NORTH SHORE HEBREW ACADEMY

ישיבת חוף הצפון

SCIENCE RESEARCH JOURNAL 2025 EDITION

EDITOR: ELIZABETH MIRHAROON

Foreword by Elizabeth Mirharoon

This year, I had the opportunity to mentor an incredible group of young scientists. These students were hardworking and curious. Each project in this journal started with a question. The students behind these papers worked carefully to find answers, and often ended up with even more questions. That is the beauty of science: it never really ends, and there is always more to learn. I have seen how science gives us the tools to explore the unknown and question what we think we already understand. In a world where there is more information than ever, true understanding has become harder to find. That is why learning to think critically, scientifically, and ethically is more important now than ever before.

To our readers: I hope these pages encourage you to keep asking questions, investigating ideas, and pushing the limits of what's possible.

And to the authors: your hard work and passion have helped lay the groundwork for future discoveries. I am proud to be part of this community of thinkers, innovators, and changemakers.

Table Of Contents

The Effects of Stimuli on Metabolic Rate of *Daphnia Magna*

A study conducted by Elaine Novogrudsky and Aliza Reiss

Abstract

Caffeine is the most widely consumed psychoactive stimulant worldwide. It is consumed in a variety of beverages such as coffee, tea, and soda, as it has been a legal drug in almost every culture going back 3000 years to the Middle East, originally serving as a defense mechanism for plants. Today, the average American consumes about 165 mg of caffeine per day, presenting a 45 mg increase since 1999.[1] Caffeine has neurological and cardiological effects, triggering an increase in both alertness and heart rate. But is caffeine 'bad' for you, and if so, how much? Indeed, there have been recorded overdoses of caffeine in anhydrous or pill form and cardiotoxic effects in people who are vulnerable and drink too much coffee, but the reverse arterial pressure usually moderates the increase in heart rate for the majority of people.

Daphnia magna are an aquatic invertebrate with some surprising similarities to humans. Daphnia have more genes than humans do, and the genomic equivalences between us and them are numerous. A BLAST analysis shows this relatedness. *Daphnia* also exhibit a myogenic heart like humans; one that does not require neural input, but functions independently due to specialized cardiac muscle.

In this study, specimens of *Daphnia* are exposed to solutions of caffeine in varying concentrations, and their heart rates are recorded over time. The highest dose (100%) is set at the concentration one might find in a strong cup of coffee, which is about 500 mg in a half-liter cup. A dilution sequence from this solution produces variables of 80%, 60%, 40%, and 20%. Hypothetically, a decreasing concentration would produce a decreasing effect on heart rate. Averages were recorded from trials of six to eight *Daphnia* per solution sample to compensate for physiological differences in specimens and to establish a reliable sample size. An effort was made to choose *Daphnia* from the same clutch and environment. The rapid heart rate of *Daphnia* necessitated video records taken through a microscope at 40X magnification, from which heartbeats were counted.

Results were most pronounced at higher concentrations of caffeine. The strongest solution produced a 17% average increase in heart rate after one minute, although variance was significant (see Results). Lesser concentrations produced lesser effects, as expected (eg, an 80% solution produced a 9% increase in beats per minute), with effects moderating over time. It is unlikely that studies such as ours will change the caffeine habits of millions or the economies

[1] https://www.ncbi.nlm.nih.gov/books/NBK202226/

built on the sale of caffeinated beverages. However, it is vital that people understand how caffeine affects not only their nervous system but also their cardiovascular function. Prevention is a core goal of this project, and it encourages others to take studies like these into account as a general blueprint to serve as reasoning for how caffeine can potentially harm humans.

Introduction

The consumption of stimulants presents prevalent concerns about the potential risks of each one presented. Stimulants are a type of drug that triggers the release of neurotransmitters in the brain and accelerates communication between the brain and the rest of the body. Nevertheless, stimulants affect many other areas of the body, such as their impact on the metabolic rate of various organisms. However, stimulants have recently been under increased scrutiny due to potential consequences that have arisen due to their content. Caffeine, specifically, has both a neurological and cardiological effect on metabolic rate due to its wide range of effects.

Daphnia Magna are an aquatic organism of particular relevance due to their similarities to humans. *Daphnia Magna* are members of the Cladocera, meaning their bodies are enclosed by an uncalcified shell, and they are planktonic crustaceans. *Daphnia* belong to the Phyllopoda due to their flattened leaf-like legs used to produce a water current for the filtering apparatus.[2] Daphnia are suspension feeders and use a filtering apparatus to gather their food. Their heart function, despite their open blood circulation system, yields similarities to the heart within the closed circulatory system of humans. *Daphnia Magna* have the extracellular respiratory protein, hemoglobin, to aid oxygen transport similar to humans. Furthermore, like humans, *Daphnia Magna* have myogenic hearts that contain specialized cardiac muscle tissue that triggers an electrical impulse without neural input. This similarity serves as a primary way to relate the functioning of the heart of *Daphnia Magna* to the hearts of human beings. *Daphnia* provide no arterial feedback, making them ideal for this study. Despite their differences in HB gene counts and structures, the results of *Daphnia Magna* can serve as a blueprint rather than a generalization of the effect of caffeine on metabolic rate.

Caffeine is a methylxanthine and a psychoactive stimulant that triggers both neurological and cardiovascular responses in the body. There are two main causes of increased heart rate due to the influence of caffeine.

The first is through the release of calcium ions. Cardiac muscles are similar to skeletal muscles in that they both contain sarcomeres, the contraction of which provides sufficient force for blood to be pumped into circulation (Ripa, George, Shumway, Sattar). Sarcomeres contain

[2] https://www.ncbi.nlm.nih.gov/books/NBK2042/

both a thick filament called myosin in addition to a thin filament referred to as actin. In order to generate muscle contractions in sarcomeres, the myosin globular head must receive sufficient energy, as it serves as the center of bioenergetic reactions that power muscle contraction. The myosin head must hydrolyze ATP to ADP and inorganic phosphate to reach a high-energy configuration, after which the myosin head will bind with the actin to stimulate muscle contraction. However, the troponin complex controls tropomyosin, which blocks the myosin binding sites on the actin receptors. Calcium ions are required to uncover the myosin receptors. Caffeine indirectly stimulates the release of Calcium ions, stored within the sarcoplasmic reticulum. When calcium ions bind to troponin, they rearrange the tropomyosin-troponin complex and expose myosin binding sites on the actin, ensuring that the sliding of the thick and thin filaments can occur for muscle contraction. Due to the presence of intercalated discs within cardiac muscle of both *Daphnia Magna* and humans, direct electrical coupling can occur without any neural input, ensuring that the heart can generate action potentials on its own. Pacemaker properties within the membranes of cardiac cells also cause rhythmic depolarization, which triggers action potentials.

Secondly, more ATP is made available to the heart muscle when caffeine stimulates the release of epinephrine, a catecholamine, due to its molecular structure, also known as adrenaline, which is linked to increased heart rate as a crucial aspect of the fight or flight response (Cleveland Clinic).[3] The fight or flight response occurs when Epinephrine binds to G protein-linked receptors, triggering glycogen breakdown through the activation of glycogen phosphorylase via the cAMP-protein kinase A cascade (BHAGAVAN).[4] Direction and amplification of the signal results in stored glycogen ultimately breaking down into glucose, thus more ATP and more biochemical energy are available to increase the rate of muscle contractions.

