Browning Bread using Mayo vs Butter

Aaron VerDow

Natural Science Lab - C683

Section I: Introduction and Literature Review

A: Summary

Several sources claim that using mayonnaise instead of butter on the outside of sandwiches makes a better grilled cheese sandwich.

According to Southern Living:

> The secret to your best-ever grilled cheese? Mayonnaise. Next time you make one, don't smother your bread in butter like usual. Instead, slather on the mayo; it'll add a tang and create a perfectly crisp exterior. (Beal, 2024)

The Food Network:

> If you butter only the inside of your bread and spread a thin schmear of mayo on the exterior of the sandwich, you create the ideal conditions for the bread to toast, cheese to melt and butter to shine. The mayonnaise doesn't actually provide flavor — if you're a mayo hater, you won't even taste it, I promise — but instead encourages ideal browning and melting. (Saladino, 2023)

I made grilled cheese sandwiches this way for many years. Recently I had to start avoiding gluten and since then have struggled to make a grilled cheese with my preferred level of darkness before the cheese starts to break down from the heat.

The specific reaction that browns food is known as the Maillard reaction. "Using mayonnaise also helps create that Maillard reaction" (Makuch, 2024, as cited in Saladino, 2024). This experiment will be testing the browning performance of mayo over butter with the specific bread and oils I eat.

Section II: Hypothesis

B: Hypothesis

Applying heavy mayo onto bread will result in darker griddled bread than using butter or a light coat of mayonnaise.

C: Justification

Proponents of the use of mayonnaise on grilled cheese claim it results in better browning of the bread. Personal anecdotal tests (making and eating grilled cheese sandwiches) back this up.

Section III: Method

D: Independent Variables

- Oil type
  - This will be controlled by applying either butter or mayonnaise to bread.
- Oil quantity
  - This will be controlled by putting oils into a syringe and applying specific quantities to each sample.

  - Light = 0.5 mL
  - Heavy = 1 mL

E: Dependent Variables

- Average darkness
  - The bread darkness will be measured by taking photographs of each sample and analyzing the pixel data.

Getting a quantitative measurement of bread darkness will be done by:

- Photographs will be taken with a camera that has all automated adjustments disabled ensuring consistency between images.
- Samples will be photographed in a light box with no external light sources. There is one internal light source set to consistent temperature and luminosity.
- The camera is mounted in a fixed position in the light box.
- Images are edited and all pixels not in the bread sample are dropped.
- Images are converted to gray scale and values of the remaining pixels are analyzed.

F: Confounding Variables

- Bread
  - Initial bread color
  - Bread size, shape and weight
  - Bread age
- Cooking
  - Griddle temperature
  - Time on griddle
  - Griddle placement
- Oil quantity
- Photography
  - Automated camera settings
  - Ambient light

Bread Bread samples are cut into uniform 35x35mm squares using a bread cutting jig. This has several benefits: * Samples are a uniform size. * More samples can be placed on the griddle at once, giving more data points for a single test. * The crust, which can greatly influence browning, is discarded. * Imperfections can be discarded.

The bread samples will be taken from a single loaf of bread so the starting color and age of the bread will be more consistent.

Photographs of each sample will be taken before the experiment so that any variety can be identified ahead of time or accounted for when analyzing the results.

Cooking The samples will be glued to a sheet of paper so they can be placed on the griddle and removed all at the same time. This will reduce differences in the temperature of the griddle and cooking times.

Oils Mayo will be taken from a single jar and butter from a single stick. Both oils will be inserted into large syringes so specific quantities can be applied to each sample.

Photography Samples will be photographed in a closed box with no external light sources. The camera will be manually set and all automated functions will be disabled.

G: Materials and Tools

Light Box GoPro Hero 9 Black

Settings as applied through GoPro Quik app:

- Lens: Narrow
- Output: Standard
- Scheduled Capture: Off
- Timer: Timer Off
- Shutter: 1/250
- EV Comp: 0
- ISO Min: 800
- ISO Max: 800
- White Balance: 4000K
- Sharpness: High
- Color: Flat

LumeCube LC-Panel1

- Brightness: 100%
- Temperature: 5600K

The camera is placed 240mm above the sample with the light placed horizontally against the camera.

Sample is enclosed so no external light sources impact the photo.

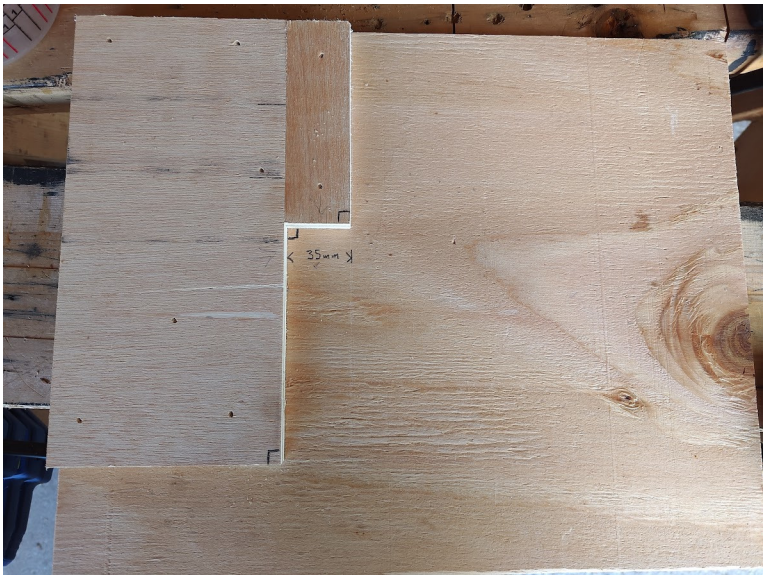
This can easily be replicated by using a 12 count glass bottle TopoChico box. Cut holes for the camera lens and light into the top and then tape over all holes. The sample is added and removed by opening and closing the side.

Placement for the samples is marked using a green Post It note. This is easily to identify and align but will still be ignored by the software if a portion is exposed.

