UNRAVELLING THE COLOUR PALETTE: THE RECONSTRUCTION AND ANALYSIS OF SYNTHETIC COLOUR STAINS

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Abstract

Over recent years the Cultural Heritage Agency of the Netherlands (Rijksdienst voor het Cultureel Erfgoed) has conducted several investigations into early synthetic dyes that are used as wood stains. Their poor light fastness means that these dyes are often severely faded. Nevertheless it is usually possible to find parts of a piece of furniture where the original colour is still visible, for example in places that are covered and therefore shielded from light. Against this background a 2007 study looked at 19th century marquetry used on 17th century furniture. These appeared to have been stained primarily with synthetic dyes, detectable particularly on the rear of the inlay work. What was striking, however, was the difficulty encountered in identifying the dyes, even in areas which were not heavily faded. The reason for this was unclear; was the concentration of the dyes applied to the wood low, or was the method used to extract the dyes from the wood unsuitable? Pronouncing judgements about the original colour also proved troublesome, while that is often the primary reason to conduct colour research. It is not only the characteristics of the dye which play a role in determining the original colour of a piece of furniture: the colour of the wood, the concentration of the dye, additives included in the recipe for the stain and other factors also need to be taken into account. That is why a research program was launched involving reconstructions: veneers were coloured with a representative selection of dyes. Studying and following historical recipes and varying various parameters allowed us to make more informed judgements about the original colours. Subsequently, these reconstructions were also used to optimise the analytical method. The results of this research are described in this article.

1 Introduction

Organic dyes obtained from vegetable or animal materials have been used to colour furniture for centuries.¹ The result is a transparent colour, through which the wood grain remains visible. Synthetic dyes were introduced during the second half of the 19th century, initially for the dyeing of textiles.² The Cultural Heritage Agency of the Netherlands has initiated extensive research into these early synthetic dyes, which involved the collection of historical information, the development of analytical techniques, the study of degradation behaviour and the investigation of a large number of objects. These dyes were used in numerous applications: as well as the dyeing of textiles and the staining of wood they were also used in drawing and writing inks, in the leather and paper industries and in fine art. In the case of textile dyes the transition from natural to synthetic dyes proceeded fairly rapidly; our research has shown that within a few decades synthetic dyes had almost entirely replaced the natural ones. Whether the transition was equally rapid in the case of furniture stains is as yet unknown. The first recipes for synthetic dyes for wood staining date from 1867, but that is not to say that they were used on a large scale at that time.³ There are even earlier references to indigo carmine and picric acid, both semi-synthetic dyes with indigo as the original substance, but the majority of the recipes are for natural original
substances. The number of pieces of furniture studied was too small to enable a well-founded judgement about when the replacement of natural dyes by synthetics took place in relation to furniture.

Earlier research does however demonstrate that these synthetic dyes were indeed in use. Research into furniture designed by Piet Kramer between 1912 – 1935 from the collections of the Stedelijk Museum in Amsterdam and the Cultural Heritage Agency of the Netherlands indicated that methyl violet, malachite green, nigrosin and probably orange II were used to stain furniture. Crocein orange, nigrosin, picric acid and a variety of red and blue synthetic colorants were encountered on clock cases dating from 1715-1745; the presence of these dyes indicate later conservation work.

In 2007 extensive research was also carried out into the use of dyes on late 19th and early 20th century marquetry. This type of inlay work was extremely popular during that period, and was also used to decorate existing pieces of 17th and 18th century furniture. As well as fragments of marquetry pieces from the workshop of Johannes Lodewijk Miner in the collections of the Amsterdam Museum, the Rijksmuseum Amsterdam and the University of Amsterdam, this research also took in a selection of furniture including pieces from Het Loo Palace. Miner was a furniture inlayer who was active in the early decades of the 20th century. He provided antique furniture with new inlay work, and a collection of prepared inlay work from his workshop has survived. In addition to natural colorants, synthetic dyes such as fuchsin, picric acid, flavazine L and Victoria blue B were principally found during this research.

While a satisfactory answer was found to the primary (chemical) question in the above study, namely “which dyes were used?” another important question remained unanswered: could a judgement be pronounced about the original colour of the piece of furniture in question? Of course some indication could be provided given the fact that the colour of the dyes was known. For example: methyl violet gives an intense purple colour while malachite green gives a strong green. But the question remains: how purple, and how green? It proved impossible to answer this question without additional studies involving reconstruction. What was clear was that the dyes are now severely faded, so much so that in some cases only the colour of the wood was visible.

