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ALKANNA TINCTORIA (L.) TAUSCH AS PURPLE DYE IN THE RECIPES OF PAPYRUS HOLMIENSIS AND PAPYRUS LEIDENSIS X

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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,[1] 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.[2] 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[3], 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.[4] 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[5,6], a completely new edition of both papyri and additional fragments with a French translation by Halleux in 1981.[7] A first attempt of a technological translation of the dyeing recipes was made by Reinking in 1938.[8] 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.[9]

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Both papyri were dated to the late 3rd or early 4th century AD (Halleux: time of Constantine).[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. "Ἄγχουσα" is the drug mentioned most often (next to "φῦκος"), especially in pLeid. For two reasons these recipes were chosen for the first series of experiments. First of all, all translators agree in identifying "ἄγχουσα" as Alkanna tinctoria, so there is no doubt about the plant used (Fig. 1).[11] Secondly alkanet is a very interesting dyestuff because it differs from other vegetable dyeing materials in a crucial point: its colourant, Alkannin[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.[14]


Figure 1: Alkanet root, cut.

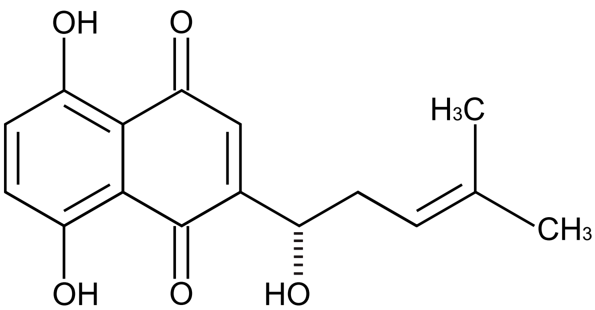

Figure 2: Alkannin, structural formula.

It is not clearly specified in the recipes which part of the plant Alkanna tinctoria has to be used. Three recipes mention that the alkanet has to be peeled first and that the bark is utilised.[15] For the ancient dyer it must have been part of his expert knowledge, if the bark of the stem, the roots or maybe even the fruits was meant, but to us it is unclear. Nowadays the cut roots are sold for dyeing purposes, so these were used for the experiments. The work of De Leo et al., who analysed the concentration of Alkannin in various tissues of the plant's stem and roots, showed that the highest concentration is reached in the bark of the roots in the time of seed ripening.[16] So most likely the ancient dyers used just the bark of the roots as well.

Less difficult to determine than some ingredients and colourants is the fibre material all these dyeing processes were meant for. Nearly all dyeing recipes (and all washing recipes) name wool, only one recipe can explicitly be used to dye linen and byssos as well as wool.[17] This is rather interesting as in Pharaonic Egypt wool was just circumstantial for the production of textiles. The linen garments were not decorated by dyeing but – on the contrary – by bleaching it and by fabric-folding (plissé). Pearls and other applications could be woven into or sewn on the textile and illustrations could be painted on the linen (e.g. on shrouds).[18] It is also important to differentiate between the divine, royal and nonroyal sphere. Tomb decorations show that gods are often depicted with very colourful garments, whereas nonroyal Egyptians are depicted with


Figure 3: Raw wool.


Figure 4: Sheep farm wool.


Figure 5: Industrially washed wool.

white linen garments (foreigners are shown in their traditional clothes). Pharaohs have coloured items as their nemes 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 whereas 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 Halleux[20] 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.

pHolm 108 (Caley: 103):

“Λαβὼν οὔρου πρὸς τὸν στατῆρα τοῦ ἐρίου κοτύλην μίαν καὶ φλοιοῦ ἀγχούσης ∫′ δ′ καὶ νίτρου πυρροῦ ∫′ α′ κ(αὶ) μίσους κυπρίου ὠμοῦ ∫′ α′ βάλε εἰς τὴν λοπάδα τοῦ οὔρου καὶ μίσγε, ἕως σοι δοκῇ καλῶς ἔχειν. [...]”[21]