Bread Bread is prepped using this jig to cut it into uniform 35mm squares.

Bread is liveGfree Gluten Free Bread Whole Grain

Cutting Jig The cutting jig is simple wood construciton. The important dimensions are the three right angles highlighted by the drawn on boxes and the 35mm gap that will make the sample square. The remaining dimensions are irrelevant as long as the knife and bread can be aligned.



Oils

- Oils are drawn into an AHS AH30S 30mL Syringe
- Mayonnaise used is Hellmann's Plant Based Mayo (squeeze bottle)
- Butter used is Land O Lakes Salted Butter
- Heavy application is 0.5 mL
- Light application is 1 mL

Oils are applied to the center and spread to the edges as uniformly as possible.

Assembly Each sample is attached with wood glue to the center of a 40x40mm square within a 240x200mm grid.

Cooking The griddle used is Breville Sear and Press Grill

Software setup This document is written in R Markdown and the software for all image processing and graph generation is included inline. Most of the code is hidden in the rendered output but the source code is available at: https://github.com/AaronVerDow/grilled_cheese_experiment/

This instance was rendered on commit ID:

```
## [1] "a73f66af3ae996eb04e0c553b829725bedb5c2ae"
```

Functions for measuring samples: (other functions are hidden in the rendered version of this document

This function accepts an image of a sample (already cropped) and per pixel will compare the red, green, and blue values. If green is the highest value the alpha channel will be set to 0 making that pixel as transparent. The accuracy of this function can be seen in the tables below and by looking at the overall pixel count per sample (though inconsistency in bread sizes can also create variety there.)

```
chromakey <- function(image) {
  pixels <- image_data(image, channels = "rgba")

  red <- pixels[1, , ]
  green <- pixels[2, , ]
  blue <- pixels[3, , ]

  mask <- (green > red) & (green > blue)
```

```
  pixels[4, , ][mask] <- as.raw(0)
  return(image_read(pixels))
}
```

This function accepts an image from the chroma key function above. It will use Image Magick to set the saturation to zero converting it to gray scale. In this state the red, green, and blue channels all contain the same values. The alpha channel is extracted and a bit mask is created excluding all pixels set to full transparency. This bit mask is applied to one of the color channels and the remaining values are returned in numeric format for analysis. The end result is a list of the relative lightness of each pixel on the sample only, all pixels that were green are ignored.

```
get_grays <- function(path) {
  # returns a vector of opaque values
  pixels <- image_read(path) %>%
    image_modulate(saturation = 0) %>%
    image_data(channels = "rgba")
  gray <- as.numeric(pixels[1, , ])
  alpha <- as.numeric(pixels[4, , ])
  mask <- alpha != 0
  return(gray[mask])
}
```

H: Procedure

Sample Numbering Reference this section every time there is mention of setting number or dice.

Samples are numbered using a 7 digit code using numbers 1-6 and 9. (Six sides of a die plus 9 as an upside down 6.)

Each digit represents a specific piece of data:

1. Grid X, 1-6
2. Grid Y, 1-5
3. Oil
    1. Light Butter
    2. Light Mayo
    3. None
    4. Heavy Butter
    5. Heavy Mayo
4. State
    - 9 Uncooked
    - 1 Grilled
5. Batch Number
    - 1-6 Experiment(s)
    - 9 Calibration Tests (ignore)
6. Unassigned
    - 9 No meaning
7. Unassigned
    - 9 No meaning

Digits 1-3 are set per sample and digits 4-7 are set per batch.

Grid View of oils in grid form followed by a detailed list of each sample. Reference these when placing any sample on the grid and taking photos.

	1	2	3	4	5	6
1	LB	LM	X	HB	HM	LB
2	LM	X	HB	HM	LB	LM
3	X	HB	HM	LB	LM	X
4	HB	HM	LB	LM	X	HB
5	HM	LB	LM	X	HB	HM

X	Y	Oil	OilName	ID
1	1	1	Light Butter	111
2	1	2	Light Mayo	212
3	1	3	None	313
4	1	4	Heavy Butter	414
5	1	5	Heavy Mayo	515
6	1	1	Light Butter	611
1	2	2	Light Mayo	122
2	2	3	None	223
3	2	4	Heavy Butter	324
4	2	5	Heavy Mayo	425
5	2	1	Light Butter	521
6	2	2	Light Mayo	622
1	3	3	None	133
2	3	4	Heavy Butter	234
3	3	5	Heavy Mayo	335
4	3	1	Light Butter	431
5	3	2	Light Mayo	532
6	3	3	None	633
1	4	4	Heavy Butter	144
2	4	5	Heavy Mayo	245
3	4	1	Light Butter	341
4	4	2	Light Mayo	442
5	4	3	None	543
6	4	4	Heavy Butter	644
1	5	5	Heavy Mayo	155
2	5	1	Light Butter	251
3	5	2	Light Mayo	352
4	5	3	None	453
5	5	4	Heavy Butter	554
6	5	5	Heavy Mayo	655

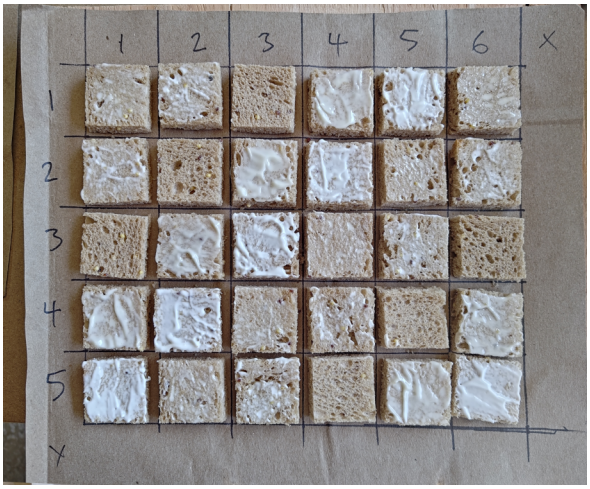
Photograph Procedure This will be repeated every time a photograph is taken.