A study conducted by Sarah Olbrantz and Megan Peterson found a 9.54 b/pm difference in heart rate between humans who consumed caffeine vs. decaffeinated beverages.[5] In contrast, a study conducted by the Journal of Undergraduate Biology Laboratory Investigations found no significant difference between *Daphnia Magna* that received caffeine for consumption relative to those that did not in both Paired and Unpaired T tests. However, they had found an increase in heart rate with the insertion of 5% caffeine, as seen by the 52.5% increase in heart rate. [6] Results such as these served as prerequisites to our study, as our study aims to analyze the extent to which caffeine impacts the metabolic rates of *Daphnia Magna*. The goal of this study is to realize the societal consequences that arise due to caffeine consumption and whether or not

[3] https://my.clevelandclinic.org/health/articles/22611-epinephrine-adrenaline
[4] https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/glycogenolysis#:~:text=However%2C%20epinephrine%20binds%20to%20beta,cAMP%2Dprotein%20kinase%20A%20cascade
[5] https://www.uwlax.edu/globalassets/offices-services/urc/jur-online/pdf/2007/olbrantz-peterson.pdf
[6] https://undergradsciencejournals.okstate.edu/index.php/JUBLI/article/viewFile/8791/1889#:~:text=Similar%20to%20humans%20and%20other,certain%20drugs%20on%20heart%20rate

caffeine consumption can potentially be linked to increased risk of heart disease. Additionally, a study cited by Harvard University found that a large cohort of 37,514 women concluded that moderate coffee drinking of 2-3 cups a day was associated with a 21% reduced risk of heart disease.[7] However, other studies, such as that conducted by Cornelis et al in 2006, found that increased heart disease was linked to caffeine consumption. Simultaneously, studies suggest that moderate consumption of caffeine is safe for humans. [8]

Our study hypothesizes that *Daphnia* forced to ingest increasing concentrations of caffeine in solution will exhibit higher heart rates initially than control specimens. These higher heart rates should decrease over time and stabilize.

Methods

This study uses multiple populations of *Daphnia Magna* obtained from a jar and placed into tanks of spring water, fed with dried yeast. *Daphnia Magna* were prepared for experimentation by insertion from jars into tanks of spring water, and were fed two days prior to their respective experiments. These populations were used to examine the effects of the independent variable of caffeine concentration on the dependent variable of the heart rate of *Daphnia Magna*. Employed in this experiment were the control variables, including 40x magnification, the room temperature of 21℃, the concentration of spring water, etc. *Daphnia magna* cultured in spring water were observed in depression slides under 40X magnification. Heartbeats were counted every 5 minutes once the specimen was acclimated to the new environment. The control group was experimented with by counting the heart rates of the *Daphnia* without any insertion of caffeine concentration. Equipment employed by this experiment includes a microscope with 40x magnification, depression slides, caffeine jars, measuring materials such as graduated cylinders, and a phone camera to record the results.

Experimental groups were made with caffeine solutions of varying concentrations and were made using pure caffeine in spring water. 1.0 g of caffeine in 1000. mL of water produces a 0.005 M solution of caffeine (MW=194 g/mol), which is equivalent to a standard cup of coffee; in this test is labeled as “100%”. From this stock, a dilution sequence with spring water produced 80%, 60%, 40%, and 20% solutions, respectively. *Daphnia* inculcated in these solutions were observed prospectively in the same manner as the Control Groups shown at top, as these heart rates too were recorded every 5 minutes once the specimen was acclimated to the new environment. The heartbeats were also recorded in 1-minute videos, respectively, in order to ensure that the original counting was correct. Each percentage of caffeine was repeated 3 times

[7] https://nutritionsource.hsph.harvard.edu/food-features/coffee/
[8] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10262944/#:~:text=According%20to%20their%20study%2C%20the,risk%20of%20coronary%20heart%20disease.

in several groups of *Daphnia* in order to ensure the accuracy of the results. Data analysis was conducted by creating both line and bar graphs for each caffeine percentage and inserting our recorded results for each time period. Additionally, a Paired T-Test was conducted, although it did not produce favorable results.

Results

The results of this study were analyzed using both line and bar graphs to view the data. Statistical data indicates the validity of our hypothesis for the 100%, 80%, and 40% caffeine solutions. This is due to the original increase in metabolic rate of *Daphnia Magna* 1 minute after insertion for the caffeine insertion of 100%, 80%, and 40% caffeine. This increase was 17%, 9%, and 10.9%, respectively, one minute after caffeine introduction. These figures are similar to percentages forwarded by the study presented by the Journal of Undergraduate Research that used human subjects and caffeinated and decaffeinated beverages. The subsequent decrease in their heart rates by the five-minute mark for those respective percentages aligns with our hypothesis that *Daphnia Magna'*s heart rate will initially increase and show higher heart rates than those of control specimens until a decrease over time. This stabilization of the heart rate of *Daphnia Magna* occurs due to a process called habituation, essentially the process by which there is a gradual decrease in response to stimuli as the organism acclimates to a persistent stimulus. These heart rates align with the Controls that received no caffeine. Average heart rates consistently support the hypothesis, although wide sample variance in student t-testing produced t-values below the threshold. These results are in congruence with the mere 2.3% increase in heart rate of the *Daphnia* that occurred one minute after the time that the others received caffeine, while these *Daphnia* did not receive caffeine. These *Daphnia* serve as a relative comparison to those that did receive caffeine, and over time, these *Daphnia* adapted to a .63% increase after 5 minutes of initial recording. These results indicate that the insertion of caffeine resulted in a much larger percentage increase initially compared to those that did not, although they both stabilized after 5 minutes. Although the line graphs and bar graphs presented this data aligned with this study's hypothesis, a Paired T-Test was conducted, but it was not due to varying initial heart rates of the selective *Daphnia.*

Contrary to the other percentages of caffeine, the results for both 60% and 20% caffeine did not align with this study's hypothesis. Rather than an initial increase in metabolic rate after caffeine insertions, there was an average initial decrease of 5.5% and 1.9%, respectively, after 1 minute of caffeine insertion. This decrease serves to question the validity of the hypothesis presented in this study, although the process of habituation does still occur in these specimens that received that specific caffeine percentage.

Figure 1

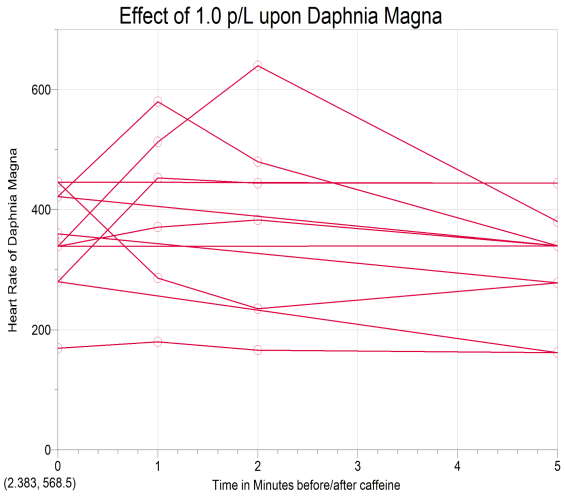
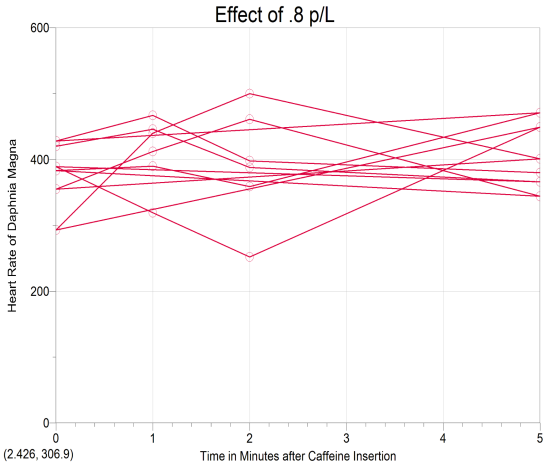


