Post-Preservation Maintenance of Cadavers to Prevent Tissue-Dehydration in Educational Environments

by
Alexandria Raquel Herrera

A THESIS

submitted to

Oregon State University

Honors College

in partial fulfillment of
the requirements for the
degree of

Honors Baccalaureate of Science in Mechanical Engineering
(Honors Scholar)

Presented May 26, 2021
Commencement June 2021

# AN ABSTRACT OF THE THESIS OF

Alexandria Raquel Herrera for the degree of Honors Baccalaureate of Science in Mechanical Engineering presented on May 26, 2021. Title: Post-Preservation Maintenance of Cadavers to Prevent Tissue-Dehydration in Educational Environments.

Abstract approved:_______________________________________________________

Devon Quick

In anatomical education, clinicians, surgeons, and anatomists support the use of human cadavers over digital or artificial alternatives. Cadaver use raises the challenge of preventing tissue dehydration. The OSU cadaver labs attempt to maintain hydration by re-covering the exposed tissues with original skin, layers of plastic wrap, and/or towels and shrouds soaked in a wetting solution. It was hypothesized that an artificial material will maintain tissue hydration levels more effectively than the current methods deployed in the OSU labs. Candidate tissue coverings were selected based on their material properties and relative costs. Punch biopsies of skeletal muscles were subjected to different coverings, and half were soaked in the wetting solution. Changes in tissue masses over time were recorded and presented as dehydration trends. It was found that skin is the most effective covering to prevent tissue dehydration, followed by plastic wrap and nitrile rubber. Respective donor skin should directly cover the cadaver tissues during storage hours. Alternatively, a combination of plastic wrap and nitrile rubber coverings can prevent dehydration. In both cases, wetting solution should be applied to the tissues, and a shroud or black plastic cover should be placed over the cadaver to maintain donor dignity.

Key Words: cadaver, anatomical education, dehydration, tissue preservation

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APPROVED:

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Devon Quick, Mentor, representing Integrative Biology

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Brian Bay, Committee Member, representing Mechanical, Industrial, and Manufacturing Engineering

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Tamara Ostervoss, Committee Member, representing Oregon Health & Science University

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Toni Doolen, Dean, Oregon State University Honors College

I understand that my project will become part of the permanent collection of Oregon State University, Honors College. My signature below authorizes release of my project to any reader upon request.

______________________________________________________________

Alexandria Raquel Herrera, Author

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Lastly, but certainly not least, I want to recognize the late Dr. Nancy Squires. As my original thesis mentor, Dr. Squires remained a strong presence in my work as she encouraged me to embrace my passions and to always follow the path of the things that I love. My time with her planted the seed of connecting engineering to the human body, providing a new lens that opened my eyes to the possibility of this research and led to the most fulfilling project that I have ever completed.

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## I. INTRODUCTION

The human cadaver has held the spotlight in anatomy and physiology education for centuries, with dissection traced back to the 3rd century BC in Ancient Greece [1]. In the past three decades, the use of the human cadaver in educational settings has been challenged by technological replacements. Alternative ways to learn gross anatomy are encouraged by negative outlooks on cadaver-based learning; specifically, the dissection process is seen as a time-consuming and costly commitment, requiring schools to spend hundreds of thousands of dollars on ventilation, safety, and storage equipment in order to comply with the U.S. Occupational Safety and Health Administration guidelines regarding formaldehyde levels [2]. Examples of replacement technology include the Anatomage Table, which allows students to virtually dissect a digital cadaver, and a mechanical cadaver created by SynDaver labs, which can replicate the bodily functions of a real person [2].

Despite the push towards virtualization, cadavers are far from obsolete. The dissection process and observational learning is "...both strange and wonderful, clinical and deeply human" [2]. Such an experience is invaluable, and in some ways, irreplaceable—the director of Clinical Anatomy at Harvard Medical School argues that cadaver dissection and study gives students a tactile idea of depth within the human body, a lesson you cannot learn from a picture [2]. An increasing number of clinicians and surgeons share this sentiment and support cadaver dissection in anatomy education, while many anatomists consider soft-preserved cadavers—as opposed to plastinated cadavers—to be the most accurate tool in anatomical learning [3][4]. The role of the human cadaver in education is further supported by anatomical learning outcomes: with respect to identification and explanation of anatomical features, a multimedia-based, virtual simulation learning system demonstrated a “significant disadvantage over the cadaver condition” [5].

Medical and non-medical students across the globe currently rely on cadaver dissection and observation in order to gain a deeper understanding of the structural and functional anatomy that exists inside of us. For students to gain the most anatomical learning from such an experience, it is imperative that the tissue hydration is maintained throughout the study [3]. A variety of methods are used for preservation, including arterial and cavity injections, the application of cold or heat, powders, evisceration, and more; however, post-preservation maintenance proves to be difficult as tissues become exposed to open air and dehydrate, altering tissue relationships and relevant anatomical presentation.

While the cadaver coverings are necessarily set aside for tissue observation, the unwanted drying process accelerates for several hours at a time. Throughout a term, a typical medical school gross anatomy course may last upwards of 100 total hours of potential drying time [2]. Accordingly, Anatomy lab directors establish procedures to try and prevent as much dehydration as possible in between class observations. Though tissues inevitably dehydrate during periods of air exposure, the rate at which dehydration occurs during storage hours may be manipulated through the application of rehydrating solutions and evaporation-preventing materials. For example, the University of Minnesota cadaver lab outlines steps and regulations that the students must adhere to after every lab session [6]. Step number five emphasizes the importance of proper storage to prevent tissue dehydration, directing the students to cover any dissected regions with a moistening fluid and cloth, as well as a plastic sheet that covers the entire cadaver; in capital, red, and bolded letters, the instructions also note, "DO NOT ALLOW THE CADAVER TO DRY OUT ANYWHERE" [6].

Determining effective methods to prevent tissue dehydration will allow for institutions to maintain a quality presentation of exposed anatomical layers during cadaver dissection; consequently, successful dehydration prevention will result in distinct and identifiable anatomical structures for longer periods of time, which will enhance the learning opportunity of students in anatomy courses. In addition to educational benefits, striding towards the highest quality cadaver presentation is an actionable step of respect in honor of those who choose to donate their bodies to science and education.

In the Anatomy and Physiology labs at Oregon State University, similar protocols aim to prevent the drying process; these include re-covering the exposed tissues with the respective cadaver skin, as well as applying layers of plastic wrap, towels and shrouds soaked in a wetting solution to the external surfaces of the body. The wetting solution is applied in order to increase the moisture content of the tissues, and consequently decrease the rate of dehydration. Ideally, every time the cadavers are observed or dissected, they are subsequently subjected to this maintenance. Dehydration will inevitably occur while tissues are exposed to air, but the time periods of storage between subsequent applications of wetting solution are opportunities to slow drying rates through means of dehydration prevention and potential rehydration. This common problem provides the opportunity to research the effectiveness of different approaches to maintaining hydrated anatomical specimens via a new variety of material coverings that may be applied between periods of observation.

With the importance of tissue quality and respect for donors in mind, the study outlined in the following sections was designed to identify material coverings that will prevent cadaver tissue dehydration. It was hypothesized that an artificial material will maintain tissue hydration levels more effectively than the current methods deployed in the OSU Anatomy and Physiology labs.

## II. EXPERIMENTAL DESIGN

### A. Project Overview

This study aims to identify ideal material coverings that outperform current means: skin, plastic wrap, and/or wetted towels and shrouds, with respect to tissue dehydration. Ideal materials are defined as low in cost and available to the OSU cadaver lab through a third-party seller. Candidate materials were selected based on mechanical and physical properties that are similar to human skin. Tissue samples from skeletal muscles were used as they are susceptible to dehydration during air exposure periods during lab observation. Six different materials were used as sample coverings, as well as direct air exposure (control). The mass of each sample was recorded every few hours, and material performance was determined from overall sample dehydration (mass loss).

### B. Materials Selection for Tissue Coverings

A materials engineering approach was deployed in order to select the candidate materials for this experiment; these materials were tested in addition to the currently-used coverings of skin, shroud, towels, and plastic wrap. This process started with the identification of objectives and constraints for the design of cadaver coverings. These components of design are outlined in Table 1.

**Table 1.** Design objectives and constraints for a cadaver covering to be used in the OSU cadaver lab.

| Objectives | Constraints |
|---|---|
| • Maximize tissue hydration (minimize dehydration)<br>• Minimize material decomposition<br>• Minimize cost (USD)<br>• Similar density to human skin | • Flexible (can conform closely to cadaver shape)<br>• Durable (does not tear under tension)<br>• Hydrophobic<br>• Does not allow bacteria/mold to grow (antimicrobial)<br>• Compatible with cadaver embalming chemicals and OSU Cadaver Lab preservation fluid<br>• Disposable or reusable (as determined by institutional environmental health and safety regulations)<br>• Safe for lab use<br>• Respectful |

Of the goals and constraints listed above, four were selected as quantifiable material properties: the material should be flexible and should not tear, the cost should be minimized, and it should have a density similar to that of human skin. One of the main functions of human skin is to maintain hydration of the person, also known as the "barrier function" [7]. The organ features the stratum corneum: layers of cells stacked as "bricks glued together" that allow for the barrier function to occur [7]. Therefore, materials with similar properties, such as tissue-compactness (density), were selected as candidates to prevent dehydration.

The associated design parameters examined were Young's modulus, tensile strength, density, and price (USD), respectively. These four parameters were then applied to the GRANTA software package, an application that contains materials property data for the materials of the universe [8]. Using the GRANTA software, several material property comparison charts were created. Figure 1 displays a comparison between Young's modulus and density, while Figure 2 displays a comparison between tensile strength and density. On both charts, the vertical line represents the density of human skin, and materials that exhibit a similar density were considered for the initial candidate material list.

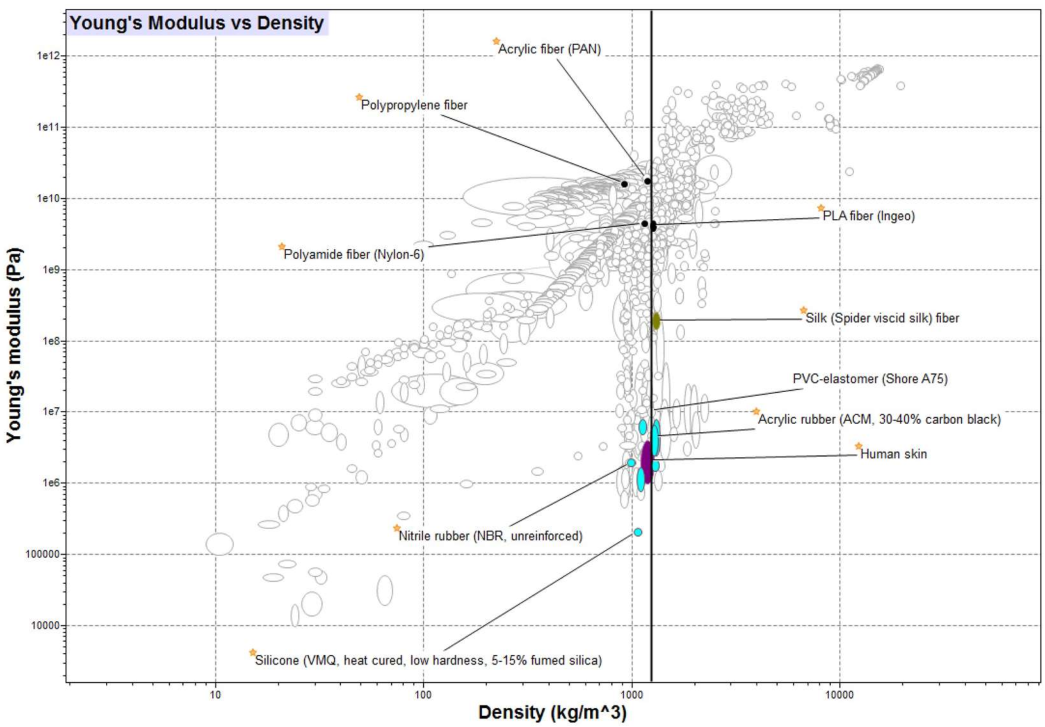


**Figure 1.** A material property comparison chart of Young's modulus vs density exhibits the relative elasticity of each candidate material with respect to human skin. Density is selected as the horizontal axis in order to identify materials of similar density to human skin.

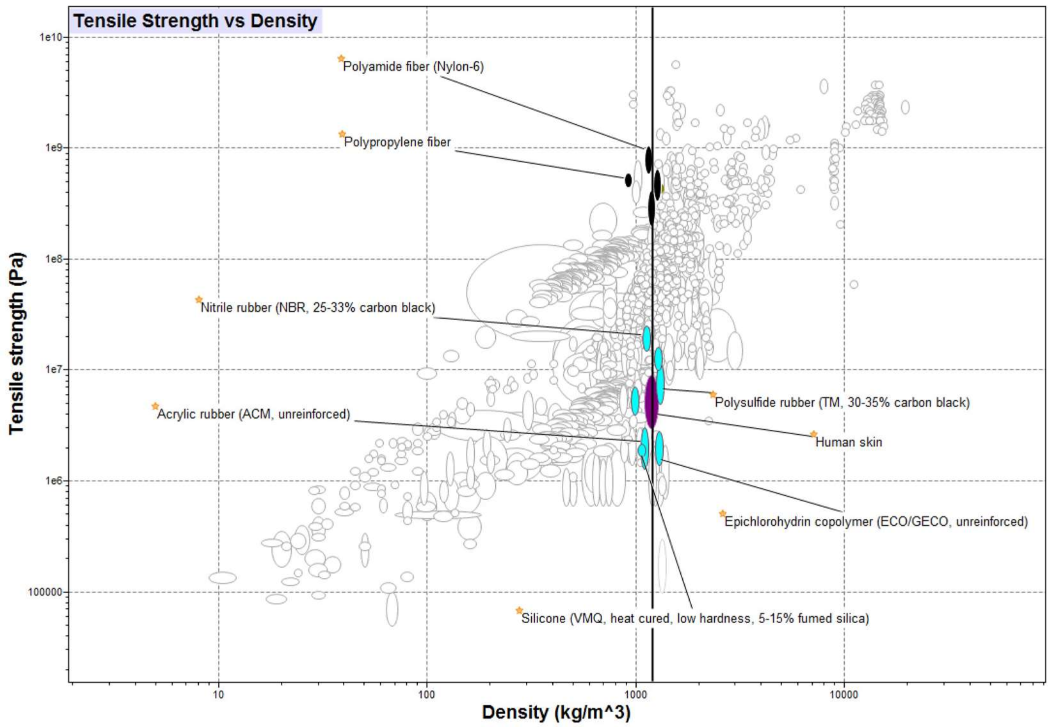


**Figure 2.** A material property comparison chart of tensile strength vs density exhibits each candidate material and its respective relative resistance to tear, with respect to human skin. Density is selected as the horizontal axis in order to identify materials of similar density to human skin.

The initial material candidates for cadaver coverings consisted of polyamide fiber, polypropylene fiber, nitrile rubber, polysulfide rubber, acrylic rubber, epichlorohydrin copolymer, and silicone rubber. Next, these materials were subjected to a cost comparison, as seen in Figure 3.