- Set dice to identify sample and oil used.
- Place sample in light box
- Check camera to make sure sample is properly aligned (no section of Post-It note is visible)
  - (GoPro Quik phone app is recommended for convenience.)
- Close light box
- Take photo
  - (GoPro Quik phone app or other remote trigger is recommended to avoid jostling the box.)
- Open box and place sample back into its place on the grid.

Experiment Procedure

- Draw a grid of 40mm squares totaling 240x200mm on a thick sheet of paper (cutout from a brown paper bag works well.)
- Set dice for experiment number and grilled state.
- Fill syringe with wood glue
- Cut and place Samples
  - Use jig to cut a 35x35mm square
  - Photograph sample
  - Apply 1 mL of wood glue to back of sample
  - Place sample on paper grid
  - Repeat until grid is filled

- Allow glue to dry
  - Wrap grid in aluminum foil to reduce drying of bread samples
  - Place a uniform weight on the grid to flatten out the bread samples and ensure proper adhesion
  - Let the glue set for an hour
- Fill butter and mayo syringes
  - Both butter and mayo should be room temperature. Butter can be left out overnight but I recommend using a new jar of mayonnaise from the store.
- Turn on griddle and set it to 450 degrees
  - This is very early to start pre-heating but the goal here is to give plenty of time for heat to be evenly distributed around the griddle surface and not just directly around the burners.
- Apply oils to samples using the charts below.
  - A single dollop in the center measured out to 1 mL for heavy samples and 0.5 mL for light samples
  - Using only one side of a butter knife scoop a quarter of the dollop and spread to each edge
  - Wipe any remaining oil on the knife onto any exposed edges
  - Clean knife between samples to avoid buildup



- Place grid in center of hot griddle.
- Place weight on top of sample grid.
- Let cook for 4:30 minutes.
- Carefully rotate the grid to break samples loose without removing them from heat.
- Once all samples are loose lift grid off the griddle and set aside.
- Once cooled carefully peel each sample off the grid and photograph.
  - The bread should separate in the middle between the glued back and grilled front.

Data Review

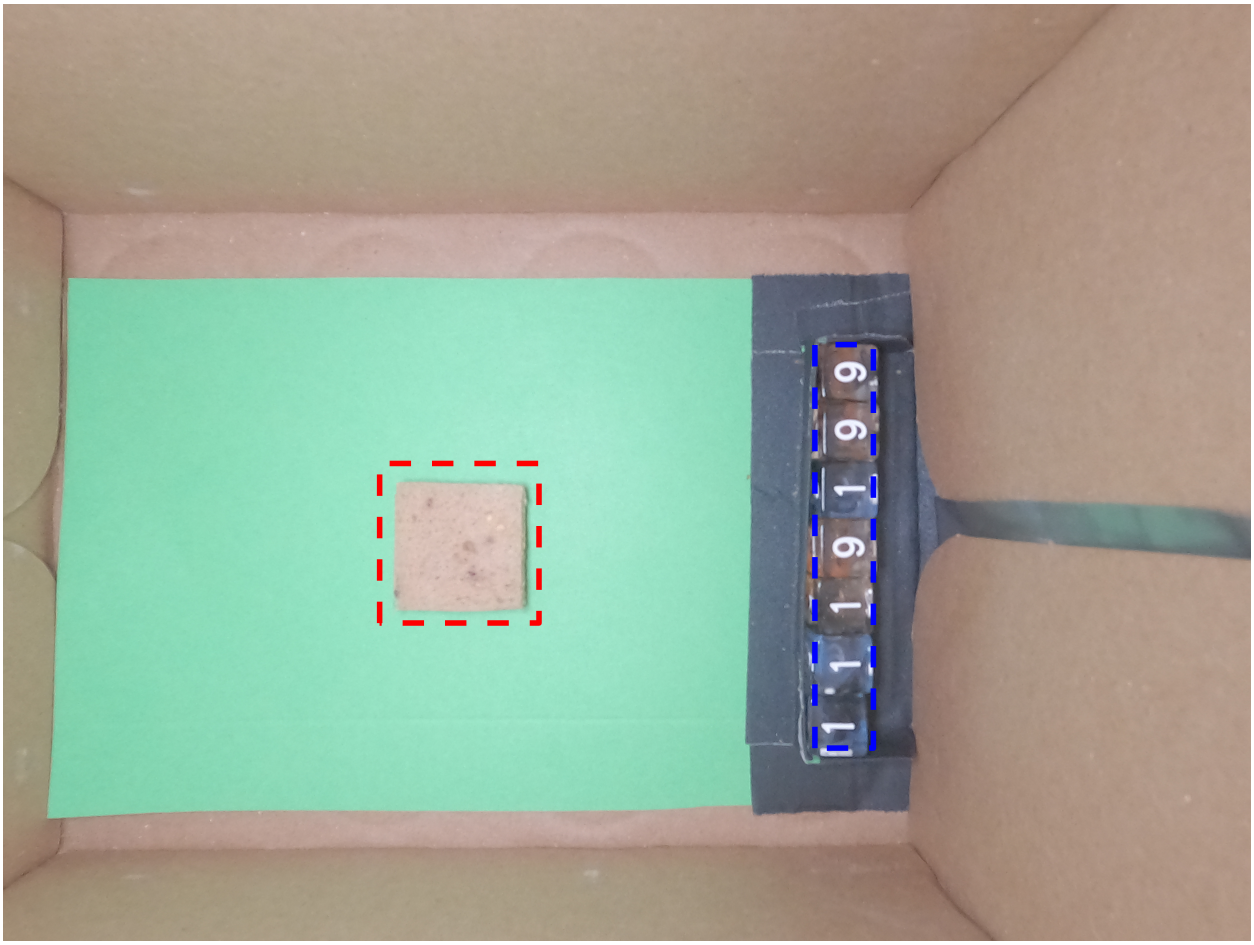
- `git clone https://github.com/AaronVerDow/grilled_cheese_experiment/`
- Copy photos of samples to a directory under `src/pictures`
- Update IMAGES_DIRECTORY in constants to point to new directory

```
IMAGES_DIRECTORY = "pictures/one"
```

