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Reviewed Article:

Comparing Mummification Processes: Egyptian & Inca

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This two-year research project was carried out as part of SUNY Potsdam's Presidential Scholars program which allows undergraduates to conduct independent research. The project employs controlled laboratory experiments to compare desiccation rates in natural and artificial mummification processes while considering the cultural context of the funerary practices. Artificial mummification techniques of the Egyptian and Inca cultures are considered. Natural mummification includes artificial heating and cooling of the carcass buried in sand within a clay pot. Egyptian mummification requires evisceration of the carcass,

treatment with alcohol to limit bacterial activity, and submergence in Natron. Inca mummification necessitates evisceration and skinning of the carcass, use of alcohol, and drying of the specimen. Rat carcasses were used in place of human cadavers, with full documentation of the process, duration, and stages of their mummification. The lab protocols established by this research will provide protocols for future taphonomic studies. This research emphasizes the necessity for considering the cultural context of taphonomy. Understanding the taphonomy of desiccated tissues is directly relevant in bioarchaeological applications.

> The protocols developed through this experimental research were designed to compare natural mummification to two artificial, anthropogenic mummification techniques. Through this experimental laboratory experiment it became clear why artificial mummification techniques were developed by these cultures. Natural mummification of a body in a desert would likely not lead to aesthetically pleasing preservation.

Introduction

Desiccation is the process of the body drying out due to natural phenomena while mummification is the result of human's use of materials to artificially desiccate a corpse, enhancing preservation of the body. When a corpse or carcass starts decomposing it goes through the process of autolysis, putrefaction, decay and skeletonization (Munkres, 2009). Desiccation of the body halts decomposition, stopping the process of putrefaction (Gashe, 2010). The rate at which a body decomposes is dependent on the environment it is in and the state of the body itself (clothed or unclothed etc). Desiccation occurs when a body is exposed to an arid environment; arid climates limit scavenging activity and reduce moisture content both of which impact decomposition (Gashe, 2010; Munkres, 2009). Previously, Dr. Bob Brier of Long Island University conducted similar research by performing royal Egyptian mummification on a cadaver (Payne, 2011). Dr. Brier inspired the development of this project and these laboratory protocols. Due to a lack of research done on taphonomic processes in the context of desiccation, this controlled laboratory experiment was created.

Both the Egyptian and Inca cultures treated their deceased differently based on social hierarchy within the culture. As Pearson (1999, p.31) explains, " [...] certain funerary practices were consistently associated with social rank, namely complexity of body treatment, construction and placement of the interment facility (i.e. grave or tomb), the extent and duration of mortuary ritual, material expenditure [...]." The Egyptian mummification technique developed over a long period of time, from the deceased being dismembered, defleshed and wrapped in linen, to desiccation achieved through use of different materials such as alcohol, evisceration, et cetera (Rosso, 2014). Eventually mummification became a religious requirement because they believed preservation of the corporeal body was necessary for reaching the afterlife successfully (Gashe, 2010).

Preservation of the corpse gave the soul of the deceased a physical place to return to. Egyptian embalmers would show families of the deceased wooden models representing the different mummification techniques they could purchase. The most costly, elaborate technique was a 70 day process incorporating materials such as myrrh, coniferous and mastic resin, bitumen and other materials that helped dry and preserve the body as well as eliminate the malodor of the body. A royal Egyptian mummy was always wrapped in linen with amulets placed within the layers of textiles (Abdel-Maksoud and El-Amin, 2011; Lace, 2012).

As for the Inca, who dominated Peru from 1400-1533 CE, their use of mummification was used both to preserve the body for passage into the afterlife and as a manifestation of Andean ancestor worship and veneration. Mummies were seen as a physical link between the living population and their gods. Inca mummies were given places of honor and were often present at important ceremonies (for example marriages or harvestings). The Inca celebrated a festival for their dead during which they carried mummies through the streets. Residents came out of their dwellings offering food and drink (Bákula, et al., 2000; Cartwright, 2014). Typically, the only people receiving mummification in Inca culture were royalty who were interred in caves dressed in elaborate textiles and given elaborate grave goods (Besom, 2013).

Research Questions

This project aimed to create protocols through a controlled laboratory experiment, allowing comparison between the desiccation rates of natural, Egyptian, and Inca mummification. The Egyptian and Inca cultures used specific materials in order to artificially mummify their deceased. Some of these materials were included in this project and the protocols developed by this project (See Figure 1). This experiment was done to assess:

1. What specifically is the taphonomic process in the context of desiccation?
2. How did Egyptian and Inca cultural activities impact the outcome of the desiccation process? What culturally specific materials did they utilize in their mummification techniques and how do these materials impact the desiccation process?
3. What are the different desiccation rates between natural mummification versus artificial mummification: Egyptian and Inca techniques?

