Christina Kreuzner

Two papyri of particular importance for our knowledge about ancient technology, chemistry and alchemy are the Papyrus Leidensis X and the Papyrus Graecus Holmiensis. They provide a vast range of alchemical recipes for methods to imitate gold, silver or gemstones and for colourants and wool dyes — especially for vegetable purple. The recipes concerning stones and metals have been object to a lot of research work, whereas the dyeing recipes have been less studied and often just been quoted as an evidence for alternate purple dyes, mostly declared as falsifications. The aim of a 5-months-project was to develop the texts as a source for dyeing technology and textile colours in the eastern Mediterranean in the Late Antiquity within an interdisciplinary approach. For the first series of experiments the recipes using alkanet as colourant were chosen. Three of these experiments are presented here. It could be proved that alkanet is suitable to achieve a broad spectrum of purple shades by various procedures.

1 Introduction

Both papyri cited in the title, which were probably found in Thebes, Egypt, were originally part of a collection of papyri written in Greek language brought together in the beginning of the 19th century AD by Giovanni Anastasi, a wealthy merchant who was appointed Consul-General for Sweden and Norway in Egypt in 1828. Anastasi sold a major part of his papyri collection to the Dutch government in 1828 and they are nowadays treasured in the Dutch National Museum of Antiquities (Rijksmuseum van Oudheden) at Leiden. Among them was Papyrus Leidensis X (abbr.: pLeid) that was published for the first time in 1843 by Conrad Leemans, who gave a Latin translation. Papyrus Graecus Holmiensis (abbr.: pHolm), another papyrus originating from this collection, was donated to the Royal Swedish Academy of Letters, History and Antiquities (Kungliga Vitterhets Historie och Antikvitets Akademien, KVHAA) by Anastasi about 1832. Lagercrantz published it with a German translation in 1913. It has been transferred to the Victoria Museum of Egyptian Antiquities at Uppsala in 1906, since 1927 it is housed in the National Library of Sweden at Stockholm. An English translation of both papyri by Caley followed in 1926, a completely new edition of both papyri and additional fragments with a French translation by Halleux in 1981. A first attempt of a technological translation of the dyeing recipes was made by Reinking in 1938. Two further translations are in preparation, an English one by Mark Clarke and a German one by Albrecht Locher and the Arbeitsgruppe Antike Farben.

In contrast to the earlier assumption that at least the purple recipes of the papyri were intended as falsifications, Steigerwald pointed out two important facts about the antique signification of the term “purple”. At first, that the term could be equally used for colours achieved with murex and for those dyed with plants, and secondly, that it covered the complete spectrum of hues that could be achieved with murex, ranging from a blood-red shade up to a blueish-violet purple.
Both papyri were dated to the late 3rd or early 4th century AD (Halleux: time of Constantine).\textsuperscript{10}

The first step to become acquainted with the texts was a very intense text work. The recipes were assembled in a table with the translations hitherto available. Comparing the latter showed that often the interpretations differ, e.g. in the identification of certain ingredients, specification of procedures or in the relationship between the recipes. It became clear that it is impossible to achieve a convincing translation either by philological or technical approach alone and the fact that many substances could not be reliably identified till now was one of the major challenges when planning experiments according to the recipes. In a next step the recipes were classified according to their trait as washing recipe, mordant, colourant and colour achieved regarding the Greek titles and the ingredients and methods mentioned. Most recipes describe only one step and will just give a complete dyeing process when combined with other recipes. Considering the characteristics described in the recipes unclear terms were narrowed down as far as possible.