- Adjust sample and ID geometry if photos are improperly cropped. All units are in pixels.

```
# This must be set to FALSE to see any changes made here
CACHE_IMAGES <- TRUE

# Highlighted in red
SAMPLE_CROP <- c(
  # size of rectangle
  662,   # X
  662,   # Y

  # location of rectangle
  1564,  # X offset
  1906   # Y offset
)

# Highlighted in blue
ID_CROP <- c(
  # size of rectangle
  243,   # X
  1674,  # Y

  # location of rectangle
  3372,  # X offset
```

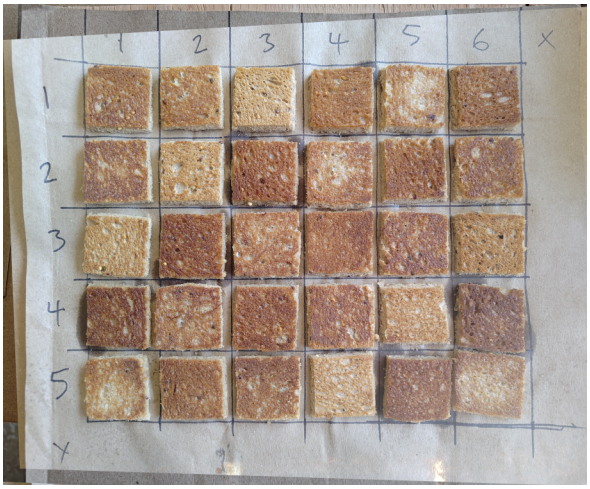
```
  1413    # Y offset
)
```



- Look over "OCR Corrections" in the Appendix and confirm all photos have been correctly identified. Adjust constants as needed:

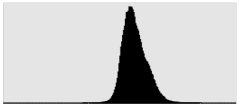
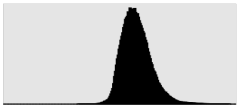
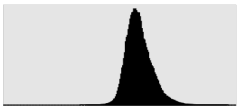
```
# adjust light cutoff for rendering numbers as black and white
ID_THRESHOLD <- "85%"

# scaling to shrink photograph of ID
# target value for tesseract is 32 px high letters
ID_SCALE <- "250"

# options for fake rendering of dice for OCR comparison
DIE_SIZE <- 36 # rough size of dice in pixels
DIE_FONT_SIZE <- 30
DIE_FONT <- "Ubuntu"
```

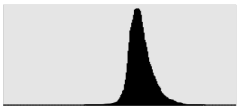
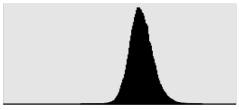
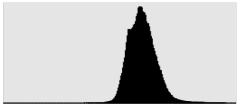
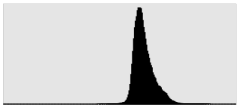
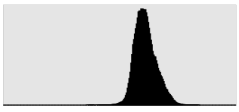
Section IV: Result

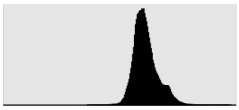
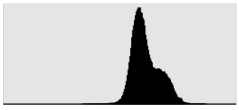
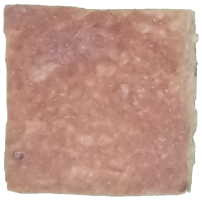
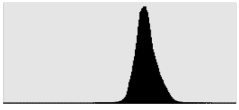
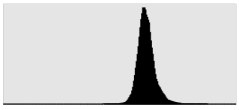
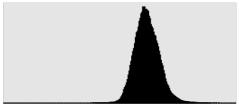


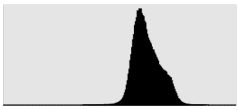
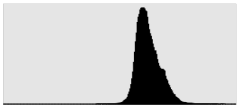
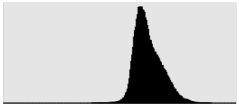
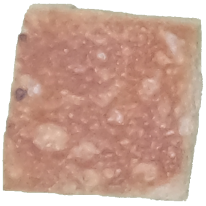
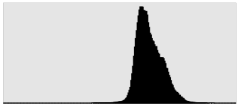
I: Data Summary

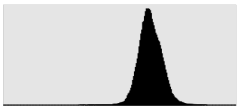
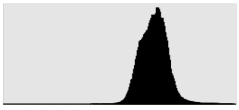
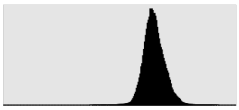
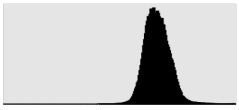
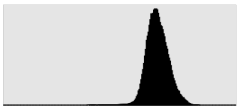
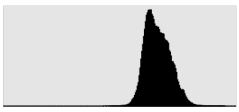
Table of each sample ordered by average darkness:

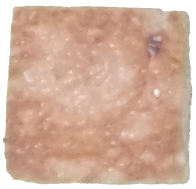
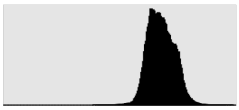
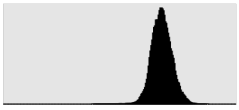
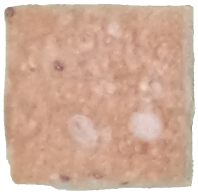
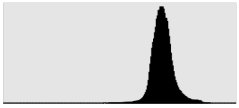
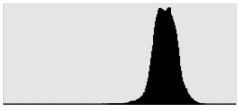
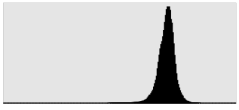
Oil	Sample	Histogram	Pixels	Min	Max	Standard_Deviation	Average
Heavy Butter			268824	88	216	12.37	144.2
Heavy Butter			255162	82	248	16	146
Heavy Butter			250860	85	246	13.83	148.9

Oil	Sample	Histogram	Pixels	Min	Max	Standard_Deviation	Average
Light Butter			255567	90	220	12.02	150.8
Heavy Butter			263394	86	217	12.36	151.3
Heavy Butter			251664	90	243	14.5	152.3
Light Butter			254702	104	226	10.25	154.2
Light Butter			255713	92	214	11.44	155.9