Natural Mummification	Egyptian Technique	Inca Technique
• Saltwater • Clay pots • Thermometer • Sand (Bonsai Tree and Carnivorous Plant Soil Mix)	• Saltwater • Cutting board • Scalpel • Wine with 14% ethyl • Natron • Bandages/wrapping	• Chicha corn beer • Cutting board • Scalpel • Toothpicks/ sticks • Grass, vegetable matter or animal hair • Twine • White ash paste/clay

FIG 1. THIS TABLE LISTS ALL THE DIFFERENT MATERIALS THAT WERE USED IN THE CONTROLLED LABORATORY EXPERIMENT AND ARE INCORPORATED INTO THE PROTOCOLS DEVELOPED BY THIS RESEARCH. THE TABLE WAS DEVELOPED BY THE RESEARCHERS AT SUNY POTSDAM.

Methods

Rat carcasses were used due to lack of access to human cadavers and lack of a desert environment which would have accommodated the use of larger animals, such as pigs. Rat carcasses were obtained through a reptilian feeding website and shipped to SUNY Potsdam. Before the protocols were carried out, a hydrated rat was weighed and measured as a base for comparison to post-mummification rats. The rat measured 10 cm in length and weighed 210 grams. Prior to mummification, rats were frozen and then refrigerated to limit bacterial activity and decomposition processes; the act of freezing and refrigerating the rats does not impact the desiccation of the rats (See Figure 2) (Micozzi, 1986; Stokes, Forbes and Tibbet, 2008). In each protocol, the rat carcass was first washed with saltwater. Washing the rat in saltwater was not necessary in any of the mummification processes; we employed the use of saltwater to further limit the possibility for bacterial activity on the rat carcasses. The laboratory lacked sufficient ventilation and we aimed to minimize the malodor from the process of desiccating the rats. Visual markers of desiccation were used to access when the rats reached a fully mummified state. A rat was considered completely desiccated when there were no longer clear signs of skin or flesh shrinkage visible, no discernable odour emanating from the carcass, and no other physical indicators of the carcass continuing to dry out.

Natural Mummification: For natural mummification it was necessary to mimic desert temperatures during the daytime and night. The Sahara desert was chosen as the model for desert temperatures since it is the located in North Africa. Circular cooking burners were used to heat the sand matrix in which the rat carcass was placed. Burners were turned on in the morning to heat the sand during the day, then turned off in the late afternoon to ensure the sand cooled overnight. The rat was rinsed with saltwater then submerged in clay pots filled with sand heated by burners to 30-57.2°C (86-135°F). Throughout the desiccation process the

sand maintained temperatures of 48.8-60ºC (120-140ºF) (See Figure 3) (Columbia Encyclopedia, 2000).

Egyptian Artificial Mummification

Egyptian mummification, an artificial preservation technique discovered through hieroglyphics, was a sacred process in Egyptian culture. The details of sacred practices such as mummification processes were not recorded by the scribes (Gashe, 2010). To mummify the rat, it was first washed in saltwater and wine (See Figure 4). The wine must have at least 14 percent ethyl alcohol, the ethyl amount equivalent to Egyptian palm wine. Palm wine was traditionally used by Egyptians to help limit bacterial activity in and on the deceased's body. Using a scalpel an incision was cut in the right side of the rat's abdomen (See Figure 5). Egyptian mummies were fully eviscerated through an incision in the abdominal cavity. This includes removal of the brain. An attempt was made to remove the brain from the rat carcass but due to the small size of its nasal cavity, removal of the brain was unsuccessful (Lace, 2012). In the 12th Dynasty (1991-1782 BC) Egyptians began leaving the heart inside the thoracic cavity due to their belief that the essence of the person lived within the organ (Abdel-Maksoud and El-Amin, 2011; Payne, 2011). Internal organs were washed with saltwater and wine (See Figure 6).

Following evisceration, the rat was submerged in natron, a natural salt mixture found in the Nile (See Figure 7). Natron is composed of four different salts: sodium bicarbonate, sodium chloride, sodium sulfate, and sodium carbonate. Historically, Egyptians filled the thoracic cavity with bags of natron for internal drying. To mimic this process, gauze was filled with natron and placed in the thoracic cavity of the rat. In order to show the effect of the mummification technique on preserving the rat carcass, it was not wrapped in linen after desiccation was completed (Abdel-Maksoud and El-Amin, 2011; Lace, 2012; Quigley, 2006; Rosso, 2014).

