Full Title:

Utilization of Steam Heat Generated via Microwave Energy in Seafood Cooking

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ABSTRCT

Most restaurants and retail food stores rely upon traditional steamers to cook seafood products to the required temperature of 145 °F as specified within the U.S. Food and Drug Administration (FDA) Food Code (1). The purpose of this study was to evaluate the effectiveness of steam heat processing of food within a covered Cambro pan containing water with energy generated via microwaves. The study was specifically designed to determine adequate heat transfer and time/temperature cooking parameters for seafood products. Five experiments were conducted in this study. The first experiment placed 45.0mL of water only in a covered Cambro pan, the second experiment placed one 1.5-pound lobster in a covered Cambro pan with 45.0mL of water, the third experiment placed one 1.5-pound lobster in an uncovered Cambro pan with 45.0mL of water, the fourth experiment placed one 1.5-pound lobster in an uncovered Cambro pan with no water added, and the fifth experiment placed 10.0 ounces of large shrimp in a covered Cambro pan with 45.0mL of water. The results showed that the internal temperature of the lobsters and shrimp were well above the FDA Food Code requirements after being steam cooked in the microwave ovens. In all experiments, the sensory quality of the seafood covered in Cambro pan with water and microwave-generated energy was excellent. The appearance, texture, color, flavor and overall eating quality were equivalent or better than traditional steam cooking. In conclusion, cooking seafood in covered Cambro pans with added water and using microwaves as the energy source to produce steam is equivalent to cooking seafood in conventional steamers. The FDA should make an amendment within the Food Code to allow for the steam heating of seafood products to a minimum internal temperature of 145 °F using microwave energy as the source.

INTRODUCTION

Traditional steamers are used in great numbers to cook seafood products. However, there are several downsides in using conventional steamers to cook seafood products. The downsides involve: high costs of the units, energy expenses, and complicated hookups. The greatest problem of using conventional steamers is the difficulty of cleaning and sanitizing the interior area.

A solution to these issues is the use of microwave-generated energy to steam-cook seafood products. This method has been developed as early as the late 1990's as researchers found significant benefits on the sensory quality of food from steam-cooking using the microwave. Advantages from steam-cooking using the microwave include: quick and complete heating of food and elimination of problems associated with the loss of moisture. (2)

There is a substantial difference in the methodology of steam-cooking foods using the microwave as opposed to conventional cooking of foods using the microwave. Conventional microwave cooking of foods does not produce good tasting and high sensory quality foods because of a drying phenomenon caused by evaporation of moisture from the food during cooking. (3) The microwave steam cooking apparatus used in Daniel Tsai's study describes the process of cooking food in the microwave using a combination of microwave heat and steam. (2) A microwave cooking apparatus can be set up so that the food is cooked by exposure to steam heat and thus, the food is cooked by a combination of steam and microwave heat. There are other benefits to steam cooking via microwave as opposed to cooking in conventional steamers. Steam cooking via microwave has many potential advantages compared to conventional steam cooking and one of the biggest advantages is the shorter heating time required to cook the food. (4)

The regulation will have a significant impact on the use of microwave-generated steam to cook seafood. Section 3-401.12 of the 2013 edition of the FDA Food Code requires that raw animal foods, including seafood, heated via microwave energy must attain an internal temperature of at least 165 °F (1). However, traditional steam heating of seafood products need only attain an internal temperature of 145 °F. This study was designed to determine whether cooking seafood in covered Cambro pans with added water and using microwaves as the energy source to produce steam was equivalent to cooking seafood in traditional-style steamers. If this premise is proven true, then it could suggest that the Food Code be amended to allow for the steam heating of seafood products to a minimum internal temperature of 145 °F using microwave energy as the source.

