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Teflon Replacement in Pans

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Teflon Replacement in Pans CHEE 497

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Executive Summary

Background

The synthetic chemical polytetrafluoroethylene (PTFE), most commonly known as Teflon, is used in a variety of everyday appliances such as cooking pots and pans. This highly hydrophobic or waterproof nature of PTFE creates a nonstick surface by limiting adhesion and friction. The problem with Teflon is that it can increase a person's risk for cancer. It is also detrimental to the environment. An example would be that PTFE carries a substantial risk for birds as it can cause PTFE toxicosis, which is one of the many environmental problems it creates (*Polytetrafluoroethylene (PTFE, teflon) toxicosis in ducks,* 2021). In order to replace the need for Teflon in pans, a method of seasoning an aluminum pan by creating a hydrophobic non-stick surface comparable to that of Teflon was produced and tested. In this project, the effects of different seasoning oils, the heating temperature, the amount of oil, and the cooking time of the egg whites on the non-stick performance of the aluminum pan are evaluated so that ultimately, the best conditions of using seasoning oil for non-stick cooking could be determined. By doing so, the risks caused by using PTFE will be eliminated.

Results

To obtain the best conditions of using an aluminum pan with oil as opposed to a Teflon pan, 4 different parameters were tested. The data shows that using oil in an aluminum pan can yield comparable results to using a Teflon pan. The results for this study show the optimum time, temperature, and amount of oil to be used for cooking 5 grams of egg whites. Egg whites were chosen as the protein source since they could provide adequate data on the non-stick performance of a pan. For parameter 1, the type of oil, **Table 1** shows that any type of oil

improves the nonstick ability of an aluminum pan. For parameter 2, the type of oil, **Table 2** demonstrates that 5-10 grams of oil is better than using a lower amount of oil when cooking 5 gram of egg whites at 200 C with a cooking time of 2 minutes. For parameter 3, the temperature at which 5 grams of egg whites are cooked, **Table 3** shows that the ideal temperatures are either 150 C or 450 C. For parameter 4, **Table 4** presents that the ideal cook time for 5 grams of egg whites at 200 C is 1 minute.

These temperature, time, amount of oil, and type of oil parameters can be changed depending on the substance or the amount of substance that needs to be cooked.

Conclusions

The results clearly demonstrate that the use of Teflon in pans is not needed and does more harm than good. Most households carry cooking oil that can be used with their normal stick pans to make them temporarily nonstick.

As a result of completing this research project, I learned several technical and career skills. One of the skills I learned was scheduling and planning out the timeline of the project. Another skill I learned was how to use the software Yawcam as well as ImageJ. This experience has allowed me to grow as an individual and feel comfortable with working independently.

The information learned from completing this project could be a benefit to society because it brings awareness to the negative effect of PFAS (polyfluoroalkyl substances), not solely from using non-stick pans, but also from our drinking water and food. By showing alternatives to using a Teflon pan, it can inspire individuals to more closely examine what they are using and how it can impact their health. The effects of PFAS not only impact our health but also the health

of animals around us and the environment. The use of these products is not worth the risk, especially with viable alternatives available.

Recommendations

Future work can be done to research different pans, such as ceramic or stainless steel instead of aluminum. Different oils can also be tested, such as coconut or avocado oil, to determine if they impact the way the surface reacts. Egg whites were the chosen protein source because of their ability to assess a surface's nonstick ability but other foods or products can be used. The ideal parameters were determined for cooking egg whites, but further testing would need to be completed to determine the ideal parameters for each different type of food and the amount of that food.

My advice for students completing these types of projects is to set small deadlines for yourself. A big project like this can be overwhelming but breaking up the project into smaller goals and deadlines will allow you to make sure you are completing everything on time and make the process less stressful. Also, do not be afraid to reach out to your professors if you have any questions regarding your project or report.

Introduction

The synthetic chemical polytetrafluoroethylene (PTFE), most commonly known as Teflon, is used in a variety of everyday appliances such as cooking pots and pans. This highly hydrophobic or waterproof nature of PTFE creates a nonstick surface by limiting adhesion and friction. The problem with Teflon is that it can increase a person's risk for cancer. It is also detrimental to the environment. An example would be that PTFE carries a substantial risk for birds as it can cause PTFE toxicosis, which is one of the many environmental problems it creates (*Polytetrafluoroethylene (PTFE, teflon) toxicosis in ducks,* 2021). In order to replace the need for Teflon in pans, a method of seasoning an aluminum pan by creating a hydrophobic non-stick surface comparable to that of Teflon was produced and tested. In this project, the effects of different seasoning oils, the heating temperature, the amount of oil, and the cooking time of the egg whites on the non-stick performance of the aluminum pan are evaluated so that ultimately, the best conditions of using seasoning oil for non-stick cooking could be determined. By doing so, the risks caused by using PTFE will be eliminated.