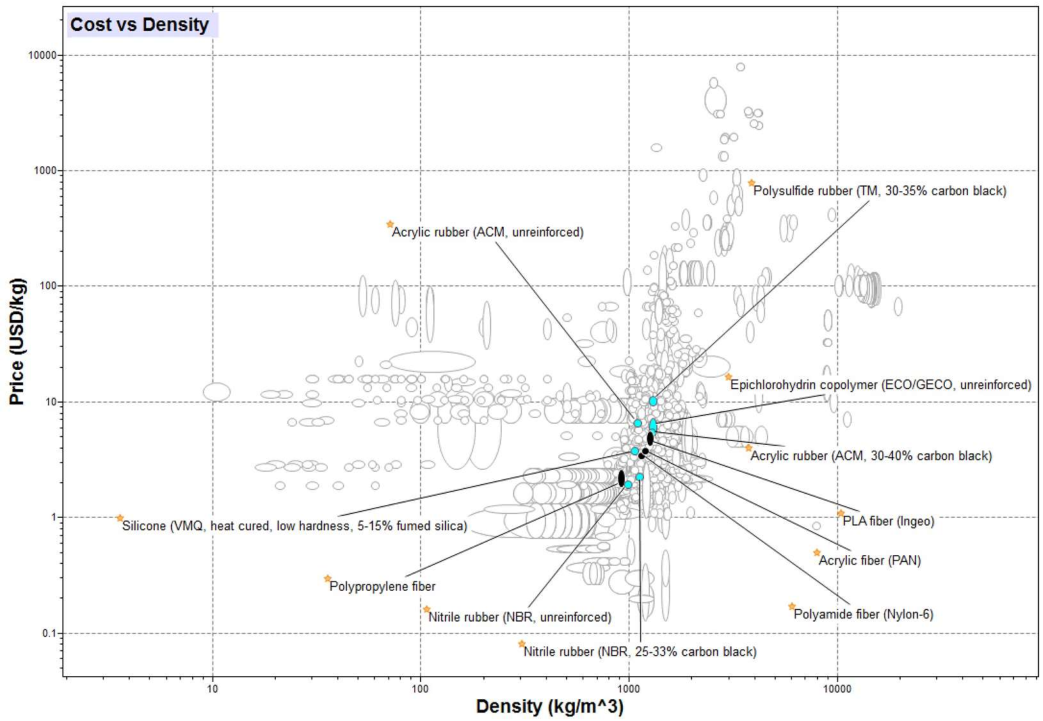


**Figure 3.** Candidate materials are compared by price per unit mass. Human skin is excluded from this property chart.

Balancing the Young's moduli, tensile strength, and cost criteria, nitrile rubber and silicone rubber were selected as the materials to be tested against the cadaver covering materials used in the OSU anatomy labs. Further documentation of these two materials was researched to confirm that the remaining constraints and objectives of Table 1 were met.

## C. Muscle Selection

Skeletal muscles are the primary focus for samples of this experiment because they are the first internal tissues revealed in dissection, and therefore the longest to be exposed to air throughout the study of each cadaver. Thinner, superficial muscles and thicker, deeper muscles were selected in order to determine if dehydration trends were consistent under the conditions of various coverings and wetness despite muscle volume.

Models from Biodigital, an anatomical software that features three-dimensional visualizations, were used to determine which muscles would be large enough to provide 14 10mm punch biopsies [9]. The 10mm diameter parameter was selected so that mass measurements were large enough to display any significant changes in mass over time. This size is similar to the 1.5cm by 1.5cm by 0.5cm tissue samples used in a study of the rehydration capacities and rates of porcine tissues [10].

Ultimately, the oblique muscles and adductor magnus were selected. These muscles are highlighted in Figure 4. Given the span of the oblique muscles, the 14 samples were extracted from a lateral, posterior region of the muscles.

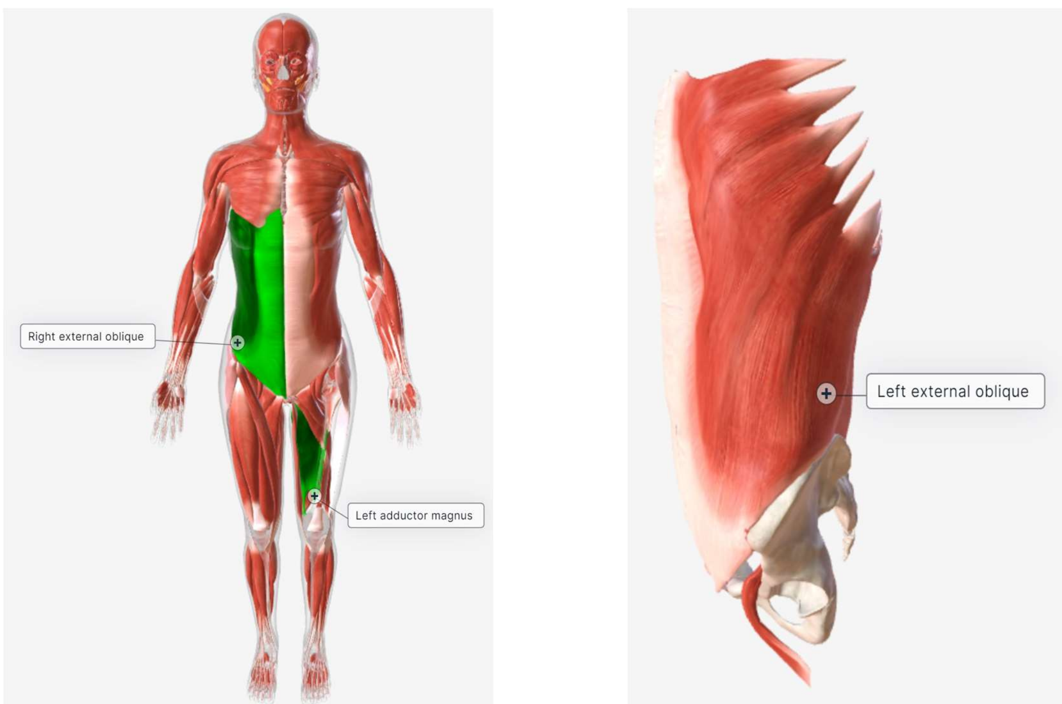


**Figure 4.** The most superficial oblique muscle and an adductor magnus are highlighted on a biodigital model [left]. A lateral view of the most superficial oblique muscle best displays the region from which muscle samples were extracted [right] [9].

The OSU anatomy and physiology labs host four cadavers: two female, two male. Due to the variability of body size between cadavers, the muscles of each cadaver were examined to determine if the selected muscles were large enough to provide 14 10mm punch biopsies. Three out of four cadavers featured oblique muscles and at least one adductor magnus that were deemed fit for the experiment. The fourth cadaver, one of the females, exhibited muscle dehydration beyond the point of possible rehydration via the lab wetting solution. This cadaver was excluded from the experimental methods, but serves as a prime example of the importance of maintaining tissue hydration over time.

### D. Monitoring Temperature & Humidity

Temperature and humidity of the OSU anatomy lab that hosted the experiment were recorded over the course of testing. This data aims to reveal the level of stability of the testing environment. A programmed Arduino circuit board and a DHT11 temperature and humidity sensor were connected to a laptop and positioned next to the sample storage location (see Figure 5). The laptop ran a Matlab program that read the time stamped data from the sensor and wrote it to a .txt file. Subsequently, a python program was used to extract the data from the .txt file and present the ranges of temperature and humidity for each day of testing. Temperature was less variable than humidity. The inter-day variation of temperature was between 1 and 2 degrees Celsius, while humidity varied by a maximum of 13 percent; between days, temperature varied by as much as 3 degrees Celsius, and humidity varied by as much as 18 percent. The codes and collected data are found in Appendix A.

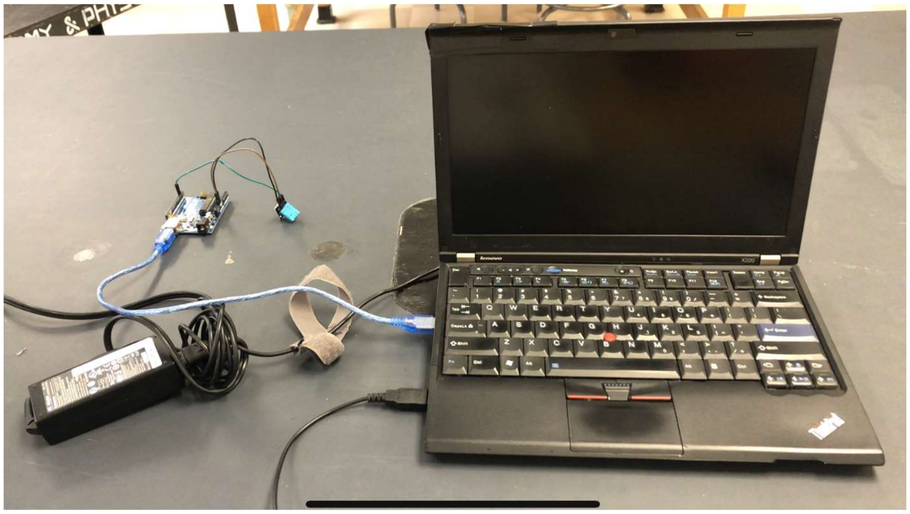

**Figure 5.** An Arduino UNO board is connected to a laptop via a blue USB cable. The Arduino UNO features three jumper wires that attach the DHT11 temperature and humidity sensor to the board.

## E. Pre-Test

A pre-test was conducted with two goals: to confirm the ability of the Mettler AT400 digital balance to measure the changing masses of the tissue samples and to determine the time frame of the measurements.

Samples of muscle were extracted from the pectoralis major and vastus lateralis of one cadaver using a 10mm punch biopsy. A biodigital model of the muscles is seen in Figure 6. These muscles were selected in order to mimic the desired “thin” and “thick” muscle types without exhausting the adductor magnus and oblique muscle resources. Two samples were subjected to 0.5 mL of wetting solution (2.5% ethanol, 15% propylene glycol, 5% Downy fabric softener, 77.5% water), while the other two were left dry. After the wetting solution was applied, the initial mass of each sample was recorded. The samples were subsequently stored in storage containers created from aluminum molds (see Experimental Methods section). Masses were measured every three to four hours over the course of three days, with the exception of a 12 hour overnight period.

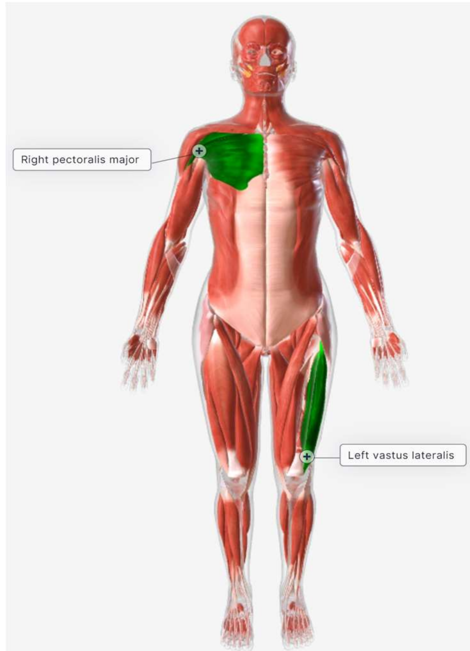


**Figure 6.** The thick and thin muscles selected for the pre-test include the pectoralis major and the vastus lateralis, as highlighted on the depicted biodigital model [9].

The pre-test demonstrated that the digital balance is sensitive enough to track changes in mass of the samples, reading to four decimal places. The three to four hour time period between measurements allowed for the illustration of exponential changes in masses over time, revealing that multiple measurements should be taken over the course of each day. Changes in mass became insignificant by the third day of the pre-test. Based on the flattened curve seen at the tail end of the data plotted in Figure 7, it was concluded that measurements do not need to be repeated after 51 hours has passed from the time of the initial measurement.

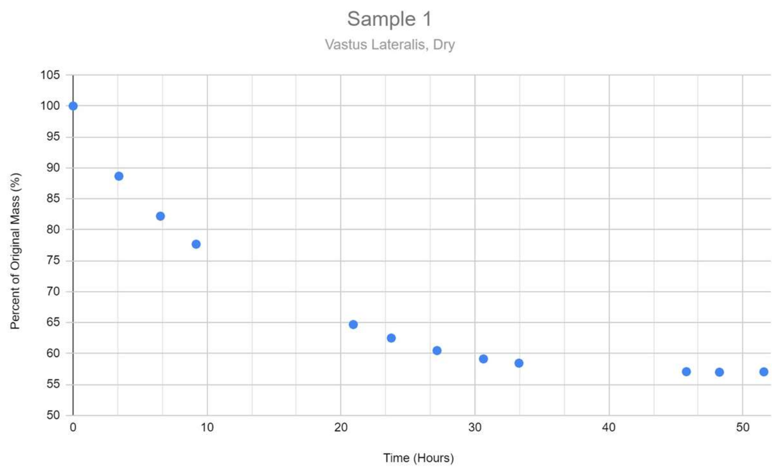


**Figure 7.** The percent of original mass of Sample 1 from the pre-test is plotted against time from the initial mass measurement.

## F. Experimental Methods

Prior to initial tissue extraction, the storage containers and trays were prepared and labeled. Each storage container was composed of two aluminum cupcake molds. In an effort to replicate the cadaver storage tanks, the molds were attached to each other at the rim, resulting in a container with a base and a lid. Eight holes were punched into the floor of the base mold, mimicking the drainage and ventilation holes featured on the cadaver tanks. Figures 8 and 9 display the storage containers and a model of the cadaver tanks, respectively.

**Figure 8.** A storage container consists of two aluminum cupcake molds taped together at one point along their concentric rims [left]. An inferior view of the bottom cupcake mold features eight holes: four along the circumference of the base and four in the center of the base [right].

**Figure 9.** A downdraft cadaver storage tank, closed [left] and open [right]. The storage tank features drainage holes along the edges of the bed on which the cadaver lays [right] [11][12].

Storage containers were anchored to the trays using blue painter's tape. In addition to the sample labels, each tray was labeled with the cadaver ID number and the cadaver tank number. The OSU cadaver lab wetting solution (2.5% ethanol, 15% propylene glycol, 5% Downy fabric softener, 77.5% water) was prepared prior to the experiment: a small-scale batch was made and stored in a 500mL flask.

To prepare the five material coverings, the bottom of an aluminum mold was used to trace circles on the cotton shroud, towels, plastic wrap, nitrile rubber, and silicone rubber. Four circles were cut out from each material and used as the coverings for the five respective sample columns.

On the morning of tissue extraction, the stored skin of the respective donor was obtained. A scalpel and surgical scissors were used to cut skin coverings of a similar shape and size to the base of the aluminum mold. The four skin coverings from a cadaver came from the same body region in order to maintain a uniform thickness of covering down the column of samples. The final preliminary step involved initializing the temperature and humidity monitor code and checking the file of data to ensure that the monitor was recording data.

Tissue samples were extracted at seven o'clock AM on the first day of each test. A total of 28 10mm punch biopsies were taken from each cadaver: 14 from the adductor magnus, and 14 from the oblique muscles. From each muscle type, half of the samples were subjected to wetting solution, while the remaining half were left dry. The degree of wetness variable was established to determine if dehydration trends are consistent when muscle type and covering are held constant.

Each sample labeled as 'wet' was placed in a designated, dry aluminum mold and soaked in 0.5mL of the wetting solution made in the cadaver lab. The solution was measured using a pipette and applied directly to the tissue rather than to the covering in order to mimic a "worst case scenario" condition in which the cadaver coverings were left to dry. Once it was visually saturated with liquid, the sample was transferred to its storage container using a pair of forceps. A soft grip was used to prevent any liquid from being pressed out of the sample.

The muscle type and wetness combinations resulted in four sets of seven samples: dry adductor magnus, wet adductor magnus, dry obliques, and wet obliques. All of the aluminum containers were arranged in four rows, each row containing one of the sets of the seven samples. Each column of containers exhibited one of the cadaver coverings, with the exception of the first column, which held the control samples that were exposed to air.