“For a stater of wool take a kotyle of urine (and) put in the bowl with the urine and mix there, 4 drachmas of alkanet bark, 1 drachma of native soda (and) 1 drachma of raw Cyprian misy until it appears to you to be good. [...]”[22]

“Prenez urine, une cotyle par statère de laine; écorce d'orcanette, 4 statères; natron roux, un statère; misy de Chypre cru, 1 statère. [...]”[23]

Here another problem with the recipes becomes clear. Caley and Halleux agree in the quantities of the wool (1 stater) and of the liquid (1 kotyle; here: urine) but differ in the amount of alkanet. The first is easy to explain because here the scale units (stater and kotyle) are written down as a complete word. For the rest of the recipe there are only abbreviations of the units. Halleux has completely revised the interpretation of the abbreviations in the whole text. For the experiments the interpretation of Halleux was used.

So the relative ratio of wool to alkanet is clear (1:4). To figure out the ratio of wool to liquid is more difficult, as the scale units were not as precisely fixed as modern metric units. As the following calculation can only be a first approach, the widest range of values for a talent and a kotyle given in literature[24] were used.

1 stater = 2 drachmai
1 talent = 60 minai = 6000 drachmai = 3000 stater

1 Aeginetic talent = 37.44 kg
1 stater = 12.48 g

1 Attic/Euboic talent = 26.196 kg
1 stater = 8.73 g

A kotyle could be 0.24 l (240 ml) or 0.27 l (270 ml).

This leads to the following possible liquor ratios:

12.48 g : 240 ml = 1 g : 19.2 ml
8.73 g : 240 ml = 1 g : 27.5 ml

12.48 g : 270 ml = 1 g : 21.6 ml
8.73 g : 270 ml = 1 g : 30.9 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.

2.2 Experiment A – pLeid 95 (Caley: 97)

“Ἄλλη.

Κάρυα διάτριψον καὶ μετ´ αὐτῶν ἄγχουσαν καλήν, εἶθ´ ὅταν τοῦτο ποιήσῃς, ὄξος ἐπίβαλλε δριμὺ καὶ πάλιν τρῖβε βαλὼν ἐκεῖ σίδιον καὶ ἔασον ἡμ(έρας) γ´ καὶ μετὰ τὰ γ´ κάθες ἐκεῖ τὸ ἔριον καὶ ἔσται ψυχροβαφής. Λέγεται δὲ ὅτι παιδερώτινον γίνεται ἐμπορφυρίζον καὶ μετὰ νίτρου βερνικαρίου βραχὺ ἀντὶ τοῦ καρύου τὸ αὐτὸ 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 walnuts[28] (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.

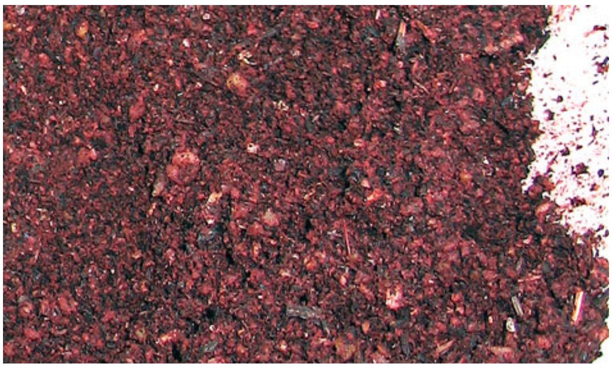

Figure 6: Alkanet roots ground with walnuts.

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.