Figure 2



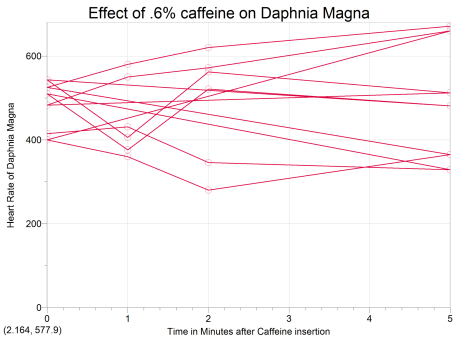


Figure 3

X=time	Y=.005M caffeine
0	169
1	180
2	166
5	162
0	280
1	453
2	444

5	444
0	446
1	286
2	235
5	278
0	360
1	371
2	383
5	340
0	422
1	580
2	480
5	340
0	339
1	513
2	640

Figure 4

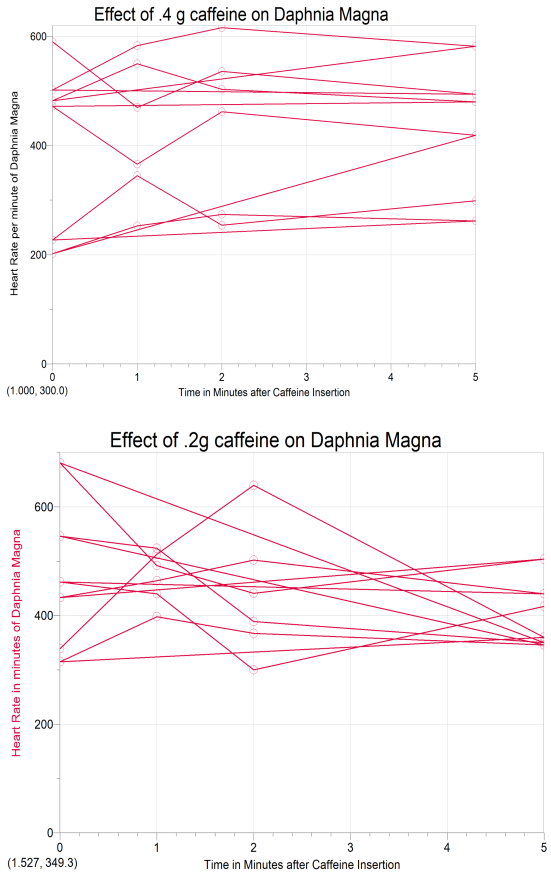


Figure 5

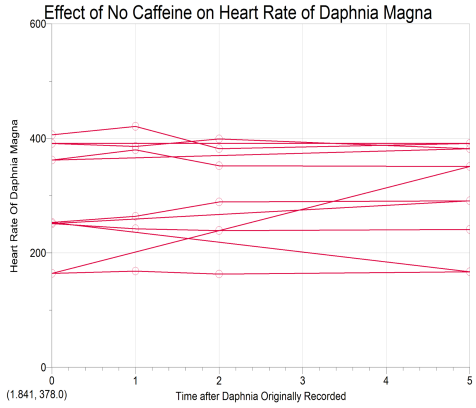
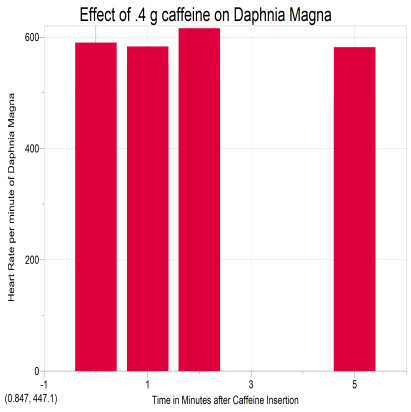


Figure 6

Table 1

Figure 7



Discussion

This study's hypothesis aligns with the respective percentages of 100%, 80%, and 40% caffeine insertions due to the initial increases of metabolic rate in *Daphnia Magna* after 1 minute of insertion, followed by the subsequent stabilization and habituation that occurs after the 5-minute mark. These specimens serve as a blueprint for human beings as humans share the characteristic of a myogenic heart with *Daphnia.* This myogenic heart, which functions without neural input due to specialized cardiac muscles, allows us to analyze the impact of caffeine on this type of heart's metabolic rate rather than strictly the neurological effects of this stimulant. This study's findings relate to *Daphnia Magna,* yet their findings are simultaneously applied to human beings. This shows the high level of applicability that this study invites, and it does utilize the results of this study to understand the fundamentals of caffeine consumption and the wide range of societal consequences that can occur.

Increased caffeine consumption has been linked with a longstanding belief to increase alertness and concentration in addition to energy level. However, when consumed in large amounts, this study presents the argument and evidence that caffeine can be linked to increased risks of cardiac arrest and heart diseases such as arrhythmia, as cited by the Cleveland Clinic.

Our study specifically pertains to the psychoactive stimulant of caffeine and its effects on the cardiovascular system of *Daphnia Magna*. In this study, we studied the impact of caffeine on the heart rate of *Daphnia Magna* and found an initial increase in the metabolic rates of *Daphnia Magna* and then a subsequent decrease. In the future, efficient statistical analysis will be aided by a more consistent average original heart rate, as noted by *Daphnia Magna*. Additionally, a shorter exposure time to the stimulant might aid the results of the experiment, as

Daphnia expresses reactions to exterior forces relatively quickly. [9] Furthermore, future research would favor a shift in focus towards additional stimulants such as nicotine and acetylcholine and the subsequent effect on the cardiovascular system of *Daphnia Magna*. Combining two stimulants simultaneously is another area of interest, as seen by studies such as that of Amundsen and Baker, as seen in source 6. In addition, exploring the wide range of depressants such as ethanol and their effect on the myogenic heart of *Daphnia* can be inspired by this study. This research would provide a greater comprehension of the immense effects of stimulants and depressants on both the myogenic heart of Daphnia and analyze that effect with respect to the human heart, both short and long term.

9 https://www.coursehero.com/file/16721955/Lab-Report-Daphnia-magna/#:~:text=The%20Daphnia%20magna's%20average%20heart%20rate%20rose%20to%20221.25,system%2C%20and%20higher%20heart%20rate.

Hormonal Variables And Their Effects on Vanessa Cardui Metamorphosis.

Shira Dishi and Mayah Rosenzweig

Introduction

Revolutionized by modern technology and driven by sustainability, modern farming is transforming how we raise our food, and thereby balancing the needs of a growing population with the need to safeguard the environment. With the increase of smart technologies and sustainable practices, this transition promises to feed the future generations and provide them with healthy, non-toxic foods. However, many conventional technologies and practices include pest control methods that come with many risks and do much harm to non-target organisms, such as butterflies and their eggs. Conventional materials are favored by farmers for various reasons, primarily economic. On the other hand, modern farming methods minimize crop damage and are easily accessible and affordable, making them attractive options for farmers looking to maximize profits and navigate the competitive market. Forcing farmers to quit these successful practices is unrealistic and simply impractical. Therefore, finding a way to scientifically mitigate the damage, as this study intends, is a great alternative.

Furthermore, some problems with insect pests are cyclic. For instance, this April, in the Midwest and Southeast of the United States, two broods of periodic cicadas, Brood XIII, which only appears every 17 years, and Brood XIX, which only appears every 13 years, started emerging simultaneously for the first time since 1803. This dual emergence has significant effects on ecosystems, overwhelming predators because of a population abundance due to this surge of food. The cicada surge also disrupts ecosystems by causing damage to young trees and temporarily rewiring the food web by altering predators' diets.

In an attempt to solve both these problems, the present study began to examine the accepted knowledge of insect metamorphosis with the hope of figuring out a way to manipulate their development. Speeding up or slowing down development to adjust to farmers’ schedules and the cycles of different broods of cicadas could be of benefit to the cicadas and their ecosystem.

According to Britannica, Vanessa Cardui, also known as the Painted Lady butterfly, is a member

of the Nymphalidae. Nymphalidae are a group of brush-footed butterflies, order Lepidoptera, named for their characteristically reduced forelegs, which are frequently hairy and resemble brushes. The Vanessa Cardui undergoes a complete metamorphosis known as holometabolous. Holometabolous insects have very distinct larval, pupal, and adult stages.