Oil	Sample	Histogram	Pixels	Min	Max	Standard_Deviation	Average
Light Butter			249880	93	249	12.74	156.1
Light Butter			254042	88	221	14.47	156.4
Light Butter			267099	100	227	10.62	156.6
Heavy Butter			245060	110	223	8.788	156.7
Heavy Mayo			274434	97	235	12.95	157.5

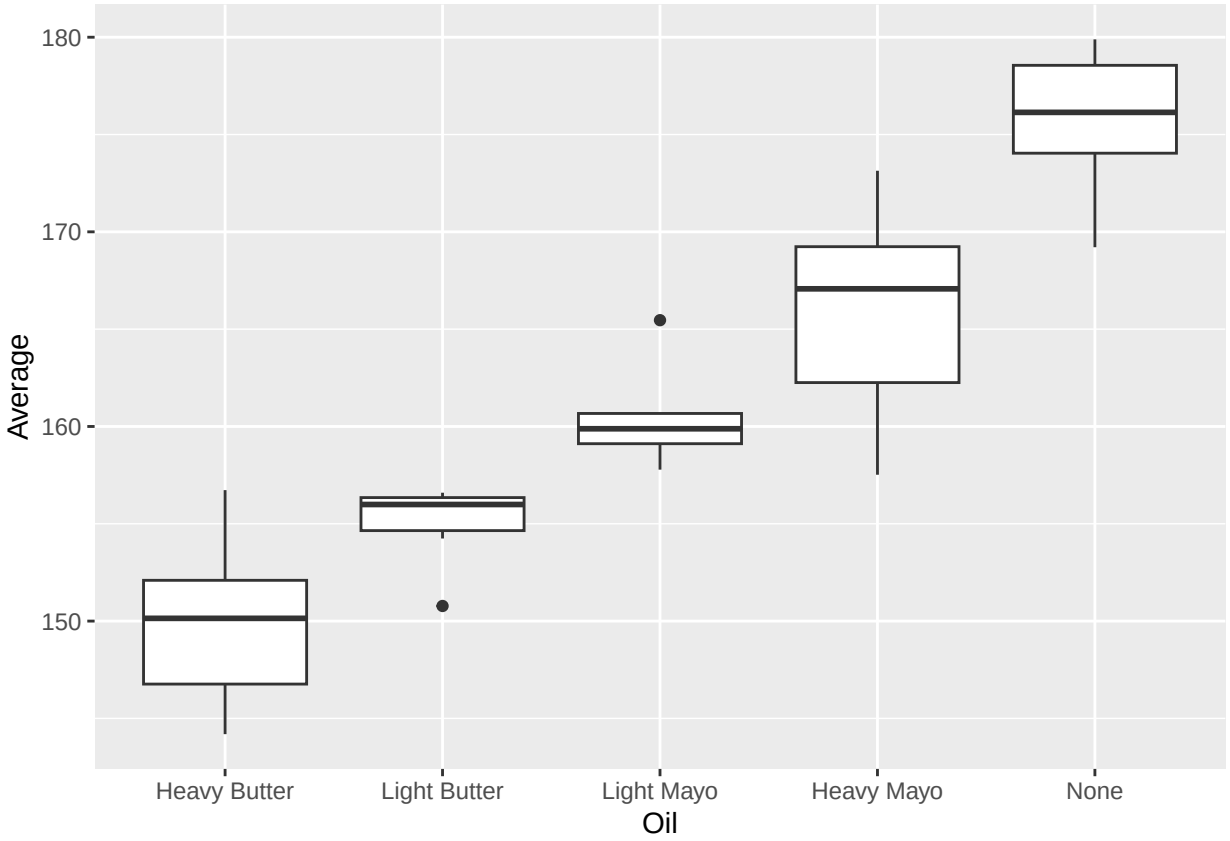
Oil	Sample	Histogram	Pixels	Min	Max	Standard_Deviation	Average
Light Mayo			270264	88	224	14.19	157.8
Light Mayo			264459	103	242	12.14	159.1
Light Mayo			267141	98	227	14.37	159.1
Light Mayo			261040	98	247	13.9	160.6
Light Mayo			262074	98	230	13.31	160.7

Oil	Sample	Histogram	Pixels	Min	Max	Standard_Deviation	Average
Heavy Mayo			275889	84	222	11.9	161.3
Heavy Mayo			252813	97	251	14.43	165.2
Light Mayo			240249	96	235	10.93	165.5
Heavy Mayo			250805	104	253	13.61	169
None			249941	93	214	11.25	169.2
Heavy Mayo			271259	111	242	13.21	169.3

Oil	Sample	Histogram	Pixels	Min	Max	Standard_Deviation	Average
Heavy Mayo			240810	99	251	14.05	173.1
None			258500	98	224	10.82	173.8
None			258675	111	226	10.7	174.8
None			242136	110	220	11.56	177.5
None			243294	116	215	8.193	178.9
None			250813	113	228	11.18	179.9

J: Visual Representation

Box plot of the average lightness values grouped by oil. 0 is black, 255 is white.



Section V: Conclusions

K: Conclusions

My hypothesis was incorrect, the mayonnaise performed worse than butter as far as browning is concerned. The results were clearer than I expected. All butter samples outperformed all mayonnaise samples. In addition heavier application of butter helped improve browning but a heavy application of mayo hurt browning.

L: Improvements

Photograph Reflections This experiment did not account for reflections in the photographs. A slight sheen can be seen in the upper right hand corner of a few of the heavy butter samples. This makes the photo appear lighter than the sample actually is. In this case however these samples ended up being the darkest anyways so these reflections do not change any conclusions, only the scale by which butter outperformed mayo.

For future experiments I recommend using multiple light sources placed around the edges of the box instead of near the camera.

Bread Drying Bread samples dried and curled in unexpected ways while prepping and photographing them.