Inca Mummification

Inca mummification is less well known than Egyptian. The early Inca culture conducted mountain sacrifices in which the deceased were naturally mummified by the cold, arid, windy environments of the mountains. The Inca also mummified the deceased in the valley; the mummification technique used derived from their ancestors, the Chincorro (7000-1500 BC) (Rosso, 2014). Chicha corn beer was used by the Inca to aid in halting bacterial activity and decomposition (See Figure 8) (Besom, 2013). The type of mummification process used varied by region; the most common technique created and utilized by the Inca was called the 'Black Technique' dating from 5050-2500 BC. The 'Black Technique' began with dismembering the body and stripping it of skin and flesh (Rosso, 2014).

To begin the 'Black Technique,' the rat was washed in saltwater, eviscerated and skinned but not dismembered. The choice was made not to dry the skin or removed flesh in hot ashes or coals, as the Inca would have done because we did not believe it would impact the overall desiccation process significantly. Drying of the skin and flesh in coals could easily be done in future applications of the protocols developed from this project. The rat carcass was washed in Chicha corn beer which was homemade for this project. Inca skin would have been set aside and stuffed with vegetable matter and animal hair. The rat carcass was stuffed with vegetable matter, specifically grass (See Figure 9). As the skeletons of the Incan deceased were often reinforced with sticks, this was attempted with the rat carcass by reinforcing its body with toothpicks. The Inca often made mummy bundles in which the deceased would be placed in a fetal position and wrapped into bundles using textiles. The rat in this study was not wrapped in textiles, but it was placed in the fetal position. The rat mummy bundle was bound together with twine (See Figure 10). Clay masks and wigs were sometimes placed on the body by the Inca (Rosso, 2014). In future uses of these protocols it would be easy to coat the outer surfaces of the specimen's face with white ash paste or clay to model the ritual of the clay mask.

Results

Natural Mummification: A human body typically takes 30-40 days to reach full desiccation in a naturally arid environment (Munkres, 2009). The rat carcass took 13 days to desiccate completely in this experiment. The rat lost 146.6 grams in total over the course of its desiccation. The rat weighed 65.4 grams fully mummified. Natural mummification lead to fair preservation of the rat. Conglomeration of sand and bodily fluids were present on the natural rat mummy. The rat's body lost its tail and ear due to the heat of the sand, but overall the body was intact (See Figure 11).

Egyptian Artificial Mummification

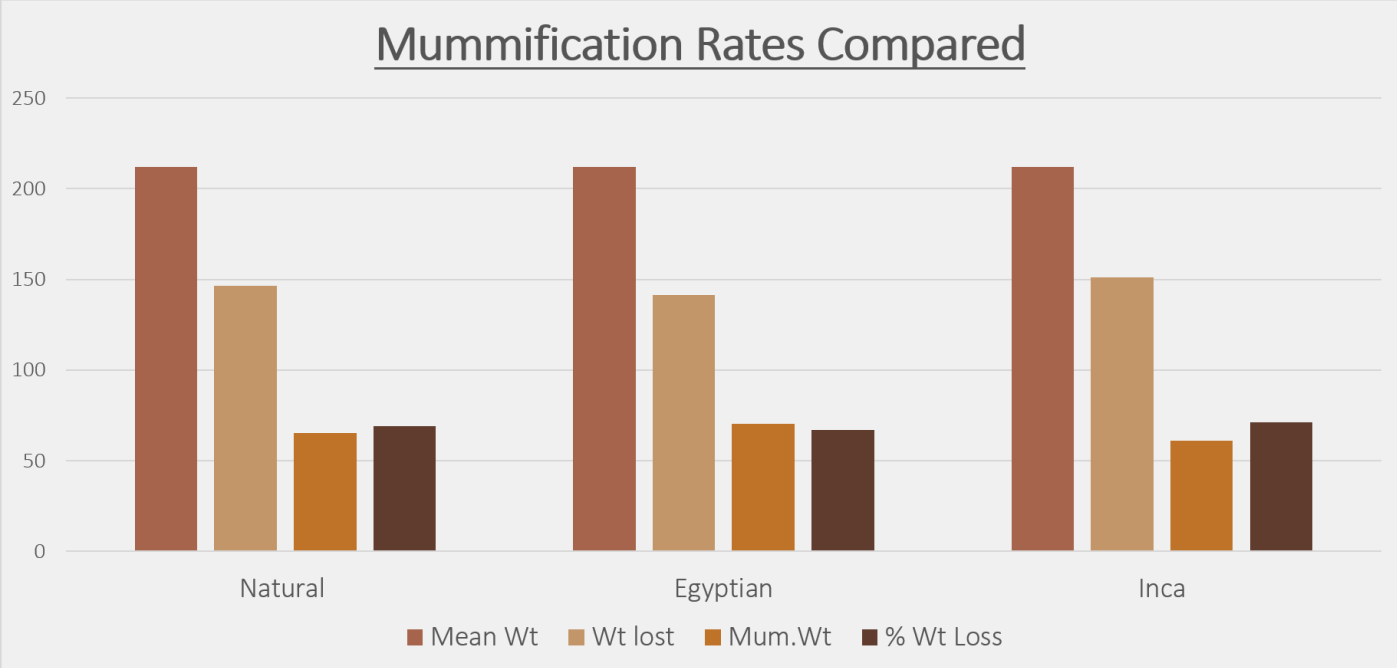
In natron, it typically takes a human body 40-70 days to reach full desiccation (Payne, 2011). Following the Egyptian mummification protocols, it took the rat carcass 23 days to fully desiccate in the natron matrix. In total, the Egyptian rat lost 141.5 grams from the mummification process. The eviscerated and desiccated organs were weighed separately from the rat-mummy and weighed 9.21 grams. The rat-mummy weighed 70.5 grams fully mummified. The rat carcass was well preserved with no loss of ears or limbs. The fur of the rat, as well as its' facial features were extremely clear (See Figure 12).