In the recipes various plants and substances to achieve a purple colour are named. “Ἄγχοσα” is the drug mentioned most often (next to “φῦκος”), especially in \textit{Pfoli}. For two reasons these recipes were chosen for the first series of experiments. First of all, all translators agree in identifying “أجهزة” as Alkanna tinctoria, so there is no doubt about the plant used (Fig. 1).\textsuperscript{11} Secondly alkanet is a very interesting dyestuff because it differs from other vegetable dyeing materials in a crucial point: its colourant, Alkannin\textsuperscript{12,13}, ((S)-5,8-dihydroxy-2-(1-hydroxy-4-methylpent-3-enyl)-1,4-naphthoquinone, Fig. 2), is not soluble in water. It is extractable with alkaline solutions (producing a blueish-violet solution) and soluble in fat/oil and various organic solvents (producing a red solution). In the plant, Alkannin is not found as free naphthoquinone but as esters. Alongside also Alkannan (5,8-Dihydroxy-2-(4-methylpentyl)-1,4-naphthoquinone) has been found.\textsuperscript{14}
white linen garments (foreigners are shown in their traditional clothes). Pharaohs have coloured items as their names headcloth. The work of Prof. Dr. Annemarie Stauffer showed, that the preference for linen garments had hardly changed in coptic times. The garment itself was woven of undyed linen where-as the dyed fibres used for the integrated decorative elements were almost without exception wool.19 So the studied recipes are thus clearly witnesses of the late antique dyeing practice in Egypt.

Sometimes it is clearly stated if washed or unwashed wool should be used for a certain recipe. As the washing recipes are not precise enough to wash all the wool needed for the experiments oneself, already washed wool had to be found. To descry the influence of modern washing tensides on the dyeing results, three kinds of wool were used for the experiments:

1. Unwashed and uncarded raw wool – yellowish, natural fat content, with dirt such as grass (Fig. 3).
2. Wool washed with natron and carded with a machine at the sheep farm – mat, still feeling greasy, rests of dirt, much lighter in colour than the raw wool (Fig. 4).
3. Industrially washed (according to the producer: 1/3 soap, 1/3 natron, 1/3 tensides) and carded wool – very low fat content, well carded, white wool (Fig. 5).

For each specification to be tested a sample of approximately 2 g was weighed out. On one end of each bunch of wool a label was fixed with a cord, containing abbreviated informations as experiment number, sort of wool, weight and tested specifications.

2 Experimental

The basis for the experiments was the German translation of Albrecht Locher. But as this has not been published yet and for a better understanding the recipes will be quoted in Greek as transliterated by Halleux20 along with the English translation of Caley. The numbers of the recipes follow the counting of Halleux; Caley used differing criteria for counting and so came to different numbers; those are complemented in brackets.

2.1 Concerning Quantities

The recipes of both papyri are no precise instructions comparable to modern laboratory prescripts but notices of ancient dyeing experts. Thus for almost each recipe one or several parameters such as quantity of ingredients, process temperature, dyeing period or liquor ratio had to be concluded from recipes complementing one another. The first sentence of recipe 108 of Papyrus Graecus Holmiensis served as a clue for the ratio of wool, alkanet and dyeing bath.

\[
\frac{1 \text{ stater}}{8.73 \text{ g}} : \frac{1 \text{ kotyle}}{270 \text{ ml}} = \frac{1 \text{ g}}{30.9 \text{ ml}}
\]

This leads to the following possible liquor ratios:

- \(12.48 \text{ g} : 240 \text{ ml} = 1 \text{ g} : 19.2 \text{ ml}\)
- \(8.73 \text{ g} : 240 \text{ ml} = 1 \text{ g} : 27.5 \text{ ml}\)
- \(12.48 \text{ g} : 270 \text{ ml} = 1 \text{ g} : 21.6 \text{ ml}\)
- \(8.73 \text{ g} : 270 \text{ ml} = 1 \text{ g} : 30.9 \text{ ml}\)

The liquor ratio lies somewhere between 1:19.2 and 1:30.9. For the experiments an average ratio of 1:25 was fixed; so relating to recipe pHolm 108 the following quantities served as base: a ratio wool to alkanet of 1:4 and a liquor ratio of 1:25, which meant that 40 g of alkanet and 250 ml of liquor were used for each 10 g wool.