A diagram of the sample arrangement is shown in Figure 10, while the labeled tray used in the experiment is displayed in Figure 11. Only samples from a single cadaver were stored on a respective tray in order to ensure that no tissues from separate donors were at risk for misplacement due to a shared storage environment.

| | | | | | | |
|---|---|---|---|---|---|---|
| Sample 1A<br>AM - Dry<br>Air | Sample 2A<br>AM - Dry<br>Skin | Sample 3A<br>AM - Dry<br>Shroud | Sample 4A<br>AM - Dry<br>Towel | Sample 5A<br>AM - Dry<br>Plastic | Sample 6A<br>AM - Dry<br>Nitrile | Sample 7A<br>AM - Dry<br>Silicone |
| Sample 1B<br>AM - Wet<br>Air | Sample 2B<br>AM - Wet<br>Skin | Sample 3B<br>AM - Wet<br>Shroud | Sample 4B<br>AM - Wet<br>Towel | Sample 5B<br>AM - Wet<br>Plastic | Sample 6B<br>AM - Wet<br>Nitrile | Sample 7B<br>AM - Wet<br>Silicone |
| Sample 1C<br>O - Dry<br>Air | Sample 2C<br>O - Dry<br>Skin | Sample 3C<br>O - Dry<br>Shroud | Sample 4C<br>O - Dry<br>Towel | Sample 5C<br>O - Dry<br>Plastic | Sample 6C<br>O - Dry<br>Nitrile | Sample 7C<br>O - Dry<br>Silicone |
| Sample 1D<br>O - Wet<br>Air | Sample 2D<br>O - Wet<br>Skin | Sample 3D<br>O - Wet<br>Shroud | Sample 4D<br>O - Wet<br>Towel | Sample 5D<br>O - Wet<br>Plastic | Sample 6D<br>O - Wet<br>Nitrile | Sample 7D<br>O - Wet<br>Silicone |

**Figure 10.** A diagram of the layout of a tray of tissue samples. Samples are divided into rows A-D and seven columns, each column containing one of the material coverings or the control samples. “AM” stands for adductor magnus, “O” stands for oblique muscles, “Dry” indicates no wetting solution, “Wet” indicates that the tissue was subjected to 0.5 mL of wetting solution.


**Figure 11.** The labeled tray and storage containers for all three tests feature redundant labeling to mitigate the risk of sample misplacement. Storage containers are anchored to the tray using blue painter’s tape.

After the tissues were extracted, the initial masses of each sample were recorded. The sets that were subjected to wetting solution were measured after the solution was applied. Samples were weighed using a Mettler AT400 digital balance (see Figure 12). The balance is in the Mason lab at OSU, while the samples remained in the OSU cadaver lab in between measurements. Since the two labs are in the same building, and time spent in the weighing room was minimized, it is assumed that differences with respect to temperature and humidity between the two labs are negligible, and therefore, the change of environments had a negligible effect on the dehydration rates of the samples.

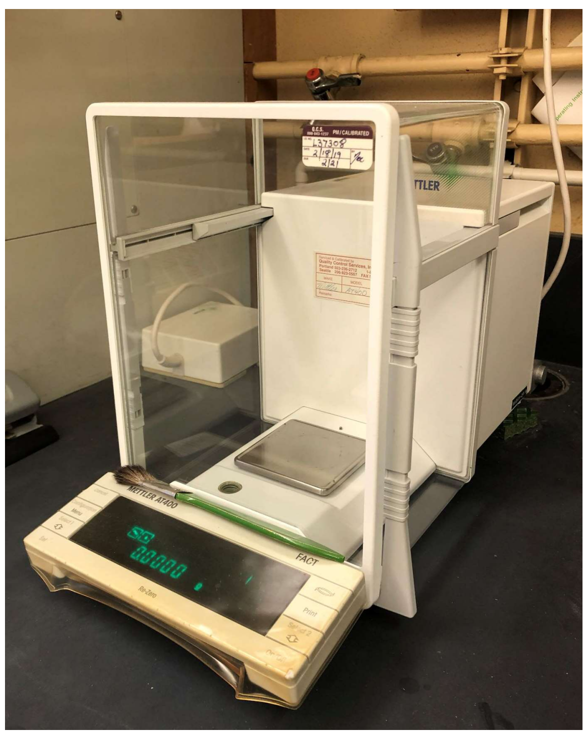


**Figure 12.** A Mettler AT499 digital balance was used to measure and record the mass of each sample.

Once initial masses were recorded, respective material coverings were applied to each sample. Coverings were only removed for measurement purposes and remained on the tissue samples at all other times.

For the next 51 hours, the masses of the samples were measured every 3 hours, except for 12-hour overnight time periods. This resulted in 12 data points per sample, per cadaver. In between measurements, the samples were strategically stored on a table at the center of one of the OSU anatomy lab rooms. The selected location is simultaneously farthest from the windows and the ventilation systems, both of which may impact the experimental environment and sample dehydration.

After the experiment, equipment was cleaned, and care was taken to ensure that all tissue samples were returned to the respective cadaver storage tank. The experimental methods were repeated with tissue samples from 3 different cadavers, for a total of 84 tissue samples.

**G. Data Processing & Statistical Analysis**

Raw mass measurements were converted to percent of original mass, respective to each sample. This decision operates under the assumption that at the starting point, all samples feature the same ratio for a given degree of wetness (dry versus wet) and a given muscle of origin (adductor magnus versus oblique muscles). The average percent of original mass was calculated from the three trials, as well as standard deviation and standard error for each sample measurement average (see Appendix B).

Subsequently, a single-factor ANOVA and multiple comparisons test were conducted (significance level of 0.05) on sample data corresponding to 12 hours post-extraction time. In the OSU anatomy lab, cadavers are subjected to wetting solutions and are stored for 12 hours overnight before rewetting; therefore, a focus is placed on the first twelve hours of sample measurements. It is assumed that the tissues will demonstrate the observed trends every time wetting solution is applied and the cadavers remain covered.

## III. RESULTS

Material performance was evaluated for each combination of muscle type and degree of wetness: dry adductor magnus (Figure 13), wet adductor magnus (Figure 14), dry oblique muscles (Figure 15), and wet oblique muscles (Figure 16).

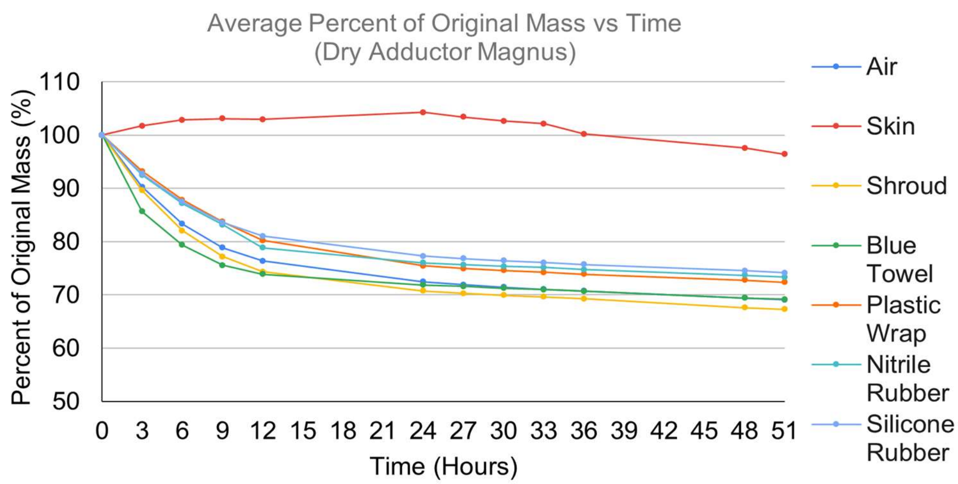


**Figure 13.** Dry Adductor magnus: The average percentages of original mass of dry adductor magnus samples generally exhibit an exponential decay over time. Samples covered in skin break this trend as mass tended to increase for several hours before any decrease.

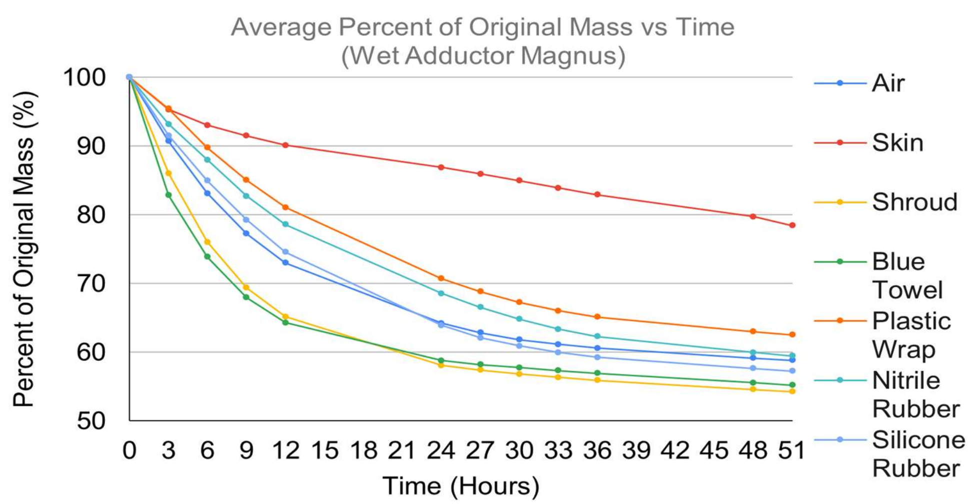


**Figure 14.** Wet Adductor Magnus: The average percentages of original mass of adductor magnus samples subjected to wetting solution generally exhibit an exponential decay over time.

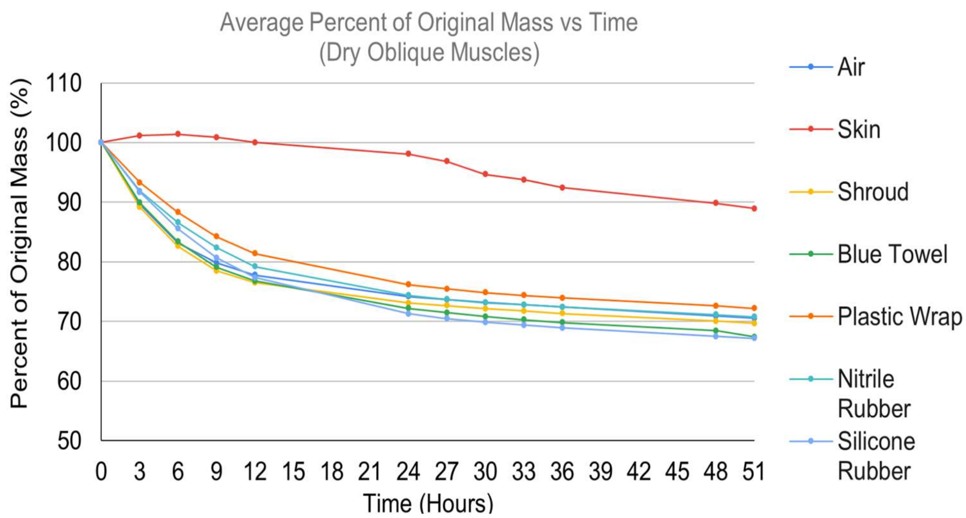


**Figure 15.** Dry Oblique Muscles: The average percentages of original mass of dry oblique muscle samples generally exhibit an exponential decay over time. Samples covered in skin break this trend as mass tended to increase for several hours before any decrease.

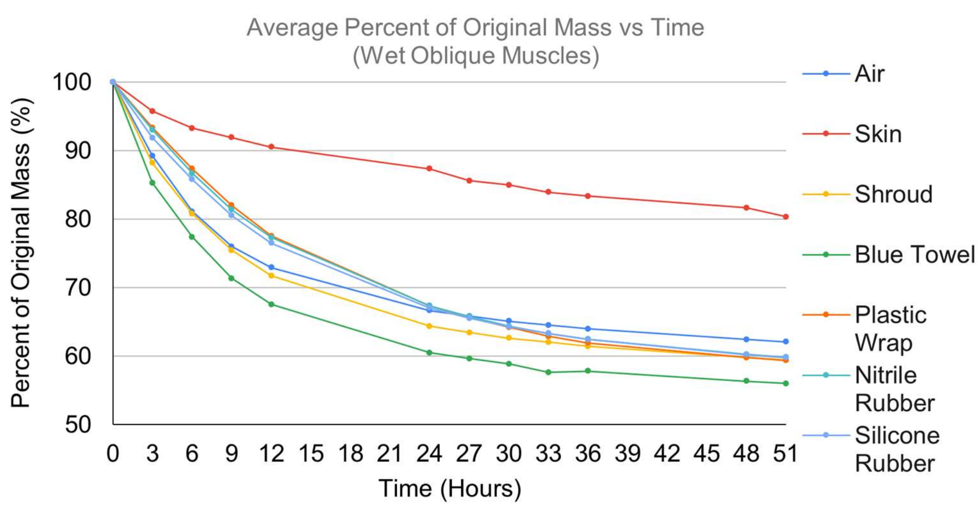


**Figure 16.** Wet Oblique Muscles: The average percentages of original mass of oblique muscle samples subjected to wetting solution generally exhibit an exponential decay over time.

Across the four combinations, skin is the only covering that demonstrated a statistically significant mass retainment when compared to samples exposed to air : by hour 12, dry adductor magnus covered in skin retained 26.6% more mass ($F(6,14) = 3.412$, $p$=.046), wet adductor magnus samples retained 17.1% more mass ($F(6,14) = 10.16$, $p$=.011), dry oblique muscle samples retained 22.2% more mass ($F(6,14) = 7.199$, $p$=.003), and wet oblique muscles samples retained 17.6% more mass ($F(6,14) = 14.09$, $p<.001$) compared to samples exposed to air.

Of tissues covered in skin, there is an observable difference in the trend of mass loss between wet and dry muscles. While wet samples lost mass consistently over time (Figures 14 and 16), dry samples gained mass before losing it again (Figures 13 and 15). The increase lasted for 24 hours in the adductor magnus sample and for 9 hours in the oblique muscle sample.

At hour 12 in all cases, the difference between the percentage of mass retained by tissue covered in skin and the next-most hydrated tissue is statistically significant; as seen in Figure 17, these values are 21.94% for the dry adductor magnus ($F(6,14) = 3.412$, $p=.131$), 9.06% for the wet adductor magnus ($F(6,14) = 10.16$, $p=.329$), 18.64% for the dry oblique muscles ($F(6,14) = 7.199$, $p=.012$), and 12.99% for the wet oblique muscles ($F(6,14) = 14.09$, $p=.004$).

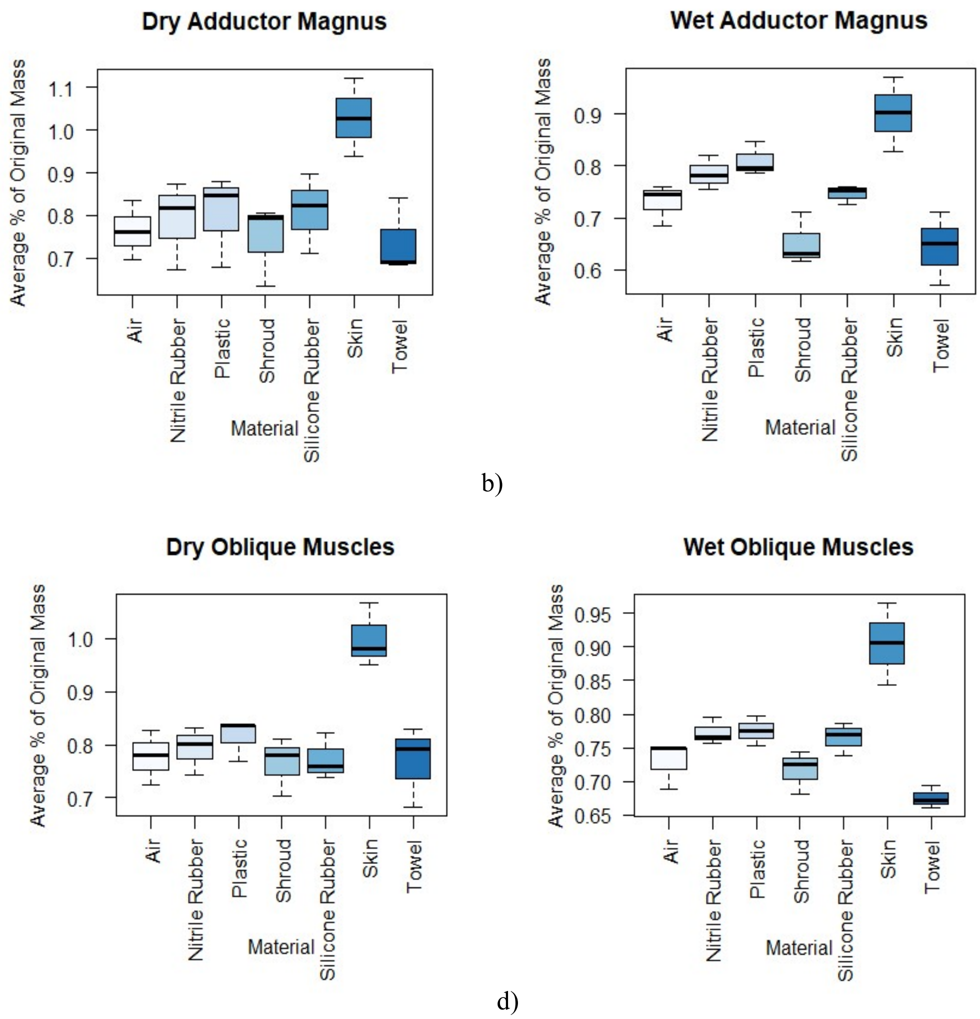


**Figure 17.** The results of the ANOVA test for each muscle-wetness combination feature the average percent of original mass for each sample type at hour 12. The box plots provide a visual comparison of the values with respect to the material used to cover each tissue.

