Experimental Mummification

by

R. Garner

Introduction

This study was carried out in order to investigate mummification as the ancient Egyptians are believed to have performed it. The intention was to study the methods and to examine factors which may have affected them. The ancient Egyptians believed the body of a dead person would be needed by the spirit, which departed at death, on its subsequent return. Therefore, it was important to maintain the body in as lifelike a condition as possible.

Modern science has provided us with three excellent methods of preservation: injection of preserving fluids into the blood vessels, deep freezing, and freeze-drying. As these were not available to the ancient Egyptians they were left with the alternative method of drying the body. They undoubtedly knew that bodies buried in the desert sand were eventually dried by the heat of the sun. Their early burials were in shallow graves, and many would have been disturbed, giving ample evidence of the process. However, the length of time necessary, and the organisational difficulties involved in arranging large 'temporary graveyards' would rule it out as a practical proposition. Drying by artificial heat from a fire would be both difficult to control and unpredictable, apart from its extravagant use of their sparse fuel supplies. No Egyptian mummies have been found which show any real evidence of having been dried in this manner.

The use of a chemical agent for desiccation was thus the only practical method available. Common salt was used in early times for preserving meat and fish, but there is little evidence to show that it was used in mummification other than in a minor role.[1] The overwhelming evidence points to the use of natron as the main agent in the preparation of a mummified body. It has been found in tombs,[1] and Herodotus, writing in the fifth century B.C., specifically named it as the material used. Less certain has been its method of use. Few accounts of mummification have survived from ancient times, and, of those which have, most give very little detail. The account of Herodotus stands out as the clearest and most detailed, but it must be borne in mind that it was written after the art of embalming had passed its peak.

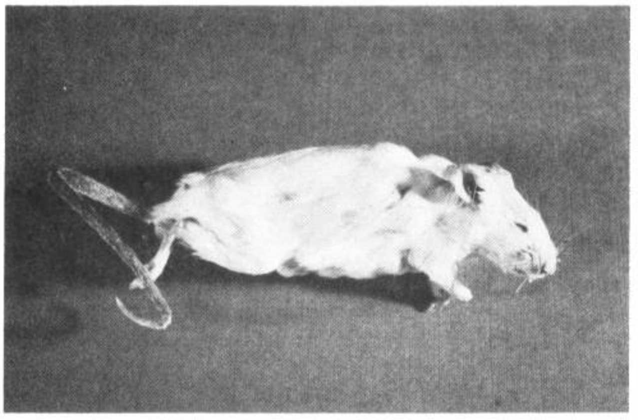
In his account Herodotus detailed three methods of mummification in decreasing order of complexity and cost. The first method involved opening the body, removing some of the organs, cleaning and packing the cavity, and then treating the whole body with natron. The second method called for filling the inside of the body with oil, treating it with natron, and finally removing any remaining oil. The third, and cheapest method involved washing out the body with an un-named fluid — possibly water or a dilute salt solution — and then treating it with natron. Early translation of this account led to a long-held misconception about the form in which natron was used. The words 'soak', 'steep' and 'brine' in these translations seemed to indicate that solutions of natron were used. Evidence from mummies was also thought to indicate the use of a solution. However, re-examination of the original Greek texts and the mummy evidence has shown them to provide no real basis for the belief.[1] Experimental work done by Lucas confirmed the modern thinking that the natron was used in its natural dry state.[2]

Methods

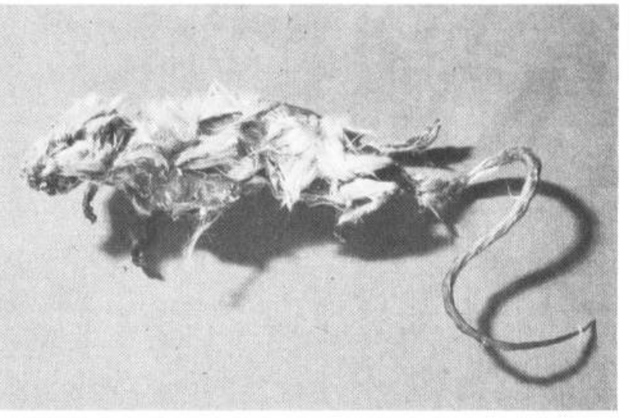
Natron is a mixture of sodium carbonate and bicarbonate which is found in natural deposits. Although sodium chloride and sulphate are also commonly found mixed with these deposits they usually constitute less than half of the total, and may be considered as impurities. Analysis of modern natron samples often shows a higher proportion of the 'true' salts — carbonate and bicarbonate — than is found in samples from tombs. If the ancient samples were used during mummification, chemical reactions would be more likely to affect these salts, thus reducing their relative proportions.