I recommend refrigerating the bread before the experiment so it stays more consistent during prep and working as quickly as possible.

Bread Cutting The cutting jig was not a very efficient use of the bread. I think a cookie cutter would be faster and allow the user to better select uniform sections of bread as well as nest more cuts into a single

piece of bread.

Crumbs and Smudges My samples were photographed on a matte green piece of paper that absorbed oils easily and could not be wiped clean. I had to be very careful when handling samples in order to avoid messing up the background and it was difficult to remove crumbs from view.

For future experiments I recommend using a surface that can be exposed to an oil and wiped clean with a paper towel.

M: Results vs Literature

My results did not line up with the literature. These references relied solely on anecdotal data and did not list any variable controls when making their claims. This experiment was also done with a specific ingredients that fit my personal diet. Testing a wider variety of ingredients may result in different results. In addition, this experiment compared oils that were cooked for identical times which is not how food is typically cooked.

Section VI: Sources

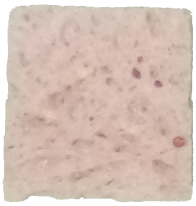
N: Sources

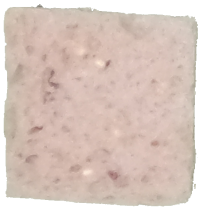
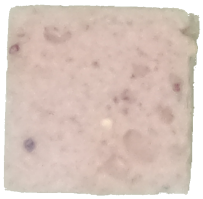
Beall C. (2024) *You Should Be Making Your Grilled Cheese With Mayonnaise—Here's Why* Southern Living. *Retrieved from https://www.southernliving.com/food/dish/sandwich/grilled-cheese-with-mayo-or-butter*

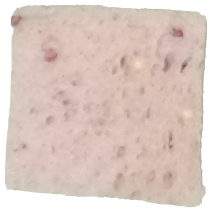
Saladino E. (2023). *The Secret Ingredient to Perfect Grilled Cheese* The Food Network. *Retrieved from https://www.foodnetwork.com/how-to/packages/food-network-essentials/how-to-make-grilled-cheese-with-mayonnaise*

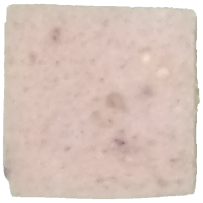
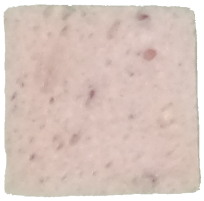
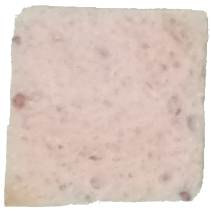
Appendix

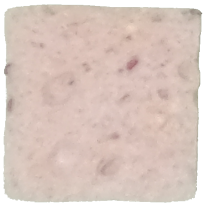
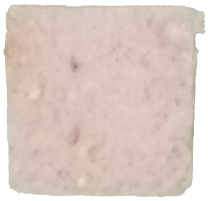
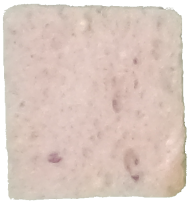
Raw Samples

Oil	Sample	Histogram	Pixels	Min	Max	Standard_Deviation	Average
Light Mayo			271905	115	226	9.186	193.8
None			276721	119	220	9.041	194.5

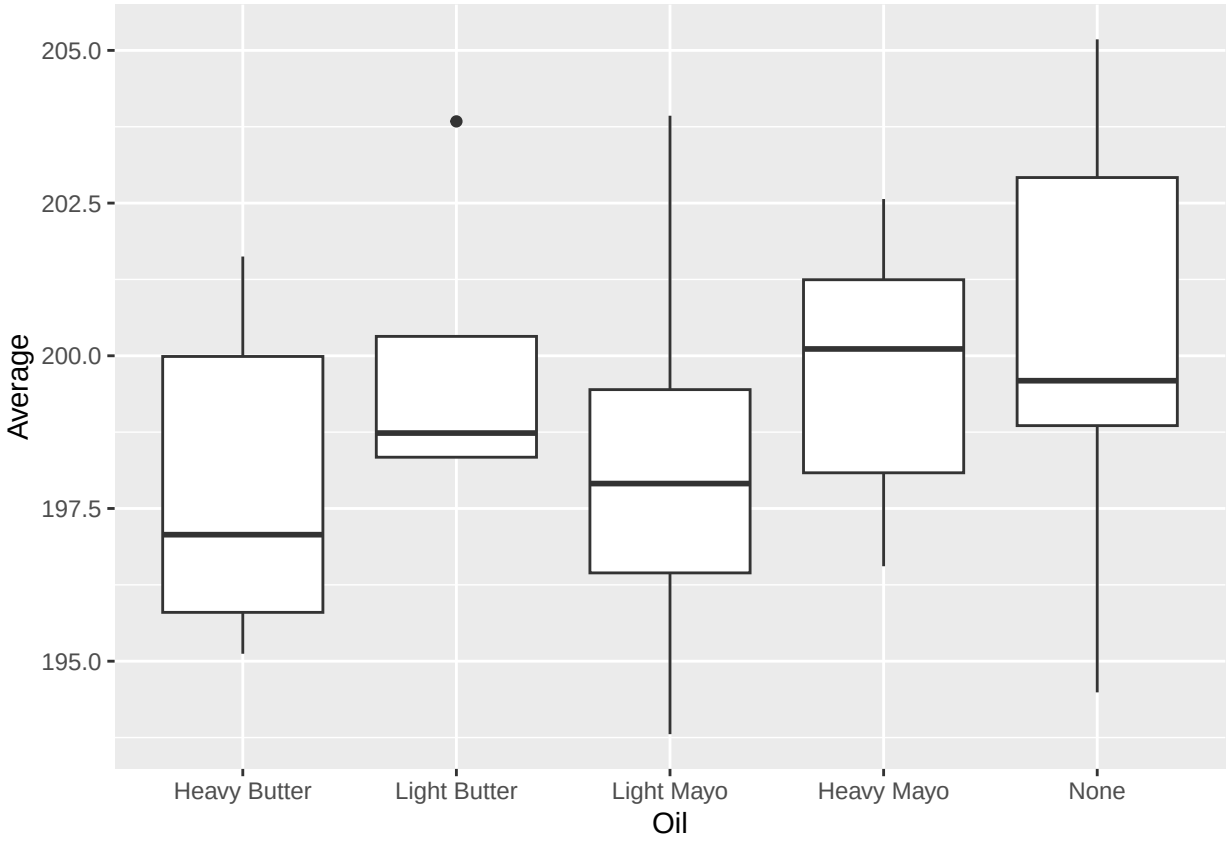
Oil	Sample	Histogram	Pixels	Min	Max	Standard_Deviation	Average
Heavy Butter			286714	104	233	9.494	195.1
Heavy Butter			273122	117	239	9.371	195.4
Light Mayo			264085	120	235	9.858	196.2
Heavy Mayo			288003	122	232	9.133	196.6
Heavy Butter			271212	124	229	10.47	196.9