As delineated by Figures 13 through 17, by hour 12, samples covered in plastic wrap, nitrile rubber, and silicone rubber, generally retained more mass than the samples in air in all four sample sets. On average, plastic wrap coverings preserved between 3.59% - 8.07% more tissue mass, nitrile rubber coverings preserved between 1.41% -5.58% more tissue mass, and silicone rubber coverings preserved between -0.4% and 4.66% more tissue mass. Those covered in towel or shroud experienced greater decreases in mass than the samples in air, in which air samples retained 1.1% to 7.8% more mass than those covered in shroud, and 1.01% to 8.69% more mass than those covered in towel. Excluding skin, nearly all of the differences between material performances are insignificant as they exhibit p-values above the 0.05 significance level (see Appendix C for the complete results of the ANOVA and multiple comparison tests).

Exceptions to this trend exist in the statistical analysis results of wet muscle samples at hour 12. In comparison to samples covered in towel, wet oblique muscle samples covered in nitrile rubber and plastic wrap retained significantly more mass (nitrile rubber: 9.72%, $F(6,14) = 10.16$, $p=.038$; plastic wrap: 9.96%, $p=.032$). Similarly, wet adductor magnus samples covered in plastic wrap preserved significantly more mass than those covered in towel and shroud, respectively ($F(6,14) = 10.16$, towel: -16.8%, $p=.013$; shroud: -15.9%, $p=.019$). Samples of the same muscle and wetness that were covered in nitrile rubber retained significantly more mass than those covered in towel (nitrile rubber: 14.3%, $F(6,14) = 10.16$, $p=.039$).

## IV. DISCUSSION

This study operates under the assumption that a change in mass is indicative of a change in hydration; therefore, all decreases or increases in tissue mass are interpreted as dehydration or rehydration compared to starting tissue water content, respectively. The goal of any cadaver covering is to preserve as much moisture as possible, that is, provide for the least amount of dehydration. Within twelve hours of tissue extraction, skin significantly outperformed all other material coverings.

In the case of dry samples, skin managed to rehydrate the tissue samples for several hours before permitting dehydration to occur. The superior performance of the skin may be attributed to its function of hydration maintenance. It is possible that there was a transfer of water from the hypodermis to the dry tissue; thus, rather than effectively preventing dehydration, the skin demonstrated to actively rehydrate the tissues. In line with this explanation, the wet tissue samples were already saturated with water; therefore, the skin only acted to optimally restrict evaporation. However, it is also possible that microscopic lipid transfer occurred along the same gradient, leading to the increase in mass seen in the dry tissue samples.

Though all differences between the performance of skin and the other coverings are statistically significant, there is stronger evidence that skin coverings have an impact on thinner muscles. Overall, these findings suggest that covering tissues in skin between periods of observation is a key practice in the effort to maintain hydrated muscles, especially for relatively thin muscles. Further studies should be conducted to determine the mechanism behind the increases in tissue mass observed in this experiment.

Despite the predictions of superior performance to current OSU methods, tissues covered in made of plastic wrap, nitrile rubber, and silicone maintained a generally insignificant amount of hydration above that of tissues exposed to air. Notably, with respect to wet muscle samples, tissues covered in nitrile rubber and plastic wrap maintained hydration better than those covered in towels and shrouds.

Muscle samples—whether wet or dry, thick or thin—that were covered in towel and shroud experienced more dehydration than samples exposed to air. These findings suggest that the dry towel and shroud coverings deployed in the OSU cadaver lab may be more harmful to the quality of muscles than neglecting to cover the tissues at all, likely absorbing moisture from the muscle samples faster than the moisture would have dried via unfacilitated evaporation.

# V. CONCLUSIONS

The results of this study exhibit that nitrile rubber, one of the candidate materials for a cadaver covering performs significantly better than two of the four dehydration-prevention coverings currently deployed in the OSU cadaver lab. With respect to muscles subjected to wetting solution, skin is the superior covering to nitrile rubber, there is no statistically significant difference between the performance of nitrile rubber and plastic wrap, and nitrile rubber prevents dehydration better than both towels and shroud.

## A. Recommendations

The outcome of this study led to a three-part recommendation of materials for cadaver tissue dehydration prevention.

1. Primarily, skin should be used to cover the cadaver for as long as possible. In OSU's case use, the skin is used as the main covering until students begin to study the cadavers in the Fall term. The skin should be applied to the tissues without intermediate materials (i.e., the internal side of the skin should be in direct contact with the skeletal muscles). Efforts should be made to continue to use the skin in between long periods of cadaver storage throughout the school year (overnight, over weekends, during extended breaks, etc.)

2. If the first suggestion is not feasible, the next recommendation for a primary covering is a combination of plastic wrap and nitrile rubber. Though the two demonstrated insignificant differences in performance, plastic wrap should be used to cover the majority of the cadaver as it has the advantage of forming to the contour of the body and minimizing air gaps, whereas the available 1/16 in. nitrile rubber did not feature an equivalent flexibility. A less-rigid form of nitrile rubber is found in the form of gloves used in the lab. Various sizes of these gloves can be used to cover the hands and feet of the cadaver. In terms of cost, a local department store sells plastic wrap for less than $0.02 per square foot, while 1/16 in. nitrile rubber is sold for $1.25 per square foot [13][14]. On a per-square foot basis, this is a significant difference; however, if the size of a covering is generously estimated to be 28 square feet, the more expensive nitrile rubber option only totals to a relatively low $35.00 per covering. To uphold respect and dignity for the donor, whole-body donation programs will ensure that any material that is not of the donor, outside of what is required for cremation, will be placed in biohazardous waste for disposal [15]. Respective environmental health and safety teams should be contacted to determine the reusability and sterilization of any material, such as a nitrile rubber sheet, in order to mitigate any potential for cross contamination (pers. [15].
3. The shroud should continue to be used to respect the presentation of the cadaver and shield views when necessary, but the material should not be in direct contact with the exposed tissues and should be saturated in the cadaver wetting solution at all times to prevent moisture absorption from the underlying cadaver. In place of the shroud, the lab directors may consider the use of a black plastic cover to achieve

the same goal of donor dignity, as outlined in the UMN cadaver lab instructions [6].

## B. Relevance

Prior to this study, OSU cadaver lab staff members selected combinations of materials and wetting solutions based on visual observation of the tissue dehydration. It was believed that skin is the ideal covering [16] followed by towels and shrouds saturated in wetting solution. This study provides concrete evidence that re-covering the cadavers in their respective skin is indeed the superior method for hydration maintenance. Moreover, the results shed light on the potentially damaging effects of towels and shrouds that may dry and absorb moisture from the cadaver tissues.

These findings are relevant to anatomy and physiology labs across the globe that attempt to minimize excessive dehydration in between periods of cadaver observation. As more steps are taken towards improved cadaver tissue hydration and maintenance, a first-hand view of intricacies of the human body will not only be made more available and clear to medical and non-medical students, alike. Most importantly, the families of whole-body donors can be confident that the opportunity of cadaver-based anatomical education is being utilized to its fullest and most dignified potential.

## C. Limitations & Considerations

A primary limitation of this study is the small sample size of each data point. Due to time constraints and muscle availability, only three tissue samples of a given muscle and wetness combination were subjected to each covering. Further research of these dehydration trends should consider a larger sample size in an effort to decrease variance and standard deviation values.

The physical size of the tissue samples is another limitation. With respect to a single muscle, the shape, size, and the initial masses of the samples varied depending on which section of the muscle the tissues were extracted from. Furthermore, as tissues began to dehydrate, relatively small pieces of the tissue separated from the sample; given the small size of the 10mm diameter punch biopsies, such tissue loss can significantly impact mass measurements. If resources allow, the 10mm diameter size should be increased so that uniformity is more attainable, and the separation of muscle strands will not dramatically impact overall mass readings.

Furthermore, the experiments should take place closer to initial cadaver dissection. The tissues from which samples were extracted have been subjected to dehydration prevention methods for seven months prior to this study. Conducting the experiments as soon as tissues are exposed to open air for the first time may reinforce the trends of dehydration depicted in this study, or new trends may be discovered.

The unforeseen rigidity of the selected rubbers may have impacted their ability to maintain tissue hydration. The thinnest nitrile and silicone rubbers available for purchase were 1/16 in. thick; though this is relatively thin, due to the small size of the punch biopsy and the small area within the storage container, the rubbers did not mold to the shape of the tissue samples in the same way plastic wrap or shroud did. A more flexible form of the rubbers may have produced different dehydration trends and should be considered in further research.

A final limitation of this study was the differing environments between rest and measurement. The tissues spent the time between mass measurements in a monitored environment, but they had to be transferred to a separate lab located one floor above that environment in order to be measured. Time periods of rest lasted almost three hours, while measurements took thirty to forty minutes to complete. The total time spent in the secondary environment may have impacted the dehydration rates of the tissue samples if its humidity or temperature was significantly different from that of the primary environment. Those who repeat this experiment are encouraged to measure the samples in their primary environment or monitor any secondary environments in order to mitigate assumptions with respect to environmental impact on test results.

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# VII. APPENDICES

## Appendix A: Temperature and Humidity Programming Codes & Output

This appendix includes the Arduino, Matlab, and Python programs that were used for the recording, writing, and extraction of temperature and humidity data for each day of testing, followed by the summarized data output by the Python code.

### 1. Arduino IDE Code for DHT11 Sensor readings

```
//ME451 Final Project Code
//Alexandria Herrera
//Fall 2020
//Reference codes: Sweep example (Arduino website) and Water Level
example (Elegoo Manual)

#include <Servo.h>  // using servo motor

int adc_id = 0;  // initial value
int OldVal = 400; // intial value for water level (ensures that a rise is not
detected during initial readings)

int norise = 1 ;     // variable to filter data; if the water level is decreasing,
norise = 1; for increasing, norise = 0

Servo myservo;  // allows for servo control

int degree = 0;    // variable to store the servo position

void setup() {
  myservo.attach(9);  // attaches the servo on pin 9 to the servo object

  Serial.begin(9600);  // Serial monitor will be used
}

void loop() {

  int value = analogRead(adc_id); // obtains adc values from water level sensor

  if (((OldVal > value) && ((OldVal - value) >= 0)))
  {
    OldVal = value;       // reassigns previous value
    norise = 1;   // water is decreasing, so norise remains = 1

    // Keep track of raw data
```

```
   Serial.print(millis());
   Serial.print(", ");
   Serial.print(value);
   Serial.print(", ");
   Serial.println(norise);
   delay(100);

   if (norise == 1)  // water level is decreasing
   {
     if (value <= 150) // first state ; less than or equal to 150 ; flag waving
     {
       int degree = 30; // sets degree value

       for (degree = 30; degree <= 150; degree += 1) { // goes from 30 to 150
degrees by 1 degree movements
         myservo.write(degree);              // servo goes to assigned degree
position
         delay(9);                      // pause for 9 ms before switching directions
       }
       for (degree = 150; degree >= 30; degree -= 1) { // goes from 150 to 30
degrees
         myservo.write(degree);              // servo goes to assigned degree
position
         delay(9);                         // pause for 9 ms before switching directions
       }
     }

     else if ( (value > 150) && (value <= 315)  )     // second state ; between
150 and 315 ; flag is in a vertical position
     {
       int degree = 90 ;
       myservo.write(degree); // raises the flag to a vertical position
     }

     else if ( value > 315 ) // third state ; above 315 ; flag is in a horizontal
opsition
     {
       int degree = 0;
       myservo.write(degree);    // lowers flag to horizontal position
     }
   }
 }

  else  if (((OldVal < value) && ((value - OldVal) > 50)))  // water level is
increasing significantly ; flag waving
  {
```

```
   int degree = 90;  // begin flag waving from 90 degree position

   norise = 0;   // data is filtered ; increasing water level indicates a rise, new
values beyond this are ignored
   OldVal = 0; // stops the other if loop from running

   // Keep track of raw data
   Serial.print(millis());
   Serial.print(", ");
   Serial.print(value);
   Serial.print(", ");
   Serial.println(norise);
   delay(100);

   for (degree = 90; degree <= 180; degree += 1) { // goes from 90 degrees to
180 degrees by 1 degree movements
     myservo.write(degree);              // servo goes to assigned degree position
     delay(9);                       // pause for 9 ms before switching directions
   }

   for (degree = 180; degree >= 90; degree -= 1) { // goes from 180 degrees to
90 degrees
     myservo.write(degree);              // servo goes to assigned degree position
     delay(9);                          // pause for 9 ms before switching directions
   }
  }
}
```

## 2. Matlab code for writing temperature and humidity data to a .txt file

```
% Code for Temp and Humidity Reading
% Alexandria Herrera
% Thesis 2021

% Close COM ports, clear data
b = instrfind();
fclose(b);
clear
clc

% Open serial info via COM4
a = serial("COM4", 'Baudrate', 9600);
fopen(a);
% Time out after 30 seconds
a.Timeout = 30;

% Continuous while loop
x = 1;

fid = fopen('DataTest_OvernightFinal.txt', 'a');

while x == 1

    % Data from serial
    data = fgets(a);
    % Convert to string
    string = convertCharsToStrings(data);
    % Write to txt file
    fprintf(fid, string);
    fprintf(fid, ' Time: %s\n ', datestr(now, 'HH:MM:SS'));
end

fclose(fid);
% Close COM4
fclose(a);
```

### 3. Python code for extracting .txt temperature and humidity data and presenting ranges for each day of testing

```
#!/usr/bin/env python3

def extract_from_txt(file_name):
    """Take in optional file name and return dictionary where the
    keys are words, and the respective sentiment scores are floats.
    If no file name is given, default to sentiment.txt
    :param file_name: name of txt file
    :return sent_dict: dictionary in which keys are words and values are
corresponding
    sentiment scores as floats"""

    # Create dictionary
    dictionary = {}

    # Temperature, humidity, time lists
    temp = []
    hum = []
    time = []

    # Open file
    with open(file_name, 'r') as file:

        # Iterate through rows, split where there is a space
        for row in file:

            split_string = row.split()

            if len(split_string) == 10:
                temp.append(split_string[2])
                hum.append(split_string[7])
                time.append(split_string[9])

            else:
                pass

        # Assign values to dictionary
        dictionary["Temperature"] = temp
        dictionary["Humidity"] = hum
        dictionary["Time"] = time

    return dictionary
```

```
if __name__ == '__main__':

    import matplotlib.pyplot as mpl

    # Data and corresponding test/day labels
    names = ['C3_Day1.txt', 'C3_Day2.txt', 'C3_Day3.txt', 'C1and2_Day1.txt',
'C1and2_Day2.txt', 'C1and2_Day3.txt']
    labels = ['Test 1, Day 1', 'Test 1, Day 2', 'Test 1, Day 3', 'Test 2/3, Day 1', 'Test
2/3, Day 2', 'Test 2/3, Day 3']

    for i in range(len(names)):
        # Extract data from txt files
        data = extract_from_txt(names[i])

        # Organize data
        times = data["Time"]
        temps = data["Temperature"]
        hums = data["Humidity"]

        # Identify max and min temperature and humidity
        max_temp = max(temps)
        min_temp = min(temps)
        max_hum = max(hums)
        min_hum = min(hums)

        # Label for printing
        day = labels[i]

        # Print temperature and humidity ranges for Test/Day
        print("\n {}: Temperature varied between {} and {} degrees
celsius.".format(day, min_temp, max_temp))
        print("\n   Humidity varied between {} and {} percent. \n".format(min_hum,
max_hum))
```

**4. Results of temperature and humidity data monitoring, as output by Python code in Appendix A-3**

```
C:\Users\arh09\miniconda3\python.exe
C:/Users/arh09/PycharmProjects/Thesis/ThesisCode.py

 Test 1, Day 1: Temperature varied between 20.0 and 21.0 degrees celsius.

   Humidity varied between 33.0 and 38.0 percent.


 Test 1, Day 2: Temperature varied between 20.0 and 21.0 degrees celsius.

   Humidity varied between 29.0 and 35.0 percent.


 Test 1, Day 3: Temperature varied between 20.0 and 21.0 degrees celsius.

   Humidity varied between 28.0 and 33.0 percent.


 Test 2/3, Day 1: Temperature varied between 20.0 and 22.0 degrees celsius.

   Humidity varied between 21.0 and 34.0 percent.


 Test 2/3, Day 2: Temperature varied between 20.0 and 21.0 degrees celsius.

   Humidity varied between 28.0 and 34.0 percent.


 Test 2/3, Day 3: Temperature varied between 19.0 and 21.0 degrees celsius.

   Humidity varied between 20.0 and 29.0 percent.


Process finished with exit code 0
```

## Appendix B. Raw & Processed Data

This appendix features the raw data values (mass, in grams) for each round of testing, followed by the calculated averages and standard error for each sample measurement.