One ingredient for the experiments A and B is vinegar. As it is not explicitly described what kind of vinegar is meant, organic white wine vinegar with an acid content of 6% was used. But the ancient dyers also could have used other sorts of vinegar such as for example palm vinegar or vinegar made of dates, figs or even beer. It also has to be considered, that in ancient times vinegar did have a lesser acid content.25

As said before all the recipes show many possible variations. In a first approach they were carried out as they were written down and not modified by our modern knowledge about dyeing processes (for example by adding water). Step by step all possible variations will have to be modified and many of them might be excluded in that way.

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2.2 Experiment A – pLeid 95 (Caley: 97)

"Αλλα.

Κάρυα διάτηρων καὶ μετ' αὐτῶν ἄγχουσαν καλῆς, εἰθ' ὅταν τούτο σόινης, ὁδὸς ἐπίβαλλε διρύμ καὶ πάλιν τρίβε βαλών ἔκει σίδιον καὶ ἔσσαν ἡμ(έρας) γ' καὶ μέτα τὰ γ' κάθες εκεῖ τὸ ξέριον καὶ ἔσται ψυχροβαφής. Λέγεται δὲ ὅτι παϊδερώτινον γίνεται ἐμπορφυρίζον καὶ μετὰ νιτρου βερνικαρίῳ βραχύ ἀντί του καρυοῦ τοῦ αὐτοῦ ποιεῖ.26

„Another (Procedure).

Grind some walnuts with some alkanet of good quality. This done, place them in some strong vinegar; grind again; add some pomegranate bark to this; lay aside three days; and after this, plunge the wool in it and it will be dyed cold. It is said that there is a certain acanthus which furnishes the purple color; moistened with some natron of Berenice in place of nuts, it produces the same effect."27

All interpreters agree on the translation of the first part of this recipe which formed experiment A. The description says that the alkanet has to be ground one time with walnuts28 (Fig. 6) and afterwards a second time adding vinegar and pomegranate bark. After three days the wool can be added.

The following part of the recipe, which has not been part of experiment A, has been interpreted in different ways. Caley stated that it is a second way or rather plant to dye the wool whereas Halleux spoke of a particular shade of the purple dyed from alkanet. The last sentence mentions ‘natron of Berenice’ as a substitute for the walnuts producing a purple dyeing too.

As the raw wool was intended to be used for the washing recipes only just the two types of washed and carded wool were used for this running: 5 samples at 2 g of industrial wool (A) and 5 samples at 2 g of the sheep farm’s wool (B) were weighed out (above), adding to 20 g. As no quantity is given in this recipe the specifications of pHolm 108 were used. Information on how long the wool has to stay in the liquor is also missing and therefore five points in time were defined to take out the wool: after one day (samples A1/B1), two days (samples A2/B2), three (samples A3/B3), four (samples A4/B4) and eight days (samples A5/B5). 80 g alkanet and 500 ml vinegar were needed, the walnut-alkanet-ratio was fixed to 1:2 (-40g walnuts) and a wool to pomegranate bark ratio to 1:1 (-20g). The alkanet as well as the walnuts were powdered with an electrical coffee mill before usage to make the grinding easier and to extend the surface area; the pomegranate bark was already finely ground.

The dye bath achieved by the given directions is rather pasty in texture than aqueous and is red coloured.

It was poured in a glass jar of about 1.3 l capacity and was covered with a watch glass to minimize the fluid loss by evaporation. After three days the samples were added starting with those to be taken out latest. A glass bar was used to make sure that the wool was completely under the dye bath’s surface and wet by it. The jar was again covered with the watch glass.

24 h later the first samples (A + B1) were taken out of the dye bath, roughly flushed out once with vinegar (liquor ratio again 1:25) and hung on a clothes line to dry. This procedure was iterated with the remaining samples at the points in time previously defined.

2.3 Experiment B – pLeid 94 (Caley: 96)

"Πορφ(ύρας) βαφή.