For the experiments carried out in this study 'artificial' natron samples were made up from laboratory chemicals. The proportion of true natron salts was kept high, in excess of 65 per cent; the remainder of the sample was made up of sodium chloride and sulphate 'impurities'. These samples were used in the investigations of the three methods of mummification mentioned by Herodotus. Later tests were designed to study the affect of high levels of impurities, and these used salt mixtures with carbonate and bicarbonate forming less than 40 per cent of the sample. A final series of experiments was carried out to compare the preservative properties of dry natron mixtures with natron solutions.

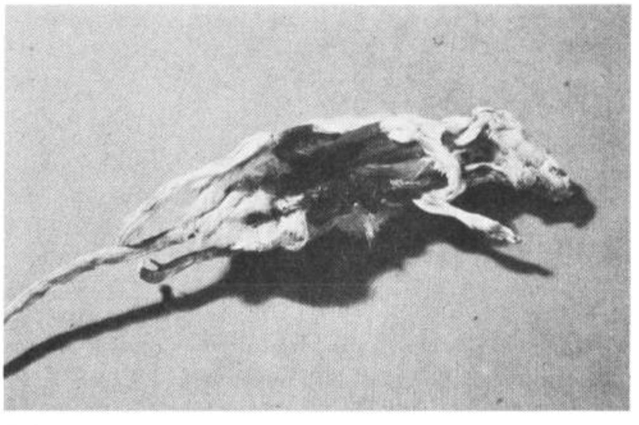
Laboratory rats and mice were used in the experiments because of their convenient size and availability. For all but the final series of experiments a ventral incision was made and the thoracic and abdominal organs were exposed. In some of the tests the organs were removed and buried separately, the body cavity being packed with salt mixture. If the organs were not removed they were packed round with salt when the animal was buried. Before salt treatment the animals were weighed, the body was then laid on a thick bed of loosely packed salt in a large open container and covered to a similar depth



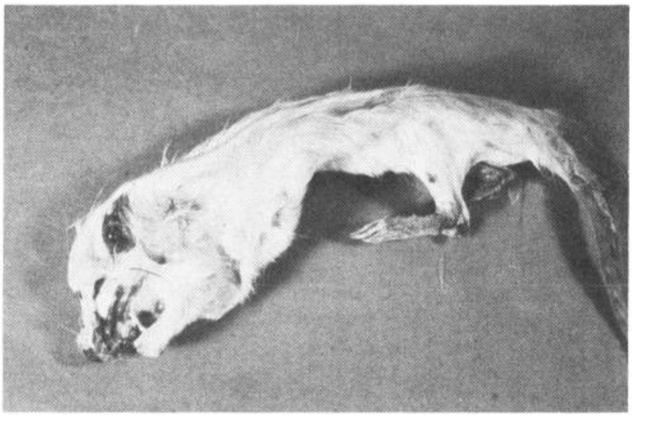
(1) An animal preserved in fresh natron, containing more than 60% sodium carbonate. There is very little shrinkage, and no loss of fur.



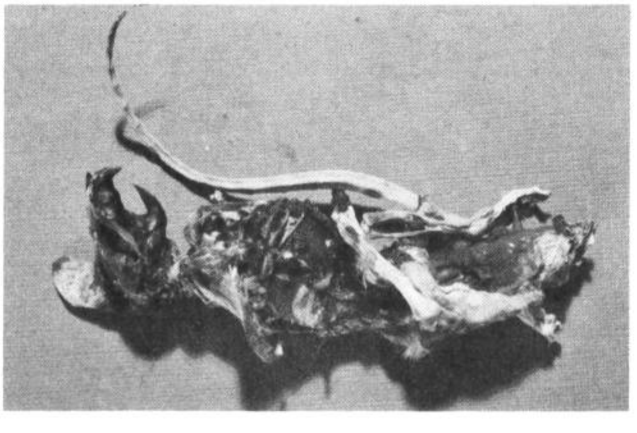
(2) An animal preserved in a re-used mixture containing a high proportion of sodium chloride. There is considerable loss of fur, and marked shrinkage on drying.