**Table C-1.** Raw data values from Test 1, samples from cadaver tank #3

| Tank 3 | Sample 1 | | Sample 2 | | Sample 3 | | Sample 4 | | Sample 5 | | Sample 6 | | Sample 7 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Row a | | Row a | | Row a | | Row a | | Row a | | Row a | | Row a | |
| Measurement | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) |
| 1 | 0 | 0.6148 | 0 | 0.5285 | 0 | 0.8117 | 0 | 0.4799 | 0 | 0.6739 | 0 | 0.4076 | 0 | 0.3501 |
| 2 | 3.05 | 0.5634 | 3.05 | 0.5148 | 3.05 | 0.7367 | 3.05 | 0.4433 | 3.05 | 0.6391 | 3.05 | 0.3849 | 3.05 | 0.3328 |
| 3 | 6 | 0.5262 | 6 | 0.5084 | 6 | 0.6951 | 6 | 0.424 | 6 | 0.6124 | 6 | 0.3743 | 6 | 0.3246 |
| 4 | 9 | 0.493 | 9 | 0.5038 | 9 | 0.6646 | 9 | 0.4112 | 9 | 0.5892 | 9 | 0.3644 | 9 | 0.3189 |
| 5 | 12 | 0.4674 | 12 | 0.4959 | 12 | 0.6434 | 12 | 0.4039 | 12 | 0.571 | 12 | 0.3332 | 12 | 0.3145 |
| 6 | 24 | 0.422 | 24 | 0.4742 | 24 | 0.6031 | 24 | 0.3917 | 24 | 0.5362 | 24 | 0.3224 | 24 | 0.3066 |
| 7 | 27 | 0.4165 | 27 | 0.4663 | 27 | 0.5986 | 27 | 0.3902 | 27 | 0.5313 | 27 | 0.3199 | 27 | 0.3043 |
| 8 | 30 | 0.4119 | 30 | 0.4514 | 30 | 0.5948 | 30 | 0.3873 | 30 | 0.5267 | 30 | 0.3183 | 30 | 0.3017 |
| 9 | 33 | 0.4091 | 33 | 0.4495 | 33 | 0.5923 | 33 | 0.3863 | 33 | 0.5235 | 33 | 0.3172 | 33 | 0.3002 |
| 10 | 36 | 0.4067 | 36 | 0.4449 | 36 | 0.5896 | 36 | 0.3855 | 36 | 0.5208 | 36 | 0.3162 | 36 | 0.2985 |
| 11 | 48 | 0.4002 | 48 | 0.4344 | 48 | 0.5718 | 48 | 0.3805 | 48 | 0.5129 | 48 | 0.3131 | 48 | 0.2947 |
| 12 | 51 | 0.399 | 51 | 0.4312 | 51 | 0.5713 | 51 | 0.3794 | 51 | 0.5111 | 51 | 0.3122 | 51 | 0.2929 |
| | Row b | | Row b | | Row b | | Row b | | Row b | | Row b | | Row b | |
| Measurement | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) |
| 1 | 0 | 0.7651 | 0 | 1.0669 | 0 | 0.7953 | 0 | 0.6691 | 0 | 0.6911 | 0 | 0.8701 | 0 | 0.6592 |
| 2 | 3.05 | 0.7013 | 3.05 | 0.9608 | 3.05 | 0.7237 | 3.05 | 0.5828 | 3.05 | 0.6445 | 3.05 | 0.7942 | 3.05 | 0.598 |
| 3 | 6 | 0.6517 | 6 | 0.9264 | 6 | 0.6542 | 6 | 0.5348 | 6 | 0.6171 | 6 | 0.7543 | 6 | 0.5608 |
| 4 | 9 | 0.6083 | 9 | 0.8977 | 9 | 0.6038 | 9 | 0.499 | 9 | 0.5784 | 9 | 0.7 | 9 | 0.5297 |
| 5 | 12 | 0.5704 | 12 | 0.8833 | 12 | 0.5651 | 12 | 0.4751 | 12 | 0.5509 | 12 | 0.6572 | 12 | 0.5014 |
| 6 | 24 | 0.4916 | 24 | 0.8226 | 24 | 0.4897 | 24 | 0.4315 | 24 | 0.487 | 24 | 0.572 | 24 | 0.4356 |
| 7 | 27 | 0.4782 | 27 | 0.8085 | 27 | 0.4817 | 27 | 0.4258 | 27 | 0.4787 | 27 | 0.5541 | 27 | 0.4258 |
| 8 | 30 | 0.4678 | 30 | 0.7924 | 30 | 0.4753 | 30 | 0.4209 | 30 | 0.4711 | 30 | 0.5361 | 30 | 0.4168 |
| 9 | 33 | 0.4617 | 33 | 0.7834 | 33 | 0.4707 | 33 | 0.4172 | 33 | 0.4669 | 33 | 0.5217 | 33 | 0.4114 |
| 10 | 36 | 0.4575 | 36 | 0.7767 | 36 | 0.467 | 36 | 0.4137 | 36 | 0.4631 | 36 | 0.513 | 36 | 0.4065 |
| 11 | 48 | 0.4481 | 48 | 0.767 | 48 | 0.4562 | 48 | 0.4042 | 48 | 0.4531 | 48 | 0.4998 | 48 | 0.3954 |
| 12 | 51 | 0.4463 | 51 | 0.7549 | 51 | 0.4545 | 51 | 0.4014 | 51 | 0.4504 | 51 | 0.4973 | 51 | 0.393 |
| | Row c | | Row c | | Row c | | Row c | | Row c | | Row c | | Row c | |
| Measurement | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) |
| 1 | 0 | 0.5947 | 0 | 0.5998 | 0 | 0.4842 | 0 | 0.42 | 0 | 0.4939 | 0 | 0.5326 | 0 | 0.417 |
| 2 | 3.05 | 0.5484 | 3.05 | 0.5888 | 3.05 | 0.44 | 3.05 | 0.3827 | 3.05 | 0.4654 | 3.05 | 0.4934 | 3.05 | 0.3794 |
| 3 | 6 | 0.5157 | 6 | 0.5815 | 6 | 0.4138 | 6 | 0.3602 | 6 | 0.4458 | 6 | 0.4661 | 6 | 0.3539 |
| 4 | 9 | 0.4877 | 9 | 0.5755 | 9 | 0.3926 | 9 | 0.3434 | 9 | 0.4284 | 9 | 0.4446 | 9 | 0.3334 |
| 5 | 12 | 0.4646 | 12 | 0.5706 | 12 | 0.3781 | 12 | 0.3322 | 12 | 0.413 | 12 | 0.4273 | 12 | 0.3171 |
| 6 | 24 | 0.4249 | 24 | 0.5555 | 24 | 0.3516 | 24 | 0.3032 | 24 | 0.3859 | 24 | 0.3951 | 24 | 0.288 |
| 7 | 27 | 0.4198 | 27 | 0.5498 | 27 | 0.3482 | 27 | 0.2977 | 27 | 0.381 | 27 | 0.3903 | 27 | 0.2841 |
| 8 | 30 | 0.4149 | 30 | 0.5449 | 30 | 0.3442 | 30 | 0.2929 | 30 | 0.3759 | 30 | 0.3857 | 30 | 0.2797 |
| 9 | 33 | 0.4107 | 33 | 0.5413 | 33 | 0.3418 | 33 | 0.2889 | 33 | 0.3721 | 33 | 0.3827 | 33 | 0.277 |
| 10 | 36 | 0.4074 | 36 | 0.5342 | 36 | 0.3396 | 36 | 0.2859 | 36 | 0.3696 | 36 | 0.3799 | 36 | 0.2744 |
| 11 | 48 | 0.3987 | 48 | 0.52 | 48 | 0.3344 | 48 | 0.2786 | 48 | 0.3617 | 48 | 0.373 | 48 | 0.2678 |
| 12 | 51 | 0.3964 | 51 | 0.5147 | 51 | 0.3328 | 51 | 0.2764 | 51 | 0.3594 | 51 | 0.371 | 51 | 0.2665 |
| | Row d | | Row d | | Row d | | Row d | | Row d | | Row d | | Row d | |
| Measurement | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) |
| 1 | 0 | 0.8069 | 0 | 0.5588 | 0 | 0.8274 | 0 | 0.5483 | 0 | 0.6846 | 0 | 0.6395 | 0 | 0.5855 |
| 2 | 3.05 | 0.7431 | 3.05 | 0.5058 | 3.05 | 0.7524 | 3.05 | 0.4772 | 3.05 | 0.6342 | 3.05 | 0.5988 | 3.05 | 0.5375 |
| 3 | 6 | 0.6832 | 6 | 0.4883 | 6 | 0.6984 | 6 | 0.4387 | 6 | 0.6028 | 6 | 0.5642 | 6 | 0.5048 |
| 4 | 9 | 0.6371 | 9 | 0.4793 | 9 | 0.6523 | 9 | 0.4037 | 9 | 0.5645 | 9 | 0.5356 | 9 | 0.476 |
| 5 | 12 | 0.6043 | 12 | 0.4716 | 12 | 0.616 | 12 | 0.3808 | 12 | 0.5301 | 12 | 0.5081 | 12 | 0.4502 |
| 6 | 24 | 0.5313 | 24 | 0.4399 | 24 | 0.5355 | 24 | 0.3382 | 24 | 0.4458 | 24 | 0.4369 | 24 | 0.385 |
| 7 | 27 | 0.5228 | 27 | 0.4313 | 27 | 0.5257 | 27 | 0.3327 | 27 | 0.4338 | 27 | 0.4244 | 27 | 0.3744 |
| 8 | 30 | 0.5142 | 30 | 0.429 | 30 | 0.5167 | 30 | 0.3273 | 30 | 0.4228 | 30 | 0.413 | 30 | 0.3647 |
| 9 | 33 | 0.5087 | 33 | 0.426 | 33 | 0.5108 | 33 | 0.3237 | 33 | 0.4155 | 33 | 0.4055 | 33 | 0.3582 |
| 10 | 36 | 0.5039 | 36 | 0.4218 | 36 | 0.5051 | 36 | 0.3207 | 36 | 0.4095 | 36 | 0.3992 | 36 | 0.3522 |
| 11 | 48 | 0.4908 | 48 | 0.4097 | 48 | 0.4919 | 48 | 0.312 | 48 | 0.396 | 48 | 0.3842 | 48 | 0.3379 |
| 12 | 51 | 0.4897 | 51 | 0.4051 | 51 | 0.4888 | 51 | 0.3099 | 51 | 0.3935 | 51 | 0.3809 | 51 | 0.3342 |