Ἀσβέστον μεθ’ ύδατος βρέξον καὶ ἄφες καταστημάτη τυφ(κτα) α’, καὶ ἀποσιρώσας κάθες τὸ ἔριον εἰς τὸ υγρόν τὸν ὕδραν τὸν ἡμέραν α’ καὶ αὐτό ἐπέβαλε δριμὺ καὶ πάλιν τρίβε τρόπῳ τῷδε · φῦκος ὕδατι ζέσον καὶ ὅτα(ν) ἐξεράσῃ ἐπίβαλλε μικρὸν χάλκανθον πρὸς ὄξεις καὶ ἐπίβαπτε ἀνίησι χρῶμα καρυκάνθιον. Εἶτα ξηράνος αὐτό ἐπιτίθεται τρόπῳ πώδη · φῦκος υδάτι ζέσον καὶ ὅτα(ν) ἐξεπράσῃ ἐκεί πορφυροῦν γένηται καὶ τότε χάλα τὸ ἔριον καὶ γίνεται. ‘Εαν δὲ περισσότερον βάλης χαλκάνθιον, μελάντερον γίνεται."29

„Dyeing with Purple. (Two Methods).

Grind lime with water and let it stand overnight. Having decanted, deposit the wool in the liquid for a day; take it out (and) dry it; having sprinkled the alkanet with some vinegar, put it to boiling and throw the wool in it and it will come out dyed in purple. Alkanet boiled with water and natron produced the purple color.

Then dry the wool, and dye it as follows: Boil the seaweed with water and when it has been exhausted, throw in the water an imperceptible quantity of copperas, it becomes darker."30

This recipe describes a two-step-dyeing, first with alkanet and afterwards with "φῦκος."31 One question was if already the first step led to a purple colour which could be modified by the second step, or if both steps were necessary. So experiment B covered only the first dyeing process using alkanet. Like in experiment A 5 samples of industrial wool (A) and 5 samples of the sheep farm’s wool (B) were weighed out. In addition for this experiment a single sample of raw wool (X) was used. It was treated in the same way as the other samples but in a second vessel.

Similar to experiment A this run expanded over several days. On the first day the lime water had to be prepared. On the second day, the lime water was decanted, then the wool was put in and left to stand overnight. Afterwards the wool had to dry. It was hung on a clothes line to loose most of the water, then carefully squeezed out in a terry cloth and put overnight in a drying cabinet at 32 °C.

Figure 6: Alkanet roots ground with walnuts.
Having ground the lees (from wine) and having placed it in a bigger glass jar (for samples A1–5/B1-5) and into a smaller one for sample X. The rest of the vinegar was added, the jars covered with a watch glass to minimize the fluid loss by evaporation and the mixtures were brought to a boil. The wool was put into the boiling dye baths and let reboil for a moment. Then both vessels were put into a drying cabinet at 60 °C to simulate a slow cool down. After 2 h the first two samples (A1+B1) were taken out and hung on a clothes line to dry. Then the vessel containing samples A2–5/B2-5 was put into a second drying cabinet at 32 °C. Another 3 h later (5 h after starting the dyeing) the next samples were taken out and treated as follows (liquor ratio 1:25).

A2 + B2 were roughly flushed out with heated vinegar. A3 + B3 were roughly flushed out with a solution of sea salt, concentration 0.5% (imitating brackish water). A4 + B4 were roughly flushed out with a solution of sea salt, concentration 3.8% (imitating the average salt content of the Mediterranean Sea).

All samples were hung on a clothes line to dry. After having taken out those six samples the vessel with the remaining samples A5 + B5 was taken out of the drying cabinet and let to stand for two days. The smaller jar with sample X stayed in the drying cabinet at 60 °C for the whole two days. Then the remaining samples were taken out of the dye bath, flushed out with vinegar and hung on the clothes line to dry.

2.4 Experiment C – pLeid 96 (Caley: 98)

Another (Procedure).

Clean the wool with fullers plant, and hold at your disposal some lamellose alum. (Then) grinding the interior or part of gall-nut, throw it in a pot with the alum, then put in the wool and let it remain several hours. Then take it out and let it dry. Follow this procedure first: Having ground the lees (from wine) and having placed them in a vessel, pour in sea water, agitate and set aside. Then decant the clear water into another vessel and hold it at your disposal. Taking the alkanet and placing it in a vessel, mix with the water from the lees until it thickens conveniently and becomes as though sandy. Then place the product in a vessel, diluting it by estimation with the preceding water which comes from the alkanet. Then, when it has become as though slimy, place it in a small kettle, add to it the remainder of the alkanet water, and leave until lukewarm. Then plunge the wool in it, lay aside several hours, and you will find the purple fast.

