News & views

Archaeology

Recipes for ancient Egyptian mummification

Salima Ikram

What ingredients and processes underlay mummification in ancient Egypt? The molecular analysis of labelled pots excavated from an embalming workshop provides some answers to this question. **See p.287**

Ancient Egyptian mummies have gripped the popular imagination from ancient times to the present day, as attested to by the many books, films and exhibitions that feature them. Yet the precise methods and materials used for mummification remain relatively unknown. On page 287, Rageot *et al.*[1] present chemical, archaeological and written analyses of the contents and hieratic (joined-up hieroglyphs) labels of 35 vessels excavated from an embalming workshop and a burial chamber. These are from the necropolis at Saqqara (Fig. 1), one of the principal burial grounds in Egypt, which has been used since at least 2900 BC. The excavated material, which dates to approximately 664–525 BC, substantially furthers our understanding of this complex technique and the substances involved in preserving the dead, as well as shedding light on the socio-economic implications of this practice.

For more than 3,000 years, ancient Egyptians artificially preserved the bodies of humans and animals with the goal of providing a permanent home for their souls. Over the course of around 70 days[2], mummification and the associated religious rituals – prayers, burning of incense, anointing and wrapping of the body – were thought to transform the deceased from an earthly to a divine being. Mummification evolved over time and varied depending on the deceased's wealth, personal preferences, the changing of fashion and beliefs and the embalmers' skill and style, similar to the way that trends emerge in the work of modern funeral homes.

The main focus of mummification was the desiccation of the body using natron salt. Evisceration (removing the lungs, stomach, intestines and liver) and excerebration (removal of the brain) also had key roles in arresting decomposition, although these processes were not always practised. Anointing the body, both inside and out, with different resins, ointments and oils to protect it from fungi, bacteria and putrefaction was a crucial part of the process. The identification of those materials has largely eluded scholars until this work by Rageot and colleagues.

Up to this point, research on mummification technology was based on a limited amount of pictorial evidence and cursory mentions of the process in ancient Egyptian texts, with details provided by Greek writers such as Herodotus in the fifth century BC and Diodorus Siculus in the first century BC. A translated Egyptian text, from approximately 1450 BC, contains a rare embalming manual that provides several details of mummification, including limited directions for producing some ointments[3]. Analyses of the embalming material of a few mummies[4–6] augmented this research, although this could not confirm the Egyptian names of these materials. In addition, scholars have engaged in experimental work, attempting to identify the materials used and to recreate the process[7–10].

Other labelled pots containing embalming deposits from roughly the same time as those found by Rageot *et al.* have been excavated[11]. However, their contents could not be analysed at the time of their discovery because of issues regarding testing. Thus, Rageot and colleagues' work is the first instance of the analysis of named materials used in mummification from the different contexts of an embalming workshop and a burial chamber. The study identifies a list of ingredients and mixtures used in embalming, their specific properties (such as antibacterial or desiccant), as well as the part

A. R. HUSSEIN, THE SAQQARA SAITE TOMBS PROJECT; B. A. EMAM, THE SAQQARA SAITE TOMBS PROJECT

Figure 1 | Ancient Egyptian burials at Saqqara. Rageot *et al.*[1] present molecular and mechanistic insights into the mummification process through analysis of pots excavated from burial chambers and an adjacent embalming workshop at the site. **a**, One of the burial chambers contained the mummy sarcophagus shown. **b**, This item, which depicts the goddess Nephthys in a position grieving for the deceased, was found at a burial site near the embalming workshop. Made of layers of papyrus and/or linen and plaster, this type of object (called a cartonnage) was typically used to cover and adorn mummies.

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of the body on which they were used (from pot labels with instructions such as "substance for the head" or "for making beautiful the skin").

For the analyses of organic residues, the authors chose 31 out of 121 vessels from the embalming area that were the most clearly labelled, together with 4 other samples that came from burial chambers. The materials identified included: oils or tars of juniper, cypress and cedar, and various resins including those from *Pistacia* trees, animal fats, beeswax and plant oils, almost all of which were identified previously in mummies[7–10]. Rageot and colleagues' most notable identifications were those of two resins, dammar and elemi, which have not been identified in excavations anywhere in Egypt before, and of bitumen from the Dead Sea.

All the resins were from the Near East Levant region (the general area of what is now Lebanon and Syria), except for dammar and elemi, which probably originate from rainforests in Asia or, a less likely possibility, Africa. These resins provide fresh evidence for long-distance trade networks, and raise the question of how and when the Egyptians learnt of these resins and obtained a specialized understanding of their properties and relevance to mummification.

Although bitumen has long been associated with mummification, it was chemically detected in mummies only a few years ago[12]. Notably, Rageot *et al.* found bitumen only in the burial-chamber vessels. Perhaps it was not used in the initial stages of embalming, but only during the final rites, and it might have also had a role in the anointing of funerary objects in addition to (or rather than) the mummy[13].