Insects all start off as eggs and then eventually grow and molt, shedding their exoskeleton. The first phase of metamorphosis is eggs, laid on the stem and leaves of a plant by a female butterfly, a stage lasting for about a week. The second phase, a caterpillar, develops during the larval stage of metamorphosis. The majority of this stage is spent eating and storing food for the next stage. During the larval stage, the caterpillar grows and develops. The time spent in this phase depends on the type of caterpillar. Preparing for the pupa/chrysalis stage, the insect begins to shrink a little. The caterpillar has fully grown and stopped eating. The cycle takes place within a chrysalis, a part of its exoskeleton that surrounds the caterpillar. Although not visible to the naked eye, amazingly sublime processes occur within the chrysalis. Specialized cells from the larva stage grow and reorganize themselves rapidly, eventually resulting in an adult butterfly. The original larva cells assist the newly growing adult cells by providing them with energy. The wings, legs, and other bodily parts of the butterfly are fully grown, perfectly prepared for the final part of their life.

Most insects, especially Lepidoptera like the Vanessa Cardui, undergo a development process known as metamorphosis, characterized by distinct life stages that take and transform the insect from their initial life stages all the way to adulthood. Though every metamorphosing organism starts as an egg, not all go through the same life stages to reach their ultimate form. In fact, there are four different types of metamorphosis: ametabolous, hemimetabolous, holometabolous, and hyper metamorphic. Insects such as butterflies and moths undergo holometabolous. Contrastingly, the “simple” metamorphosis process only results in a bigger version of the initial organism. Holometabolous metamorphosis is known as complete metamorphosis, resulting in the insect developing into a completely “new” organism, taking a different

form than its immature self.

Metamorphosis is influenced by hormones found within insects. Ecdysone is a hormone released by the Prothoracic gland into the layer of cells underneath the cuticle (Epidermal Cells). Juvenile hormone is released by the Corpus Allatum (part of the brain). Juvenile hormone (JH) causes the insect to grow and develop in size and structure, but it keeps it at its status quo. The cyclic interplay of hormones has been identified as key to the changes observed in lepidoptera, or the order of moths and butterflies. Essentially, a lipid hormone known as ecdysone, which in the peripheral tissues can be converted to another hormone, 20-hydroxyecdysone (20-E), is responsible for insect molting and transformation to the adult, but only if a third hormone, JH, is degraded.

Hypothesis: The manipulation of ecdysone and juvenile hormones will affect the growth rate and speed of metamorphosis within the Vanessa Cardui and will lead to the groups receiving the most ecdysone to metamorphose quickest, while the groups receiving the most JH to metamorphose the slowest.

This study intends to discover the appropriate proportion of each hormone that will cause the speed of Vanessa Cardui's metamorphosis to be dramatically altered, while leaving most alive and healthy.

Methodology

Experimental design: In this experiment, the complete metamorphosis of the painted lady butterfly (Vanessa Cardui) is described. In subsequent tests, the sequence is altered by the ingestion of varying concentrations of 20-hydroxyecdysone (20-E) and Juvenile Hormone III (JH III). The expectation is that experimental groups of larval stages of Vanessa exposed to higher concentrations of 20-E (and lesser concentrations of JH III) will undergo quicker molting and faster transformation into adults.

Hypothetically, larval sizes should grow larger than controls before transformation. The result will be larger and later blooming caterpillars than larvae exposed to lesser concentrations of 20-E and control groups of standardized larvae. In this experiment, there were five experimental groups of Vanessa Cardui larvae, which were exposed to varying ratios of 20-E dissolved in water and JH III dissolved in a fat-soluble, ethanol solution. A stock solution using ethanol and water (depending on the hormone) was used to dissolve the hormone, creating a 100% concentration of each hormone. Following, a varying numbers of drops from each stock solution were given; the control group received no hormones, group one received 100% ecdyson, group two received 80% ecdysone and 20% juvenile, group three was given 60% ecdysone and 40% juvenile, group four was given 40% ecdysone and 60% juvenile, and group five received 20% ecdysone and 80% juvenile. These varying ratios of hormones were placed in the nutrients of the caterpillar. The insects were kept in plastic containers sealed with cloth, and measurements of length were taken at regular intervals to identify hormonal effects on size. Along with measurements and numerical information, descriptions about the change in metamorphosis and altered qualitative information were recorded. (Material list provided at the bottom)

Methodology continuation:

Image of the ratio given to each group:

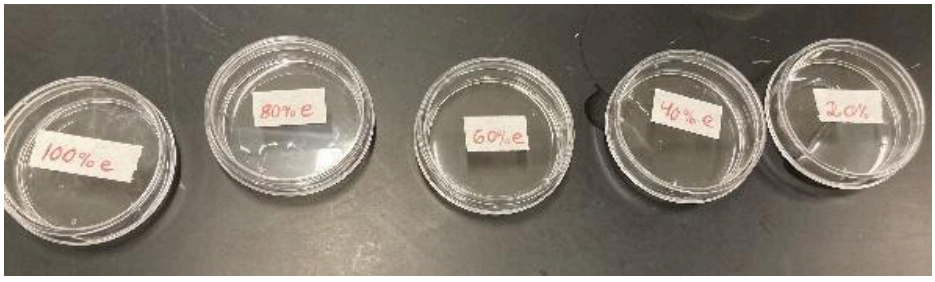
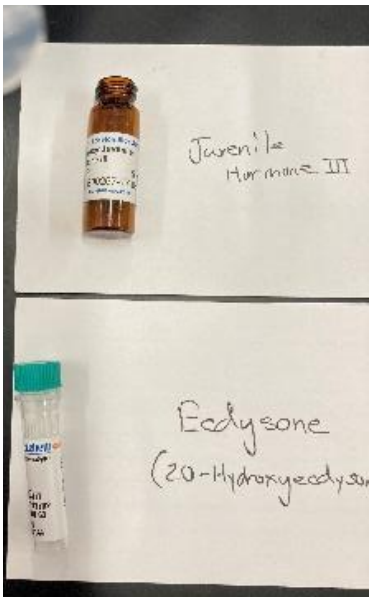


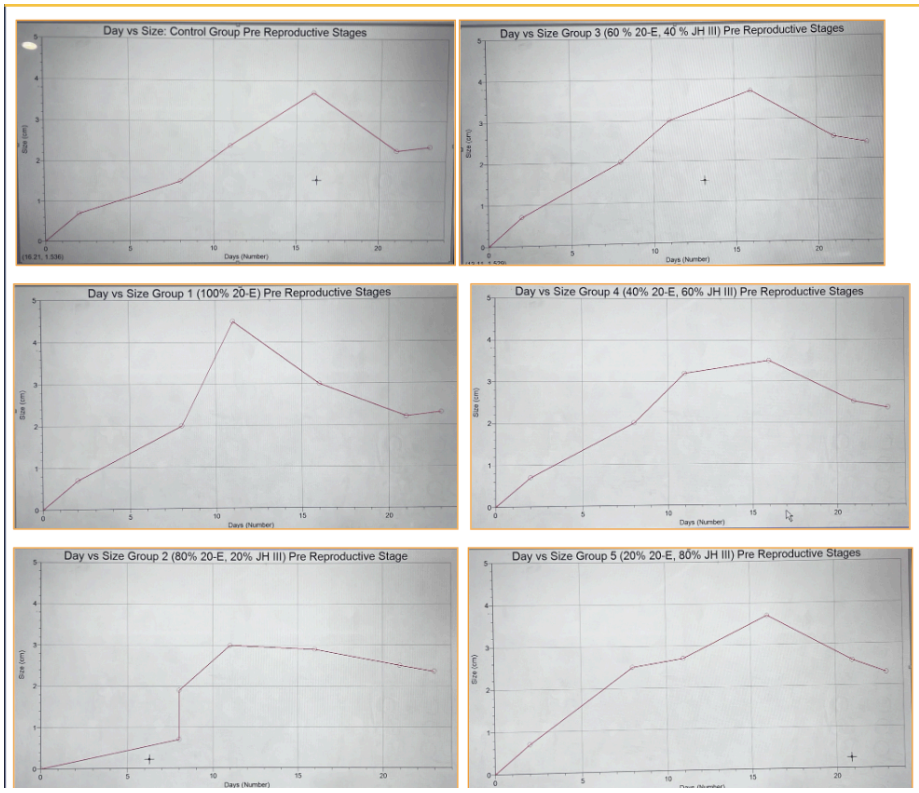
Image of groups:

Images of how hormones were put into the nutrient of the caterpillar:

Hormones:



Results



BZ"H

Day Number	Qualitative Data/Observation
Day 16	Control Group: • One Full Chrysalis • Four partially moving, hanging caterpillars (preparing for chrysalis) • Two minimally active, not hanging caterpillars Group 1: • Two full Chrysalis • Four partially moving, hanging caterpillars (preparing for chrysalis) • One moving Group 2: • No Full Chrysalis • Five partially moving, hanging caterpillars (preparing for chrysalis) Group 3: • One full Chrysalis • Four partially moving, hanging caterpillars (preparing for chrysalis) • Two minimally active, not hanging Group 4: • Two full Chrysalis • Two partially moving, hanging caterpillars (preparing for chrysalis) • Two regularly/completely active Group 5: • One full Chrysalis • Four regularly/completely active • Two minimally active
Day 21 (and a few days prior)	Everyone of them, in every group are now in Chrysalis
Day 16- Day 22	Deaths: Control Group: 2, Group 1: 1, Group 2: 0, Group 3: 1, Group 4: 0, Group 5: 1
Day 27	Control Group: 1 Adult Butterfly Group 1: 3 Adult Butterflies Group 2: 1 Adult Butterfly Group 3: 1 Adult Butterfly Group 4: 1 Adult Butterfly Group 5: 0 Adult Butterfly

Data analysis

In order to best analyze the results, the length of the insects as well as their form were analyzed every couple of days. To most clearly visualize and understand the data, digital graphs were made. For the qualitative analysis, one graph was made separating the days and the observations. From this graph, it is clearly understood that the group with the most 20-E and the least JH III, group one, did in fact metamorphose the quickest out of all the groups, even the control, and that the group with the opposite delusions, group 5, metamorphosed the slowest. To be specific, group one was the first to have 3 caterpillars perform complete metamorphosis, while, on that same day, day 27, group 5's caterpillars still had not metamorphosed.

From the quantitative data that was graphed for each group, it is observed that initially the caterpillars grow in size; however, once they reach their final instar phases, they begin to shrink in preparation for chrysalis. For a more specific analysis, group 1 has the greatest differences and the most significant changes. This is a result of the ecdysone speeding up their metamorphosis, resulting in their growth and final, shrinking larval stages happening rapidly. The middle groups, groups 2, 3, and 4, however, had similar results, implying that the delusions given to them were not significant enough. This could also be a result of uneven ingestion of the hormones by each individual caterpillar, as the graphs represent the average results of each group. These results display that it was successfully proved that diluting a significant amount of 20-E will speed up metamorphosis, and doing the same with JH III will slow down these larval stages and complete metamorphosis.

Conclusion

From this experiment, our hypothesis is confirmed: The manipulation of juvenile hormone and ecdysone affects the growth and speed of caterpillar metamorphosis. Diluting ecdysone will speed up metamorphosis, while diluting juvenile hormone will slow it down. It is, however, also concluded that only significant proportions of the two hormones will make a difference.

Errors: Recording averages rather than data from each individual caterpillar, having an immensely small sample size, being unaware of the exact amount of diluted hormone each caterpillar digested, and only testing it once. These errors have an impact on the results, and relieving them could cause the experiment to be far more accurate.

References

1. Butterfly Life Cycle. The Academy Of Natural Sciences Of Drexel University, https://ansp.org/exhibits/online-exhibits/butterflies/lifecycle/.
2. “The Butterfly Life Cycle Explained”. AMNH, Apr 3, 2017, https://www.amnh.org/explore/news-blogs/on-exhibit-posts/butterfly-life-cycle.
3. “Insect Growth and Development”. Youtube, Jul 20, 2013, https://www.youtube.com/watch?v=NoMBSm8KkjI&t=12s.
4. “Painted Lady”. Missouri Department of Conservation, https://mdc.mo.gov/discover-nature/field-guide/painted-lady.
5. “How Did Insect Metamorphosis Evolve. “ Scientific American, https://www.scientificamerican.com/article/insect-metamorphosis-evolution/#:~:text=The%20primary%20advantage%20of%20complete,occupy%20very%20different%20ecological%20niches.
6. “Nymphs, Naiads, and Larvae.” wild creatures hong kong, https://www.wildcreatureshongkong.org/single-post/2019/04/28/nymphs-naiads-and-larvae.

Antibiotic Resistance in Bacteria from Kitchen Sponges

Researchers' Names: Sara Abda, Devorah Shabatian, Eva Yaghoubi

Abstract:

Antibiotic resistance is a growing global health crisis, with millions of infections each year becoming harder to treat (WHO). This is due to the bacteria evolving, introducing resistance to common medications. After 2 weeks of use, a kitchen sponge can have around 8 million bacteria cultures (CDC.gov). Kitchen sponges, commonly used for cleaning, are frequently exposed to food residues and moisture, creating an ideal environment for bacterial growth. This study aims to investigate the level of antibiotic resistance in bacteria isolated from used kitchen sponges and compare the effectiveness of synthetic (e.g., amoxicillin, penicillin) and natural antimicrobial agents (e.g., garlic extract, honey) in inhibiting bacterial growth. Bacteria were cultured from used sponges and exposed to antibiotic discs and natural agents using the Kirby-Bauer method. As hypothesized, antibiotics were more effective in reducing bacterial growth compared to natural agents. However, some bacterial strains still showed resistance to the antibiotics, which emphasizes the growing concern of antibiotic resistance. While natural agents like garlic extract and honey showed some antibacterial properties, they were less effective in comparison to the antibiotics. These findings underline the importance of understanding antimicrobial resistance and suggest that antibiotics remain the more reliable option for combating bacterial growth, though their decreasing effectiveness due to resistance is a significant public health issue.

Problem:

The problem addressed in this experiment is the growing concern of antibiotic resistance in everyday environments, specifically in commonly used kitchen sponges. Kitchen sponges provide an ideal breeding ground for bacteria due to their exposure to food residues and moisture. As these sponges are frequently used for cleaning, they can harbor harmful bacteria, potentially spreading infections. With the overuse and misuse of antibiotics, some bacterial strains are becoming resistant, making common antibiotics less effective. This experiment aims to understand the extent of bacterial contamination in used kitchen sponges, assess the resistance of these bacteria to antibiotics, and compare the effectiveness of synthetic antibiotics versus natural antimicrobial agents in controlling bacterial growth. The goal is to highlight the issue of antibiotic resistance in household environments and explore alternative methods to combat bacterial contamination.

Hypothesis:

In our experiment, we are determining the level of antibiotic resistance in bacteria isolated from used kitchen sponges and testing the efficiency of synthetic and natural antimicrobial agents on those bacteria. We hypothesize that used kitchen sponges will show significant bacterial growth due to their exposure to food particles and moisture. We also predict that bacteria on the sponges will be more resistant to natural agents, and that antibiotics will be more effective in reducing bacterial growth, as antibiotics are specifically designed to target and kill bacteria, while natural agents may have less consistent antibacterial effects.