In this study, microwave-generated energy will be used to steam-cook seafood products within Cambro covered pans. This method has many more benefits than cooking with conventional steamers. First, the microwave units are portable and don’t require expensive and complicated steam and wastewater plumbing hookups. Second, the Cambro pans are available in different sizes to economically accommodate the volume of food items being prepared. Third, the stainless steel microwave units as well as the Cambro pans are easily cleaned and sanitized. Fourth, cooking time is reduced significantly in that a traditional 1.5-pound lobster can be steamed to a minimal internal temperature of 145 °F in a total of 4 minutes (2 minutes cooking and 2 minutes holding). Fifth, there is a large savings in energy costs using microwaves to generate steam as opposed to using conventional steamers.

MATERIALS AND METHODS

Materials

Four microwave ovens were used in this study, including a Panasonic microwave steamer (Sonic steamer, model, 3200 watt, company, state, country), Panasonic Inverter microwave oven (model, 1200 watt, company, state, country), Panasonic industrial microwave oven (model, 1200 watt, company, state, country), and GE microwave oven (GE-JES1451DN1BB, 1100 watt, company, state, country).

The medium-size Cambro pan (12” x 20” x 4”), composed of high density polyethylene, was used for all the cooking. Lobsters weighing 1 ¼ - 1 ½ pounds each and large shrimp (10 oz/12) were used as the examples of seafood typically steamed by traditional methods in food establishments. A thermocouple integrated with an 80B-A DMN probe (Fluke model 189 True RMS Multimeter thermocouple, company, state) was used to monitor the internal food product and steam temperatures.

Determination of temperature of steam generated by microwave energy

The steam temperature was monitored in all the four microwave ovens over 5 min. Cold water (45 ml) was added into a medium-size Cambro pan, which was then covered. The pan was put in a microwave oven and heated at full power for 0, 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5 min. The steam temperature was measured with a thermocouple.

Cooking seafood in microwave steamer with three different methods

A lobster (1 ¼ - 1 ½ pounds) was cooked in microwave steamer (Sonic steamer) in three different ways: (1) Cambro pan with 45 ml water added and with cover; (2) Cambro pan without water added and with cover; and (3) Cambro pan without water and without cover. The first method utilized the steam generated by microwave energy to cook the lobsters, where water served as a catalyst to create steam. The second and third methods simulated the traditional microwave cooking. The lobster was cooked in sonic steamer at full power for 2 min followed by 2 min standing to obtain temperature equilibrium. The internal temperature of lobster was measured at multiple locations, including head (point 1), cervical groove (point 2), cephalothorax (point 3), abdomen (point 4), tail (point 5), left claw (point 6), and right claw (point 7) with a thermocouple.

Cooking seafood using steam generated by four different microwave ovens

In addition to microwave steamer, three commonly used models of microwave oven (Panasonic Inverter, Panasonic-1200, and GE) were evaluated for their effectiveness in cooking seafood using microwave-generated steam.

A lobster (1 ¼ - 1 ½ pounds) was cooked in a covered Cambro pan with 45 ml water for 2 min in Sonic steamer and for 4 min in the other three microwave ovens at full power. The cooked lobsters stood for another 2 min before temperature measurement or were measured immediately after cooking.

Twelve large shrimp (10 oz/12) were cooked in a covered Cambro pan with 45 ml water for 1 min in Sonic steamer and for 3 min in the other three microwave ovens at full power. The internal temperature of each shrimp was taken immediately after cooking.

RESULTS

Generation of steam via microwave energy

In order to evaluate the effectiveness of cooking seafood using microwave-generated steam and determine the proper cooking time, we first observed the generation of steam via microwave energy and monitored the temperature change of steam over time. A small amount of water (45 ml) was added into Cambro pan to serve as a catalyst to create steam upon heating in microwave oven.