As well as the question about the original colour there was also an issue of an analytical chemical nature: the responses found during analysis were generally fairly weak. This means that only a small amount of dye was being recovered in relation to the sample size (generally some grammings taken from an unfaded area). This low response could of course simply be the result of a low level of dye in the sample. The dye may already have faded, or the quantity of dye required to obtain a particular colour may have been small. This latter hypothesis can also be tested by means of reconstruction research. There is however another possible explanation for the low response: the analytical technique used is optimised for samples of textile and paints, but not for wood. Before the analysis can be carried out the dye must first be placed in a solution. This is achieved by way of extraction using a strong acid, such as hydrochloric acid. This is an effective method for textile and paint samples, certainly for synthetic dyes. In the case of wood stains however it is known that the colorant penetrates the wood. It is not clear whether the extraction medium also does so, to allow effective extraction of the dye. In addition, the binding mechanism between the dye and wood is not the same as in the case of textiles, so that a different method may be required to break that bond.

The aim of this study is therefore twofold. Following study of the historical sources, reconstructions were carried out in order to gain a better understanding of the original colour of items on furniture. This can assist conservators and curators in their understanding of the original appearance of a piece. The same reconstructions may also be used for analytical research, to optimise sample preparation for wood.

2 Recipes and reconstructions

A selection of historical sources were investigated in order to allow good reconstructions to be made. One important source was Vom Färben des Holzes by Hans Michaelsen and Ralf Buchholz, which consists primarily of descriptions from other sources. This book contains recipes and transcriptions of recipes in which synthetic dyes were used. Another important source was Beitsen, kleuren en oppervlaktebehandeling van hout by C P van Hoek. This book was based on a German publication by W Zimmerman from 1907, but adapted for the Dutch market. This book sets out not just recipes for stains but also other treatments applied to wood before or after staining. A practical handbook to marquetry, woodstaining and kindred arts by Eliza Turck was published towards the end of the 19th century. Another practical manual is the Pocket Guide to the Application of Dyestuffs from the Badische Anilin & Soda Fabrik, published by the dye manufacturers BASF themselves. We must note that this book of over three hundred pages deals primarily with textile dyeing, the staining of wood occupying only a couple of pages, which offers some indication of the relative importance of textile dyeing and wood staining for the manufacturer. Finally, one Italian source was studied, Coloritura, verniciatura e laccatura del legno, by A Turco, 1985.

Rather than providing a complete survey, the primary objective of the study was to identify similarities and differences in the recipes, in order to determine the most important parameters and to arrive at a standard recipe. The standard recipe developed during the study had in any event to cover the most significant parameters, and the effects of these parameters could then be investigated by varying them individually.

While there are clear differences between the different recipes, the number of parameters for the synthetics is limited compared to those in the case of natural dyes. This is only to be expected: one reason for the rapid replacement of natural dyes with synthetics (in addition to lower costs) was that the synthetics allowed simplified recipes, which could also be produced more quickly. While the dyeing of a textile with natural dyes could take anything from a day to several weeks (including a period of fermentation when applicable), it could be carried out in less than an hour using synthetics. The number of separate actions and of ingre-
The chemistry of the dye also plays a significant role. In the first place there are basic and acid dyes, so called because they are used in a basic or acidic dye bath, respectively. These dyes have basic or acid side-groups which enter into the bond with the substrate (textile or wood). As well as the effect of these side-groups on the bonding mechanism, the solubility of the dye also plays a role. Hydrophobic dyes are also soluble in organic solvents such as ethanol. Obviously the concentration of the dissolved substances also plays a role: the higher the concentration, the stronger the colour, although this is not necessarily a linear relationship. Additives may also be included in the dye bath to improve adhesion. Additives commonly mentioned include aluminium sulphate, ammonia and acetic acid. The staining method also has effects: smaller pieces of veneer can simply be dipped, resulting in a homogeneous colour. The duration of the dye bath also affects the final colour. Larger pieces were often stained using a brush or sponge, and one would need to work quickly to achieve a homogeneous colour. In such cases it is not only the concentration of the dissolved dye that plays a role but also the number of times the brush or sponge passes over the surface. In addition, mixtures of dyes may be used: the manufacturer may supply a mixture of colorants to achieve a certain shade, but the person applying the stain can also choose to mix several dyes together. Finally there is the finishing coat of wax or varnish to consider, which will also affect the way the colour is perceived in the end-product. Such finishing coats have not been included in the scope of this study.