Background/Introduction:

Antibiotic resistance is a serious problem happening around the world because antibiotics are being overused and misused, which makes infections harder to treat. The World Health Organization (WHO) says that antimicrobial resistance is one of the biggest health threats today. In 2019, antibiotic resistance caused over 1.27 million deaths, and that number has increased to nearly 5 million deaths today. Many bacteria that were once easily treated with antibiotics are now resistant, which means simple infections could become deadly in the future. Kitchen sponges, which are often wet and used for cleaning, are perfect environments for bacteria to grow. Harmful bacteria like *E. coli*, *Salmonella*, and *Staphylococcus aureus* can live on sponges for days, and without proper cleaning, they can multiply and cause illnesses.

This experiment will look at the bacteria found on kitchen sponges and test how well both regular antibiotics (like amoxicillin and penicillin) and natural substances (like garlic extract and honey) can stop bacterial growth. The Kirby-Bauer test will be used to see how effective these substances are. In this test, bacteria are spread on a special plate, and disks soaked in antibiotics are placed on it. If the antibiotics work, they stop the bacteria from growing around the disk, leaving a clear area. The size of this clear area shows how well the antibiotic works to kill the bacteria.

The goal of this experiment is to find out if the bacteria found in sponges are resistant to antibiotics and if natural alternatives, like garlic and honey, can help reduce harmful bacteria. The results of the experiment could lead to better cleaning methods for sponges and provide ways to fight antibiotic resistance in everyday life. Understanding how to stop bacteria from spreading in common household items could help improve health and hygiene practices.

Materials:

- 2 old kitchen sponges
- 1 new kitchen sponge
- 3 cylinders
- 9 Agar plates
- Sterile swabs
- Incubator
- Antibiotic discs (Amoxicillin and penicillin)
- Natural agents: garlic cloves and honey
- Sterile distilled water
- Gloves
- Tweezers
- Exacto knife

Procedure:

1. Gather 3 sponges (2 dirty, one clean)

2. Soak all 3 sponges in a cylinder filled with room temperature sink water
3. Leave each sponge in the cylinder for 5 minutes
4. Soak the sterile cotton tipped applicators for ten seconds in each cylinder filled with water that the sponges were soaking in
5. Take these sterile cotton tip applicators and swab them onto the Agar plates for 10 seconds
6. Incubate the Agar plates for 24-48 hours
7. Place antibiotic discs (amoxicillin and penicillin) and the natural agents (honey and garlic) on the Agar plates
8. Incubate and observe zones of inhibition after 24–48 hours.
9. Compare efficacy between antibiotics and natural agents.
10. Note any resistance (no zone = resistant).

Results/Data Analysis:

In our experiment, we hypothesized that used kitchen sponges will show significant bacterial growth due to their exposure to food particles and moisture. We also predicted that the bacteria extracted from the sponges would be more resistant to natural agents (such as garlic and honey) than normal antibiotics (such as amoxicillin and penicillin). Although our results came close to our hypothesis, there were still a few discrepancies that should be noted.

Our experiment consisted of three sponges: one new sponge (control group), one lightly used sponge (experimental 1), and one used many times (experimental 2). We placed these sponges in water and used sterile cotton swabs to swab some of the liquid on our Agar plates. After the Agar plates sat in the incubator for 24 hours we took them out and recognized that the Agar plates from experimental 2 had significant bacterial growth, while experimental 1 barely had any bacterial growth, just like the control group. We then placed our natural agents and antibiotics on the plates and placed them back in the incubator. After a total of 48 hours, we concluded that there was no effect whatsoever on the control group–which makes sense because there was no bacteria. In experimental 1, we saw that the bacteria was only resistant to the natural agents and not to the antibiotics; however, in experimental 2, there was a lot of resistance to the natural agents, but surprisingly minimal resistance with the amoxicillin and penicillin, which was not something we had anticipated. These results confirmed our concerns over the growing concern of antibiotic-resistant bacteria.

Conclusion:

Based on the findings of the experiment, it can be concluded that kitchen sponges, due to their frequent exposure to food residues and moisture, serve as ideal environments for bacterial proliferation, including potentially harmful and antibiotic-resistant strains. The study demonstrated that used kitchen sponges harbor significant bacterial contamination, emphasizing the need for proper cleaning and disinfection practices to reduce microbial load.

The experiment confirmed the hypothesis that synthetic antibiotics (amoxicillin and penicillin) were more effective in inhibiting bacterial growth compared to natural antimicrobial

agents (garlic extract and honey). The Kirby-Bauer disk diffusion method showed comparably clear zones of inhibition around the antibiotic discs, indicating their effectiveness. In contrast, the natural agents displayed smaller or no zones of inhibition, suggesting limited antibacterial activity against the strains tested, and much resistance.

However, the experiment also revealed that some bacteria exhibited resistance to antibiotics, as evidenced by the absence of clear inhibition zones in certain cases. This finding highlights the growing public health issue of antibiotic resistance, which poses significant challenges in both healthcare and household environments.

While natural antimicrobial agents showed some potential, their effectiveness was inconsistent and generally lower than that of the antibiotics. This supports the understanding that, although natural agents can play a role in reducing bacterial contamination, they may not be reliable substitutes for antibiotics, particularly when dealing with resistant strains.

The study underscores the importance of continued research into antibiotic resistance and the potential role of natural antimicrobial agents. Future investigations could focus on exploring combinations of natural agents to enhance efficacy, examining the specific bacterial species present in sponges, and assessing the long-term effectiveness of alternative disinfection methods in household settings.

Ultimately, the findings show that while antibiotics are still the best way to fight bacteria, the rise of resistance means we need new ways to control bacteria and use antibiotics more carefully, both in healthcare and daily life.

Future Work:

In our experiment, we need to look more closely at various things such as bacterial diversity, resistance mechanisms, effectiveness of natural vs synthetic agents, and environmental factors. It's important to examine the different types of bacteria present on the sponges because that can help us figure out which species are most commonly resistant. We also need to examine how different amounts and concentrations of natural and synthetic agents affect different bacterial species. Another thing we need to explore is how factors like how frequently we use sponges, the types of food residues, and cleaning habits affect bacterial growth and resistance.

References

- "Bacteria Survive on Kitchen Sponges and Towels in Recent Study." *American Society for Microbiology*, 7 July 2020
- Centers for Disease Control and Prevention (CDC). "Antimicrobial Resistance: Fact Sheets." *Centers for Disease Control and Prevention*, 19 Apr. 2021
- Centers for Disease Control and Prevention (CDC). "Antimicrobial Resistance: Facts and Statistics." *Centers for Disease Control and Prevention*, 2022
- World Health Organization (WHO). "Antimicrobial Resistance." *World Health Organization*, 15 Apr. 2021
- "Kitchen Sponges Are Home to a Surprising Number of Bacteria." *Science News*, 8 Nov. 2017, Accessed 7 Apr. 2025.
- "Kitchen Hygiene: Let's Talk About That Sponge!" Home & Garden Information Center, 28 Jan. 2021, Accessed 7 Apr. 2025.
- "Kirby-Bauer Disk Diffusion Susceptibility Test Protocol." *American Society for Microbiology*, Accessed 7 Apr. 2025.
- "Kirby-Bauer Disk Susceptibility Test." *LibreTexts*, 25 Mar. 2021, Accessed 7 Apr. 2025.
- "A Review of Antimicrobial and Other Medicinal Properties." *PubMed Central (PMC)*, National Library of Medicine, 2005

The Effect of Temperature on Battery Life

A study conducted by Tamar Katz

Abstract

Almost as important as how to generate electricity is the question of how to store it. Batteries have evolved to be the imperfect answer to this question. Since a battery is essentially a self-contained reaction that converts chemical potential energy into electrical energy, the factors that influence chemical reactions will undoubtedly affect battery life and performance. According to Collision Theory, temperature is a major factor which dictates the kinetic energy and hence frequency of effective collisions between reactants. (LeMay). It follows that batteries would have an optimal temperature for storage and discharge, and that temperatures that are less than ideal would compromise efficiency.