Ἄσβεστον μεθ´ ὕδατος βρέξον καὶ ἄφες καταστῆναι νύ(κτα) α´, καὶ αποσιρώσας κάθες τὸ ἔριον εἰς τὸ ὑγρόν {ὑγρόν} ἡμ(έραν) α´ καὶ ἄρας ξήρανον, καὶ ἄγχουσαν βρέξας ὄξει ζέσον καὶ ἐπίβαλε ἐκεῖ τὸ ἔριον καὶ ἀναβήσεται σοι κογχυλιωτὸν καὶ δὶα ὕδατος δὲ καὶ νίτρου ζεσθεῖσα ἀνίησι χρῶμα κογνχύλιον. Εἶτα ξηράνας αὐτὸ ἐπίβαπτε τρόπῳ τῷδε · φῦκος ὕδατι ζέσον καὶ ὅτα(ν) ἐξεράσῃ ἐπίβαλλε μικρὸν χάλκανθον πρὸς ὄφθαλμον ἵνα πορφυροῦν γένηται καὶ τότε χάλα τὸ ἔριον καὶ γίνεται. Ἐὰν δὲ περισσότερον βάλῃς 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, in order to develop the purple, and then plunge the wool in it, and it will be dyed. If there is too much 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.

Just like in experiment A important specifications are missing. While it is said, that the wool has to be put into a boiling dye bath composed from alkanet ground with vinegar, there is no hint how long it has to stay in the bath and if it has to be heated any further after putting the wool in.

The following procedure was established: The alkanet was powdered with an electrical coffee mill, ground with some vinegar and put into 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 then 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)

“Ἄλλο.

Στρούθισον τὸ ἔριον καὶ ἔξε ἐν ἑτοίμῳ στυπτηρίαν σχιστὴν καὶ κηκίδος τὸ ἔσω. Τρίψας βάλε μετὰ τῆς στυπτερίας εἶς χυτρίδιον καὶ ἐπίβαλὼν ἔασον ὥρας ὀλίγας καὶ ἄρας ἔασον ξηρανθῆναι. Προγεγονέτω δέ σοί ἡ ἀγωγὴ αΰτη · φαίκλην τρίψας βαλὼν εἰς ἀγγεῖον ἐπίβαλε ὕδωρ καὶ ταράξας ἔα καταστῆναι, εἶτα ἀποσιρώσας τὸ καθαρὸν ὕδωρ εἰς ἕτερον ἀγγεῖον ἔξε ἐν ἑτοίμῳ. [[ολβον]] Λαβὼν δὲ ἄγχουσαν καὶ βαλὼν εἰς ἀγγεῖον τῷ ὕδατι τῆς φαίκλης μεῖξον ἕως ἐπιμελῶς ἐμπαχυνθῇ καὶ γένηται ὡς ἀμμῶδες, τότε ἐπιβαλε εἰς ἀγγεῖον ὑπὸ χεῖρα τρίβων ἐκ τοῦ προκειμένου ὕδατος τοῦ τῆς ἀγχούσης. Εἶθ΄ ὅταν γένηται ὡς γλοιῶδες, βαλὼν αὐτὸ εἰς χυτρίδιον προσεπίβαλε τὸ λοιπὸν ὅδωρ τῆς ἀγχούσης καὶ ἔα ἕως αὐτὸ χλιαρὸν ποιήσῃς, καὶ τότε χαλάσας τὸ ἔριον ἄφες ὡς ὥρας ὀλίγας καὶ εὑρήσεις πόρφυρας μένουσαν.”[32]

„Another (Procedure).

Clean the wool with fullers plant, and hold at your disposal some lamellose alum. (Then) grinding the interior 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.“[33]

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, K_2CO_3 and KOH[34].

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 (500ml each):

1: Tartar from a white wine barrel (saturated)
2: Potassium bitartrate (saturated)
3: Calcium tartrate (saturated)[35]
4: KOH (0.01M, pH=12)
5: K_2CO_3 (10%)

This leads to 25 possible combinations with two samples each (Tab. 1).