This experiment was the one with the most complex set-up. Two variables should be tested with this run: the ratio between gall-nut and alum for the best possible mordant and the identity of "φαίκλη". For the latter several substances have been proposed: lees (the only one that was not available and has to be tested in a following series of experiments), tartar, K2CO3 and KOH.

As in this recipe it is explicitly instructed to use washed wool, only the industrial wool (I) and sheep farm wool (II) has been used, 25 samples of each sort were weighed out (see below).

For the mordant five variations were tested:

A: Gall-nut : alum = 3:0
B: Gall-nut : alum = 2:1
C: Gall-nut : alum = 1:1
D: Gall-nut : alum = 1:2
E: Gall-nut : alum = 0:3

For the dye bath five different solutions were set (500 ml each):

1. Tartar from a white wine barrel (saturated)
2. Potassium bitartrate (saturated)
3. Calcium tartrate (saturated)
4. KOH (0.01M, pH=12)
5. K2CO3 (10%)

This leads to 25 possible combinations with two samples each (Tab. 1).
3 Results and discussion

3.1 Concerning Quantities

It emerged from these tests that the liquor ratio was too small. The dye baths with walnuts were rather pasty than liquid. Especially those baths that had to be heated (not only in experiment B but also in other recipes) the liquid evaporated too fast and had to be restored.

So on the one hand the wool did take up the dye inhomogeneously due to the inadequate wetting of the wool fibres. On the other hand at least for the heated dye baths there is the risk that they become too hot and either the wool or the colourant are overheated.

The liquor ratio should at least be 1:30, better 1:40.

3.2 Experiment A – pLeid 95 (Caley: 97)

This recipe describes a cold dye. The oil from the walnuts serves to extract the alkannin. In the results of this experiment no significant difference can be seen between the machine washed and the industrially washed wool. After 1-3 days the wool is more or less brown (Fig. 8). After four days it has a reddish, rustlike purple colour intensifying in hue with any further day (Fig. 9).

Figure 8: Wool after eight days in the dye bath.

Figure 9: Washed wool after 5 h in the dye bath.

3.3 Experiment B – pLeid 94 (Caley: 96)

This recipe describes a hot dye. This time the dye bath does not include a fatty component as the walnuts of the recipe above. That is why it is not red coloured but appears brown, like black tea. Nevertheless it dyes the wool in a regular manner (Fig. 10). Still the most intense result was achieved with the raw wool and two days at 60 °C (Fig. 11). The lime water degreases the wool. In the papyri it is also deemed to be a mordant. The raw wool lost approximately 40 % of its weight in the lime water bath (wool fat). The higher the fat content of the wool is and the longer it stays in the dye bath, the better are the results.

Figure 7: Wool samples after one day in the dye bath.

Figure 10: Raw wool after 2 days in dye bath.
The different washing solutions for samples A + B2, A + B3, A + B4 were chosen in order to see which influence which kind of washing solution had on the dyeing result. Till now no result could be achieved.

3.4 Experiment C – pLeid 96 (Caley: 98)

In this recipe a lukewarm dye bath is used. The higher the alum content of the mordant mixture the better the dyeing result. The dye bath is brown like in experiment B. Here the sheep farm wool achieves better dyeing results than the industrial wool. "φαίκλη" has been interpreted as a substance originating from a wine barrel (wine lees or tartar) or substances that can be gained by processing tartar. The tartar from a white wine barrel (wine lees or tartar) or substances that can been interpreted as a substance originating from a "φαίκλη

So "φαίκλη" actually seems to be a substance originating from a wine barrel just as tartar. Wine lees has still to be tested.

5 Acknowledgements

I would like to thank the Fritz Thyssen Stiftung, Cologne, for supporting the 5-months-project and Albrecht Locher for the permission to use his not yet published German translation.