As shown in Figure 1, the steam temperature reached 200 ºF within 1 min in Sonic steamer, and remained higher than 200 ºF over 5 min. The steam temperature changes in GE and Panasonic Inverter microwave ovens share the similar pattern, climbing to 200 ºF within 3 min and remaining high over 5 min. The steam produced by Panasonic-1200 hit 180 ºF before becoming stable. (Can we provide a possible explanation here for Panasonic-1200?) Above all, all the four microwave ovens were able to generate steam well above 170 ºF. This indicated that microwave energy can effectively and consistently be utilized to generate steam within the covered Cambro pan, which allowed us to further evaluate the cooking effectiveness of the steam. Based on these results, we decided to cook lobsters for 2 min in Sonic steamer and 4 min in the other three microwave ovens.

Effectiveness of three different methods to cook seafood in microwave steamer

In an effort to determine the effectiveness of microwave steamer cooking and optimize the cooking condition, we compared three different methods using Sonic steamer, including (1) covered pan with water, (2) covered pan without water, and (3) uncovered pan without water. The second and third methods simulate the traditional microwave cooking. After 2 min standing, the internal temperature of lobster was then determined at 7 locations, from head to tail and both claws (Figure 2A).

As shown in Figure 2A and 2B, the three cooking methods produced significantly different results (P value < ?). The internal temperature readings of the lobster cooked by the first method (covered pan with water) were all well above 145 ºF (as required by FDA for steamed seafood) and very close to each other, with the average of 153.17 ºF and standard deviation of 6.49 (Figure 2B). The combination of microwave energy with the covered Cambro pan containing water generated a "steam environment" similar to traditional steaming. By contrast, both of the other two cooking methods resulted in uneven heating, with the standard deviation approximately 14 (Figure 2B). More importantly, we observed that the third cooking method (open pan without water), which is the traditional microwave cooking, was the least effective one. In this condition, the internal temperatures taken at multiple locations of the lobster were well below 145 ºF (Figure 2A & 2B), the FDA standard for steamed seafood, and the lobster was not well cooked (Figure 2C). On the other hand, although the second cooking method (covered pan without water) resulted in higher than 145 ºF internal temperatures, the uneven heating produced low quality, e.g., rubbery texture. As shown in Figure 2C, the lobster split into two parts due to the difference between high pressure inside and lack of steam outside.

Therefore, we decided to focus on the first method, which utilized the steam generated by microwave energy to cook the lobsters, for the rest of the study.

Effectiveness of steam cooking of seafood in different microwave ovens

Since we had demonstrated that microwave steamer was effective in cooking lobster when a covered Cambro pan with a small amount of water was used, we then investigated other microwave ovens as well as optimized cooking condition. The three models we used well represented the microwave ovens commonly owned by food establishments.

All the microwave ovens under study produced consistent results, with internal temperature readings of lobsters all well above 145 ºF, regardless of the standing time (Figure 3A & 3B). Even heating and high sensory quality were observed in all the cooked lobsters.

Next, we expanded the food products to shrimp. We cooked twelve large shrimp in a covered Cambro pan with a small amount of water. Because traditional steaming usually does not require standing time and our results in lobsters had shown that standing time is not necessary, we measured the internal temperature of shrimp immediately after cooking. As shown in Figure 4, all the shrimp reached internal temperature well above 145 ºF, as required by FDA for steamed seafood.

Taken together, these results indicate that utilizing microwave energy to generate steam for seafood cooking is highly feasible and effective. The internal temperatures of lobsters and shrimp all reached FDA requirement for steamed seafood.