	A 3:0	B 1:2	C 1:1	D 1:2	E 0:3
1 Tartar	A1-I A1-II	B1-I B1-II	C1-I C1-II	D1-I D1-II	E1-I E1-II
2 Potassium bitartrate	A2-I A2-II	B2-I B2-II	C2-I C2-II	D2-I D2-II	E2-I E2-II
3 Calcium tartrate	A3-I A3-II	B3-I B3-II	C3-I C3-II	D3-I D3-II	E3-I E3-II
4 Potassium hydroxide	A4-I A4-II	B4-I B4-II	C4-I C4-II	D4-I D4-II	E4-I E4-II
5 Potassium carbonate	A5-I A5-II	B5-I B5-II	C 5-I C5-II	D5-I D5-II	E5-I E5-II

Table 1: Wool-Mordant-Dye bath combinations.

First of all, the solutions for the dye baths were made up according to the recipe.

Then the five mordant baths (500 ml each for 10 samples at a time) were prepared. Again no quantity for the mordant is given in the recipe. Modern prescripts give a quantity of 15 g alum per 100 g wool, so for each mordant bath 3 g of the gall-nut-and-alum-mixture were needed. The gall-nuts were ground, mixed with alum and filled up with water. Then 5 samples of each sort of wool (I/II) were put into each of the five mordant baths (A-E) and let there for 2.5 h. Afterwards the wool was taken out, hung on a clothes line and dried as in the experiments above.

When the wool was dry it was assorted anew so that one sample of each sort of wool (I/II) out of each mordant bath (A-E) could afterwards be dyed in each dye bath (1-5), resulting in 10 samples per dye bath again.

Five heating plates, mortars with pestles and glass jars were prepared. The required amount of alkanet (powdered again with an electrical coffee mill) for each dye bath was ground with a bit of the particular solution in an unused mortar, filled into one of the jars, filled up with the rest of the respective solution and heated up to 45 °C. Then the wool samples were added. The temperature of the dye bath was controlled with a thermometer and held at about 45 °C. The wool stayed in each of the dye baths for about 6 h. After taking out the samples they were all flushed out with a 3%-vinegar solution at 45 °C and then hung on the clothes line to dry.

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

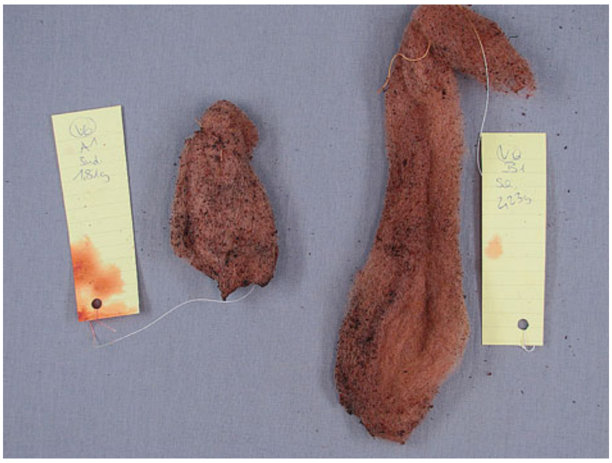

Figure 7: Wool samples after one day in the dye bath.

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

brown (Fig. 8). After four days it has a reddish, rustlike purple colour intensifying in hue with any further day (Fig. 9).

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.[36] 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 9: Washed wool after 5 h in the dye bath.

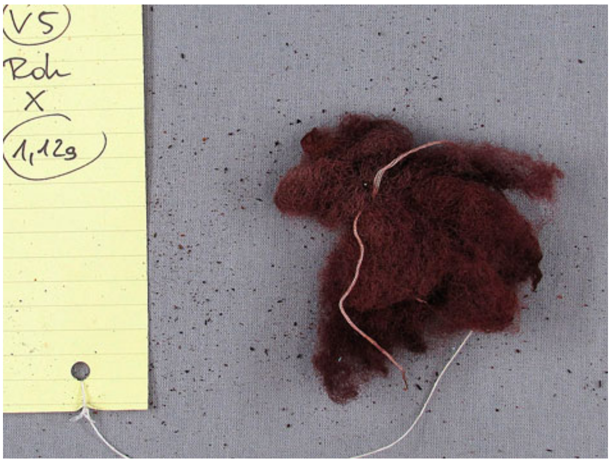

Figure 10: Raw wool after 2 days in dye bath.