Inca Mummification

There was no information available regarding the length of time it took an Inca valley mummy to desiccate. Using the 'Black Technique' protocol, the rat carcass took 17-20 days to desiccate and lost 151.12 grams from the mummification process (See Figure 13). On day 17 when

checking the rat, its visual markers of desiccation were not clear; the rat appeared to need more time to reach full desiccation. When checked on day 20 there were no significant visible changes from day 17 and so we decided to assign a range of days to account for our visual assessments of desiccation. The Inca rat carcass weighed 60.88 grams fully mummified.

Quigley (2006) argues that when a body is fully desiccated it will weigh 70-77% less than before desiccation. In comparing the wet rat to the desiccated rats, the results support Quigley's argument. The naturally mummified rat lost 69% of its body mass while the rat mummified via the Egyptian technique lost 67%. The Inca mummified rat lost the highest percentage of weight at 71% (See Graph 1). All of the desiccated rat carcasses lost around 70% of their overall body mass. The results of this research suggest the culturally specific material significantly impacting desiccation was alcohol. Alcohol was a substance used in the mummification techniques for the elite in both Egyptian and Inca society. Its purpose was to limit bacterial activity on the cadaver. Alcohol appeared to have the greatest effect on desiccation by ensuring the bacteria impacting decomposition processes ceased.



GRAPH 1. DATA COLLECTED FROM THE RATS DURING THE DESICCATION PROCESS IN ORDER TO COMPARE DESICCATION RATES. THE INCA MUMMIFICATION RESULTED IN THE HIGHEST PERCENTAGE OF WEIGHT BEING LOST DUE TO THE DESICCATION. ALL THE RATS LOST OVER 50% OF THEIR ENTIRE BODY WEIGHT.

Conclusions

The protocols developed through this experimental research were designed to compare natural mummification to two artificial, anthropogenic mummification techniques. Through this experimental laboratory experiment it became clear why artificial mummification techniques were developed by these cultures. Natural mummification of a body in a desert would likely not lead to aesthetically pleasing preservation. As the rat carcass showed, loss of limbs or facial features such as ears or a nose and conglomeration of fluid could happen with a human body if mummified naturally. The process of natural mummification also had an

extremely displeasing aroma. It is no surprise the Egyptians used to place their bodies in desert areas far away from their living populations. Use of the Egyptian mummification technique lead to a beautifully preserved rat carcass, with limbs intact and fur still lifelike. This process is a result of the Egyptian's developing their technique over a long period of time, testing what materials worked in favor of preserving the body and minimized the smell of decomposition. The Egyptian mummification technique increased the aesthetics of the deceased in order to preserve general facial and body characteristics. Like the Egyptian technique, the Inca mummification technique lead to good preservation of the rat carcass with limited smell. Though Egyptian and Inca techniques for desiccating their deceased were different, both resulted in the rat carcass preserved in excellent condition. The process of skinning the rat was the smelliest part of the Inca desiccation process due to the exposure of the wet tissues and bodily fluids. Inca people's use of vegetable matter to replace the insides of their deceased is also fascinating to consider, as it is plausible they may have chosen sweet or pleasant smelling plants in order to further limit the smell of the deceased.