Figure 1: steam temperature in four MWOs

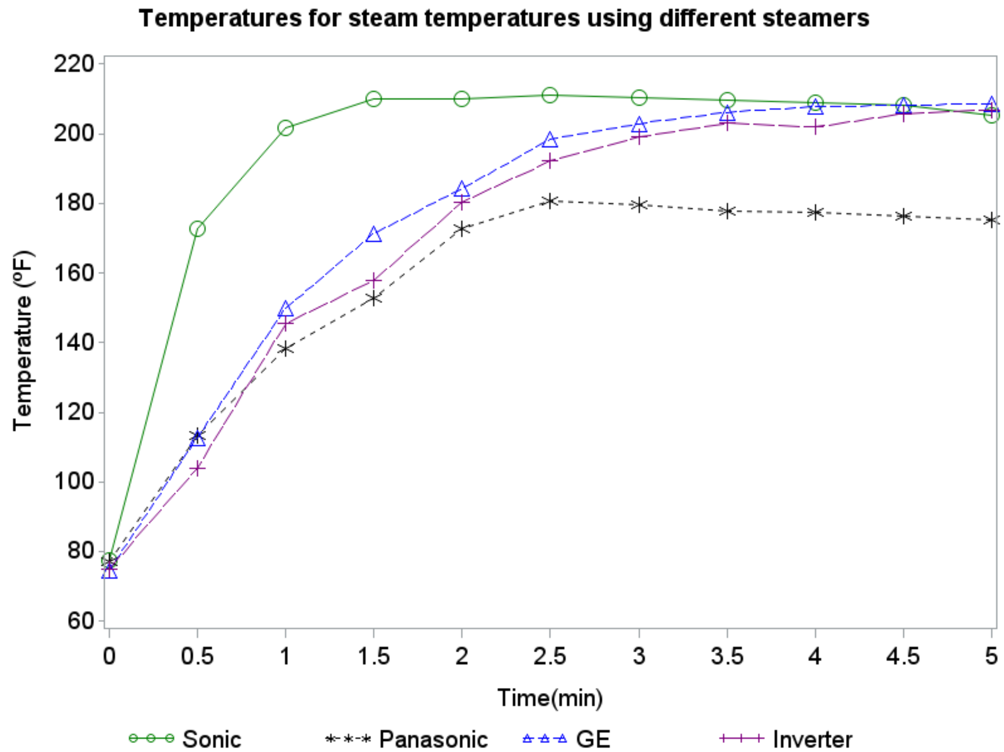
Temperatures for steam temperatures using different steamers
Temperature (ºF)
220
200
180
160
140
120
100
80
60
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time(min)
Sonic
Panasonic
GE
Inverter

Figure 2A: Mean temperature with standard error sign for different treatments in Sonic steamer(with standing)