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 gave the best results, at which Calcium tartrate seems to play a bigger part in the dying process than potassium bitartrate. K_2CO_3 did not solve any Alkannin from the alkanet and resulted in a grey dyeing.

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

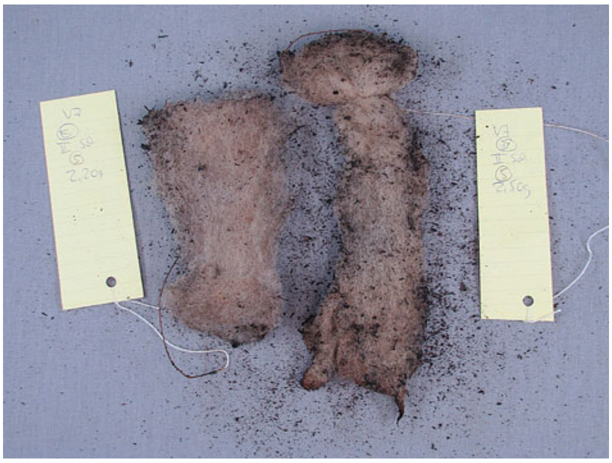

Figure 11: Sheep farm wool, mordant solution E (left, alum only) and D (right), K_2CO_3 used to extract the alkanet.

Figure 12: Sheep farm wool, mordant solution E (alum only), tartar used to extract the alkanet.

4 Conclusions

Even these first results show that alkanet can be used as a dyestuff for purple in many different processes and produce different shades of purple. Still the presented results are just the very beginning of further studies. Many tests will be needed, for alkanet as well as for the other colourants and procedures specified in the recipes.

5 Acknowledgements

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6 References and Notes

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15. pLeid 97 (Caley: 99), pHolm 138 (Caley: 132), pHolm 108 (Caley: 103). For the counting of the recipes see Part 2: Experimental.

16. P. de Leo et al., *Extraction and Purification of Alkannin from Alkanna tinctoria Tausch. Its Location in the Plant and Time Course Accumulation in the Tissue,* in: Agr. Med, 1992, **122**, 334-339.

17. pHolm 94 (Caley: 89). *Byssos* is a fine linen cloth. The antique term must not be mistaken for the modern word *byssos* as a synonym for sea-silk. On the etymology of *byssos* and the ambiguity in the modern use see: F. Maeder, *Sea-Silk in Acquincum: First Production Proof in Antiquity*, in: C. Alfaro Giner, L. Karali, Eds., *Purpureae vestes II. Textiles y tintes del Mediterráneo en época romana. Actas del II Symposium Internacional sobre Textiles y Tintes del Mediterráneo en época romana (Atenas, 24 al 26 noviembre, 2005)*, Valencia, 2008, 109-118, especially footnote 3.

18. G. Vogelsang-Eastwood, *Die Kleider des Pharao. Die Verwendung von Stoffen im Alten Ägypten*, Kestner Museum, Hannover / Batavian Lion, Amsterdam, 1995.

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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 diacritical signs and harmonizing the spelling. For example "ἄγχουσα" is always spelled "ἄνχουσα" 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 pronounciation (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" [ἄλλη/ἄλλο (gr.) or *k.t* (egyptian)] too.

21. *Ibid.* ref. 1, 138.

22. *Ibid.* ref. 6, 993.

23. *Ibid.* ref. 1, 138.

24. O. Dilke, *Mathematik, Maße und Gewichte in der Antike*, Reclam, Stuttgart, 6th ed., 2012. Especially pages 51, 98, 103.

25. Communication by Catarina Miguel at the symposium *Sources and Serendipity*, Glasgow 2008.

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. 75500) 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 "ἄγχουσα", "φῦκος" is not yet clearly identified. Some translators identify it as orchil from some *Rocella* spec. (Reinking, l.c., 8: Orseille; Lagercrantz, l.c., passim: Orseille; 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 K_2O 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 soluable 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).