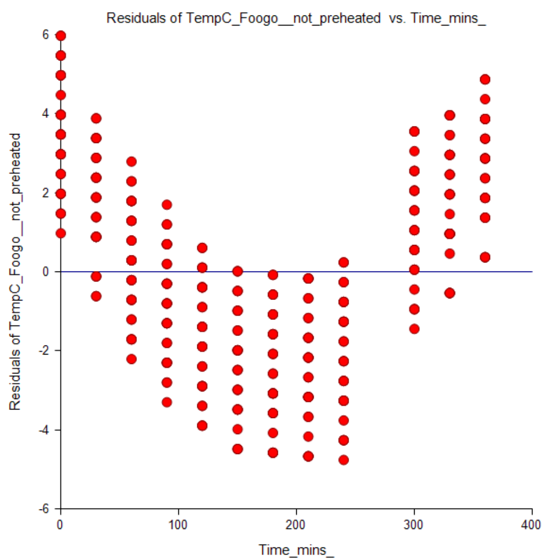
No Serial Correlation?
Evaluate the Serial-Correlation report and the Durbin-Watson test if you have equal-spaced, time series data.

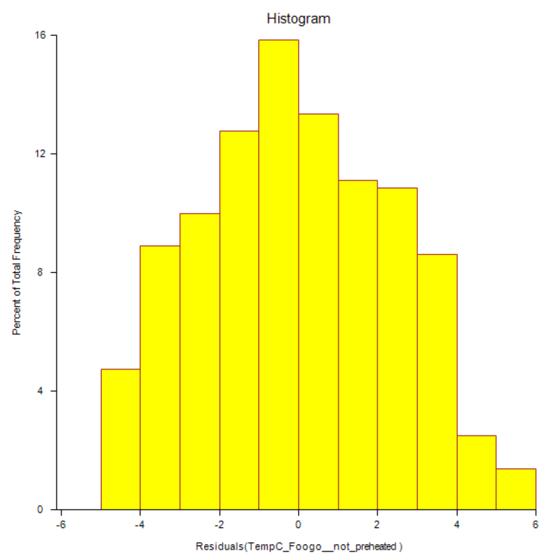
Notes:
A 'Yes' means there is not enough evidence to make this assumption seem unreasonable. This lack of evidence may be because the sample size is too small, the assumptions of the test itself are not met, or the assumption is valid. A 'No' means the that the assumption is not reasonable. However, since these tests are related to sample size, you should assess the role of sample size in the tests by also evaluating the appropriate plots and graphs. A large dataset (say N > 500) will often fail at least one of the normality tests because it is hard to find a large dataset that is perfectly normal.

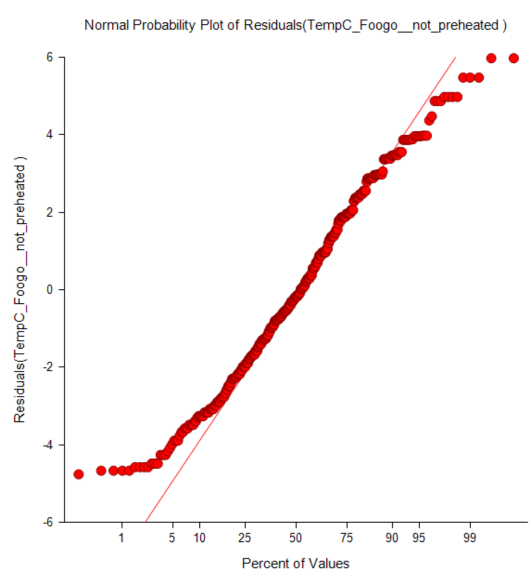
Normality and Constant Residual Variance:
Possible remedies for the failure of these assumptions include using a transformation of Y such as the log or square root, correcting data-recording errors found by looking into outliers, adding additional independent variables, using robust regression, or using bootstrap methods.

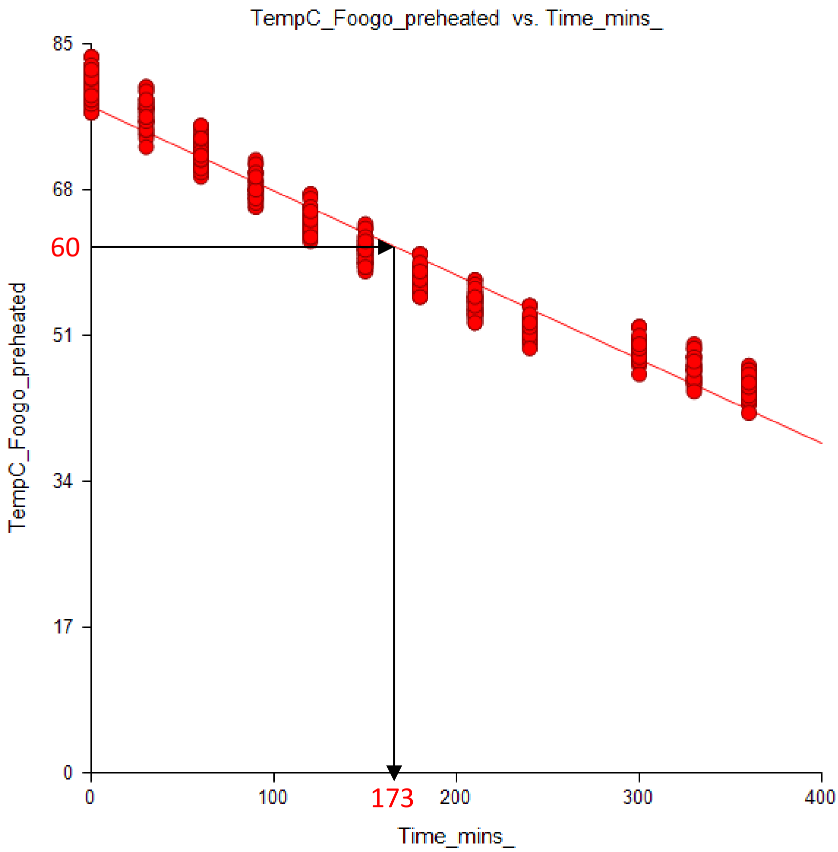
Straight-Line:
Possible remedies for the failure of this assumption include using nonlinear regression or polynomial regression.

Residual Plots Section









Run Summary Section

Parameter	Value	Parameter	Value
Dependent Variable	TempC_Foogo_preheated	Rows Processed	2160
Independent Variable	Time_mins_	Rows Used in Estimation	360
Frequency Variable	None	Rows with X Missing	1800
Weight Variable	None	Rows with Freq Missing	0
Intercept	76.8954	Rows Prediction Only	0
Slope	-0.0977	Sum of Frequencies	360
R-Squared	0.9484	Sum of Weights	360.0000
Correlation	-0.9739	Coefficient of Variation	0.0604
Mean Square Error	13.48425	Square Root of MSE	3.672091

Summary Statement

The equation of the straight line relating TempC_Foogo_preheated and Time_mins_ is estimated as: TempC_Foogo_preheated = (76.8954) + (-0.0977) Time_mins_ using the 360 observations in this dataset. The y-intercept, the estimated value of TempC_Foogo_preheated when Time_mins_ is zero, is 76.8954 with a standard error of 0.2487. The slope, the estimated change in TempC_Foogo_preheated per unit change in Time_mins_ , is -0.0977 with a standard error of 0.0012. The value of R-Squared, the proportion of the variation in TempC_Foogo_preheated that can be accounted for by variation in Time_mins_ , is 0.9484. The correlation between TempC_Foogo_preheated and Time_mins_ is -0.9739.

A significance test that the slope is zero resulted in a t-value of -81.1264. The significance level of this t-test is 0.0000. Since 0.0000 < 0.0500, the hypothesis that the slope is zero is rejected.

The estimated slope is -0.0977. The lower limit of the 95% confidence interval for the slope is -0.1000 and the upper limit is -0.0953. The estimated intercept is 76.8954. The lower limit of the 95% confidence interval for the intercept is 76.4062 and the upper limit is 77.3845.

Descriptive Statistics Section

Parameter	**Dependent**	**Independent**
Variable	TempC_Foogo_preheated	Time_mins_
Count	360	360
Mean	60.7889	172.5000
Standard Deviation	16.1447	160.9642
Minimum	42.0000	0.0000
Maximum	83.5000	360.0000

Regression Estimation Section

Parameter	**Intercept B(0)**	**Slope B(1)**
Regression Coefficients	76.8954	-0.0977
Lower 95% Confidence Limit	76.4062	-0.1000
Upper 95% Confidence Limit	77.3845	-0.0953
Standard Error	0.2487	0.0012
Standardized Coefficient	0.0000	-0.9739
T Value	309.1552	-81.1264
Prob Level (T Test)	0.0000	0.0000
Reject H0 (Alpha = 0.0500)	Yes	Yes
Power (Alpha = 0.0500)	1.0000	1.0000
Regression of Y on X	76.8954	-0.0977
Inverse Regression from X on Y	78.5550	-0.1030
Orthogonal Regression of Y and X	77.6464	-0.0977

Notes:
The above report shows the least-squares estimates of the intercept and slope followed by the corresponding standard errors, confidence intervals, and hypothesis tests. Note that these results are based on several assumptions that should be validated before they are used.

Estimated Model

(76.8953918722787) + (-.0976786002257699) * (Time_mins_)

Analysis of Variance Section

Source	**DF**	**Sum of Squares**	**Mean Square**	**F-Ratio**	**Prob Level**	**Power (5%)**
Intercept	1	2595962	2595962			
Slope	1	88746.63	88746.63	6581.5009	0.0000	1.0000
Error	358	4827.363	13.48425			
Lack of Fit	10	4041.746	404.1746	179.0348	0.0000	
Pure Error	348	785.6166	2.257519			
Adj. Total	359	93573.98	260.6518			
Total	360	2689536				

s = Square Root(13.48425) = 3.672091

Notes:
The above report shows the F-Ratio for testing whether the slope is zero, the degrees of freedom, and the mean square error. The mean square error, which estimates the variance of the residuals,is used extensively in the calculation of hypothesis tests and confidence intervals.