Background

Polytetrafluoroethylene, or Teflon, is a carbon fluorine polymer that is used as a coating to create non-stick surfaces. The chemical formula can be viewed in **Figure 1** below.

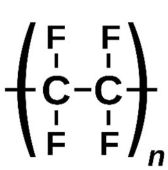

Figure 1: Chemical Formula of PTFE

Teflon works to create a nonstick surface because the carbon and fluorine atoms are bound so tightly to each other that they do not allow food or other substances to also bond with them. The polar covalent bonds between the fluorine and carbon atoms prevent the fluorine from interacting with other atoms. The fluorine atoms on the outside of the molecule also make the polymer hydrophobic. All these characteristics give it the ability to have a low coefficient of friction, aiding in the Teflon pan's ability to have a non-stick surface (Helmenstine, 2021).

There are two methods to coating a pan with Teflon. The first method uses sintering, and it requires the surface of the metal to be roughened up through sanding or other methods. This allows the Teflon to seep into the grooves, allowing a second layer of Teflon to stick to the previous layer through heating to complete the process. The second method requires ion bombardment to the side of the polymer that is meant to stick on the pan. This breaks the chemical bonds to remove the fluorine atoms on one side so the carbon atoms can adhere to the metal of the pan. Once that layer is adhered, a second layer can be sintered on top (Helmenstine, 2021).

The reason PFAS (polyfluoroalkyl substances), such as Teflon, are considered a health concern is because they do not break down easily. This causes the substance to remain in the environment or the human body for a long period of time. Worldwide, there are people with trace amounts of PFAS in their blood. Studies in the lab show that increased exposure to PFAS increases the risk of tumors in animals as well as increasing the risk of cancer in humans. The International Agency for Research on Cancer (IARC) classified perfluorooctanoic acid (PFOA, a type of PFAS) as a Group 2B "possibly carcinogenic to humans" substance ("*Perfluorooctanoic acid"*).

In the United States, most of the exposure to PFAS comes from our drinking water. Currently, the EPA (Environmental Protection Agency) does not enforce PFAS limits on drinking water,

but it does have some established health advisories. These advisories were set based on lab data from studying rats and mice. Another source of PFAS exposure is through food or its packaging. Previously, the FDA has allowed PFAS to be used on paper that comes in contact with food to prevent grease. Since 2019, the FDA has been testing food for PFAS in order to create the correct regulations ("*Perfluorooctanoic acid*").

Experimental Methods

To obtain the best method for seasoning an aluminum pan, four different parameters were varied. These parameters include: the type of oil (olive oil, vegetable oil, and vegetable shortening, 5 g each, at 200°C for 2 minutes), the amount of oil (2.5 g, 5 g and 10 g with vegetable oil, 200°C for 2 minutes), the cooking temperature (150°C, 200°C, 250°C, 350°C, 5 g of vegetable oil for 2 minutes), and the cooking time (5 g of vegetable oil at 200°C for 1 minute, 2 minutes or 4 minutes). The pan without any oil was used to serve as the negative control, while the Teflon coated pan was served as the positive control. At least three runs for each condition were carried out, and the average of the three runs was determined along with the statistical analysis of all the data gathered.

The materials and equipment used for the experiments included an aluminum pan, a small bowl or plastic container, an electric stove top, a kitchen scale, a microscope zoom lens and its camera, a laptop computer, an infra-red (IR) thermometer, a timer, three different oils (olive oil, vegetable oil, and vegetable shortening), large chicken eggs (~ 57 g), a silicon spatula, and basic dish washing supplies. The project used two types of software, Yawcam was used for capturing images from the microscope zoom lens camera, and ImageJ was used to analyze the captured images.