In this experiment a sample of dry cell batteries (AA, AAA, D, button and 9V: three of each type) were placed in room temperature, a refrigerator (4° C) and a freezer (-8° C) for a period of 6 months. Following the 6-month period the batteries were connected to a circuit that was constructed to drain the voltage over a period of hours. Voltage decrease over time was recorded for comparison. As anticipated, all batteries drained at a consistent rate over a period of four hours by as much as 33% (1.5 V to 1.0 V). In each case batteries stored in colder temperatures (red and yellow plots) drained less than room temperature (blue plot) but is the difference enough to prove conclusively that temperature was the influencing variable?

Construction of a battery

The alkaline battery comprises a hollow steel drum, serving as both its body and cathode, with the positive terminal extending from the top. The inner surface of the drum hosts a cathode mixture of fine-grained manganese dioxide (MnO_2) and coal dust, separated by a paper separator. Within this separator lies zinc powder and a potassium hydroxide electrolyte, acting as the anode. A metallic pin, typically brass, functions as the negative collector, inserted along the central axis and connecting to a metallic end-sealed cap. A plastic cover within the cap electrically isolates the positive steel drum and negative end cap, ensuring proper function and safety of the battery.

How alkaline batteries work

Both Energizer and Duracell are types of alkaline batteries. Alkaline batteries work since there is a cell within the alkaline battery that represents a distinct segment of the overall power supply mechanism. Classified as a primary battery, a dry cell represents a disposable energy source that converts chemical potential into electrical power. Its essential components consist of manganese dioxide as the positive electrode and a zinc cylinder serving as the negative electrode, making it easier for the flow of electrons through an external circuit. This electrochemical process relies on the principle of oxidation and reduction, wherein zinc, being more reactive than manganese, undergoes oxidation, losing electrons, while manganese undergoes reduction, gaining electrons. Through this organized exchange of electrons, the dry cell generates electrical energy, enabling the battery to fulfill its intended function within various electronic devices.

Hypothesis

- Batteries stored in the fridge (4 °C) and freezer (-8 °C) for 6 months will drain more slowly than batteries stored at room temperature (22 °C)

Methodology

- Control

The control group is the batteries at room temperature. It is the control group since any change in the voltage of the batteries in the fridge or freezer can be linked back to the change of temperature. However, any change in the room temperature battery can't be linked to a change in temperature.

- Experimental

The experimental group would be the batteries in the freezer and the fridge. These batteries would be the experimental group since any change in the batteries is able to be linked back to the change in temperature, unlike the control group.

Results

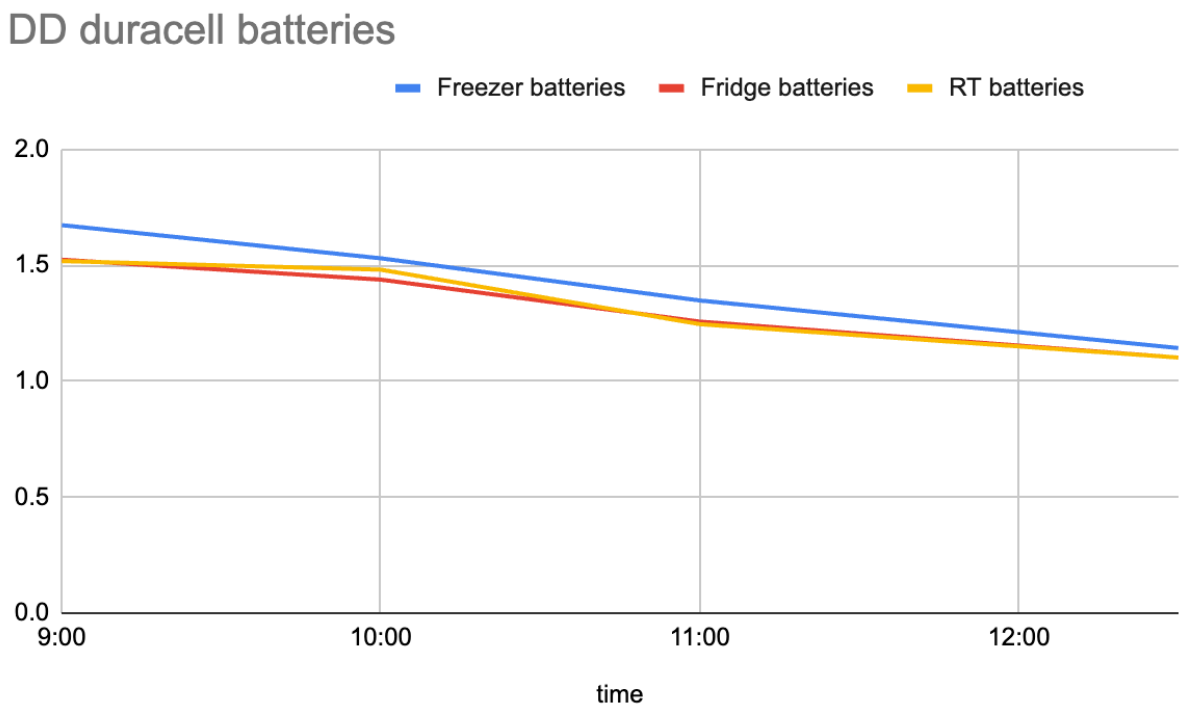
- Timeline

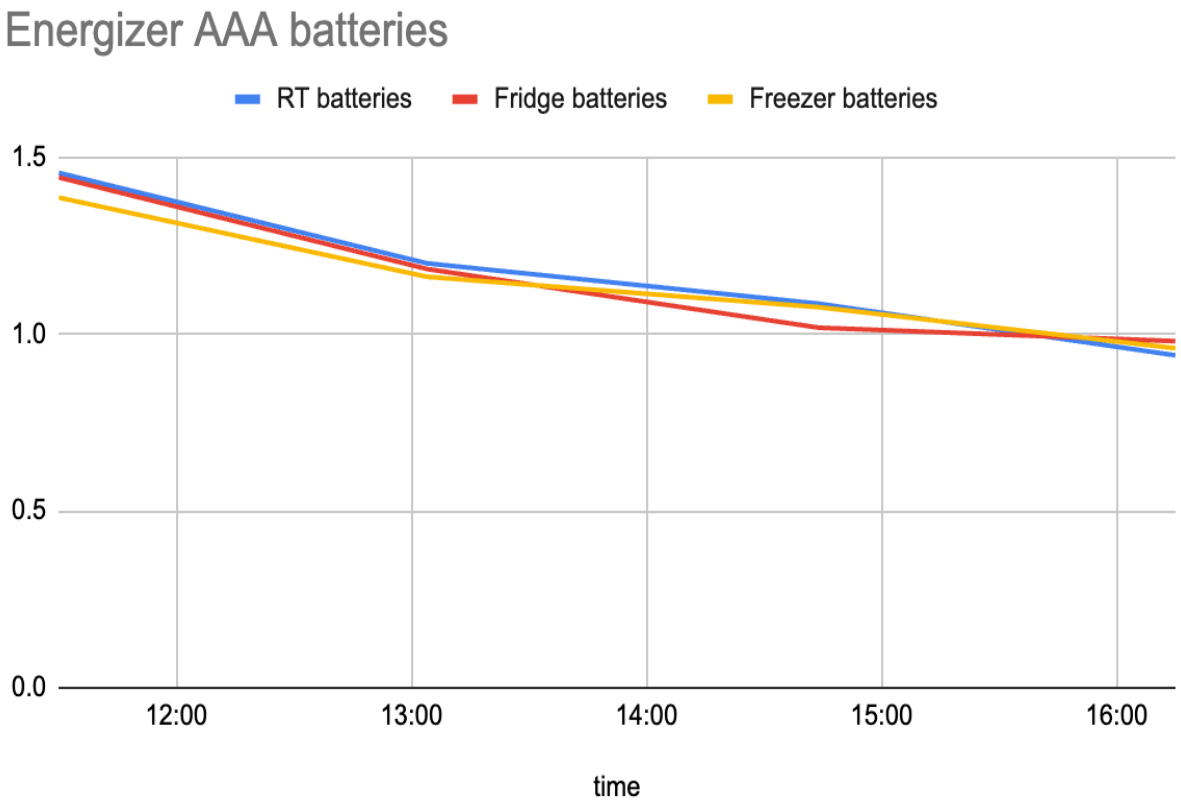
This experiment shows the effect of temperature over time on different batteries. I tested AA, AAA, DD, Button batteries, and 9V batteries. I had three of each kind of battery from each brand (overall 6 of each battery). I kept one battery from each brand in the freezer, then in the fridge, then at room temperature (RT). I tested the voltage of the batteries bi-weekly. After six months (October-April) I started testing the batteries. I constructed a circuit that would drain the voltage from the battery to see how long it was able to work. I put the batteries from the freezer, fridge, and room temperature into the circuit and tested it every hour. The batteries would drain at a consistent rate; however, there would always be a battery which drained slower than the rest of the batteries.