Analyses on pots labelled *antiu* and *sefet*, traditionally identified as myrrh and oil, respectively, show that the former consists of a mixture of oil or tar of cedar, juniper and cypress and animal fat. The recipe for the latter was more varied: some vessels contained animal fats mixed with oil or tar of juniper and cypress, and one had ruminant fat and elemi. Although the recipes for *antiu* and *sefet* are similar, they are not identical. Further work might explain which properties of these substances the embalmers valued, and why they blended them in a particular fashion to create these mixtures for use on different parts of the body.

Rageot and colleagues' work provides an important step forward in our understanding of ancient Egyptian embalming materials and methods. These analyses can be further built on if the team can 'mummy-truth' (verify) the materials' prescribed use on the mummies themselves, and can see how or whether the mixtures relate to those listed in the translated embalming manual[3]. Similar work should be carried out on other mummies to elucidate evolving mummification methods, to examine geographical variations, to assess the socio-economic status of the deceased and to understand the diverse trade routes that supplied embalmers for more than 3,000 years.

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1. Rageot, M. *et al.* *Nature* **614**, 287–293 (2023).
2. Ikram, S. *Death and Burial in Ancient Egypt* (Am. Univ. Cairo Press, 2015).
3. Schiødt, S. *Papyrus Ægyptol. Tidsskr.* **36**, 18–25 (2016).
4. Buckley, S. A., Clark, K. A. & Evershed, R. P. *Nature* **431**, 294–299 (2004).
5. Clark, K. A., Ikram, S. & Evershed, R. P. *Proc. Natl Acad. Sci. USA* **110**, 20392–20395 (2013).
6. Jones, J. *et al.* *J. Archaeol. Sci.* **100**, 191–200 (2018).
7. Brier, B. & Wade, R. S. *Z. Ägypt. Sprache Altertumsk.* **124**, 89–100 (1997).
8. Ikram, S. in *Divine Creatures: Animal Mummies in Ancient Egypt* Ch. 2, 16–43 (Am. Univ. Cairo Press, 2005).
9. Ikram, S. in *Egyptology in the Present: Experiential and Experimental Methods in Archaeology* (ed. Graves-Brown, C.) Ch. 4, 53–74 (Classical Press Wales, 2015).
10. Nerlich, A. G. *et al.* in *Pharmacy and Medicine in Ancient Egypt: Proc. Conf. Barcelona (2018)* 68–77 (Archaeopress, 2021).
11. Bareš, L. & Smoláriková, K. *Abusir XXV, The Shaft Tomb of Menekhibnekau* Vol. 1 (Czech Inst. Egyptol., 2011).
12. Dutoit, C. E., Binet, L., Fujii, H., Lattuati-Derieux, A. & Gourier, D. *Anal. Chem.* **92**, 15445–15453 (2020).
13. Fulcher, K., Serpico, M., Taylor, J. H. & Stacey, R. *Proc. Natl Acad. Sci. USA* **118**, e2100885118 (2021).

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Catalysis

Catalysts light a path to sustainable chemistry

Emiliano Cortés

A light-activated 'plasmonic' catalyst, made from abundant elements, produces as much hydrogen from ammonia as do the most-used heat-activated catalysts based on a rarer element, suggesting a strategy for sustainable chemical production.

Future sustainable industrial processes for synthesizing chemicals should avoid burning fossil fuels, produce no carbon emissions and be cheaper than current processes — industry will not adopt sustainable processes that are more costly than existing ones. Writing in *Science*, Yuan *et al.*[1] report that a plasmonic catalyst — a type of light-activated catalyst — based on abundantly available copper and iron can be used to produce hydrogen gas, a green fuel, from ammonia (NH_3). This light-powered process generates hydrogen as efficiently as does a widely used heat-driven catalyst based on ruthenium, a much scarcer element. The findings reveal opportunities for plasmonic catalysts in sustainable industrial processes, and might help to establish the wide-scale use of light to power chemical reactions. Moreover, it suggests that catalysts based on Earth-abundant elements might finally emerge for use in a broad range of industrial applications.

> **"The observation that an almost inactive thermal catalyst can became a top performer under illumination is striking."**

Of all the industrial sectors, the chemical industry is the largest consumer of energy and the third-largest direct producer of carbon dioxide emissions (see go.nature.com/3r4ufgm). In 2021, the global chemical industry emitted 925 megatonnes of CO_2. About 75% of these emissions came from fossil-fuel combustion, which is used to produce the high temperatures and pressures required for most industrial chemical reactions.

A long-standing strategy for mitigating these issues is to develop new catalysts for industrial reactions, to reduce the overall energy input. Precious metals are currently the preferred catalysts for most chemical reactions. However, such metals are expensive and are not abundant in Earth's crust, making them unsustainable for long-term industrial use. The challenge is therefore to find alternative Earth-abundant catalysts.

Another challenge for the chemical industry is to replace fossil fuels with green fuels, such as hydrogen, that (ideally) can be obtained sustainably and produce no CO_2 on combustion. A future hydrogen-based economy will require methods for the long-term, large-scale storage and transport of hydrogen, a highly reactive gas. One approach is to react hydrogen with nitrogen to produce ammonia

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