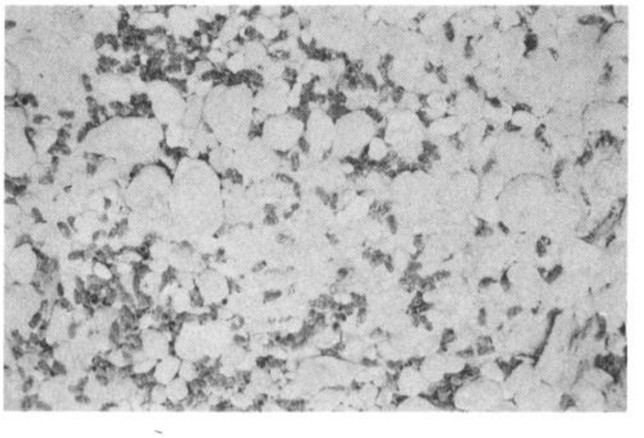
(3) An animal preserved in natron after water injection. The general preservation is very poor.



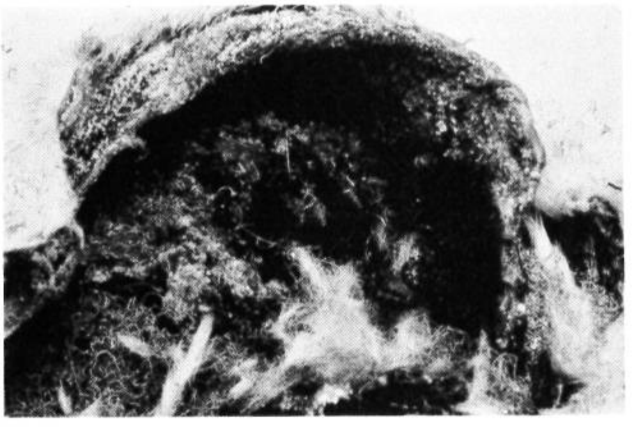
(4) An animal preserved in natron after oil injection. There is considerable shrinkage on drying, but the general preservation is good.



(5) An animal preserved in natron solution. There is considerable tissue loss during treatment due to extensive decay.



(6) Natron sample, showing large numbers of dead fly larvae.



(7) Close-up of rat showing larvae of *Dermestes lardarius*. The pale brown fibrous material is body tissue which has been attacked by the insects.

(**8**) Samples of natron and salt mixtures showing clumping and staining after use.
Left hand row: (*Top*) Natron some distance from the body — unsoiled. (*Middle*) Natron closer to the body — some soiling and clumping. (*Bottom*) High-chloride mixture, away from the body — some soiling and clumping.
Middle row: (*Top*) High-chloride mixture close to the body — some clumping, heavy soiling. (*Middle*) High-sulphate mixture, away from the body — slight soiling, some clumping. (*Bottom*) High-sulphate mixture close to the body — some clumping, heavy soiling.
Right hand row: Natron samples from close to the body — large hard lumps.

with more salt. Initially ten animals were buried, then individually removed from the natron at approximately weekly intervals. On removal the excess salt was brushed off and the condition of the body was noted. It was then weighed and left exposed to the atmosphere, its condition and weight were checked periodically. In this way it was possible to obtain an approximate figure for the minimum time required for natron treatment. Shorter times resulted in noticeable decay after removal, while longer times gave little improvement in subsequent preservation. Repeated experiments confirmed this time.

For the second series of tests the salt mixtures contained over 60 per cent sodium chloride or sulphate. The animals were then buried and checked as in the first series. After the completion of the treatments two samples were taken from each mixture, one close to the body, the other several inches away. These were checked to determine the amount of moisture they had taken up during the treatment. Some of the mixtures were then re-used up to four times in order to compare their effectiveness with fresh mixtures.

To investigate the possibility of fluids being used for preservation a series of solutions were made. They were of the same composition as those used in the first series of tests, with the salts dissolved in water to give 3 per cent or 10 per cent solutions.

To study the second method mentioned by Herodotus, rats were injected, through the rectum, with a mixture of turpentine and cedar-wood oils. For Herodotus's third method the intestines were washed out with water. Both of these operations were difficult to carry out and several animals had oil or water injected into their body cavities. After injection the animals were buried in natron. A few rats were also opened and buried in dry sand. This was done in order to compare the effectiveness of an inert drying medium with a chemical one such as natron.