For each experiment, an egg was cracked into a small bowl with the yolk removed. The aluminum pan and the bowl containing the egg white were first weighed using the kitchen scale (unit: grams) and the weights were recorded. The burner was then turned on and the temperature of the stovetop was monitored using the IR thermometer until the temperature reached ~ 200°C. Once reached, the pan was placed on the stovetop with 5 g of oil added to the pan to create a thin layer. The temperature of the oil/pan was monitored until a relative stable value was reached. This temperature was recorded, and the egg was then poured from the bowl into the pan to cook for various lengths of time (2 minutes for most cases). The bowl, after the egg was poured out, was measured to determine the exact mass of egg to be cooked. After the egg was cooked, it was removed from the pan using a spatula. The residual egg left on the pan was examined using the microscope zoom lens camera that is connected to the laptop computer. The images were captured using the Yawcam software. If any egg residual was seen in the pan, a paper towel was used to gently remove any oil left in the pan. The weight of the pan was then measured to determine the actual mass of egg stuck to the pan.

Data and Results

The amount of egg white left on the pans for all 4 parameters was measured in 2 different methods. The first method required a picture to be taken and then analyzed using ImageJ to determine the area, in cm^2 of the egg white residual. The second method required each pan to be measured before and after the egg was cooked in order to determine how many grams of egg whites were left on the pan. Each of the 4 parameters and the results will be discussed in further detail below.

The first parameter measured was the type of oil. The amount of egg left on the pan was weighed and the area was calculated for the Teflon pan, the aluminum pan without oil, and the aluminum pan with the 3 different oils. These oils include olive oil, vegetable oil, and vegetable shortening. The results can be found in **Table 1** below. The graph for these results is shown in Appendix A, **Figure 5**.

Table 1: The amount of egg white residual on the pan for Parameter 1

Parameter 1	residual	residual
5 g, 200 C, 2 minutes	area (cm^2)	mass (g)
alum pan with no oil	4.564 ± 0.030	0.230 ± 0.005
alum pan with olive	0	0
alum with vegetable oil	0	0
alum pan with shortening	0	0
Teflon pan	0	0

The second parameter evaluated was the amount of vegetable oil used in the aluminum pan. This was measured against the negative control (the aluminum pan without oil) and the positive control (the Teflon pan). The temperature and time were kept constant at 200 C and 2 minutes. The results can be found in **Table 2** below. The graph for these results is shown in Appendix A, **Figure 6**.

Table 2: The egg white residual on the pan for Parameter 2

Parameter 2	residual	residual
200 C for 2 mins	area (cm^2)	mass (g)
alum pan with no oil	4.593 ± 0.010	0.220 ± 0.004
alum pan with 2.5 g oil	1.166 ± 0.019	0.057 ± 0.005
alum pan with 5 g oil	0	0
alum pan with 10 g oil	0	0
Teflon pan	0	0

Some representing pictures taken of the egg white residual on the pan that was used for the area measurements are shown in **Figure 2** below. This left image shows parameter 2 of an aluminum pan with 2.5 g of oil cooked for 2 minutes at 200 °C, some egg white residual was observed. The right image shows parameter 2 of an aluminum pan with 10 g of oil cooked for 2 minutes at 200 °C, no egg residual resulted.

Figure 2: Parameter 2: Aluminum pan with (left) 2.5 grams and (right) 10 grams of oil.

3The third parameter examined was the cooking temperature. The amount of oil and the cooking time were kept constant at 5 grams and 2 minutes. The egg was cooked at 150 C, 200 C, 250 C, and 350 C. The results can be found in **Table 3** below. The graph for these results is shown in Appendix A, **Figure 7**.

Table 3: The egg white residual on the pan for Parameter 3

Parameter 3	residual	residual
5 g for 2 mins	area (cm^2)	mass (g)
alum pan at 150 C, oil	0	0
alum pan at 200 C, oil	1.792 ± 0.016	0.091 ± 0.003
alum pan at 250 C, oil	2.187 ± 0.029	0.100 ± 0.003
alum pan at 450 C, oil	0	0
Teflon pan at 150 C	0	0
Teflon pan at 200 C	0	0
Teflon pan at 250 C	0	0
Teflon pan at 450 C	0	0
alum pan at 150 C	3.783 ± 0.022	0.190 ± 0.004
alum pan at 200 C	4.621 ± 0.018	0.240 ± 0.006
alum pan at 250 C	4.988 ± 0.026	0.260 ± 0.005
alum pan at 450 C	3.575 ± 0.028	0.320 ± 0.004

The fourth parameter investigated was the cooking time. The amount of oil and the temperature were kept constant at 5 grams and 200 C. The egg was cooked for 1 minute, 2 minutes, and 4 minutes. The results can be found in **Table 4** below. The graph for these results is shown in Appendix A, **Figure 8**.