Oil	Sample	Histogram	Pixels	Min	Max	Standard_Deviation	Average
Heavy Butter			276257	117	230	10.01	197.2
Light Mayo			274407	127	233	8.134	197.2
Heavy Mayo			291749	128	222	10.46	197.6
Light Butter			277409	128	236	10.09	198.3
Light Butter			280077	96	229	9.428	198.3

Oil	Sample	Histogram	Pixels	Min	Max	Standard_Deviation	Average
Light Mayo			275415	121	232	8.807	198.6
Light Butter			276662	120	231	7.485	198.7
None			274563	125	224	7.758	198.8
None			276448	95	236	8.027	199
Heavy Mayo			284350	107	238	9.526	199.4
Light Mayo			287115	120	231	8.625	199.7

Oil	Sample	Histogram	Pixels	Min	Max	Standard_Deviation	Average
None			283220	122	235	7.771	200.2
Light Butter			274941	125	228	9.888	200.3
Heavy Mayo			259928	141	228	7.346	200.8
Heavy Butter			270079	117	228	7.412	200.9
Heavy Mayo			258104	107	240	9.45	201.4
Heavy Butter			268872	144	227	7.123	201.6

Oil	Sample	Histogram	Pixels	Min	Max	Standard_Deviation	Average
Heavy Mayo			262940	142	225	7.07	202.6
None			253198	134	238	6.978	203.8
Light Butter			285686	128	228	7.274	203.8
Light Mayo			272534	146	238	6.254	203.9
None			273806	135	231	6.85	205.2



OCR Corrections

All data is processed using numbers derived from Optical Character Recognition (OCR). Use this section to ensure the all numbers have been identified correctly. The top row is the picture of the dice (heavily filtered for better processing) and the shaded gray text is the detected number. If there are any mistakes edit `ocr.yaml` to make corrections and re-knit this document.

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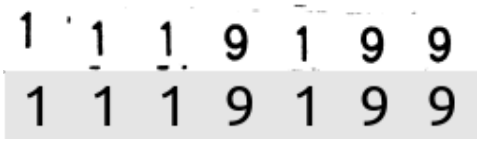
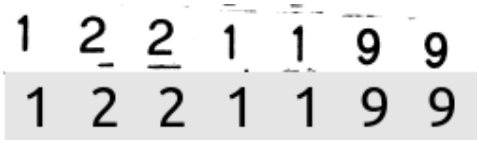
GOPR0309.JPG	
GOPR0348.JPG	

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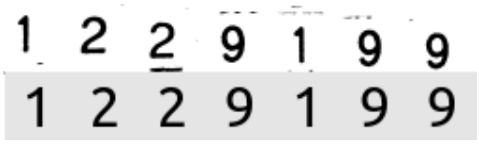
GOPR0316.JPG	
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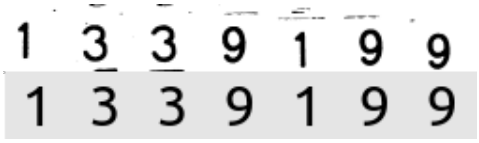
GOPR0322.JPG	
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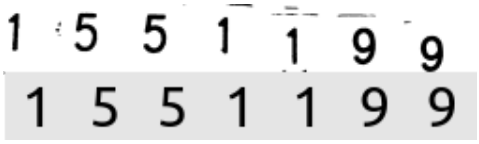
GOPR0366.JPG	
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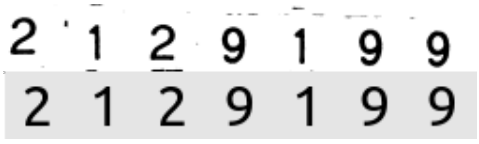
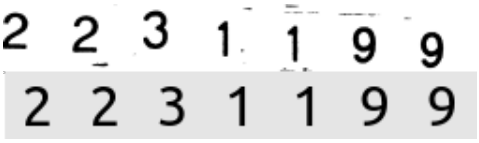
GOPR0310.JPG	
GOPR0349.JPG	
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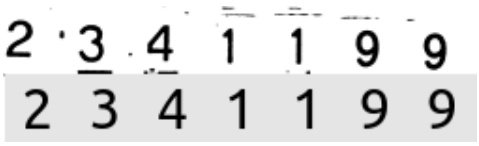
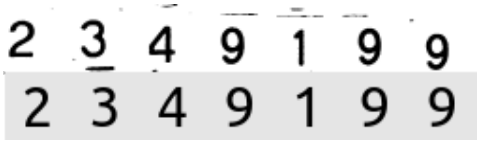
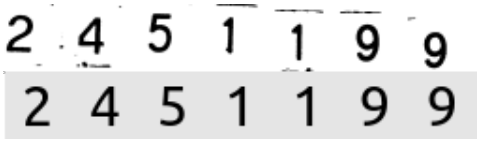
GOPR0355.JPG	
GOPR0323.JPG	
GOPR0361.JPG	
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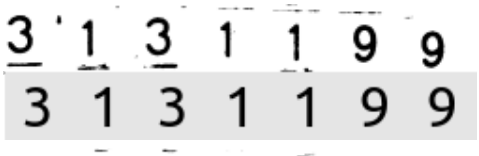
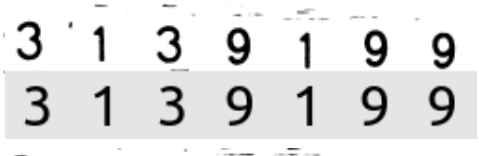
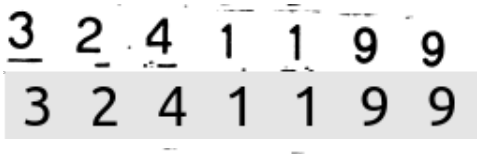
GOPR0344.JPG	
GOPR0311.JPG	
GOPR0350.JPG	
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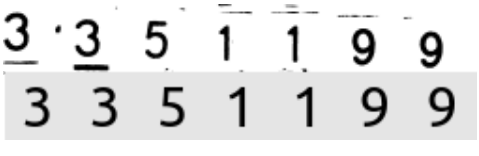
GOPR0356.JPG	