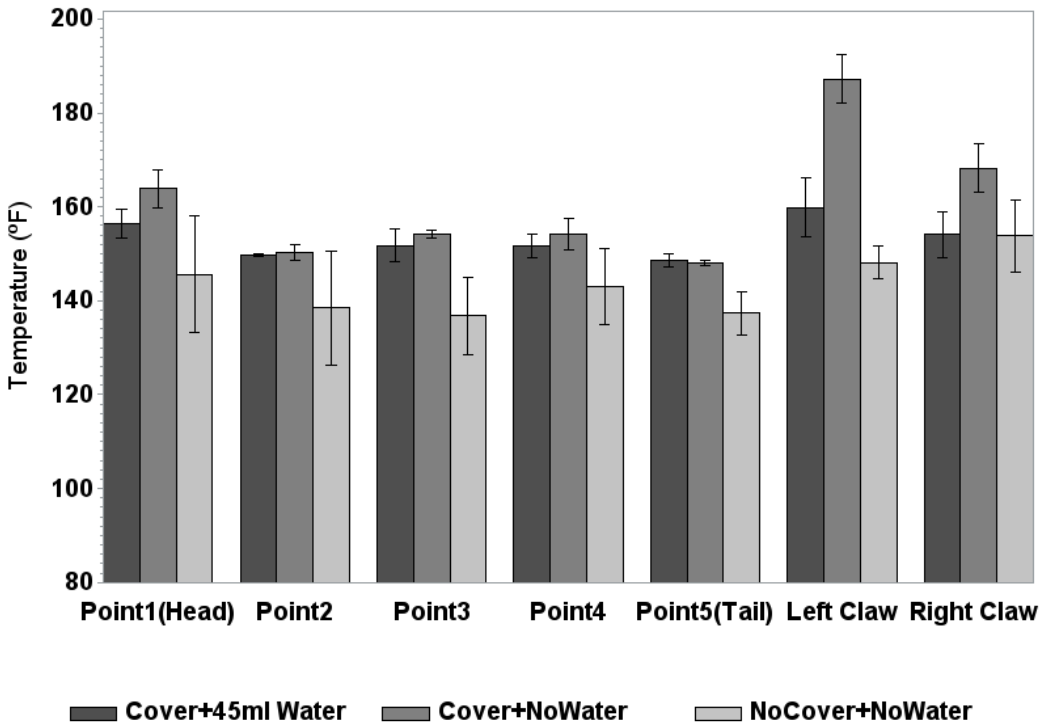

Figure 2B. Compare three treatments for using steamer on cooking lobster with standing;

The three treatments are significantly different from each other.

Level of Condition	**N**	**ltemp Mean**	**Std Dev**
Cover+45ml Water	**21**	153.171429	6.4897722
Cover+No Water	**21**	160.857143	13.9583871
NoCover+N	**2**	143	13.9

Lev **el of** **Condition**	**N**	**ltemp** **Me** **an**	 **Std** **Dev**
oWater	**1**	.304762	340761

<table>
<tr><th>Parameter</th><th>Esti
mate</th><th>Standar
d Error</th><th>t
Value</th><th>P
r > |t|</th></tr>
<tr><td>Cover+45ml Water vs
NoCover+NoWater</td><td>-
7.6857143</td><td>3.69947
311</td><td>-
2.08</td><td>0
.0420</td></tr>
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.0098</td></tr>
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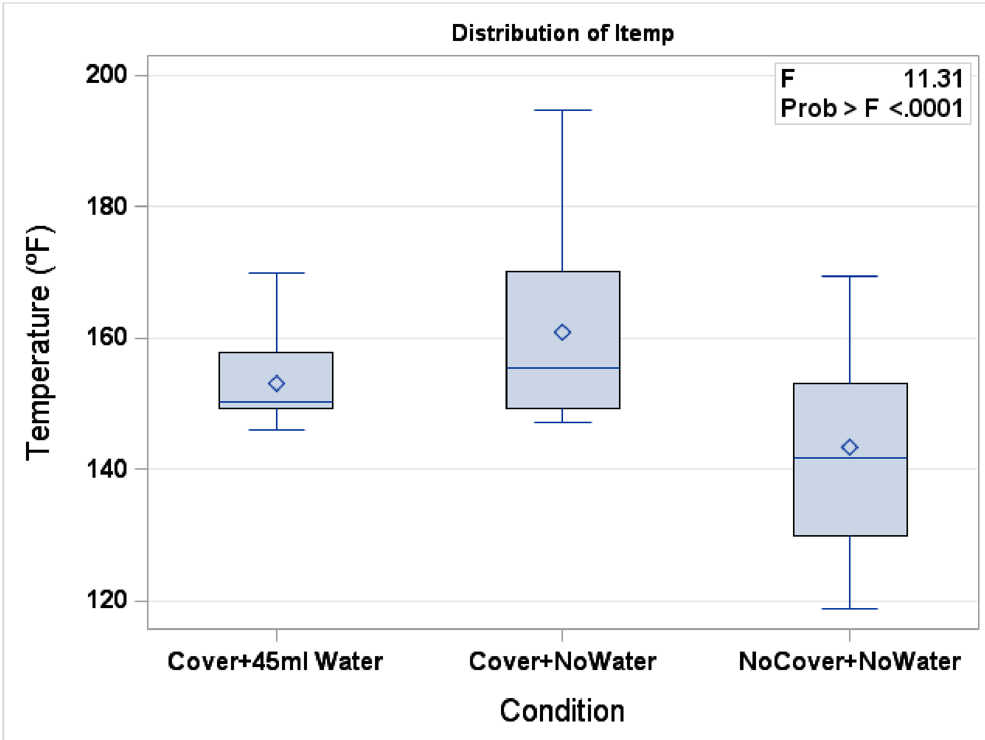


Figure 2C Lobster picture.