During all three processes of mummification, there was no insect activity or decomposition noted on the rats. As all three mummification techniques took place in arid, dry areas, the lack of scavenger activity on the bodies is not surprising. It is easy to imagine a body, when desiccating in the desert, would be the most vulnerable to scavengers. Regardless, all the mummification techniques resulted in successful desiccation and preserved the carcass of the rat.

These protocols allow comparison of desiccation techniques used to prepare the bodies of the deceased in Egyptian and Inca cultures. Further research applying these protocols on animal carcasses that closely resemble human cadavers is needed. The hope is for these protocols to be performed on human cadavers in order to collect data on ancient funerary practices designed to preserve the dead. Research leading to development of protocols representing the everyday Egyptian or Inca would be beneficial to taphonomic studies in cultural contexts. Mummification, as many funerary practices, reflects the cultural beliefs of its people and provides a physical representation thereof. Cultural context of human remains must be considered when studying taphonomy. Taphonomic processes can be directly impacted and influenced by variable cultural beliefs, including social stratification, gender roles and age.

The protocols developed during this research could be utilized to desiccate human cadavers in order to compare them to ancient remains preserved by the same funerary methods. Researchers investigating and/or recreating animal mummies might apply the protocols developed in this project. Finally, the protocols may be employed by scientists to conduct chemical studies on ancient materials in order to discover chemical signatures of culturally specific materials used in various funerary practices.

Keywords mummification
post depositional process
funerary

Country Argentina
Chile
Colombia
Egypt
Peru

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Gallery Image

Natural Mummification	Egyptian Technique	Inca Technique
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FIG 2. ONE OF THE RATS IN ANTERIOR VIEW PRIOR TO DESICCATION. © SUNY POTSDAM BIOARCHAEOLOGY LABORATORY

FIG 3. THE NATURAL MUMMIFICATION OF THE RAT CARCASS WAS CARRIED OUT IN A CLAY POT. DESERT TEMPERATURES OF THE SAND MATRIX WERE MONITORED WITH A THERMOMETER. © SUNY POTSDAM BIOARCHAEOLOGY LABORATORY

FIG 4. THE BEGINNING OF THE EGYPTIAN MUMMIFICATION TECHNIQUE IN WHICH THE CARCASS IS WASHED IN SALTWATER AND WINE. © SUNY POTSDAM BIOARCHAEOLOGY LABORATORY

FIG 5. EVISCERATION IN THE EGYPTIAN TECHNIQUE. THE EGYPTIANS WOULD HAVE ALWAYS CUT THE INCISION FOR EVISCERATION ON THE LEFT SIDE, WE ACCIDENTALLY MADE THE INCISION ON THE RIGHT. EGYPTIANS WOULD HAVE TRADITIONALLY USED OBSIDIAN BLADES TO MAKE THE INCISION BUT WE USED A SCALPEL. © SUNY POTSDAM BIOARCHAEOLOGY LABORATORY

FIG 6. THE ORGANS OF THE RAT CARCASS WERE WASHED IN SALTWATER AND WINE. THIS WAS JUST ONE OF THE STEPS TO PREPARE THEM FOR DESICCATION AND PRESERVATION. © SUNY POTSDAM BIOARCHAEOLOGY LABORATORY

FIG 7. AFTER BEING WASHED, THE RAT CARCASS WAS SUBMERGED IN NATRON. THE RAT CARCASS WAS DRIED BOTH EXTERNALLY AND INTERNALLY WITH NATRON. © SUNY POTSDAM BIOARCHAEOLOGY LABORATORY

FIG 8. THE CHICHA CORN BEER WAS MADE AT ONE OF THE RESEARCHER'S HOMES FOLLOWING A RECIPE FOR CHICHA CORN BEER PUBLISHED BY DRAFT MAGAZINE: HTTP://DRAFTMAG.COM/HOW-TO-MAKE-CHICHA/