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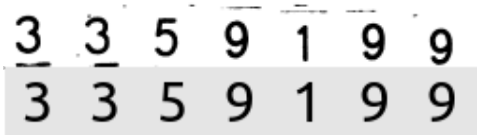
GOPR0324.JPG	
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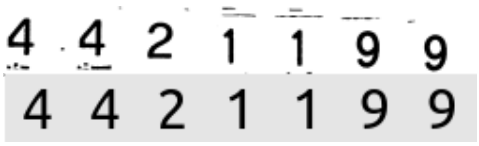
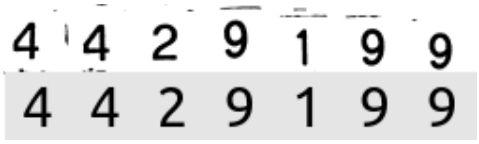
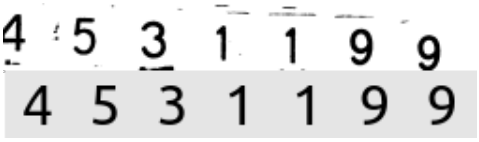
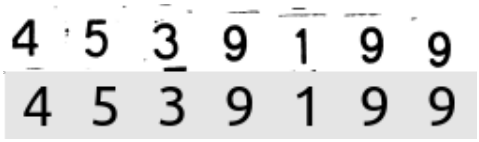
GOPR0363.JPG	
GOPR0331.JPG	
GOPR0369.JPG	
GOPR0337.JPG	
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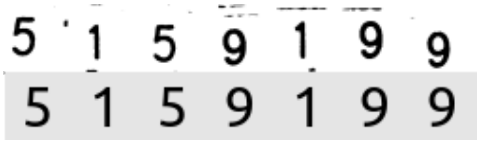
GOPR0313.JPG	
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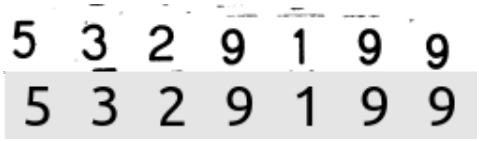
GOPR0326.JPG	
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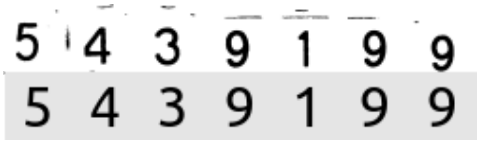
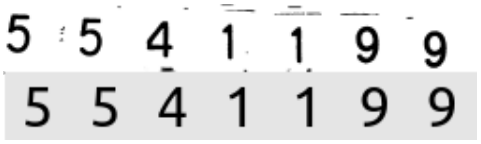
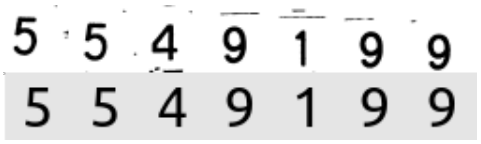
GOPR0332.JPG	
GOPR0370.JPG	
GOPR0338.JPG	
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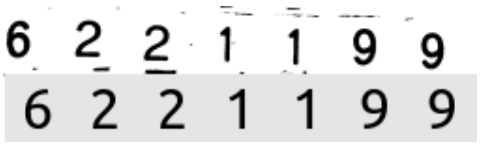
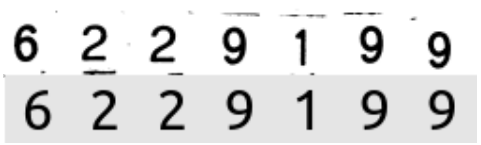
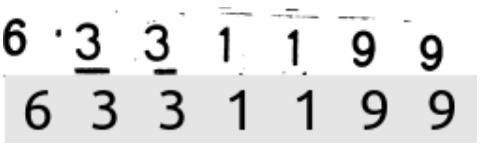
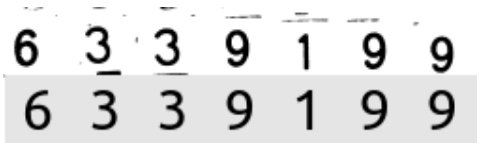
GOPR0353.JPG	
GOPR0321.JPG	
GOPR0359.JPG	
GOPR0327.JPG	
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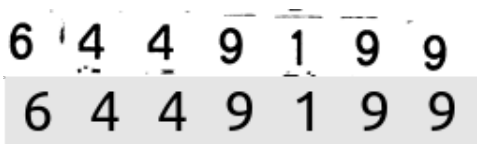
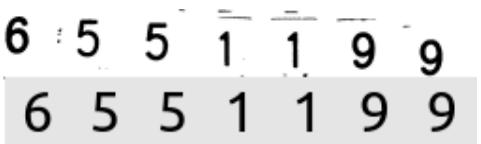
GOPR0333.JPG	
GOPR0371.JPG	

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