A standard recipe was developed based on the study of historical sources, and the variables within the parameters of this recipe were charted. The parameters listed in the following table have been numbered, the numbers referring to Tab. 1, which sets out the variables. The standard recipe consists of the following stages:

First the wood (1) is sanded very finely. It is then thoroughly wetted (2), and subsequently dried. The colorant (3) is placed in a solution (4) at the correct concentration (5a/b). Depending on the recipe additives may also be added here (6). The dye bath is heated to the correct temperature (7). The stain is applied to the wood using one of two methods. The dipping method (8) entails the wood being placed in the heated dye bath, ensuring that the wood is free on all sides (that is to say it is not in contact with the walls of the dye bath or with other pieces of wood). Following dipping (9) the dye bath is removed from the heat source and allowed to cool (10). The wood is then removed from the dye bath and dried. A sponge was used in the method where the colorant is applied directly to the wood (8), as this gave the most homogeneous result. Following this treatment the wood was dried. In all cases the wood received no post-treatment.

It is of course possible to combine several different parameters, but this would lead to a completely unmanageable outcome with more than a thousand reconstructions. It was therefore decided to employ the standard recipe with two colorants, one acidic and one basic, to apply this to both types of wood (= four reconstructions) and subsequently to vary all other parameters only in relation to the standard recipe, and not to carry out any further combinations. In the four reconstructions mentioned above an acidic and a basic dye were applied to both oak and maple wetted with, respectively, water, 5% ammonia and common salt. Of these however, only the reconstructions damaged with water were further investigated using the other parameters. For each colorant/wood combination this resulted in ten reconstructions for the dipping method (making a total of forty), and five for the sponge application method, where only the concentration is varied.

<table>
<thead>
<tr>
<th>Nr Parameter</th>
<th>Variable 1</th>
<th>Variable 2</th>
<th>Variable 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Wood species</td>
<td>Oak</td>
<td>Maple</td>
<td></td>
</tr>
<tr>
<td>2 Pre wetting</td>
<td>Water</td>
<td>5% ammonia</td>
<td>100 g/l common salt (NaCl) in water</td>
</tr>
<tr>
<td>3 Dye</td>
<td>Acid dye, Ponceau 2R</td>
<td>Basic dye, Methyl violet</td>
<td></td>
</tr>
<tr>
<td>4 Solvent</td>
<td>Water</td>
<td>20% ethanol in water</td>
<td>100% ethanol</td>
</tr>
<tr>
<td>5a Concentration dye, dipping method</td>
<td>1.0 g/l acid dye</td>
<td>0.1 g/l basic dye</td>
<td></td>
</tr>
<tr>
<td>5b Concentration dye, sponge method</td>
<td>Range of 1.0 to 15 g/l acid dyes</td>
<td>Range of 0.1 to 5 g/l basic dyes</td>
<td></td>
</tr>
<tr>
<td>6 Additives to the dye bath</td>
<td>No additives or ammonia for acid and basic dye</td>
<td>Aluminium sulphate for acid dyes</td>
<td>Acetic acid for basic dyes</td>
</tr>
<tr>
<td>7 Temperature</td>
<td>90 °C aqueous solution</td>
<td>70 °C for 20% or 100% ethanol</td>
<td></td>
</tr>
<tr>
<td>8 Method</td>
<td>Dipping in dye bath</td>
<td>Apply directly with a sponge</td>
<td></td>
</tr>
<tr>
<td>9 Duration</td>
<td>Dipping: 15 min</td>
<td>Dipping: 30 min</td>
<td>Sponge: As fast as possible</td>
</tr>
<tr>
<td>10 Cool dye bath with wood inserted (dipping only)</td>
<td>1 h</td>
<td>2 h</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. The various parameters in the recipes (corresponding to the numbering in the text) and the associated variables.
Ponceau 2R, also known as Ponceau RR (Colour Index Name: Acid Red 26, CI no. 16150), belongs to the class of monoazo dyes (Figure 2). It is a typical representative of this class of dyes. The Ponceau dyes belong to a group used in the 19th century to dye textiles and stain furniture. Ponceau 2R is reasonably light fast (ISO 4-5) and is easily soluble in both water and ethanol.