Tests of Assumptions Section

Assumption/Test	**Test Value**	**Prob Level**	**Is the Assumption Reasonable at the 0.2000 Level of Significance?**
Residuals follow Normal Distribution?			
Shapiro Wilk	0.9806	0.000092	No
Anderson Darling	1.6686	0.000280	No
D'Agostino Skewness	1.4849	0.137568	No
D'Agostino Kurtosis	-5.0869	0.000000	No
D'Agostino Omnibus	28.0818	0.000001	No

Constant Residual Variance?			
Modified Levene Test	0.9758	0.323895	Yes
Relationship is a Straight Line?			
Lack of Linear Fit F(10, 348) Test	179.0348	0.000000	No

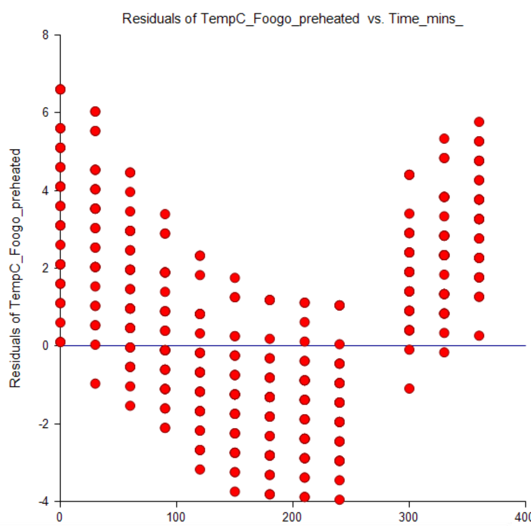
No Serial Correlation?
Evaluate the Serial-Correlation report and the Durbin-Watson test if you have equal-spaced, time series data.

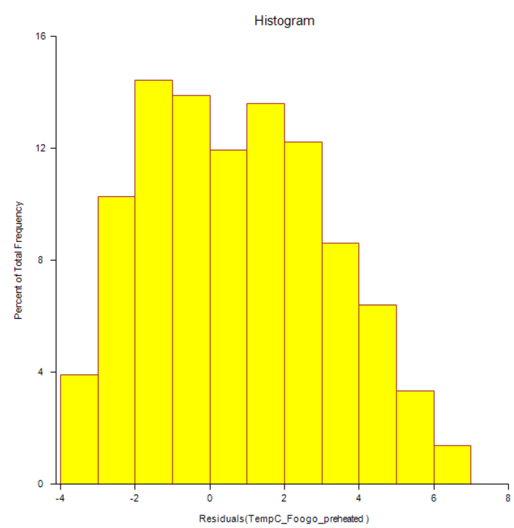
Notes:
A 'Yes' means there is not enough evidence to make this assumption seem unreasonable. This lack of evidence may be because the sample size is too small, the assumptions of the test itself are not met, or the assumption is valid. A 'No' means the that the assumption is not reasonable. However, since these tests are related to sample size, you should assess the role of sample size in the tests by also evaluating the appropriate plots and graphs. A large dataset (say N > 500) will often fail at least one of the normality tests because it is hard to find a large dataset that is perfectly normal.

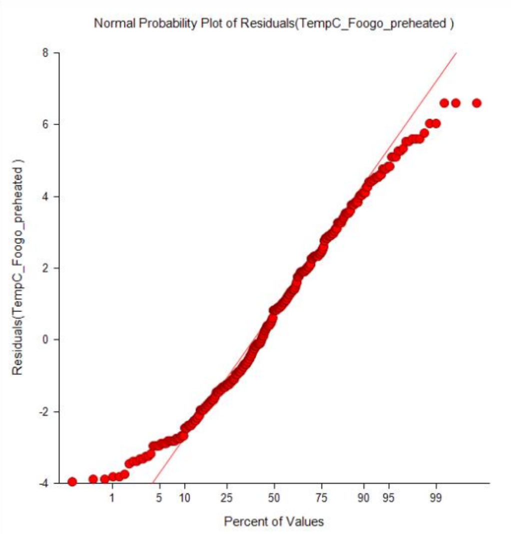
Normality and Constant Residual Variance:
Possible remedies for the failure of these assumptions include using a transformation of Y such as the log or square root, correcting data-recording errors found by looking into outliers, adding additional independent variables, using robust regression, or using bootstrap methods.

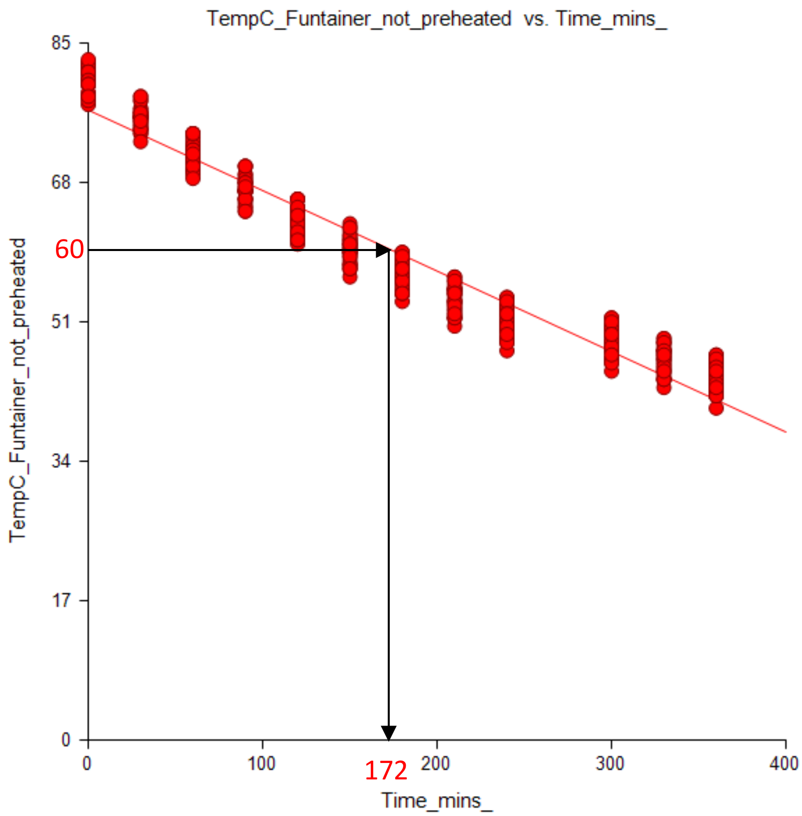
Straight-Line:
Possible remedies for the failure of this assumption include using nonlinear regression or polynomial regression.

Residual Plots Section









Run Summary Section

Parameter	Value	Parameter	Value
Dependent Variable	TempC_Funtainer_not_preheated	Rows Processed	2160
Independent Variable	Time_mins_	Rows Used in Estimation	360
Frequency Variable	None	Rows with X Missing	1800
Weight Variable	None	Rows with Freq Missing	0
Intercept	76.9045	Rows Prediction Only	0
Slope	-0.0980	Sum of Frequencies	360
R-Squared	0.9473	Sum of Weights	360.0000
Correlation	-0.9733	Coefficient of Variation	0.0761
Mean Square Error	20.78642	Square Root of MSE	4.559213

Summary Statement

The equation of the straight line relating TempC_Funtainer_not_preheated and Time_mins_ is estimated as: TempC_Funtainer_not_preheated = (76.9045) + (-0.0980) Time_mins_ using the 360 observations in this dataset. The y-intercept, the estimated value of TempC_Funtainer_not_preheated when Time_mins_ is zero, is 76.9045 with a standard error of 0.2521. The slope, the estimated change in TempC_Funtainer_not_preheated per unit change in Time_mins_ , is -0.0980 with a standard error of 0.0012. The value of R-Squared, the proportion of the variation in TempC_Funtainer_not_preheated that can be accounted for by variation in Time_mins_ , is 0.9473. The correlation between TempC_Funtainer_not_preheated and Time_mins_ is -0.9733.

A significance test that the slope is zero resulted in a t-value of -80.2518. The significance level of this t-test is 0.0000. Since 0.0000 < 0.0500, the hypothesis that the slope is zero is rejected.

The estimated slope is -0.0980. The lower limit of the 95% confidence interval for the slope is -0.1004 and the upper limit is -0.0956. The estimated intercept is 76.9045. The lower limit of the 95% confidence interval for the intercept is 76.4086 and the upper limit is 77.4004.

Descriptive Statistics Section

Parameter	**Dependent**	**Independent**
Variable	TempC_Funtainer_not_preheated	Time_mins_
Count	360	360
Mean	59.9306	172.5000
Standard Deviation	19.8401	197.1401
Minimum	40.5000	0.0000
Maximum	83.0000	360.0000

Regression Estimation Section

Parameter	**Intercept B(0)**	**Slope B(1)**
Regression Coefficients	76.9045	-0.0980
Lower 95% Confidence Limit	76.4086	-0.1004
Upper 95% Confidence Limit	77.4004	-0.0956
Standard Error	0.2521	0.0012
Standardized Coefficient	0.0000	-0.9733
T Value	304.9981	-80.2518
Prob Level (T Test)	0.0000	0.0000
Reject H0 (Alpha = 0.0500)	Yes	Yes
Power (Alpha = 0.0500)	1.0000	1.0000
Regression of Y on X	76.9045	-0.0980
Inverse Regression from X on Y	77.7669	-0.1034
Orthogonal Regression of Y and X	76.8361	-0.0980

Notes:
The above report shows the least-squares estimates of the intercept and slope followed by the corresponding standard errors, confidence intervals, and hypothesis tests. Note that these results are based on several assumptions that should be validated before they are used.

Estimated Model

(76.9044885233564) + (-.0979540934257916) * (Time_mins_)

Analysis of Variance Section

Source	**DF**	**Sum of Squares**	**Mean Square**	**F-Ratio**	**Prob Level**	**Power (5%)**
Intercept	1	3888960	3888960			
Slope	1	133871.9	133871.9	6440.3522	0.0000	1.0000
Error	358	7441.541	20.78642			
Lack of Fit	10	6547.44	654.744	254.8383	0.0000	
Pure Error	348	894.1	2.569253			
Adj. Total	359	141313.4	393.6308			
Total	360	4030274				

s = Square Root(20.78642) = 4.559213

Notes:
The above report shows the F-Ratio for testing whether the slope is zero, the degrees of freedom, and the mean square error. The mean square error, which estimates the variance of the residuals, is used extensively in the calculation of hypothesis tests and confidence intervals.