Table 4: The egg white residual on the pan for Parameter 4

Parameter 4	residual	residual
5 g at 200 C	area (cm^2)	mass (g)
alum pan for 1 min	5.996 ± 0.006	0.240 ± 0.003
alum pan for 2 mins	4.826 ± 0.008	0.320 ± 0.003
alum pan for 4 mins	0.916 ± 0.019	0.440 ± 0.005
Teflon pan for 1 min	0	0
Teflon pan for 2 mins	0	0
Teflon pan for 4 mins	0	0
alum pan for 1 min, O	1.016 ± 0.010	0.053 ± 0.004
alum pan for 2 mins, O	5.499 ± 0.014	0.081± 0.006
alum pan for 4 mins, O	5.704 ± 0.09	0.120 ± 0.005

For the results, the average area and average weight might be inconsistent because a bigger area might not necessarily yield a higher weight. For example, the pictures below in **Figure 4** show that even though the area was bigger for the aluminum pan with oil, the weight was lower than the aluminum pan without oil. The aluminum pan without oil had a larger weight and a smaller area than the pan with oil.

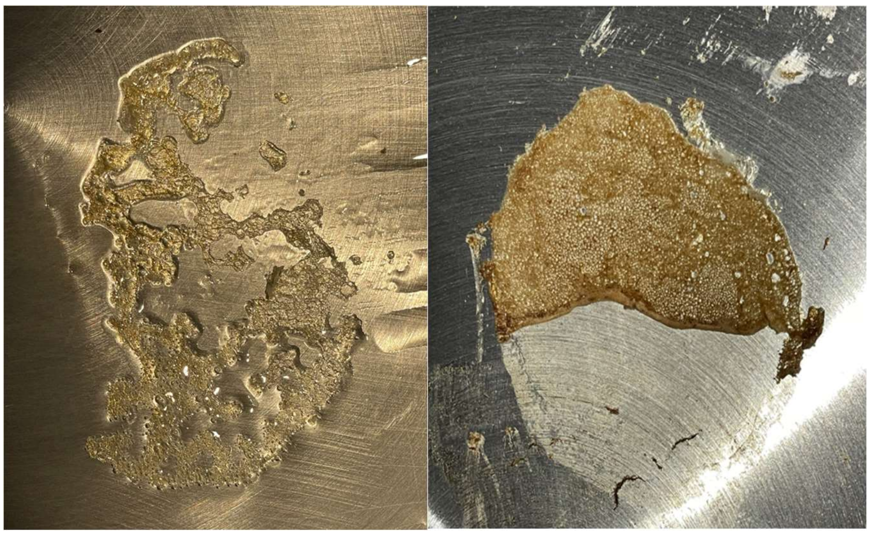

Figure 4: Comparison of Parameter 4: Aluminum pan with (left) and without (right) oil at 2 mins.

Discussion/Analysis

For the first parameter, adding oil yields the same result, i.e., no egg remaining in the pan, as the Teflon pan. However, the aluminum pan without oil showed statistically different results (all p-values < 0.05 from student t-test when compared to those with oil), with egg white residual occupying an area of 4.564 cm^2 compared to an area of 0 cm^2 from that of the Teflon pan. The second parameter determined that the suitable amount of vegetable oil to add to the aluminum pan for the egg not to stick and for the results to match that of a Teflon pan is 5 to 10 grams of oil. Completing a t-test statistical analysis yielded a p value of 7.74E-06 between the

aluminum pan with no oil and the Teflon pan. For the aluminum pan with 2.5 g of oil, a p value of 0.0004 between this case and the Teflon pan was obtained, indicating there is a difference. For the third parameter, the effect of the temperature at which the vegetable oil is heated was tested and the results show that the oil heated to 150 C and 450 C yields the same results as that of a Teflon pan. But, at 200 C, the average area of egg white left on the pan was 1.792 cm^2, and at 250 C, the average area of egg white left on the pan was 2.187 cm^2. The results show that these temperatures are not ideal and lead to a difference in the non-stick performance as compared to the Teflon pan. Completing a t-test statistical analysis yielded a p value of 0.000117 between the aluminum pan with oil at 200 C and the Teflon pan. The p value between the aluminum pan with oil at 250 C and the Teflon pan was 0.00026. The fourth parameter showed that a cooking time of 1 minute yielded similar results to that of a Teflon pan. But a cooking time of 2 minutes left an average area of 5.499 cm^2 of egg white on the pan, and a cooking time of 4 minutes left an average area of 5.704 cm^2 of egg white on the pan. Completing a t-test statistical analysis yielded a p value of 5.02E-05 between the aluminum pan with oil cooked for 1 minute and the Teflon pan. The p-value at 2 minutes was 3.19E-06 and the p-value at 4 minutes was 1.68E-05. The potential causes for some of the unexpected results on oiled pans are briefly described below. All the results for the statistical analysis can be found in Appendix D.