**Table C-2.** Raw data from Test 2, samples from cadaver tank #2

| Tank 2 | Sample 1 | | Sample 2 | | Sample 3 | | Sample 4 | | Sample 5 | | Sample 6 | | Sample 7 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Row a | | Row a | | Row a | | Row a | | Row a | | Row a | | Row a | |
| Measurement | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) |
| 1 | 0 | 0.6507 | 0 | 0.4225 | 0 | 0.5356 | 0 | 0.4705 | 0 | 0.2231 | 0 | 0.281 | 0 | 0.4188 |
| 2 | 3 | 0.6074 | 3 | 0.4474 | 3 | 0.4915 | 3 | 0.3641 | 3 | 0.2109 | 3 | 0.2635 | 3 | 0.3901 |
| 3 | 6 | 0.5759 | 6 | 0.462 | 6 | 0.46 | 6 | 0.3393 | 6 | 0.2029 | 6 | 0.2536 | 6 | 0.3677 |
| 4 | 9 | 0.5565 | 9 | 0.468 | 9 | 0.4425 | 9 | 0.3272 | 9 | 0.1993 | 9 | 0.2479 | 9 | 0.3537 |
| 5 | 12 | 0.5429 | 12 | 0.4743 | 12 | 0.4311 | 12 | 0.3216 | 12 | 0.1965 | 12 | 0.2458 | 12 | 0.3444 |
| 6 | 24 | 0.521 | 24 | 0.4848 | 24 | 0.4197 | 24 | 0.3167 | 24 | 0.1939 | 24 | 0.2439 | 24 | 0.3318 |
| 7 | 27 | 0.5172 | 27 | 0.4791 | 27 | 0.4169 | 27 | 0.3151 | 27 | 0.1933 | 27 | 0.2432 | 27 | 0.3303 |
| 8 | 30 | 0.5147 | 30 | 0.4751 | 30 | 0.4138 | 30 | 0.3139 | 30 | 0.1925 | 30 | 0.2424 | 30 | 0.3288 |
| 9 | 33 | 0.5115 | 33 | 0.4687 | 33 | 0.412 | 33 | 0.312 | 33 | 0.192 | 33 | 0.2417 | 33 | 0.3274 |
| 10 | 36 | 0.5093 | 36 | 0.448 | 36 | 0.4098 | 36 | 0.3106 | 36 | 0.1909 | 36 | 0.2402 | 36 | 0.326 |
| 11 | 48 | 0.4979 | 48 | 0.4174 | 48 | 0.4002 | 48 | 0.3024 | 48 | 0.1879 | 48 | 0.2358 | 48 | 0.3204 |
| 12 | 51 | 0.4947 | 51 | 0.4086 | 51 | 0.397 | 51 | 0.3002 | 51 | 0.1865 | 51 | 0.2342 | 51 | 0.3183 |
| | Row b | | Row b | | Row b | | Row b | | Row b | | Row b | | Row b | |
| Measurement | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) |
| 1 | 0 | 0.4983 | 0 | 0.7253 | 0 | 0.4358 | 0 | 0.566 | 0 | 0.6157 | 0 | 0.7109 | 0 | 0.5379 |
| 2 | 3 | 0.4493 | 3 | 0.7284 | 3 | 0.3614 | 3 | 0.453 | 3 | 0.6151 | 3 | 0.6721 | 3 | 0.4937 |
| 3 | 6 | 0.4134 | 6 | 0.7233 | 6 | 0.3162 | 6 | 0.4084 | 6 | 0.5747 | 6 | 0.6372 | 6 | 0.4575 |
| 4 | 9 | 0.3918 | 9 | 0.7176 | 9 | 0.2902 | 9 | 0.3834 | 9 | 0.5449 | 9 | 0.6083 | 9 | 0.4285 |
| 5 | 12 | 0.3786 | 12 | 0.705 | 12 | 0.2746 | 12 | 0.3683 | 12 | 0.5223 | 12 | 0.5842 | 12 | 0.4046 |
| 6 | 24 | 0.3555 | 24 | 0.6796 | 24 | 0.2524 | 24 | 0.3431 | 24 | 0.4759 | 24 | 0.5333 | 24 | 0.3627 |
| 7 | 27 | 0.3518 | 27 | 0.672 | 27 | 0.2497 | 27 | 0.3392 | 27 | 0.4673 | 27 | 0.5243 | 27 | 0.3554 |
| 8 | 30 | 0.3488 | 30 | 0.664 | 30 | 0.2473 | 30 | 0.3369 | 30 | 0.4617 | 30 | 0.517 | 30 | 0.3519 |
| 9 | 33 | 0.3466 | 33 | 0.6501 | 33 | 0.2455 | 33 | 0.3338 | 33 | 0.4553 | 33 | 0.5109 | 33 | 0.3484 |
| 10 | 36 | 0.3437 | 36 | 0.6381 | 36 | 0.2432 | 36 | 0.3316 | 36 | 0.4507 | 36 | 0.5063 | 36 | 0.3457 |
| 11 | 48 | 0.3351 | 48 | 0.5799 | 48 | 0.2368 | 48 | 0.323 | 48 | 0.4369 | 48 | 0.492 | 48 | 0.338 |
| 12 | 51 | 0.3329 | 51 | 0.5684 | 51 | 0.2349 | 51 | 0.3208 | 51 | 0.433 | 51 | 0.4885 | 51 | 0.3355 |
| | Row c | | Row c | | Row c | | Row c | | Row c | | Row c | | Row c | |
| Measurement | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) |
| 1 | 0 | 0.4229 | 0 | 0.489 | 0 | 0.394 | 0 | 0.3915 | 0 | 0.4287 | 0 | 0.3071 | 0 | 0.5064 |
| 2 | 3 | 0.3833 | 3 | 0.4982 | 3 | 0.3591 | 3 | 0.3592 | 3 | 0.4014 | 3 | 0.2844 | 3 | 0.4731 |
| 3 | 6 | 0.3631 | 6 | 0.4968 | 6 | 0.3372 | 6 | 0.3394 | 6 | 0.3807 | 6 | 0.2726 | 6 | 0.4476 |
| 4 | 9 | 0.3543 | 9 | 0.4899 | 9 | 0.3245 | 9 | 0.3289 | 9 | 0.3657 | 9 | 0.2644 | 9 | 0.4282 |
| 5 | 12 | 0.35 | 12 | 0.48 | 12 | 0.3191 | 12 | 0.3251 | 12 | 0.3584 | 12 | 0.2551 | 12 | 0.4168 |
| 6 | 24 | 0.3414 | 24 | 0.4532 | 24 | 0.3096 | 24 | 0.316 | 24 | 0.3415 | 24 | 0.2472 | 24 | 0.3959 |
| 7 | 27 | 0.3401 | 27 | 0.4419 | 27 | 0.3082 | 27 | 0.3144 | 27 | 0.3397 | 27 | 0.2456 | 27 | 0.3924 |
| 8 | 30 | 0.3386 | 30 | 0.4312 | 30 | 0.3071 | 30 | 0.3126 | 30 | 0.3378 | 30 | 0.2444 | 30 | 0.3901 |
| 9 | 33 | 0.3373 | 33 | 0.4219 | 33 | 0.3057 | 33 | 0.3113 | 33 | 0.3368 | 33 | 0.2434 | 33 | 0.3882 |
| 10 | 36 | 0.3365 | 36 | 0.4122 | 36 | 0.3044 | 36 | 0.3101 | 36 | 0.3353 | 36 | 0.2424 | 36 | 0.3864 |
| 11 | 48 | 0.3303 | 48 | 0.388 | 48 | 0.2998 | 48 | 0.3046 | 48 | 0.3293 | 48 | 0.2387 | 48 | 0.3797 |
| 12 | 51 | 0.3286 | 51 | 0.3824 | 51 | 0.2986 | 51 | 0.2963 | 51 | 0.3281 | 51 | 0.2375 | 51 | 0.3783 |
| | Row d | | Row d | | Row d | | Row d | | Row d | | Row d | | Row d | |
| Measurement | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) |
| 1 | 0 | 0.376 | 0 | 0.5899 | 0 | 0.4385 | 0 | 0.4317 | 0 | 0.4765 | 0 | 0.5091 | 0 | 0.5449 |
| 2 | 3 | 0.3288 | 3 | 0.5788 | 3 | 0.373 | 3 | 0.3602 | 3 | 0.445 | 3 | 0.4717 | 3 | 0.5053 |
| 3 | 6 | 0.3016 | 6 | 0.5572 | 6 | 0.3427 | 6 | 0.3228 | 6 | 0.416 | 6 | 0.4384 | 6 | 0.4727 |
| 4 | 9 | 0.2884 | 9 | 0.5476 | 9 | 0.3268 | 9 | 0.3019 | 9 | 0.3961 | 9 | 0.411 | 9 | 0.4481 |
| 5 | 12 | 0.2824 | 12 | 0.5344 | 12 | 0.3182 | 12 | 0.2901 | 12 | 0.3801 | 12 | 0.3902 | 12 | 0.4288 |
| 6 | 24 | 0.2714 | 24 | 0.5162 | 24 | 0.3024 | 24 | 0.2723 | 24 | 0.3468 | 24 | 0.3462 | 24 | 0.3902 |
| 7 | 27 | 0.2697 | 27 | 0.4977 | 27 | 0.3008 | 27 | 0.2695 | 27 | 0.3408 | 27 | 0.3383 | 27 | 0.3838 |
| 8 | 30 | 0.2679 | 30 | 0.4866 | 30 | 0.2983 | 30 | 0.2671 | 30 | 0.3329 | 30 | 0.3321 | 30 | 0.3789 |
| 9 | 33 | 0.2663 | 33 | 0.4781 | 33 | 0.2968 | 33 | 0.2564 | 33 | 0.3265 | 33 | 0.3274 | 33 | 0.3749 |
| 10 | 36 | 0.2649 | 36 | 0.4702 | 36 | 0.2948 | 36 | 0.2638 | 36 | 0.3218 | 36 | 0.3237 | 36 | 0.3712 |
| 11 | 48 | 0.2595 | 48 | 0.4478 | 48 | 0.2888 | 48 | 0.2579 | 48 | 0.311 | 48 | 0.313 | 48 | 0.3622 |
| 12 | 51 | 0.258 | 51 | 0.4373 | 51 | 0.2871 | 51 | 0.2564 | 51 | 0.3091 | 51 | 0.3111 | 51 | 0.3605 |

**Table C-3.** Raw data from Test 3, samples from cadaver tank #1

| Tank 1 | Sample 1 | | Sample 2 | | Sample 3 | | Sample 4 | | Sample 5 | | Sample 6 | | Sample 7 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Row a | | Row a | | Row a | | Row a | | Row a | | Row a | | Row a | |
| Measurement | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) |
| 1 | 0 | 0.484 | 0 | 0.5125 | 0 | 0.5223 | 0 | 0.5149 | 0 | 0.4851 | 0 | 0.356 | 0 | 0.4397 |
| 2 | 3 | 0.4156 | 3 | 0.5222 | 3 | 0.4505 | 3 | 0.449 | 3 | 0.4377 | 3 | 0.3177 | 3 | 0.3959 |
| 3 | 6 | 0.3674 | 6 | 0.5278 | 6 | 0.3894 | 6 | 0.3998 | 6 | 0.396 | 6 | 0.2828 | 6 | 0.3602 |
| 4 | 9 | 0.3429 | 9 | 0.5285 | 9 | 0.3497 | 9 | 0.3678 | 9 | 0.3609 | 9 | 0.2557 | 9 | 0.3306 |
| 5 | 12 | 0.337 | 12 | 0.5268 | 12 | 0.3307 | 12 | 0.3556 | 12 | 0.3291 | 12 | 0.2396 | 12 | 0.3122 |
| 6 | 24 | 0.3321 | 24 | 0.5555 | 24 | 0.3107 | 24 | 0.3428 | 24 | 0.2902 | 24 | 0.2212 | 24 | 0.2859 |
| 7 | 27 | 0.3316 | 27 | 0.5566 | 27 | 0.3098 | 27 | 0.3421 | 27 | 0.2881 | 27 | 0.2205 | 27 | 0.2844 |
| 8 | 30 | 0.3306 | 30 | 0.5643 | 30 | 0.3091 | 30 | 0.3411 | 30 | 0.2875 | 30 | 0.2197 | 30 | 0.2838 |
| 9 | 33 | 0.3292 | 33 | 0.5658 | 33 | 0.3081 | 33 | 0.3404 | 33 | 0.2861 | 33 | 0.2192 | 33 | 0.2822 |
| 10 | 36 | 0.328 | 36 | 0.5656 | 36 | 0.3066 | 36 | 0.3387 | 36 | 0.2852 | 36 | 0.218 | 36 | 0.2814 |
| 11 | 48 | 0.3225 | 48 | 0.5723 | 48 | 0.3009 | 48 | 0.3329 | 48 | 0.2808 | 48 | 0.2148 | 48 | 0.277 |
| 12 | 51 | 0.3207 | 51 | 0.5684 | 51 | 0.2999 | 51 | 0.3326 | 51 | 0.2795 | 51 | 0.2139 | 51 | 0.2757 |

| | Row b | | Row b | | Row b | | Row b | | Row b | | Row b | | Row b | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Measurement | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) |
| 1 | 0 | 0.8276 | 0 | 0.668 | 0 | 0.562 | 0 | 0.5175 | 0 | 0.5954 | 0 | 0.8017 | 0 | 0.6523 |
| 2 | 3 | 0.7476 | 3 | 0.6375 | 3 | 0.4729 | 3 | 0.4211 | 3 | 0.5548 | 3 | 0.7515 | 3 | 0.6009 |
| 3 | 6 | 0.6719 | 6 | 0.6185 | 6 | 0.4116 | 6 | 0.3599 | 6 | 0.5161 | 6 | 0.7034 | 6 | 0.5534 |
| 4 | 9 | 0.6092 | 9 | 0.6108 | 9 | 0.3686 | 9 | 0.3186 | 9 | 0.4939 | 9 | 0.6585 | 9 | 0.5077 |
| 5 | 12 | 0.567 | 12 | 0.6041 | 12 | 0.3456 | 12 | 0.2944 | 12 | 0.4686 | 12 | 0.6261 | 12 | 0.4727 |
| 6 | 24 | 0.4723 | 24 | 0.6008 | 24 | 0.3081 | 24 | 0.2654 | 24 | 0.3837 | 24 | 0.5204 | 24 | 0.3799 |
| 7 | 27 | 0.4591 | 27 | 0.5972 | 27 | 0.3054 | 27 | 0.264 | 27 | 0.365 | 27 | 0.4989 | 27 | 0.3632 |
| 8 | 30 | 0.45 | 30 | 0.595 | 30 | 0.3033 | 30 | 0.2635 | 30 | 0.3488 | 30 | 0.4816 | 30 | 0.3526 |
| 9 | 33 | 0.4435 | 33 | 0.5925 | 33 | 0.3012 | 33 | 0.262 | 33 | 0.3368 | 33 | 0.4668 | 33 | 0.3437 |
| 10 | 36 | 0.439 | 36 | 0.5879 | 36 | 0.2992 | 36 | 0.2608 | 36 | 0.3285 | 36 | 0.4546 | 36 | 0.3381 |
| 11 | 48 | 0.4272 | 48 | 0.5835 | 48 | 0.2927 | 48 | 0.2548 | 48 | 0.3125 | 48 | 0.4266 | 48 | 0.3269 |
| 12 | 51 | 0.4248 | 51 | 0.5757 | 51 | 0.2911 | 51 | 0.2533 | 51 | 0.3105 | 51 | 0.4214 | 51 | 0.3251 |

| | Row c | | Row c | | Row c | | Row c | | Row c | | Row c | | Row c | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Measurement | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) |
| 1 | 0 | 0.315 | 0 | 0.4438 | 0 | 0.3135 | 0 | 0.4273 | 0 | 0.4754 | 0 | 0.3497 | 0 | 0.3953 |
| 2 | 3 | 0.2709 | 3 | 0.4592 | 3 | 0.2681 | 3 | 0.3714 | 3 | 0.4377 | 3 | 0.316 | 3 | 0.3585 |
| 3 | 6 | 0.2419 | 6 | 0.469 | 6 | 0.2407 | 6 | 0.332 | 6 | 0.4079 | 6 | 0.2921 | 6 | 0.3298 |
| 4 | 9 | 0.2323 | 9 | 0.4729 | 9 | 0.2257 | 9 | 0.3055 | 9 | 0.3833 | 9 | 0.2713 | 9 | 0.3061 |
| 5 | 12 | 0.2282 | 12 | 0.4738 | 12 | 0.2208 | 12 | 0.2912 | 12 | 0.3656 | 12 | 0.2597 | 12 | 0.2914 |
| 6 | 24 | 0.2216 | 24 | 0.4832 | 24 | 0.2135 | 24 | 0.2718 | 24 | 0.3364 | 24 | 0.2392 | 24 | 0.2633 |
| 7 | 27 | 0.2205 | 27 | 0.4816 | 27 | 0.2126 | 27 | 0.2699 | 27 | 0.3327 | 27 | 0.2371 | 27 | 0.2604 |
| 8 | 30 | 0.2197 | 30 | 0.4657 | 30 | 0.2112 | 30 | 0.2683 | 30 | 0.3307 | 30 | 0.2358 | 30 | 0.2586 |
| 9 | 33 | 0.219 | 33 | 0.465 | 33 | 0.2103 | 33 | 0.2671 | 33 | 0.3289 | 33 | 0.2353 | 33 | 0.2572 |
| 10 | 36 | 0.2177 | 36 | 0.4616 | 36 | 0.2089 | 36 | 0.2657 | 36 | 0.3273 | 36 | 0.2344 | 36 | 0.2558 |
| 11 | 48 | 0.2129 | 48 | 0.459 | 48 | 0.2037 | 48 | 0.2613 | 48 | 0.3219 | 48 | 0.2296 | 48 | 0.2499 |
| 12 | 51 | 0.2116 | 51 | 0.4562 | 51 | 0.2023 | 51 | 0.2595 | 51 | 0.32 | 51 | 0.2284 | 51 | 0.2486 |

| | Row d | | Row d | | Row d | | Row d | | Row d | | Row d | | Row d | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Measurement | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start (hr) | Mass (g) | Time from start | Mass |
| 1 | 0 | 0.4688 | 0 | 0.6272 | 0 | 0.6906 | 0 | 0.6861 | 0 | 0.3938 | 0 | 0.4769 | 0 | 0.4154 |
| 2 | 3 | 0.4132 | 3 | 0.6187 | 3 | 0.6116 | 3 | 0.5855 | 3 | 0.3699 | 3 | 0.4424 | 3 | 0.3781 |
| 3 | 6 | 0.3673 | 6 | 0.6144 | 6 | 0.551 | 6 | 0.5302 | 6 | 0.3411 | 6 | 0.4087 | 6 | 0.3504 |
| 4 | 9 | 0.3386 | 9 | 0.609 | 9 | 0.504 | 9 | 0.4831 | 9 | 0.3165 | 9 | 0.3797 | 9 | 0.3239 |
| 5 | 12 | 0.3224 | 12 | 0.6054 | 12 | 0.4707 | 12 | 0.453 | 12 | 0.2967 | 12 | 0.3612 | 12 | 0.3069 |
| 6 | 24 | 0.2904 | 24 | 0.6006 | 24 | 0.4099 | 24 | 0.3894 | 24 | 0.2521 | 24 | 0.3133 | 24 | 0.2647 |
| 7 | 27 | 0.2861 | 27 | 0.5976 | 27 | 0.4016 | 27 | 0.3823 | 27 | 0.244 | 27 | 0.3071 | 27 | 0.2582 |
| 8 | 30 | 0.2827 | 30 | 0.5996 | 30 | 0.3963 | 30 | 0.3776 | 30 | 0.2401 | 30 | 0.3016 | 30 | 0.2536 |
| 9 | 33 | 0.2796 | 33 | 0.5928 | 33 | 0.3913 | 33 | 0.3731 | 33 | 0.2339 | 33 | 0.2964 | 33 | 0.2492 |
| 10 | 36 | 0.2769 | 36 | 0.5946 | 36 | 0.3866 | 36 | 0.3696 | 36 | 0.23 | 36 | 0.2926 | 36 | 0.245 |
| 11 | 48 | 0.269 | 48 | 0.6005 | 48 | 0.3737 | 48 | 0.3594 | 48 | 0.2214 | 48 | 0.2825 | 48 | 0.2345 |
| 12 | 51 | 0.2671 | 51 | 0.5918 | 51 | 0.3706 | 51 | 0.3572 | 51 | 0.2195 | 51 | 0.2806 | 51 | 0.2325 |