Results

Animals buried in natron showed little sign of reaching a stable condition in less than twenty days. If they were removed before that time the tissue was still very soft and moist, and they continued to decay. As treatment was extended beyond twenty days the amount of subsequent decay decreased. In general, animals which were dry and free from strong odour when they were removed from natron were found to be stable. No absolute time could be found for treatment, after which further decay would be minimal, but the time usually fell within the range of thirty to forty days. One of the main factors appeared to be the amount of fat in the body. Large amounts of fat not only increased the treatment time, they also gave the body a greater degree of flexibility when it was finally removed from the natron. As has been mentioned there was often a noticeable smell, particularly while the animals were being treated. It was impossible to quantify this, but it was rarely very strong and was usually tolerable.

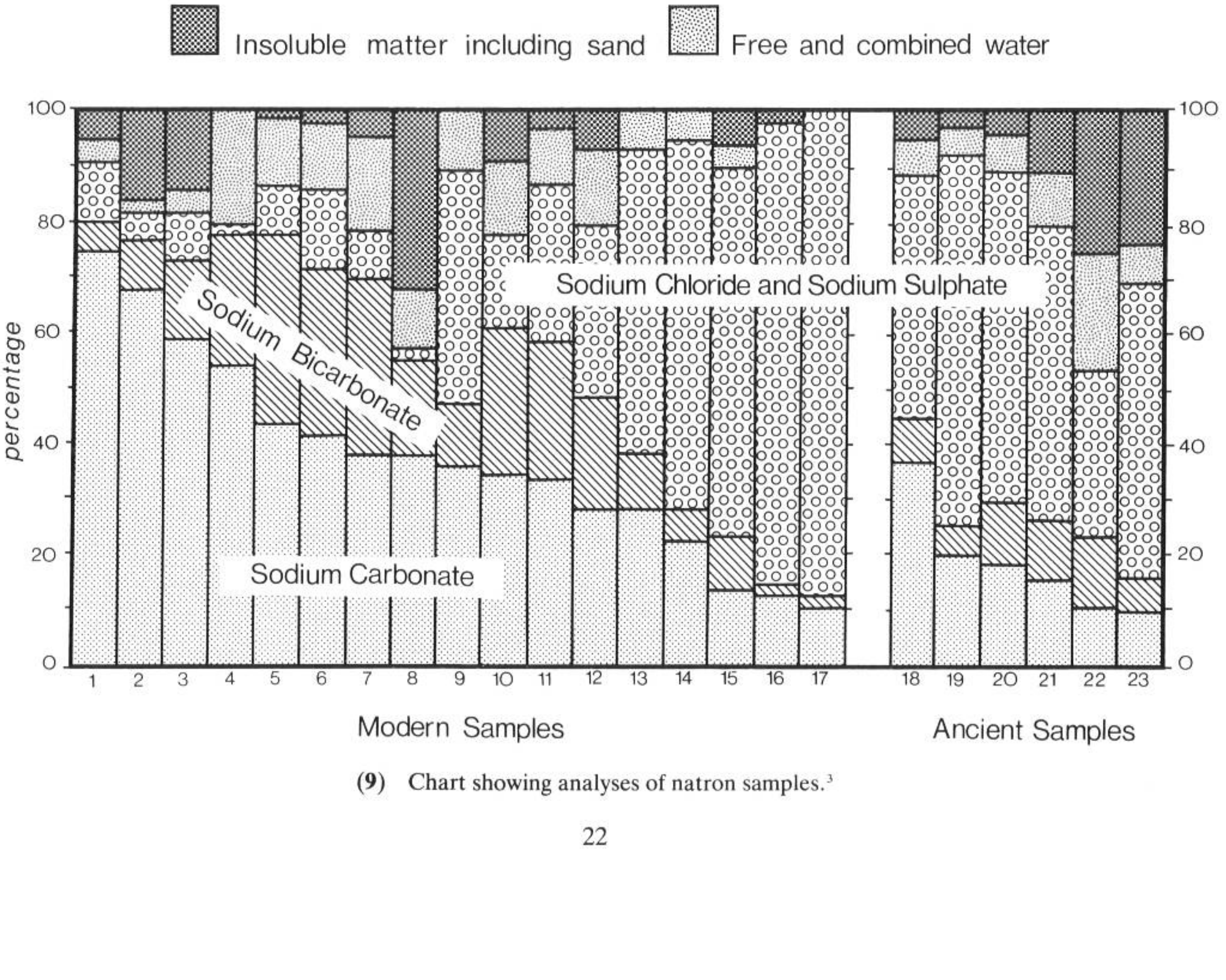
The results obtained with salt mixtures containing large amounts of sodium chloride or sulphate showed considerable differences. Where the chloride was used the bodies often remained moist, soft and flexible after forty days. After any given time they usually showed more decay than those treated with natron for a comparable period. In general they reached a stable condition after forty-five to fifty days. On removal they dried slowly for the first few days, and then began to harden. The most obvious sign of decay, the smell of putrefaction, was not noticeably different from that of the earlier tests. In the tests carried out with mixtures containing large amounts of sodium sulphate the bodies dried out more slowly than those in natron, but faster than those in high-chloride mixtures; they were usually stable in forty to forty-five days. The greatest difference was that in these tests there was usually a very strong unpleasant smell of decay.