To increase the accuracy of these results, both the Teflon and aluminum pans were cleaned before and after each variable or parameter was tested. Everything was weighed and measured using the same devices to prevent discrepancies between the data. Since the thickness of the egg whites on the pan were not measured, a larger area may not mean that more grams of the egg whites were left on the pan. Measuring both the area of the eggs whites as well as the mass amount left on the pans helped to accurately interpret the data. Some of the same temperatures,

cooking times, and oil amounts have led to different results between parameters, which may have been caused by a difference in the stove used, the weather, as well as how well the pan was cleaned.

Future work can be done to research different pans, such as ceramic or stainless steel instead of aluminum. Different oils can also be tested, such as coconut or avocado oil, to determine if they impact the way the surface reacts. Egg whites were the chosen protein source because of their ability to assess a surface's nonstick ability but other foods or products can be used. The ideal parameters were determined for cooking egg whites, but further testing would need to be completed to determine the ideal parameters for each different type of food and the amount of that food. Regardless, the risk of using Teflon pans is avoidable as there are methods that replace the need to use PFAS nonstick pans.

Literature Cited

Helmenstine, A. (2021, July 12). *How teflon works and how it sticks to pans*. Science Notes and Projects. Retrieved April 17, 2023, from https://sciencenotes.org/how-teflon-works-and-how-it-sticks-to-pans/

Perfluorooctanoic acid (PFOA), perfluorooctane sulfonate (PFOS), and Related Chemicals. American Cancer Society. (n.d.). Retrieved April 17, 2023, from https://www.cancer.org/healthy/cancer-causes/chemicals/teflon-and-perfluorooctanoic-acid-pfoa.html

Polytetrafluoroethylene (PTFE, teflon) toxicosis in ducks. Cornell University College of Veterinary Medicine. (2021, March 8). Retrieved April 17, 2023, from https://www.vet.cornell.edu/animal-health-diagnostic-center/news/polytetrafluoroethylene-ptfe-teflon-toxicosis-ducks#:~:text=Clinical%20signs%20of%20PTFE%20toxicity,dead%20with%20no%20premonitory%20signs.

Appendices

Appendix A: Parameter Graphs

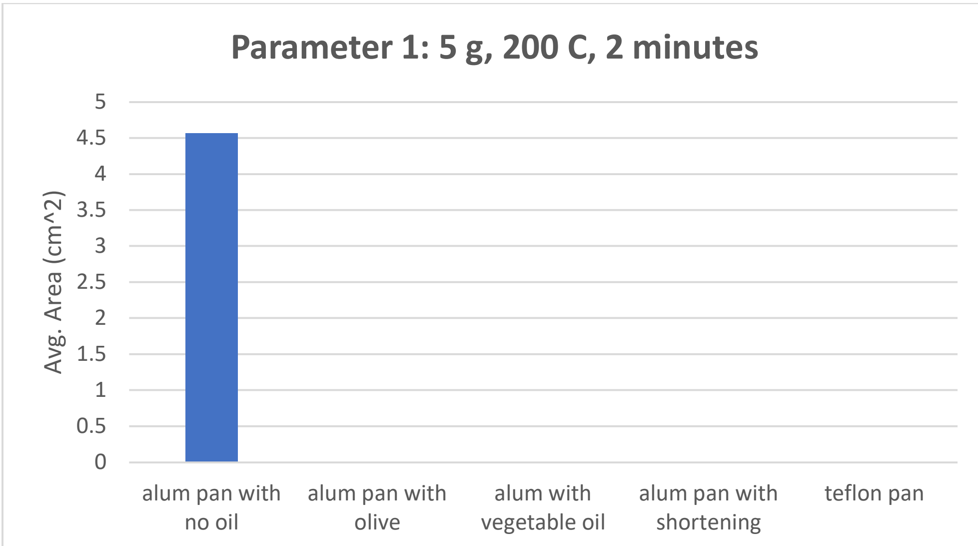

Figure 5: Graph of average area for Parameter 1.