**Table C-4.** Average percentage of original mass calculated for each sample measurement

| Average Percentage of Original Mass (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Air | Skin | Shroud | Blue Towel | Plastic Wrap | Nitrile Rubber | Silicone Rubber |
| | | Sample 1 | Sample 2 | Sample 3 | Sample 4 | Sample 5 | Sample 6 | Sample 7 |
| Measurement | Time | Row a - Averages | | | | | | |
| 1 | 0 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| 2 | 3 | 90.28 | 101.73 | 89.59 | 85.65 | 93.20 | 92.48 | 92.75 |
| 3 | 6 | 83.33 | 102.84 | 82.02 | 79.37 | 87.82 | 87.17 | 87.48 |
| 4 | 9 | 78.85 | 103.07 | 77.15 | 75.55 | 83.72 | 83.15 | 83.58 |
| 5 | 12 | 76.36 | 102.96 | 74.36 | 73.86 | 80.22 | 78.84 | 81.02 |
| 6 | 24 | 72.44 | 104.29 | 70.72 | 71.84 | 75.43 | 76.01 | 77.27 |
| 7 | 27 | 71.91 | 103.41 | 70.30 | 71.57 | 74.96 | 75.66 | 76.82 |
| 8 | 30 | 71.47 | 102.66 | 69.91 | 71.22 | 74.57 | 75.36 | 76.41 |
| 9 | 33 | 71.06 | 102.13 | 69.63 | 70.97 | 74.24 | 75.14 | 76.03 |
| 10 | 36 | 70.73 | 100.19 | 69.28 | 70.71 | 73.88 | 74.76 | 75.70 |
| 11 | 48 | 69.41 | 97.55 | 67.59 | 69.40 | 72.74 | 73.69 | 74.56 |
| 12 | 51 | 69.06 | 96.40 | 67.31 | 69.15 | 72.35 | 73.34 | 74.12 |
| Measurement | Time | Row b - Averages | | | | | | |
| 1 | 0 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| 2 | 3 | 90.72 | 95.31 | 86.02 | 82.84 | 95.45 | 93.19 | 91.54 |
| 3 | 6 | 83.11 | 93.05 | 76.02 | 73.88 | 89.77 | 88.02 | 84.99 |
| 4 | 9 | 77.25 | 91.51 | 69.37 | 67.96 | 85.05 | 82.72 | 79.28 |
| 5 | 12 | 73.01 | 90.14 | 65.19 | 64.32 | 81.08 | 78.60 | 74.58 |
| 6 | 24 | 64.22 | 86.91 | 58.10 | 58.80 | 70.74 | 68.56 | 63.92 |
| 7 | 27 | 62.86 | 85.94 | 57.40 | 58.19 | 68.82 | 66.55 | 62.12 |
| 8 | 30 | 61.84 | 84.96 | 56.83 | 57.78 | 67.25 | 64.80 | 60.90 |
| 9 | 33 | 61.16 | 83.92 | 56.37 | 57.32 | 66.02 | 63.35 | 59.96 |
| 10 | 36 | 60.61 | 82.93 | 55.92 | 56.94 | 65.13 | 62.29 | 59.26 |
| 11 | 48 | 59.15 | 79.73 | 54.59 | 55.57 | 63.00 | 59.95 | 57.64 |
| 12 | 51 | 58.82 | 78.44 | 54.28 | 55.21 | 62.55 | 59.48 | 57.28 |
| Measurement | Time | Row c - Averages | | | | | | |
| 1 | 0 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| 2 | 3 | 89.62 | 101.17 | 89.18 | 89.93 | 93.31 | 91.87 | 91.70 |
| 3 | 6 | 83.12 | 101.41 | 82.61 | 83.38 | 88.29 | 86.60 | 85.56 |
| 4 | 9 | 79.84 | 100.90 | 78.48 | 79.09 | 84.22 | 82.38 | 80.65 |
| 5 | 12 | 77.78 | 100.02 | 76.50 | 76.76 | 81.38 | 79.19 | 77.36 |
| 6 | 24 | 74.18 | 98.06 | 73.10 | 72.17 | 76.18 | 74.36 | 71.28 |
| 7 | 27 | 73.67 | 96.85 | 72.65 | 71.45 | 75.45 | 73.69 | 70.50 |
| 8 | 30 | 73.19 | 94.65 | 72.13 | 70.79 | 74.82 | 73.14 | 69.84 |
| 9 | 33 | 72.78 | 93.77 | 71.75 | 70.27 | 74.36 | 72.80 | 69.38 |
| 10 | 36 | 72.40 | 92.46 | 71.34 | 69.82 | 73.96 | 72.43 | 68.94 |
| 11 | 48 | 70.91 | 89.82 | 70.04 | 68.43 | 72.59 | 71.14 | 67.47 |
| 12 | 51 | 70.51 | 88.94 | 69.68 | 67.41 | 72.20 | 70.77 | 67.17 |
| Measurement | Time | Row d - Averages | | | | | | |
| 1 | 0 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| 2 | 3 | 89.23 | 95.76 | 88.19 | 85.27 | 93.32 | 93.02 | 91.85 |
| 3 | 6 | 81.08 | 93.27 | 80.78 | 77.35 | 87.32 | 86.68 | 85.77 |
| 4 | 9 | 75.96 | 91.90 | 75.45 | 71.32 | 81.98 | 81.37 | 80.50 |
| 5 | 12 | 72.92 | 90.50 | 71.72 | 67.56 | 77.51 | 77.28 | 76.49 |
| 6 | 24 | 66.66 | 87.33 | 64.35 | 60.50 | 67.31 | 67.34 | 67.03 |
| 7 | 27 | 65.85 | 85.61 | 63.43 | 59.61 | 65.62 | 65.74 | 65.51 |
| 8 | 30 | 65.09 | 84.95 | 62.62 | 58.87 | 64.20 | 64.35 | 64.29 |
| 9 | 33 | 64.50 | 83.93 | 62.03 | 57.60 | 62.87 | 63.29 | 63.32 |
| 10 | 36 | 63.99 | 83.33 | 61.42 | 57.82 | 61.92 | 62.45 | 62.42 |
| 11 | 48 | 62.41 | 81.66 | 59.81 | 56.34 | 59.78 | 60.27 | 60.21 |
| 12 | 51 | 62.09 | 80.33 | 59.40 | 55.99 | 59.36 | 59.84 | 59.74 |

**Table C-5.** The standard deviation associated with each **a**verage percentage of original mass

| Standard Deviation of Sample Averages | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Air | Skin | Shroud | Blue Towel | Plastic Wrap | Nitrile Rubber | Silicone Rubber |
| | | Sample 1 | Sample 2 | Sample 3 | Sample 4 | Sample 5 | Sample 6 | Sample 7 |
| Measurement | Time | Row a - Standard Deviation | | | | | | |
| 1 | 0 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 3 | 3.919 | 4.245 | 2.936 | 7.613 | 2.577 | 2.825 | 2.534 |
| 3 | 6 | 6.594 | 6.577 | 6.471 | 8.255 | 5.356 | 6.745 | 5.406 |
| 4 | 9 | 7.429 | 7.722 | 8.838 | 8.825 | 8.130 | 9.824 | 7.987 |
| 5 | 12 | 6.909 | 9.216 | 9.581 | 8.931 | 10.847 | 10.394 | 9.473 |
| 6 | 24 | 6.605 | 13.005 | 9.934 | 8.482 | 14.009 | 12.618 | 11.403 |
| 7 | 27 | 6.567 | 13.363 | 9.731 | 8.435 | 14.035 | 12.546 | 11.259 |
| 8 | 30 | 6.642 | 14.980 | 9.499 | 8.215 | 13.862 | 12.501 | 10.968 |
| 9 | 33 | 6.582 | 14.791 | 9.423 | 8.248 | 13.866 | 12.440 | 10.942 |
| 10 | 36 | 6.579 | 14.034 | 9.367 | 8.333 | 13.708 | 12.364 | 10.792 |
| 11 | 48 | 6.199 | 14.776 | 8.904 | 8.561 | 13.488 | 12.096 | 10.722 |
| 12 | 51 | 6.069 | 14.661 | 8.766 | 8.588 | 13.336 | 11.967 | 10.606 |
| Measurement | Time | Row b - Standard Deviation | | | | | | |
| 1 | 0 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 3 | 0.819 | 5.187 | 4.350 | 3.754 | 3.859 | 1.701 | 0.733 |
| 3 | 6 | 2.000 | 6.459 | 5.415 | 5.401 | 3.356 | 1.491 | 0.130 |
| 4 | 9 | 3.181 | 7.399 | 5.699 | 6.509 | 3.012 | 2.607 | 1.303 |
| 5 | 12 | 3.964 | 7.209 | 5.138 | 7.088 | 3.285 | 3.352 | 1.880 |
| 6 | 24 | 7.137 | 8.703 | 3.380 | 6.788 | 6.429 | 5.611 | 4.962 |
| 7 | 27 | 7.570 | 8.951 | 3.115 | 6.488 | 7.307 | 6.275 | 5.622 |
| 8 | 30 | 7.835 | 9.342 | 2.899 | 6.180 | 8.241 | 6.903 | 6.030 |
| 9 | 33 | 8.015 | 9.098 | 2.796 | 6.035 | 8.792 | 7.426 | 6.402 |
| 10 | 36 | 7.996 | 8.772 | 2.743 | 5.892 | 9.160 | 7.811 | 6.559 |
| 11 | 48 | 7.831 | 7.732 | 2.649 | 5.735 | 9.499 | 8.289 | 6.675 |
| 12 | 51 | 7.751 | 7.713 | 2.696 | 5.668 | 9.368 | 8.323 | 6.586 |
| Measurement | Time | Row c - Standard Deviation | | | | | | |
| 1 | 0 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 3 | 3.230 | 2.722 | 3.172 | 2.627 | 1.115 | 1.305 | 1.501 |
| 3 | 6 | 5.498 | 4.368 | 5.049 | 4.947 | 2.274 | 2.735 | 2.551 |
| 4 | 9 | 5.355 | 5.340 | 5.653 | 6.672 | 3.196 | 4.361 | 3.612 |
| 5 | 12 | 5.167 | 6.032 | 5.455 | 7.715 | 3.872 | 4.493 | 4.443 |
| 6 | 24 | 5.702 | 9.371 | 5.255 | 8.553 | 4.758 | 6.049 | 6.097 |
| 7 | 27 | 5.854 | 10.125 | 5.243 | 8.585 | 4.853 | 6.097 | 6.158 |
| 8 | 30 | 5.953 | 9.003 | 5.365 | 8.577 | 4.749 | 6.109 | 6.283 |
| 9 | 33 | 6.048 | 9.739 | 5.349 | 8.600 | 4.765 | 6.041 | 6.337 |
| 10 | 36 | 6.221 | 10.287 | 5.414 | 8.647 | 4.743 | 6.027 | 6.401 |
| 11 | 48 | 6.235 | 12.340 | 5.622 | 8.522 | 4.586 | 6.111 | 6.521 |
| 12 | 51 | 6.233 | 12.591 | 5.689 | 7.604 | 4.637 | 6.088 | 6.547 |
| Measurement | Time | Row d - Standard Deviation | | | | | | |
| 1 | 0 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 3 | 2.507 | 4.549 | 2.954 | 1.799 | 0.649 | 0.538 | 0.857 |
| 3 | 6 | 3.248 | 5.387 | 3.245 | 2.619 | 0.717 | 1.355 | 1.259 |
| 4 | 9 | 3.425 | 5.719 | 3.035 | 2.009 | 1.437 | 2.140 | 2.240 |
| 5 | 12 | 3.597 | 6.065 | 3.229 | 1.741 | 2.214 | 1.936 | 2.432 |
| 6 | 24 | 5.166 | 8.520 | 4.815 | 3.321 | 4.774 | 1.432 | 4.095 |
| 7 | 27 | 5.428 | 9.112 | 5.223 | 3.479 | 5.163 | 1.163 | 4.356 |
| 8 | 30 | 5.600 | 9.653 | 5.323 | 3.492 | 4.923 | 1.015 | 4.584 |
| 9 | 33 | 5.733 | 9.476 | 5.518 | 2.797 | 4.937 | 1.084 | 4.781 |
| 10 | 36 | 5.847 | 10.156 | 5.634 | 3.665 | 4.914 | 1.114 | 4.975 |
| 11 | 48 | 5.977 | 12.267 | 5.882 | 3.711 | 4.823 | 1.134 | 5.457 |
| 12 | 51 | 5.947 | 12.177 | 5.912 | 3.694 | 4.848 | 1.159 | 5.590 |