Methyl violet and Ponceau 2R were used to carry out the experiment investigating the recipe parameters. Additionally, a small selection of representative dyes were selected (see Tab. 2) and applied to both oak and maple using the dipping method, and also in five different concentrations using the sponge method. This allowed us to obtain a good impression of the colour variations and the colour palette.

3. Research methodologies

The assessment of the effects of the different recipes on the end-colour of the reconstructions was carried out primarily with the naked eye. Transverse sections were also carried out on a limited number of samples in order to study the penetration of the colorant into the wood. Sections of veneer were taken, embedded in epoxy resin, polished and studied under a microscope at magnifications of 40x and 100x.

Samples were also taken for use in the study of different extraction methods, the aim being to identify which method delivered the highest yield. The sampling was complicated by the quantitative nature of the research. The problems with the wood samples are that it is not known precisely what concentration of colorant is present and, above all, how deeply the colorant has penetrated the wood. Normally a scraping would be taken from a piece of furniture, but because this makes it difficult to determine the sample size it was decided to take relatively large samples by making a large transverse section right through the whole veneer. These samples were then weighed. While this sampling is of course not representative of the normal method of taking samples from objects, it does allow quantification of the results. Each analysis was performed 5 times.

Samples were then extracted using a variety of solvents. Extraction is necessary to detach the dyes from the wood and get them into the solution. Six different extraction methods were compared:

- Extraction using hydrochloric acid, water and methanol;
- A two-stage extraction process, using DMF and then hydrochloric acid;
- A two-stage extraction process, using dimethylformamide (DMF) and then hydrochloric acid;
- Extraction using ammonia (for acidic dyes only);
- Extraction using concentrated acetic acid;
- Extraction using ethanol;
- Extraction using concentrated hydrochloric acid, water and methanol (ratio 2:1:1).

The vial was then transferred to a boiling water bath and heated for ten minutes. The hydrochloric acid solution was then evaporated to dryness with the aid of a desiccator.

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particularly apparent in the annual rings in the oak veneer, where the basic methyl violet adheres less than the acidic Ponceau 2R. As a result of this the late wood was more lightly stained than the rest of the wood, while it were the annual rings that were darker in the case of Ponceau 2R. No satisfactory explanation can as yet be given for this phenomenon. This effect is far less visible in the case of maple, which has a finer structure.

Sections were also made of the reconstructions, which were then viewed under the microscope.

The difference in penetration of the two dyes is clearly visible: the basic methyl violet primarily adheres to the surface while the acidic Ponceau 2R penetrates far more deeply into both types of wood, with penetrative staining particularly apparent in the maple, staining it through and through. An explanation could perhaps lie in the structure of the dyes: the basic dyes adhere strongly to the acidic present in the wood and do not stain it through and through, as the acidic dyes do. This hypothesis needs to be investigated further, by taking
different concentrations.

Figure 7. Colour variation following the staining of maple and oak with methyl violet using the dipping method and brush application, at different concentrations.

We can find an explanation for this when we look at the chemical structure: Ponceau 2R, with its two strongly acidic groups, is far more hydrophilic than methyl violet. It is also worth noting that many suppliers of these staining materials indicate how the dye can best be dissolved.

In a subsequent experiment a variety of chemicals were added to the dye bath in order to investigate their effects on the staining. The effects of ammonia, aluminium sulphate and acetic acid were investigated (in a concentration equivalent to the quantity of dye): see Fig. 6.

In the case of methyl violet the effect of the additives to the dye bath is limited, and only in the case of ammonia on oak can it be seen that the staining is reduced, while with maple the colour in that case is somewhat more intense. The additives have more effect with the acidic dye Ponceau 2R, with aluminium sulphate in particular intensifying the staining of both oak and maple. Probably a so-called “salting out” effect is involved here, where the solubility of the dyes is reduced through the addition of salt, resulting in better adhesion to the wood. Stronger staining was also observed in the case of acetic acid, particularly in the oak. The addition of ammonia to the Ponceau 2R dye bath had a particularly marked effect on the oak, in which a clear colour difference was could be observed and the wood grain appeared to be accentuated.