6 References and Notes

10. Ibid. ref. 1, 22 f.
11. R. Halleux, loc. cit., 205; Lagerncrantz, I.c., 163; Reinking, l.c., 4; Caley passim. See also: D. Carmon, Purple dyeing Boraginaceae: The Mediterranean sub-plot, in: Journal of Dyed & Medicinal Plants, 2009,1, 2-17.

20. Halleux does not give the texts in the form they are written on the papyri but transcribes them into the correct greek spelling adding dia-critical signs and harmonizing the spelling. For example "ἀγχουσα" is always spelled "ἀνχουσα" in the original text. Many more examples could be cited, they were all discussed in detail by Lagercrantz (see Lagercrantz, l.c., 52 ff) and Halleux (see Halleux, l.c., 9 ff). These spelling mistakes might be worth a further investigation. They could hint at the possibility, that the scribe was not a Greek but an Egyptian who did not write the words in the Greek spelling but according to the pronunciation (compare Latin: anchusa). In Hieroglyphic script many words could be written in different variations and none of them was wrong, vowels were completely left out.

The composition of the papyri as compilations of specialised texts and with the recipes arranged by topics is well-known for the ancient Egyptian medical texts. And in these texts similar recipes can be connected with the expression "another" [ἀλλή/ἀλλο (gr.) or κτ (egyptian)] too.

21. Ibid. ref. 1, 138.

22. Ibid. ref. 6, 993.

23. Ibid. ref. 1, 138.


26. Ibid. ref. 1, 107.

27. Ibid. ref. 5, 1162.

28. Walnut seeds were used. The green husks (C.I. Natural Brown 7, C.I. 79550) are not suitable here. They can be used to dye wool (and human hair) brown. The fresh husk contains hydrojuglone glucoside, which can be converted by glycolysis and oxidation to juglone. H.P.T. Ammon (Ed.), *Hunnius. Pharmazeutisches Wörterbuch*, De Gruyter, Berlin / New York, 10th edition, 2010, 897 (Juglans regia).

29. Ibid. ref. 1, 106.

30. Ibid. ref. 5, 1162.

31. In contrast to "ἀγχουσα", "φῦκος" is not yet clearly identified. Some translators identify it as orchil from some Rocella spec. (Reinking, l.c., 8. Orselle; Lagercrantz, l.c., passim: Orselle; Cardon, l.c., 12). Halleux translates it as "fucus" (Halleux, l.c., 233), Caley as "sea-weed", not giving a certain species (Caley, Stockholm l.c., 996). The recipes using "φῦκος" (including the second part of pLeid 94) will be part of future experiments. The same applies to modifications of the colour shade with vitriol or copperas.

32. Ibid. ref. 1, 107.

33. Ibid. ref. 5, 1162.

34. Bartl et al. found that, when burning tartar at a high temperature for a long time, next to potassium carbonate also potassium oxide K2O can be formed, which changes into KOH under the influence of air. As the Egyptians were very good in controlling technical processes, they might have been able to produce KOH and so it is worth trying it as well. See: A. Bartl, C. Krekel, M. Lautenschlager, D. Oltrogge, Der „Liber illuministarum“ aus Kloster Tegernsee. Edition, Übersetzung und Kommentar der kunsttechnologischen Rezepte, Veröffentlichung des Instituts für Kunsttechnik und Konservierung am Germanischen Nationalmuseum, Steiner, Stuttgart, 2005, 8, 736 (glossary: Weinsteinsalz).

35. The natural crystallisation products of wine are a mixture of hardly soluble potassium and calcium salts of tartaric acids, mainly potassium bitartrate and calcium tartrate. H. Otteneder, *Wein*, and subitem Kristallisationsausscheidungen, Römpp online, version 3.32 (www.roempp.com).

36. Wool dyeing recipes that identify burnt lime / lime water explicitly as a mordant: pHolm 107, pHolm 135, pHolm 152, pHolm 155 (all: lime water), pLeid 92 (burnt lime). For other recipes lime water is used without labelling its function (as for example pLeid 94 = experiment B).