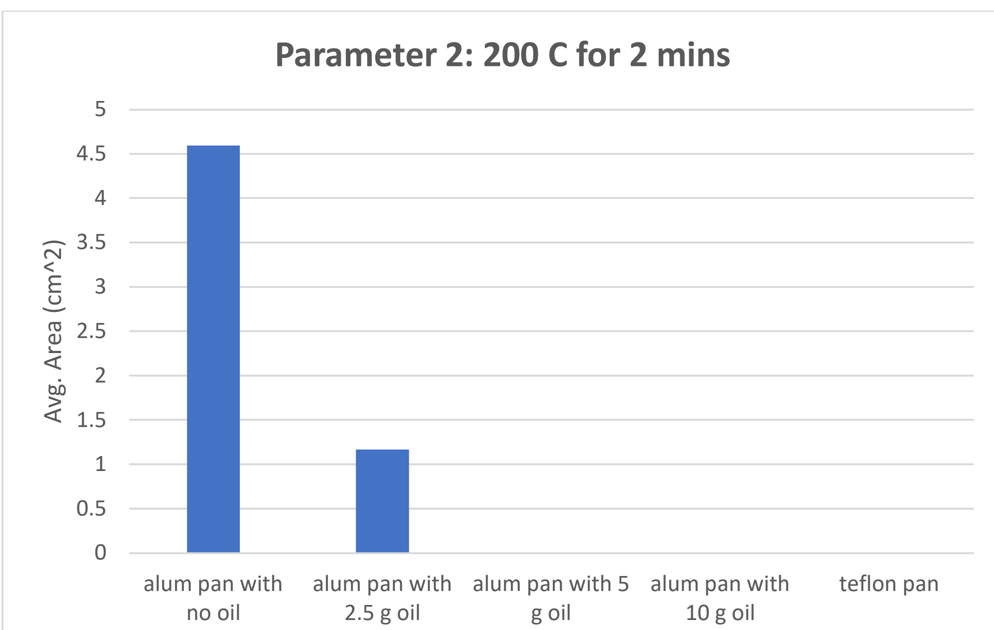

Figure 6: Graph of average area for Parameter 2.

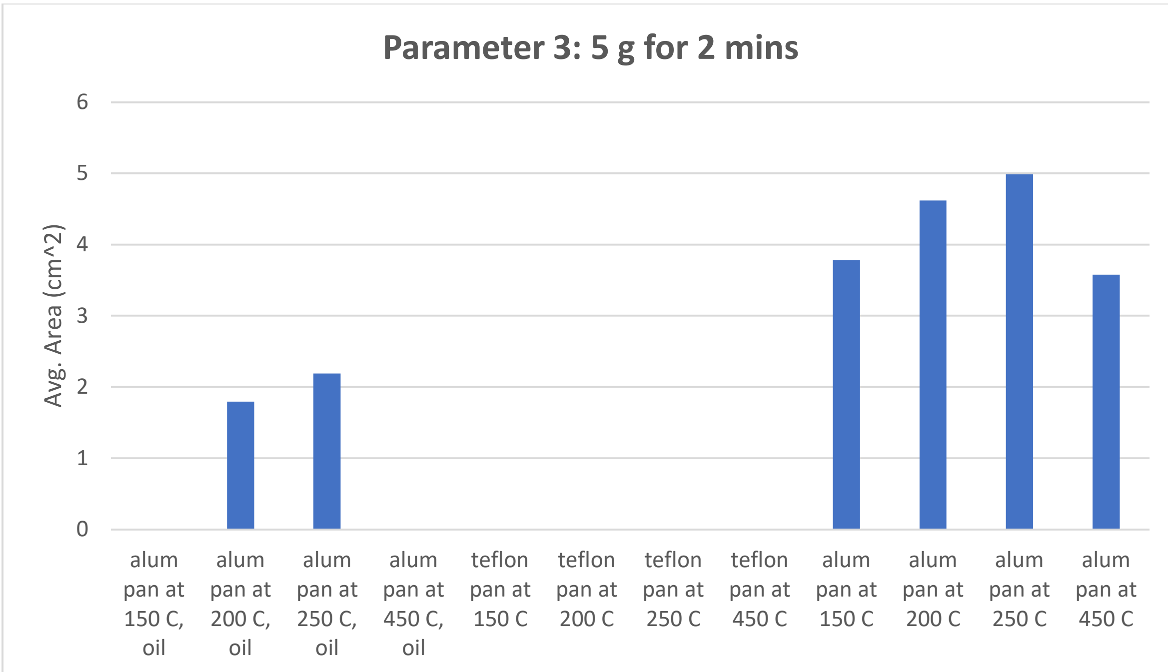

Figure 7: Graph of average area for Parameter 3.