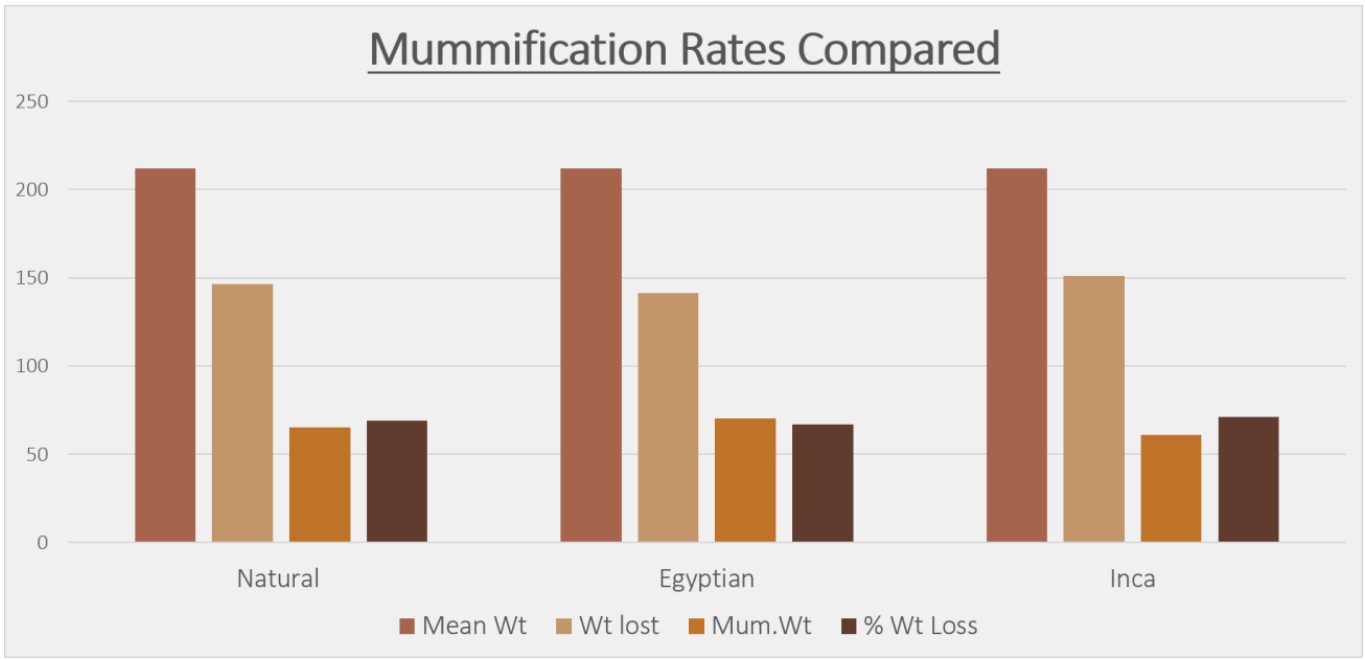
FIG 9. INCA RAT AFTER SKINNING AND DURING THE PROCESS OF REPLACING THE INNARDS WITH VEGETABLE MATTER. WE SIMPLY USED GRASS FROM THE CAMPUS GROUNDS. © SUNY POTSDAM BIOARCHAEOLOGY

FIG 10. INCA RAT IN FETAL POSITION WITH ITS SKELETON REINFORCED WITH TOOTHPICKS. PICTURE WAS TAKEN PRE-DESICCATION. © SUNY POTSDAM BIOARCHAEOLOGY LABORATORY

FIG 11: ANTERIOR VIEW OF THE NATURALLY MUMMIFIED RAT. IT TOOK THE RAT A TOTAL OF 13 DAYS TO REACH FULL DESICCATION IN AN ARID ENVIRONMENT SUBMERGED IN A SAND MATRIX. © SUNY POTSDAM BIOARCHAEOLOGY LABORATORY

FIG 12. ANTERIOR VIEW OF THE RAT MUMMIFIED VIA THE EGYPTIAN TECHNIQUE. THE RAT TOOK 23 DAYS TO REACH COMPLETE DESICCATION. COMPARE THE PRESERVATION TO FIGURE 11. © SUNY POTSDAM BIOARCHAEOLOGY LABORATORY

FIG 13. THE COMPLETELY DESICCATED RAT VIA THE INCA MUMMIFICATION TECHNIQUE. THE MUMMY BUNDLE HELD UP WELL. IT TOOK 17-20 DAYS FOR THE INCA RAT TO COMPLETELY DESICCATE. © SUNY POTSDAM BIOARCHAEOLOGY LABORATORY



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