Tests of Assumptions Section

Assumption/Test	**Test Value**	**Prob Level**	**Is the Assumption Reasonable at the 0.2000 Level of Significance?**
Residuals follow Normal Distribution?			
Shapiro Wilk	0.9861	0.001531	No
Anderson Darling	1.0069	0.011846	No
D'Agostino Skewness	0.6131	0.539814	Yes
D'Agostino Kurtosis	-4.4223	0.000010	No
D'Agostino Omnibus	19.9328	0.000047	No

Constant Residual Variance?

Modified Levene Test	1.7471	0.187081	No

Relationship is a Straight Line?

Lack of Linear Fit F(10, 348) Test	254.8383	0.000000	No

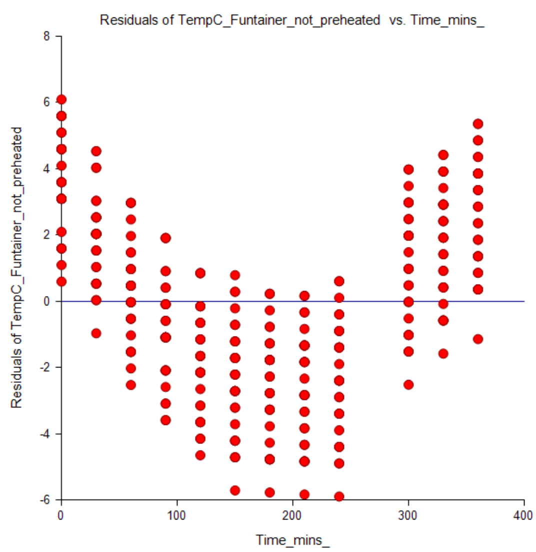
No Serial Correlation?
Evaluate the Serial-Correlation report and the Durbin-Watson test if you have equal-spaced, time series data.

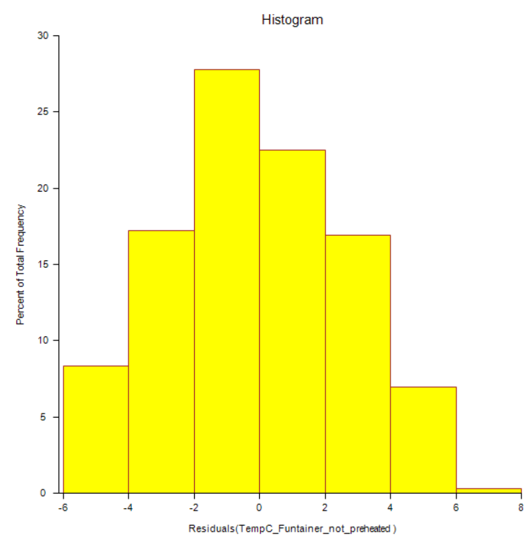
Notes:
A 'Yes' means there is not enough evidence to make this assumption seem unreasonable. This lack of evidence may be because the sample size is too small, the assumptions of the test itself are not met, or the assumption is valid.
A 'No' means the that the assumption is not reasonable. However, since these tests are related to sample size, you should assess the role of sample size in the tests by also evaluating the appropriate plots and graphs. A large dataset (say N > 500) will often fail at least one of the normality tests because it is hard to find a large dataset that is perfectly normal.

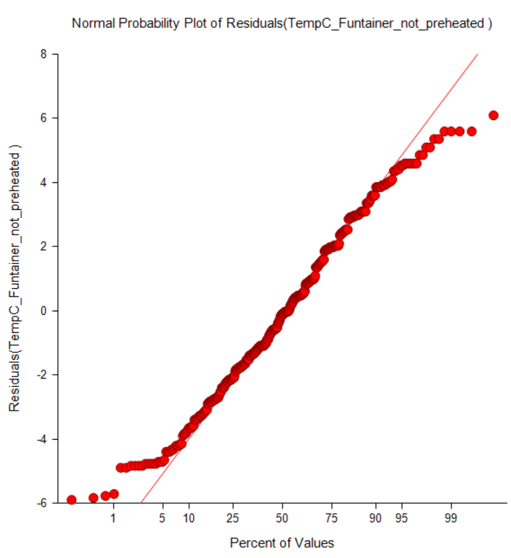
Normality and Constant Residual Variance:
Possible remedies for the failure of these assumptions include using a transformation of Y such as the log or square root, correcting data-recording errors found by looking into outliers, adding additional independent variables, using robust regression, or using bootstrap methods.

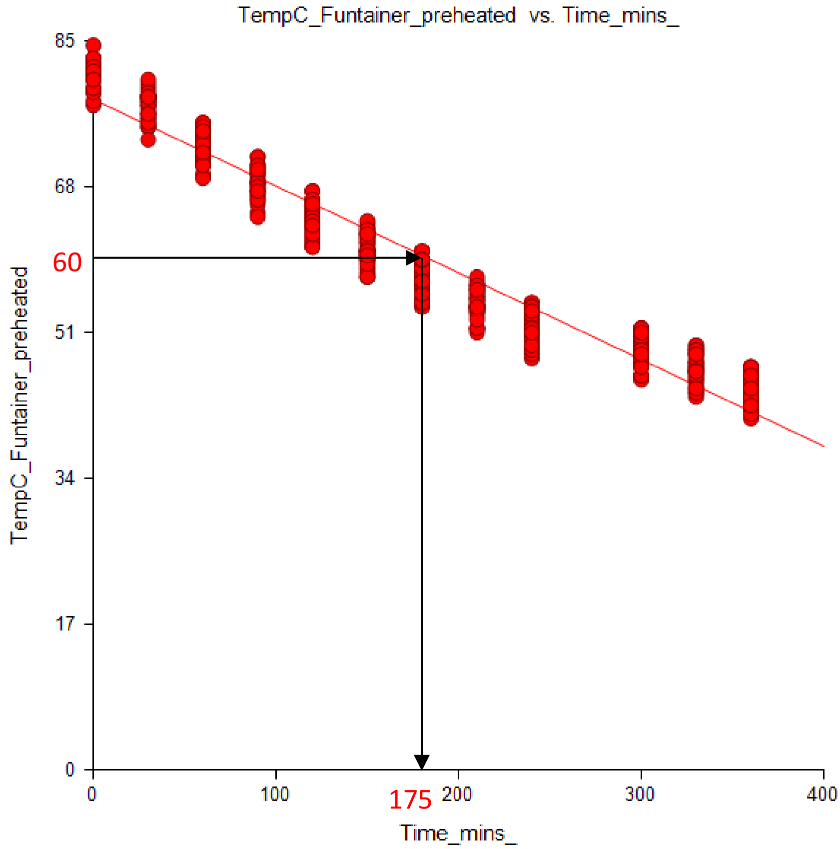
Straight-Line:
Possible remedies for the failure of this assumption include using nonlinear regression or polynomial regression.

Residual Plots Section









Run Summary Section

Parameter	Value	Parameter	Value
Dependent Variable	TempC_Funtainer_preheated	Rows Processed	2160
Independent Variable	Time_mins_	Rows Used in Estimation	360
Frequency Variable	None	Rows with X Missing	1800
Weight Variable	None	Rows with Freq Missing	0
Intercept	77.2216	Rows Prediction Only	0
Slope	-0.0987	Sum of Frequencies	360
R-Squared	0.9465	Sum of Weights	360.0000
Correlation	-0.9729	Coefficient of Variation	0.0881
Mean Square Error	28.64338	Square Root of MSE	5.351951

Summary Statement

The equation of the straight line relating TempC_Funtainer_preheated and Time_mins_ is estimated as: TempC_Funtainer_preheated = (77.2216) + (-0.0987) Time_mins_ using the 360 observations in this dataset. The y-intercept, the estimated value of TempC_Funtainer_preheated when Time_mins_ is zero, is 77.2216 with a standard error of 0.2563. The slope, the estimated change in TempC_Funtainer_preheated per unit change in Time_mins_ , is -0.0987 with a standard error of 0.0012. The value of R-Squared, the proportion of the variation in TempC_Funtainer_preheated that can be accounted for by variation in Time_mins_ , is 0.9465. The correlation between TempC_Funtainer_preheated and Time_mins_ is -0.9729.

A significance test that the slope is zero resulted in a t-value of -79.5617. The significance level of this t-test is 0.0000. Since 0.0000 < 0.0500, the hypothesis that the slope is zero is rejected.

The estimated slope is -0.0987. The lower limit of the 95% confidence interval for the slope is -0.1012 and the upper limit is -0.0963. The estimated intercept is 77.2216. The lower limit of the 95% confidence interval for the intercept is 76.7175 and the upper limit is 77.7257.

Descriptive Statistics Section

Parameter	**Dependent**	**Independent**
Variable	TempC_Funtainer_preheated	Time_mins_
Count	360	360
Mean	60.7444	172.5000
Standard Deviation	23.1002	227.6377
Minimum	41.0000	0.0000
Maximum	84.5000	360.0000

Regression Estimation Section

Parameter	**Intercept B(0)**	**Slope B(1)**
Regression Coefficients	77.2216	-0.0987
Lower 95% Confidence Limit	76.7175	-0.1012
Upper 95% Confidence Limit	77.7257	-0.0963
Standard Error	0.2563	0.0012
Standardized Coefficient	0.0000	-0.9729
T Value	301.2531	-79.5617
Prob Level (T Test)	0.0000	0.0000
Reject H0 (Alpha = 0.0500)	Yes	Yes
Power (Alpha = 0.0500)	1.0000	1.0000
Regression of Y on X	77.2216	-0.0987
Inverse Regression from X on Y	78.7375	-0.1043
Orthogonal Regression of Y and X	77.7832	-0.0988

Notes:
The above report shows the least-squares estimates of the intercept and slope followed by the corresponding standard errors, confidence intervals, and hypothesis tests. Note that these results are based on several assumptions that should be validated before they are used.