Apart from the condition of the bodies, there was a marked difference between all three salt mixtures after they had been used. The natron tended to form large, very hard, clumps close to the body after about twenty days. These clumps were dry to the touch and often stained brown. Further from the body, or where there was no clumping on a large scale, there were small firm lumps in the natron. Beyond these the salt was clean, dry and apparently unaffected. High-sulphate mixtures also showed some staining and clumping, although the clumps were smaller and not as hard as those in the natron. The clumps were often moist, and this dampness often extended quite a distance from the body, but the salt was not always stained. Salt mixtures containing large amounts of chloride rarely clumped, but they were usually extensively stained and, except where large quantities were used, all of the mixture was damp.

When salt mixtures were re-used their effectiveness reflected the degree of soiling caused by earlier use. As soiling increased so did the time required for the body to become stable, consequently there was more decay. Natron which had been used four times took up to forty-five days to mummify satisfactorily. Re-used mixtures containing high proportions of sulphate extended the treatment time to at least fifty-five days. However, high chloride mixtures which had been re-used four times showed no sign of working effectively even after seventy days.

Within a few days of the beginning of the tests with solutions it became clear that it was unlikely to be a satisfactory method of preservation. The fluid became very dark and there was a very strong smell of decay. Although some of the rats were left in the solution for seventy days none of them were satisfactorily preserved. The worst cases were almost unrecognizable on removal, having lost most of the fur and muscle to leave discoloured skin, bones and fat. Others had decayed to varying extents, but they were all soft and pulpy. It was difficult to remove them from the solutions, and several disintegrated while they were being moved. Those which were removed reasonably intact were washed carefully and allowed to dry. As they dried they all shrank and distorted, and many continued to decay.

After forty days in natron the oil-injected rats were still slightly soft and flexible. They had all shrunk slightly and, in two cases, there was a soft mass in the abdomen. When they were opened this was found to be an oily fluid, and in all cases the organs were dark and soft, but



(9) Chart showing analyses of natron samples.[3]

still intact and recognizable. Although there was some smell during treatment it was never strong. After removal from the natron the animals dried slowly and shrank a little, but they showed no signs of further decay and did not become completely hard. In contrast, the animals injected with water gave off a strong smell during treatment and while they were drying after removal. After the treatment they had shrunk considerably and had started to harden. No fluid was found in the abdomen, but the organs were shrunken, almost unrecognizable, dark green and clay-like in consistency.

When animals were buried in sand it was usually between fifty and fifty-five days before they became stable, many took up to seventy days. In all cases there was a strong unpleasant smell of decay, and, after treatment, most of the sand was damp.

The early experiments in the study were carried out in the laboratory, and there was no sign of insect attack. Later experiments allowed free access of insects to the containers after the animals were buried, and to the bodies when they were removed. After burial large numbers of flies were attracted to the containers. When treatment was completed some dead larvae were found near several of the rats; they were identified as bluebottle larvae (*Calliphora erythrocephala*). These were found more frequently when the animal was buried in soiled material. After removal most of the bodies were attacked by the Larder beetle (*Dermestes lardarius*) and its larvae; two *Dermestes peruvianus* larvae were also found.

In order to discover how well insects might be able to survive on an animal buried in natron, two rats were opened with a ventral incision and left exposed for several hours; during that time large numbers of flies alighted on them. One of the rats was then buried, the other being left until larvae hatched out. When the rats were removed from the natron, after thirty days, no live insects were found, but it was clear that many had survived for a long period. In the natron around the rat which was buried first there were several larvae and pupae close to the body. There were also two flies which had just emerged from pupae; these were identified as bluebottles. In the other case some larvae had travelled several inches from the body, their progress being clearly indicated by 'tunnels' in the natron. There were also large numbers of pupae and many empty cases; the adult flies, still with partly folded wings, had often travelled a few inches from the pupal case. One fully formed adult was found on the natron surface, and as this was covered with a fine mesh it could only have emerged from the natron. As before, most of these flies were identified as bluebottles, although one was a flesh-fly (*Sarcophaga sp.*).