The manner in which the stain was applied also had strong effects on the final colour, as can be seen in Fig. 7.

This experiment demonstrated that the dipping method, which involves the wood being fully immersed in the dye bath, produced colours that were far more intense than in the case of application using a brush or sponge. An explanation for this can be found in the duration of the dye bath. In the case of dipping the wood was left in the dye bath for fifteen to thirty minutes. The longer the staining period, the higher the colour intensity of the wood. A pronounced change in colour can be observed particularly during the first few minutes of staining; as the staining lasts longer the colour appears to become saturated. When a brush or sponge is used the staining process is very rapid. The concentration in the dye bath needed to be increased to obtain a good colour. With methyl violet it can be observed that the dipping bath method requires a concentration lower by a factor of 100 than the concentration required when a brush or sponge are used.

When using the brush or sponge the colour can be subtly varied by repeating the process. It is clear that the total immersion of the wood in a dye bath results in a more homogeneous and intense colour than can be obtained with the use of a brush or sponge. The latter method is however particularly suitable for larger areas, in addition to which the final colour can be determined much more easily and shading is simpler. That having been said, it is also possible to effectively control colour shades when using the dipping method. If the concentration in the dye bath is not too high the final colour can be determined by the duration of immersion (after frequent checking). A fairly subtle control can even be exercised, if, following heating, the dye bath is allowed to cool with the wood immersed in it and the colour is then checked frequently.
The above experiments show that the application method, the concentration and the duration of the staining are the most significant factors in determining the final colour. Additives like ammonia and aluminium sulphate have subtle effects on the colour, while pretreatment with water, a solution of common salt or ammonia hardly affect the final colour. It is difficult to achieve homogeneous results when staining with basic dyes. The basic dyes adhere strongly to acids found in the wood. If the acid is not uniformly distributed, an even staining effect will not be achieved. This is not a problem in the case of acidic dyes, which probably explains why they were used far more frequently than basic dyes.

The effect of the concentration on the final colour was subsequently investigated for the series of dyes specified in Table 2. The standard recipe was followed, with a sponge used to apply the dyes, with a concentration range of 1 to 15 g/l for the acidic dyes and 0.1 to 5 g/l for the basic dyes, applied to both oak and maple. Unfortunately it is not possible to show all the reconstructions, but a selection is presented in Fig. 8.

5 Preparation of Samples

The second objective of this research was to investigate whether the extraction method could be improved. Maple veneer was used in this investigation, stained with, respectively, methyl violet, Ponceau 2R, methylene blue and naphthol yellow S. Methylene blue is a basic dye in the thiazine class, while naphthol yellow S is an acidic dye in the nitro class. Staining was carried out using the standard recipe with the dipping method: this provides the most homogeneous stain and therefore the most homogeneous sampling.

The four dyes used are very different from a chemical point of view, and a suitable extraction method would need to be effective for all four. All extractions were repeated 5 times to obtain an indication of the reproducibility. As stated above the samples were accurately weighed and the results were subsequently corrected for the weight difference.

The degree of extraction was affected by three parameters. Firstly, the stability of the dyes in the extraction media. It is possible for the dyes to have decomposed, which would mean the original substances are no longer detectable. This is mainly a problem relating to natural dyes, some of which are not able to withstand hydrochloric acid for example. Research on this topic for this set of dyes has however already been completed and published.9 In that study both the pure dyes and wool dyed with them were treated with hydrochloric acid using an identical method to that employed with the veneer samples. The research indicated that the majority of these dyes are stable.

The second parameter is the solubility of the dyes: depending on their structure they can be hydrophobic or hydrophilic, therefore dissolving better in organic or in aqueous solvents, respectively. Since this cannot be determined in advance, DMF was used as the solvent in all cases, since it is able to effectively dissolve both hydrophobic and hydrophilic dyes. The third and crucial parameter is the degree to which the extraction agent is able to loosen the dye from the substrate, in this case wood. It is possible that the degree to which the solvent penetrates the wood also plays a role. The results of the extraction tests, by measuring the peak area of the dyes extracted, are presented in Fig. 9.