Estimated Model

(77.2216255442671) + (-.098724399290437) * (Time_mins_)

Analysis of Variance Section

Source	**DF**	**Sum of Squares**	**Mean Square**	**F-Ratio**	**Prob Level**	**Power (5%)**
Intercept	1	5217173	5217173			
Slope	1	181314.3	181314.3	6330.0585	0.0000	1.0000
Error	358	10254.33	28.64338			
Lack of Fit	10	9212.413	921.2413	307.6945	0.0000	
Pure Error	348	1041.917	2.994013			
Adj. Total	359	191568.6	533.6172			
Total	360	5408742				

s = Square Root(28.64338) = 5.351951

Notes:
The above report shows the F-Ratio for testing whether the slope is zero, the degrees of freedom, and the mean square error. The mean square error, which estimates the variance of the residuals, is used extensively in the calculation of hypothesis tests and confidence intervals.

Tests of Assumptions Section

Assumption/Test	**Test Value**	**Prob Level**	**Is the Assumption Reasonable at the 0.2000 Level of Significance?**
Residuals follow Normal Distribution?			
Shapiro Wilk	0.9865	0.001998	No
Anderson Darling	1.0707	0.008250	No
D'Agostino Skewness	-0.4177	0.676135	Yes
D'Agostino Kurtosis	-4.2913	0.000018	No
D'Agostino Omnibus	18.5896	0.000092	No

Constant Residual Variance?

Modified Levene Test	0.2484	0.618530	Yes

Relationship is a Straight Line?

Lack of Linear Fit F(10, 348) Test	307.6945	0.000000	No

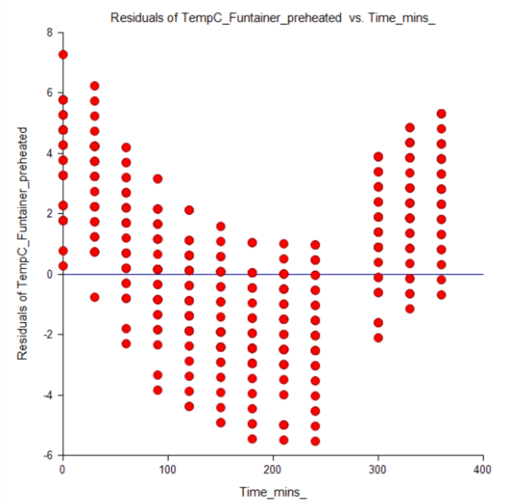
No Serial Correlation?
Evaluate the Serial-Correlation report and the Durbin-Watson test if you have equal-spaced, time series data.

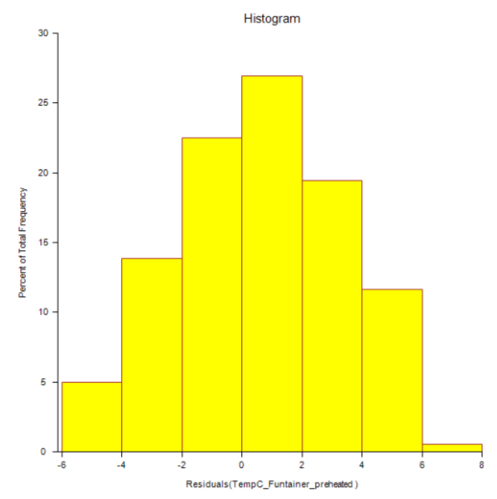
Notes:
A 'Yes' means there is not enough evidence to make this assumption seem unreasonable. This lack of evidence may be because the sample size is too small, the assumptions of the test itself are not met, or the assumption is valid.
A 'No' means the that the assumption is not reasonable. However, since these tests are related to sample size, you should assess the role of sample size in the tests by also evaluating the appropriate plots and graphs. A large dataset (say N > 500) will often fail at least one of the normality tests because it is hard to find a large dataset that is perfectly normal.

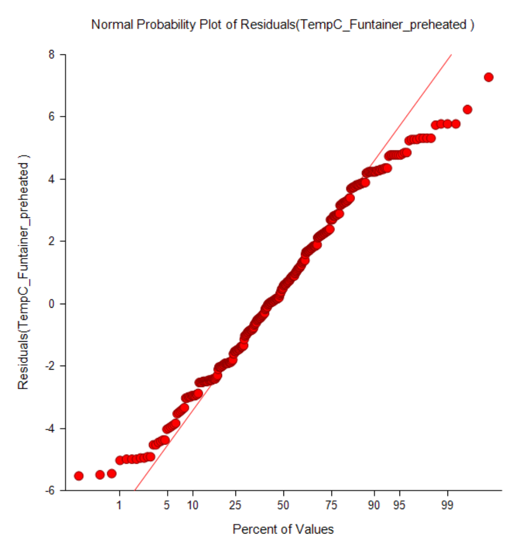
Normality and Constant Residual Variance:
Possible remedies for the failure of these assumptions include using a transformation of Ysuch as the log or square root, correcting data-recording errors found by looking into outliers, adding additional independent variables, using robust regression, or using bootstrap methods.

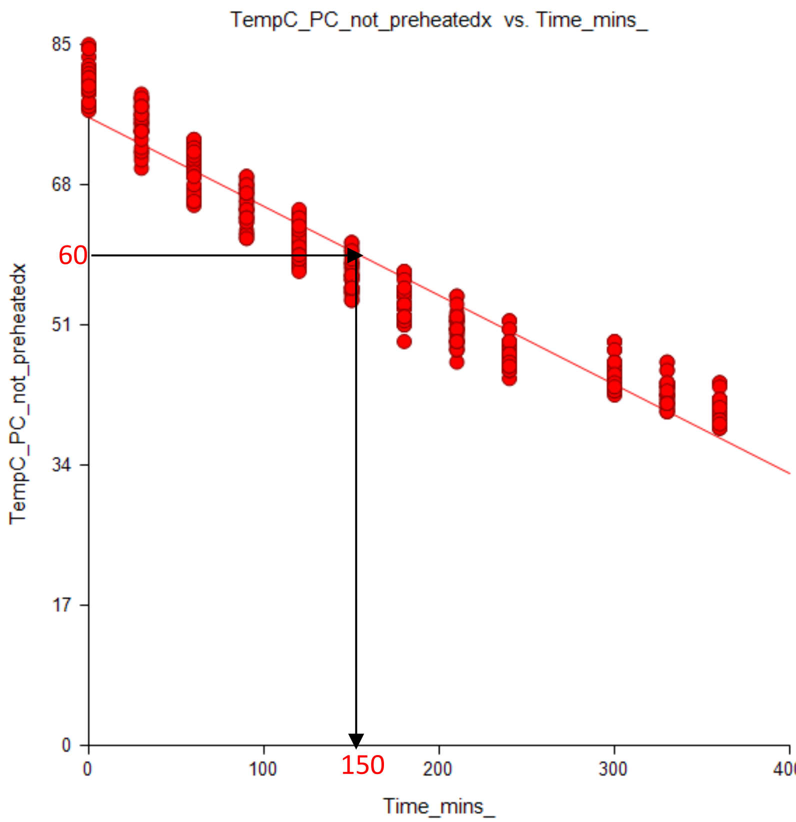
Straight-Line:
Possible remedies for the failure of this assumption include using nonlinear regression or polynomial regression.

Residual Plots Section









Run Summary Section

Parameter	Value	Parameter	Value
Dependent Variable	TempC_PC_not_preheatedx	Rows Processed	2160
Independent Variable	Time_mins_	Rows Used in Estimation	360
Frequency Variable	None	Rows with X Missing	1800
Weight Variable	None	Rows with Freq Missing	0
Intercept	76.2080	Rows Prediction Only	0
Slope	-0.1082	Sum of Frequencies	360
R-Squared	0.9324	Sum of Weights	360.0000
Correlation	-0.9656	Coefficient of Variation	0.0577
Mean Square Error	11.02425	Square Root of MSE	3.320279

Summary Statement

The equation of the straight line relating TempC_PC_not_preheatedx and Time_mins_ is estimated as: TempC_PC_not_preheatedx = (76.2080) + (-0.1082) Time_mins_ using the 360 observations in this dataset. The y-intercept, the estimated value of TempC_PC_not_preheatedx when Time_mins_ is zero, is 76.2080 with a standard error of 0.3181. The slope, the estimated change in TempC_PC_not_preheatedx per unit change in Time_mins_ , is -0.1082 with a standard error of 0.0015. The value of R-Squared, the proportion of the variation in TempC_PC_not_preheatedx that can be accounted for by variation in Time_mins_ , is 0.9324. The correlation between TempC_PC_not_preheatedx and Time_mins_ is -0.9656.

A significance test that the slope is zero resulted in a t-value of -70.2580. The significance level of this t-test is 0.0000. Since 0.0000 < 0.0500, the hypothesis that the slope is zero is rejected. The estimated slope is -0.1082. The lower limit of the 95% confidence interval for the slope is -0.1112 and the upper limit is -0.1051. The estimated intercept is 76.2080. The lower limit of the 95% confidence interval for the intercept is 75.5825 and the upper limit is 76.8335.

Descriptive Statistics Section

Parameter	**Dependent**	**Independent**
Variable	TempC_PC_not_preheatedx	Time_mins_
Count	360	360
Mean	57.5486	172.5000
Standard Deviation	12.7505	113.8189
Minimum	38.5000	0.0000
Maximum	85.0000	360.0000

Regression Estimation Section

Parameter	**Intercept B(0)**	**Slope B(1)**
Regression Coefficients	76.2080	-0.1082
Lower 95% Confidence Limit	75.5825	-0.1112
Upper 95% Confidence Limit	76.8335	-0.1051
Standard Error	0.3181	0.0015
Standardized Coefficient	0.0000	-0.9656
T Value	239.6077	-70.2580
Prob Level (T Test)	0.0000	0.0000
Reject H0 (Alpha = 0.0500)	Yes	Yes
Power (Alpha = 0.0500)	1.0000	1.0000
Regression of Y on X	76.2080	-0.1082
Inverse Regression from X on Y	77.5613	-0.1160
Orthogonal Regression of Y and X	76.2237	-0.1083

Notes:
The above report shows the least-squares estimates of the intercept and slope followed by the corresponding standard errors, confidence intervals, and hypothesis tests. Note that these results are based on several assumptions that should be validated before they are used.