Cover + 45 ml water   No cover + no water   Cover + no water

Figure 3A: Lobster with standing: Compare four steamers on the same experiment for lobster (mean with 1 standard error)

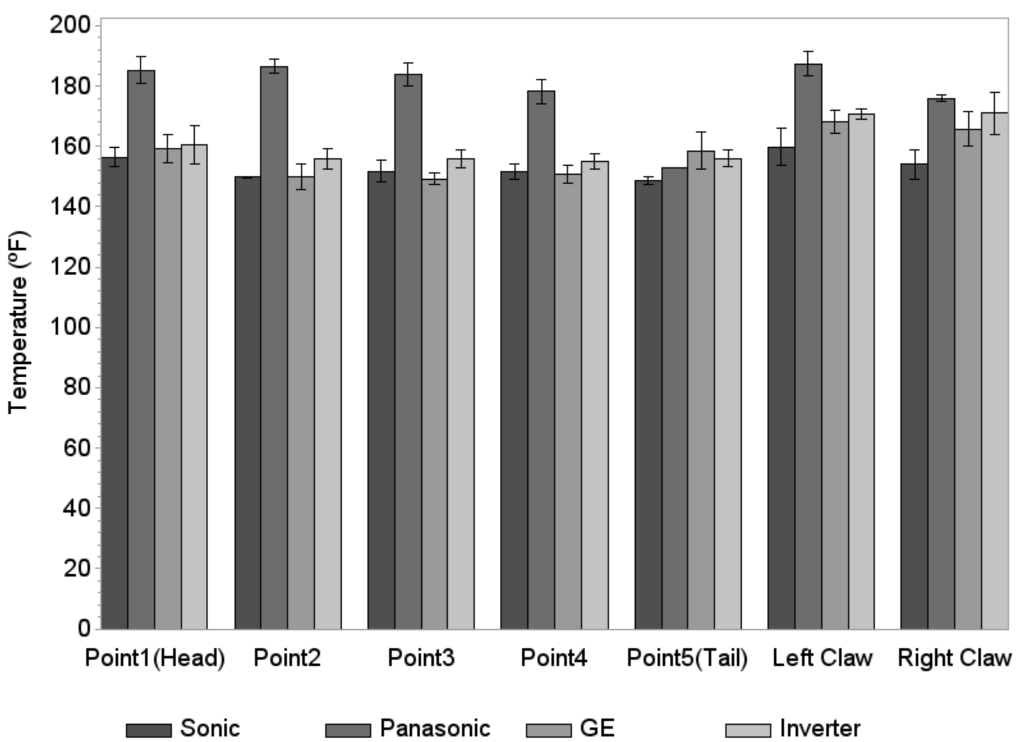


Figure 3B:Lobster no standing : compare 4 steamers on the same experiments.