On the basis of these measurements it appears that methyl violet is best extracted with acetic acid, with the combined method (DMF and hydrochloric acid) coming a close second. There are however only minor differences between the four extraction methods. The differences are much greater for methylene blue, with the yield resulting from the use of hydrochloric acid extraction the highest by far. Here, again, the combined extraction method using first DMF and then hydrochloric acid comes a close second, while extraction with ethanol and acetic acid delivers a clearly infe-
rior result. The acidic dyes Ponceau 2R and napthol yellow S are best extracted with a combination of DMF and hydrochloric acid, as the other methods all produce poorer results. In the case of these two dyes, extractions were also carried out using ammonia, on the assumption that the basic solution would effectively dissolve the acidic dyes. However, this proved not to be the case.

This investigation showed that the combined extraction method, using DMF and subsequently a solution of hydrochloric acid, produced the best results for all dyes. As a final test a second extraction was carried out on all the extracted samples, in order to determine how much dye could then be found. This investigation revealed that the initial combined extraction using DMF and hydrochloric acid extracted more than 90% of the dye: the method is therefore highly efficient. These extractions were carried out using pieces of wood, while it is more customary to use scrapings. The expectation is that extraction using scrapings would produce better rather than worse results, because the solvent would not then be required to fully penetrate the wood. It is worth noting that these days the combined extraction method is also frequently applied to textile samples.

The method described above was subsequently used for an analysis of the staining of an object from the collection of the Cultural Heritage Agency of the Netherlands. This was a desk made of oak, mahogany and coromandel, dating from 1930 and made in the Amsterdam School style of Eibink and Snellebrand. The desk now looks brown in appearance, but a red colour is still clearly apparent on the insides of the doors. The fading of the finish is particularly evident in the sliding desk top. The further the desk top is exposed, the more pronounced is the effect of fading, with the desk top appearing almost white in places. Two samples were obtained by scraping, one from the faded area and one from the area where the colour finish is still in good condition. The two samples were treated with the combined extraction method and subsequently analysed using HPLC. Analysis indicated that a mixture of the dye: the method is therefore highly efficient. Some other components with comparable spectra were also found, but at far lower concentrations.

These were probably subsidiary components of Ponceau G. The Ponceau dyes were found in both the faded and unfaded (or less faded) areas; however, the concentration in the faded area was much lower. Ponceau G (C.I. Acid Orange 14, C.I. 16100) is an azo dye; very similar to Ponceau 2R in its chemical composition, this stain has a vivid reddish orange colour. The light fastness of Ponceau G on textiles is good at ISO 6. Nevertheless in places the colour had disappeared completely, particularly where it was exposed to light. Further research will be required to demonstrate whether the light fastness of this colorant on wood is identical to that on textiles.

6 Conclusion and Further Research

While this study has not produced an exhaustive survey of recipes, it seems clear that the number of parameters within the recipes is limited. The recipes are far less complex than in the case of natural dyes. The most significant parameters are the application method (dipping or brush/sponge), the duration of the staining process, the concentration of the dye and the actual dye used. If the recipes are followed this often results in very intense colours, which are no longer visible today. More object-based research is required to establish what effect this has on the appearance of late 19th and early 20th century furniture. Whether furniture from that period could and should be returned to its original colour is in part an ethical discussion. Reconstructions, digital and otherwise, would also be useful here in providing a better understanding of these items of furniture. This would however require supplementary research on items furniture in order to establish the original colour as precisely as possible. The extraction technique has been optimised in the interim and an initial analysis of a desk from 1930 shows that the dye can be effectively analysed using this method. It would be interesting to conduct a study looking at the minimum quantity of sampling material required for an accurate analysis based partly on reconstructions and partly on furniture.

A follow-up investigation should also consider the ageing of dyes. The light fastness of most dyes is known, but this is when they are used on textiles. Whether their light fastness on wood is comparable has still to be investigated. It is not only the fading of the dye which of interest, as colour changes in the wood itself will alter the appearance of the furniture. As well as ageing due to the effects of light, the ageing of dyes in dark conditions must also be investigated. In many items of furniture it is possible to find areas that were stained but which have had very little or no exposure to light. It is tempting to assume that the original colour will be visible in such areas, but it has still to be investigated whether that is actually the case and whether the wood and the dye have not changed in colour.

Figure 9: Yield from different extraction methods for various dyes, corrected for the weight of the sample.
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