Estimated Model

(76.2080148363168) + (-.108170456378003) * (Time_mins_)

Analysis of Variance Section

Source	**DF**	**Sum of Squares**	**Mean Square**	**F-Ratio**	**Prob Level**	**Power (5%)**
Intercept	1	1192263	1192263			
Slope	1	54417.72	54417.72	4936.1823	0.0000	1.0000
Error	358	3946.682	11.02425			
Lack of Fit	10	2502.424	250.2424	60.2969	0.0000	
Pure Error	348	1444.258	4.150167			
Adj. Total	359	58364.4	162.5749			
Total	360	1250628				

s = Square Root(11.02425) = 3.320279

Notes:
The above report shows the F-Ratio for testing whether the slope is zero, the degrees of freedom, and the mean square error. The mean square error, which estimates the variance of the residuals, is used extensively in the calculation of hypothesis tests and confidence intervals.

Tests of Assumptions Section

Assumption/Test	**Test Value**	**Prob Level**	**Is the Assumption Reasonable at the 0.2000 Level of Significance?**
Residuals follow Normal Distribution?			
Shapiro Wilk	0.9833	0.000356	No
Anderson Darling	1.7262	0.000202	No
D'Agostino Skewness	0.9161	0.359601	Yes
D'Agostino Kurtosis	-4.7177	0.000002	No
D'Agostino Omnibus	23.0960	0.000010	No

Constant Residual Variance?			
Modified Levene Test	0.0010	0.974542	Yes
Relationship is a Straight Line?			
Lack of Linear Fit F(10, 348) Test	60.2969	0.000000	No

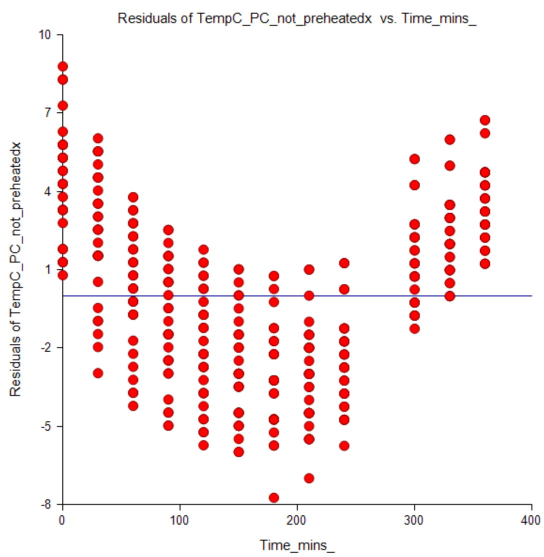
No Serial Correlation?
Evaluate the Serial-Correlation report and the Durbin-Watson test if you have equal-spaced, time series data.

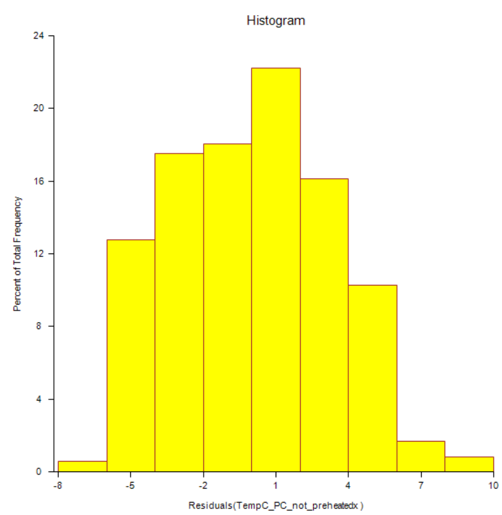
Notes:
A 'Yes' means there is not enough evidence to make this assumption seem unreasonable. This lack of evidence may be because the sample size is too small, the assumptions of the test itself are not met, or the assumption is valid. A 'No' means the that the assumption is not reasonable. However, since these tests are related to sample size, you should assess the role of sample size in the tests by also evaluating the appropriate plots and graphs. A large dataset (say N > 500) will often fail at least one of the normality tests because it is hard to find a large dataset that is perfectly normal.

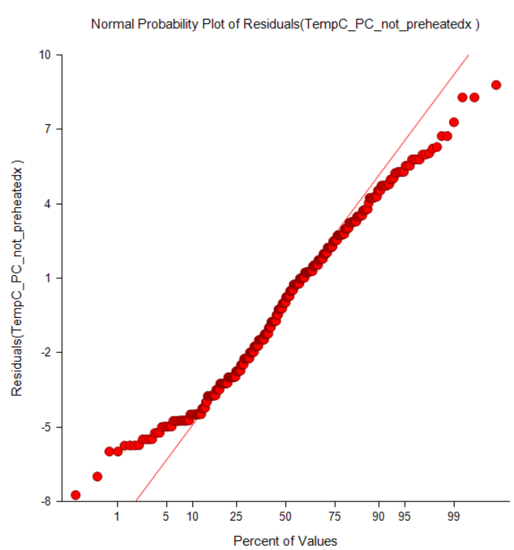
Normality and Constant Residual Variance:
Possible remedies for the failure of these assumptions include using a transformation of Y such as the log or square root, correcting data-recording errors found by looking into outliers, adding additional independent variables, using robust regression, or using bootstrap methods.

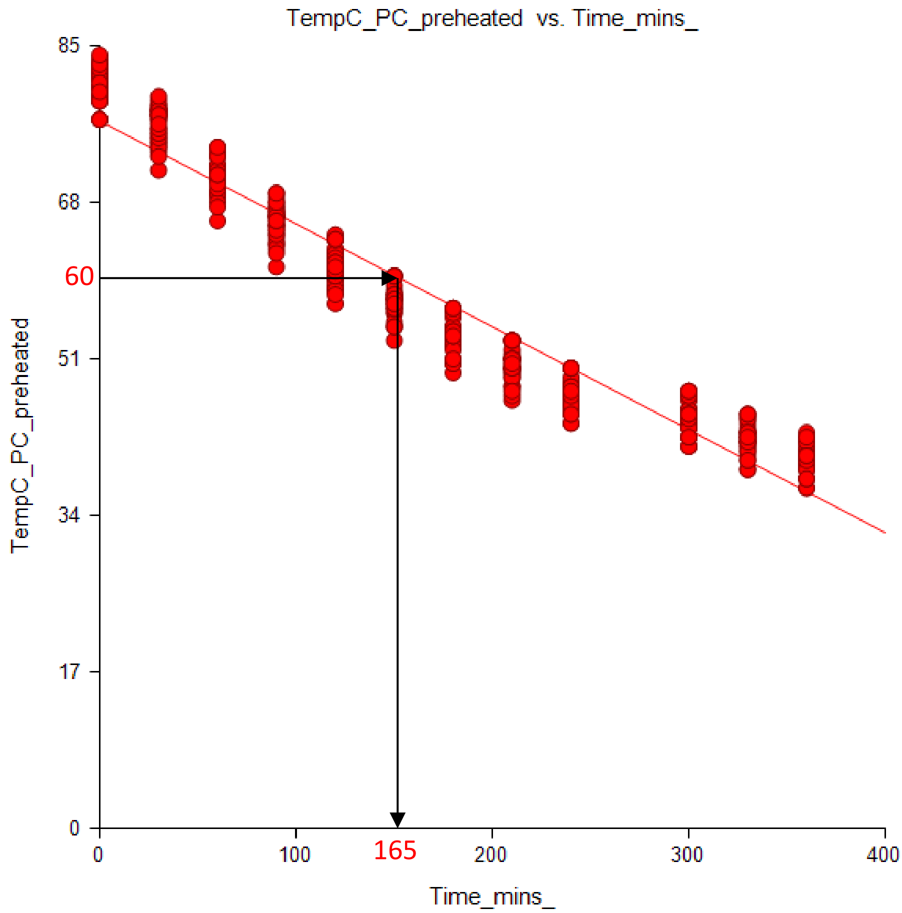
Straight-Line:
Possible remedies for the failure of this assumption include using nonlinear regression or polynomial regression.

Residual Plots Section









Run Summary Section

Parameter	Value	Parameter	Value
Dependent Variable	TempC_PC_preheated	Rows Processed	2160
Independent Variable	Time_mins_	Rows Used in Estimation	360
Frequency Variable	None	Rows with X Missing	1800
Weight Variable	None	Rows with Freq Missing	0
Intercept	76.9471	Rows Prediction Only	0
Slope	-0.1025	Sum of Frequencies	360
R-Squared	0.9242	Sum of Weights	360.0000
Correlation	-0.9614	Coefficient of Variation	0.1423
Mean Square Error	67.11378	Square Root of MSE	8.1923

Summary Statement

The equation of the straight line relating TempC_PC_preheated and Time_mins_ is estimated as: TempC_PC_preheated = (76.9471) + (-0.1025) Time_mins_ using the 360 observations in this dataset. The y-intercept, the estimated value of TempC_PC_preheated when Time_mins_ is zero, is 76.9471 with a standard error of 0.3204. The slope, the estimated change in TempC_PC_preheated per unit change in Time_mins_ , is -0.1025 with a standard error of 0.0016. The value of R-Squared, the proportion of the variation in TempC_PC_preheated that can be accounted for by variation in Time_mins_ , is 0.9242. The correlation between TempC_PC_preheated and Time_mins_ is -0.9614.

A significance test that the slope is zero resulted in a t-value of -66.0753. The significance level of this t-test is 0.0000. Since 0.0000 < 0.0500, the hypothesis that the slope is zero is rejected.

The estimated slope is -0.1025. The lower limit of the 95% confidence interval for the slope is -0.1055 and the upper limit is -0.0994. The estimated intercept is 76.9471. The lower limit of the 95% confidence interval for the intercept is 76.3171 and the upper limit is 77.5772.

Descriptive Statistics Section

Parameter	**Dependent**	**Independent**
Variable	TempC_PC_preheated	Time_mins_
Count	360	360
Mean	57.5903	172.5000
Standard Deviation	29.7174	278.7982
Minimum	37.0000	0.0000
Maximum	84.0000	360.0000

Regression Estimation Section

Parameter	**Intercept B(0)**	**Slope B(1)**
Regression Coefficients	76.9471	-0.1025
Lower 95% Confidence Limit	76.3171	-0.1055
Upper 95% Confidence Limit	77.5772	-0.0994
Standard Error	0.3204	0.0016
Standardized Coefficient	0.0000	-0.9614
T Value	240.1800	-66.0753
Prob Level (T Test)	0.0000	0.0000
Reject H0 (Alpha = 0.0500)	Yes	Yes
Power (Alpha = 0.0500)	1.0000	1.0000
Regression of Y on X	76.9471	-0.1025
Inverse Regression from X on Y	76.7162	-0.1109
Orthogonal Regression of Y and X	75.2792	-0.1025

Notes:
The above report shows the least-squares estimates of the intercept and slope followed by the corresponding standard errors, confidence intervals, and hypothesis tests. Note that these results are based on several assumptions that should be validated before they are used.