**Table C-6.** The standard error associated with each **a**verage percentage of original mass

| Standard Error of Sample Averages | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Air | Skin | Shroud | Blue Towel | Plastic Wrap | Nitrile Rubber | Silicone Rubber |
| | | Sample 1 | Sample 2 | Sample 3 | Sample 4 | Sample 5 | Sample 6 | Sample 7 |
| **Measurement** | **Time** | Row a - Standard Error | | | | | | |
| 1 | 0 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 3 | 2.263 | 2.451 | 1.695 | 4.395 | 1.488 | 1.631 | 1.463 |
| 3 | 6 | 3.807 | 3.797 | 3.736 | 4.766 | 3.092 | 3.894 | 3.121 |
| 4 | 9 | 4.289 | 4.458 | 5.102 | 5.095 | 4.694 | 5.672 | 4.611 |
| 5 | 12 | 3.989 | 5.321 | 5.532 | 5.156 | 6.262 | 6.001 | 5.469 |
| 6 | 24 | 3.813 | 7.508 | 5.736 | 4.897 | 8.088 | 7.285 | 6.583 |
| 7 | 27 | 3.791 | 7.715 | 5.618 | 4.870 | 8.103 | 7.244 | 6.500 |
| 8 | 30 | 3.835 | 8.649 | 5.484 | 4.743 | 8.003 | 7.218 | 6.332 |
| 9 | 33 | 3.800 | 8.540 | 5.440 | 4.762 | 8.005 | 7.182 | 6.317 |
| 10 | 36 | 3.799 | 8.102 | 5.408 | 4.811 | 7.914 | 7.139 | 6.231 |
| 11 | 48 | 3.579 | 8.531 | 5.141 | 4.943 | 7.787 | 6.983 | 6.191 |
| 12 | 51 | 3.504 | 8.465 | 5.061 | 4.958 | 7.700 | 6.909 | 6.123 |
| **Measurement** | **Time** | Row b - Standard Error | | | | | | |
| 1 | 0 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 3 | 0.473 | 2.995 | 2.511 | 2.167 | 2.228 | 0.982 | 0.423 |
| 3 | 6 | 1.155 | 3.729 | 3.127 | 3.118 | 1.937 | 0.861 | 0.075 |
| 4 | 9 | 1.836 | 4.272 | 3.290 | 3.758 | 1.739 | 1.505 | 0.752 |
| 5 | 12 | 2.289 | 4.162 | 2.967 | 4.092 | 1.896 | 1.935 | 1.085 |
| 6 | 24 | 4.121 | 5.024 | 1.951 | 3.919 | 3.712 | 3.239 | 2.865 |
| 7 | 27 | 4.370 | 5.168 | 1.798 | 3.746 | 4.219 | 3.623 | 3.246 |
| 8 | 30 | 4.524 | 5.394 | 1.674 | 3.568 | 4.758 | 3.985 | 3.481 |
| 9 | 33 | 4.628 | 5.253 | 1.614 | 3.484 | 5.076 | 4.287 | 3.696 |
| 10 | 36 | 4.616 | 5.065 | 1.583 | 3.402 | 5.289 | 4.510 | 3.787 |
| 11 | 48 | 4.521 | 4.464 | 1.530 | 3.311 | 5.484 | 4.785 | 3.854 |
| 12 | 51 | 4.475 | 4.453 | 1.556 | 3.272 | 5.408 | 4.805 | 3.803 |
| **Measurement** | **Time** | Row c - Standard Error | | | | | | |
| 1 | 0 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 3 | 1.865 | 1.572 | 1.831 | 1.516 | 0.644 | 0.754 | 0.867 |
| 3 | 6 | 3.174 | 2.522 | 2.915 | 2.856 | 1.313 | 1.579 | 1.473 |
| 4 | 9 | 3.092 | 3.083 | 3.263 | 3.852 | 1.845 | 2.518 | 2.085 |
| 5 | 12 | 2.983 | 3.483 | 3.150 | 4.454 | 2.236 | 2.594 | 2.565 |
| 6 | 24 | 3.292 | 5.410 | 3.034 | 4.938 | 2.747 | 3.492 | 3.520 |
| 7 | 27 | 3.380 | 5.846 | 3.027 | 4.957 | 2.802 | 3.520 | 3.556 |
| 8 | 30 | 3.437 | 5.198 | 3.097 | 4.952 | 2.742 | 3.527 | 3.627 |
| 9 | 33 | 3.492 | 5.623 | 3.088 | 4.965 | 2.751 | 3.488 | 3.659 |
| 10 | 36 | 3.591 | 5.939 | 3.126 | 4.992 | 2.738 | 3.480 | 3.696 |
| 11 | 48 | 3.600 | 7.125 | 3.246 | 4.920 | 2.647 | 3.528 | 3.765 |
| 12 | 51 | 3.599 | 7.269 | 3.284 | 4.390 | 2.677 | 3.515 | 3.780 |
| **Measurement** | **Time** | Row d - Standard Error | | | | | | |
| 1 | 0 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 3 | 1.447 | 2.626 | 1.706 | 1.038 | 0.375 | 0.310 | 0.495 |
| 3 | 6 | 1.875 | 3.110 | 1.874 | 1.512 | 0.414 | 0.782 | 0.727 |
| 4 | 9 | 1.978 | 3.302 | 1.752 | 1.160 | 0.830 | 1.235 | 1.293 |
| 5 | 12 | 2.077 | 3.502 | 1.864 | 1.005 | 1.278 | 1.118 | 1.404 |
| 6 | 24 | 2.983 | 4.919 | 2.780 | 1.917 | 2.756 | 0.827 | 2.364 |
| 7 | 27 | 3.134 | 5.261 | 3.016 | 2.009 | 2.981 | 0.671 | 2.515 |
| 8 | 30 | 3.233 | 5.573 | 3.073 | 2.016 | 2.842 | 0.586 | 2.646 |
| 9 | 33 | 3.310 | 5.471 | 3.186 | 1.615 | 2.850 | 0.626 | 2.760 |
| 10 | 36 | 3.376 | 5.864 | 3.253 | 2.116 | 2.837 | 0.643 | 2.872 |
| 11 | 48 | 3.451 | 7.083 | 3.396 | 2.142 | 2.785 | 0.655 | 3.151 |
| 12 | 51 | 3.433 | 7.030 | 3.413 | 2.133 | 2.799 | 0.669 | 3.227 |

## Appendix C. ANOVA & Multiple Comparisons Code & Test Results

This appendix contains a sample of the R Studio code used to conduct the ANOVA and Multiple Comparisons Tests for the data of each muscle-wetness combination, followed by the test results output by the R statistical analysis software.

1. **RStudio Sample Code for ANOVA & Multiple Comparisons Tests and Box Plots – Row A, Dry Adductor Magnus**

```
# Hour 12
# Data
avg = c( 0.760247235,        0.834332258,  0.696280992,
      0.938315989,    1.12260355,    1.027902439,
      0.792657386,    0.80489171,    0.633161019,
      0.841633674,    0.683528162,  0.690619538,
      0.847306722,    0.880770955,  0.678416821,
      0.817468106,    0.874733096,  0.673033708,
      0.898314767,    0.82234957,    0.710029566)

# Organizing data for average calculation
treatment = c(rep("Air", 3), rep("Skin", 3), rep("Shroud", 3), rep("Towel", 3),
         rep("Plastic", 3), rep("Nitrile Rubber", 3),
         rep("Silicone Rubber", 3))
my.data = cbind(avg,as.factor(treatment))
my.data

# Create boxplot visualization of data
boxplot(avg~treatment, data = my.data, col = blues9, las = 2, names = c(
  "Air", "Nitrile Rubber", "Plastic", "Shroud", "Silicone Rubber", "Skin",
  "Towel"), ylab = "Average % of Original Mass", xlab = "",
  par(mar = c(8, 5, 4, 2)+ 0.1), main = "Dry Adductor Magnus")
mtext("Material", side=1, 5)

aggregate(avg~treatment, data = my.data, median) # This gives order in the
output
aggregate(avg~treatment, data = my.data, var)
aggregate(avg~treatment, data = my.data, length)

mod = aov(avg~treatment)
summary(mod)

# Conduct multiple comparisons test
TukeyHSD(mod, conf.level = 0.99)
```

## 2. Complete ANOVA & Multiple Comparisons Results

### Row A – Dry Adductor Magnus

```
           Df Sum Sq  Mean Sq F value Pr(>F)  
treatment   6 0.1812 0.030206   3.412 0.0274 *
Residuals  14 0.1239 0.008852                 
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

| | diff | lwr | upr | p adj |
|---|---|---|---|---|
| Nitrile Rubber-Air | 0.024791475 | -0.30572843 | 0.35531138 | 0.9998711 |
| Plastic-Air | 0.038544671 | -0.29197523 | 0.36906457 | 0.9984034 |
| Shroud-Air | -0.020050123 | -0.35057003 | 0.31046978 | 0.9999628 |
| Silicone Rubber-Air | 0.046611139 | -0.28390876 | 0.37713104 | 0.9954856 |
| Skin-Air | 0.265987164 | -0.06453274 | 0.59650707 | 0.0459063 |
| Towel-Air | -0.025026370 | -0.35554627 | 0.30549353 | 0.9998639 |
| Plastic-Nitrile Rubber | 0.013753196 | -0.31676671 | 0.34427310 | 0.9999960 |
| Shroud-Nitrile Rubber | -0.044841598 | -0.37536150 | 0.28567830 | 0.9963359 |
| Silicone Rubber-Nitrile Rubber | 0.021819664 | -0.30870024 | 0.35233957 | 0.9999388 |
| Skin-Nitrile Rubber | 0.241195689 | -0.08932421 | 0.57171559 | 0.0810413 |
| Towel-Nitrile Rubber | -0.049817845 | -0.38033775 | 0.28070206 | 0.9935645 |
| Shroud-Plastic | -0.058594794 | -0.38911470 | 0.27192511 | 0.9851092 |
| Silicone Rubber-Plastic | 0.008066468 | -0.32245343 | 0.33858637 | 0.9999998 |
| Skin-Plastic | 0.227442493 | -0.10307741 | 0.55796240 | 0.1100500 |
| Towel-Plastic | -0.063571041 | -0.39409094 | 0.26694886 | 0.9776739 |
| Silicone Rubber-Shroud | 0.066661263 | -0.26385864 | 0.39718117 | 0.9719010 |
| Skin-Shroud | 0.286037288 | -0.04448261 | 0.61655719 | 0.0286962 |
| Towel-Shroud | -0.004976247 | -0.33549615 | 0.32554366 | 1.0000000 |
| Skin-Silicone Rubber | 0.219376025 | -0.11114388 | 0.54989593 | 0.1311389 |
| Towel-Silicone Rubber | -0.071637510 | -0.40215741 | 0.25888239 | 0.9605336 |
| Towel-Skin | -0.291013535 | -0.62153344 | 0.03950637 | 0.0255159 |

### Row B – Wet Adductor Magnus

```
           Df  Sum Sq  Mean Sq F value Pr(>F)    
treatment   6 0.14795 0.024658   10.16  2e-04 ***
Residuals  14 0.03398 0.002427                   
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

| | diff | lwr | upr | p adj |
|---|---|---|---|---|
| Nitrile Rubber-Air | 0.055878613 | -0.117189417 | 0.228946643 | 0.7988318 |
| Plastic-Air | 0.080683790 | -0.092384241 | 0.253751820 | 0.4521037 |
| Shroud-Air | -0.078272885 | -0.251340915 | 0.094795145 | 0.4849987 |
| Silicone Rubber-Air | 0.015683204 | -0.157384826 | 0.188751235 | 0.9996162 |
| Skin-Air | 0.171281746 | -0.001786285 | 0.344349776 | 0.0108425 |
| Towel-Air | -0.086922138 | -0.259990169 | 0.086145892 | 0.3722471 |
| Plastic-Nitrile Rubber | 0.024805177 | -0.148262854 | 0.197873207 | 0.9950762 |
| Shroud-Nitrile Rubber | -0.134151498 | -0.307219528 | 0.038916532 | 0.0575763 |
| Silicone Rubber-Nitrile Rubber | -0.040195409 | -0.213263439 | 0.132872622 | 0.9459299 |
| Skin-Nitrile Rubber | 0.115403133 | -0.057664898 | 0.288471163 | 0.1282956 |
| Towel-Nitrile Rubber | -0.142800751 | -0.315868782 | 0.030267279 | 0.0392387 |
| Shroud-Plastic | -0.158956675 | -0.332024705 | 0.014111356 | 0.0189538 |
| Silicone Rubber-Plastic | -0.065000585 | -0.238068616 | 0.108067445 | 0.6755597 |
| Skin-Plastic | 0.090597956 | -0.082470074 | 0.263665986 | 0.3293736 |
| Towel-Plastic | -0.167605928 | -0.340673958 | 0.005462102 | 0.0128075 |
| Silicone Rubber-Shroud | 0.093956089 | -0.079111941 | 0.267024120 | 0.2931794 |
| Skin-Shroud | 0.249554631 | 0.076486600 | 0.422622661 | 0.0003586 |
| Towel-Shroud | -0.008649253 | -0.181717284 | 0.164418777 | 0.9999881 |
| Skin-Silicone Rubber | 0.155598541 | -0.017469489 | 0.328666572 | 0.0220646 |
| Towel-Silicone Rubber | -0.102605343 | -0.275673373 | 0.070462688 | 0.2133638 |
| Towel-Skin | -0.258203884 | -0.431271914 | -0.085135854 | 0.0002521 |

## Row C – Dry Oblique Muscles

| | Df | Sum Sq | Mean Sq | F value | Pr(>F) | |
|---|---|---|---|---|---|---|
| treatment | 6 | 0.12792 | 0.021319 | 7.199 | 0.00117 | ** |
| Residuals | 14 | 0.04146 | 0.002961 | | | |

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Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

| | diff | lwr | upr | p adj |
|---|---|---|---|---|
| Nitrile Rubber-Air | 0.014101247 | -0.177072289 | 0.2052748 | 0.9998831 |
| Plastic-Air | 0.035985540 | -0.155187996 | 0.2271591 | 0.9799175 |
| Shroud-Air | -0.012739045 | -0.203912581 | 0.1784345 | 0.9999354 |
| Silicone Rubber-Air | -0.004213142 | -0.195386678 | 0.1869604 | 0.9999999 |
| Skin-Air | 0.222404238 | 0.031230702 | 0.4135778 | 0.0028144 |
| Towel-Air | -0.010153597 | -0.201327133 | 0.1810199 | 0.9999830 |
| Plastic-Nitrile Rubber | 0.021884293 | -0.169289243 | 0.2130578 | 0.9985602 |
| Shroud-Nitrile Rubber | -0.026840292 | -0.218013828 | 0.1643332 | 0.9955923 |
| Silicone Rubber-Nitrile Rubber | -0.018314390 | -0.209487926 | 0.1728591 | 0.9994726 |
| Skin-Nitrile Rubber | 0.208302990 | 0.017129454 | 0.3994765 | 0.0049704 |
| Towel-Nitrile Rubber | -0.024254845 | -0.215428381 | 0.1669187 | 0.9974571 |
| Shroud-Plastic | -0.048724585 | -0.239898121 | 0.1424490 | 0.9190196 |
| Silicone Rubber-Plastic | -0.040198683 | -0.231372219 | 0.1509749 | 0.9657435 |
| Skin-Plastic | 0.186418697 | -0.004754839 | 0.3775922 | 0.0121529 |
| Towel-Plastic | -0.046139138 | -0.237312674 | 0.1450344 | 0.9359247 |
| Silicone Rubber-Shroud | 0.008525902 | -0.182647634 | 0.1996994 | 0.9999939 |
| Skin-Shroud | 0.235143282 | 0.043969746 | 0.4263168 | 0.0016959 |
| Towel-Shroud | 0.002585447 | -0.188588089 | 0.1937590 | 1.0000000 |
| Skin-Silicone Rubber | 0.226617380 | 0.035443844 | 0.4177909 | 0.0023783 |
| Towel-Silicone Rubber | -0.005940455 | -0.197113991 | 0.1852331 | 0.9999993 |
| Towel-Skin | -0.232557835 | -0.423731371 | -0.0413843 | 0.0018783 |

## Row D – Wet Oblique Muscles

| | Df | Sum Sq | Mean Sq | F value | Pr(>F) | |
|---|---|---|---|---|---|---|
| treatment | 6 | 0.09389 | 0.015648 | 14.09 | 3.23e-05 | *** |
| Residuals | 14 | 0.01555 | 0.001111 | | | |

| | diff | lwr | upr | p adj |
|---|---|---|---|---|
| Nitrile Rubber-Air | 0.043558772 | -0.07351831 | 0.16063586 | 0.6842700 |
| Plastic-Air | 0.045915888 | -0.07116120 | 0.16299297 | 0.6341074 |
| Shroud-Air | -0.011985007 | -0.12906209 | 0.10509208 | 0.9992315 |
| Silicone Rubber-Air | 0.035654022 | -0.08142306 | 0.15273111 | 0.8365477 |
| Skin-Air | 0.175805728 | 0.05872864 | 0.29288281 | 0.0002356 |
| Towel-Air | -0.053644797 | -0.17072188 | 0.06343229 | 0.4708672 |
| Plastic-Nitrile Rubber | 0.002357116 | -0.11471997 | 0.11943420 | 0.9999999 |
| Shroud-Nitrile Rubber | -0.055543779 | -0.17262087 | 0.06153331 | 0.4331717 |
| Silicone Rubber-Nitrile Rubber | -0.007904750 | -0.12498184 | 0.10917234 | 0.9999302 |
| Skin-Nitrile Rubber | 0.132246956 | 0.01516987 | 0.24932404 | 0.0036487 |
| Towel-Nitrile Rubber | -0.097203569 | -0.21428066 | 0.01987352 | 0.0377096 |
| Shroud-Plastic | -0.057900895 | -0.17497798 | 0.05917619 | 0.3885692 |
| Silicone Rubber-Plastic | -0.010261866 | -0.12733895 | 0.10681522 | 0.9996829 |
| Skin-Plastic | 0.129889840 | 0.01281275 | 0.24696693 | 0.0042623 |
| Towel-Plastic | -0.099560685 | -0.21663777 | 0.01751640 | 0.0322575 |
| Silicone Rubber-Shroud | 0.047639028 | -0.06943806 | 0.16471611 | 0.5970877 |
| Skin-Shroud | 0.187790735 | 0.07071365 | 0.30486782 | 0.0001167 |
| Towel-Shroud | -0.041659790 | -0.15873688 | 0.07541730 | 0.7236912 |
| Skin-Silicone Rubber | 0.140151706 | 0.02307462 | 0.25722879 | 0.0021758 |
| Towel-Silicone Rubber | -0.089298819 | -0.20637591 | 0.02777827 | 0.0632578 |
| Towel-Skin | -0.229450525 | -0.34652761 | -0.11237344 | 0.0000122 |