Conclusion

Several factors make it difficult to attempt any direct comparison between the experiments in this study and ancient Egyptian mummification. The most obvious of these would seem to be the relatively hairless state of the human body when compared with that of a rat or mouse. However, early parallel tests with normal and shaved rats showed little difference in drying times. There is also the influence of body size and such related factors as the thickness of skin, muscle and fat layers. Within the limitations of the study this was less easy to investigate, but, in general, the use of animals ranging from young mice to large adult rats gave comparable results. A further point is that no attempt was made to simulate the temperature and humidity of the Egyptian climate. A few experiments were carried out at temperatures between 5°C and 8°C higher than the others; this usually resulted in the drying time dropping by two or three days. Despite these reservations the study did highlight several factors which could influence the final condition of the body and its subsequent stability. The most important of these are the composition of the natron, and the way it was used. Obviously the use of too little would either allow considerable decay before the body dried, or make satisfactory drying impossible. There is no way of knowing how much natron the Egyptians used for each body. During the course of this study, it was found that a salt volume at least ten times the volume of the body was necessary to ensure adequate drying. If the natron contained large amounts of sodium chloride or sulphate they would influence the mummification in two ways. When the salt mixture was used for the first time it would probably be necessary to use at least 50 per cent more than would be required if 'pure' natron was used. However, it is when the possibility of re-use occurs that real differences arise. The experiments carried out with 'pure' natron indicated that much of the soiled material formed compact clumps around the body. This would make it easy to remove the worst affected salt before another body was buried. If it was not removed it would form at least a partial barrier between the rest of the natron and the next body. Similar considerations apply to natron mixtures which contain large proportions of sodium sulphate. As the clumps tend to be smaller and not as form they would be more difficult to remove, conversely they would be less of a barrier if they were left. The greatest problem with re-used material occurs when there is a high proportion of sodium chloride. Such mixtures quickly become soiled, and, more importantly, the soiling is extensive which makes it almost impossible to remove without replacing the whole salt bed.

A few of the rats used in the early experiments had started to decay before they were buried in natron, and this appeared to influence the action of the salt. In fresh natron they took two or three days longer before decay was arrested and drying began, but in soiled material the time was extended by over a week.

As has been indicated, many factors may prevent perfect mummification whereby the body is dried and rendered stable as quickly as possible, with the minimum of decay. That 'ideal' conditions could be achieved is shown by the many fine mummies still in existence. However, more late period Egyptian mummies show signs of poor preservation than might otherwise be expected. It is possible that changes in the social and religious aspects of life, after the peak of the Egyptian empire, were reflected in a decline in demand for the embalmer's work at its best. This may have led to a lowering of their standards, which allowed factors influencing mummification to assume a greater significance than before.

References

[1] For a broader consideration of these points, see A. Lucas, *Ancient Egyptian Materials and Industries*, 1962, Chapter XII.
[2] A. Lucas, *Preservative Materials*, pp. 9–10. A Lucas, *J.E.A.*, XVIII (1932), 133–34, 137–38.
[3] Compiled from data in A. Lucas, *Ancient Egyptian Materials and Industries*, 1962, pp. 493–4.

Comparison of Weight Loss during Drying with Different Materials

	Main Constituent of Drying Mixture						
	Sodium[1] Carbonate	Sodium[2] Carbonate	Sodium[1,3] Carbonate	Sodium[1,4] Carbonate	Sodium[1] Sulphate	Sodium[1] Chloride	Sand[1]
Weight loss of body during treatment (%)	50	16	34[7]	55[7]	44	38	38
Total weight loss (%)[5]	64	61	63[8]	64[8]	62	61	63
Moisture gain by drying mixture during treatment (% weight)[6]	35	23	10	14	23	2	4

The figures given are averages

[1] Fresh salt
[2] Re-used salt
[3] Rat injected with oil
[4] Rat injected with water
[5] Includes loss during treatment and while exposed to the atmosphere after removal
[6] Close to the body
[7] Taken as a percentage of the weight of the body plus injected fluid
[8] Percentage of original body weight