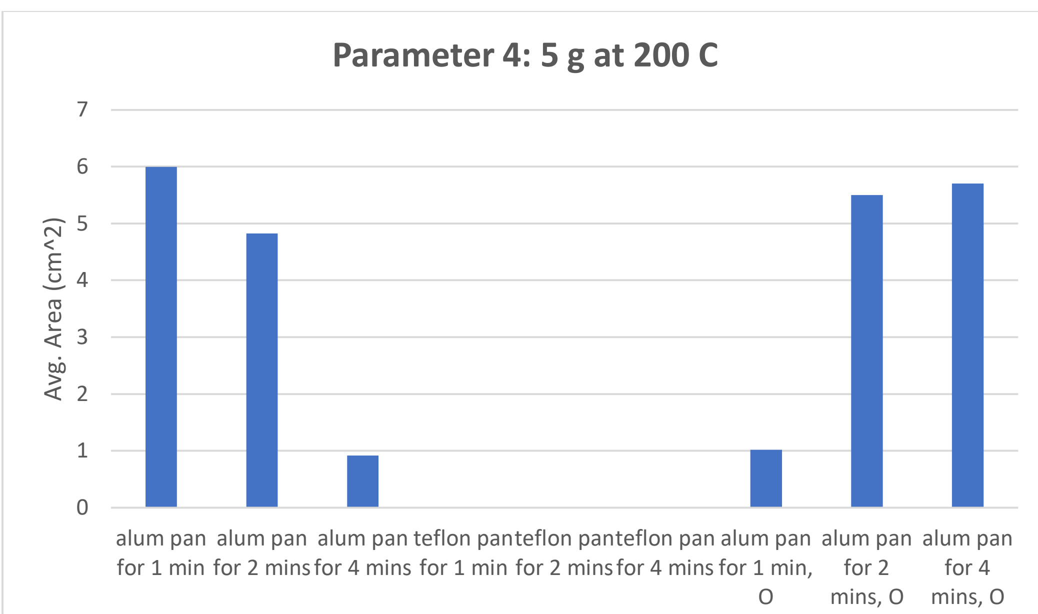

Figure 8: Graph of average area for Parameter 4.

Appendix B: Examples of Pictures Used for Measurements

Figure 9: Picture of Parameter 4: Aluminum pan with no oil at 1 min.

Figure 10: Picture of Parameter 4: Aluminum pan with oil at 1 min.

Figure 11: Parameter 4: Aluminum Pan with no oil at 2 mins.

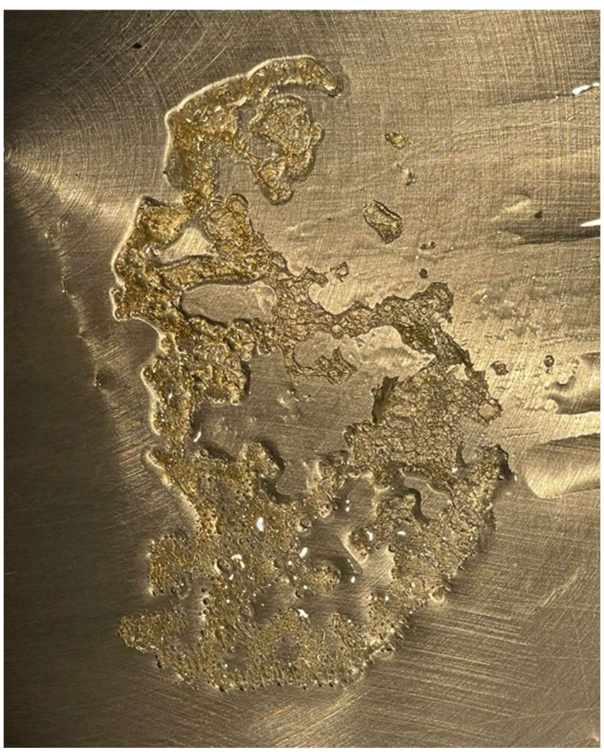

Figure 12: Parameter 4: Aluminum pan with oil at 2 mins.