- What aspect of battery life are you measuring?

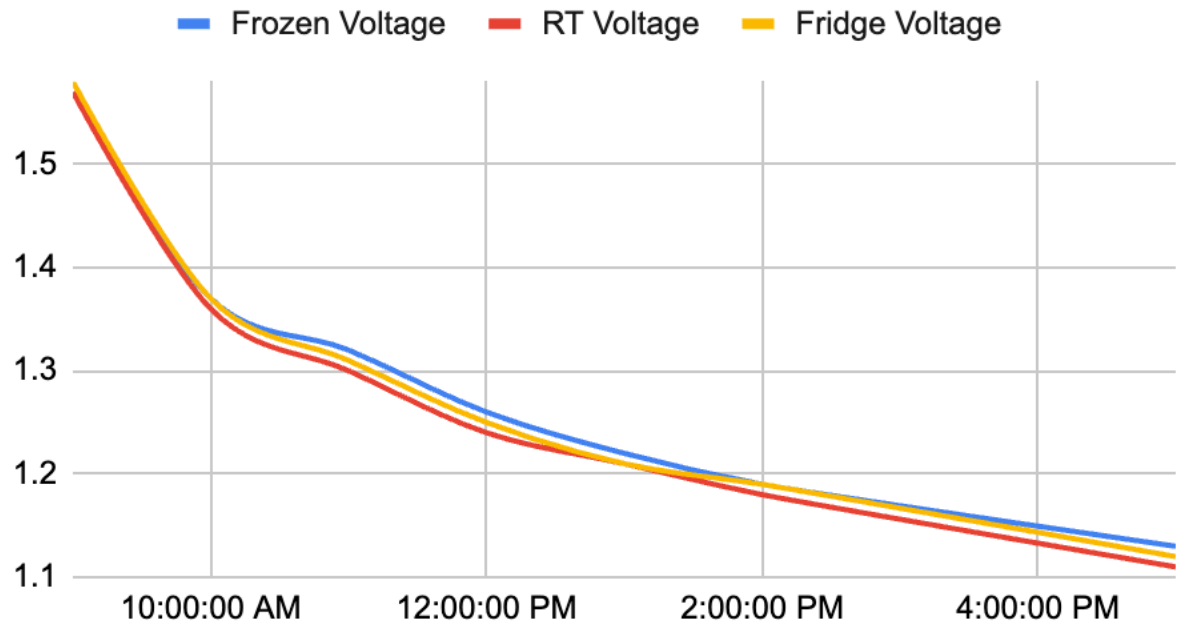
  I am measuring the life span of different types and brands of battery

Data

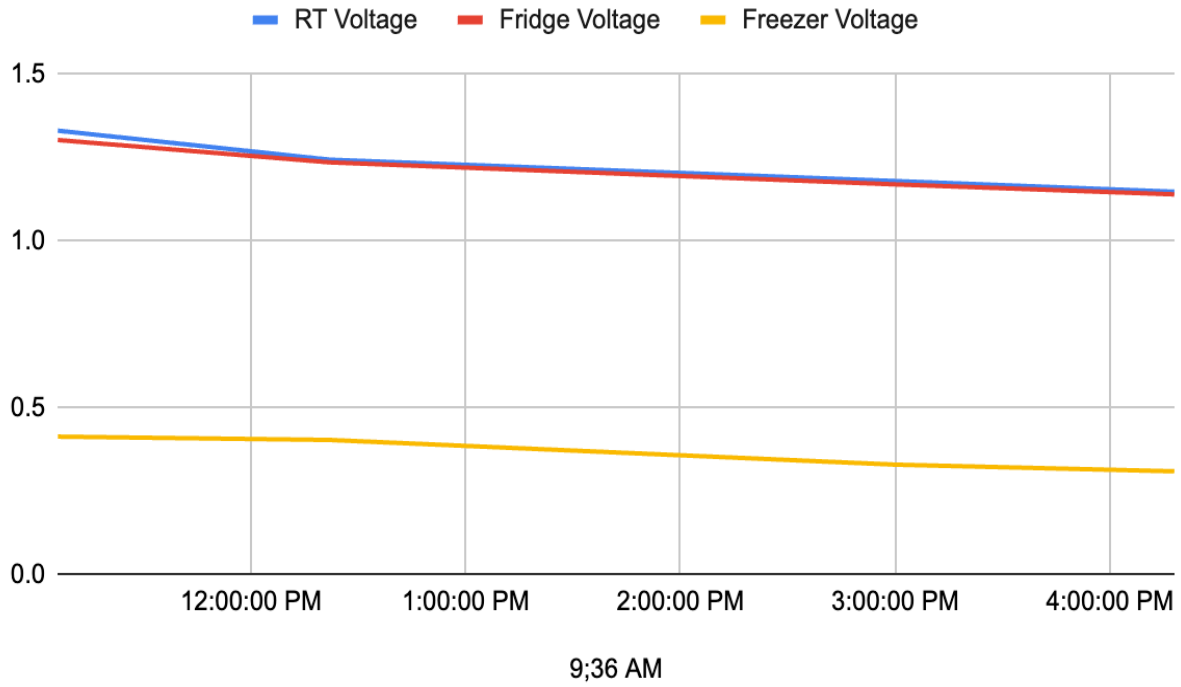

DD duracell batteries
Freezer batteries
Fridge batteries
RT batteries
2.0
1.5
1.0
0.5
0.0
9:00
10:00
11:00
12:00
time


Energizer AAA batteries
RT batteries
Fridge batteries
Freezer batteries
1.5
1.0
0.5
0.0
12:00
13:00
14:00
15:00
16:00
time

AA Durcell batteries



AA Energizer batteries



Chi Square Analysis / Conclusion

After four hours under load, the voltage of batteries decreased an average of 32%. This is in agreement with independent testing. (Alex Hibert/Cold Testing 2017).

After the same four hours under cold and freezing conditions, voltage differences were .121v and .148v above RT (Room Temp) respectively. Chi-Square Testing with these values produces a p-value of .023. This supports the null hypothesis, suggesting that the difference may be due to chance. The question of whether or not temperature has a negative effect on battery storage/voltage over time is inconclusive. Further testing is required.

Future Work

Future work for this experiment would be to test Lithium batteries under different temperatures. The batteries I used for this experiment were alkaline batteries. Testing Lithium batteries may lead to a different outcome with cold temperature since a lithium battery does not have a water based electrolyte.

References

"How Do Alkaline Batteries Work?" *BYJU'S*, https://byjus.com/chemistry/how-do-alkaline-batteries-work/.

Intercel. "What Are Temperature Effects on Batteries?" *Intercel Batteries*, https://batteries.intercel.eu/faq/what-are-temperature-effects-on-batteries/.

"What Are Alkaline Batteries?" *BatteryGuy.com Knowledge Base*, 3 May 2024, https://batteryguy.com/kb/knowledge-base/what-are-alkaline-batteries/.