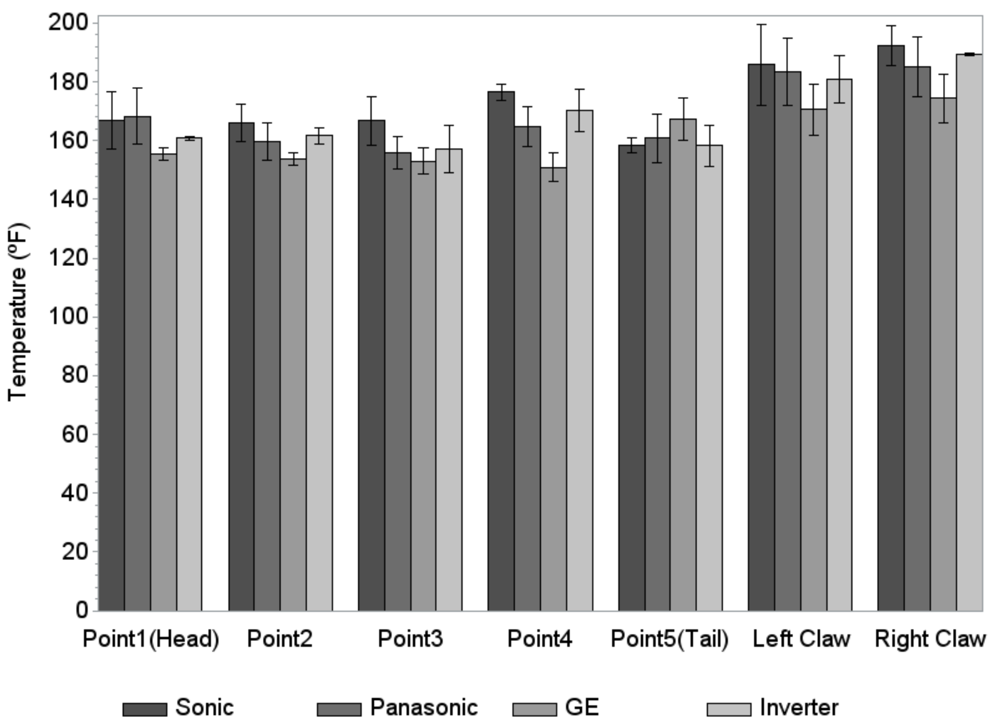
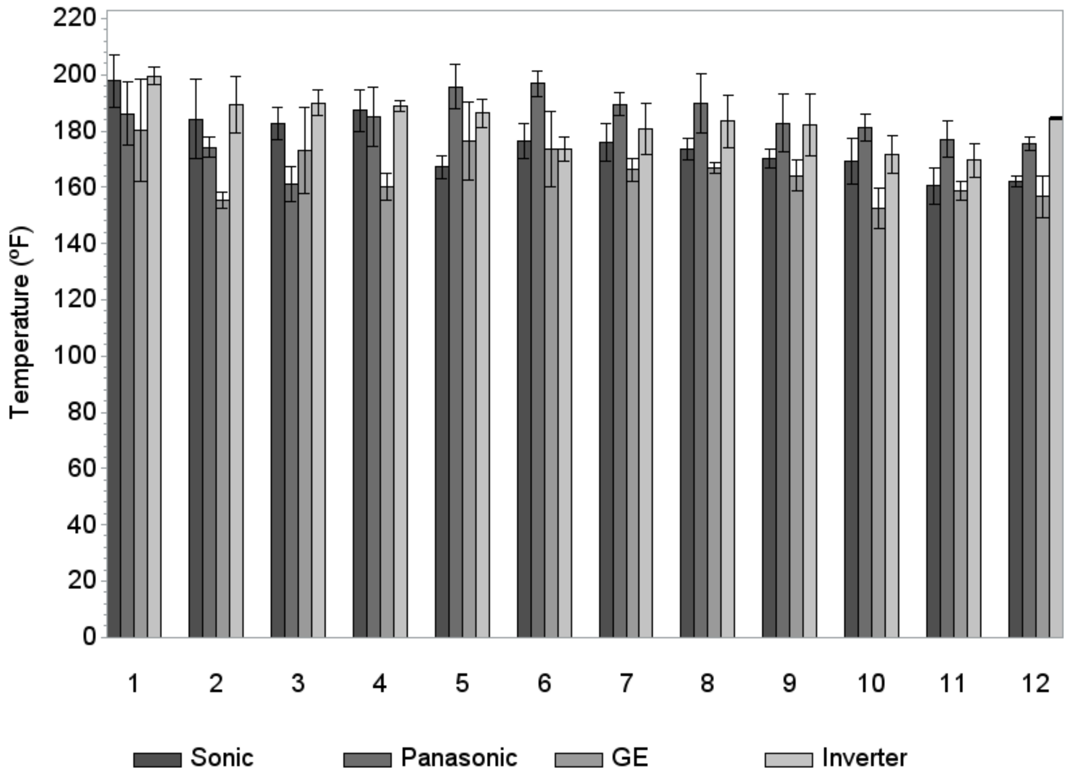