Estimated Model

(76.9471227758963) + (-.102472585066925) * (Time_mins_)

Analysis of Variance Section

Source	**DF**	**Sum of Squares**	**Mean Square**	**F-Ratio**	**Prob Level**	**Power (5%)**
Intercept	1	7588089	7588089			
Slope	1	293014.8	293014.8	4365.9415	0.0000	1.0000
Error	358	24026.73	67.11378			
Lack of Fit	10	22873.71	2287.371	690.3624	0.0000	
Pure Error	348	1153.025	3.31329			
Adj. Total	359	317041.6	883.1242			
Total	360	7905131				

s = Square Root(67.11378) = 8.1923

Notes:
The above report shows the F-Ratio for testing whether the slope is zero, the degrees of freedom, and the mean square error. The mean square error, which estimates the variance of the residuals, is used extensively in the calculation of hypothesis tests and confidence intervals.

Tests of Assumptions Section

Assumption/Test	**Test Value**	**Prob Level**	**Is the Assumption Reasonable at the 0.2000 Level of Significance?**
Residuals follow Normal Distribution?			
Shapiro Wilk	0.9873	0.003116	No
Anderson Darling	1.0748	0.008059	No
D'Agostino Skewness	1.9641	0.049513	No
D'Agostino Kurtosis	-2.3163	0.020542	No
D'Agostino Omnibus	9.2231	0.009937	No

Constant Residual Variance?

Modified Levene Test	12.2839	0.000515	No

Relationship is a Straight Line?

Lack of Linear Fit F(10, 348) Test	690.3624	0.000000	No

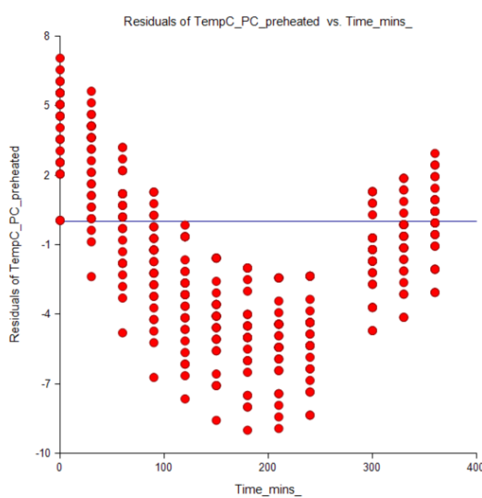
No Serial Correlation?
Evaluate the Serial-Correlation report and the Durbin-Watson test if you have equal-spaced, time series data.

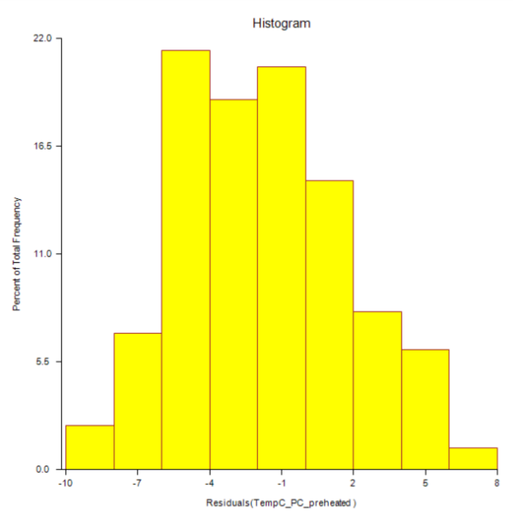
Notes:
A 'Yes' means there is not enough evidence to make this assumption seem unreasonable. This lack of evidence may be because the sample size is too small, the assumptions of the test itself are not met, or the assumption is valid.
A 'No' means the that the assumption is not reasonable. However, since these tests are related to sample size, you should assess the role of sample size in the tests by also evaluating the appropriate plots and graphs. A large dataset (say N > 500) will often fail at least one of the normality tests because it is hard to find a large dataset that is perfectly normal.

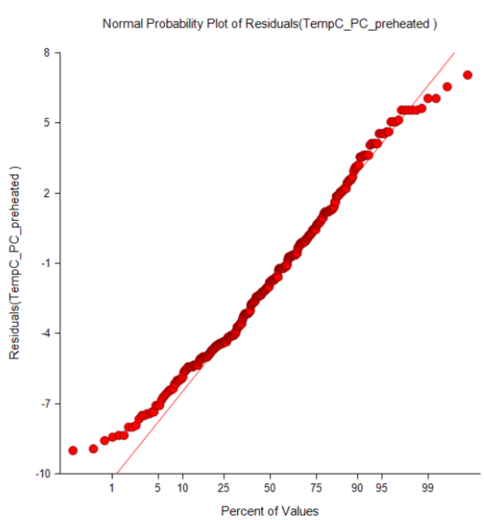
Normality and Constant Residual Variance:
Possible remedies for the failure of these assumptions include using a transformation of Y such as the log or square root, correcting data-recording errors found by looking into outliers, adding additional independent variables, using robust regression, or using bootstrap methods.

Straight-Line:
Possible remedies for the failure of this assumption include using nonlinear regression or polynomial regression.

Residual Plots Section







APPENDIX 6

Statistical Analysis – 3-way ANOVA

Analysis of Variance Report

Response Temperature_C

Expected Mean Squares Section

Source Term	**DF**	**Term Fixed?**	**Denominator Term**	**Expected Mean Square**
A: Container	2	Yes	S(ABC)	S+bcsA
B: Time_mins	11	Yes	S(ABC)	S+acsB
AB	22	Yes	S(ABC)	S+csAB
C: Preheated	1	Yes	S(ABC)	S+absC
AC	2	Yes	S(ABC)	S+bsAC
BC	11	Yes	S(ABC)	S+asBC
ABC	22	Yes	S(ABC)	S+sABC
S(ABC)	2088	No		S

Note: Expected Mean Squares are for the balanced cell-frequency case.

Analysis of Variance Table

Source Term	**DF**	**Sum of Squares**	**Mean Square**	**F-Ratio**	**Prob Level**	**Power (Alpha=0.05)**
A: Container	2	3331.129	1665.564	579.49	**0.000000***	**1.000000**
B: Time_mins	11	304353	27668.46	9626.54	**0.000000***	**1.000000**
AB	22	985.0157	44.77344	15.58	**0.000000***	**1.000000**
C: Preheated	1	329.0042	329.0042	114.47	**0.000000***	**1.000000**
AC	2	188.0778	94.03889	32.72	**0.000000***	**1.000000**
BC	11	85.30695	7.755177	2.70	**0.001874***	**0.978471**
ABC	22	11.29444	0.5133839	0.18	**0.999993**	**0.148051**
S	2088	6001.3	2.874186			
Total (Adjusted)	2159	315284.1				
Total	2160					

* Term significant at alpha = 0.05

Means and Standard Error Section

Term	**Count**	**Mean**	**Standard Error**
All	2160	59.31759	
A: Container			
Foogo	720	60.04583	0.06318168
Funtainer	720	60.3375	0.06318168
PC	720	57.56944	0.06318168
B: Time_mins			
0	180	80.56111	0.1263634
30	180	76.14167	0.1263634
60	180	71.35278	0.1263634
90	180	66.96944	0.1263634
120	180	62.91945	0.1263634
150	180	59.23889	0.1263634
180	180	55.86945	0.1263634
210	180	52.83611	0.1263634
240	180	50.06944	0.1263634
300	180	47.53889	0.1263634
330	180	45.225	0.1263634
360	180	43.08889	0.1263634
C: Preheated			
No	1080	58.92731	0.05158763
Yes	1080	59.70787	0.05158763
AB: Container,Time_mins			
Foogo,0	60	80.01667	0.2188678
Foogo,30	60	75.93333	0.2188678
Foogo,60	60	71.50833	0.2188678
Foogo,90	60	67.425	0.2188678
Foogo,120	60	63.60833	0.2188678
Foogo,150	60	60.13334	0.2188678

Means and Standard Error Section

Term	**Count**	**Mean**	**Standard Error**
Foogo,180	60	56.95	0.2188678
Foogo,210	60	54.025	0.2188678
Foogo,240	60	51.275	0.2188678
Foogo,300	60	48.8	0.2188678
Foogo,330	60	46.49166	0.2188678
Foogo,360	60	44.38334	0.2188678
Funtainer,0	60	80.88333	0.2188678
Funtainer,30	60	76.63333	0.2188678
Funtainer,60	60	72.06667	0.2188678
Funtainer,90	60	67.825	0.2188678
Funtainer,120	60	63.9	0.2188678
Funtainer,150	60	60.325	0.2188678
Funtainer,180	60	57.08333	0.2188678
Funtainer,210	60	54.09167	0.2188678
Funtainer,240	60	51.375	0.2188678
Funtainer,300	60	48.85	0.2188678
Funtainer,330	60	46.58333	0.2188678
Funtainer,360	60	44.43333	0.2188678
PC,0	60	80.78333	0.2188678
PC,30	60	75.85833	0.2188678
PC,60	60	70.48333	0.2188678
PC,90	60	65.65833	0.2188678
PC,120	60	61.25	0.2188678
PC,150	60	57.25834	0.2188678
PC,180	60	53.575	0.2188678
PC,210	60	50.39167	0.2188678
PC,240	60	47.55833	0.2188678
PC,300	60	44.96667	0.2188678
PC,330	60	42.6	0.2188678
PC,360	60	40.45	0.2188678
AC: Container,Preheated			
Foogo,No	360	59.30278	0.08935239
Foogo,Yes	360	60.78889	0.08935239
Funtainer,No	360	59.93056	0.08935239
Funtainer,Yes	360	60.74445	0.08935239
PC,No	360	57.54861	0.08935239
PC,Yes	360	57.59028	0.08935239
BC: Time_mins,Preheated			
0,No	90	80.31111	0.1787048
0,Yes	90	80.81111	0.1787048
30,No	90	75.37778	0.1787048
30,Yes	90	76.90556	0.1787048
60,No	90	70.64445	0.1787048
60,Yes	90	72.06111	0.1787048
90,No	90	66.38889	0.1787048
90,Yes	90	67.55	0.1787048
120,No	90	62.45	0.1787048
120,Yes	90	63.38889	0.1787048
150,No	90	58.8	0.1787048
150,Yes	90	59.67778	0.1787048
180,No	90	55.5	0.1787048
180,Yes	90	56.23889	0.1787048
210,No	90	52.51111	0.1787048
210,Yes	90	53.16111	0.1787048
240,No	90	49.8	0.1787048
240,Yes	90	50.33889	0.1787048
300,No	90	47.33333	0.1787048
300,Yes	90	47.74445	0.1787048
330,No	90	45.05	0.1787048