Figure 13: Parameter 4: Aluminum pan with no oil at 4 mins.

Figure 14: Parameter 4: Aluminum pan with oil at 4 mins.

Appendix C: How Measurements Were Obtained Using ImageJ

To measure the average area in cm^2 of the egg white left on the pan, the picture was first uploaded into the software "ImageJ." The scale was then set by using the straight-line tool to draw the scale and the exact measurement was inputted. This can be seen in **Figure 12** below.

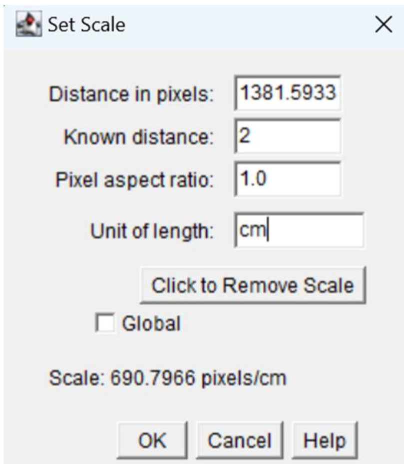

Figure 15: ImageJ example of setting the scale.

After the scale was set, the freehand tool was selected and used to trace the perimeter of the egg white on the pan. An example of this can be seen in **Figure 13** below.

Figure 16: Example of freehand selection tool being used.

Once the perimeter of the egg white was selected, the option "Analyze" was selected from the toolbar, and then "Measure," which showed the results in the correct units. An example of this screen can be seen in **Figure 14** below.

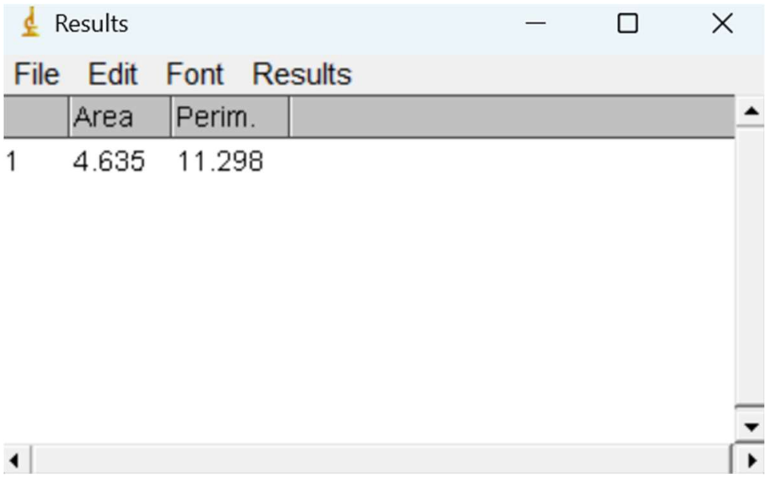

Figure 17: Example of the results screen on ImageJ.

Appendix D: Statistical Analysis Results

Table 5: t-Test results for Parameter 1 between the aluminum pan with oil and the Teflon pan.

t-test	
Parameter 1: Aluminum with oil vs Teflon	**p-value**
no oil	6.7E-05
olive oil	-
vegetable oil	-
shortening	-

Dashes in box signify that the value was divided by zero.

Table 6: t-test results for Parameter 2 between the aluminum pan with oil and the Teflon pan.

t-test	
Parameter 2: Aluminum with oil vs Teflon	**p-value**
no oil	7.74E-06
2.5 g	0.000404
5 g	-
10 g	-

Dashes in box signify that the value was divided by zero.

Table 7: t-test results for Parameter 3 between the aluminum pan with oil and the Teflon pan.

t-test	
Parameter 3: Aluminum with oil vs Teflon	**p-value**
150 C	-
200 C	0.000117
250 C	0.00026
450 C	-

Dashes in box signify that the value was divided by zero.

Table 8: t-test results for Parameter 4 between the aluminum pan with oil and the Teflon pan.

t-test	
Parameter 4: Aluminum with oil vs Teflon	**p-value**
1 minute	5.02E-05
2 minutes	3.19E-06
4 minutes	1.68E-05