Figure 4: Compare 4 steamers on shrimps. (CHOOSE ONE FROM THE two figures)


220
200
180
160
140
120
100
80
60
40
20
0
Temperature (ºF)
1 2 3 4 5 6 7 8 9 10 11 12
Sonic
Panasonic
GE
Inverter

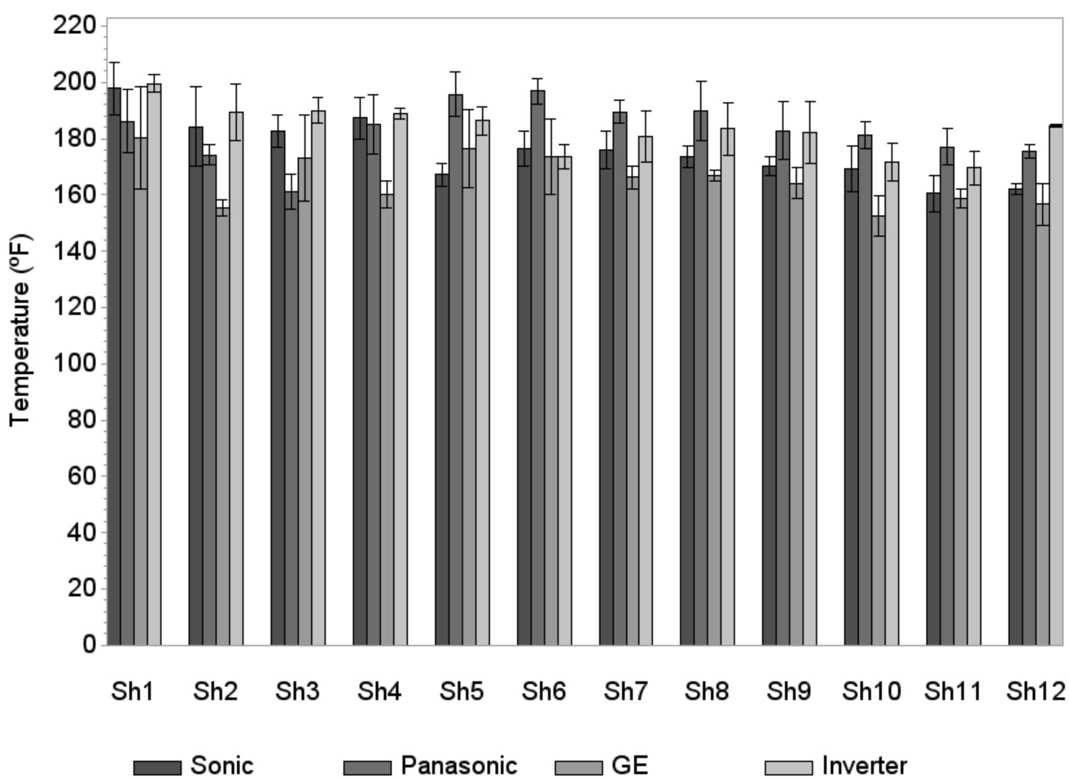

220
200
180
160
140
120
100
80
60
40
20
0
Temperature (ºF)
Sh1 Sh2 Sh3 Sh4 Sh5 Sh6 Sh7 Sh8 Sh9 Sh10 Sh11 Sh12
Sonic
Panasonic
GE
Inverter

Figure 5: two lobster in sonic steamer. (MAYBE DON'T SHOW?)