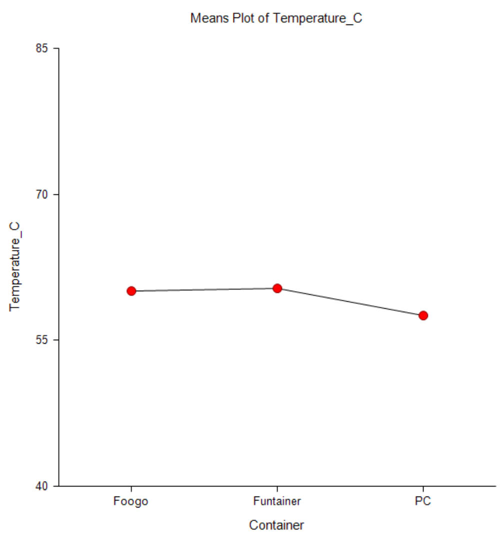
Means and Standard Error Section

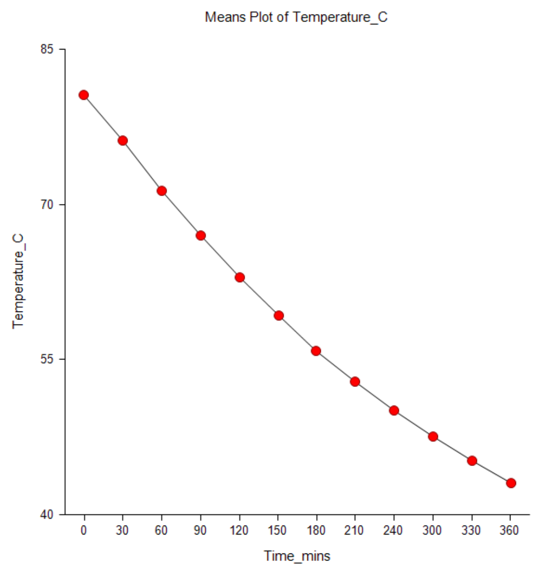
Term	**Count**	**Mean**	**Standard Error**
330,Yes	90	45.4	0.1787048
360,No	90	42.96111	0.1787048
360,Yes	90	43.21667	0.1787048
ABC: Container,Time_mins,Preheated			
Foogo,0,No	30	79.63333	0.3095258
Foogo,0,Yes	30	80.4	0.3095258
Foogo,30,No	30	74.91666	0.3095258
Foogo,30,Yes	30	76.95	0.3095258
Foogo,60,No	30	70.48333	0.3095258
Foogo,60,Yes	30	72.53333	0.3095258
Foogo,90,No	30	66.5	0.3095258
Foogo,90,Yes	30	68.35	0.3095258
Foogo,120,No	30	62.73333	0.3095258
Foogo,120,Yes	30	64.48333	0.3095258
Foogo,150,No	30	59.31667	0.3095258
Foogo,150,Yes	30	60.95	0.3095258
Foogo,180,No	30	56.2	0.3095258
Foogo,180,Yes	30	57.7	0.3095258
Foogo,210,No	30	53.3	0.3095258
Foogo,210,Yes	30	54.75	0.3095258
Foogo,240,No	30	50.61666	0.3095258
Foogo,240,Yes	30	51.93333	0.3095258
Foogo,300,No	30	48.2	0.3095258
Foogo,300,Yes	30	49.4	0.3095258
Foogo,330,No	30	45.91667	0.3095258
Foogo,330,Yes	30	47.06667	0.3095258
Foogo,360,No	30	43.81667	0.3095258
Foogo,360,Yes	30	44.95	0.3095258
Funtainer,0,No	30	80.63333	0.3095258
Funtainer,0,Yes	30	81.13333	0.3095258
Funtainer,30,No	30	75.88333	0.3095258
Funtainer,30,Yes	30	77.38333	0.3095258
Funtainer,60,No	30	71.36667	0.3095258
Funtainer,60,Yes	30	72.76667	0.3095258
Funtainer,90,No	30	67.21667	0.3095258
Funtainer,90,Yes	30	68.43333	0.3095258
Funtainer,120,No	30	63.36666	0.3095258
Funtainer,120,Yes	30	64.43333	0.3095258
Funtainer,150,No	30	59.85	0.3095258
Funtainer,150,Yes	30	60.8	0.3095258
Funtainer,180,No	30	56.7	0.3095258
Funtainer,180,Yes	30	57.46667	0.3095258
Funtainer,210,No	30	53.76667	0.3095258
Funtainer,210,Yes	30	54.41667	0.3095258
Funtainer,240,No	30	51.08333	0.3095258
Funtainer,240,Yes	30	51.66667	0.3095258
Funtainer,300,No	30	48.63334	0.3095258
Funtainer,300,Yes	30	49.06667	0.3095258
Funtainer,330,No	30	46.36666	0.3095258
Funtainer,330,Yes	30	46.8	0.3095258
Funtainer,360,No	30	44.3	0.3095258
Funtainer,360,Yes	30	44.56667	0.3095258
PC,0,No	30	80.66666	0.3095258
PC,0,Yes	30	80.9	0.3095258
PC,30,No	30	75.33334	0.3095258
PC,30,Yes	30	76.38333	0.3095258
PC,60,No	30	70.08334	0.3095258
PC,60,Yes	30	70.88333	0.3095258

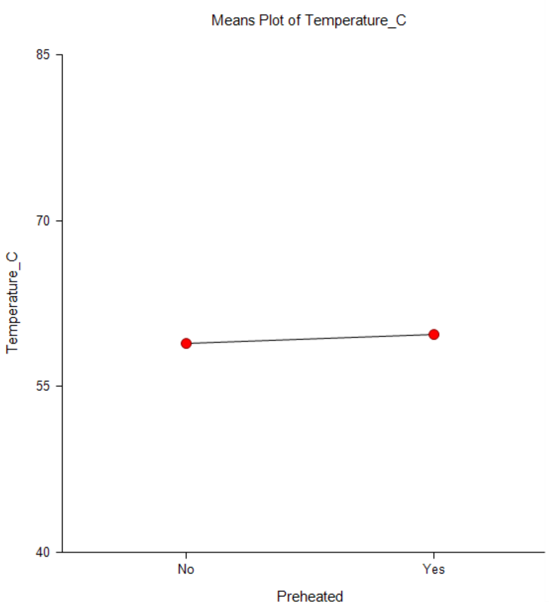
Means and Standard Error Section

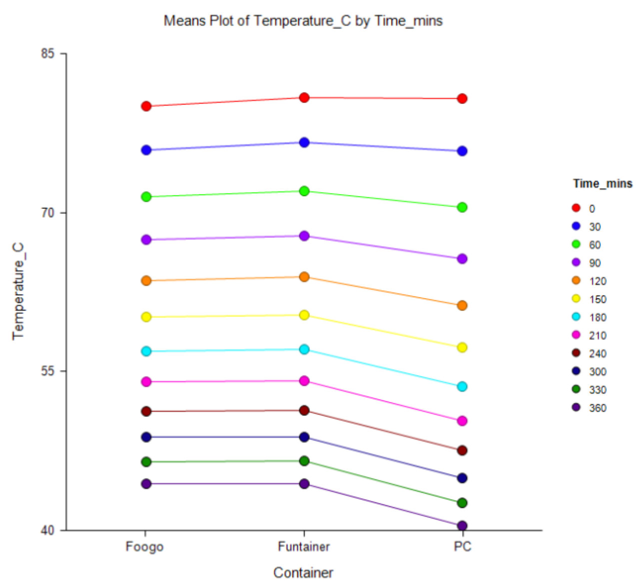
Term	Count	Mean	Standard Error
PC,90,No	30	65.45	0.3095258
PC,90,Yes	30	65.86667	0.3095258
PC,120,No	30	61.25	0.3095258
PC,120,Yes	30	61.25	0.3095258
PC,150,No	30	57.23333	0.3095258
PC,150,Yes	30	57.28333	0.3095258
PC,180,No	30	53.6	0.3095258
PC,180,Yes	30	53.55	0.3095258
PC,210,No	30	50.46667	0.3095258
PC,210,Yes	30	50.31667	0.3095258
PC,240,No	30	47.7	0.3095258
PC,240,Yes	30	47.41667	0.3095258
PC,300,No	30	45.16667	0.3095258
PC,300,Yes	30	44.76667	0.3095258
PC,330,No	30	42.86666	0.3095258
PC,330,Yes	30	42.33333	0.3095258
PC,360,No	30	40.76667	0.3095258
PC,360,Yes	30	40.13334	0.3095258

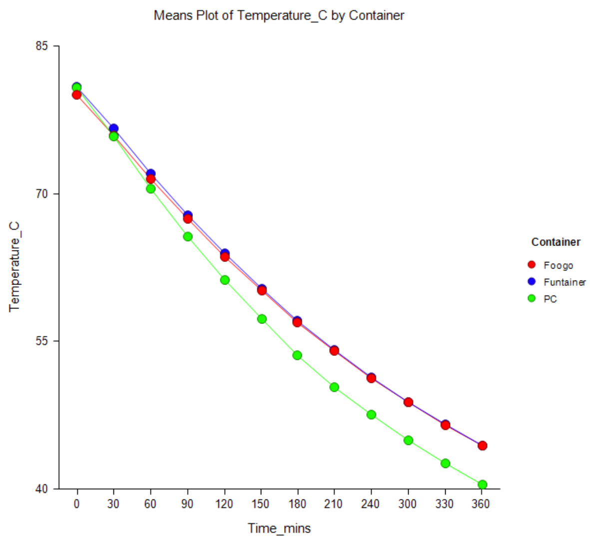
Plots Section

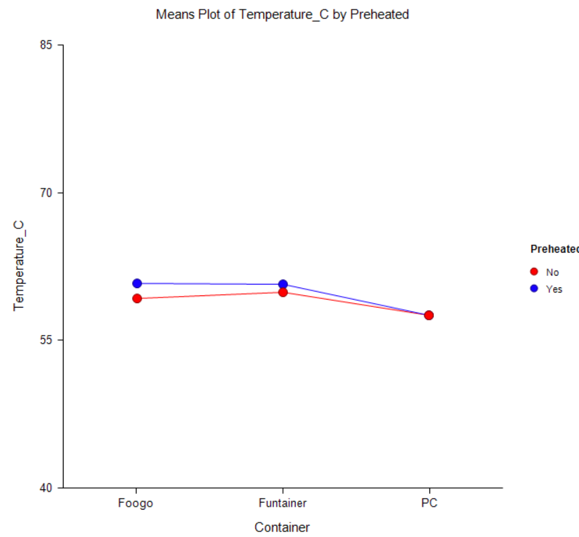


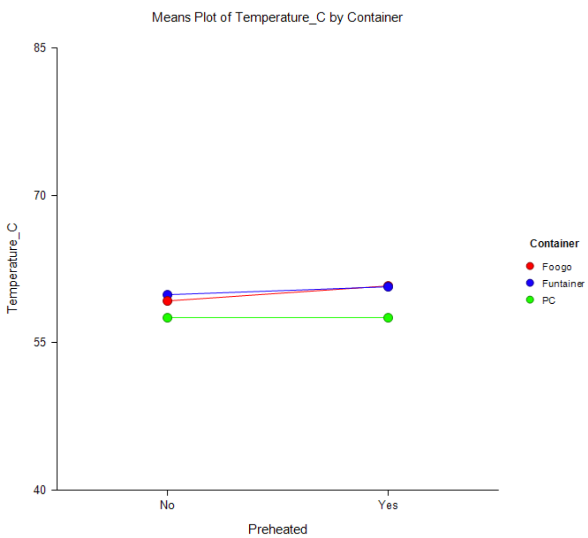


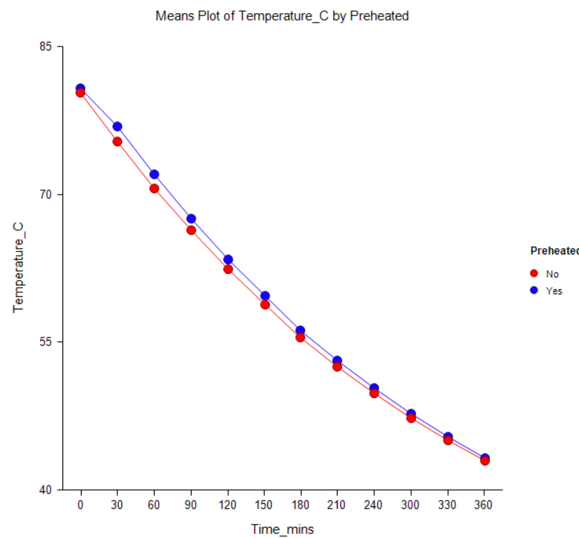


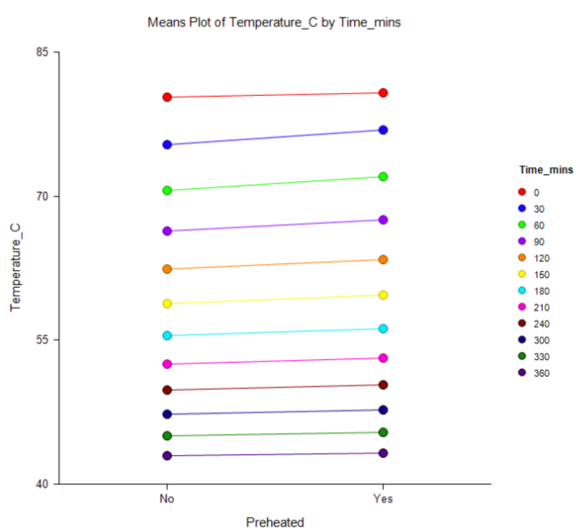



Means Plot of Temperature_C by Container
Temperature_C
85
70
55
40
0 30 60 90 120 150 180 210 240 300 330 360
Time_mins
Container
Foogo
Funtainer
PC


Means Plot of Temperature_C by Preheated
Temperature_C
85
70
55
40
Foogo
Funtainer
PC
Container
Preheated
No
Yes


Means Plot of Temperature_C by Container
Temperature_C
85
70
55
40
No
Yes
Preheated
Container
Foogo
Funtainer
PC


Means Plot of Temperature_C by Preheated
Temperature_C
85
70
55
40
0 30 60 90 120 150 180 210 240 300 330 360
Time_mins
Preheated
No
Yes


Means Plot of Temperature_C by Time_mins
Temperature_C
85
70
55
40
No
Yes
Preheated
Time_mins
0
30
60
90
120
150
180
210
240
300
330
360

Scheffe's Multiple-Comparison Test

Response: Temperature_C
Term A: Container

Alpha=0.050 Error Term=S(ABC) DF=2088 MSE=2.874186 Critical Value=2.4495

Group	Count	Mean	Different From Groups
Foogo	720	60.04583	Funtainer, PC
Funtainer	720	60.3375	Foogo, PC
PC	720	57.56944	Foogo, Funtainer

Notes:
This report provides multiple comparison tests for all possible contrasts among the the means. These contrasts may involve more groups than just each pair, so the method is much stricter than need be. The Tukey-Kramer method provides more accurate results when only pairwise comparisons are needed.

Tukey-Kramer Multiple-Comparison Test

Response: Temperature_C
Term A: Container

Alpha=0.050 Error Term=S(ABC) DF=2088 MSE=2.874186 Critical Value=3.3169

Group	Count	Mean	Different From Groups
Foogo	720	60.04583	Funtainer, PC
Funtainer	720	60.3375	Foogo, PC
PC	720	57.56944	Foogo, Funtainer

Notes:
This report provides multiple comparison tests for all pairwise differences between the means.

Scheffe's Multiple-Comparison Test

Response: Temperature_C
Term B: Time_mins

Alpha=0.050 Error Term=S(ABC) DF=2088 MSE=2.874186 Critical Value=4.4413

Group	Count	Mean	Different From Groups
0	180	80.56111	30, 60, 90, 120, 150, 180, 210, 240, 300, 330, 360
30	180	76.14167	0, 60, 90, 120, 150, 180, 210, 240, 300, 330, 360
60	180	71.35278	0, 30, 90, 120, 150, 180, 210, 240, 300, 330, 360
90	180	66.96944	0, 30, 60, 120, 150, 180, 210, 240, 300, 330, 360
120	180	62.91945	0, 30, 60, 90, 150, 180, 210, 240, 300, 330, 360
150	180	59.23889	0, 30, 60, 90, 120, 180, 210, 240, 300, 330, 360
180	180	55.86945	0, 30, 60, 90, 120, 150, 210, 240, 300, 330, 360
210	180	52.83611	0, 30, 60, 90, 120, 150, 180, 240, 300, 330, 360
240	180	50.06944	0, 30, 60, 90, 120, 150, 180, 210, 300, 330, 360
300	180	47.53889	0, 30, 60, 90, 120, 150, 180, 210, 240, 330, 360
330	180	45.225	0, 30, 60, 90, 120, 150, 180, 210, 240, 300, 360
360	180	43.08889	0, 30, 60, 90, 120, 150, 180, 210, 240, 300, 330

Notes:
This report provides multiple comparison tests for all possible contrasts among the means. These contrasts may involve more groups than just each pair, so the method is much stricter than need be. The Tukey-Kramer method provides more accurate results when only pairwise comparisons are needed.

Tukey-Kramer Multiple-Comparison Test

Response: Temperature_C
Term B: Time_mins

Alpha=0.050 Error Term=S(ABC) DF=2088 MSE=2.874186 Critical Value=4.6270

Group	Count	Mean	Different From Groups
0	180	80.56111	30, 60, 90, 120, 150, 180, 210, 240, 300, 330, 360
30	180	76.14167	0, 60, 90, 120, 150, 180, 210, 240, 300, 330, 360
60	180	71.35278	0, 30, 90, 120, 150, 180, 210, 240, 300, 330, 360
90	180	66.96944	0, 30, 60, 120, 150, 180, 210, 240, 300, 330, 360
120	180	62.91945	0, 30, 60, 90, 150, 180, 210, 240, 300, 330, 360
150	180	59.23889	0, 30, 60, 90, 120, 180, 210, 240, 300, 330, 360
180	180	55.86945	0, 30, 60, 90, 120, 150, 210, 240, 300, 330, 360
210	180	52.83611	0, 30, 60, 90, 120, 150, 180, 240, 300, 330, 360
240	180	50.06944	0, 30, 60, 90, 120, 150, 180, 210, 300, 330, 360
300	180	47.53889	0, 30, 60, 90, 120, 150, 180, 210, 240, 330, 360
330	180	45.225	0, 30, 60, 90, 120, 150, 180, 210, 240, 300, 360
360	180	43.08889	0, 30, 60, 90, 120, 150, 180, 210, 240, 300, 330

Notes:
This report provides multiple comparison tests for all pairwise differences between the means.

Scheffe's Multiple-Comparison Test

Response: Temperature_C
Term C: Preheated

Alpha=0.050 Error Term=S(ABC) DF=2088 MSE=2.874186 Critical Value=1.9611

Group	Count	Mean	Different From Groups
No	1080	58.92731	Yes
Yes	1080	59.70787	No

Notes:
This report provides multiple comparison tests for all possible contrasts among the means. These contrasts may involve more groups than just each pair, so the method is much stricter than need be. The Tukey-Kramer method provides more accurate results when only pairwise comparisons are needed.

Tukey-Kramer Multiple-Comparison Test

Response: Temperature_C
Term C: Preheated

Alpha=0.050 Error Term=S(ABC) DF=2088 MSE=2.874186 Critical Value=2.7734

Group	Count	Mean	Different From Groups
No	1080	58.92731	Yes
Yes	1080	59.70787	No

Notes:
This report provides multiple comparison tests for all pairwise differences between the means.